Stormwater Runoff Quality and Quantity from Small Watersheds in Austin, TX: Updated through 2008

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Prepared by

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Executive Summary

Almost all stormwater quality activities rely upon monitoring as their foundation to one degree or another. Design and construction of water quality controls or other best management practices (BMPs) are, or should be, based on monitoring data to ensure the BMP meets the desired goals. Rules and regulations that are not based on monitoring data may reflect the desire of the rule maker more than the science of the physical world. Modeling, which may be used to develop rules and design guidelines, is dependant on monitoring to first develop the stochastic or physical theories on which the model is based and then to calibrate the model for a specific location.

The City of Austin (COA) engages in all of the above activities; proposing and enforcing development rules and regulation, developing design guidelines for and construction of BMPs, and modeling small and large watersheds. These activities are all based on a solid foundation of stormwater monitoring that has encompassed more than twenty-five years. The City participated in the Nationwide Urban Runoff Program (NURP) in 1981 (Engineering Science and COA, 1983) and included monitoring of two water quality control systems in their 1983-84 cooperative monitoring program agreement with the U.S. Geological Survey (USGS). These two monitoring projects were limited in both scope and duration (COA, 1984; USGS, 1987).

In the mid-1980s, COA initiated a more comprehensive monitoring program to collect data to support a series of watershed management ordinances adopted by the City (COA, 1985). The original plan was to monitor eleven sites including seven water quality controls over a five-year period. The longer monitoring period was supposed to allow for monitoring that better reflected the local rainfall and runoff patterns since the earlier programs focused mainly on smaller events. The data from this program were the basis for much of the quality and quantity information in the current COA Environmental Criteria Manual (ECM) as well as initial discussions on the first-flush phenomena and design criteria for the Austin sand filter design.

In 1990 COA started a comprehensive monitoring program to meet the City's ongoing stormwater monitoring needs (COA, 1996). These needs include evaluating the design and

performance of different types of structural BMPs, evaluating effectiveness of education programs, evaluating and refining quality and quantity of runoff from different types of land use and meeting the requirements of the City's MS4 discharge permit under the National Pollution Discharge Elimination System (NPDES) and Texas Pollution Discharge Elimination System (TPDES) portions of the Clean Water Act. Through 2008, the Stormwater Quality Evaluation (SQE) Section of the Watershed Protection Department has collected runoff quality and quantity data from more than one hundred monitoring locations including twenty-eight BMPs and ten watersheds greater than five hundred acres.

This report is intended to summarize the runoff quality and quantity data collected by the city of since 1981. During the preceding thirty years collection techniques, equipment and personnel have changed, all having an impact on data quality. However, the data used in this report represent a unique dataset in both scope and duration. While far from an exhaustive examination of the data, this report does verify some existing hypotheses and also challenges some existing assumptions.

The relationship between total impervious cover (TIC) and *Rv* found in this report differs significantly from that found in the COA ECM (2009). If the relationship found in this report is adopted there will be no changes in capture volume requirements for BMPs currently found in the COA ECM except wet ponds which would be larger for most cases. There could be impacts on the designs for alternative controls as well. An earlier COA study (2006) found no difference between the runoff from recharge and non-recharge areas, so only one relationship is presented here.

It was demonstrated that some mean pollutant concentrations changed with development conditions. Ammonia (NH_3), lead (Pb) and zinc (Zn) increased exponentially with impervious cover. Total phosphorus (TP), dissolved phosphorus (DP), total Kjeldahl nitrogen (TKN) and total nitrogen (TN) increased as the fraction of non-urban land decreased. Chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD), cadmium (Cd) and copper (Cu) increased linearly as total impervious cover increased. Fecal coliform (FCOL) increased as the fraction of single-family residential (SFR) land use increased while volatile suspended solids (VSS) varied with changes in SFR and commercial land uses. Nitrate + nitrite (NO_3+NO_2)

concentrations were different between developed and undeveloped areas but there were no significant relationships with impervious cover or land use. Fecal streptococci (FSTR), total organic carbon (TOC) and total suspended solids (TSS) were not significantly related to any changes in development condition tested in this report. A table was prepared to replace the existing COA ECM (2009) stormwater concentration assumption in Tables 1.10 and 1.11. This change would have no impact on existing BMP designs but would impact the design of alternative controls.

It was found that using disconnected impervious area (DCIA) instead of TIC did not result in improved predictions of mean concentrations or runoff-rainfall ratios, *Rv.* DCIA was estimated in this report based on empirical relationships developed elsewhere. If local relationships are developed or if DCIA were actually measured, this conclusion may be different.

Significant relationships were developed to predict event mean concentrations (EMCs) for the pollutants studied and four classes of development. The models used one or more of the following as predictive variables: preceding dry time, 15-minute peak rainfall intensity and total rainfall. While these models were statistically significant, most models resulted in predictions that were no better than using the mean of the observed values. Better physical models are needed to predict EMCs, rather than relying on stochastic relationships.

The analyses confirmed results of earlier studies that indicated runoff concentrations are not constant during a runoff event in small watersheds with moderate to high impervious cover. The first-flush effect was less pronounced (even non-existent for some pollutants) in undeveloped areas. While other studies focused solely on impervious cover, this report also examined the type of land use associated with the impervious cover. It was found that in SFR areas, nutrients, especially dissolved nutrients, exhibited a 'last-flush' with pollutant concentrations increasing rather than decreasing as runoff volume increased. This effect may have a substantial impact future BMP design.

Testing of proposed modifications to the NRCS curve number method found a slight improvement over the currently accepted method but it still under predicts runoff volumes for smaller events: those of most concern for water quality design. While the curve number method may still be used for flood design, models based on physical processes should be employed when attempting to perform continuous simulations for water quality design.

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1 Introduction

Almost all stormwater quality activities rely upon monitoring as their foundation to one degree or another. Design and construction of water quality controls or other best management practices (BMPs) are, or should be, based on monitoring data to ensure the BMP meets the desired goals. Rules and regulations that are not based on monitoring data may reflect the desire of the rule maker more than the science of the physical world. Modeling, which may be used to develop rules and design guidelines, is dependant on monitoring to first develop the stochastic or physical theories on which the model is based and then to calibrate the model for a specific location.

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In the mid-1980s COA initiated a more comprehensive monitoring program to collect data to support a series of watershed management ordinances adopted by the City (COA, 1985). The original plan was to monitor eleven sites including seven water quality controls over a five-year period. The longer monitoring period was supposed to allow for monitoring that better reflected the local rainfall and runoff patterns since the earlier programs focused mainly on smaller events. The data from this program were the basis for much of the quality and quantity information in the current COA Environmental Criteria Manual as well as initial discussions on the first-flush phenomena and design criteria for the Austin sand filter design.

In 1990 COA started a comprehensive monitoring program to meet the City's ongoing stormwater monitoring needs (COA, 1996). These needs include evaluating the design and performance of different types of structural BMPs, evaluating effectiveness of education programs, evaluating and refining quality and quantity of runoff from different types of land use and meeting the requirements of the City's MS4 discharge permit under the National Pollution Discharge Elimination System (NPDES) and Texas Pollution Discharge Elimination System (TPDES) portions of the Clean Water Act. Through 2008, Stormwater Quality Evaluation (SQE) Section of the Watershed Protection Department has collected runoff quality and quantity data from more than one hundred monitoring locations including twenty-eight BMPs and ten watersheds greater than five hundred acres.

This report will focus on characterizing the runoff quality and quantity from forty-six small watershed (<500 ac.) sites. The pollutants addressed in this report include four metals, cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn); six nutrients, dissolved phosphorus (DP), total phosphorus (TP), ammonia (NH_3), nitrate + nitrite (NO_3+NO_2), total Kjeldahl nitrogen (TKN) and total nitrogen (TN); two bacteria, fecal Streptococci (FSTR) and fecal coliform (FCOL); two measures of suspended solids, total suspended solids (TSS) and volatile suspended solids (VSS); two measures of oxygen demand, 5-day biochemical oxygen demand (BOD) and chemical oxygen demand (COD); and total organic carbon (TOC). (NOTE: Throughout this report units are mg/L except metals, which are µg/L and bacteria which cfu/100 mL.) The sites used in this report are listed in Table 1.1 and their locations are shown in Figure 1.1. Several hypotheses will be examined in this report:

- The mean runoff-rainfall ratio is related to impervious cover.
- The mean event mean concentration is related to impervious cover.
- The mean event mean concentration is related to impervious cover and land use.
- The NRCS curve number method can be modified to predict runoff from small storms and be used for water quality design.
- Event mean concentrations are related to total runoff, total rainfall, rainfall intensity and preceding dry interval.
- Runoff concentrations change during a runoff event.

Table 1.1: City of Austin small watershed stormwater monitoring site descriptions.

Site ID	Site Name	Major Land Use
ARA	Austin Recreation Center	Civic
BC	Bear Ck. near Lake Travis	Undeveloped
BCU	Barton Creek Undeveloped	Undeveloped
BI	Brodie Oaks Influent	Commercial
BNI	Highway BMP #6 Influent	Transportation
BRI	Barton Ridge Plaza Influent	Commercial
BSI	Highway BMP #5 Influent	Transportation
BUA	Burton Road	Multi-Family Residential
CMI	Central Market Influent	Mixed Urban
CTI	Ceylon Tea Influent East	Single-Family Residential
CTJ	Ceylon Tea Influent North	Single-Family Residential
CTK	Ceylon Tea Influent West	Single-Family Residential
E7A	East Austin at East 7th	Industrial
EBA	East Austin at Belfast	Single-Family Residential
EHA	Holly Street at Anthony	Single-Family Residential
EMA	Mansell at Boggy Creek	Single-Family Residential
ERA	Robert Mueller Airport	Transportation
FPI	Far West Pond Influent	Mixed Urban
FSU	Sycamore Ck. at Republic of Texas	Undeveloped
FWU	Windago Way Undeveloped	Undeveloped
GPI	Gillis Park O/G Chamber Influent	Mixed Urban
HI	Highwood Apartments Influent	Multi-Family Residential
HLA	Trib. at Hart Lane	Single-Family Residential
HPA	Avenue C at 41st St.	Single-Family Residential
JVI	Jollyville Road Pond Influent	Transportation
LCA	Lost Creek Subdivision	Single-Family Residential
LGA	Lost Creek Golf Course Undeveloped	Undeveloped
LUA	Lavaca Street at 2nd St.	Commercial
MBA	Metric Blvd.	Industrial
MI	Maple Run Pond Influent	Single-Family Residential
OFA	Spyglass Office Site	Commercial
PA3	Parking Area 3 at Dell	Commercial
RO	Rollingwood	Single-Family Residential
RRI	Berdoll Farms Wet Pond Influent	Single-Family Residential
S1M	Hargraves Service Center	Industrial
SCA	Burnet Road @ 40th Street	Single-Family Residential
SI	Barton Creek Square Mall Influent	Commercial

Table 1.1 (cont.): City of Austin small watershed stormwater monitoring site descriptions.

Site ID	Site Name	Major Land Use
SWI	St. Elmo Wet Pond East Influent	Industrial
SWJ	St. Elmo Wet Pond West Influent	Industrial
TBA	Tar Branch at Carriage Parkway	Single-Family Residential
TCA	Travis Country Channel	Single-Family Residential
TPA	Travis Country Pipe	Single-Family Residential
W5A	5th St. at Red River	Commercial
WBA	Wells Branch Community Center	Civic
WCI	3rd Street at Neches	Commercial
WDI	45th & Duval O/G Chamber Influent	Industrial

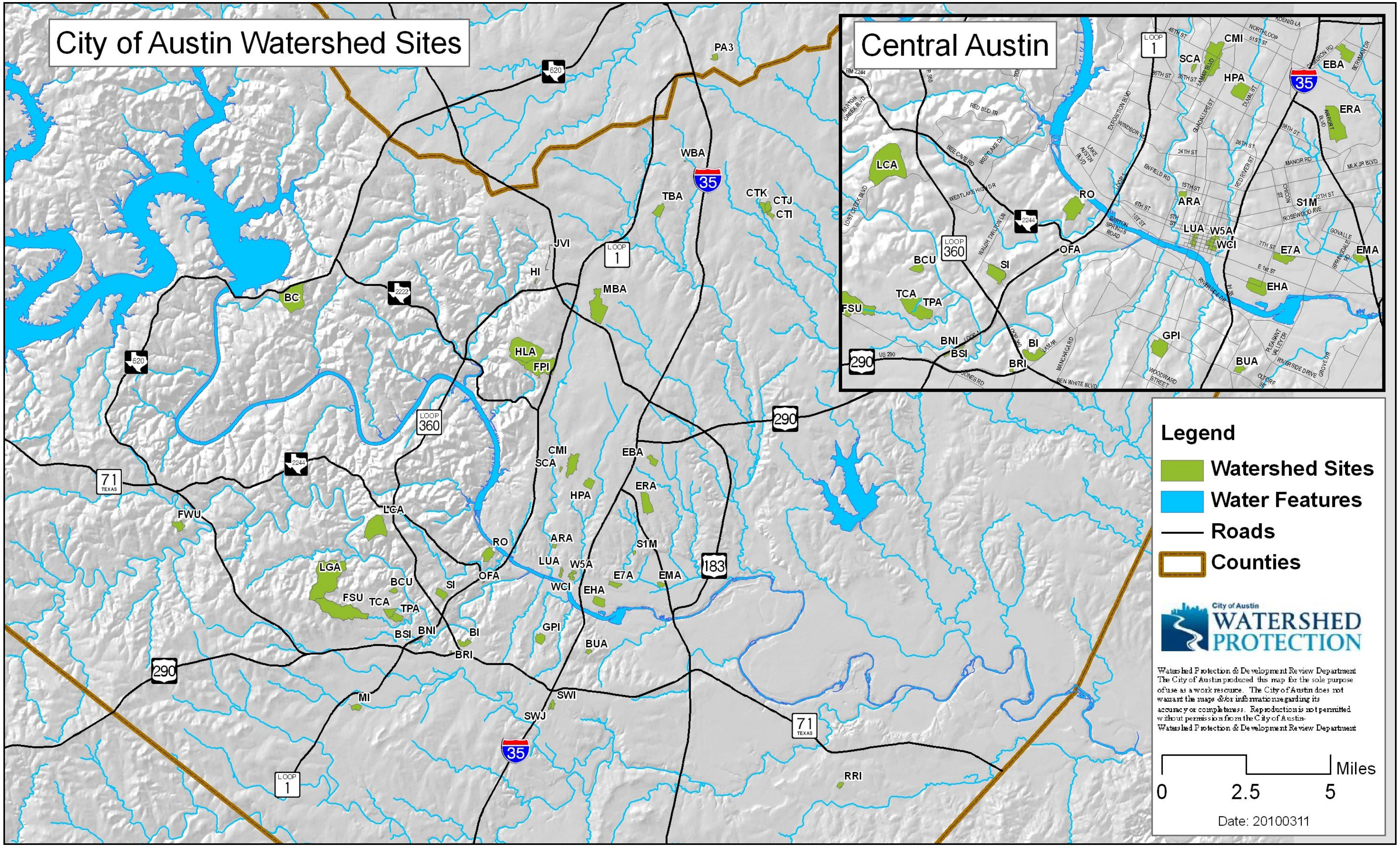

Figure 1.1: City of Austin stormwater monitoring site locations.

2 Data Collection, Processing and Analyses

SQE has a detailed system for collecting, screening and processing water quality and quantity data. For ease of discussion, these data may be broken in to three main groups: flow data, rainfall data, and water quality data. A flow chart of the data management and processing used by SQE may be found in Figure 2.1. The main objective of these steps is to produce the best quality event mean concentration (EMC) and runoff-rainfall ratio (Rv) data possible for use in other analyses.

2.1 Flow Data

SQE monitoring stations are equipped with automatic stage recorders and data loggers that measure and record stage in 1-minute increments. Stage may be measured using several different methods based on the conditions at the monitoring site; methods include pressure transducers, ultrasonic devices, and bubbler meters. SQE uses bubbler meters in most instances because they have proven to be the most reliable for two main reasons. First, bubbler meters do not exhibit calibration problems that may be associated with pressure probes installed under normally dry conditions. This is important because installations at small watersheds do not normally have baseflow and are usually dry under non-storm conditions. In addition, it is difficult and time consuming to calibrate pressure probes that are installed in storm sewers that require confined-space entry procedures for service. Ultrasonic meters do not have the calibration drift problems associated with pressure probes, but they do require a minimum distance between the probe and the water surface, which may not be possible in some applications. Bubbler meters do have problems accurately measuring depth if the flow velocity surpasses approximately 5 fps, but otherwise they are accurate, reliable and easy to maintain. SQE uses bubbler-type meters from a single supplier unless velocity problems exist and the flow measurement structure cannot be modified. In these cases, an area-velocity meter or an ultrasonic meter may be used, but these are rare cases. Figure 2.2 demonstrates flow ratings at FWU station before and after calibration using an area-velocity meter.

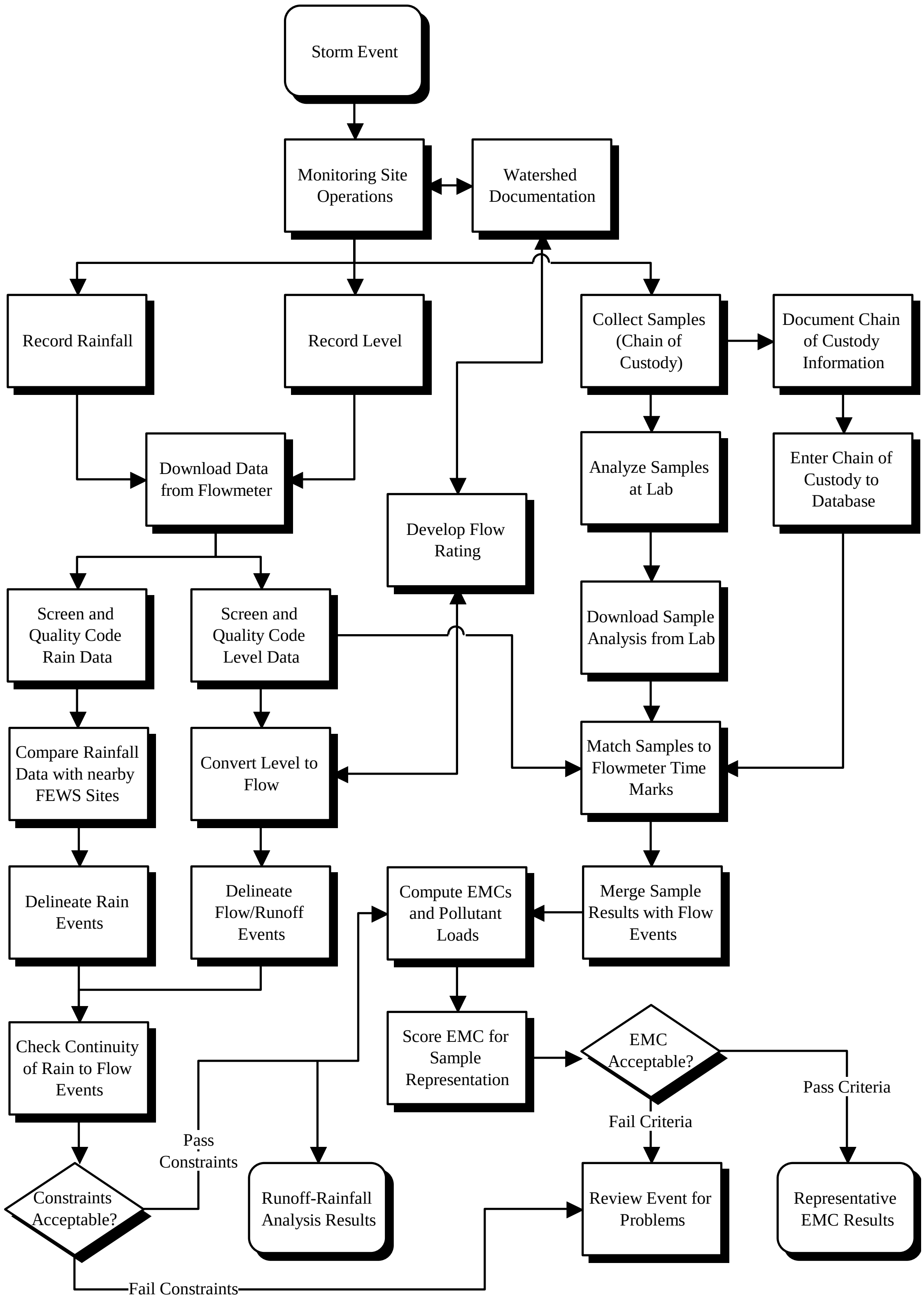

Figure 2.1. SQE data processing and management flowchart.

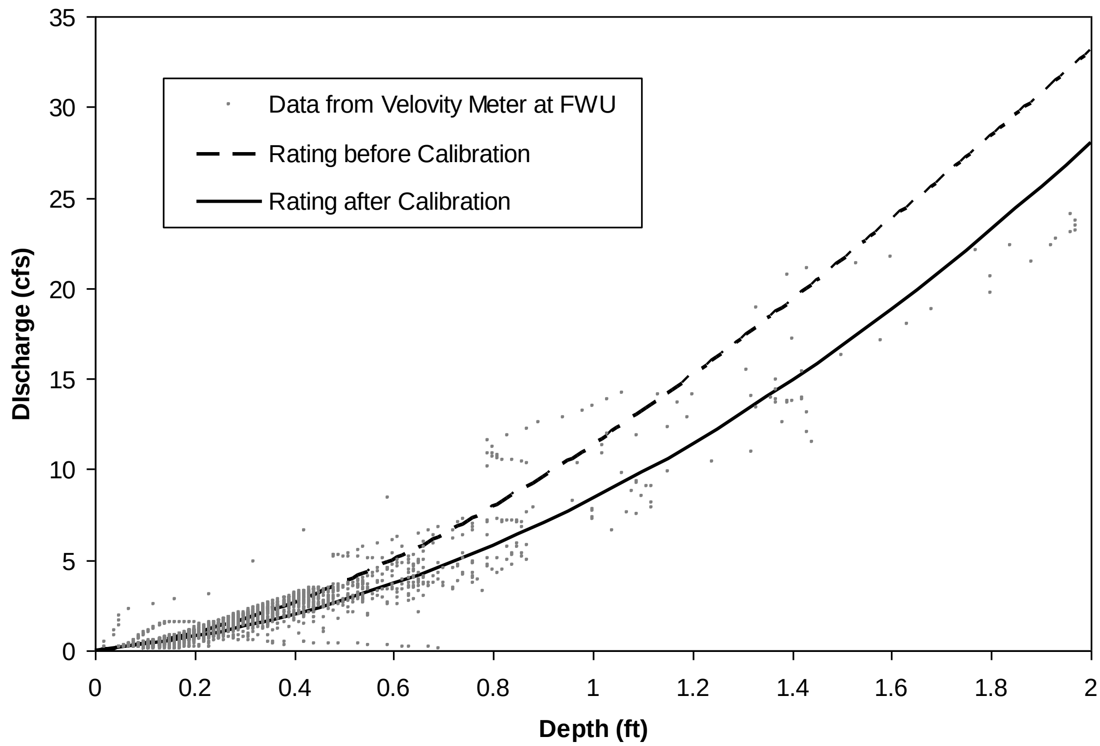

Figure 2.2: Flow ratings before and after calibration using an area-velocity meter at FWU station.

Regardless of meter type, SQE staff downloads level data from each meter on a regular basis and stores it on a central server. The level data are then loaded into a time-series database for further processing. SQE uses the Hydstra/TS Time-Series Data Management module to store, screen, edit and process flow and level data. Hydstra/TS provides the tools for staff to dynamically verify data loggers were properly operating and recording data, thus reviewing large quantities of data in a short period of time. While screening level data, staff may delete spurious points, adjust levels that are out of calibration, or simply code the data as unreliable. SQE often installs multiple meters at each monitoring site to examine and verify site hydraulics and provide redundancy. If the data from the primary meter are unavailable, the data from the secondary meter may be used to complete the flow record. At this time staff also identifies the start and end times of flow events.

The start and end of a flow event depend on the type of measurement structure and the site characteristics. If the site uses a weir for the flow control, identifying the start and end of flow is quite easy: one simply identifies the time level corresponding to the crest of the weir and sets that as the start of flow or end of flow respectively. If the flow structure is a flume or open channel that is normally dry, the start of flow is set at the time some minimum depth, usually 0.1 ft, is reached and the end of flow is at the time when the level drops below that point. If the site in question normally has flow, or if there is excessive flow after the end of rain due to groundwater flow, the start and end of the event are identified on a case by case basis. In all cases, City staff who are familiar with the site review the start and end of the event to verify their accuracy.

SQE strives to measure flow as accurately as possible. In furtherance of this goal SQE often installs standard flow measure structures including flumes, weirs or orifices. These structures are installed according to the manufacturers' specifications and standard practice. In cases where installing a structure is not feasible, SQE uses open-channel flow techniques (Manning's equation, slope-area method, etc.) to estimate the stage-discharge relationships. When open-channel flow techniques are used to estimate flow, SQE may also use a separate area-velocity meter to calibrate the flow at the site. Even taking these precautions, some sites may not have stage-discharge relationships that are accurate enough to measure flow sufficiently for use in runoff quantity computations. In these cases, the data from the site will be excluded from runoff quantity computation but may still be used in runoff quality computations.

Once the data screening and other quality checks have been completed, Hydstra is used to compute the cumulative volume of runoff for each individual runoff event that has been delineated. These data are stored in a database for further processing and analyses.

2.2 Rainfall Data

SQE collects rainfall data from several sources. Most SQE stations are equipped with 0.01-inch tipping-bucket rain gauges. Data from these gauges are stored in the same data logger used for the stage data as one-minute cumulative rainfall depths. These data are downloaded and stored along with the stage data and screened in Hydstra/TS. Rainfall data are checked for spikes or other extraneous data and for clogged or partially clogged rain gauges by comparing the data to the hydrograph and nearby rain gauges.

SQE also collects rainfall data from the City's Flood Early Warning System (FEWS). FEWS stations are used primarily to predict flooding conditions and are equipped with 1-mm tipping-bucket rain gauges. These stations instantaneously report bucket tips to the FEWS central server via radio communication to be used for flood warnings. SQE downloads these data quarterly from the FEWS server to be used to supplement its own rainfall data. FEWS data are converted to one-minute rainfall depths in inches and screened to removed spikes, transmission errors and potential clogging.

After the data from each individual rain gauge have been screened and problematic data have been marked, SQE substitutes good rainfall data for missing or bad data from the nearest operable gauge. Substituted data are marked as such for future reference; a good quality is assigned if the data are from within 1.5 miles and an acceptable quality is assigned if the data are between 1.5 and 3 miles from the site in question. No substitution is allowed if there are no reliable data within three miles.

After each site has a complete, screened rainfall record, the start and end of individual rainfall events are delineated. Generally, an event must have a minimum of 0.04 inch (1 mm) of rainfall and should be followed by a 6-hour dry period. Up to 0.02 inches of rain are allowed during a dry period. These data are stored in a database for further processing and analyses.

2.3 Water Quality Data

The time each water quality sample is collected, whether automatic or manual, grab or composite aliquot, is recorded to link water quality results to the flow record. These sample times are stored in a database for further processing. Water quality results are transferred electronically from the analytical laboratory along with laboratory QA/QC results. The results are screened for statistical outliers that may be due to contamination or laboratory error. Laboratory QA/QC data for each samples are compared against control limits; results that fall outside control limits are flagged for further analyses.

Sample times are compared against previously recorded flow event starts and ends. If a sample falls outside a delineated flow event, staff may include the sample by adjusting the event start or end or by excluding the sample from computation if it is not representative of the flow event.

2.4 Final Data Processing

Once the individual components are processed, the final stage of processing reconciles any discrepancies. Rainfall events are compared with flow events to create a single start and end for each event. Sample times are checked to ensure samples fall within events. Other logical checks are performed to ensure events have been correctly screened. These include checking for flow before the start of rain or for rain after the end of flow, verifying that events do not overlap or that one event is not entirely contained within another event. Once these checks have been completed, event data are stored in a common database.

SQE has worked extensively with the developers of Hydstra to customize data reporting unique to COA needs. The customized program queries the database containing the start and end times for each event. The program then uses these times to query the times series data to report various event statistics that may be needed for further analyses. These statistics include total rainfall (in), total flow (ft^2), peak flow rate (cfs), peak rainfall intensity (5-min, 15-min, 60-min) (in/hr), preceding dry interval (hr), preceding event rainfall (in), time to peak flow rate (min), time to peak rainfall intensity (5-min, 15-min, 60-min) (min), time to rain centroid (min), time to rain mid-point (min), time to flow centroid (min), time to flow mid-point (min), and event runoff-rainfall ratio.

2.5 *Rv* Computations

Rv is defined as the ratio of stormwater runoff volume to storm rainfall volume for a given watershed. Individual event runoff ratios are computed; however, they are strongly influenced by factors such as antecedent conditions, rainfall intensity and rainfall volume and are normally only used to help verify site data such as watershed area and flow rating. The site *Rv* is defined as:

$$Rv = \frac{\sum_{i=1}^{n} RO_i}{\sum_{j=1}^{n} RF_j} \qquad [2.1]$$

where RO is the volume of runoff for the event and RF is volume of rainfall for the associated event. Only events that have both valid rainfall and flow are used for this computation.

2.6 EMC Computations

The computation of an EMC is more complex that the computation of an *Rv* for an event. The first step in computing an EMC is dealing with the unsampled potion of the event at the beginning and end of an event since samples are rarely collected precisely at beginning and end of flow. To account for this, “anchor” samples are placed at the start and end of flow. For small watersheds, the water quality of the first and last samples collected is assigned to the “anchor” sample at the start and end of the event respectively. While not part of this report, it should be noted that for larger watersheds that normally have baseflow, the water quality values for the anchor samples are set to be equal to the average baseflow concentrations for that site, assuming the baseflow average is less than the first or last sample respectively. Since each water quality sample represents a point in time, the assumption was made that water quality changes linearly between each sample. This assumption allows Hydstra/TS to construct a time-varying concentration record. This record is combined with the hydrograph to create a pollutograph, mass/time plotted against time. Once this is completed, Hydstra/TS computes a total load for the event. This process is repeated for each water quality parameter. Figure 2.3 is an example of combining the flow hydrograph and individual samples to create a pollutograph. Cumulative load and flow can be computed from these data.

Once the loads for the event have been computed, the EMCs for the event are computed in a manner similar to the *Rv*, total load of the event divided by the total volume of the event. The loads and EMCs are stored in an external database for later computations.

SQE evaluates each EMC to determine if the event was sufficiently sampled to be representative of the water quality during the event. Several items are checked during the event

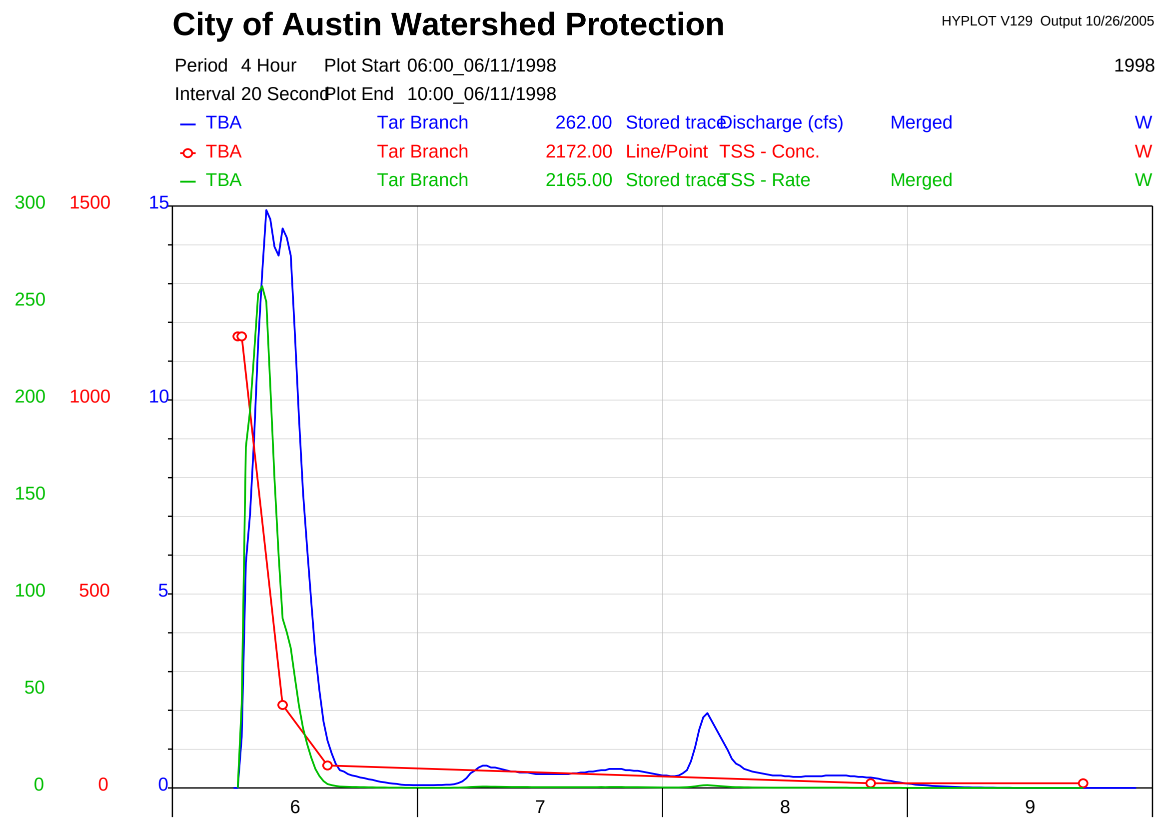

Figure 2.3. Hydrograph, water quality samples and pollutograph used to compute an EMC.

scoring including the volume sampled, the load sampled, the peak flow rate relative to the flow rate at the time of sampling and the number of samples relative to the size of the event.

The first evaluation, the volume score, examines unsampled portions of the event. These analyses are divided into three components: 1) the portion of the event before the first sample, 2) the maximum portion of the event between each sample, and 3) the portion of the event after the last sample. The first sample is important because other COA studies have shown that concentrations usually decrease after the “first-flush” for small urbanized watersheds. (See Section 4.3 of this report for a more detailed examination of first-flush effects.) An initial score of 120 is assigned to the event and two points are deducted for every percent of the volume between the start of the event and the first sample. For the volume between samples, an initial score of 120 is assigned and one point is deducted for each percent of the volume represented by the largest gap between adjacent samples. The end of the events is scored similar to the intra-sample scoring; 120 is initially assigned as the score and one point is deducted for each percent of the volume after the last sample. The overall score is the minimum of the three components with the maximum set at 100.

The second evaluation, the load score, is computed by the same methodology as the volume score. However, the load score is not normally used to exclude events but may be used to flag an event for potential problems.

The next evaluation, the flow rate score, examines the flow rate at the time samples are collected relative to the maximum flow rate of the event. This score is important for pollutants that are related to erosion where concentrations may be related to the flow rate. The score is computed by taking the square root of the ratio of the maximum flow rate of the samples to maximum flow rate of the event and multiplying by 100.

The final evaluation determines if an adequate number of samples were analyzed for the size of the given runoff event. This analysis is more difficult than the others, is site specific and changes over time. The initial assumption was that the median-sized sampled runoff event at a site may be adequately characterized by four well-placed water quality samples; this event is arbitrarily assigned a score of 75. If the event size (runoff volume) is doubled, one additional sample is required to maintain a score of 75. One additional sample is required each time the volume of the runoff doubles. If the runoff volume is one-half the size of the median runoff event, only three samples are required to achieve a score of 75. The score is computed using the formula:

$$SampleScore = 75 + \left(10 * \left(EventSamples - \left(\left(\frac{\log\left(\frac{EventVolume}{MedianVolume}\right)}{\log(2)}\right) + 4\right)\right)\right) \qquad [2.2]$$

An initial score is set as the volume score. One-sample EMCs use the sample score only. For two-sample EMCs, the score is the larger of the volume or sample score if the sample score is at least 50. For three or more sample EMCs the score is the larger of the sample or volume score if the volume score is at least 50. All EMCs are then checked against the flow rate score and it is used if it is lower than the other assigned score. WQM staff review all event scores and may override individual score components or the total score based on professional judgment and experience.

Once the score has been assigned, the level of acceptance is determined. Because environmental data are inherently variable, a sufficient number of samples are required to produce a valid mean of said data. While power analyses have not been conducted, SQE strives for a minimum of 10 EMCs to compute an MC to reduce the potential for error in estimating the mean. As such, the acceptable score for a site is based on a sliding scale. A score as low as 50 is acceptable if there are ten or fewer EMCs. A score of 70 is the minimum if there are thirty or more EMCs. Scores lower than 50 are never acceptable while scores greater than 70 are always acceptable. Data from unacceptable EMCs are preserved for possible use in other analyses.

2.6.1 Detection Limits and Censored Data

Censored data should always be addressed when working with environmental data. SQE has multiple types of censored data and each is dealt with separately.

If an individual sample result in an event is reported as $<X$, $X/2$ will be used to compute a flow-weighted mean if the detection limit is reasonable given the concentrations of the other samples and EMCs at the site. Since concentration data cannot be less than zero, and if all values between zero and the detection limit are equally likely to occur, the mid-point is the expected value. In 1976, Kushner examined lognormally distributed data and found the bias of using the mid-point would be overshadowed by measurement error (Gilbert 1987). If the detection limit is not reasonable, the sample will be dropped from the computation of the EMC. This is based on the assumption that a reasonable approximation of the concentration for a sample is better than a missing sample when computing an EMC.

If all samples in an EMC are reported as non-detect, the EMC will be flagged as non-detect and these EMCs may be used in further analyses of that constituent at that site using maximum likelihood estimators (MLE) on the EMCs, depending on the number of non-detects. In practical terms, this applies only to Cd at most sites and Cu at a few sites as most other sites and parameters have relatively few non-detect EMC. The difficulty of MLE analyses is compounded by changing detection limits, in these cases the detection limit reported by the laboratory at the time of analysis are used.

Data are seldom censored on the upper end and in most instances there is little that can be done with the result. This most often happens when the sample was not diluted properly before analyses, primarily with bacteria and BOD. In the cases of BOD, the result is estimated from the result of the COD analyses based on long-term regression relationship between COD and BOD. Bacteria results that are censored high are arbitrarily set at twice the upper limit.

2.7 Other Data

In addition to level, flow, rainfall and water quality data, SQE collects other information associated with the watersheds it monitors, most notably watershed size, impervious cover and land use. These data are generally handled using the geographic information system (GIS) ArcMAP, existing COA data sources (planimetric maps, land use maps, DEMs, etc.) and field investigations. Summaries of these data for each site may be found in Table 2.1

2.7.1 Watershed delineation

Watershed boundaries are initially determined using topographic maps and DEMs. Then the surface boundary is adjusted based on storm sewer information. The watershed boundary is then field verified, preferably during several runoff events. Feedback from monitoring aids staff in determining the watershed. If the measured *Rv*s for a site are too high or too low it may mean the flow rating is incorrect or the watershed boundary is incorrect and both are verified.

2.7.2 Impervious cover

Impervious cover refers to any surface with a significantly reduced infiltration rate such as rooftops, roadways, sidewalks etc. Impervious cover for each catchment was determined using planimetric maps developed from aerial photographs. COA planimetric maps include buildings, roads, parking lots, driveways longer than 100 feet, and impervious sports courts. The planimetric maps do not include sidewalks or driveways shorter than 100 feet. Individual parcels of different land uses were sampled and the planimetric maps were compared with the aerial photographs. These analyses found that the omission of sidewalks and short driveways had a

Table 2.1: Summaries of drainage area, total impervious cover, connected impervious cover and land use for monitoring sites included in this report.

SITE	DA	TIC	DCIA	COM	INDU	NU	SFR	TRANS
ARA	9.00	0.528	0.384	0.75	0.00	0.05	0.00	0.20
BC	301.00	0.030	0.001	0.00	0.00	0.93	0.00	0.07
BCU	17.33	0.001	0.000	0.00	0.00	1.00	0.00	0.00
BI	30.90	0.950	0.945	0.96	0.00	0.00	0.01	0.03
BNI	4.93	0.585	0.448	0.00	0.00	0.13	0.00	0.87
BRI	3.04	0.803	0.772	0.98	0.00	0.00	0.00	0.02
BSI	4.63	0.642	0.514	0.00	0.00	0.00	0.00	1.00
BUA	11.59	0.820	0.743	0.88	0.00	0.00	0.00	0.12
CMI	100.03	0.547	0.404	0.66	0.00	0.00	0.13	0.21
CTI	17.89	0.389	0.242	0.00	0.00	0.01	0.74	0.25
CTJ	28.99	0.290	0.156	0.00	0.00	0.54	0.27	0.19
CTK	23.82	0.392	0.245	0.00	0.00	0.57	0.15	0.27
E7A	29.28	0.601	0.466	0.26	0.21	0.11	0.00	0.42
EBA	35.24	0.404	0.256	0.00	0.00	0.05	0.73	0.22
EHA	51.34	0.434	0.286	0.00	0.00	0.09	0.62	0.29
EMA	15.73	0.420	0.273	0.04	0.01	0.00	0.64	0.30
ERA	99.79	0.460	0.268	0.03	0.00	0.97	0.00	0.00
FPI	240.01	0.569	0.430	0.52	0.00	0.24	0.04	0.20
FSU	329.75	0.064	0.016	0.04	0.00	0.87	0.02	0.07
FWU	45.90	0.008	0.000	0.00	0.00	0.94	0.00	0.06
GPI	64.17	0.554	0.412	0.36	0.00	0.09	0.38	0.17
HI	3.00	0.500	0.354	1.00	0.00	0.00	0.00	0.00
HLA	329.14	0.391	0.244	0.03	0.00	0.06	0.71	0.21
HPA	43.04	0.450	0.301	0.08	0.00	0.07	0.48	0.38
JVI	7.02	0.944	0.937	0.15	0.00	0.00	0.00	0.85
LCA	209.87	0.225	0.107	0.00	0.00	0.13	0.75	0.12
LGA	481.07	0.007	0.000	0.00	0.00	0.87	0.12	0.01
LUA	13.65	0.974	0.974	0.44	0.03	0.12	0.00	0.41
MBA	202.94	0.609	0.476	0.27	0.34	0.24	0.00	0.15
MI	27.80	0.360	0.216	0.00	0.00	0.00	0.73	0.27
OFA	1.54	0.862	0.841	1.00	0.00	0.00	0.00	0.00
PA3	18.13	0.783	0.749	1.00	0.00	0.00	0.00	0.00
RO	62.90	0.264	0.136	0.00	0.00	0.02	0.76	0.22
RRI	15.72	0.305	0.168	0.00	0.00	0.65	0.06	0.28

Table 2.1(cont.): Summaries of drainage area, total impervious cover, connected impervious cover and land use for monitoring sites included in this report.

SITE	DA	TIC	DCIA	COM	INDU	NU	SFR	TRANS
S1M	5.87	0.882	0.864	0.00	0.98	0.00	0.00	0.01
SCA	5.56	0.409	0.261	0.00	0.00	0.00	0.76	0.24
SI	47.00	0.860	0.838	0.90	0.00	0.00	0.00	0.10
SWI	16.41	0.604	0.470	0.00	0.99	0.00	0.00	0.01
SWJ	5.82	0.838	0.813	0.00	0.99	0.00	0.00	0.01
TBA	49.42	0.452	0.304	0.00	0.00	0.00	0.76	0.24
TCA	40.71	0.374	0.228	0.00	0.00	0.17	0.61	0.22
TPA	41.60	0.415	0.267	0.02	0.00	0.17	0.61	0.20
W5A	6.66	0.871	0.851	0.51	0.00	0.00	0.00	0.49
WBA	0.93	0.306	0.134	0.00	0.00	0.99	0.00	0.01
WCI	16.85	0.930	0.921	0.36	0.16	0.00	0.00	0.49
WDI	0.10	0.950	0.945	0.00	1.00	0.00	0.00	0.00

minimal impact on impervious cover estimates for most land uses; however impervious cover in high- and medium-density single-family residential areas were underestimated by 10.97% and 10.44% respectively. These errors were addressed by adjusting the impervious areas for those land uses resulting in the following formula for the fraction of impervious cover:

$$TIC = \frac{P_{area} + 0.1097 \times SFR_{high} + 0.1044 \times SFR_{med}}{C_{area}} \qquad [2.3]$$

where IC is the decimal fraction of impervious cover in the catchment, P_{area} is the area of impervious features from the planimetric maps in the catchment, SFR_{high} is the area of high-density single-family residential land use in the catchment, SFR_{med} is the area of medium-density single-family residential land use in the catchment, and C_{area} is the area of the catchment. (Glick, 2009)

Equation 2.3 estimates total impervious cover (TIC) in the watershed but not all impervious cover is directly connected to the drainage system. Runoff from some impervious areas may flow over pervious areas and have a chance to infiltrate. This is called disconnected impervious cover. It has been suggested that using directly connected impervious area (DCIA) or effective impervious cover may provide better results when predicting runoff from rainfall (Sutherland, 1995). Disconnecting impervious cover is also a common practice in low-impact developments (LIDs). Directly measuring DCIA in the field is difficult because each impervious area needs to be examined. While this may be possible for very small areas, it quickly becomes cost and time prohibitive as the size of the watershed being monitored increases. Sutherland (1995) proposed five equations to estimate DCIA from TIC based on the degree of connectivity in the watershed using the following classes: totally connected, highly connected, average, somewhat disconnected, and extremely disconnected. SQE used these relationships to estimate DCIA for the watersheds in this study.

A final note on impervious cover: TIC as defined in equation 2.3 is based on the total or gross area draining to the monitoring point. COA development regulations require certain deductions in the gross site area before computing the fraction of impervious cover using the net site area. This difference in definition should be considered prior to applying the information in the report.

2.7.3 Land Use

Land use used in this report is derived from the COA land use maps and field verifications. The COA land use maps are parcel based, which may introduce some confusion when comparing these data to other studies. The most notable difference is that residential streets are not incorporated into the residential land use but are part of the transportation land use. The transportation land use includes all roadways with no distinction between different traffic volumes. The land uses considered are commercial (COM), industrial (INDU), non-urban (NU), single-family residential (SFR) and transportation (TRANS). Multi-family residential is included in COM. In addition to agricultural and undeveloped areas, NU also includes parks and cemeteries.

2.8 Site Statistical Summaries

After event EMCs and *Rv*s are computed, certain statistics are computed to aid further analyses. These include tests on data distribution, maximum, minimum, various representations of the mean and standard deviation. The following discussion will explain the various methods used and where they might be applied.

2.8.1 Data Distribution

Most environmental data do not fit a normal distribution and many studies have proposed that environmental data are generally log-normally distributed (Gilbert, 1987; Glick, 1992; COA 2006; Geosyntec and Wright Water, 2009). While this assumption is generally true, tests should be performed on the data to validate the assumption. The first step in assessing data distribution is a visual inspection of the data (Law and Kelton, 1982). This is easily done by first sorting the data from smallest to largest, and then plotting the data, x_i versus i/n where n is the number of points in the data set. This will result in the cumulative distribution of the data. The cumulative distribution function (CDF) for standard distributions (based on the parameters of the data) may be plotted on the same graph and visually compared to the distribution of the data. This has been done for EMCs from all COA sites aggregated together, sorted by pollutant (COA, 2006). It was clear from visual inspection that the aggregated data in that study fit a log-normal distribution better than a normal distribution and were treated as such.

The 2006 report on COA data did not test the distribution of EMCs from individual sites but assumed a log-normal distribution based on the CDF plots and the experience of the SQE staff (COA, 2006). In this study, tests for normal and log-normality for each site were conducted. Coefficients of skewness and kurtosis may be used to test for normality but other more powerful tests exist. (That not withstanding, skewness and kurtosis were computed for each dataset and the log-transformed dataset.) The W test developed by Shapiro and Wilk in 1965 is one of the most powerful tests for detecting departure from normal or log-normal distributions for small (n<50) datasets (Gilbert, 1987). The test is computed by:

$$W = \frac{\left(\sum_1^k a_i\left(x_{n-i+1} - x_i\right)\right)^2}{\sum_1^n\left(x_i - \bar{x}\right)^2} \qquad [2.4]$$

where k=n/2 if n is even and k=(n-1)/2 if n is odd and a_i are coefficients developed by Shapiro and Wilk (1965). Normality is rejected if the value of W is less than a value associated with n and the desired α. Log-normality is tested using the same test on log-transformed data.

The original version of the *W* test was designed for $3 \leq n \leq 50$ but the current versions for SAS have incorporated Royston approximations to adjust the upper limit to $n \leq 2000$ (SAS, 2009). Since SQE rarely has more that 50 EMCs for any site, the *W* test is the primary test for the distribution of data.

While it often is difficult to reject normality in favor of a lognormal distribution with small sample sizes (Motulsky, 2007), out of 738 sets of EMCs used in the study only 90 rejected log-normality in favor of normality. In 134 cases neither normality nor log-normality could be rejected at the 0.05 level and in 19 cases both normality and log-normality were rejected. In all other cases normality was rejected and log-normality was not. In the cases where neither distribution could be rejected, bootstrapping methods were used. The same was done with cases where both distributions were rejected. *W* tests were also conducted on the runoff-rainfall ratios and both distributions were rejected in all but four cases; in these cases, log-normality was not rejected but so many zero values had to be excluded to test for log-normality that log-normality could not be the proper distribution therefore neither distribution may be assumed for *Rv* data.

2.8.2 Estimating Mean and Variance

Gilbert (1987) states there are four methods to estimate the mean, μ, and the variance, σ^2, for log-normally distributed data. The first is the simple arithmetic sample mean, $\bar{x}$. This is easy to compute and is a statistically unbiased estimator of the mean regardless of the underlying distribution. It is also the minimum variance unbiased (MVU) estimator if the underlying distribution is normal. If the underlying distribution is lognormal, it is not the MVU estimator and will be sensitive to large values.

It is tempting to estimate μ of a log-normal distribution using the geometric mean; however, the geometric mean is a biased estimator of the true mean of the data (Gilbert, 1987). For reference, the geometric mean is computed by taking the arithmetic mean of the log-transformed data, then transforming with the exponential. While not recommended for use, the geometric mean is computed and reported with statistical results from tests on the log-transformed data.

A simplified method to estimate μ and σ^2 for log-normally distributed data that has long been used and was accepted by EPA as part of the NURP report and the BMP database project is presented in Equations 2.5 and 2.6 (Driscoll, et al., 1989; Geosyntec and Wright Water, 2009). This method is referenced in City data as the 'Driscoll mean' is defined as follows:

$$\hat{\mu} = e^{\left(\bar{y}+\frac{s_y^2}{2}\right)} \qquad [2.5]$$

and

$$\hat{\sigma}^2 = \hat{\mu}^2\left(e^{s_y^2} - 1\right) \qquad [2.6]$$

where $\hat{\mu}$ is the estimate of the mean of data from a lognormal distribution, $\hat{\sigma}^2$ is the estimate of the variance of data from a lognormal distribution, $\bar{y}$ is the arithmetic sample mean of the log transformed data, and s_y^2 is the sample variance of the log-transformed data.

This method has been used by COA in the past but it does have some drawbacks, mainly a positive bias. Kendall and Stuart (1961) found that the bias approaches zero as *n* becomes large. One advantage of this method is it is simple to compute; however, with current computing capacities this is not an issue. While this method has been widely used in the past to compute the mean of log-normally distributed data, the bias should be considered for small, highly variable datasets (Gilbert, 1987). The bias on the mean of Equation 2.5 may be estimated by:

$$\left(1 - \frac{\hat{\sigma}_y^2}{n}\right)^{-(n-1)/2} \exp\left(-\frac{n-1}{2n}\hat{\sigma}_y^2\right) \qquad [2.7]$$

For the data used in this report the bias was generally small, less than 1% in 635 cases; but it was over 5% in 28 cases including one with over 1000% upward bias. Failure to account for this bias could have unwanted influence on any subsequent analyses.

Finney (1941) and Sichel (1952, 1966) independently developed the minimum variance unbiased (MVE) method to compute the mean for log-normally distributed data. This method has been recommended by USEPA for computing the mean of log-normally distributed data (Singh, et al, 1997). This method has been referenced in City data as the 'Gilbert mean' and is defined as follows:

$$\hat{\mu} = \left(e^{\bar{y}}\right)\Psi_n\left(\frac{s_y^2}{2}\right) \qquad [2.8]$$

and

$$\hat{\sigma}^2 = \left(e^{(2\bar{y})}\right)\left[\Psi_n\left(2s_y^2\right) - \Psi_n\left(\frac{s_y^2(n-2)}{n-1}\right)\right] \qquad [2.9]$$

There are two other methods of computing summary statistics on data that are not dependent on the data distributions, a volume-weighted mean or using bootstrapping techniques. COA computes a volume-weighted mean (Eqn. 2.10) to estimate the mean watershed concentration. Two issues arise when using this method. First, the distribution of sampled events should follow the distribution of rainfall events; second, a variance cannot be computed. COA strives to minimize bias in its sample collection to address the first issue. The second issue is less problematic since other methods of analysis are used when the analyses are using the EMC and a variance is required.

$$MC = \frac{\sum_{i=1}^{n}\left(EMC_i\right)\left(RO_i\right)}{\sum_{i=1}^{n} RO_i} \qquad [2.10]$$

Bootstrap methods are a class of resampling techniques that can be used to compute summary statistics and their standard errors. The basic bootstrapping method consists of several steps. First, given a dataset of size *n*, select *n* samples, with replacement. Next, compute the desired statistics on the resampled dataset. Repeat several thousand times. The bootstrap statistics are the means of those statistics computing for each resampling. Bootstrapping has the advantages of being robust, not dependent on knowing an underlying distribution and the accuracy of the statistics may be computed in the form of a standard error. However, with small sample sets (n>30) inaccurate estimates of population statistics may result due to the multiple resampling magnifying variability. In these cases, parametric methods may be better if the underlying distribution is known (Geosyntec and Wright Water, 2009).

Any of these methods for estimating the mean of the data may be considered valid, depending on the application. For this report the 'Gilbert' method was used to compute means and variances (Eqns. 2.8 and 2.9) if the W test indicated the data followed a log-normal distribution as recommended by the USEPA (Singh et al., 1997). The computational complexity of this method is no longer an issue with current computing capacity and it eliminates the possibility of bias introduced by using the 'Driscoll' method. If the W test indicates a normal distribution, the arithmetic mean and variance are used. If the W test was inconclusive, both distributions either rejected or accepted, bootstrap estimates of the mean were use. This conforms to recommended BMP performance reporting methodology (Geosyntec and Wright Water, 2009) with the exception of the method use to compute the mean of log-normally distributed data. Using the 'Gilbert' method rather that the 'Driscoll' method will conform to USEPA recommendations (Singh et al., 1997) and, with the addition of bootstrapping in cases where the distribution is questionable, should not deviate appreciable (personal communications with Marcus Quigley, 2009).

Site summaries of the water quality data are presented in Table 2.2. Values in bold represent those used for further analyses in this report. Due to space limitations event data are not presented in this report but may be obtained from SQE in electronic form.

Table 2.2. Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
BOD	BC	21	1.45	16.55	6.71	7.22	3.95	0.547	0.9533	0.3929	6.11	7.34	4.73	0.644	0.9737	0.8131	**6.69**	**0.85**	**6.21**	**1.10**	6.17	7.41
BOD	BCU	12	1.09	6.50	2.10	3.01	1.98	0.657	0.7965	0.0085	**2.47**	**2.98**	**1.90**	**0.637**	**0.8944**	**0.1342**	3.01	0.54	2.30	0.73	2.51	2.00
BOD	BI	11	1.00	24.76	5.59	7.19	6.69	0.931	0.7960	0.0083	**4.84**	**7.29**	**7.20**	**0.987**	**0.9822**	**0.9770**	7.20	1.95	5.68	1.63	5.03	8.10
BOD	BNI	1	2.50	2.50	**2.50**	**2.50**	---	---	---	---	---	---	---	---	---	---	2.50	---	2.50	---	2.50	2.50
BOD	BRI	24	2.59	42.20	5.57	9.06	10.00	1.104	0.6252	0.0001	**6.33**	**8.46**	**7.15**	**0.846**	**0.9030**	**0.0249**	**9.06**	**2.01**	**5.66**	**0.98**	6.41	6.42
BOD	BSI	2	2.00	3.00	**2.50**	**2.50**	**0.71**	**0.283**	---	---	2.40	2.50	0.71	0.283	---	---	2.50	0.35	2.50	0.35	2.45	2.57
BOD	BUA	20	2.00	195.50	14.24	25.19	42.57	1.690	0.4852	0.0001	**13.36**	**22.01**	**25.92**	**1.178**	**0.9547**	**0.4443**	24.25	8.86	12.56	3.33	13.70	12.74
BOD	CMI	11	2.00	79.43	11.17	19.99	21.82	1.092	0.7246	0.0010	**12.35**	**19.98**	**21.65**	**1.083**	**0.9820**	**0.9764**	20.01	6.37	13.49	4.95	12.92	11.33
BOD	E7A	25	1.76	15.35	7.62	8.04	3.54	0.440	0.9561	0.3422	7.19	8.16	4.29	0.526	0.9401	0.1484	**8.05**	**0.69**	**7.55**	**0.63**	7.23	5.76
BOD	EBA	23	3.12	100.01	8.80	16.42	21.02	1.280	0.6050	0.0001	**10.34**	**15.20**	**15.27**	**1.005**	**0.9476**	**0.2608**	16.41	4.30	9.36	2.51	10.52	10.95
BOD	EHA	36	3.46	174.19	16.72	30.88	34.78	1.126	0.6875	0.0001	**20.04**	**29.66**	**30.86**	**1.040**	**0.9699**	**0.4227**	30.94	5.78	17.49	3.48	20.26	17.51
BOD	EMA	27	5.57	959.70	19.22	91.79	206.81	2.253	0.4443	0.0001	28.60	62.88	105.88	1.684	0.8554	0.0015	**92.45**	**39.94**	**21.98**	**5.24**	29.47	28.98
BOD	ERA	17	3.29	45.02	7.46	11.83	10.36	0.876	0.7238	0.0002	**9.09**	**11.45**	**8.34**	**0.729**	**0.9518**	**0.4860**	11.87	2.45	8.25	1.67	9.21	7.33
BOD	FPI	15	2.25	20.20	5.88	6.31	4.20	0.666	0.6783	0.0001	**5.45**	**6.20**	**3.27**	**0.528**	**0.9290**	**0.2635**	6.30	1.05	5.65	0.82	5.50	6.22
BOD	FSU	6	1.00	5.29	1.60	2.46	1.85	0.750	0.8011	0.0601	1.89	2.43	1.74	0.717	0.8591	0.1861	**2.46**	**0.68**	**2.07**	**1.05**	1.97	3.45
BOD	FWU	21	1.26	16.67	3.13	4.52	4.27	0.945	0.6356	0.0001	**3.44**	**4.30**	**3.11**	**0.723**	**0.9124**	**0.0612**	4.37	0.83	3.18	0.30	3.47	3.68
BOD	GPI	17	4.57	115.34	15.12	21.91	25.76	1.176	0.5821	0.0001	**15.18**	**20.50**	**17.41**	**0.849**	**0.9541**	**0.5253**	22.02	6.08	14.75	3.08	15.45	12.69
BOD	HI	18	2.35	23.21	6.65	8.23	5.48	0.665	0.8774	0.0236	**6.71**	**8.22**	**5.58**	**0.679**	**0.9805**	**0.9554**	8.30	1.25	7.00	1.75	6.79	7.41
BOD	HLA	21	1.75	25.72	8.07	9.30	5.90	0.635	0.8320	0.0021	**7.73**	**9.38**	**6.23**	**0.665**	**0.9475**	**0.3053**	9.29	1.26	7.88	0.80	7.80	9.64
BOD	HPA	18	1.00	40.40	9.78	14.16	11.99	0.847	0.8542	0.0099	**9.41**	**14.99**	**16.72**	**1.116**	**0.9637**	**0.6751**	14.17	2.76	10.21	2.87	9.66	16.30
BOD	JVI	30	2.42	25.33	5.34	7.16	4.83	0.674	0.8057	0.0001	**5.98**	**7.09**	**4.42**	**0.624**	**0.9628**	**0.3645**	7.16	0.86	5.73	1.14	6.01	5.52
BOD	LCA	25	1.88	20.00	6.00	7.59	4.96	0.653	0.9084	0.0280	**6.07**	**7.68**	**5.76**	**0.750**	**0.9621**	**0.4589**	7.60	0.97	6.28	1.43	6.12	5.80
BOD	LGA	7	1.00	1.56	1.08	1.17	0.21	0.177	0.8385	0.0962	1.15	1.17	0.19	0.167	0.8603	0.1523	**1.17**	**0.07**	**1.12**	**0.11**	1.15	1.27
BOD	LUA	30	5.00	188.00	12.68	21.47	33.83	1.576	0.4359	0.0001	13.77	18.67	16.41	0.879	0.8850	0.0037	**21.39**	**6.03**	**12.88**	**1.89**	13.91	9.45
BOD	MBA	27	3.09	78.43	8.30	16.41	18.47	1.125	0.6795	0.0001	10.69	15.39	15.06	0.979	0.9194	0.0383	**16.47**	**3.56**	**9.07**	**2.03**	10.84	10.10
BOD	MI	25	1.13	42.63	7.40	8.68	8.06	0.929	0.6642	0.0001	**6.44**	**8.68**	**7.50**	**0.864**	**0.9677**	**0.5880**	8.69	1.58	7.37	1.07	6.51	11.53
BOD	OFA	18	2.00	44.00	11.27	14.51	10.59	0.730	0.8810	0.0271	**11.08**	**14.84**	**12.43**	**0.838**	**0.9847**	**0.9853**	14.49	2.41	12.15	2.92	11.26	12.69
BOD	RO	15	1.00	10.54	**5.83**	**6.48**	**2.99**	**0.462**	**0.9314**	**0.2864**	5.46	6.81	4.83	0.710	0.8140	0.0056	6.61	0.70	6.55	1.14	5.54	6.97
BOD	S1M	28	1.44	22.00	6.33	8.35	5.83	0.698	0.8579	0.0014	**6.61**	**8.38**	**6.31**	**0.753**	**0.9693**	**0.5631**	8.35	1.07	6.57	1.32	6.67	6.06
BOD	SI	21	1.30	39.55	8.03	11.65	10.70	0.919	0.8106	0.0010	**7.73**	**11.92**	**12.83**	**1.076**	**0.9737**	**0.8128**	11.45	2.19	8.04	1.84	7.90	15.36

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
BOD	SWI	12	3.76	12.00	6.06	6.48	2.52	0.389	0.9098	0.2118	6.03	6.47	2.49	0.385	0.9349	0.4347	**6.49**	**0.69**	**6.18**	**1.08**	6.06	5.27
BOD	SWJ	11	1.42	39.00	12.05	13.52	10.13	0.749	0.8621	0.0613	9.81	14.33	13.51	0.943	0.9313	0.4245	**13.55**	**2.95**	**12.08**	**2.91**	10.16	8.03
BOD	TBA	30	1.12	98.00	7.08	12.71	17.76	1.398	0.5397	0.0001	**7.65**	**12.04**	**13.67**	**1.135**	**0.9816**	**0.8665**	12.67	3.16	7.71	2.14	7.77	8.55
BOD	TCA	21	2.01	15.20	4.79	5.36	3.29	0.614	0.8391	0.0028	**4.58**	**5.31**	**3.04**	**0.572**	**0.9689**	**0.7075**	5.27	0.68	4.43	0.73	4.61	4.65
BOD	TPA	24	1.96	104.07	12.70	18.75	20.84	1.111	0.6297	0.0001	**12.95**	**18.18**	**16.92**	**0.931**	**0.9846**	**0.9635**	18.72	4.19	12.94	2.40	13.13	10.27
BOD	W5A	29	6.40	186.00	27.74	41.34	43.17	1.044	0.7234	0.0001	**27.60**	**40.17**	**40.21**	**1.001**	**0.9730**	**0.6445**	41.32	7.84	27.39	4.56	27.96	24.67
BOD	WBA	22	2.01	74.89	6.47	13.41	17.86	1.332	0.6501	0.0001	**7.34**	**12.32**	**15.00**	**1.217**	**0.9247**	**0.0953**	13.39	3.74	6.68	1.69	7.52	7.95
BOD	WCI	32	2.94	84.81	7.97	16.05	18.24	1.137	0.6730	0.0001	**10.49**	**15.19**	**15.14**	**0.997**	**0.9433**	**0.0929**	16.54	3.27	9.12	2.15	10.61	8.88
CD	ARA	7	0.050	2.660	0.370	0.684	0.903	1.320	0.6841	0.0025	**0.331**	**0.671**	**0.842**	**1.256**	**0.9692**	**0.8927**	0.687	0.317	0.408	0.282	0.369	0.841
CD	BCU	25	0.300	2.387	0.500	0.594	0.399	0.671	0.3328	0.0001	0.538	0.576	0.218	0.378	0.4243	0.0001	**0.594**	**0.078**	**0.500**	**0.000**	0.539	0.507
CD	BNI	1	0.200	0.200	**0.200**	**0.200**	---	---	---	---	---	0.200	---	---	---	---	0.200	---	0.200	---	0.200	0.200
CD	BRI	14	0.150	2.728	0.264	0.570	0.689	1.210	0.6061	0.0001	0.374	0.519	0.459	0.884	0.8406	0.0166	**0.551**	**0.167**	**0.290**	**0.080**	0.383	0.547
CD	BSI	2	0.200	0.809	**0.505**	**0.505**	**0.431**	**0.854**	---	---	0.308	0.505	0.431	0.854	---	---	0.508	0.215	0.508	0.215	0.402	0.546
CD	BUA	11	0.250	8.291	0.508	1.175	2.368	2.015	0.4141	0.0001	0.538	0.851	0.897	1.054	0.7121	0.0007	**1.175**	**0.690**	**0.471**	**0.095**	0.562	0.823
CD	CMI	24	0.050	1.400	0.500	0.547	0.268	0.489	0.7509	0.0001	0.467	0.580	0.411	0.709	0.6734	0.0001	**0.547**	**0.054**	**0.500**	**0.006**	0.472	0.533
CD	CTI	15	0.012	0.602	0.094	0.169	0.195	1.151	0.7141	0.0004	**0.092**	**0.168**	**0.218**	**1.296**	**0.9544**	**0.5960**	0.168	0.049	0.096	0.041	0.096	0.091
CD	CTJ	17	0.060	0.888	0.351	0.357	0.229	0.642	0.9040	0.0793	0.271	0.374	0.332	0.889	0.8994	0.0664	**0.358**	**0.054**	**0.374**	**0.119**	0.276	0.471
CD	CTK	16	0.015	0.666	0.186	0.259	0.213	0.822	0.8760	0.0336	**0.158**	**0.289**	**0.376**	**1.301**	**0.9280**	**0.2269**	0.259	0.051	0.211	0.101	0.165	0.266
CD	E7A	26	0.500	3.133	0.500	0.725	0.597	0.824	0.4423	0.0001	0.619	0.691	0.339	0.491	0.5404	0.0001	**0.726**	**0.115**	**0.501**	**0.008**	0.621	0.751
CD	EBA	35	0.500	0.651	0.500	0.506	0.027	0.054	0.2399	0.0001	0.505	0.506	0.025	0.049	0.2432	0.0001	**0.506**	**0.005**	**0.500**	**0.000**	0.506	0.513
CD	EHA	34	0.199	2.986	0.500	0.703	0.576	0.819	0.5036	0.0001	0.595	0.675	0.358	0.530	0.7407	0.0001	**0.701**	**0.097**	**0.501**	**0.011**	0.597	0.784
CD	EMA	48	0.500	1.451	0.500	0.557	0.168	0.301	0.3906	0.0001	0.542	0.554	0.117	0.212	0.4464	0.0001	**0.563**	**0.024**	**0.500**	**0.001**	0.542	0.530
CD	ERA	20	0.300	32.710	1.782	3.641	7.032	1.932	0.4199	0.0001	**1.832**	**3.005**	**3.516**	**1.170**	**0.9418**	**0.2594**	3.651	1.536	1.782	0.413	1.879	4.580
CD	FPI	15	0.500	0.562	0.500	0.504	0.016	0.032	0.2841	0.0001	0.504	0.504	0.015	0.030	0.2841	0.0001	**0.504**	**0.004**	**0.500**	**0.000**	0.504	0.510
CD	FSU	29	0.012	0.973	0.500	0.418	0.212	0.507	0.7062	0.0001	0.302	0.520	0.669	1.286	0.6306	0.0001	**0.418**	**0.038**	**0.500**	**0.010**	0.308	0.481
CD	FWU	22	0.160	1.000	0.500	0.518	0.245	0.473	0.8306	0.0016	0.459	0.522	0.278	0.531	0.8600	0.0051	**0.497**	**0.049**	**0.496**	**0.024**	0.462	0.622
CD	GPI	18	0.200	3.091	0.777	1.161	0.959	0.826	0.7606	0.0004	**0.863**	**1.145**	**0.940**	**0.821**	**0.9257**	**0.1631**	1.158	0.220	0.788	0.173	0.877	1.257
CD	HLA	1	0.303	0.303	**0.303**	**0.303**	---	---	---	---	---	0.303	---	---	---	---	0.303	---	0.303	---	0.303	0.303
CD	HPA	27	0.500	0.819	0.500	0.512	0.061	0.120	0.1930	0.0001	0.509	0.511	0.049	0.095	0.1930	0.0001	0.512	0.012	0.500	0.000	0.509	0.508
CD	JVI	17	0.209	1.500	0.500	0.776	0.439	0.565	0.8866	0.0408	0.649	0.783	0.509	0.650	0.9215	0.1565	**0.777**	**0.103**	**0.677**	**0.237**	0.656	0.584

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
CD	LCA	12	0.200	0.534	0.250	0.329	0.136	0.413	0.7763	0.0051	0.304	0.328	0.132	0.401	0.8146	0.0138	**0.330**	**0.037**	**0.288**	**0.073**	0.306	0.299
CD	LGA	30	0.012	0.500	0.500	0.375	0.211	0.562	0.5673	0.0001	0.222	0.543	1.024	1.888	0.6052	0.0001	**0.379**	**0.037**	**0.499**	**0.016**	0.229	0.408
CD	LUA	7	0.250	2.683	0.276	1.068	1.099	1.029	0.7531	0.0137	0.569	1.050	1.221	1.163	0.7481	0.0121	**1.072**	**0.387**	**0.761**	**0.751**	0.625	0.965
CD	MBA	15	0.182	4.032	0.500	0.827	1.010	1.222	0.6291	0.0001	**0.528**	**0.764**	**0.726**	**0.950**	**0.9231**	**0.2146**	0.825	0.252	0.493	0.109	0.542	1.157
CD	OFA	11	0.184	2.551	0.500	0.591	0.671	1.135	0.5663	0.0001	**0.417**	**0.549**	**0.431**	**0.786**	**0.8569**	**0.0526**	0.591	0.195	0.433	0.132	0.428	0.426
CD	RRI	24	0.122	1.719	0.500	0.486	0.293	0.604	0.5101	0.0001	0.424	0.486	0.265	0.546	0.6904	0.0001	**0.485**	**0.059**	**0.500**	**0.008**	0.427	0.544
CD	S1M	29	0.500	1.430	0.500	0.607	0.224	0.369	0.5556	0.0001	0.578	0.602	0.175	0.291	0.5828	0.0001	**0.607**	**0.041**	**0.500**	**0.005**	0.579	0.572
CD	SCA	27	0.016	0.584	0.154	0.183	0.141	0.767	0.9057	0.0181	**0.128**	**0.197**	**0.216**	**1.096**	**0.9514**	**0.2317**	0.184	0.027	0.151	0.035	0.130	0.139
CD	SWI	13	0.200	1.009	0.557	0.635	0.319	0.502	0.8564	0.0345	**0.544**	**0.646**	**0.396**	**0.614**	**0.8712**	**0.0544**	0.637	0.085	0.620	0.190	0.551	0.700
CD	SWJ	13	0.200	1.768	0.483	0.561	0.427	0.761	0.7667	0.0028	**0.450**	**0.551**	**0.370**	**0.672**	**0.9392**	**0.4466**	0.563	0.114	0.461	0.083	0.457	0.472
CD	TBA	31	0.500	2.124	0.500	0.636	0.362	0.569	0.4300	0.0001	0.584	0.621	0.224	0.361	0.5172	0.0001	**0.636**	**0.064**	**0.500**	**0.004**	0.585	0.678
CD	TCA	20	0.050	1.000	0.311	0.442	0.312	0.706	0.8193	0.0017	**0.341**	**0.453**	**0.376**	**0.830**	**0.9296**	**0.1516**	0.443	0.068	0.345	0.085	0.346	0.630
CD	TPA	18	0.208	1.000	0.404	0.531	0.307	0.578	0.8131	0.0023	0.450	0.529	0.316	0.598	0.8866	0.0338	**0.530**	**0.070**	**0.434**	**0.105**	0.455	0.764
CD	W5A	18	0.250	1.924	0.670	0.824	0.416	0.504	0.9164	0.1116	0.728	0.826	0.434	0.525	0.9771	0.9151	**0.823**	**0.095**	**0.737**	**0.153**	0.733	0.769
CD	WBA	33	0.490	0.578	0.500	0.502	0.014	0.027	0.2090	0.0001	0.502	0.502	0.013	0.026	0.2124	0.0001	**0.502**	**0.002**	**0.500**	**0.000**	0.502	0.507
CD	WCI	36	0.289	3.382	0.501	0.733	0.603	0.823	0.4860	0.0001	0.625	0.700	0.350	0.500	0.6935	0.0001	**0.756**	**0.103**	**0.528**	**0.033**	0.627	0.614
COD	ARA	8	32.00	96.00	56.00	58.34	20.32	0.348	0.9550	0.7614	54.97	58.33	20.25	0.347	0.9870	0.9891	**58.50**	**6.68**	**55.87**	**8.29**	55.38	63.91
COD	BC	21	5.24	92.20	12.62	21.47	19.37	0.902	0.7081	0.0001	**16.25**	**20.86**	**16.06**	**0.770**	**0.9506**	**0.3490**	23.27	3.97	17.54	5.62	16.44	27.27
COD	BCU	24	12.18	94.02	49.50	52.12	23.55	0.452	0.9696	0.6561	45.73	53.21	30.93	0.581	0.9228	0.0675	**52.06**	**4.75**	**50.69**	**5.29**	46.02	57.22
COD	BI	12	5.68	64.17	25.57	26.79	17.06	0.637	0.9384	0.4774	20.86	27.66	22.20	0.803	0.9333	0.4169	**26.83**	**4.66**	**25.88**	**6.06**	21.36	22.60
COD	BNI	13	7.00	99.77	48.90	54.35	29.27	0.539	0.9403	0.4603	43.99	57.22	44.33	0.775	0.8752	0.0614	**54.52**	**7.78**	**52.44**	**16.05**	44.90	49.46
COD	BRI	24	10.54	212.91	56.93	70.14	48.43	0.690	0.8543	0.0026	**56.30**	**70.64**	**51.64**	**0.731**	**0.9783**	**0.8633**	70.88	9.62	58.52	6.74	56.84	54.96
COD	BSI	10	7.00	241.61	35.68	56.43	69.98	1.240	0.6937	0.0007	**30.88**	**54.61**	**64.59**	**1.183**	**0.9702**	**0.8925**	56.55	21.06	36.85	17.13	32.78	39.99
COD	BUA	21	34.00	520.00	97.71	147.39	127.90	0.868	0.7402	0.0001	**111.97**	**142.93**	**108.53**	**0.759**	**0.9501**	**0.3426**	147.10	27.26	101.57	17.68	113.29	97.58
COD	CMI	24	10.00	267.76	57.45	85.01	75.60	0.889	0.8025	0.0003	**58.30**	**86.24**	**87.82**	**1.018**	**0.9697**	**0.6586**	84.79	15.20	62.30	13.11	59.28	45.73
COD	CTI	17	17.24	168.78	38.68	58.38	47.30	0.810	0.7484	0.0004	**45.32**	**56.83**	**40.98**	**0.721**	**0.9204**	**0.1498**	58.59	11.17	39.86	9.27	45.93	39.67
COD	CTJ	24	21.93	313.34	64.00	88.21	70.04	0.794	0.8035	0.0003	**68.11**	**87.07**	**66.65**	**0.766**	**0.9673**	**0.6006**	88.04	14.08	65.14	11.32	68.82	58.86
COD	CTK	22	15.47	139.76	36.66	49.00	33.73	0.688	0.8206	0.0011	**40.07**	**48.37**	**31.67**	**0.655**	**0.9368**	**0.1698**	48.95	7.04	36.56	6.83	40.42	35.14
COD	E7A	26	23.35	180.51	74.76	77.49	41.53	0.536	0.9346	0.0996	66.68	78.09	46.55	0.596	0.9710	0.6487	**77.50**	**8.05**	**70.71**	**9.69**	67.09	62.81
COD	EBA	37	21.91	372.84	54.08	88.81	81.72	0.920	0.7090	0.0001	66.62	85.32	66.46	0.779	0.9315	0.0250	**88.82**	**13.32**	**55.25**	**8.46**	67.07	58.77

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
COD	EHA	37	22.78	452.36	117.01	146.54	107.22	0.732	0.8835	0.0011	**110.68**	**150.45**	**133.80**	**0.889**	**0.9723**	**0.4729**	146.49	17.41	122.76	20.15	111.61	102.20
COD	EMA	48	46.83	1286.69	116.15	183.33	241.83	1.319	0.5355	0.0001	121.59	165.64	149.06	0.900	0.8979	0.0005	**180.22**	**33.88**	**110.89**	**13.80**	122.38	126.21
COD	ERA	21	32.24	245.72	60.46	81.22	51.42	0.633	0.7952	0.0006	**69.71**	**80.06**	**44.17**	**0.552**	**0.9503**	**0.3444**	81.11	10.95	63.29	9.20	70.18	62.96
COD	FPI	15	19.09	81.23	47.08	47.62	18.80	0.395	0.9632	0.7474	43.69	47.87	20.99	0.438	0.9596	0.6852	**47.55**	**4.76**	**46.24**	**5.58**	43.96	40.36
COD	FSU	31	19.31	126.25	45.20	53.61	28.11	0.524	0.9173	0.0200	**46.75**	**53.70**	**29.84**	**0.556**	**0.9548**	**0.2115**	53.64	4.97	48.51	7.06	46.96	54.46
COD	FWU	24	7.09	125.14	**49.08**	**51.88**	**27.81**	**0.536**	**0.9593**	**0.4238**	42.85	54.40	40.96	0.753	0.8872	0.0116	49.88	4.95	48.63	4.67	43.28	49.51
COD	GPI	18	55.83	408.76	113.26	146.47	91.58	0.625	0.8428	0.0065	**123.92**	**145.21**	**86.00**	**0.592**	**0.9542**	**0.4943**	146.19	20.89	119.38	26.26	125.03	102.29
COD	HI	19	11.04	145.22	20.28	37.51	37.87	1.009	0.7218	0.0001	25.50	35.68	32.60	0.914	0.8684	0.0135	**40.08**	**8.54**	**22.42**	**7.61**	25.96	31.83
COD	HLA	21	5.71	135.94	22.68	30.80	28.51	0.926	0.7171	0.0001	**22.71**	**30.22**	**25.17**	**0.833**	**0.9827**	**0.9585**	30.76	6.07	23.59	6.08	23.03	23.93
COD	HPA	28	18.45	370.26	73.61	86.84	70.59	0.813	0.7339	0.0001	**68.67**	**85.53**	**61.62**	**0.720**	**0.9825**	**0.9058**	86.95	13.11	72.73	11.75	69.21	66.37
COD	JVI	33	11.21	148.32	59.04	63.94	34.09	0.533	0.9542	0.1766	54.08	65.63	44.12	0.672	0.9435	0.0861	**63.88**	**5.90**	**57.82**	**6.79**	54.40	56.47
COD	LCA	28	10.33	147.00	61.86	63.37	37.44	0.591	0.9464	0.1605	51.01	65.51	50.97	0.778	0.9460	0.1566	**63.38**	**6.94**	**58.65**	**9.48**	51.47	48.99
COD	LGA	31	2.50	81.08	14.29	17.67	14.73	0.834	0.6645	0.0001	13.99	17.57	12.97	0.738	0.9320	0.0498	**17.25**	**2.56**	**14.21**	**0.74**	14.09	22.78
COD	LUA	31	34.84	544.00	92.45	140.86	120.56	0.856	0.7528	0.0001	**107.57**	**137.05**	**104.90**	**0.765**	**0.9560**	**0.2279**	141.01	21.39	98.93	16.03	108.42	91.29
COD	MBA	27	32.00	227.65	62.43	81.39	55.84	0.686	0.7878	0.0001	67.34	80.00	50.12	0.627	0.9166	0.0327	**81.55**	**10.76**	**62.57**	**7.68**	67.77	57.51
COD	MI	26	10.00	223.50	32.56	38.41	39.81	1.037	0.4882	0.0001	30.38	36.43	23.48	0.644	0.9094	0.0255	**38.48**	**7.67**	**31.91**	**3.58**	30.60	30.26
COD	OFA	18	40.18	266.83	96.04	117.87	70.15	0.595	0.8913	0.0406	**98.69**	**117.92**	**74.44**	**0.631**	**0.9456**	**0.3598**	117.71	16.06	99.03	24.44	99.68	97.18
COD	RO	16	5.00	107.26	26.70	36.36	29.17	0.802	0.8870	0.0499	**25.47**	**37.65**	**37.29**	**0.990**	**0.9709**	**0.8527**	36.37	6.64	29.47	8.03	26.11	23.38
COD	RRI	32	22.87	585.86	55.67	105.88	113.55	1.072	0.6818	0.0001	**72.36**	**101.12**	**94.48**	**0.934**	**0.9361**	**0.0582**	103.71	19.32	58.88	16.13	73.13	51.96
COD	S1M	29	9.07	224.97	57.37	82.60	60.42	0.731	0.9041	0.0123	**59.90**	**87.01**	**86.80**	**0.998**	**0.9486**	**0.1687**	82.55	10.97	62.01	16.37	60.69	61.29
COD	SCA	27	23.31	340.66	130.93	141.24	75.10	0.532	0.9603	0.3750	118.66	145.68	100.80	0.692	0.9337	0.0852	**141.49**	**14.42**	**133.62**	**22.96**	119.57	132.10
COD	SI	22	7.73	81.17	22.87	29.53	21.63	0.732	0.8328	0.0017	**23.23**	**29.32**	**21.71**	**0.740**	**0.9634**	**0.5612**	31.41	4.68	23.75	5.37	23.48	20.71
COD	SWI	13	4.88	98.21	**43.26**	**49.26**	**26.95**	**0.547**	**0.9493**	**0.5883**	38.81	53.35	46.07	0.864	0.8328	0.0172	49.38	7.19	46.07	7.60	39.80	38.39
COD	SWJ	13	7.21	259.00	69.76	86.58	72.75	0.840	0.8793	0.0699	55.56	94.83	111.67	1.178	0.9311	0.3525	**86.96**	**19.41**	**70.10**	**18.13**	57.97	48.78
COD	TBA	30	2.50	247.57	63.75	77.15	64.32	0.834	0.8699	0.0017	**51.13**	**85.74**	**106.59**	**1.243**	**0.9433**	**0.1113**	77.13	11.50	60.74	11.78	52.04	59.99
COD	TCA	27	11.18	72.43	32.96	37.41	17.03	0.455	0.9253	0.0531	33.63	37.58	18.46	0.491	0.9686	0.5662	**37.05**	**3.09**	**32.62**	**3.94**	33.77	41.08
COD	TPA	24	28.64	347.09	60.64	80.01	63.51	0.794	0.6088	0.0001	**67.39**	**77.44**	**42.93**	**0.554**	**0.9263**	**0.0808**	79.88	12.78	62.87	6.49	67.78	61.41
COD	W5A	30	67.94	1470.00	146.88	238.68	279.01	1.169	0.5767	0.0001	168.40	222.09	184.02	0.829	0.9161	0.0212	**238.06**	**49.79**	**151.85**	**30.83**	169.97	136.66
COD	WBA	33	9.22	319.63	40.06	57.76	57.73	1.000	0.6653	0.0001	**42.24**	**56.10**	**47.35**	**0.844**	**0.9887**	**0.9760**	57.65	9.92	41.89	6.76	42.61	37.33
COD	WCI	34	5.98	565.73	79.51	127.45	125.67	0.986	0.7344	0.0001	**87.01**	**127.98**	**131.38**	**1.027**	**0.9390**	**0.0577**	132.24	21.25	85.82	13.81	88.02	75.07

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
CU	ARA	9	2.900	28.000	**14.000**	**14.856**	**6.900**	**0.464**	**0.9537**	**0.7308**	12.671	15.441	10.030	0.650	0.8251	0.0394	14.860	2.167	14.373	1.917	12.958	14.350
CU	BC	22	1.000	33.000	10.000	9.727	8.300	0.853	0.6768	0.0001	6.674	10.500	11.685	1.113	0.8127	0.0008	**9.544**	**1.619**	**9.650**	**0.905**	6.815	10.510
CU	BCU	25	1.000	7.677	3.000	3.087	1.432	0.464	0.7370	0.0001	2.749	3.130	1.671	0.534	0.7321	0.0001	**3.090**	**0.280**	**3.000**	**0.021**	2.764	2.652
CU	BI	12	1.000	11.719	5.046	5.985	3.144	0.525	0.9224	0.3067	5.023	6.185	4.191	0.678	0.8781	0.0828	**5.992**	**0.857**	**5.283**	**1.064**	5.112	5.351
CU	BNI	1	2.505	2.505	**2.505**	**2.505**	**---**	**---**	**---**	**---**	---	2.505	---	---	---	---	2.505	---	2.505	---	2.505	2.505
CU	BRI	14	1.056	18.925	4.014	6.581	6.180	0.939	0.8289	0.0116	**4.042**	**6.660**	**7.578**	**1.138**	**0.9140**	**0.1801**	6.777	1.513	5.016	2.515	4.194	6.139
CU	BSI	2	5.000	7.094	**6.047**	**6.047**	**1.481**	**0.245**	**---**	**---**	5.865	6.047	1.481	0.245	---	---	6.057	0.740	6.057	0.740	5.956	6.189
CU	BUA	13	7.988	60.000	22.275	26.055	18.079	0.694	0.8723	0.0562	20.159	26.284	20.465	0.779	0.9116	0.1929	**26.137**	**4.821**	**22.611**	**6.689**	20.582	21.849
CU	CMI	24	5.000	45.800	16.786	20.358	12.091	0.594	0.8960	0.0178	**17.035**	**20.466**	**13.248**	**0.647**	**0.9750**	**0.7887**	20.322	2.428	17.086	2.815	17.167	12.795
CU	CTI	17	1.698	18.581	4.795	6.412	4.444	0.693	0.7992	0.0020	**5.290**	**6.329**	**4.005**	**0.633**	**0.9577**	**0.5889**	6.431	1.048	4.862	0.814	5.346	4.998
CU	CTJ	24	3.040	29.219	8.487	9.710	6.757	0.696	0.8255	0.0008	**7.888**	**9.621**	**6.513**	**0.677**	**0.9484**	**0.2501**	9.692	1.358	8.074	1.653	7.954	9.332
CU	CTK	22	2.065	18.741	3.681	6.402	4.455	0.696	0.8237	0.0012	5.114	6.358	4.527	0.712	0.8967	0.0255	**6.399**	**0.937**	**4.739**	**1.879**	5.165	5.065
CU	E7A	26	2.328	68.464	13.846	19.833	15.521	0.783	0.7364	0.0001	**15.705**	**19.750**	**14.560**	**0.737**	**0.9278**	**0.0688**	19.840	2.986	14.298	1.863	15.845	19.319
CU	EBA	35	3.000	19.330	4.601	6.507	4.184	0.643	0.8072	0.0001	5.496	6.419	3.808	0.593	0.9010	0.0042	**6.512**	**0.699**	**4.845**	**0.803**	5.521	4.883
CU	EHA	34	1.000	83.620	11.613	15.303	14.519	0.949	0.6687	0.0001	**11.223**	**15.461**	**14.083**	**0.911**	**0.9638**	**0.3118**	15.256	2.425	12.030	1.323	11.330	11.338
CU	EMA	48	3.713	69.100	12.619	14.735	10.665	0.724	0.7195	0.0001	**12.311**	**14.551**	**9.045**	**0.622**	**0.9792**	**0.5449**	14.985	1.517	12.724	0.863	12.354	12.026
CU	ERA	20	11.974	513.902	28.116	63.830	111.195	1.742	0.4486	0.0001	35.603	53.190	54.410	1.023	0.8873	0.0240	**64.002**	**24.273**	**31.748**	**7.798**	36.338	73.695
CU	FPI	15	1.000	14.400	**8.912**	**8.018**	**4.204**	**0.524**	**0.9551**	**0.6072**	6.371	8.627	7.312	0.848	0.8369	0.0114	7.998	1.064	8.116	1.751	6.504	6.701
CU	FSU	31	0.530	23.882	3.000	4.648	4.785	1.030	0.5635	0.0001	3.470	4.491	3.570	0.795	0.8790	0.0022	**4.651**	**0.848**	**3.183**	**0.304**	3.499	3.657
CU	FWU	23	1.000	23.083	3.586	4.613	4.824	1.046	0.6813	0.0001	**3.189**	**4.480**	**4.164**	**0.930**	**0.9564**	**0.3950**	4.720	0.971	3.473	0.584	3.237	4.210
CU	GPI	18	17.184	341.632	64.940	98.104	85.914	0.876	0.8431	0.0066	**67.005**	**99.325**	**99.642**	**1.003**	**0.9594**	**0.5901**	97.887	19.597	72.373	25.264	68.515	82.496
CU	HI	19	1.000	33.000	10.000	8.644	7.700	0.891	0.7751	0.0005	5.410	9.538	12.164	1.275	0.8506	0.0069	**10.094**	**2.004**	**9.402**	**1.349**	5.578	9.120
CU	HLA	19	1.000	51.070	10.000	15.179	12.210	0.804	0.7994	0.0011	10.945	16.055	15.899	0.990	0.8899	0.0321	**15.268**	**2.726**	**10.693**	**1.795**	11.172	14.362
CU	HPA	27	3.000	15.634	6.947	7.106	3.512	0.494	0.9267	0.0575	6.253	7.137	3.857	0.540	0.9332	0.0830	**7.126**	**0.676**	**6.848**	**1.107**	6.284	5.846
CU	JVI	33	2.983	103.413	12.452	17.555	17.901	1.020	0.6183	0.0001	**13.003**	**17.031**	**13.937**	**0.818**	**0.9793**	**0.7663**	17.518	3.073	12.419	2.102	13.111	14.776
CU	LCA	20	1.000	68.917	5.069	11.154	15.064	1.351	0.5861	0.0001	**6.522**	**10.486**	**11.945**	**1.139**	**0.9621**	**0.5871**	11.187	3.288	5.982	1.810	6.682	19.199
CU	LGA	31	0.066	15.361	3.000	2.811	2.605	0.927	0.5149	0.0001	1.868	3.293	4.382	1.331	0.7293	0.0001	**2.815**	**0.442**	**2.998**	**0.053**	1.903	2.932
CU	LUA	24	1.825	79.587	**30.159**	**30.399**	**22.865**	**0.752**	**0.9269**	**0.0833**	18.291	36.775	55.706	1.515	0.8550	0.0027	30.353	4.613	29.475	5.055	18.846	23.247
CU	MBA	18	2.126	40.000	7.163	11.994	9.785	0.816	0.8083	0.0020	**9.039**	**11.889**	**9.594**	**0.807**	**0.9663**	**0.7268**	11.969	2.231	8.437	2.521	9.180	8.965
CU	MI	26	0.000	35.125	6.167	7.912	8.344	1.055	0.8302	0.0006	4.927	9.378	13.486	1.438	0.9077	0.0314	**7.921**	**1.608**	**5.679**	**2.032**	5.053	7.961

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
CU	OFA	13	1.016	31.802	6.558	10.448	10.178	0.974	0.8577	0.0359	**5.645**	**11.175**	**15.372**	**1.376**	**0.9191**	**0.2437**	10.500	2.716	7.683	4.418	5.963	7.228
CU	RO	15	1.000	14.934	**10.000**	**7.646**	**4.223**	**0.552**	**0.9064**	**0.1191**	5.770	8.410	8.104	0.964	0.7955	0.0032	7.225	1.044	8.233	2.009	5.920	6.964
CU	RRI	33	3.000	55.111	7.114	11.166	11.399	1.021	0.6895	0.0001	7.849	10.654	9.412	0.883	0.9208	0.0193	**11.220**	**2.024**	**7.172**	**1.226**	7.923	7.779
CU	S1M	29	3.597	34.017	8.027	11.490	8.181	0.712	0.8132	0.0001	**9.286**	**11.347**	**7.760**	**0.684**	**0.9428**	**0.1187**	11.486	1.485	8.527	1.816	9.351	8.995
CU	SCA	27	2.516	25.029	8.429	10.885	6.743	0.619	0.9004	0.0137	**8.822**	**11.026**	**8.007**	**0.726**	**0.9527**	**0.2485**	10.909	1.295	8.810	1.978	8.896	7.999
CU	SI	22	1.000	15.391	6.309	6.544	4.675	0.714	0.8874	0.0168	4.498	7.031	7.751	1.103	0.8742	0.0094	**6.559**	**0.929**	**6.418**	**2.453**	4.592	6.470
CU	SWI	13	1.000	22.551	**9.343**	**10.498**	**5.566**	**0.530**	**0.9636**	**0.8087**	8.482	11.312	9.227	0.816	0.8235	0.0131	10.525	1.486	9.696	1.521	8.675	10.503
CU	SWJ	13	1.124	81.300	18.465	23.928	23.138	0.967	0.8318	0.0167	**12.478**	**29.191**	**46.444**	**1.591**	**0.8846**	**0.0823**	24.031	6.174	18.995	4.594	13.369	11.717
CU	TBA	31	1.000	55.750	5.406	8.776	10.748	1.225	0.6505	0.0001	**5.379**	**8.499**	**9.732**	**1.145**	**0.9853**	**0.9360**	8.788	1.897	5.475	1.250	5.460	5.089
CU	TCA	21	1.000	19.013	3.226	4.758	4.424	0.930	0.7397	0.0001	**3.460**	**4.644**	**3.939**	**0.848**	**0.9709**	**0.7529**	4.749	0.942	3.371	0.576	3.509	5.771
CU	TPA	20	1.000	31.612	6.212	7.923	6.875	0.868	0.7771	0.0004	**5.617**	**8.188**	**8.052**	**0.983**	**0.9510**	**0.3821**	7.937	1.498	6.431	0.987	5.725	6.718
CU	W5A	20	7.328	130.000	26.566	32.939	26.802	0.814	0.7260	0.0001	**26.087**	**32.391**	**22.908**	**0.707**	**0.9826**	**0.9635**	33.001	5.850	26.448	5.269	26.373	25.217
CU	WBA	33	3.000	241.244	4.868	12.664	41.134	3.248	0.2162	0.0001	5.479	7.660	7.171	0.936	0.6671	0.0001	**12.579**	**7.016**	**4.998**	**0.747**	5.535	6.572
CU	WCI	36	3.793	248.200	13.119	27.732	43.226	1.559	0.5156	0.0001	15.705	24.599	28.019	1.139	0.9189	0.0117	**29.084**	**7.250**	**13.606**	**3.962**	15.904	14.192
DP	BCU	23	0.010	0.109	0.016	0.023	0.022	0.944	0.6126	0.0001	0.018	0.022	0.015	0.677	0.8624	0.0046	**0.023**	**0.004**	**0.016**	**0.003**	0.018	0.030
DP	BNI	10	0.037	0.150	0.066	0.072	0.033	0.451	0.8556	0.0677	0.066	0.072	0.029	0.408	0.9665	0.8570	**0.072**	**0.010**	**0.066**	**0.008**	0.067	0.093
DP	BRI	20	0.005	0.391	0.091	0.119	0.096	0.807	0.8731	0.0133	**0.080**	**0.133**	**0.160**	**1.197**	**0.9209**	**0.1032**	0.119	0.021	0.096	0.018	0.082	0.138
DP	BSI	7	0.033	0.083	0.055	0.055	0.017	0.312	0.9757	0.9361	0.052	0.055	0.017	0.316	0.9902	0.9937	**0.055**	**0.006**	**0.054**	**0.009**	0.052	0.061
DP	BUA	18	0.010	1.640	0.195	0.301	0.375	1.248	0.6542	0.0001	**0.167**	**0.318**	**0.441**	**1.386**	**0.9695**	**0.7873**	0.332	0.086	0.213	0.059	0.173	0.216
DP	CMI	16	0.101	0.667	0.201	0.242	0.144	0.596	0.7852	0.0017	**0.211**	**0.238**	**0.121**	**0.507**	**0.9538**	**0.5527**	0.241	0.035	0.206	0.029	0.213	0.158
DP	CTI	17	0.053	0.293	0.107	0.132	0.071	0.543	0.8557	0.0131	**0.115**	**0.131**	**0.068**	**0.518**	**0.9496**	**0.4510**	0.132	0.017	0.108	0.018	0.116	0.167
DP	CTJ	24	0.042	0.307	0.106	0.123	0.062	0.500	0.9020	0.0238	**0.109**	**0.123**	**0.064**	**0.516**	**0.9744**	**0.7757**	0.123	0.012	0.114	0.017	0.110	0.130
DP	CTK	22	0.020	0.427	0.100	0.129	0.100	0.777	0.7768	0.0002	**0.101**	**0.129**	**0.097**	**0.757**	**0.9754**	**0.8310**	0.129	0.021	0.104	0.020	0.102	0.204
DP	E7A	25	0.085	1.145	0.138	0.192	0.207	1.080	0.4301	0.0001	0.154	0.179	0.102	0.572	0.7836	0.0001	**0.192**	**0.041**	**0.141**	**0.006**	0.155	0.219
DP	EBA	37	0.074	1.215	0.190	0.271	0.252	0.932	0.6474	0.0001	0.208	0.258	0.183	0.709	0.9093	0.0054	**0.271**	**0.041**	**0.189**	**0.018**	0.210	0.209
DP	EHA	36	0.100	0.802	0.263	0.348	0.216	0.620	0.8893	0.0018	**0.286**	**0.349**	**0.240**	**0.689**	**0.9522**	**0.1225**	0.348	0.036	0.279	0.054	0.287	0.265
DP	EMA	48	0.057	2.177	0.222	0.355	0.410	1.155	0.6424	0.0001	0.238	0.333	0.317	0.952	0.9518	0.0473	**0.351**	**0.058**	**0.220**	**0.024**	0.239	0.209
DP	ERA	17	0.051	0.535	0.142	0.187	0.119	0.639	0.8494	0.0105	**0.157**	**0.186**	**0.114**	**0.616**	**0.9912**	**0.9996**	0.187	0.028	0.159	0.032	0.158	0.196
DP	FPI	15	0.044	0.126	0.074	0.083	0.026	0.315	0.9290	0.2638	0.079	0.083	0.027	0.324	0.9510	0.5398	**0.083**	**0.007**	**0.077**	**0.010**	0.079	0.088
DP	FSU	31	0.008	0.263	0.056	0.074	0.059	0.802	0.8719	0.0015	**0.053**	**0.076**	**0.075**	**0.986**	**0.9828**	**0.8843**	0.074	0.011	0.057	0.014	0.054	0.037

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
DP	FWU	20	0.010	0.139	0.024	0.040	0.035	0.887	0.8119	0.0013	**0.028**	**0.039**	**0.036**	**0.924**	**0.9281**	**0.1418**	0.039	0.007	0.027	0.008	0.028	0.043
DP	GPI	18	0.052	0.594	0.124	0.170	0.133	0.784	0.7557	0.0004	**0.136**	**0.166**	**0.112**	**0.675**	**0.9592**	**0.5871**	0.169	0.030	0.126	0.021	0.137	0.153
DP	HLA	2	0.047	0.082	**0.065**	**0.065**	**0.025**	**0.387**	**---**	**---**	0.060	0.065	0.025	0.387	---	---	0.065	0.013	0.065	0.013	0.062	0.050
DP	HPA	28	0.091	1.181	0.168	0.264	0.227	0.862	0.6787	0.0001	0.209	0.254	0.172	0.676	0.9216	0.0381	**0.264**	**0.042**	**0.187**	**0.043**	0.211	0.215
DP	JVI	15	0.010	0.256	0.079	0.093	0.074	0.802	0.8906	0.0686	0.063	0.099	0.108	1.089	0.9363	0.3378	**0.092**	**0.019**	**0.073**	**0.023**	0.065	0.090
DP	LCA	25	0.005	0.328	0.080	0.104	0.085	0.819	0.8695	0.0042	**0.070**	**0.114**	**0.135**	**1.184**	**0.9438**	**0.1810**	0.104	0.017	0.082	0.016	0.071	0.089
DP	LGA	30	0.001	0.098	0.017	0.023	0.020	0.882	0.7929	0.0001	**0.016**	**0.024**	**0.025**	**1.029**	**0.9484**	**0.1533**	0.023	0.004	0.016	0.004	0.016	0.021
DP	LUA	25	0.083	1.080	0.270	0.432	0.315	0.730	0.8730	0.0050	**0.319**	**0.442**	**0.401**	**0.907**	**0.9374**	**0.1288**	0.432	0.062	0.328	0.100	0.324	0.366
DP	MBA	27	0.024	0.519	0.129	0.181	0.133	0.733	0.9159	0.0315	**0.131**	**0.189**	**0.185**	**0.981**	**0.9560**	**0.2991**	0.182	0.026	0.151	0.043	0.133	0.113
DP	OFA	17	0.012	0.329	0.111	0.137	0.097	0.706	0.8936	0.0531	0.102	0.145	0.133	0.923	0.9433	0.3597	**0.138**	**0.023**	**0.111**	**0.029**	0.104	0.128
DP	RRI	32	0.051	0.675	0.196	0.238	0.150	0.630	0.9134	0.0138	**0.194**	**0.240**	**0.171**	**0.710**	**0.9810**	**0.8275**	0.236	0.026	0.200	0.039	0.196	0.227
DP	S1M	29	0.034	0.390	0.090	0.120	0.073	0.607	0.8239	0.0002	**0.104**	**0.120**	**0.067**	**0.563**	**0.9836**	**0.9189**	0.120	0.013	0.100	0.018	0.104	0.120
DP	SCA	27	0.023	2.385	0.237	0.413	0.520	1.259	0.7014	0.0001	**0.218**	**0.414**	**0.597**	**1.442**	**0.9807**	**0.8769**	0.415	0.101	0.225	0.074	0.223	0.443
DP	SWI	10	0.034	0.210	0.062	0.073	0.050	0.689	0.6686	0.0004	**0.063**	**0.071**	**0.038**	**0.525**	**0.8855**	**0.1508**	0.073	0.015	0.062	0.008	0.064	0.061
DP	SWJ	12	0.010	0.092	0.019	0.036	0.030	0.847	0.8171	0.0148	0.024	0.036	0.034	0.954	0.8518	0.0387	**0.036**	**0.008**	**0.026**	**0.015**	0.025	0.031
DP	TBA	29	0.013	0.758	0.096	0.147	0.154	1.046	0.6890	0.0001	**0.101**	**0.146**	**0.144**	**0.988**	**0.9845**	**0.9354**	0.147	0.028	0.104	0.020	0.102	0.145
DP	TCA	19	0.033	0.382	0.138	0.137	0.083	0.610	0.8878	0.0295	**0.112**	**0.140**	**0.099**	**0.709**	**0.9312**	**0.1819**	0.137	0.018	0.133	0.016	0.114	0.139
DP	TPA	20	0.080	0.550	0.153	0.215	0.141	0.654	0.8085	0.0012	**0.180**	**0.212**	**0.129**	**0.605**	**0.9233**	**0.1145**	0.216	0.031	0.161	0.028	0.182	0.237
DP	W5A	26	0.056	2.250	0.169	0.338	0.445	1.318	0.5889	0.0001	**0.208**	**0.313**	**0.329**	**1.050**	**0.9472**	**0.1989**	0.338	0.086	0.184	0.057	0.212	0.235
DP	WBA	34	0.054	0.455	0.134	0.169	0.098	0.581	0.8286	0.0001	**0.147**	**0.168**	**0.092**	**0.549**	**0.9553**	**0.1771**	0.169	0.017	0.136	0.010	0.147	0.189
DP	WCI	31	0.020	0.756	0.083	0.147	0.176	1.198	0.6364	0.0001	**0.094**	**0.137**	**0.137**	**1.005**	**0.9393**	**0.0789**	0.148	0.032	0.086	0.021	0.095	0.156
FCOL	BC	22	10	169609	6625	16633	35938	2.161	0.4264	0.0001	4831	25755	81537	3.166	0.8330	0.0017	**15281**	**6960**	**6137**	**1028**	5240	23443
FCOL	BCU	10	2500	120000	13241	22364	34919	1.561	0.5431	0.0001	**11051**	**20114**	**24499**	**1.218**	**0.9254**	**0.4043**	22421	10495	13148	4462	11767	16691
FCOL	BI	11	3780	49634	21412	24575	15060	0.613	0.9567	0.7295	18488	26158	23440	0.896	0.8953	0.1618	**24607**	**4366**	**23968**	**7212**	19096	20344
FCOL	BNI	2	970	2800	**1885**	**1885**	**1294**	**0.686**	**---**	**---**	1422	1885	1294	0.686	---	---	1893	647	1893	647	1648	2143
FCOL	BRI	19	106	101000	4742	20229	31878	1.576	0.6630	0.0001	**4029**	**29313**	**104660**	**3.570**	**0.9623**	**0.6192**	20451	7130	6601	4983	4515	41252
FCOL	BSI	3	372	8800	400	3191	4858	1.523	0.7525	0.0055	575	2648	3576	1.350	0.7672	0.0384	**3213**	**2289**	**2611**	**3708**	1094	660
FCOL	BUA	15	5000	186000	24970	53722	59889	1.115	0.7720	0.0016	**28171**	**53894**	**73158**	**1.357**	**0.9462**	**0.4674**	53189	13956	31090	13440	29463	58219
FCOL	CMI	9	23897	335708	90948	110349	99661	0.903	0.7996	0.0202	**75885**	**109759**	**99969**	**0.911**	**0.9373**	**0.5539**	110462	31615	86467	30961	79168	72583
FCOL	E7A	24	2390	396220	29967	79573	98746	1.241	0.7381	0.0001	**37744**	**84823**	**143788**	**1.695**	**0.9532**	**0.3175**	79305	19817	34410	16131	39080	67863

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
FCOL	EBA	19	10180	604125	70242	105261	134577	1.279	0.6215	0.0001	**62194**	**102561**	**120345**	**1.173**	**0.9756**	**0.8803**	106200	29974	67710	15398	63892	79987
FCOL	EHA	25	500	683121	90081	130462	135275	1.037	0.6890	0.0001	77296	177433	308616	1.739	0.7799	0.0001	**130553**	**26447**	**95773**	**27403**	79989	129774
FCOL	EMA	22	7471	563101	57465	91840	117804	1.283	0.6244	0.0001	**50900**	**92722**	**124709**	**1.345**	**0.9604**	**0.4974**	91885	24855	63991	28066	52342	54568
FCOL	ERA	13	764	76665	16399	25658	26484	1.032	0.8496	0.0281	**10027**	**32384**	**64694**	**1.998**	**0.9095**	**0.1807**	23611	7227	14746	10814	11048	24155
FCOL	FPI	14	3000	64739	15023	22697	21247	0.936	0.8071	0.0061	**14486**	**23019**	**24999**	**1.086**	**0.9627**	**0.7670**	22738	5456	15865	5358	14987	23518
FCOL	FSU	3	5144	70445	10000	28530	36381	1.275	0.8054	0.1276	10976	26398	29777	1.128	0.9254	0.4715	**28700**	**17157**	**24716**	**27468**	15359	17062
FCOL	FWU	17	200	68787	11175	16912	18236	1.078	0.8270	0.0049	**7245**	**24051**	**52395**	**2.178**	**0.9266**	**0.1906**	13213	2974	9574	4238	7809	16968
FCOL	GPI	15	2224	324892	56974	69661	80692	1.158	0.7309	0.0005	**34163**	**81818**	**136288**	**1.666**	**0.9492**	**0.5122**	69533	20148	52039	20970	36317	44165
FCOL	HI	17	70	94523	11494	21491	26302	1.224	0.7836	0.0012	5208	52532	208699	3.973	0.8751	0.0265	**22326**	**5751**	**15531**	**6037**	6061	24118
FCOL	HLA	20	63	964860	15338	97801	248438	2.540	0.4287	0.0001	**12024**	**94416**	**358194**	**3.794**	**0.9437**	**0.2810**	98217	54156	14578	4592	13453	108548
FCOL	HPA	11	25194	350000	99937	127692	95160	0.745	0.8806	0.1058	96195	129126	105464	0.817	0.9735	0.9191	**128496**	**27762**	**109161**	**36582**	98863	104072
FCOL	JVI	27	24	21000	1186	3742	6278	1.677	0.6217	0.0001	**797**	**4538**	**15969**	**3.519**	**0.9614**	**0.3969**	3758	1210	1044	461	853	3634
FCOL	LCA	23	571	3800000	12113	201864	788693	3.907	0.2654	0.0001	**13537**	**88279**	**319557**	**3.620**	**0.9422**	**0.2000**	200854	161205	17309	9821	14774	39362
FCOL	LGA	6	165	11139	1260	3371	4321	1.282	0.7853	0.0432	**1194**	**3488**	**5268**	**1.510**	**0.9751**	**0.9245**	3366	1602	2235	2076	1460	5772
FCOL	LUA	24	34	567884	24565	56685	116140	2.049	0.4691	0.0001	14803	96793	356303	3.681	0.9050	0.0275	**56477**	**23332**	**22945**	**6501**	16095	25401
FCOL	MBA	19	213	153377	6625	31877	42607	1.337	0.7572	0.0003	**9163**	**43349**	**121939**	**2.813**	**0.9509**	**0.4088**	32185	9526	14724	11819	10002	14299
FCOL	MI	25	1109	175625	31250	41920	40297	0.961	0.8440	0.0014	**22669**	**52624**	**92512**	**1.758**	**0.9201**	**0.0515**	41978	7891	32716	8474	23470	49676
FCOL	OFA	9	2098	349861	8298	48824	113516	2.325	0.4670	0.0001	**9805**	**30282**	**53171**	**1.756**	**0.8775**	**0.1478**	49124	36054	9876	16836	11252	33566
FCOL	RO	15	114	65841	6706	13107	17637	1.346	0.7054	0.0003	**5133**	**16891**	**35452**	**2.099**	**0.9450**	**0.4497**	12928	4119	7192	2545	5587	14927
FCOL	S1M	27	3958	249292	22422	41271	55628	1.348	0.6585	0.0001	**21800**	**39119**	**52648**	**1.346**	**0.9685**	**0.5636**	41460	10763	20705	6404	22287	37460
FCOL	SI	21	69	76868	11180	17017	18976	1.115	0.7548	0.0001	8014	25155	55264	2.197	0.8829	0.0165	**16530**	**3903**	**11200**	**3531**	8485	17032
FCOL	SWI	6	2196	168365	22648	44010	63461	1.442	0.7253	0.0113	**12786**	**44974**	**73796**	**1.641**	**0.9491**	**0.7329**	43933	23607	27494	25995	16268	36062
FCOL	SWJ	11	100	266184	2400	35260	79445	2.253	0.5074	0.0001	**3341**	**35064**	**112630**	**3.212**	**0.9695**	**0.8810**	35278	23146	6802	8524	4292	24612
FCOL	TBA	27	2400	164429	32193	48698	51465	1.057	0.8269	0.0004	**22942**	**55847**	**103724**	**1.857**	**0.9333**	**0.0833**	48850	9886	29181	13603	23734	51886
FCOL	TCA	15	217	192250	34026	47716	55889	1.171	0.8254	0.0079	**12591**	**87292**	**275701**	**3.158**	**0.9124**	**0.1471**	46067	13028	30643	22954	14529	74389
FCOL	TPA	14	200	604821	39860	105092	157934	1.503	0.6418	0.0001	**32720**	**174751**	**473063**	**2.707**	**0.8852**	**0.0690**	105327	41125	53061	29865	37327	75280
FCOL	W5A	24	13586	600000	94816	135318	138987	1.027	0.7927	0.0002	**80468**	**141388**	**183566**	**1.298**	**0.9615**	**0.4699**	134994	27952	90792	24640	82421	84840
FCOL	WBA	19	522	72618	8929	22539	23923	1.061	0.8133	0.0018	**10323**	**27683**	**52797**	**1.907**	**0.9477**	**0.3615**	22695	5352	14062	7639	10899	25874
FCOL	WCI	26	1562	286818	14406	37520	59140	1.576	0.5752	0.0001	**17430**	**35834**	**56073**	**1.565**	**0.9805**	**0.8849**	38404	11615	17005	8311	17932	21817
FSTR	BC	22	88	26965	5490	8778	8860	1.009	0.8576	0.0046	3077	14783	43903	2.970	0.8972	0.0262	**8109**	**1754**	**4898**	**2708**	3319	8221

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
FSTR	BCU	10	5000	296888	44442	88741	109713	1.236	0.6714	0.0004	**43666**	**88399**	**118831**	**1.344**	**0.9222**	**0.3755**	88638	32995	49201	31971	47045	36471
FSTR	BI	12	1976	27139	20493	17597	9195	0.523	0.8023	0.0100	12734	20096	21293	1.060	0.6944	0.0007	**17617**	**2528**	**20387**	**3043**	13243	15601
FSTR	BNI	2	1510	4800	**3155**	**3155**	**2326**	**0.737**	**---**	**---**	2255	3155	2326	0.737	---	---	3170	1162	3170	1162	2692	3619
FSTR	BRI	19	613	32450	5366	7358	7606	1.034	0.7775	0.0005	**4419**	**7687**	**9646**	**1.255**	**0.9740**	**0.8528**	7410	1696	5491	1942	4553	9242
FSTR	BSI	3	1984	11600	10500	8028	5263	0.656	0.8345	0.1999	5248	8446	7513	0.890	0.7922	0.0959	**8050**	**2493**	**8603**	**3918**	6229	8822
FSTR	BUA	16	6239	379301	34550	63534	89200	1.404	0.5620	0.0001	**36618**	**59559**	**67566**	**1.134**	**0.9650**	**0.7526**	63997	20381	38933	10687	37779	53231
FSTR	CMI	10	12199	206412	77384	76566	53387	0.697	0.8422	0.0469	**58920**	**79035**	**64020**	**0.810**	**0.9240**	**0.3913**	76555	16115	71986	12735	60719	78415
FSTR	E7A	24	29526	398214	104636	128932	100729	0.781	0.8241	0.0008	**98426**	**128270**	**102698**	**0.801**	**0.9657**	**0.5630**	128711	20325	101307	15261	99529	138596
FSTR	EBA	20	18801	670866	134442	183304	172785	0.943	0.7852	0.0005	**120902**	**188829**	**206502**	**1.094**	**0.9755**	**0.8639**	183722	37676	142621	38063	123683	144885
FSTR	EHA	30	60924	1434705	302920	424815	370879	0.873	0.8205	0.0002	**296376**	**426878**	**420292**	**0.985**	**0.9693**	**0.5213**	424780	66036	299653	42138	300044	386918
FSTR	EMA	25	64440	1188404	402626	506196	374684	0.740	0.9033	0.0216	343970	547135	624188	1.141	0.9056	0.0243	**506729**	**73371**	**434706**	**108990**	350526	465480
FSTR	ERA	13	17041	182215	49255	60665	42798	0.705	0.7941	0.0058	**49731**	**60163**	**38968**	**0.648**	**0.9746**	**0.9427**	59598	12024	48106	7539	50474	50661
FSTR	FPI	15	30000	258127	77768	89325	56609	0.634	0.7955	0.0032	**76430**	**88320**	**49489**	**0.560**	**0.9650**	**0.7777**	89196	14171	75362	14448	77177	105412
FSTR	FSU	6	5648	487788	24445	103232	189734	1.838	0.5957	0.0004	**25159**	**80995**	**127957**	**1.580**	**0.9357**	**0.6244**	102965	70610	44914	69254	31408	36736
FSTR	FWU	17	4213	167147	21860	50721	50904	1.004	0.7866	0.0013	**30142**	**51957**	**63767**	**1.227**	**0.9337**	**0.2507**	45164	11317	24375	8204	31151	66592
FSTR	GPI	16	72823	468455	152674	171397	99415	0.580	0.8077	0.0034	**150381**	**169618**	**86262**	**0.509**	**0.9638**	**0.7310**	171195	23920	149767	18635	151525	130245
FSTR	HI	18	1753	109826	14940	23996	28017	1.168	0.7688	0.0006	**12033**	**25866**	**40381**	**1.561**	**0.9590**	**0.5815**	25042	6132	16590	6250	12576	23484
FSTR	HLA	20	1228	194882	15386	32646	47395	1.452	0.6410	0.0001	**14039**	**34464**	**61636**	**1.788**	**0.9641**	**0.6278**	32749	10336	17053	4904	14710	35935
FSTR	HPA	13	42212	538793	301458	253509	157940	0.623	0.9337	0.3805	190507	267460	239726	0.896	0.8908	0.1002	**254987**	**42280**	**265365**	**77495**	195657	191201
FSTR	JVI	30	263	87931	9036	13867	17969	1.296	0.6335	0.0001	**7697**	**14706**	**21522**	**1.464**	**0.9616**	**0.3400**	13832	3203	8482	1724	7868	13428
FSTR	LCA	21	610	193248	22116	38345	44075	1.149	0.7430	0.0001	**19291**	**46258**	**81679**	**1.766**	**0.9513**	**0.3610**	38243	9373	24092	8358	20143	40270
FSTR	LGA	6	61	152507	2351	27029	61486	2.275	0.5171	0.0001	**1363**	**18887**	**45458**	**2.407**	**0.9284**	**0.5676**	26942	22907	7592	21613	2423	60580
FSTR	LUA	28	550	660000	37000	78179	127380	1.629	0.5574	0.0001	**28247**	**105485**	**280539**	**2.660**	**0.9499**	**0.1975**	78374	23734	41909	16366	29668	33344
FSTR	MBA	20	10000	205000	36239	51020	47067	0.923	0.7757	0.0004	**36174**	**50319**	**45606**	**0.906**	**0.9732**	**0.8195**	51130	10252	37387	11122	36785	45242
FSTR	MI	25	2273	109571	30375	36358	28347	0.780	0.9186	0.0476	**24289**	**40039**	**48015**	**1.199**	**0.9476**	**0.2215**	36401	5547	30787	7278	24788	32130
FSTR	OFA	12	2762	51187	17287	20150	16275	0.808	0.8783	0.0834	13509	21180	22247	1.050	0.9442	0.5548	**20171**	**4428**	**17209**	**5416**	14042	17175
FSTR	RO	16	2309	139005	32611	42627	37190	0.872	0.7822	0.0016	**28511**	**46605**	**53210**	**1.142**	**0.9049**	**0.0964**	41557	8583	32340	5303	29425	30830
FSTR	S1M	27	23351	1484516	133828	267583	336139	1.256	0.7160	0.0001	**139692**	**263503**	**376360**	**1.428**	**0.9693**	**0.5836**	268807	65081	134988	44613	143087	212322
FSTR	SI	21	1426	100672	4654	15525	24144	1.555	0.6271	0.0001	**6530**	**14205**	**22923**	**1.614**	**0.9317**	**0.1487**	14861	4974	5418	2561	6785	14589
FSTR	SWI	7	3789	400000	20642	78490	142558	1.816	0.5516	0.0001	**25638**	**64599**	**94117**	**1.457**	**0.9245**	**0.5051**	78817	50027	31352	39621	29638	43990

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
FSTR	SWJ	10	5600	400000	20869	63077	120735	1.914	0.5247	0.0001	**20851**	**50485**	**78093**	**1.547**	**0.9006**	**0.2225**	63303	36273	23279	16595	22923	61240
FSTR	TBA	25	4000	609119	73161	102636	119293	1.162	0.5847	0.0001	68806	103856	109503	1.054	0.9151	0.0396	**102733**	**23371**	**74217**	**11275**	69966	154661
FSTR	TCA	15	7559	165682	31733	46991	42872	0.912	0.8291	0.0089	**31585**	**47373**	**47723**	**1.007**	**0.9767**	**0.9418**	56923	13886	38639	13655	32470	58527
FSTR	TPA	16	5384	1000428	102000	184787	263567	1.426	0.6287	0.0001	**85120**	**191033**	**304562**	**1.594**	**0.9663**	**0.7765**	184404	63752	103356	24376	89730	105436
FSTR	W5A	22	1188	2000000	256591	429073	479918	1.119	0.7743	0.0002	204422	636890	1404963	2.206	0.8634	0.0059	**428726**	**100596**	**267057**	**93781**	215774	268589
FSTR	WBA	19	4869	325281	26949	53818	73088	1.358	0.6237	0.0001	**28979**	**52184**	**68222**	**1.307**	**0.9759**	**0.8849**	54319	16273	32787	14549	29916	41891
FSTR	WCI	28	16956	623061	78291	113857	118573	1.041	0.6808	0.0001	**77151**	**113458**	**115387**	**1.017**	**0.9682**	**0.5323**	117920	23256	90397	24453	78235	93636
NH3	ARA	9	0.500	12.600	0.500	2.076	3.973	1.914	0.4676	0.0001	0.858	1.527	1.789	1.172	0.6480	0.0003	**2.084**	**1.262**	**0.660**	**0.642**	0.918	1.381
NH3	BC	22	0.021	0.275	0.058	0.076	0.058	0.759	0.7936	0.0004	**0.061**	**0.075**	**0.054**	**0.716**	**0.9637**	**0.5676**	0.084	0.015	0.062	0.016	0.061	0.066
NH3	BCU	24	0.010	0.147	0.045	0.053	0.035	0.659	0.9185	0.0541	0.041	0.055	0.046	0.836	0.9379	0.1468	**0.053**	**0.007**	**0.047**	**0.006**	0.042	0.043
NH3	BI	12	0.018	0.568	0.201	0.249	0.207	0.831	0.8886	0.1131	0.139	0.290	0.414	1.426	0.8915	0.1233	**0.249**	**0.056**	**0.215**	**0.091**	0.148	0.234
NH3	BNI	1	0.085	0.085	**0.085**	**0.085**	---	---	---	---	---	0.085	---	---	---	---	0.085	---	0.085	---	0.085	0.085
NH3	BRI	24	0.040	0.631	0.224	0.244	0.158	0.648	0.9213	0.0623	0.194	0.248	0.190	0.766	0.9791	0.8789	**0.253**	**0.031**	**0.229**	**0.041**	0.196	0.186
NH3	BSI	2	0.060	0.176	**0.118**	**0.118**	**0.082**	**0.695**	---	---	0.088	0.118	0.082	0.695	---	---	0.118	0.041	0.118	0.041	0.103	0.126
NH3	BUA	16	0.114	0.770	0.227	0.301	0.197	0.656	0.7946	0.0023	**0.253**	**0.297**	**0.177**	**0.596**	**0.9325**	**0.2669**	0.322	0.049	0.245	0.046	0.255	0.224
NH3	CMI	22	0.068	1.476	0.500	0.517	0.348	0.674	0.8281	0.0014	0.410	0.532	0.421	0.792	0.9084	0.0439	**0.516**	**0.073**	**0.472**	**0.052**	0.415	0.348
NH3	CTI	17	0.055	0.755	0.219	0.252	0.153	0.607	0.7849	0.0013	**0.216**	**0.253**	**0.150**	**0.592**	**0.9422**	**0.3457**	0.253	0.036	0.228	0.028	0.218	0.259
NH3	CTJ	24	0.088	1.225	0.243	0.282	0.219	0.775	0.5791	0.0001	**0.240**	**0.274**	**0.146**	**0.534**	**0.9225**	**0.0664**	0.281	0.044	0.236	0.027	0.242	0.277
NH3	CTK	22	0.081	0.628	0.237	0.266	0.136	0.509	0.9113	0.0503	0.235	0.268	0.144	0.537	0.9674	0.6503	**0.266**	**0.028**	**0.243**	**0.039**	0.236	0.323
NH3	E7A	26	0.020	0.707	0.184	0.225	0.163	0.725	0.8982	0.0143	**0.167**	**0.236**	**0.221**	**0.939**	**0.9623**	**0.4378**	0.225	0.031	0.183	0.036	0.170	0.206
NH3	EBA	37	0.010	2.040	0.230	0.331	0.387	1.170	0.6349	0.0001	0.199	0.365	0.515	1.412	0.9149	0.0079	**0.331**	**0.063**	**0.236**	**0.030**	0.203	0.239
NH3	EHA	36	0.044	1.330	0.293	0.368	0.308	0.838	0.8342	0.0001	**0.260**	**0.380**	**0.385**	**1.014**	**0.9700**	**0.4263**	0.368	0.051	0.295	0.040	0.263	0.278
NH3	EMA	48	0.010	2.901	0.130	0.302	0.512	1.692	0.5180	0.0001	**0.142**	**0.288**	**0.468**	**1.628**	**0.9907**	**0.9660**	0.298	0.071	0.146	0.036	0.144	0.189
NH3	ERA	21	0.012	0.696	0.123	0.195	0.185	0.953	0.7573	0.0002	**0.132**	**0.199**	**0.207**	**1.042**	**0.9579**	**0.4740**	0.194	0.040	0.131	0.032	0.134	0.138
NH3	FPI	15	0.013	0.422	0.157	0.188	0.131	0.695	0.9275	0.2499	0.132	0.208	0.226	1.083	0.9127	0.1489	**0.188**	**0.033**	**0.167**	**0.042**	0.136	0.172
NH3	FSU	31	0.008	0.293	0.055	0.062	0.056	0.892	0.6963	0.0001	**0.047**	**0.063**	**0.054**	**0.856**	**0.9483**	**0.1402**	0.062	0.010	0.053	0.005	0.047	0.056
NH3	FWU	23	0.013	0.152	0.044	0.052	0.038	0.717	0.8588	0.0039	**0.041**	**0.052**	**0.039**	**0.744**	**0.9744**	**0.7927**	0.054	0.007	0.044	0.010	0.042	0.036
NH3	GPI	18	0.068	1.220	0.149	0.279	0.305	1.095	0.7204	0.0001	**0.178**	**0.265**	**0.266**	**1.007**	**0.9063**	**0.0739**	0.278	0.069	0.158	0.054	0.182	0.166
NH3	HI	19	0.054	2.134	0.168	0.309	0.470	1.521	0.4944	0.0001	**0.188**	**0.271**	**0.261**	**0.965**	**0.9140**	**0.0876**	0.319	0.085	0.181	0.036	0.191	0.356
NH3	HLA	21	0.046	0.662	0.120	0.203	0.166	0.821	0.8311	0.0020	**0.150**	**0.201**	**0.170**	**0.848**	**0.9619**	**0.5555**	0.202	0.035	0.143	0.042	0.152	0.239

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
NH3	HPA	25	0.010	1.166	0.148	0.246	0.301	1.225	0.7642	0.0001	**0.102**	**0.291**	**0.613**	**2.109**	**0.9432**	**0.1753**	0.247	0.059	0.150	0.063	0.106	0.165
NH3	JVI	32	0.083	0.589	0.308	0.322	0.152	0.474	0.9489	0.1338	0.282	0.326	0.186	0.571	0.9486	0.1318	**0.322**	**0.026**	**0.304**	**0.042**	0.283	0.322
NH3	LCA	21	0.024	0.570	0.180	0.189	0.123	0.650	0.8777	0.0133	**0.152**	**0.193**	**0.145**	**0.749**	**0.9553**	**0.4277**	0.189	0.026	0.171	0.042	0.154	0.144
NH3	LGA	31	0.003	0.099	0.028	0.029	0.021	0.717	0.9003	0.0073	**0.021**	**0.031**	**0.031**	**1.004**	**0.9356**	**0.0625**	0.030	0.004	0.028	0.004	0.022	0.029
NH3	LUA	25	0.138	1.570	0.388	0.505	0.387	0.766	0.7709	0.0001	**0.402**	**0.495**	**0.343**	**0.694**	**0.9425**	**0.1693**	0.506	0.076	0.382	0.055	0.405	0.327
NH3	MBA	25	0.010	0.543	0.161	0.223	0.167	0.749	0.8975	0.0162	**0.152**	**0.247**	**0.292**	**1.179**	**0.9307**	**0.0904**	0.223	0.033	0.187	0.053	0.155	0.172
NH3	MI	26	0.020	0.580	0.179	0.211	0.166	0.785	0.8989	0.0148	**0.141**	**0.228**	**0.266**	**1.166**	**0.9418**	**0.1479**	0.211	0.032	0.170	0.042	0.144	0.313
NH3	OFA	18	0.050	0.596	0.203	0.231	0.140	0.604	0.9107	0.0886	0.192	0.234	0.156	0.666	0.9795	0.9451	**0.231**	**0.032**	**0.207**	**0.028**	0.194	0.207
NH3	RO	16	0.062	0.586	0.162	0.170	0.125	0.735	0.7084	0.0002	**0.141**	**0.167**	**0.101**	**0.605**	**0.9429**	**0.3865**	0.197	0.038	0.156	0.026	0.143	0.140
NH3	RRI	32	0.080	2.880	0.215	0.428	0.568	1.328	0.5989	0.0001	0.261	0.390	0.410	1.051	0.9282	0.0350	**0.417**	**0.097**	**0.216**	**0.052**	0.264	0.219
NH3	S1M	29	0.034	0.542	0.122	0.173	0.117	0.676	0.8571	0.0011	**0.140**	**0.173**	**0.122**	**0.705**	**0.9623**	**0.3737**	0.173	0.021	0.131	0.031	0.141	0.149
NH3	SCA	27	0.007	0.531	0.161	0.172	0.131	0.760	0.9102	0.0230	0.112	0.205	0.283	1.378	0.8857	0.0064	**0.172**	**0.025**	**0.157**	**0.033**	0.115	0.142
NH3	SI	22	0.030	1.160	0.139	0.199	0.236	1.183	0.5970	0.0001	**0.133**	**0.192**	**0.186**	**0.970**	**0.9723**	**0.7628**	0.191	0.048	0.138	0.029	0.135	0.253
NH3	SWI	13	0.019	0.672	0.167	0.234	0.201	0.859	0.8900	0.0977	0.145	0.250	0.299	1.195	0.9413	0.4735	**0.235**	**0.053**	**0.188**	**0.097**	0.151	0.193
NH3	SWJ	13	0.020	0.810	**0.370**	**0.370**	**0.227**	**0.613**	**0.9676**	**0.8640**	0.262	0.428	0.479	1.120	0.8361	0.0189	0.371	0.060	0.375	0.076	0.272	0.315
NH3	TBA	28	0.022	0.560	0.197	0.219	0.173	0.793	0.9004	0.0117	0.141	0.239	0.301	1.259	0.9223	0.0396	**0.218**	**0.032**	**0.184**	**0.047**	0.144	0.204
NH3	TCA	26	0.019	0.416	0.094	0.119	0.104	0.876	0.7838	0.0001	**0.086**	**0.118**	**0.104**	**0.885**	**0.9713**	**0.6585**	0.126	0.021	0.091	0.015	0.087	0.112
NH3	TPA	23	0.050	0.900	0.235	0.298	0.239	0.800	0.8785	0.0093	**0.210**	**0.305**	**0.300**	**0.984**	**0.9427**	**0.2055**	0.299	0.049	0.231	0.092	0.213	0.266
NH3	W5A	29	0.017	1.590	0.324	0.413	0.327	0.791	0.8444	0.0006	**0.296**	**0.446**	**0.474**	**1.061**	**0.9365**	**0.0811**	0.413	0.059	0.326	0.047	0.300	0.308
NH3	WBA	33	0.010	1.137	0.332	0.406	0.312	0.770	0.8808	0.0018	0.283	0.450	0.520	1.157	0.9173	0.0155	**0.405**	**0.054**	**0.320**	**0.057**	0.287	0.341
NH3	WCI	34	0.158	3.425	0.698	0.941	0.775	0.824	0.8082	0.0001	**0.706**	**0.932**	**0.775**	**0.832**	**0.9793**	**0.7491**	0.960	0.131	0.704	0.138	0.712	0.662
NO23	ARA	8	0.200	1.890	0.430	0.574	0.540	0.941	0.5786	0.0001	0.444	0.544	0.357	0.655	0.8016	0.0298	**0.577**	**0.177**	**0.433**	**0.091**	0.456	0.489
NO23	BC	22	0.020	0.503	0.100	0.137	0.117	0.853	0.8052	0.0006	**0.097**	**0.140**	**0.137**	**0.976**	**0.9444**	**0.2431**	0.166	0.041	0.107	0.016	0.099	0.139
NO23	BCU	24	0.025	3.117	0.314	0.589	0.746	1.267	0.7368	0.0001	**0.273**	**0.626**	**1.084**	**1.731**	**0.9756**	**0.8037**	0.587	0.150	0.312	0.122	0.283	0.227
NO23	BI	12	0.038	0.477	**0.308**	**0.278**	**0.137**	**0.494**	**0.9568**	**0.7377**	0.225	0.296	0.234	0.792	0.8333	0.0230	0.278	0.038	0.296	0.045	0.230	0.296
NO23	BNI	11	0.184	1.022	0.316	0.426	0.297	0.696	0.7697	0.0038	**0.350**	**0.419**	**0.261**	**0.623**	**0.8958**	**0.1640**	0.427	0.086	0.335	0.092	0.356	0.555
NO23	BRI	24	0.248	1.175	0.524	0.576	0.259	0.449	0.9279	0.0877	0.520	0.576	0.271	0.470	0.9542	0.3329	**0.574**	**0.052**	**0.537**	**0.085**	0.522	0.535
NO23	BSI	6	0.140	0.583	0.266	0.335	0.200	0.597	0.8307	0.1089	0.279	0.334	0.203	0.608	0.8975	0.3594	**0.335**	**0.074**	**0.311**	**0.125**	0.287	0.256
NO23	BUA	20	0.127	4.349	0.833	1.076	1.029	0.956	0.7661	0.0003	**0.726**	**1.090**	**1.124**	**1.031**	**0.9692**	**0.7379**	1.056	0.214	0.808	0.102	0.741	0.784
NO23	CMI	24	0.025	2.431	0.410	0.627	0.526	0.839	0.7396	0.0001	0.463	0.663	0.640	0.965	0.8507	0.0023	**0.626**	**0.106**	**0.446**	**0.062**	0.470	0.365

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
NO23	CTI	17	0.149	1.362	0.476	0.567	0.347	0.612	0.9042	0.0799	0.467	0.571	0.386	0.675	0.9600	0.6306	**0.569**	**0.081**	**0.487**	**0.126**	0.472	0.605
NO23	CTJ	24	0.120	1.163	0.557	0.568	0.275	0.484	0.9685	0.6292	0.492	0.580	0.353	0.608	0.9360	0.1330	**0.568**	**0.055**	**0.565**	**0.066**	0.495	0.569
NO23	CTK	22	0.163	1.828	0.449	0.661	0.491	0.743	0.8480	0.0031	**0.508**	**0.659**	**0.520**	**0.789**	**0.9550**	**0.3951**	0.660	0.103	0.481	0.106	0.514	0.878
NO23	E7A	26	0.264	1.711	0.706	0.765	0.358	0.468	0.9180	0.0404	**0.688**	**0.767**	**0.372**	**0.486**	**0.9796**	**0.8658**	0.765	0.070	0.713	0.054	0.690	0.571
NO23	EBA	37	0.138	2.598	0.460	0.608	0.489	0.805	0.7479	0.0001	**0.482**	**0.595**	**0.423**	**0.710**	**0.9668**	**0.3276**	0.608	0.080	0.451	0.069	0.484	0.473
NO23	EHA	36	0.158	2.110	0.627	0.744	0.503	0.676	0.8500	0.0002	**0.604**	**0.744**	**0.523**	**0.703**	**0.9754**	**0.5897**	0.744	0.083	0.609	0.089	0.607	0.604
NO23	EMA	48	0.108	2.184	0.442	0.548	0.407	0.742	0.8229	0.0001	**0.436**	**0.545**	**0.402**	**0.738**	**0.9895**	**0.9423**	0.542	0.057	0.432	0.057	0.438	0.399
NO23	ERA	20	0.110	1.637	0.489	0.650	0.435	0.669	0.9119	0.0692	0.497	0.669	0.570	0.852	0.9422	0.2641	**0.651**	**0.095**	**0.579**	**0.208**	0.504	0.493
NO23	FPI	15	0.149	0.715	0.319	0.346	0.152	0.440	0.8363	0.0112	**0.318**	**0.344**	**0.140**	**0.405**	**0.9461**	**0.4647**	0.345	0.038	0.311	0.029	0.320	0.296
NO23	FSU	31	0.101	1.724	0.346	0.502	0.387	0.771	0.8518	0.0006	**0.381**	**0.504**	**0.419**	**0.833**	**0.9755**	**0.6789**	0.503	0.069	0.379	0.099	0.385	0.261
NO23	FWU	24	0.018	2.129	0.248	0.432	0.569	1.318	0.6726	0.0001	**0.214**	**0.436**	**0.670**	**1.538**	**0.9712**	**0.6975**	0.438	0.113	0.243	0.052	0.220	0.190
NO23	GPI	18	0.221	1.830	0.897	0.874	0.402	0.460	0.9683	0.7649	0.774	0.885	0.477	0.539	0.9600	0.6008	**0.873**	**0.092**	**0.864**	**0.135**	0.780	0.761
NO23	HI	19	0.092	0.738	0.222	0.255	0.174	0.682	0.8372	0.0042	**0.209**	**0.252**	**0.165**	**0.653**	**0.9527**	**0.4388**	0.300	0.058	0.221	0.045	0.211	0.221
NO23	HLA	21	0.298	1.215	0.741	0.702	0.236	0.336	0.9554	0.4281	0.658	0.706	0.273	0.386	0.9224	0.0970	**0.702**	**0.050**	**0.736**	**0.086**	0.660	0.655
NO23	HPA	28	0.086	2.483	0.404	0.581	0.491	0.844	0.7761	0.0001	**0.433**	**0.586**	**0.512**	**0.874**	**0.9802**	**0.8552**	0.582	0.091	0.456	0.113	0.437	0.461
NO23	JVI	30	0.100	2.180	0.334	0.473	0.449	0.949	0.6331	0.0001	0.363	0.452	0.326	0.721	0.9272	0.0414	**0.472**	**0.080**	**0.339**	**0.030**	0.366	0.355
NO23	LCA	26	0.091	1.800	0.593	0.662	0.396	0.598	0.8949	0.0120	**0.552**	**0.675**	**0.463**	**0.686**	**0.9599**	**0.3890**	0.662	0.077	0.592	0.082	0.556	0.572
NO23	LGA	31	0.100	1.545	0.278	0.377	0.308	0.818	0.7294	0.0001	**0.300**	**0.366**	**0.250**	**0.683**	**0.9606**	**0.3021**	0.373	0.053	0.274	0.027	0.302	0.315
NO23	LUA	31	0.091	3.900	0.531	0.758	0.768	1.014	0.7092	0.0001	**0.526**	**0.746**	**0.715**	**0.958**	**0.9926**	**0.9985**	0.759	0.136	0.539	0.092	0.533	0.428
NO23	MBA	27	0.058	2.074	0.678	0.654	0.405	0.619	0.8826	0.0055	0.522	0.691	0.576	0.833	0.9003	0.0136	**0.655**	**0.078**	**0.634**	**0.113**	0.528	0.447
NO23	MI	26	0.100	0.838	0.399	0.450	0.209	0.464	0.9400	0.1347	0.399	0.455	0.245	0.539	0.9487	0.2159	**0.450**	**0.041**	**0.410**	**0.066**	0.401	0.473
NO23	OFA	18	0.198	2.470	0.716	0.793	0.551	0.694	0.8304	0.0042	**0.648**	**0.788**	**0.526**	**0.667**	**0.9873**	**0.9948**	0.791	0.126	0.673	0.125	0.655	0.740
NO23	RO	16	0.135	2.393	0.482	0.768	0.614	0.800	0.8161	0.0045	**0.578**	**0.762**	**0.616**	**0.808**	**0.9512**	**0.5086**	0.776	0.140	0.561	0.174	0.588	1.333
NO23	RRI	32	0.228	2.940	0.759	0.974	0.687	0.706	0.8453	0.0003	**0.781**	**0.967**	**0.687**	**0.710**	**0.9670**	**0.4213**	0.956	0.118	0.710	0.134	0.786	0.713
NO23	S1M	28	0.185	1.032	0.549	0.544	0.237	0.436	0.9635	0.4195	0.488	0.548	0.275	0.502	0.9580	0.3123	**0.543**	**0.044**	**0.531**	**0.071**	0.490	0.526
NO23	SCA	27	0.004	1.134	0.221	0.335	0.311	0.929	0.7846	0.0001	0.213	0.387	0.530	1.369	0.8586	0.0017	**0.336**	**0.060**	**0.220**	**0.054**	0.218	0.220
NO23	SI	22	0.055	0.645	**0.324**	**0.335**	**0.177**	**0.529**	**0.9580**	**0.4490**	0.274	0.351	0.268	0.763	0.8908	0.0195	0.332	0.035	0.311	0.049	0.277	0.268
NO23	SWI	12	0.176	1.198	0.479	0.559	0.300	0.536	0.9229	0.3107	0.483	0.561	0.317	0.565	0.9778	0.9731	**0.559**	**0.082**	**0.492**	**0.097**	0.489	0.457
NO23	SWJ	12	0.226	1.888	0.702	0.870	0.569	0.654	0.9043	0.1802	0.684	0.883	0.670	0.759	0.9440	0.5515	**0.872**	**0.155**	**0.759**	**0.219**	0.699	0.674
NO23	TBA	28	0.119	1.600	0.496	0.602	0.363	0.602	0.9275	0.0533	0.496	0.613	0.434	0.708	0.9705	0.5950	**0.602**	**0.067**	**0.523**	**0.080**	0.500	0.485

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
NO23	TCA	25	0.087	1.998	0.368	0.455	0.370	0.812	0.6589	0.0001	**0.369**	**0.448**	**0.301**	**0.672**	**0.9511**	**0.2653**	0.452	0.070	0.363	0.032	0.372	0.304
NO23	TPA	24	0.187	1.431	0.670	0.725	0.333	0.460	0.9555	0.3557	0.643	0.735	0.398	0.541	0.9461	0.2226	**0.726**	**0.067**	**0.671**	**0.106**	0.647	0.607
NO23	W5A	30	0.151	2.053	0.552	0.797	0.505	0.634	0.8488	0.0006	**0.664**	**0.796**	**0.514**	**0.646**	**0.9522**	**0.1937**	0.797	0.090	0.602	0.106	0.668	0.644
NO23	WBA	32	0.204	3.583	0.619	0.836	0.751	0.899	0.7214	0.0001	**0.626**	**0.818**	**0.666**	**0.814**	**0.9564**	**0.2183**	0.836	0.131	0.633	0.087	0.631	0.906
NO23	WCI	33	0.216	3.231	0.549	0.866	0.746	0.861	0.7818	0.0001	**0.645**	**0.847**	**0.697**	**0.823**	**0.9540**	**0.1745**	0.895	0.132	0.579	0.120	0.650	0.578
PB	ARA	7	6.30	25.00	16.90	16.01	6.29	0.393	0.9880	0.9889	14.54	16.16	7.50	0.464	0.9335	0.5812	**16.04**	**2.22**	**16.18**	**2.98**	14.76	14.68
PB	BC	22	1.00	8.06	2.55	3.25	2.05	0.632	0.8878	0.0171	**2.65**	**3.27**	**2.27**	**0.694**	**0.9385**	**0.1844**	4.04	0.89	2.80	0.52	2.68	2.80
PB	BCU	25	1.50	19.00	4.51	5.13	4.11	0.802	0.8035	0.0003	**3.90**	**5.10**	**4.12**	**0.808**	**0.9374**	**0.1289**	5.13	0.80	4.22	1.07	3.94	4.74
PB	BI	12	2.64	66.07	22.65	25.44	19.27	0.758	0.9238	0.3187	17.69	27.02	27.40	1.014	0.9610	0.7981	**25.48**	**5.26**	**21.94**	**6.24**	18.34	21.73
PB	BNI	8	5.16	42.03	13.97	18.13	13.54	0.747	0.8908	0.2382	13.35	18.21	14.94	0.820	0.9286	0.5039	**18.24**	**4.46**	**15.64**	**6.95**	13.89	15.86
PB	BRI	14	0.50	25.13	8.86	10.86	8.98	0.827	0.8944	0.0936	5.97	13.09	20.00	1.528	0.9013	0.1179	**11.14**	**2.21**	**10.13**	**3.68**	6.33	8.89
PB	BSI	6	1.00	48.40	10.72	16.34	17.34	1.062	0.8479	0.1513	7.83	18.09	24.05	1.329	0.9701	0.8931	**16.32**	**6.43**	**12.67**	**7.54**	9.12	10.95
PB	BUA	13	2.50	98.16	23.82	27.60	23.04	0.835	0.6938	0.0005	**20.42**	**28.77**	**25.95**	**0.902**	**0.8705**	**0.0531**	27.69	6.17	24.42	3.62	20.98	24.48
PB	CMI	24	0.50	119.00	27.28	33.01	24.90	0.754	0.8368	0.0013	23.39	39.50	48.76	1.234	0.8030	0.0003	**32.97**	**5.02**	**27.43**	**3.82**	23.91	25.70
PB	CTI	17	0.39	10.00	2.26	3.36	3.06	0.910	0.8124	0.0030	**2.20**	**3.47**	**3.80**	**1.095**	**0.9625**	**0.6797**	3.38	0.72	2.42	0.64	2.26	2.53
PB	CTJ	24	1.27	29.49	5.73	7.76	6.70	0.863	0.7751	0.0001	**5.71**	**7.74**	**6.73**	**0.869**	**0.9797**	**0.8903**	7.76	1.35	6.12	1.56	5.79	7.62
PB	CTK	22	0.65	10.00	2.70	4.14	3.32	0.801	0.8228	0.0012	**2.94**	**4.21**	**4.04**	**0.959**	**0.9391**	**0.1893**	4.14	0.69	3.01	0.98	2.99	3.38
PB	E7A	26	9.13	290.12	29.09	54.70	59.25	1.083	0.6391	0.0001	**38.64**	**51.73**	**44.02**	**0.851**	**0.9363**	**0.1093**	54.76	11.39	32.26	6.84	39.08	62.52
PB	EBA	35	2.31	33.52	10.37	11.84	6.34	0.536	0.9258	0.0210	**10.17**	**12.02**	**7.42**	**0.618**	**0.9704**	**0.4542**	11.84	1.06	10.86	1.30	10.22	9.37
PB	EHA	34	14.35	242.50	48.82	51.80	40.71	0.786	0.6783	0.0001	**42.42**	**50.88**	**33.03**	**0.649**	**0.9635**	**0.3067**	51.68	6.79	46.59	6.43	42.65	43.82
PB	EMA	48	5.04	86.10	24.77	27.00	15.28	0.566	0.8942	0.0004	**23.16**	**27.24**	**16.66**	**0.612**	**0.9852**	**0.8000**	27.73	2.29	25.25	2.39	23.23	22.32
PB	ERA	20	2.95	60.97	10.52	17.34	15.17	0.874	0.8290	0.0024	**12.10**	**17.31**	**16.50**	**0.953**	**0.9614**	**0.5715**	17.39	3.30	11.97	4.06	12.32	21.35
PB	FPI	15	5.20	19.52	8.38	10.68	4.74	0.444	0.8796	0.0468	**9.73**	**10.66**	**4.66**	**0.437**	**0.9350**	**0.3234**	10.67	1.20	9.21	1.78	9.79	9.77
PB	FSU	31	0.14	14.65	3.60	4.32	3.50	0.809	0.8858	0.0032	**2.90**	**4.77**	**5.78**	**1.211**	**0.9333**	**0.0540**	4.33	0.62	3.49	0.94	2.95	4.75
PB	FWU	22	0.50	10.23	1.68	2.41	2.12	0.881	0.6972	0.0001	**1.86**	**2.35**	**1.74**	**0.743**	**0.9554**	**0.4015**	2.65	0.52	1.71	0.21	1.88	2.15
PB	GPI	18	11.61	88.32	40.04	43.51	21.92	0.504	0.9565	0.5354	37.72	44.04	25.76	0.585	0.9691	0.7798	**43.45**	**5.01**	**40.66**	**6.55**	38.05	47.56
PB	HI	19	1.96	37.68	8.81	11.44	10.44	0.912	0.8265	0.0028	**7.47**	**11.68**	**12.75**	**1.091**	**0.9357**	**0.2203**	11.47	2.21	9.17	2.16	7.65	10.30
PB	HLA	19	2.25	452.05	17.18	50.67	100.57	1.985	0.4559	0.0001	**20.17**	**44.07**	**70.43**	**1.598**	**0.9704**	**0.7843**	51.33	22.39	20.10	9.57	21.04	51.63
PB	HPA	27	6.93	43.78	21.69	22.70	9.16	0.404	0.9693	0.5845	20.72	22.90	10.63	0.464	0.9517	0.2356	**22.73**	**1.76**	**21.71**	**1.62**	20.80	19.24
PB	JVI	33	1.80	474.49	29.77	42.67	79.03	1.852	0.3334	0.0001	25.20	39.56	45.01	1.138	0.8907	0.0031	**42.50**	**13.50**	**28.79**	**4.06**	25.55	35.60

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
PB	LCA	20	0.76	22.31	6.64	8.29	6.71	0.810	0.8623	0.0086	**5.70**	**8.62**	**8.99**	**1.042**	**0.9361**	**0.2025**	8.31	1.46	6.43	2.04	5.83	6.33
PB	LGA	31	0.14	9.95	2.25	3.06	2.83	0.925	0.8737	0.0017	1.60	3.86	7.26	1.879	0.8904	0.0042	**3.01**	**0.49**	**2.12**	**0.58**	1.64	3.50
PB	LUA	23	4.00	247.36	82.54	97.79	69.95	0.715	0.9133	0.0480	69.53	108.28	119.09	1.100	0.9132	0.0478	**97.88**	**14.26**	**80.54**	**19.37**	70.91	99.62
PB	MBA	18	7.00	95.00	16.96	25.93	25.08	0.967	0.7060	0.0001	**18.57**	**24.93**	**20.99**	**0.842**	**0.9316**	**0.2073**	25.88	5.71	17.70	4.34	18.88	21.31
PB	MI	26	0.00	18.00	7.85	8.10	5.07	0.625	0.9710	0.6483	7.32	9.05	6.38	0.704	0.9179	0.0524	**8.10**	**0.99**	**7.93**	**1.36**	7.38	7.67
PB	OFA	13	1.86	43.00	12.61	15.10	12.12	0.803	0.8662	0.0466	**10.66**	**15.68**	**15.14**	**0.966**	**0.9637**	**0.8098**	15.16	3.23	12.06	3.12	10.99	11.35
PB	RO	15	1.34	29.61	14.01	13.42	8.22	0.613	0.9644	0.7681	10.08	14.48	13.63	0.941	0.9072	0.1225	**15.02**	**2.45**	**14.11**	**3.51**	10.33	15.80
PB	RRI	33	1.50	11.90	2.90	4.50	3.50	0.777	0.7852	0.0001	3.35	4.47	3.82	0.853	0.8455	0.0003	**4.34**	**0.59**	**2.87**	**0.92**	3.38	4.17
PB	S1M	29	3.31	71.88	12.36	19.84	17.99	0.907	0.7776	0.0001	**14.16**	**19.49**	**17.61**	**0.904**	**0.9664**	**0.4664**	19.83	3.27	13.02	2.20	14.32	16.42
PB	SCA	27	0.56	24.17	**9.10**	**10.76**	**7.12**	**0.662**	**0.9393**	**0.1174**	7.64	12.15	13.93	1.146	0.8920	0.0088	10.78	1.37	9.49	1.85	7.78	8.34
PB	SI	22	3.00	152.03	21.29	30.90	32.14	1.040	0.7146	0.0001	**19.94**	**31.61**	**35.56**	**1.125**	**0.9756**	**0.8358**	31.57	6.44	23.50	6.50	20.37	20.92
PB	SWI	13	0.50	20.94	6.59	7.16	6.01	0.839	0.8672	0.0480	**4.74**	**7.72**	**8.60**	**1.114**	**0.9554**	**0.6825**	7.19	1.61	5.92	1.81	4.92	6.43
PB	SWJ	13	1.33	55.12	10.83	14.05	14.88	1.059	0.7821	0.0042	**8.09**	**14.74**	**18.65**	**1.265**	**0.9650**	**0.8280**	14.13	3.98	10.28	3.51	8.49	8.91
PB	TBA	31	1.86	37.80	9.77	13.13	11.36	0.865	0.7978	0.0001	**9.17**	**13.22**	**13.03**	**0.986**	**0.9613**	**0.3156**	13.15	2.01	9.40	2.26	9.28	12.57
PB	TCA	21	1.30	58.18	5.45	10.18	14.53	1.427	0.6381	0.0001	**5.02**	**9.29**	**12.66**	**1.362**	**0.9180**	**0.0790**	10.15	3.09	4.96	1.55	5.18	5.52
PB	TPA	20	1.06	28.84	9.17	11.45	8.65	0.755	0.8841	0.0210	**8.16**	**12.08**	**12.16**	**1.007**	**0.9580**	**0.5040**	11.47	1.88	9.32	1.89	8.33	6.31
PB	W5A	20	14.84	240.00	46.58	66.21	56.63	0.855	0.7657	0.0003	**49.90**	**65.14**	**51.96**	**0.798**	**0.9704**	**0.7633**	66.36	12.32	49.31	8.30	50.58	46.54
PB	WBA	33	1.50	23.55	7.31	8.39	5.08	0.605	0.9194	0.0176	**6.92**	**8.53**	**6.00**	**0.703**	**0.9778**	**0.7193**	8.38	0.88	7.31	0.87	6.96	8.40
PB	WCI	36	4.00	281.00	31.77	52.22	52.62	1.008	0.7199	0.0001	**35.71**	**52.06**	**52.76**	**1.013**	**0.9789**	**0.7069**	50.30	8.37	32.24	6.31	36.09	34.62
TKN	ARA	8	0.50	17.40	2.94	4.51	5.37	1.190	0.6548	0.0007	**2.71**	**4.38**	**4.56**	**1.040**	**0.9452**	**0.6624**	4.55	1.77	3.03	1.08	2.88	3.50
TKN	BC	19	0.06	0.98	0.35	0.40	0.24	0.614	0.8720	0.0156	**0.32**	**0.41**	**0.30**	**0.735**	**0.9285**	**0.1623**	0.42	0.06	0.36	0.04	0.33	0.35
TKN	BCU	24	0.27	2.10	0.95	1.00	0.50	0.499	0.9401	0.1637	0.87	1.02	0.59	0.578	0.9567	0.3752	**1.00**	**0.10**	**0.94**	**0.14**	0.88	0.87
TKN	BI	12	0.38	1.80	0.61	0.66	0.38	0.578	0.6524	0.0003	0.59	0.65	0.29	0.440	0.8340	0.0234	**0.66**	**0.10**	**0.59**	**0.07**	0.60	0.60
TKN	BNI	11	0.35	2.83	0.94	1.23	0.83	0.672	0.8813	0.1080	0.98	1.23	0.86	0.699	0.9690	0.8765	**1.23**	**0.24**	**1.02**	**0.34**	1.00	1.05
TKN	BRI	24	0.46	6.60	1.21	1.82	1.74	0.954	0.7265	0.0001	**1.29**	**1.77**	**1.57**	**0.889**	**0.9233**	**0.0690**	1.89	0.35	1.43	0.37	1.31	1.32
TKN	BSI	7	0.40	1.57	0.62	0.71	0.41	0.578	0.7783	0.0248	**0.62**	**0.70**	**0.35**	**0.493**	**0.8845**	**0.2474**	0.71	0.14	0.62	0.17	0.64	0.60
TKN	BUA	21	0.71	12.60	1.69	2.76	2.70	0.978	0.6486	0.0001	**2.07**	**2.63**	**1.97**	**0.747**	**0.9411**	**0.2288**	2.75	0.57	1.94	0.45	2.10	2.01
TKN	CMI	24	0.50	7.13	1.47	2.29	1.81	0.792	0.8122	0.0005	**1.74**	**2.28**	**1.86**	**0.817**	**0.9465**	**0.2274**	2.29	0.37	1.60	0.29	1.76	1.59
TKN	CTI	17	0.24	2.08	0.99	1.05	0.45	0.430	0.9708	0.8327	0.94	1.06	0.55	0.515	0.9307	0.2237	**1.05**	**0.11**	**1.00**	**0.10**	0.95	0.99
TKN	CTJ	24	0.41	3.23	1.19	1.43	0.73	0.515	0.8841	0.0101	**1.26**	**1.42**	**0.73**	**0.514**	**0.9797**	**0.8909**	1.42	0.15	1.21	0.13	1.27	1.51

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TKN	CTK	22	0.40	2.88	0.85	1.04	0.55	0.526	0.8074	0.0007	**0.94**	**1.03**	**0.47**	**0.459**	**0.9593**	**0.4751**	1.04	0.12	0.87	0.09	0.94	1.11
TKN	E7A	26	0.53	2.50	1.08	1.26	0.57	0.456	0.9167	0.0377	**1.14**	**1.26**	**0.58**	**0.466**	**0.9670**	**0.5476**	1.26	0.11	1.12	0.14	1.14	1.16
TKN	EBA	37	0.37	12.21	1.78	2.78	2.80	1.010	0.6909	0.0001	**1.94**	**2.71**	**2.54**	**0.936**	**0.9779**	**0.6590**	2.78	0.46	1.88	0.35	1.96	2.02
TKN	EHA	36	0.67	17.20	3.00	4.02	2.99	0.745	0.7520	0.0001	**3.27**	**3.99**	**2.72**	**0.682**	**0.9828**	**0.8341**	4.02	0.50	3.22	0.62	3.29	3.04
TKN	EMA	47	0.19	16.87	2.55	3.41	3.14	0.919	0.7679	0.0001	**2.38**	**3.52**	**3.69**	**1.047**	**0.9773**	**0.4873**	3.43	0.45	2.58	0.31	2.40	2.55
TKN	ERA	21	0.77	3.74	1.21	1.43	0.74	0.518	0.7917	0.0005	**1.29**	**1.41**	**0.63**	**0.442**	**0.9156**	**0.0708**	1.43	0.16	1.21	0.12	1.30	1.30
TKN	FPI	15	0.29	1.06	0.86	0.78	0.27	0.349	0.8486	0.0166	0.72	0.79	0.36	0.451	0.8008	0.0038	**0.78**	**0.07**	**0.86**	**0.10**	0.73	0.67
TKN	FSU	31	0.29	3.88	0.87	1.11	0.84	0.763	0.7936	0.0001	**0.88**	**1.09**	**0.77**	**0.709**	**0.9671**	**0.4442**	1.11	0.15	0.85	0.12	0.89	0.77
TKN	FWU	24	0.22	2.74	0.95	1.12	0.65	0.577	0.9280	0.0880	0.94	1.14	0.77	0.671	0.9739	0.7625	**1.06**	**0.11**	**0.96**	**0.16**	0.95	0.89
TKN	GPI	18	0.94	7.76	1.73	2.38	1.61	0.676	0.7400	0.0002	**2.02**	**2.34**	**1.31**	**0.562**	**0.9340**	**0.2280**	2.38	0.37	1.89	0.40	2.04	1.83
TKN	HI	17	0.08	2.62	0.36	0.60	0.61	1.028	0.7383	0.0003	**0.38**	**0.61**	**0.67**	**1.102**	**0.9601**	**0.6331**	0.61	0.12	0.46	0.15	0.39	0.70
TKN	HLA	21	0.13	1.63	0.70	0.70	0.40	0.562	0.9592	0.4999	0.58	0.73	0.53	0.734	0.9368	0.1879	**0.70**	**0.08**	**0.68**	**0.12**	0.58	0.68
TKN	HPA	28	0.58	9.67	1.61	2.21	1.83	0.830	0.7005	0.0001	**1.77**	**2.15**	**1.46**	**0.677**	**0.9581**	**0.3138**	2.22	0.34	1.61	0.32	1.78	1.70
TKN	JVI	31	0.34	2.23	0.87	0.98	0.45	0.463	0.8926	0.0047	**0.89**	**0.98**	**0.44**	**0.453**	**0.9868**	**0.9597**	0.98	0.08	0.88	0.07	0.89	0.94
TKN	LCA	28	0.38	7.07	1.20	1.66	1.38	0.831	0.7633	0.0001	**1.27**	**1.64**	**1.29**	**0.787**	**0.9723**	**0.6428**	1.66	0.26	1.30	0.31	1.28	1.21
TKN	LGA	31	0.05	0.73	0.33	0.38	0.23	0.604	0.9251	0.0323	0.29	0.40	0.37	0.929	0.8915	0.0045	**0.37**	**0.04**	**0.34**	**0.08**	0.29	0.40
TKN	LUA	31	0.68	9.98	1.79	2.55	2.23	0.872	0.7587	0.0001	**1.92**	**2.49**	**2.00**	**0.802**	**0.9459**	**0.1204**	2.56	0.39	1.74	0.37	1.93	1.51
TKN	MBA	27	0.57	5.49	1.17	1.71	1.26	0.739	0.7576	0.0001	1.39	1.67	1.07	0.643	0.9220	0.0442	**1.71**	**0.24**	**1.26**	**0.21**	1.40	1.25
TKN	MI	26	0.07	4.51	0.73	0.96	0.96	1.001	0.7868	0.0001	**0.58**	**1.03**	**1.36**	**1.326**	**0.9669**	**0.5450**	0.96	0.18	0.73	0.24	0.59	1.25
TKN	OFA	18	0.36	4.72	1.36	2.00	1.35	0.676	0.9002	0.0580	1.54	2.04	1.69	0.826	0.9430	0.3261	**2.00**	**0.31**	**1.68**	**0.60**	1.56	1.59
TKN	RO	16	0.10	1.97	0.79	0.91	0.54	0.593	0.9519	0.5196	0.72	0.96	0.79	0.822	0.9183	0.1583	**0.94**	**0.13**	**0.87**	**0.22**	0.74	0.90
TKN	RRI	32	0.18	5.26	1.01	1.64	1.48	0.905	0.7936	0.0001	**1.13**	**1.63**	**1.63**	**0.997**	**0.9619**	**0.3086**	1.59	0.26	1.03	0.30	1.14	1.10
TKN	S1M	29	0.19	1.99	1.04	1.05	0.50	0.479	0.9687	0.5238	0.91	1.07	0.67	0.620	0.9349	0.0737	**1.05**	**0.09**	**1.01**	**0.14**	0.91	1.07
TKN	SCA	27	0.33	13.62	3.07	3.66	2.68	0.732	0.7971	0.0001	**2.91**	**3.74**	**2.91**	**0.779**	**0.9505**	**0.2200**	3.67	0.52	3.12	0.38	2.93	2.88
TKN	SI	20	0.05	1.78	0.60	0.71	0.52	0.737	0.9295	0.1512	0.47	0.80	0.98	1.231	0.9058	0.0530	**0.71**	**0.11**	**0.63**	**0.17**	0.48	0.55
TKN	SWI	13	0.29	2.21	0.93	0.97	0.46	0.468	0.8618	0.0407	**0.88**	**0.98**	**0.48**	**0.492**	**0.9254**	**0.2966**	0.98	0.12	0.95	0.10	0.88	0.78
TKN	SWJ	13	0.43	6.67	1.47	2.01	1.70	0.844	0.7993	0.0067	**1.48**	**2.01**	**1.68**	**0.836**	**0.9696**	**0.8889**	2.02	0.45	1.56	0.42	1.52	1.29
TKN	TBA	30	0.25	5.66	1.11	1.54	1.33	0.862	0.7847	0.0001	**1.13**	**1.54**	**1.35**	**0.881**	**0.9849**	**0.9357**	1.54	0.24	1.14	0.17	1.14	1.20
TKN	TCA	27	0.37	2.64	0.88	0.98	0.54	0.546	0.8460	0.0010	**0.87**	**0.98**	**0.50**	**0.508**	**0.9711**	**0.6315**	0.98	0.10	0.86	0.07	0.87	0.92
TKN	TPA	24	0.69	9.34	1.74	2.26	1.75	0.773	0.6772	0.0001	**1.88**	**2.21**	**1.34**	**0.606**	**0.9584**	**0.4071**	2.26	0.35	1.80	0.24	1.89	1.68

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TKN	W5A	30	0.99	14.10	2.60	3.51	2.70	0.769	0.7697	0.0001	**2.81**	**3.45**	**2.39**	**0.693**	**0.9625**	**0.3583**	3.51	0.48	2.63	0.57	2.83	2.41
TKN	WBA	33	0.35	5.13	1.56	1.97	1.33	0.673	0.8534	0.0004	**1.58**	**1.99**	**1.48**	**0.741**	**0.9671**	**0.4045**	1.97	0.23	1.61	0.16	1.60	1.73
TKN	WCI	35	0.26	11.42	1.65	2.41	2.44	1.013	0.7459	0.0001	**1.62**	**2.38**	**2.43**	**1.022**	**0.9881**	**0.9626**	2.59	0.42	1.75	0.31	1.64	1.46
TN	ARA	7	0.97	17.84	3.10	4.82	5.82	1.206	0.6155	0.0004	**3.05**	**4.45**	**3.99**	**0.897**	**0.8971**	**0.3136**	4.84	2.04	3.15	1.62	3.23	3.75
TN	BC	19	0.17	1.19	0.49	0.55	0.28	0.520	0.9221	0.1240	0.48	0.55	0.30	0.554	0.9771	0.9043	**0.60**	**0.10**	**0.49**	**0.07**	0.48	0.50
TN	BCU	24	0.46	5.16	1.34	1.59	1.17	0.732	0.8263	0.0008	**1.26**	**1.58**	**1.15**	**0.726**	**0.9629**	**0.4993**	1.59	0.23	1.29	0.21	1.28	1.10
TN	BI	12	0.43	2.27	0.88	0.94	0.46	0.494	0.7390	0.0021	**0.86**	**0.93**	**0.39**	**0.418**	**0.9105**	**0.2165**	0.94	0.13	0.86	0.07	0.86	0.90
TN	BNI	11	0.55	3.32	1.63	1.66	0.86	0.519	0.9289	0.3994	1.44	1.66	0.93	0.559	0.9681	0.8664	**1.66**	**0.25**	**1.56**	**0.29**	1.46	1.61
TN	BRI	24	0.76	7.77	1.84	2.40	1.93	0.804	0.7484	0.0001	**1.88**	**2.34**	**1.67**	**0.712**	**0.9344**	**0.1221**	2.46	0.38	1.97	0.31	1.90	1.85
TN	BSI	6	0.54	2.15	0.96	1.10	0.60	0.544	0.8951	0.3460	0.96	1.09	0.56	0.514	0.9654	0.8600	**1.10**	**0.22**	**1.00**	**0.28**	0.98	0.89
TN	BUA	19	0.84	14.08	2.48	3.69	3.11	0.843	0.7132	0.0001	**2.90**	**3.59**	**2.53**	**0.704**	**0.9500**	**0.3953**	3.72	0.66	2.74	0.35	2.93	2.73
TN	CMI	24	0.53	8.88	2.02	2.92	2.20	0.754	0.8158	0.0005	**2.28**	**2.90**	**2.21**	**0.760**	**0.9680**	**0.6177**	2.91	0.44	2.11	0.36	2.30	1.96
TN	CTI	17	0.39	3.44	1.42	1.61	0.77	0.476	0.9608	0.6467	1.43	1.63	0.88	0.542	0.9668	0.7608	**1.62**	**0.18**	**1.49**	**0.24**	1.44	1.59
TN	CTJ	24	0.53	4.00	1.82	1.99	0.87	0.435	0.9362	0.1341	1.81	2.01	0.95	0.472	0.9632	0.5050	**1.99**	**0.17**	**1.81**	**0.14**	1.82	2.08
TN	CTK	22	0.57	4.26	1.46	1.70	0.89	0.522	0.9012	0.0314	**1.50**	**1.70**	**0.89**	**0.522**	**0.9842**	**0.9687**	1.70	0.19	1.52	0.27	1.51	1.99
TN	E7A	26	1.02	3.49	1.84	2.02	0.70	0.348	0.9470	0.1973	1.90	2.02	0.73	0.360	0.9650	0.5002	**2.02**	**0.14**	**1.93**	**0.26**	1.91	1.73
TN	EBA	37	0.63	14.80	2.26	3.38	3.11	0.919	0.7111	0.0001	**2.52**	**3.29**	**2.68**	**0.813**	**0.9728**	**0.4885**	3.38	0.51	2.38	0.41	2.54	2.50
TN	EHA	35	0.83	19.31	3.81	4.73	3.40	0.718	0.7681	0.0001	**3.90**	**4.70**	**3.11**	**0.661**	**0.9848**	**0.8991**	4.74	0.57	3.80	0.65	3.92	3.53
TN	EMA	47	0.40	19.06	3.05	3.97	3.46	0.873	0.7664	0.0001	**2.91**	**4.00**	**3.66**	**0.915**	**0.9825**	**0.6961**	3.97	0.49	3.10	0.30	2.93	2.95
TN	ERA	20	1.03	4.76	1.86	2.08	0.88	0.423	0.8732	0.0134	**1.93**	**2.08**	**0.81**	**0.389**	**0.9776**	**0.8998**	2.09	0.19	1.93	0.23	1.94	1.80
TN	FPI	15	0.53	1.76	1.14	1.13	0.37	0.330	0.9466	0.4730	1.06	1.14	0.43	0.376	0.9085	0.1283	**1.13**	**0.09**	**1.15**	**0.10**	1.07	0.97
TN	FSU	31	0.58	5.28	1.21	1.61	1.12	0.698	0.8209	0.0001	**1.32**	**1.59**	**1.05**	**0.662**	**0.9446**	**0.1103**	1.61	0.20	1.24	0.18	1.32	1.03
TN	FWU	23	0.39	2.87	1.31	1.48	0.81	0.547	0.9214	0.0716	1.23	1.51	1.04	0.690	0.9197	0.0656	**1.56**	**0.16**	**1.49**	**0.34**	1.24	1.06
TN	GPI	18	1.16	9.59	2.71	3.25	1.93	0.593	0.7896	0.0011	**2.84**	**3.23**	**1.70**	**0.527**	**0.9680**	**0.7601**	3.25	0.44	2.82	0.53	2.86	2.59
TN	HI	17	0.18	3.36	0.59	0.87	0.76	0.881	0.7576	0.0006	**0.64**	**0.86**	**0.72**	**0.837**	**0.9779**	**0.9355**	0.93	0.17	0.70	0.20	0.65	0.94
TN	HLA	21	0.45	2.51	1.40	1.41	0.50	0.355	0.9806	0.9334	1.30	1.42	0.60	0.422	0.9272	0.1212	**1.40**	**0.11**	**1.40**	**0.09**	1.31	1.33
TN	HPA	28	0.84	12.15	2.13	2.79	2.23	0.798	0.6813	0.0001	**2.29**	**2.72**	**1.69**	**0.622**	**0.9629**	**0.4065**	2.80	0.41	2.18	0.35	2.31	2.16
TN	JVI	30	0.48	3.34	1.20	1.41	0.72	0.510	0.8473	0.0005	**1.26**	**1.40**	**0.67**	**0.479**	**0.9652**	**0.4172**	1.41	0.13	1.20	0.10	1.27	1.30
TN	LCA	26	0.94	8.87	1.90	2.38	1.64	0.690	0.7382	0.0001	**2.02**	**2.34**	**1.35**	**0.578**	**0.9527**	**0.2684**	2.38	0.32	1.97	0.32	2.03	1.80
TN	LGA	31	0.25	2.08	0.68	0.75	0.43	0.571	0.8820	0.0026	**0.65**	**0.75**	**0.44**	**0.582**	**0.9743**	**0.6448**	0.74	0.07	0.68	0.09	0.65	0.72

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TN	LUA	30	0.90	12.28	2.34	3.33	2.77	0.831	0.7464	0.0001	**2.59**	**3.24**	**2.36**	**0.730**	**0.9465**	**0.1358**	3.33	0.49	2.39	0.46	2.61	1.96
TN	MBA	27	0.92	6.17	1.80	2.36	1.47	0.624	0.7750	0.0001	2.03	2.33	1.28	0.549	0.9152	0.0302	**2.37**	**0.28**	**1.81**	**0.16**	2.04	1.70
TN	MI	26	0.31	4.72	1.14	1.41	0.97	0.693	0.8628	0.0026	**1.12**	**1.42**	**1.06**	**0.750**	**0.9781**	**0.8303**	1.41	0.19	1.22	0.27	1.13	1.72
TN	OFA	18	0.78	6.26	2.35	2.79	1.64	0.586	0.9095	0.0842	2.32	2.81	1.84	0.655	0.9449	0.3511	**2.79**	**0.37**	**2.42**	**0.72**	2.35	2.33
TN	RO	16	0.51	3.53	1.41	1.68	0.87	0.517	0.9345	0.2866	1.46	1.69	0.97	0.574	0.9578	0.6224	**1.72**	**0.20**	**1.65**	**0.41**	1.47	2.23
TN	RRI	32	0.41	8.00	1.77	2.61	2.05	0.784	0.7870	0.0001	**2.02**	**2.58**	**1.97**	**0.765**	**0.9523**	**0.1673**	2.55	0.35	1.79	0.28	2.04	1.81
TN	S1M	28	0.42	2.96	1.44	1.56	0.61	0.392	0.9835	0.9240	1.43	1.58	0.75	0.472	0.9435	0.1355	**1.56**	**0.11**	**1.52**	**0.16**	1.43	1.43
TN	SCA	27	0.44	14.36	3.29	4.00	2.86	0.716	0.8111	0.0002	**3.21**	**4.05**	**3.02**	**0.747**	**0.9668**	**0.5192**	4.01	0.55	3.34	0.41	3.23	3.10
TN	SI	20	0.11	2.35	0.88	1.05	0.66	0.627	0.9483	0.3424	0.80	1.11	1.01	0.910	0.9308	0.1602	**1.04**	**0.14**	**0.95**	**0.21**	0.81	0.81
TN	SWI	12	0.46	2.60	1.44	1.54	0.62	0.404	0.9809	0.9870	1.39	1.56	0.77	0.495	0.9252	0.3324	**1.54**	**0.17**	**1.52**	**0.26**	1.40	1.23
TN	SWJ	12	0.66	5.80	2.08	2.49	1.54	0.616	0.9126	0.2303	2.03	2.53	1.76	0.697	0.9462	0.5827	**2.50**	**0.42**	**2.17**	**0.47**	2.07	1.85
TN	TBA	28	0.66	7.26	1.66	2.18	1.56	0.716	0.7971	0.0001	**1.78**	**2.16**	**1.43**	**0.663**	**0.9693**	**0.5624**	2.18	0.29	1.73	0.30	1.80	1.71
TN	TCA	25	0.68	4.64	1.28	1.48	0.80	0.539	0.7018	0.0001	1.34	1.46	0.61	0.420	0.9178	0.0456	**1.47**	**0.15**	**1.25**	**0.06**	1.35	1.28
TN	TPA	22	1.43	10.27	2.48	3.04	1.92	0.631	0.7076	0.0001	**2.66**	**2.99**	**1.50**	**0.500**	**0.9240**	**0.0921**	3.04	0.40	2.50	0.30	2.68	2.35
TN	W5A	30	1.41	16.01	2.91	4.26	3.13	0.735	0.7730	0.0001	**3.49**	**4.18**	**2.70**	**0.646**	**0.9507**	**0.1760**	4.26	0.56	3.13	0.63	3.51	3.11
TN	WBA	32	0.55	8.54	2.19	2.83	1.88	0.664	0.8478	0.0004	**2.32**	**2.83**	**1.92**	**0.679**	**0.9893**	**0.9837**	2.83	0.33	2.34	0.36	2.34	2.64
TN	WCI	33	0.54	14.16	2.07	3.11	2.97	0.955	0.7389	0.0001	**2.23**	**3.03**	**2.68**	**0.885**	**0.9784**	**0.7367**	3.32	0.53	2.26	0.45	2.25	1.95
TOC	ARA	9	4.00	14.40	5.79	7.97	4.04	0.507	0.8021	0.0216	**7.08**	**7.93**	**3.86**	**0.487**	**0.8583**	**0.0919**	7.95	1.27	6.78	2.41	7.17	6.87
TOC	BC	21	1.00	25.32	7.65	8.16	5.99	0.733	0.8978	0.0317	5.72	8.89	9.67	1.088	0.8807	0.0151	**8.03**	**1.17**	**7.25**	**0.86**	5.85	8.87
TOC	BCU	24	5.64	29.55	16.43	17.70	6.28	0.355	0.9775	0.8456	16.48	17.81	7.20	0.404	0.9563	0.3694	**17.68**	**1.26**	**16.91**	**1.78**	16.54	15.39
TOC	BI	12	1.67	66.59	5.73	11.70	17.87	1.528	0.5406	0.0001	**6.41**	**10.27**	**11.08**	**1.080**	**0.9296**	**0.3758**	11.73	4.90	6.16	1.60	6.68	11.15
TOC	BNI	12	3.60	20.91	6.49	8.31	4.86	0.584	0.7663	0.0040	**7.30**	**8.20**	**4.05**	**0.494**	**0.9038**	**0.1777**	8.33	1.33	6.68	1.07	7.37	6.56
TOC	BRI	19	2.95	18.90	6.69	8.04	4.35	0.541	0.8701	0.0145	**7.06**	**8.00**	**4.18**	**0.523**	**0.9665**	**0.7055**	8.07	0.97	6.74	1.23	7.10	7.71
TOC	BSI	10	3.01	18.05	5.05	6.54	4.80	0.735	0.7088	0.0011	**5.41**	**6.35**	**3.72**	**0.586**	**0.8552**	**0.0670**	6.54	1.45	4.96	1.04	5.50	5.46
TOC	BUA	15	4.37	52.61	10.61	15.27	12.83	0.840	0.7823	0.0022	**11.58**	**14.97**	**11.54**	**0.771**	**0.9619**	**0.7255**	14.73	3.03	10.84	2.48	11.78	9.63
TOC	CMI	21	2.65	68.70	10.90	17.20	18.37	1.068	0.7459	0.0001	**10.73**	**16.84**	**18.63**	**1.106**	**0.9553**	**0.4261**	17.16	3.91	11.03	2.85	10.96	8.64
TOC	CTI	17	3.82	26.16	9.63	11.48	6.56	0.571	0.8994	0.0664	9.78	11.47	6.82	0.594	0.9622	0.6727	**11.50**	**1.54**	**9.68**	**2.33**	9.87	8.94
TOC	CTJ	24	4.04	41.05	8.83	11.94	9.13	0.764	0.7345	0.0001	9.73	11.62	7.38	0.636	0.9214	0.0626	**11.92**	**1.83**	**8.70**	**0.95**	9.80	8.31
TOC	CTK	22	3.98	24.20	6.68	9.43	6.43	0.682	0.7625	0.0001	7.85	9.25	5.62	0.607	0.8831	0.0138	**9.42**	**1.34**	**6.90**	**1.24**	7.91	7.84
TOC	E7A	25	3.42	20.54	7.38	8.70	4.50	0.517	0.8866	0.0095	**7.71**	**8.67**	**4.39**	**0.506**	**0.9773**	**0.8268**	8.71	0.88	7.65	0.94	7.75	6.61

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TOC	EBA	37	4.78	89.11	11.49	19.69	20.17	1.025	0.6739	0.0001	14.00	18.66	15.92	0.853	0.9171	0.0091	**19.69**	**3.29**	**11.58**	**1.19**	14.11	11.78
TOC	EHA	37	3.84	105.19	17.97	25.71	24.10	0.938	0.7902	0.0001	**17.66**	**25.49**	**25.41**	**0.997**	**0.9745**	**0.5433**	25.71	3.92	17.65	2.73	17.84	15.78
TOC	EMA	48	6.10	339.22	18.11	40.60	71.05	1.750	0.4597	0.0001	21.61	33.34	37.57	1.127	0.8794	0.0001	**39.69**	**9.95**	**18.03**	**2.71**	21.81	20.26
TOC	ERA	20	5.68	59.68	8.91	12.15	11.74	0.966	0.4898	0.0001	9.93	11.45	6.40	0.559	0.8071	0.0011	**12.17**	**2.56**	**9.01**	**0.80**	10.00	9.03
TOC	FPI	15	2.25	10.85	5.31	5.75	2.54	0.441	0.9451	0.4507	5.18	5.78	2.79	0.482	0.9528	0.5703	**5.74**	**0.64**	**5.36**	**0.68**	5.22	4.81
TOC	FSU	31	5.89	22.84	10.74	11.95	3.89	0.325	0.9591	0.2766	11.34	11.95	3.95	0.331	0.9885	0.9788	**11.95**	**0.69**	**11.29**	**0.98**	11.36	9.14
TOC	FWU	23	4.84	23.07	7.47	8.89	3.77	0.424	0.7566	0.0001	**8.32**	**8.82**	**3.09**	**0.350**	**0.9331**	**0.1273**	9.04	0.75	8.23	1.02	8.34	8.57
TOC	GPI	17	4.91	113.77	15.30	24.10	26.06	1.081	0.6678	0.0001	**16.48**	**23.06**	**20.92**	**0.907**	**0.9652**	**0.7301**	24.21	6.15	16.24	4.80	16.82	13.65
TOC	HI	19	1.00	31.79	5.35	7.50	7.08	0.944	0.7581	0.0003	**5.12**	**7.68**	**7.88**	**1.026**	**0.9633**	**0.6384**	8.00	1.57	6.26	1.42	5.23	6.16
TOC	HLA	20	1.68	13.91	6.10	6.93	3.41	0.492	0.9412	0.2531	6.09	6.99	3.86	0.552	0.9711	0.7785	**6.94**	**0.74**	**6.28**	**0.95**	6.13	7.07
TOC	HPA	25	5.12	69.79	12.63	18.75	16.41	0.875	0.7706	0.0001	**13.89**	**18.29**	**15.01**	**0.821**	**0.9346**	**0.1109**	18.79	3.22	12.87	3.92	14.04	16.00
TOC	JVI	29	3.02	42.93	12.36	14.36	11.16	0.777	0.8667	0.0017	**10.47**	**14.61**	**13.56**	**0.928**	**0.9347**	**0.0729**	14.36	2.03	12.22	2.75	10.59	11.61
TOC	LCA	21	3.56	32.60	6.08	9.11	7.51	0.825	0.7209	0.0001	7.20	8.79	5.95	0.676	0.8923	0.0249	**9.09**	**1.60**	**6.20**	**1.14**	7.27	5.96
TOC	LGA	31	3.07	14.30	6.06	6.58	2.45	0.373	0.9093	0.0124	**6.18**	**6.57**	**2.35**	**0.357**	**0.9881**	**0.9755**	7.21	0.74	6.19	0.49	6.20	6.93
TOC	LUA	25	0.44	107.00	13.25	17.57	21.51	1.225	0.6037	0.0001	10.17	20.09	30.00	1.493	0.8750	0.0055	**17.58**	**4.22**	**12.82**	**2.19**	10.46	15.13
TOC	MBA	25	4.13	44.48	8.76	13.17	10.93	0.830	0.7739	0.0001	**10.04**	**12.83**	**9.83**	**0.766**	**0.9258**	**0.0697**	13.19	2.15	9.10	1.65	10.14	8.71
TOC	MI	26	4.38	55.33	11.69	13.87	10.19	0.734	0.6954	0.0001	**11.67**	**13.57**	**7.87**	**0.580**	**0.9648**	**0.4958**	13.88	1.96	11.23	1.35	11.74	12.63
TOC	OFA	16	4.09	50.21	13.57	18.53	13.91	0.751	0.8438	0.0110	**14.27**	**18.49**	**14.37**	**0.777**	**0.9761**	**0.9251**	18.50	3.34	14.10	3.53	14.50	15.57
TOC	RO	16	4.95	71.01	9.30	17.82	17.83	1.000	0.7287	0.0004	**12.29**	**17.13**	**15.39**	**0.898**	**0.9096**	**0.1147**	17.63	4.09	11.83	4.27	12.55	13.40
TOC	RRI	32	4.54	164.00	11.15	22.91	31.19	1.361	0.5654	0.0001	14.29	20.62	20.44	0.991	0.9067	0.0092	**22.35**	**5.30**	**11.21**	**2.22**	14.45	10.43
TOC	S1M	29	3.25	38.56	12.60	14.72	8.33	0.566	0.9235	0.0374	**12.51**	**14.84**	**9.26**	**0.624**	**0.9833**	**0.9134**	14.72	1.51	13.01	2.31	12.58	11.23
TOC	SCA	27	3.82	110.35	22.85	28.33	24.91	0.879	0.8076	0.0002	**20.13**	**28.52**	**27.12**	**0.951**	**0.9850**	**0.9537**	28.42	4.82	21.30	5.13	20.40	27.85
TOC	SI	22	1.47	34.61	5.96	9.27	9.31	1.004	0.7717	0.0002	**5.95**	**9.23**	**10.06**	**1.091**	**0.9581**	**0.4510**	10.17	2.06	6.50	1.63	6.07	5.91
TOC	SWI	12	4.93	23.45	7.61	8.78	5.12	0.583	0.7158	0.0012	**7.81**	**8.64**	**3.97**	**0.460**	**0.8866**	**0.1065**	8.79	1.40	7.54	1.16	7.88	6.78
TOC	SWJ	12	2.81	26.60	11.88	11.98	7.39	0.617	0.9371	0.4613	9.37	12.35	9.79	0.793	0.9040	0.1787	**11.99**	**2.03**	**11.67**	**2.89**	9.59	8.56
TOC	TBA	27	2.36	24.08	5.84	7.88	5.65	0.716	0.8382	0.0007	**6.30**	**7.81**	**5.56**	**0.712**	**0.9556**	**0.2921**	7.90	1.09	5.91	1.02	6.35	7.26
TOC	TCA	23	3.62	19.56	6.72	8.16	4.09	0.502	0.8289	0.0012	**7.36**	**8.10**	**3.66**	**0.452**	**0.9481**	**0.2667**	8.07	0.81	6.79	0.69	7.40	8.63
TOC	TPA	23	3.29	32.20	9.50	11.60	7.60	0.655	0.7980	0.0004	**9.78**	**11.48**	**6.87**	**0.598**	**0.9748**	**0.8025**	11.61	1.55	9.53	1.39	9.85	8.65
TOC	W5A	30	3.66	135.00	14.55	27.10	28.91	1.067	0.7205	0.0001	**17.88**	**26.12**	**26.35**	**1.009**	**0.9611**	**0.3297**	27.06	5.16	15.45	3.97	18.11	17.54
TOC	WBA	33	3.33	73.91	6.50	12.04	14.92	1.239	0.5579	0.0001	8.26	10.92	9.14	0.836	0.8668	0.0008	**12.02**	**2.56**	**6.88**	**1.18**	8.33	7.05

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TOC	WCI	32	1.61	169.80	8.95	23.34	33.39	1.431	0.6124	0.0001	**12.15**	**21.67**	**29.33**	**1.354**	**0.9530**	**0.1750**	23.81	5.95	9.85	2.49	12.38	10.70
TP	BC	21	0.020	0.240	0.040	0.059	0.053	0.898	0.7381	0.0001	0.043	0.057	0.046	0.814	0.8975	0.0313	**0.066**	**0.013**	**0.042**	**0.012**	0.044	0.059
TP	BCU	24	0.010	0.214	0.050	0.069	0.053	0.762	0.8697	0.0052	**0.052**	**0.070**	**0.061**	**0.866**	**0.9824**	**0.9353**	0.069	0.011	0.052	0.010	0.053	0.105
TP	BI	12	0.025	0.303	0.093	0.107	0.088	0.816	0.8085	0.0117	**0.079**	**0.107**	**0.088**	**0.825**	**0.9480**	**0.6084**	0.107	0.024	0.087	0.023	0.081	0.093
TP	BNI	10	0.023	0.839	0.243	0.320	0.259	0.809	0.9195	0.3526	0.203	0.354	0.412	1.167	0.9446	0.6056	**0.322**	**0.079**	**0.273**	**0.117**	0.215	0.283
TP	BRI	24	0.048	1.036	0.256	0.345	0.283	0.822	0.8507	0.0023	**0.245**	**0.348**	**0.330**	**0.949**	**0.9607**	**0.4523**	0.347	0.057	0.256	0.077	0.249	0.269
TP	BSI	7	0.060	0.356	0.133	0.160	0.097	0.604	0.8399	0.0991	0.137	0.159	0.089	0.559	0.9586	0.8067	**0.161**	**0.034**	**0.138**	**0.035**	0.140	0.144
TP	BUA	21	0.092	2.940	0.470	0.674	0.666	0.988	0.6762	0.0001	**0.488**	**0.656**	**0.558**	**0.851**	**0.9675**	**0.6783**	0.673	0.142	0.473	0.085	0.495	0.566
TP	CMI	16	0.249	1.150	0.524	0.620	0.298	0.480	0.9206	0.1726	0.549	0.622	0.321	0.517	0.9496	0.4834	**0.619**	**0.071**	**0.563**	**0.116**	0.553	0.420
TP	CTI	17	0.104	0.579	0.259	0.287	0.151	0.526	0.8569	0.0137	**0.252**	**0.286**	**0.150**	**0.523**	**0.9498**	**0.4541**	0.288	0.035	0.246	0.039	0.254	0.299
TP	CTJ	24	0.145	0.790	0.370	0.404	0.175	0.433	0.9218	0.0641	0.368	0.405	0.184	0.453	0.9665	0.5825	**0.404**	**0.035**	**0.366**	**0.034**	0.370	0.407
TP	CTK	22	0.101	0.488	0.216	0.248	0.108	0.437	0.8953	0.0239	**0.227**	**0.247**	**0.106**	**0.430**	**0.9656**	**0.6092**	0.248	0.023	0.221	0.029	0.228	0.302
TP	E7A	25	0.267	2.595	0.560	0.714	0.546	0.764	0.7635	0.0001	**0.576**	**0.698**	**0.463**	**0.664**	**0.9234**	**0.0613**	0.715	0.107	0.521	0.100	0.581	0.725
TP	EBA	37	0.187	2.694	0.462	0.618	0.479	0.776	0.6965	0.0001	**0.511**	**0.601**	**0.366**	**0.609**	**0.9473**	**0.0790**	0.618	0.078	0.477	0.056	0.513	0.491
TP	EHA	37	0.353	3.384	1.281	1.456	0.912	0.627	0.9062	0.0044	**1.176**	**1.476**	**1.092**	**0.740**	**0.9526**	**0.1175**	1.456	0.148	1.265	0.152	1.183	1.406
TP	EMA	48	0.241	4.032	0.579	0.901	0.737	0.818	0.7432	0.0001	0.709	0.876	0.624	0.713	0.9330	0.0088	**0.917**	**0.105**	**0.606**	**0.083**	0.712	0.690
TP	ERA	20	0.176	1.849	0.489	0.635	0.416	0.655	0.8637	0.0091	**0.523**	**0.633**	**0.417**	**0.658**	**0.9798**	**0.9316**	0.636	0.091	0.521	0.123	0.529	0.793
TP	FPI	15	0.099	0.297	0.174	0.179	0.053	0.297	0.9419	0.4062	0.172	0.179	0.053	0.294	0.9744	0.9175	**0.179**	**0.013**	**0.171**	**0.017**	0.172	0.159
TP	FSU	31	0.011	0.810	0.171	0.209	0.168	0.803	0.8383	0.0003	**0.150**	**0.223**	**0.232**	**1.040**	**0.9537**	**0.1978**	0.209	0.030	0.167	0.025	0.152	0.212
TP	FWU	23	0.038	0.568	0.170	0.205	0.137	0.670	0.8714	0.0068	**0.165**	**0.207**	**0.150**	**0.726**	**0.9872**	**0.9871**	0.180	0.022	0.160	0.024	0.167	0.176
TP	GPI	17	0.315	1.030	0.529	0.629	0.231	0.367	0.9119	0.1076	0.587	0.629	0.239	0.380	0.9373	0.2877	**0.629**	**0.054**	**0.574**	**0.099**	0.590	0.556
TP	HI	18	0.020	0.582	0.161	0.175	0.158	0.902	0.8710	0.0185	0.095	0.199	0.302	1.520	0.8435	0.0067	**0.168**	**0.035**	**0.139**	**0.076**	0.099	0.203
TP	HLA	21	0.020	0.775	0.143	0.221	0.211	0.954	0.7753	0.0003	**0.148**	**0.222**	**0.229**	**1.031**	**0.9793**	**0.9154**	0.221	0.045	0.149	0.036	0.151	0.223
TP	HPA	28	0.222	1.773	0.471	0.543	0.335	0.616	0.7933	0.0001	**0.471**	**0.537**	**0.289**	**0.539**	**0.9584**	**0.3202**	0.544	0.062	0.463	0.076	0.473	0.451
TP	JVI	33	0.035	0.595	0.179	0.219	0.119	0.542	0.8888	0.0028	**0.190**	**0.221**	**0.131**	**0.591**	**0.9485**	**0.1206**	0.219	0.021	0.185	0.025	0.191	0.234
TP	LCA	28	0.003	1.203	0.203	0.330	0.273	0.827	0.8796	0.0039	0.191	0.468	0.882	1.883	0.8234	0.0003	**0.330**	**0.050**	**0.264**	**0.097**	0.197	0.290
TP	LGA	31	0.004	0.256	0.031	0.052	0.053	1.003	0.7252	0.0001	**0.036**	**0.052**	**0.052**	**0.997**	**0.9676**	**0.4558**	0.055	0.009	0.034	0.008	0.036	0.074
TP	LUA	31	0.148	1.710	0.376	0.571	0.409	0.717	0.8301	0.0002	**0.457**	**0.564**	**0.399**	**0.707**	**0.9439**	**0.1060**	0.571	0.073	0.402	0.085	0.460	0.425
TP	MBA	27	0.219	1.356	0.449	0.498	0.260	0.521	0.8217	0.0003	**0.448**	**0.494**	**0.227**	**0.459**	**0.9614**	**0.3985**	0.499	0.050	0.439	0.051	0.450	0.446
TP	MI	26	0.020	0.511	**0.249**	**0.257**	**0.126**	**0.491**	**0.9831**	**0.9326**	0.211	0.276	0.222	0.806	0.8411	0.0010	0.257	0.025	0.251	0.030	0.214	0.235

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TP	OFA	18	0.037	0.859	0.199	0.287	0.234	0.815	0.8560	0.0105	**0.205**	**0.293**	**0.277**	**0.944**	**0.9818**	**0.9667**	0.287	0.053	0.219	0.064	0.210	0.238
TP	RO	16	0.020	0.721	0.170	0.216	0.194	0.897	0.8783	0.0366	**0.131**	**0.236**	**0.303**	**1.282**	**0.9441**	**0.4021**	0.211	0.045	0.161	0.058	0.136	0.312
TP	RRI	32	0.113	2.133	0.420	0.547	0.480	0.877	0.7240	0.0001	**0.413**	**0.538**	**0.434**	**0.807**	**0.9753**	**0.6565**	0.544	0.081	0.429	0.062	0.417	0.429
TP	S1M	28	0.073	0.588	0.215	0.254	0.157	0.616	0.8865	0.0056	**0.210**	**0.255**	**0.172**	**0.676**	**0.9523**	**0.2267**	0.254	0.029	0.212	0.040	0.211	0.206
TP	SCA	27	0.126	2.870	0.751	0.869	0.537	0.618	0.8435	0.0009	**0.725**	**0.884**	**0.600**	**0.678**	**0.9601**	**0.3707**	0.871	0.104	0.770	0.102	0.731	0.829
TP	SI	22	0.020	0.391	0.093	0.113	0.096	0.848	0.8430	0.0026	**0.079**	**0.116**	**0.117**	**1.006**	**0.9462**	**0.2651**	0.115	0.019	0.096	0.020	0.080	0.092
TP	SWI	13	0.043	0.402	**0.232**	**0.245**	**0.098**	**0.400**	**0.9612**	**0.7722**	0.217	0.254	0.150	0.589	0.7957	0.0061	0.246	0.026	0.237	0.033	0.219	0.218
TP	SWJ	13	0.066	1.270	0.200	0.288	0.314	1.092	0.6092	0.0001	**0.206**	**0.270**	**0.213**	**0.790**	**0.9372**	**0.4215**	0.289	0.084	0.200	0.036	0.210	0.173
TP	TBA	28	0.078	1.398	0.363	0.414	0.299	0.723	0.8661	0.0020	**0.322**	**0.417**	**0.331**	**0.793**	**0.9824**	**0.9042**	0.414	0.055	0.342	0.054	0.325	0.454
TP	TCA	27	0.077	0.948	0.189	0.245	0.179	0.733	0.7282	0.0001	**0.204**	**0.240**	**0.147**	**0.610**	**0.9672**	**0.5302**	0.242	0.033	0.192	0.022	0.205	0.229
TP	TPA	24	0.131	1.841	0.363	0.455	0.336	0.740	0.6300	0.0001	**0.388**	**0.444**	**0.243**	**0.546**	**0.9229**	**0.0678**	0.454	0.068	0.365	0.032	0.390	0.421
TP	W5A	30	0.182	3.460	0.592	0.903	0.744	0.824	0.7616	0.0001	**0.699**	**0.887**	**0.673**	**0.758**	**0.9653**	**0.4186**	0.902	0.132	0.635	0.126	0.704	0.640
TP	WBA	33	0.084	0.915	0.367	0.413	0.203	0.491	0.9673	0.4088	0.359	0.421	0.253	0.601	0.9523	0.1549	**0.413**	**0.035**	**0.386**	**0.050**	0.360	0.392
TP	WCI	35	0.068	2.421	0.316	0.547	0.557	1.019	0.7517	0.0001	**0.359**	**0.544**	**0.588**	**1.081**	**0.9770**	**0.6611**	0.574	0.092	0.383	0.094	0.363	0.480
TSS	ARA	21	14.0	699.0	101.0	138.5	152.5	1.101	0.6755	0.0001	**91.4**	**136.1**	**138.9**	**1.020**	**0.9865**	**0.9873**	138.2	32.5	97.7	16.1	93.2	117.3
TSS	BC	22	0.8	438.1	46.1	95.5	118.2	1.237	0.7920	0.0004	**30.1**	**147.0**	**440.8**	**2.998**	**0.9437**	**0.2355**	87.9	23.2	41.4	23.4	32.5	61.0
TSS	BCU	24	2.0	221.9	10.0	33.0	56.2	1.704	0.5723	0.0001	**13.0**	**27.7**	**44.6**	**1.608**	**0.9196**	**0.0572**	32.8	11.3	10.4	3.0	13.4	76.6
TSS	BI	12	2.2	198.6	45.0	64.0	63.0	0.985	0.8872	0.1084	27.5	83.6	157.5	1.884	0.9076	0.1985	**64.1**	**17.2**	**49.1**	**23.7**	30.4	54.5
TSS	BNI	12	35.9	1014.7	398.4	407.1	312.6	0.768	0.9395	0.4917	248.4	466.5	602.2	1.291	0.8817	0.0922	**408.3**	**85.4**	**384.2**	**124.7**	262.4	308.3
TSS	BRI	27	50.0	1001.2	91.3	239.4	272.9	1.140	0.7033	0.0001	144.2	224.8	250.3	1.113	0.8705	0.0030	**240.5**	**52.5**	**108.5**	**35.6**	146.6	173.1
TSS	BSI	10	14.5	295.0	62.0	86.5	82.8	0.957	0.7868	0.0100	**58.0**	**86.2**	**82.6**	**0.958**	**0.9838**	**0.9823**	86.6	24.9	66.7	23.5	60.4	63.7
TSS	BUA	21	13.5	1948.4	134.3	289.7	459.3	1.585	0.6156	0.0001	**112.9**	**290.8**	**546.5**	**1.879**	**0.9695**	**0.7218**	288.9	97.8	134.6	51.1	118.3	279.5
TSS	CMI	24	5.0	778.7	161.1	210.9	176.4	0.836	0.8689	0.0050	133.0	249.7	350.6	1.404	0.9063	0.0294	**210.5**	**35.6**	**170.6**	**29.4**	136.7	166.8
TSS	CTI	17	27.5	591.9	86.3	134.5	131.7	0.979	0.6680	0.0001	**99.4**	**129.7**	**102.7**	**0.792**	**0.9691**	**0.8021**	135.1	31.1	97.6	26.0	101.0	95.2
TSS	CTJ	24	82.3	2193.1	264.1	505.7	562.2	1.112	0.7313	0.0001	**308.1**	**489.1**	**554.6**	**1.134**	**0.9475**	**0.2388**	504.1	112.8	282.2	80.9	314.2	484.4
TSS	CTK	22	30.0	504.9	103.1	137.3	119.7	0.872	0.7852	0.0003	**100.8**	**135.3**	**115.0**	**0.850**	**0.9709**	**0.7322**	137.2	25.0	102.0	17.4	102.2	89.7
TSS	E7A	26	38.6	693.3	126.8	186.7	175.6	0.941	0.7582	0.0001	**131.6**	**181.8**	**164.6**	**0.906**	**0.9536**	**0.2807**	186.7	33.8	126.5	30.6	133.3	350.2
TSS	EBA	37	17.3	577.5	73.3	88.2	91.3	1.034	0.5325	0.0001	**68.0**	**85.1**	**62.6**	**0.735**	**0.9566**	**0.1569**	88.3	14.9	73.0	7.6	68.4	74.0
TSS	EHA	37	31.1	1130.5	192.2	292.3	261.9	0.896	0.7865	0.0001	**208.3**	**291.2**	**273.8**	**0.940**	**0.9825**	**0.8145**	292.2	42.6	198.4	42.0	210.2	265.5
TSS	EMA	48	30.3	875.6	241.1	292.7	207.6	0.709	0.8899	0.0003	**222.7**	**305.0**	**277.7**	**0.910**	**0.9542**	**0.0589**	302.1	30.9	247.2	36.5	224.1	267.5

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
TSS	ERA	21	4.5	182.0	42.3	52.7	40.4	0.766	0.8240	0.0016	**40.2**	**54.4**	**46.8**	**0.862**	**0.9493**	**0.3311**	52.7	8.6	40.9	7.0	40.8	57.6
TSS	FPI	15	40.3	213.3	85.6	94.9	42.5	0.448	0.8666	0.0301	**87.0**	**94.5**	**39.5**	**0.417**	**0.9763**	**0.9379**	94.7	10.7	86.6	12.7	87.5	92.3
TSS	FSU	31	3.6	466.0	87.5	118.6	121.9	1.028	0.8062	0.0001	**67.2**	**131.2**	**197.7**	**1.506**	**0.9690**	**0.4928**	118.7	21.6	78.0	24.0	68.7	134.3
TSS	FWU	24	19.0	910.0	179.0	261.4	239.1	0.915	0.8235	0.0007	**170.0**	**273.9**	**317.3**	**1.159**	**0.9788**	**0.8730**	218.7	37.8	150.5	44.5	173.4	207.6
TSS	GPI	18	60.2	758.3	208.6	226.6	171.8	0.758	0.8179	0.0027	**176.7**	**225.7**	**170.6**	**0.756**	**0.9590**	**0.5832**	226.1	39.2	196.8	41.4	179.2	232.2
TSS	HI	19	4.9	585.9	79.9	120.5	133.8	1.110	0.6734	0.0001	**75.2**	**127.1**	**153.9**	**1.211**	**0.9289**	**0.1652**	126.2	30.7	76.9	14.4	77.4	109.7
TSS	HLA	21	9.8	521.3	100.5	153.2	159.8	1.044	0.7989	0.0006	**84.4**	**162.9**	**232.9**	**1.429**	**0.9688**	**0.7052**	152.7	33.9	94.4	30.7	87.1	151.0
TSS	HPA	28	35.8	254.3	92.2	112.3	66.0	0.588	0.9159	0.0275	**93.3**	**113.3**	**76.0**	**0.671**	**0.9431**	**0.1326**	112.4	12.2	98.0	18.6	93.9	97.5
TSS	JVI	34	39.9	990.1	145.6	261.7	253.4	0.968	0.7013	0.0001	186.2	251.9	221.2	0.878	0.9193	0.0154	**260.9**	**42.7**	**152.4**	**22.8**	187.9	222.4
TSS	LCA	24	10.0	528.9	92.4	161.1	150.5	0.934	0.8381	0.0013	**96.7**	**171.3**	**224.4**	**1.310**	**0.9550**	**0.3467**	160.6	30.2	103.5	45.6	99.1	145.7
TSS	LGA	31	1.8	488.1	15.2	55.6	115.1	2.068	0.4610	0.0001	**18.0**	**48.0**	**98.9**	**2.060**	**0.9620**	**0.3286**	62.4	20.9	18.0	8.3	18.6	83.6
TSS	LUA	31	22.8	686.7	160.0	184.9	141.6	0.766	0.8112	0.0001	**143.1**	**187.4**	**152.9**	**0.816**	**0.9754**	**0.6766**	185.0	25.0	155.0	24.0	144.4	161.4
TSS	MBA	26	40.0	639.4	157.9	247.5	182.7	0.738	0.8578	0.0020	**185.4**	**252.3**	**222.0**	**0.880**	**0.9436**	**0.1636**	247.6	35.2	173.3	39.5	187.6	304.5
TSS	MI	26	6.3	981.0	227.8	296.3	272.3	0.919	0.8875	0.0083	153.7	389.9	747.9	1.918	0.9175	0.0393	**296.3**	**52.5**	**222.2**	**59.3**	159.5	319.5
TSS	OFA	27	2.5	206.0	47.4	65.6	52.7	0.803	0.8905	0.0082	**43.5**	**73.8**	**92.4**	**1.252**	**0.9354**	**0.0938**	65.8	10.1	49.9	10.3	44.4	52.1
TSS	PA3	15	8.0	117.0	37.0	46.5	36.8	0.790	0.8386	0.0120	33.8	46.8	41.4	0.884	0.9543	0.5948	**46.4**	**9.3**	**34.4**	**12.0**	34.5	45.3
TSS	RO	16	31.9	677.8	122.0	220.0	218.4	0.993	0.8045	0.0031	**131.1**	**222.8**	**266.9**	**1.198**	**0.9339**	**0.2809**	219.8	49.8	150.4	57.7	135.7	414.2
TSS	RRI	32	27.8	970.9	186.7	263.6	224.9	0.853	0.7956	0.0001	**191.4**	**268.3**	**252.1**	**0.940**	**0.9696**	**0.4884**	264.3	38.2	200.4	31.7	193.5	263.4
TSS	S1M	29	8.4	394.4	48.7	87.2	99.6	1.142	0.7357	0.0001	**49.8**	**86.7**	**113.0**	**1.304**	**0.9658**	**0.4520**	87.2	18.1	47.6	16.1	50.8	70.0
TSS	SCA	27	17.4	404.9	117.8	141.8	98.9	0.697	0.9157	0.0312	**106.9**	**148.6**	**136.6**	**0.919**	**0.9553**	**0.2880**	142.1	19.0	121.2	20.3	108.2	109.3
TSS	SI	22	3.8	143.6	41.5	59.7	42.7	0.716	0.8805	0.0123	43.1	64.7	67.0	1.035	0.9066	0.0404	**59.5**	**8.5**	**46.2**	**9.3**	44.0	52.4
TSS	SWI	13	17.1	338.9	100.7	118.9	96.4	0.810	0.8512	0.0296	**83.6**	**122.6**	**117.9**	**0.962**	**0.9540**	**0.6597**	119.3	25.7	101.0	24.8	86.2	119.6
TSS	SWJ	13	8.9	964.0	71.1	165.8	260.5	1.571	0.5806	0.0001	**77.6**	**150.2**	**202.1**	**1.345**	**0.9530**	**0.6449**	167.1	69.9	75.1	30.2	81.9	73.8
TSS	TBA	30	14.2	585.1	168.4	195.9	143.0	0.730	0.9270	0.0408	137.3	215.7	244.1	1.132	0.9265	0.0396	**195.8**	**25.5**	**169.3**	**40.1**	139.5	178.3
TSS	TCA	26	1.7	475.1	19.9	68.1	126.5	1.856	0.5263	0.0001	**23.0**	**60.5**	**120.0**	**1.984**	**0.9602**	**0.3951**	66.7	23.9	20.6	3.7	23.9	47.9
TSS	TPA	25	12.7	712.6	81.7	140.4	174.2	1.240	0.6256	0.0001	**85.4**	**134.7**	**151.7**	**1.126**	**0.9668**	**0.5649**	140.5	34.2	81.2	13.5	87.0	106.8
TSS	W5A	28	39.0	687.3	129.9	186.3	163.0	0.875	0.7643	0.0001	**138.3**	**182.4**	**150.9**	**0.827**	**0.9672**	**0.5091**	186.3	30.1	130.8	20.1	139.6	150.6
TSS	WBA	33	7.7	234.0	89.3	97.8	70.5	0.721	0.9183	0.0164	65.8	108.5	132.6	1.223	0.9055	0.0074	**97.7**	**12.2**	**89.7**	**20.6**	66.8	86.8
TSS	WCI	36	10.0	678.8	88.6	125.3	138.3	1.103	0.6560	0.0001	**83.9**	**123.3**	**126.6**	**1.027**	**0.9758**	**0.6044**	132.1	25.3	89.8	12.5	84.9	93.5
VSS	BCU	24	0.92	41.87	4.76	8.73	10.22	1.171	0.7112	0.0001	**5.14**	**8.50**	**10.22**	**1.202**	**0.9776**	**0.8470**	8.70	2.05	5.08	1.23	5.25	16.00

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
VSS	BNI	1	9.52	9.52	**9.52**	**9.52**	**---**	**---**	**---**	**---**	---	9.52	---	---	---	---	9.52	---	9.52	---	9.52	9.52
VSS	BRI	23	1.53	123.31	20.96	36.03	33.17	0.921	0.8133	0.0006	**23.51**	**38.10**	**44.36**	**1.164**	**0.9508**	**0.3038**	36.13	6.78	23.83	6.70	24.02	25.79
VSS	BSI	2	6.00	19.53	**12.76**	**12.76**	**9.57**	**0.749**	**---**	**---**	8.99	12.76	9.57	0.749	---	---	12.83	4.78	12.83	4.78	10.82	13.68
VSS	BUA	16	4.43	236.00	37.19	55.87	65.31	1.169	0.6954	0.0002	**31.11**	**57.62**	**76.23**	**1.323**	**0.9480**	**0.4587**	56.56	14.95	40.07	8.99	32.37	43.70
VSS	CMI	15	27.31	171.74	53.65	62.97	36.41	0.578	0.7782	0.0020	**55.66**	**62.17**	**30.16**	**0.485**	**0.9554**	**0.6132**	62.89	9.10	53.96	6.21	56.08	39.72
VSS	CTI	17	5.69	40.51	12.84	16.72	11.83	0.707	0.7991	0.0020	**13.43**	**16.51**	**11.29**	**0.684**	**0.9225**	**0.1630**	16.77	2.78	12.79	2.62	13.60	11.23
VSS	CTJ	24	9.86	131.43	26.39	35.32	28.78	0.815	0.7911	0.0002	**27.13**	**34.75**	**26.71**	**0.769**	**0.9629**	**0.4994**	35.24	5.79	26.46	4.21	27.42	31.14
VSS	CTK	22	5.24	47.70	11.96	16.16	10.98	0.679	0.8331	0.0017	**13.30**	**16.01**	**10.42**	**0.650**	**0.9644**	**0.5822**	16.14	2.30	12.65	2.24	13.41	10.45
VSS	E7A	26	6.45	114.34	21.83	31.51	27.37	0.868	0.7221	0.0001	**24.12**	**30.68**	**23.27**	**0.759**	**0.9656**	**0.5124**	31.53	5.27	22.62	4.16	24.34	60.59
VSS	EBA	37	7.49	320.71	23.25	38.46	54.44	1.415	0.4802	0.0001	25.66	34.78	30.77	0.885	0.9350	0.0320	**38.48**	**8.88**	**23.96**	**3.26**	25.87	27.13
VSS	EHA	37	10.88	276.24	52.33	78.14	64.45	0.825	0.8049	0.0001	**58.54**	**77.28**	**64.59**	**0.836**	**0.9640**	**0.2704**	78.14	10.49	53.04	8.03	58.98	65.66
VSS	EMA	48	13.12	312.33	49.92	74.39	66.88	0.899	0.7421	0.0001	**55.25**	**72.90**	**61.26**	**0.840**	**0.9779**	**0.4927**	75.13	9.45	52.54	7.92	55.57	66.32
VSS	ERA	21	3.79	54.27	12.62	17.58	12.00	0.682	0.8188	0.0013	**14.49**	**17.47**	**11.39**	**0.652**	**0.9766**	**0.8699**	17.55	2.55	13.87	2.42	14.62	16.61
VSS	FPI	15	10.12	34.40	16.05	17.63	6.65	0.377	0.9008	0.0980	16.54	17.59	6.27	0.357	0.9639	0.7598	**17.61**	**1.67**	**16.29**	**2.28**	16.61	15.87
VSS	FSU	31	0.53	67.31	13.78	19.29	18.49	0.958	0.8216	0.0001	**11.53**	**21.63**	**31.08**	**1.437**	**0.9553**	**0.2185**	19.32	3.28	13.58	3.46	11.77	22.56
VSS	FWU	23	3.49	95.52	19.39	30.25	26.60	0.879	0.8264	0.0010	**20.65**	**30.70**	**31.44**	**1.024**	**0.9766**	**0.8413**	27.25	4.93	18.52	3.98	21.02	23.80
VSS	GPI	18	16.20	76.89	34.38	41.04	18.58	0.453	0.9170	0.1143	36.89	41.11	19.81	0.482	0.9418	0.3110	**40.99**	**4.26**	**37.69**	**8.82**	37.12	47.07
VSS	HLA	2	15.16	19.27	**17.22**	**17.22**	**2.90**	**0.169**	**---**	**---**	16.97	17.22	2.90	0.169	---	---	17.24	1.45	17.24	1.45	17.10	15.89
VSS	HPA	26	11.54	98.27	35.09	40.95	25.82	0.630	0.8969	0.0133	**33.38**	**41.20**	**28.91**	**0.702**	**0.9571**	**0.3377**	41.04	5.02	34.35	6.32	33.65	34.48
VSS	JVI	16	9.65	77.16	26.52	32.10	19.65	0.612	0.8906	0.0570	26.86	32.06	20.11	0.627	0.9797	0.9611	**32.05**	**4.72**	**26.83**	**5.53**	27.16	22.68
VSS	LCA	17	2.08	121.00	25.84	43.14	34.33	0.796	0.8962	0.0587	28.49	47.74	56.57	1.185	0.9308	0.2248	**43.25**	**8.07**	**32.42**	**13.37**	29.40	32.46
VSS	LGA	31	0.38	47.71	2.80	5.77	8.97	1.555	0.5207	0.0001	**3.22**	**5.27**	**6.37**	**1.208**	**0.9758**	**0.6898**	5.95	1.55	3.23	0.76	3.27	9.77
VSS	LUA	17	8.35	188.81	44.72	64.86	54.14	0.835	0.8301	0.0054	**45.53**	**66.02**	**63.68**	**0.964**	**0.9580**	**0.5936**	65.08	12.77	52.74	20.02	46.55	42.33
VSS	MBA	24	3.84	210.51	27.31	42.44	43.17	1.017	0.7073	0.0001	**29.01**	**42.39**	**42.28**	**0.998**	**0.9878**	**0.9881**	42.37	8.68	29.03	6.43	29.48	39.53
VSS	OFA	17	4.30	220.91	24.67	45.39	52.61	1.159	0.7092	0.0001	**26.39**	**45.88**	**56.89**	**1.240**	**0.9787**	**0.9440**	45.60	12.41	29.14	10.57	27.28	37.10
VSS	RRI	32	4.00	104.35	24.82	30.50	23.54	0.772	0.7993	0.0001	**23.47**	**30.87**	**25.50**	**0.826**	**0.9772**	**0.7140**	30.34	4.22	24.88	3.76	23.67	25.74
VSS	S1M	29	2.85	81.85	10.23	20.79	21.92	1.055	0.7678	0.0001	**12.71**	**20.48**	**24.02**	**1.173**	**0.9539**	**0.2307**	20.78	3.99	11.68	3.46	12.93	15.95
VSS	SCA	27	9.69	178.75	55.00	67.51	44.86	0.664	0.9348	0.0908	51.61	70.53	62.68	0.889	0.9487	0.1994	**67.65**	**8.63**	**57.62**	**11.83**	52.22	52.52
VSS	SWI	13	4.07	40.07	10.69	14.44	9.68	0.670	0.7944	0.0059	**12.03**	**14.29**	**8.75**	**0.612**	**0.9308**	**0.3493**	14.49	2.59	11.06	2.80	12.20	12.32
VSS	SWJ	13	2.85	108.00	14.76	24.45	27.86	1.139	0.7015	0.0006	**14.74**	**24.32**	**27.48**	**1.130**	**0.9745**	**0.9415**	24.59	7.44	16.47	6.23	15.34	12.53

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
VSS	TBA	28	3.48	104.00	29.45	33.52	22.89	0.683	0.9128	0.0232	**25.85**	**34.90**	**30.32**	**0.869**	**0.9660**	**0.4787**	33.52	4.23	29.02	5.05	26.13	28.60
VSS	TCA	25	1.31	64.08	6.47	12.89	17.03	1.321	0.6419	0.0001	**7.00**	**12.11**	**15.48**	**1.278**	**0.9460**	**0.2033**	12.63	3.21	6.15	1.02	7.16	11.37
VSS	TPA	24	3.97	301.77	27.73	44.31	58.87	1.329	0.5319	0.0001	**28.09**	**42.80**	**45.68**	**1.067**	**0.9600**	**0.4391**	44.17	11.83	28.74	4.54	28.59	28.01
VSS	W5A	28	16.00	279.86	46.08	70.07	65.02	0.928	0.7378	0.0001	**51.22**	**67.69**	**56.19**	**0.830**	**0.9506**	**0.2050**	70.07	11.99	47.27	9.40	51.74	48.65
VSS	WBA	33	3.61	82.00	25.05	32.25	22.44	0.696	0.9276	0.0299	**23.70**	**34.17**	**33.86**	**0.991**	**0.9473**	**0.1112**	32.22	3.88	27.44	5.51	23.96	27.60
VSS	WCI	35	3.81	101.28	25.27	29.05	21.46	0.739	0.8565	0.0003	**22.41**	**29.57**	**24.65**	**0.834**	**0.9865**	**0.9362**	29.99	3.86	25.02	2.89	22.59	22.52
ZN	ARA	9	57.10	211.00	84.00	100.90	48.59	0.482	0.8053	0.0234	**92.03**	**100.05**	**41.47**	**0.415**	**0.9177**	**0.3739**	100.95	15.41	87.68	14.55	92.90	91.79
ZN	BC	22	3.49	42.67	6.77	11.30	10.76	0.953	0.6389	0.0001	8.51	10.75	7.97	0.742	0.8789	0.0115	**11.25**	**2.13**	**7.13**	**1.44**	8.60	9.36
ZN	BCU	25	3.00	84.09	14.13	18.90	21.27	1.126	0.7475	0.0001	10.67	18.88	24.82	1.315	0.9083	0.0279	**18.93**	**4.18**	**12.28**	**5.20**	10.92	39.14
ZN	BI	12	16.75	158.08	48.36	56.62	37.71	0.666	0.8310	0.0215	**46.83**	**56.42**	**36.00**	**0.638**	**0.9829**	**0.9928**	56.71	10.31	49.54	8.84	47.57	47.20
ZN	BNI	14	12.61	220.00	40.00	63.65	60.22	0.946	0.7964	0.0045	**43.16**	**62.44**	**59.15**	**0.947**	**0.9602**	**0.7265**	63.79	15.55	42.90	14.96	44.34	46.28
ZN	BRI	15	10.00	118.00	58.74	60.69	33.71	0.555	0.9273	0.2488	49.44	63.11	47.24	0.749	0.9001	0.0954	**58.69**	**7.99**	**55.16**	**7.76**	50.26	51.21
ZN	BSI	12	9.70	350.00	66.57	109.93	119.55	1.087	0.7711	0.0045	**58.80**	**111.94**	**146.48**	**1.309**	**0.9457**	**0.5749**	110.06	32.58	68.48	33.14	62.19	52.06
ZN	BUA	14	24.99	320.00	84.33	114.99	89.28	0.776	0.8334	0.0133	**87.28**	**114.17**	**89.90**	**0.787**	**0.9686**	**0.8579**	115.16	22.99	85.87	23.69	89.00	81.70
ZN	CMI	24	38.80	413.00	138.63	161.32	100.57	0.623	0.9129	0.0407	**132.10**	**162.69**	**113.20**	**0.696**	**0.9773**	**0.8405**	161.09	20.23	137.84	23.38	133.26	102.67
ZN	CTI	17	13.82	109.02	32.90	42.14	27.00	0.641	0.8602	0.0154	**34.94**	**41.99**	**26.95**	**0.642**	**0.9573**	**0.5815**	42.25	6.35	34.82	5.71	35.32	28.82
ZN	CTJ	24	5.53	219.48	44.10	63.64	56.88	0.894	0.7500	0.0001	**45.88**	**63.52**	**57.60**	**0.907**	**0.9382**	**0.1485**	63.47	11.41	43.60	6.74	46.51	39.39
ZN	CTK	22	5.00	87.56	23.27	29.73	22.56	0.759	0.8174	0.0009	**22.93**	**29.70**	**23.36**	**0.787**	**0.9664**	**0.6282**	29.69	4.72	23.56	3.88	23.20	20.09
ZN	E7A	26	91.68	945.44	195.38	234.87	162.47	0.692	0.6121	0.0001	205.51	229.19	111.48	0.486	0.9201	0.0453	**235.17**	**31.34**	**193.59**	**15.93**	206.38	229.66
ZN	EBA	35	13.58	180.80	51.32	57.00	35.27	0.619	0.8381	0.0001	**48.63**	**56.70**	**33.44**	**0.590**	**0.9878**	**0.9579**	57.05	5.90	49.05	4.87	48.84	41.86
ZN	EHA	34	41.18	1500.00	116.34	182.58	256.07	1.402	0.4444	0.0001	127.27	164.45	130.57	0.794	0.9103	0.0087	**181.60**	**42.73**	**119.39**	**12.94**	128.24	145.84
ZN	EMA	48	66.94	594.38	123.76	152.85	94.21	0.616	0.7386	0.0001	134.27	150.49	75.51	0.502	0.9514	0.0453	**154.97**	**13.41**	**129.86**	**12.44**	134.59	134.73
ZN	ERA	20	30.78	325.23	89.97	105.86	79.61	0.752	0.8386	0.0035	**81.86**	**105.63**	**82.09**	**0.777**	**0.9481**	**0.3390**	106.06	17.34	88.03	19.09	82.92	140.86
ZN	FPI	15	20.72	115.96	72.83	66.84	25.55	0.382	0.9801	0.9705	61.03	67.62	31.54	0.466	0.9255	0.2334	**66.74**	**6.44**	**69.16**	**9.61**	61.45	57.24
ZN	FSU	31	3.00	45.09	16.45	17.38	11.44	0.658	0.9330	0.0530	13.35	18.01	15.68	0.870	0.9436	0.1040	**17.39**	**2.02**	**16.43**	**3.08**	13.48	16.43
ZN	FWU	23	10.04	231.71	34.38	45.57	47.12	1.034	0.6677	0.0001	**31.89**	**44.22**	**40.13**	**0.907**	**0.9450**	**0.2297**	48.33	8.37	37.43	10.83	32.35	24.11
ZN	GPI	18	40.31	244.62	92.19	99.47	53.95	0.542	0.8152	0.0025	**88.37**	**98.60**	**47.79**	**0.485**	**0.9541**	**0.4932**	99.37	12.30	87.05	12.34	88.91	80.75
ZN	HI	19	6.00	228.88	32.45	42.49	50.15	1.180	0.6129	0.0001	**28.11**	**40.67**	**39.37**	**0.968**	**0.9748**	**0.8670**	44.97	12.12	29.18	6.95	28.67	35.69
ZN	HLA	19	6.00	153.70	36.56	55.87	45.38	0.812	0.8864	0.0278	**37.69**	**58.77**	**63.88**	**1.087**	**0.9608**	**0.5885**	56.17	10.12	43.20	16.05	38.60	52.78
ZN	HPA	27	34.34	227.95	103.00	112.34	47.17	0.420	0.9551	0.2847	102.60	112.79	50.89	0.451	0.9823	0.9101	**112.51**	**9.09**	**104.82**	**9.51**	102.96	91.54

Table 2.2 (cont). Summary water quality data information from all sites, including means and distribution tests. Values in bold were used for additional analyses.

Pollutant	Site	n	Min	Max	Normal						Log-normal						Bootstrap				Geometric Mean	Volume Mean
					Med	Mean	SD	CV	W	Prob. W	Med	Mean	SD	CV	W	Prob. W	Mean	SE_{mean}	Med	SE_{med}		
ZN	JVI	33	22.82	963.13	88.93	133.06	159.08	1.196	0.4692	0.0001	**99.67**	**124.78**	**91.52**	**0.733**	**0.9402**	**0.0686**	132.75	27.23	93.52	12.49	100.35	114.08
ZN	LCA	21	5.00	230.00	50.00	66.26	55.66	0.840	0.8078	0.0009	45.72	71.82	79.48	1.107	0.8965	0.0300	**66.18**	**11.84**	**50.95**	**7.18**	46.74	46.13
ZN	LGA	31	2.53	41.93	7.79	10.26	9.15	0.892	0.7751	0.0001	**7.48**	**10.03**	**8.64**	**0.861**	**0.9444**	**0.1095**	10.64	1.61	7.39	1.54	7.55	11.31
ZN	LUA	23	15.76	825.44	290.00	328.56	221.35	0.674	0.8990	0.0241	242.48	363.31	376.73	1.037	0.8828	0.0114	**328.92**	**45.20**	**294.72**	**53.34**	246.85	278.47
ZN	MBA	18	33.57	453.90	78.02	120.48	111.63	0.927	0.6565	0.0001	**92.10**	**115.01**	**82.24**	**0.715**	**0.9063**	**0.0741**	120.25	25.38	81.46	11.13	93.25	85.59
ZN	MI	26	0.00	82.00	21.06	24.67	18.38	0.745	0.8886	0.0088	**21.72**	**27.30**	**20.11**	**0.737**	**0.9458**	**0.2194**	24.69	3.57	21.00	2.66	21.91	23.71
ZN	OFA	13	7.59	147.46	65.10	70.57	52.77	0.748	0.8571	0.0352	**48.43**	**74.81**	**77.64**	**1.038**	**0.9168**	**0.2271**	70.83	14.08	61.19	26.06	50.12	55.48
ZN	RO	15	7.99	76.24	25.04	34.73	18.86	0.543	0.9304	0.2763	29.43	35.21	22.18	0.630	0.9507	0.5361	**35.94**	**4.50**	**34.30**	**9.35**	29.79	36.60
ZN	RRI	33	5.00	275.66	37.61	56.09	55.86	0.996	0.6914	0.0001	**39.91**	**54.93**	**49.88**	**0.908**	**0.9574**	**0.2179**	49.39	7.03	36.11	3.92	40.30	41.68
ZN	S1M	29	16.29	227.75	42.54	62.40	50.39	0.807	0.7968	0.0001	**48.08**	**61.36**	**47.08**	**0.767**	**0.9640**	**0.4110**	62.37	9.16	44.75	8.39	48.48	49.76
ZN	SCA	27	17.36	244.39	64.11	76.83	52.66	0.685	0.8843	0.0059	**61.12**	**77.44**	**58.24**	**0.752**	**0.9777**	**0.8082**	77.02	10.17	65.69	13.30	61.66	60.75
ZN	SI	22	16.62	359.96	93.23	110.16	85.37	0.775	0.8170	0.0009	**84.26**	**110.99**	**90.66**	**0.817**	**0.9826**	**0.9517**	117.27	18.36	96.55	19.03	85.33	102.97
ZN	SWI	13	22.62	214.69	72.88	90.84	52.58	0.579	0.9327	0.3695	76.08	91.82	59.06	0.643	0.9825	0.9894	**91.09**	**14.02**	**83.37**	**20.06**	77.21	83.31
ZN	SWJ	13	38.64	505.00	153.00	182.76	130.96	0.717	0.8810	0.0735	140.36	185.98	149.73	0.805	0.9606	0.7625	**183.44**	**34.94**	**157.58**	**33.30**	143.49	113.03
ZN	TBA	31	16.06	529.00	59.76	95.73	119.09	1.244	0.5970	0.0001	**61.78**	**88.94**	**87.63**	**0.985**	**0.9469**	**0.1284**	95.80	21.11	57.10	9.44	62.52	66.43
ZN	TCA	20	3.90	67.30	15.18	22.31	18.11	0.811	0.8508	0.0055	**16.03**	**22.45**	**20.60**	**0.917**	**0.9542**	**0.4355**	22.35	3.94	16.61	6.42	16.31	17.87
ZN	TPA	21	10.03	137.78	37.92	51.78	38.84	0.750	0.8260	0.0017	**39.85**	**51.77**	**40.95**	**0.791**	**0.9650**	**0.6216**	51.68	8.24	39.02	5.91	40.36	37.06
ZN	W5A	20	89.18	1200.00	249.30	390.73	324.69	0.831	0.7852	0.0005	**293.57**	**384.23**	**308.27**	**0.802**	**0.9578**	**0.5008**	391.53	70.72	276.51	71.69	297.60	213.15
ZN	WBA	33	53.72	749.37	139.82	185.28	144.43	0.780	0.7559	0.0001	**148.59**	**181.98**	**125.65**	**0.690**	**0.9709**	**0.5064**	185.04	24.84	143.77	20.22	149.51	143.80
ZN	WCI	37	63.64	2821.00	183.26	361.10	509.35	1.411	0.5258	0.0001	228.30	325.65	317.83	0.976	0.9289	0.0207	**367.28**	**83.30**	**197.60**	**37.91**	230.52	193.81

3 Runoff Quantity

The methods used to estimate runoff quantity depend greatly on the reason for estimation. If the purpose is to estimate peak runoff rates, the rational method is often used while the NRCS curve number method (CN) may be used to estimate runoff volume from large storms for flood detention computation. These methods are commonly used in many models such as the HEC suite but they do have drawbacks when applied to water quality design. To address this, COA criteria (COA, 2009) currently rely upon long-term average runoff-rainfall ratios to size water quality controls.

The ratio between runoff and rainfall, *Rv*, has been used to estimate runoff volume to size water quality controls for some time. But, there are some issues related to its use that may be problematic. At first inspection of the data in this report, it may appear that too little runoff is generated from areas with high impervious cover. Pitt (2003) found that there is a substantial amount of infiltration from roadways either through the aggregate or in the joints in the case of concrete and that it is the road base that is impermeable. Parking lots, on the other hand, do have higher runoff rates because of the extensive area. It may be tempting to use the *Rv* to predict event runoff but the estimates may not be reliable without considering other event variables (Glick, 2009). The first part of this section will focus on the relationship of *Rv* to impervious cover and how that relationship may be used to size water quality controls.

While the CN method may produce reasonable results for large events, the vast majority of rainfall events of concern to water quality engineers and planners are small events (Pitt, 2003). In addition, the value of the curve number used in the model is not a constant but changes with the size of the event. The second part of this section will examine proposed modifications to the CN method that may allow it to be more suitably used to estimate runoff volume from small rainfall events.

3.1 Estimation of Annual Average Runoff

SQE has been monitoring runoff from many watersheds over the past 20 years, resulting in a broad localized dataset of rainfall and runoff for analysis. The runoff-rainfall ratio, *Rv*, for each watershed was computed based on these data for small watersheds in the Austin area. The watershed characteristics and the computed annual average runoff coefficients are presented in Table 3.1 for thirty-six City of Austin small watersheds used in these analyses. The directly connected impervious area (DCIA) in Table 3.1 is the portion of the total impervious cover (TIC) within a watershed that is directly connected to the drainage collection system. Because the direct measurement of DCIA is impractical for most watersheds, the values of DCIA in Table 3.1 were estimated based on different empirical equations that describe the relationship between TIC and DCIA (Sutherland, 1995).

Several curve-fitting models were applied to the runoff coefficient and impervious cover data in Table 3.1. After comparing standard errors and correlation coefficients for the different models, it was found that quadratic models produced the best fits. For TIC-*Rv* relationships, the linear model and the quadratic model are very close to each other; further statistical analyses indicated that the second-degree term in the quadratic model was not significant. Therefore, the linear TIC-*Rv* model is recommended to represent the relationship between runoff coefficient and total impervious cover. The linear relationship between TIC and *Rv* and the quadratic relationship between DCIA and *Rv* are shown in Figure 3.1. It is understandable that the r^2 of the DCIA-*Rv* relationship is lower than the r^2 of the TIC-*Rv* relationship because the values of DCIA are not from direct measurement in the field, but derived from the values of TIC based on empirical equations. Therefore, the errors of DCIA values should usually be higher than the errors in TIC values. Because the values of TIC are more reliable than the values of DCIA, further analyses will focus on the TIC-*Rv* relationship instead of DCIA-*Rv* relationship in this study. The intercept of the linear model, where total impervious cover is zero, results in a runoff coefficient of 0.0644.

The depression storage (Sd) is defined as the amount of water in a rainfall event retained in the watershed before runoff is generated. In this study, we use two methods to estimate Sd values for all watersheds. The first method is the method presented in Adams and Papa (2000) and the second method is to take the average value of depression storages for all events as the depression storage of the watershed.

The Adams and Papa method is to plot event runoff volume versus event rainfall for each watershed, and then find the rainfall value from a regression curve (linear or quadratic) when the runoff volume is zero. That intercept rainfall value is the depression storage Sd for the watershed. Runoff versus rainfall data must be physically plausible; if the intercept of the regression is greater than zero, then it is problematic as it indicates that runoff is generated when there is no rainfall. When using the Adams and Papa method, Sd values could be determined for only 31 out of 36 watersheds. For the other watersheds, the intercept was a negative number and not a reasonable result for Sd.

The second method is, for each event, to take the rainfall amount before the direct runoff hydrograph begins as depression storage Sd for this event, and then take the average value of depression storages for all events as the depression storage of the watershed. The Sd values can be determined for all 36 watersheds using this method.

The exponential relationship between Sd and TIC produced the best fit among several curve-fitting models and is shown in Figure 3.2. Because Sd values for all 36 watersheds can be obtained with the second method (Sd_COA in Figure 3.2) and because the r^2 of exponential model from the second method is much higher than the r^2 of exponential model from the first method (Sd_Adams in Figure 3.2), the values of Sd from the second method were used in the following study and presented in Table 3.1. Both methods resulted in a wide range of values of Sd for low TIC sites; this may be due to the site being in the recharge zone or differences in vegetative cover.

Based on the mean annual storm statistics from long-term rainfall data, the average number of rainfall events in Austin area is 79.33 per year and the average annual rainfall volume is 31.73 inch. Therefore, the average rainfall event volume is 0.40 inch. Using the mean annual storm statistics and based on equations presented in Adams and Papa (2000), the average annual number of runoff events and the average annual runoff volume can be estimated for different impervious covers. In Table 3.2, the recommended runoff coefficient (*Rv*) from zero to 100% total impervious cover is presented. The depression storage (Sd), the average annual runoff

Table 3.1: Computed runoff coefficients and characteristics of watersheds

Site ID	Total Impervious Cover	Connected Impervious Cover	Watershed Area (ac.)	Runoff Coefficient	Depression Storage (in.)	Recharge Zone	No. of Events	Period of Monitoring
BC	0.0300	0.0009	301	0.007	0.603	No	51	1984-1991
BCU	0.0007	0.0000	17.33	0.020	0.828	Yes	431	1996-2004
BRI	0.8032	0.7724	3.04	0.758	0.042	No	419	1993-2002
BSI	0.6420	0.5144	4.63	0.716	0.078	Yes	125	1994-1997
CMI	0.5468	0.4043	100.03	0.302	0.071	No	291	1996-2002
CTI	0.3885	0.2422	17.89	0.660	0.048	No	148	2005-2007
CTJ	0.2899	0.1561	28.99	0.374	0.037	No	156	2005-2007
CTK	0.3917	0.2451	23.82	0.569	0.068	No	154	2005-2007
E7A	0.6007	0.4656	29.28	0.380	0.051	No	258	1995-1999
EBA	0.4036	0.2564	35.24	0.105	0.059	No	230	1999-2003
EHA	0.4342	0.2861	51.34	0.416	0.053	No	449	1994-2003
EMA	0.4204	0.2726	15.73	0.503	0.062	No	232	1999-2003
ERA	0.4600	0.2684	99.79	0.355	0.070	No	268	1994-1999
FSU	0.0640	0.0162	329.75	0.060	1.034	Yes	618	1998-Present
FWU	0.0080	0.0001	45.9	0.045	0.258	No	369	1994-2001
HI	0.5000	0.3536	3	0.565	0.097	Yes	59	1985-1987
HPA	0.4495	0.3014	43.04	0.430	0.066	No	215	2000-2003
JVI	0.9436	0.9371	7.02	0.690	0.058	Yes	510	1994-2002
LCA	0.2250	0.1067	209.87	0.127	0.053	No	279	1992-1999
LGA	0.0072	0.0001	481.07	0.079	0.369	No	544	1999-Present
LUA	0.9742	0.9737	13.65	0.627	0.036	No	247	1992-1998
MBA	0.6093	0.4756	202.94	0.415	0.163	No	178	1992-1995
MGA	0.0568	0.0032	13.02	0.101	0.151	No	169	2006-Present
OFA	0.8620	0.8408	1.54	0.746	0.100	Yes	304	1993-1997
PA3	0.7828	0.7489	18.13	0.485	0.052	No	80	2007-Present
RRI	0.3047	0.1682	15.72	0.362	0.041	No	270	2003-2007
S1M	0.8818	0.8640	5.87	0.484	0.057	No	186	1995-1999
SCA	0.4088	0.2614	6.42	0.224	0.045	No	130	2006-Present
SI	0.8600	0.8384	47	0.781	0.083	Yes	33	1985-1987
SWI	0.6043	0.4698	16.41	0.541	0.101	No	104	1995-1997
TBA	0.4521	0.3040	49.42	0.191	0.045	No	210	1996-2000
TCA	0.3736	0.2284	40.71	0.213	0.234	Yes	189	1993-1997
TPA	0.4145	0.2669	41.6	0.221	0.125	Yes	193	1993-1997
W5A	0.8708	0.8511	6.66	0.741	0.036	No	320	1993-1999
WBA	0.3059	0.1341	0.93	0.548	0.041	No	201	1999-2003
WCI	0.9298	0.9207	16.85	0.869	0.025	No	247	1999-2003

event number (Nr), and the average annual runoff volume (ROV) from zero to 100% total impervious cover is also presented In Table 3.2.

The City of Austin Environmental Criteria Manual (COA, 2009) (ECM) has included data to be used for estimating the average annual runoff based on impervious cover for a number of years. These data were based on early research by the City and best engineering judgment at the time. Figure 3.3 compares the data in the ECM with the linear relationship from this study for all watersheds. The ECM data, a quadratic relationship, falls outside the 95% confidence limit for the data used in this study, indicating a significant difference. The ECM model generally predicts a lower volume of runoff for a given impervious cover. Other studies including that by Barrett et al. (1998) also found an under-prediction of runoff to be the case.

The runoff coefficient and impervious cover relationship is also compared with the model proposed by Barrett et al. (see Figure 3.4). This study was based in large part on City of Austin data; however it was a limited dataset. Because most of the Barrett et al. model is within the 95% confidence limit of the linear model from this study, the two models are not significantly different statistically. The Barrett et al. model is a quadratic model instead of a linear model. This model generally predicts lower runoff at lower impervious cover and greater runoff for impervious covers exceeding 60%.

The linear model for the relationship between runoff coefficient and impervious cover is further compared with data presented in an EPA Nationwide Urban Runoff Program (NURP) (Environmental Science and COA, 1983) report in the early 1980s (see Figure 3.5). The linear models for NURP mean and median data are generally within 95% confidence of the linear model from this study. The mean NURP data result in a higher *Rv* at higher impervious cover and the median data result in a slightly lower *Rv* and slightly higher *Rv* at low and high impervious cover respectively. The NURP median data may be represented by the linear model presented in this study. While the NURP data were not collected in the Austin area, they were used to develop the original runoff rainfall relationships presented in the ECM. This may be one reason for the relationship currently in the ECM differing significantly from the one presented in this study. Additionally, SQE cannot apply current QA/QC criteria to the NURP data; therefore the NURP data from other areas should not be included in any City of Austin data analyses.

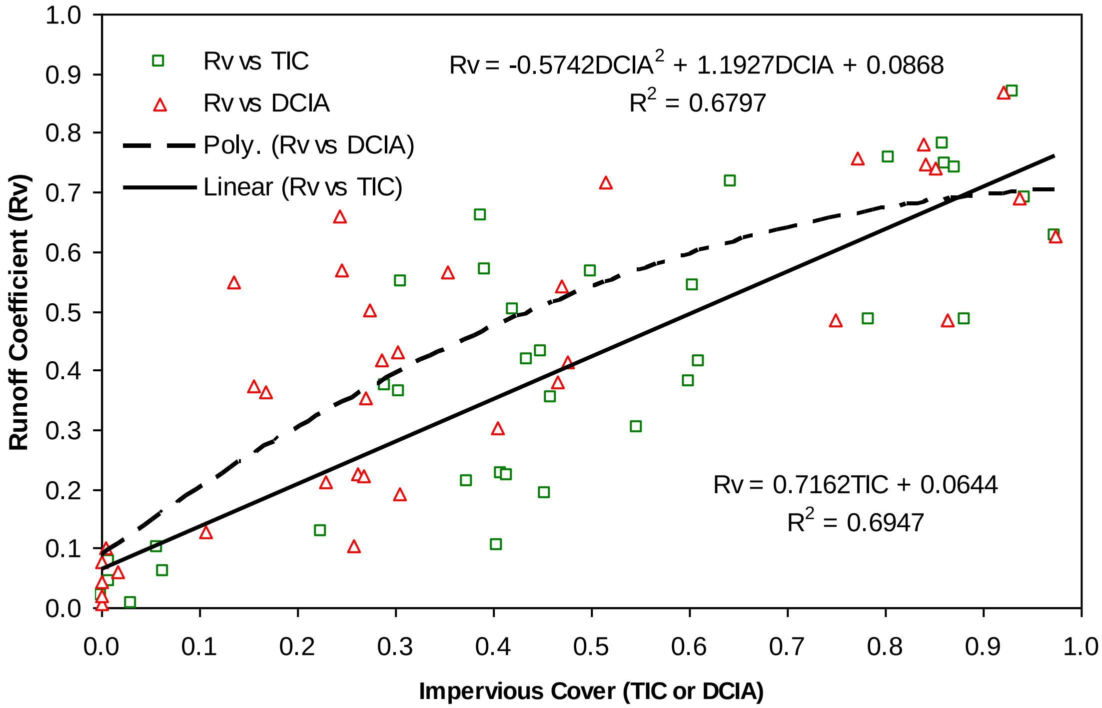

Figure 3.1: Relationships between runoff coefficient and impervious covers

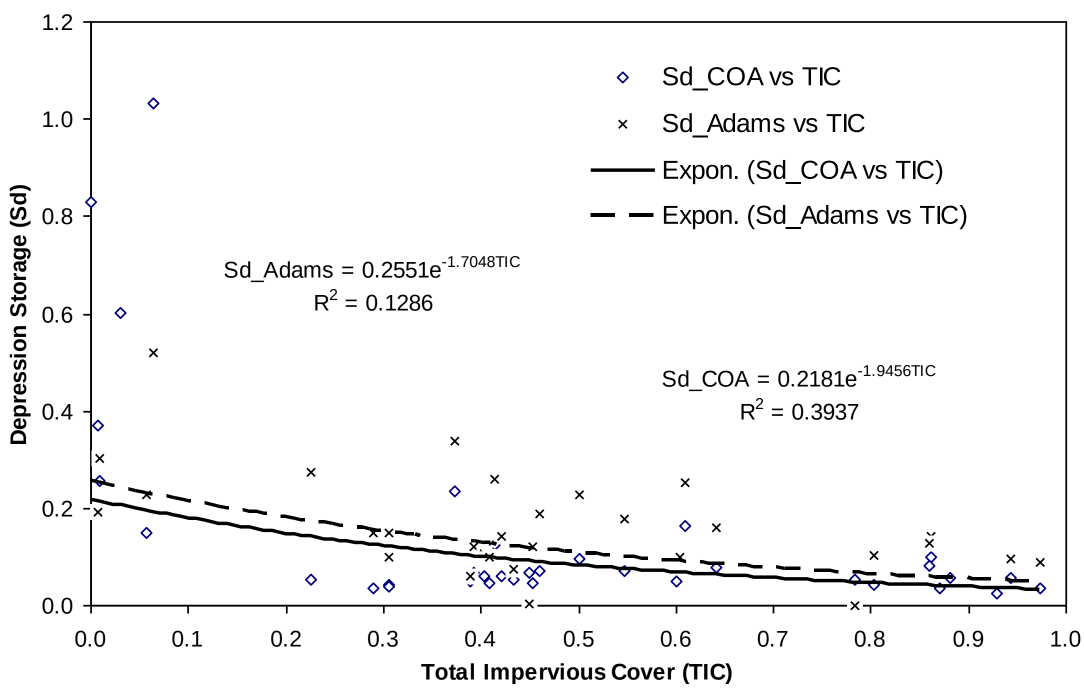

Figure 3.2: Relationship between depression storage and total impervious cover

Table 3.2: Recommended *Rv* and Summary of Runoff Parameters

TIC	Rv	Sd	Runoff Events	Runoff (in.)
0%	0.064	0.218	46.0	1.18
5%	0.100	0.198	48.4	1.94
10%	0.136	0.180	50.6	2.76
15%	0.172	0.163	52.8	3.63
20%	0.208	0.148	54.8	4.55
25%	0.243	0.134	56.7	5.52
30%	0.279	0.122	58.5	6.54
35%	0.315	0.110	60.2	7.59
40%	0.351	0.100	61.8	8.67
45%	0.387	0.091	63.2	9.78
50%	0.423	0.082	64.6	10.91
55%	0.458	0.075	65.8	12.06
60%	0.494	0.068	66.9	13.23
65%	0.530	0.062	68.0	14.42
70%	0.566	0.056	69.0	15.61
75%	0.602	0.051	69.9	16.82
80%	0.637	0.046	70.7	18.03
85%	0.673	0.042	71.5	19.24
90%	0.709	0.038	72.2	20.46
95%	0.745	0.034	72.8	21.69
100%	0.781	0.031	73.4	22.91

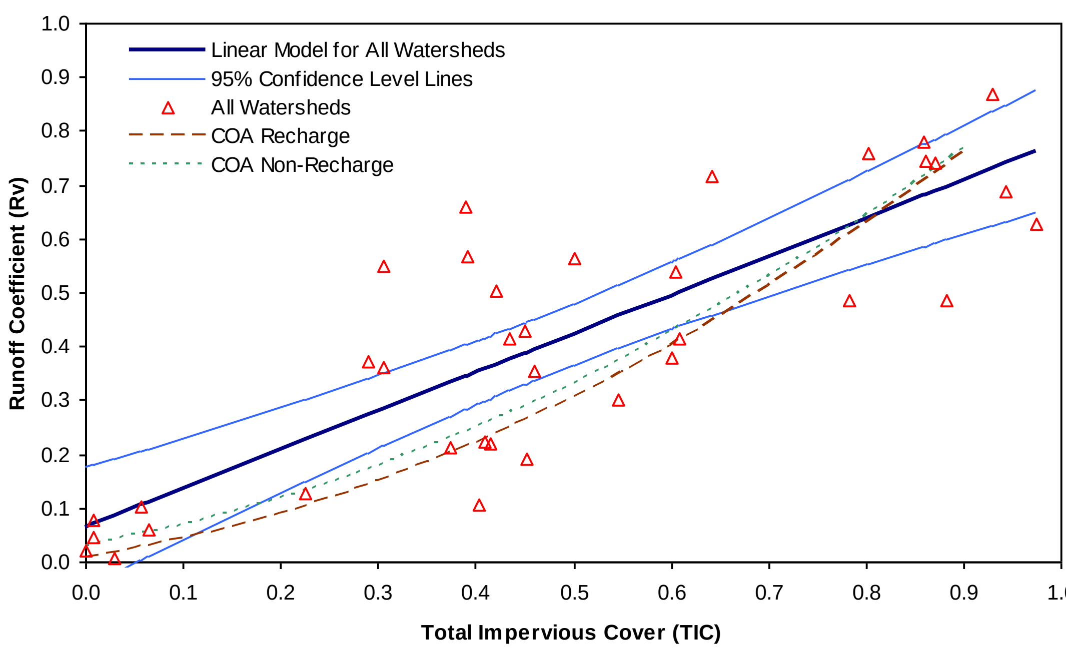

Figure 3.3: Comparison of runoff coefficient and impervious cover relationship with models in COA Environmental Criteria Manual (represented by dashed lines)

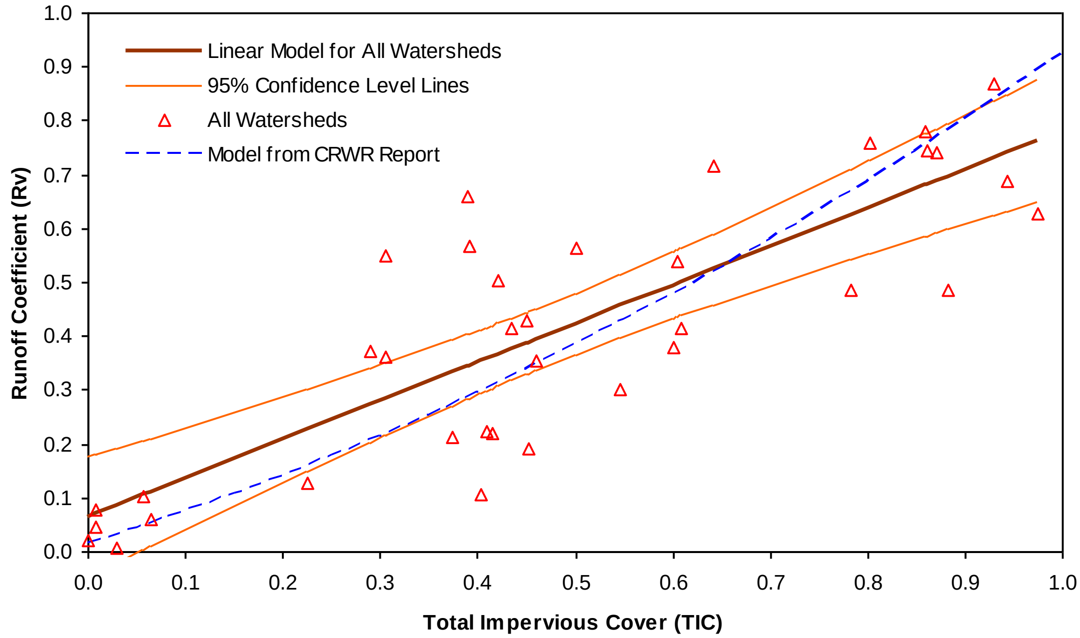

Figure 3.4: Comparison of runoff coefficient and impervious cover relationship with model recommended in Barrett et al.

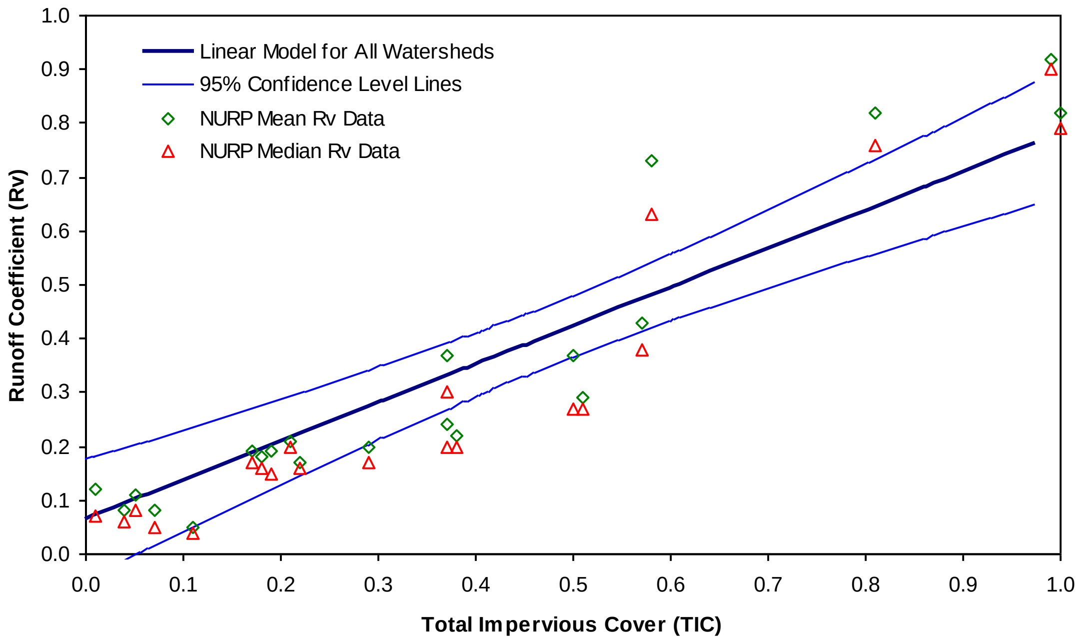

Figure 3.5: Comparison of runoff coefficient and impervious cover relationship with linear models based on EPA NURP data

3.2 Estimation of Event Runoff

The curve number method for estimating event runoff from event rainfall has been used since 1950s (Schwab et al., 1981). The general runoff equation in curve number method is:

$$Q = (P - Ia)^2 / (P - Ia + S) \qquad P \geq Ia \qquad (3.1)$$

$$Q = 0 \qquad P \leq Ia \qquad (3.2)$$

Where Q is event runoff depth, P is event rainfall depth, Ia is initial abstraction or event rainfall required for the initiation of runoff, and S is a watershed index defined as the maximum possible difference between P and Q as $P \rightarrow \infty$. P – Ia is also called effective rainfall, or Pe. The index S can be transformed to the more intuitive "curve number" by the equation:

$$CN = 1000 / (10 + S) \qquad (3.3)$$

where S is in inches. CN, which is dimensionless, may take values from zero to100.

The relationship between Ia and S was fixed at Ia = 0.2S. Inserting that value into equation 3.1 gives:

$$Q = (P - 0.2S)^2 / (P + 0.8S) \qquad P \geq 0.2S \qquad (3.4a)$$

$$Q = 0 \qquad P \leq 0.2S \qquad (3.4b)$$

The ratio of Ia/S is called initial abstraction ratio (λ). The value of λ was examined using rainfall-runoff data from 134 watersheds from states mainly in the East, Midwest, and South of the United State (Hawkins et al, 2002). The results showed that λ is not a constant from storm to storm or watershed to watershed, and that the assumption of λ=0.20 is unusually high. It was concluded that the initial abstraction ratio λ value of 0.05 fits observed rainfall-runoff data much better than does the handbook value of 0.20. With λ=0.05, the runoff equation becomes:

$$Q = (P - 0.05S_{0.05})^2 / (P + 0.95S_{0.05}) \qquad P \geq 0.05S_{0.05} \qquad (3.5a)$$

$$Q = 0 \qquad P \leq 0.05S_{0.05} \qquad (3.5b)$$

Using the observed rainfall and runoff data of thirty-six COA small watersheds, the values of initial abstraction ratio λ were estimated for all runoff events. The watershed λ value is defined as the median λ value of all events in the watershed. The values of watershed λ are presented in Table 3.3 for all events and for events with different rainfall ranges. In Table 3.4, the values of watershed λ are summarized statistically and can be compared with the results from Hawkins et al (2002). It can be seen that for events with higher rainfall amount, the values of λ are smaller and close to the value of 0.05 proposed by Hawkins et al; for events with lower rainfall amount, the values of λ are higher and close to the handbook value of 0.20.

The S (or $S_{0.2}$) value in Eqn. 3.4 and the $S_{0.05}$ value in Eqn. 3.5 can be estimated by curve fitting using the observed rainfall and runoff data. In Table 3.5, the estimated $S_{0.2}$ and $S_{0.05}$ values are presented for all thirty-six COA small watersheds. The corresponding curve number $CN_{0.2}$ and $CN_{0.05}$ values can be determined using Eqn. 3.3 and are also presented in Table 3.5. The relationships between curve numbers ($CN_{0.2}$ or $CN_{0.05}$) and total impervious cover (TIC) are shown in Figure 3.6; a third degree polynomial resulted in the best fit for these relationships. These CN~TIC relationships are recommended to estimate curve number from total impervious cover in Austin area. In Table 3.6, the recommended curve number values from zero to 100% total impervious cover are presented.

From Figure 3.7 to 3.11, the observed rainfall and runoff values for five typical watersheds with very different total impervious covers are shown along with predicted runoff curves from the recommended *Rv* ~ TIC model, $CN_{0.2}$ ~ TIC model, and $CN_{0.05}$ ~ TIC model. The values of total impervious cover for these five watersheds are 0.974 for LUA, 0.803 for BRI, 0.547 for CMI, 0.305 for RRI, and 0.008 for FWU. It can be seen that for the majority of events, especially for events with rainfall amount less than 1 inch, the Curve Number models under-predict runoff compared with *Rv* model. This can be seen more clearly in Figure 3.12, in which only events with less than 1 inch rainfall are shown for BRI watershed. It also can be seen in Figure 3.12 that the $CN_{0.05}$ model is a little bit better than the $CN_{0.2}$ model for predicting runoff with less than 1 inch rainfall.

Table 3.3: Initial abstraction ratio λ for all watersheds

Site ID	All Events	Events with P<0.75inch	Events with P≥0.75 inch	Events with Pe≥1.0 inch
BC	0.0023	0.1111	0.0015	0.0013
BCU	0.0184	0.6867	0.0183	0.0078
BRI	0.1949	0.2299	0.1085	0.1059
BSI	0.4099	0.4979	0.3387	0.2824
CMI	0.0810	0.1373	0.0282	0.0258
CTI	0.3196	0.5161	0.0516	0.0516
CTJ	0.0696	0.1165	0.0186	0.0179
CTK	0.2032	0.3162	0.0764	0.0649
E7A	0.0992	0.1542	0.0285	0.0245
EBA	0.0236	0.0452	0.0053	0.0047
EHA	0.0934	0.1769	0.0310	0.0221
EMA	0.1350	0.2824	0.0416	0.0307
ERA	0.0624	0.0881	0.0319	0.0293
FSU	0.6426	0.0796	0.7152	0.2150
FWU	0.0120	0.0107	0.0157	0.0023
HI	0.1047	0.0637	0.1916	0.1311
HPA	0.1576	0.3479	0.0423	0.0333
JVI	0.2651	0.3399	0.1060	0.0817
LCA	0.0064	0.0081	0.0025	0.0020
LGA	0.0787	0.0899	0.0685	0.0526
LUA	0.1408	0.2347	0.0525	0.0512
MBA	0.2944	0.3611	0.1759	0.1436
MGA	0.0173	0.0038	0.0358	0.0349
OFA	0.1459	0.2805	0.0899	0.0990
PA3	0.1866	0.3638	0.0626	0.0609
RRI	0.0398	0.0653	0.0102	0.0093
S1M	0.1629	0.4397	0.0326	0.0225
SCA	0.0473	0.0650	0.0104	0.0083
SI	0.1919	0.4841	0.1878	0.1622
SWI	0.3811	0.5322	0.1956	0.2207
TBA	0.0131	0.0230	0.0056	0.0046
TCA	0.1489	0.3375	0.0808	0.0515
TPA	0.0899	0.1905	0.0333	0.0290
W5A	0.2038	0.4656	0.0375	0.0309
WBA	0.0945	0.1863	0.0239	0.0221
WCI	0.0842	0.1513	0.0301	0.0280

Table 3.4: Statistical summary of watershed Initial abstraction ratio λ

Statistics	All Events	P<0.75inch	P≥0.75 inch	Pe≥1.0 inch	Pe≥1.0 inch (ARS*)
Min	0.0023	0.0038	0.0015	0.0013	0.0005
Median	0.1019	0.1884	0.0366	0.0308	0.0476
Mean	0.1451	0.2356	0.0830	0.0602	0.0701
Max	0.6426	0.6867	0.7152	0.2824	0.4910
STDV	0.1346	0.1793	0.1300	0.0686	0.0812
Skewness	1.8053	0.6243	3.7003	1.7904	2.5899
% ≤0.20	75.7%	51.4%	91.9%	89.2%	93.7%
Watershed #	36	36	36	36	134
Event #	5461	3771	1690	960	12499

* ARS = USDA-Agricultural Research Service.

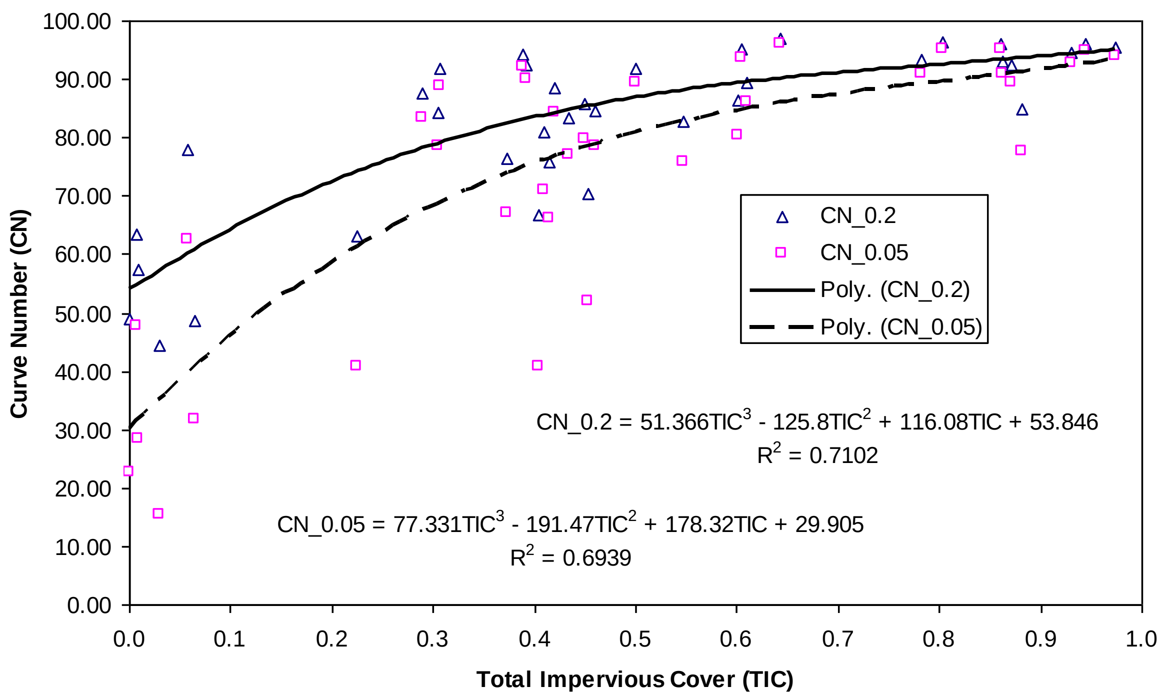

Figure 3.6: Relationship between curve numbers and total impervious cover

Table 3.5: Values of S and CN for all watersheds

Site	TIC	$S_{0.2}$	$S_{0.05}$	$CN_{0.2}$	$CN_{0.05}$
BC	0.0300	12.57	55.20	44.30	15.34
BCU	0.0007	10.45	34.36	48.91	22.54
BRI	0.8032	0.39	0.51	96.27	95.14
BSI	0.6420	0.33	0.42	96.83	96.00
CMI	0.5468	2.07	3.18	82.83	75.87
CTI	0.3885	0.61	0.84	94.21	92.23
CTJ	0.2899	1.39	1.99	87.76	83.40
CTK	0.3917	0.81	1.11	92.49	89.97
E7A	0.6007	1.58	2.44	86.35	80.38
EBA	0.4036	5.01	14.52	66.63	40.79
EHA	0.4342	1.98	2.98	83.47	77.02
EMA	0.4204	1.28	1.86	88.61	84.30
ERA	0.4600	1.81	2.75	84.71	78.43
FSU	0.0640	10.58	21.48	48.59	31.77
FWU	0.0080	7.41	25.06	57.43	28.53
HI	0.5000	0.88	1.17	91.94	89.53
HPA	0.4495	1.66	2.52	85.75	79.87
JVI	0.9436	0.41	0.55	96.05	94.83
LCA	0.2250	5.81	14.49	63.24	40.83
LGA	0.0072	5.75	10.94	63.48	47.75
LUA	0.9742	0.49	0.64	95.36	93.99
MBA	0.6093	1.17	1.61	89.52	86.13
MGA	0.0568	2.85	6.01	77.83	62.46
OFA	0.8620	0.75	1.01	93.04	90.81
PA3	0.7828	0.70	0.98	93.47	91.04
RRI	0.3047	1.85	2.73	84.41	78.57
S1M	0.8818	1.78	2.87	84.88	77.70
SCA	0.4088	2.33	4.06	81.07	71.13
SI	0.8600	0.39	0.50	96.21	95.23
SWI	0.6043	0.52	0.69	95.07	93.55
TBA	0.4521	4.19	9.25	70.48	51.94
TCA	0.3736	3.06	4.90	76.58	67.10
TPA	0.4145	3.18	5.14	75.90	66.05
W5A	0.8708	0.82	1.17	92.38	89.52
WBA	0.3059	0.90	1.25	91.73	88.86
WCI	0.9298	0.56	0.78	94.71	92.77

Table 3.6: Recommended $CN_{0.2}$ and $CN_{0.05}$

TIC	CN0.2	CN0.05
0%	53.85	29.91
5%	59.34	38.35
10%	64.25	45.90
15%	68.60	52.61
20%	72.44	58.53
25%	75.81	63.73
30%	78.73	68.26
35%	81.27	72.18
40%	83.44	75.55
45%	85.29	78.42
50%	86.86	80.86
55%	88.18	82.93
60%	89.30	84.67
65%	90.25	86.15
70%	91.08	87.43
75%	91.81	88.57
80%	92.50	89.61
85%	93.17	90.63
90%	93.87	91.68
95%	94.63	92.81
100%	95.49	94.09

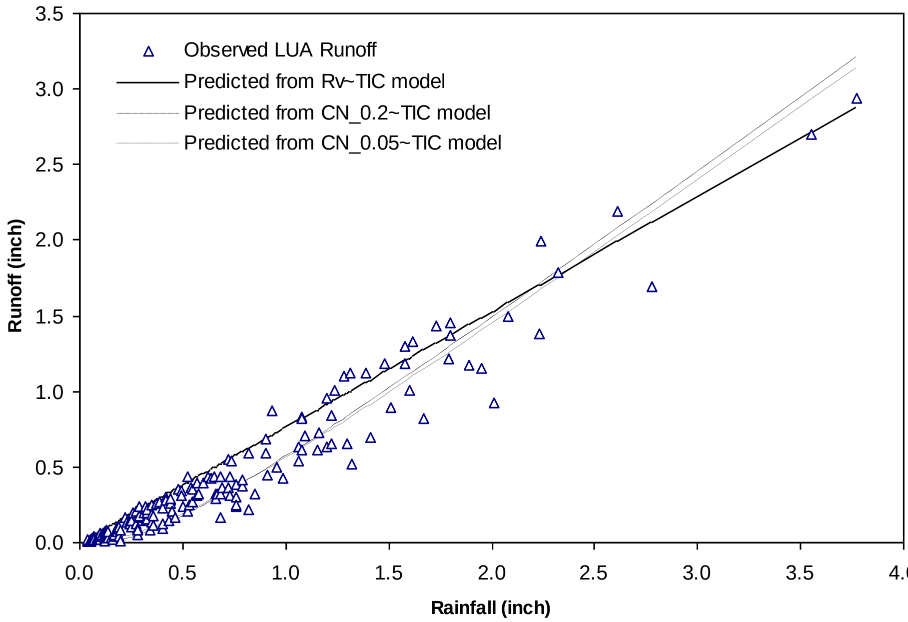

Figure 3.7: Observed and predicted runoff for LUA watershed

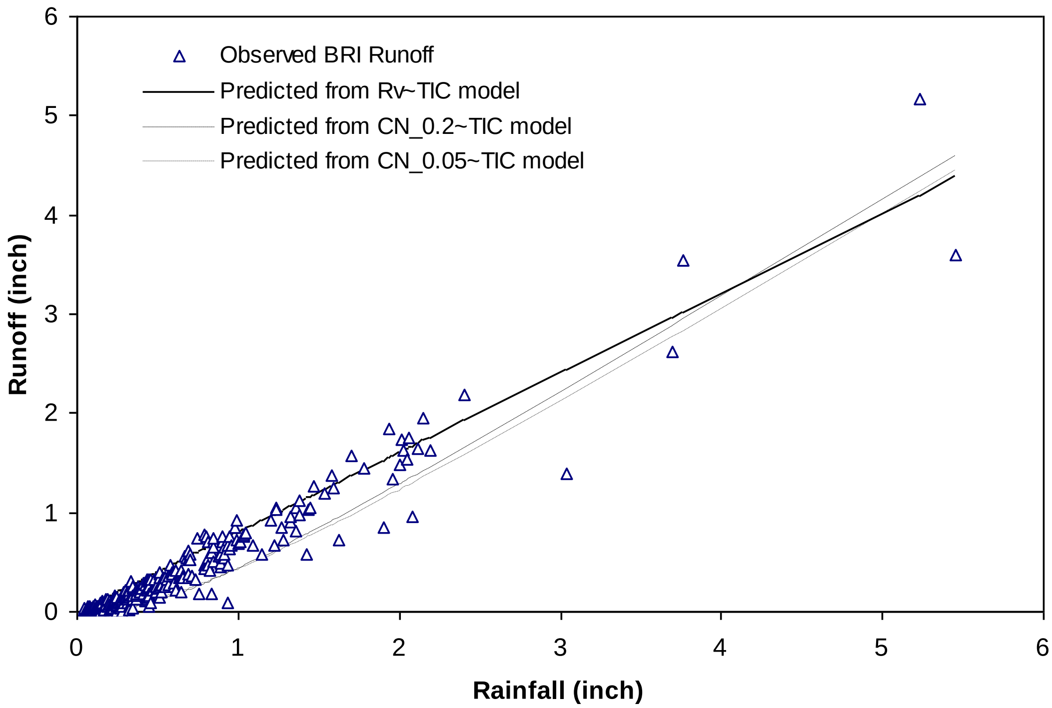

Figure 3.8: Observed and predicted runoff for BRI watershed

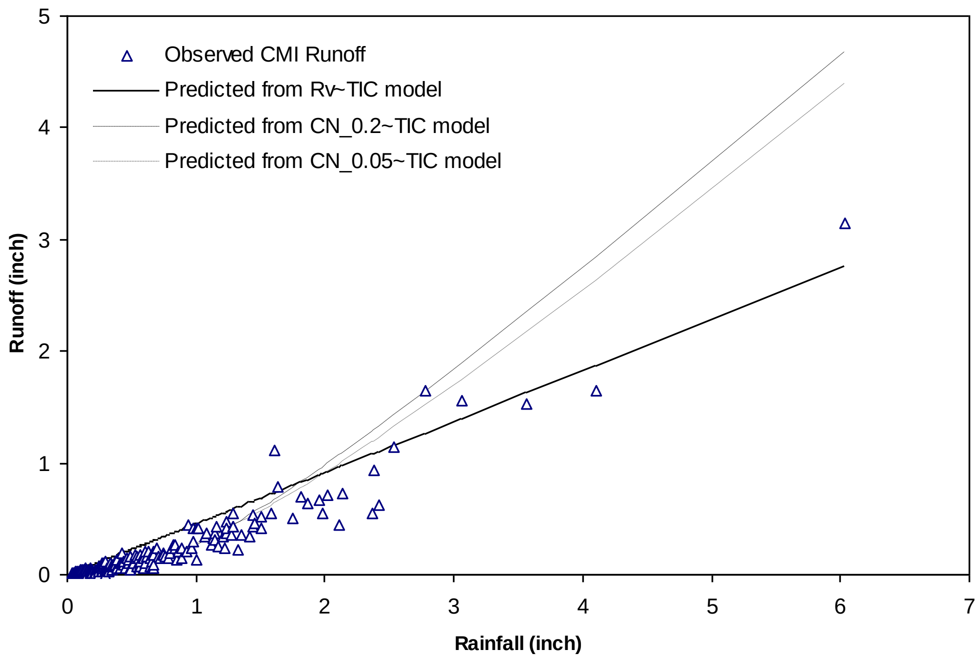

Figure 3.9: Observed and predicted runoff for CMI watershed

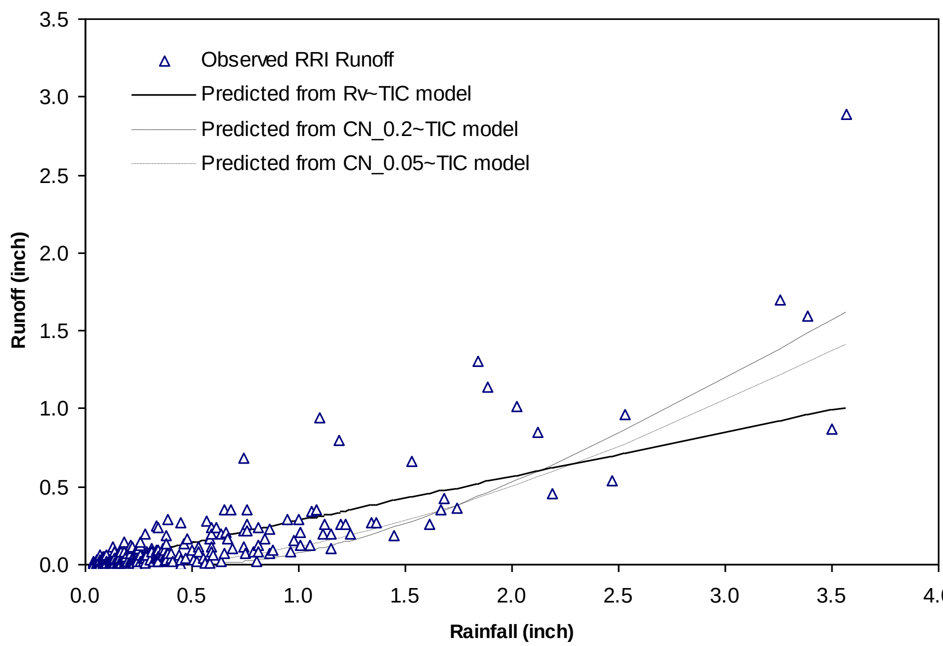

Figure 3.10: Observed and predicted runoff for RRI watershed

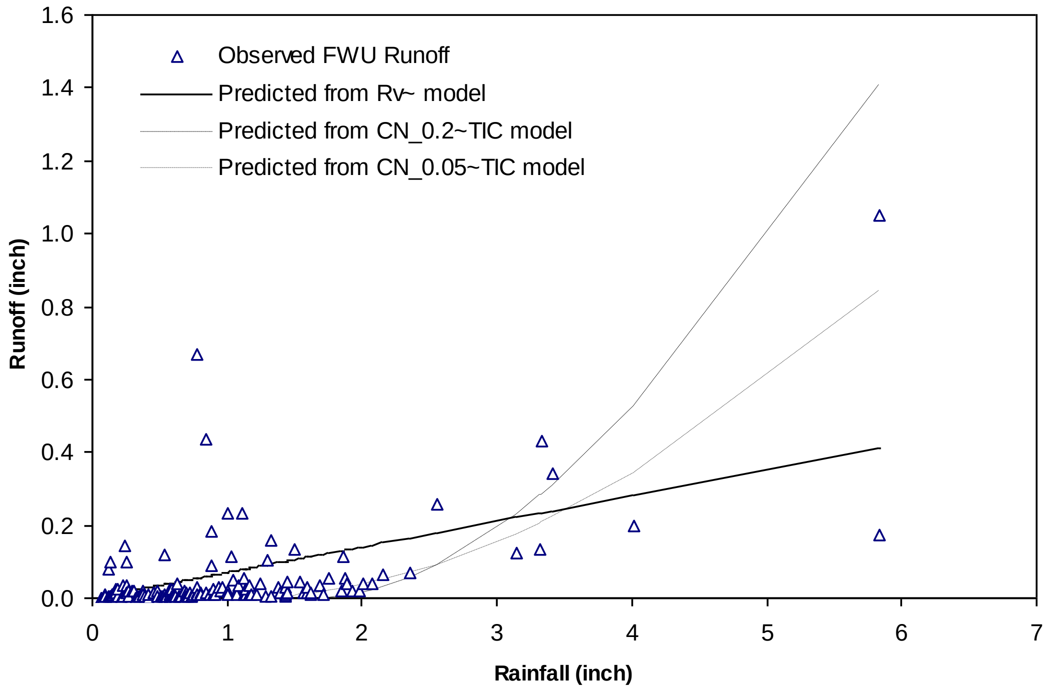

Figure 3.11: Observed and predicted runoff for FWU watershed

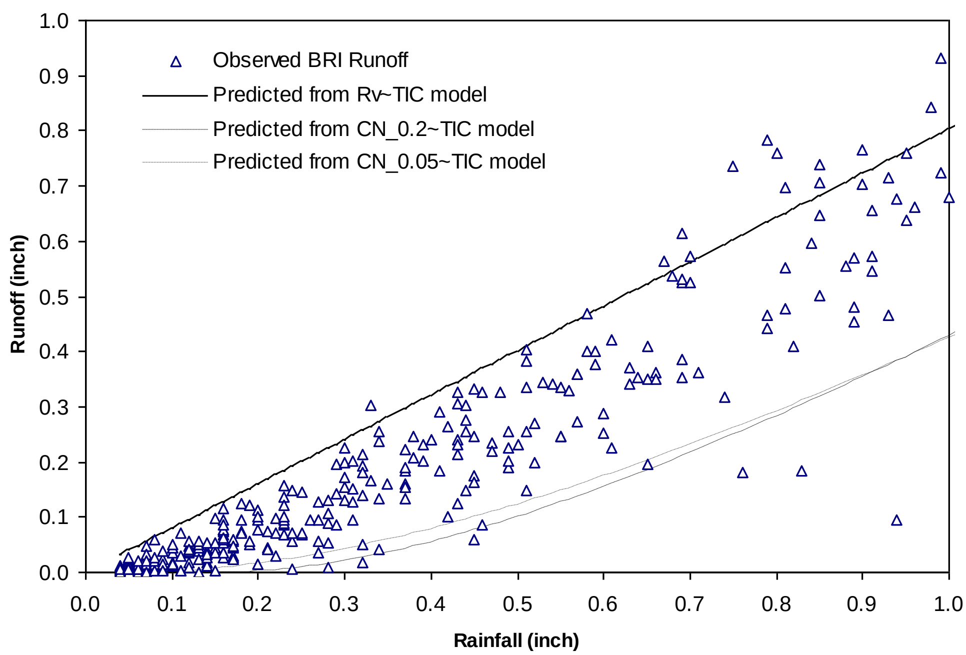

Figure 3.12: Observed and predicted runoff with rainfall less than 1 inch for BRI watershed

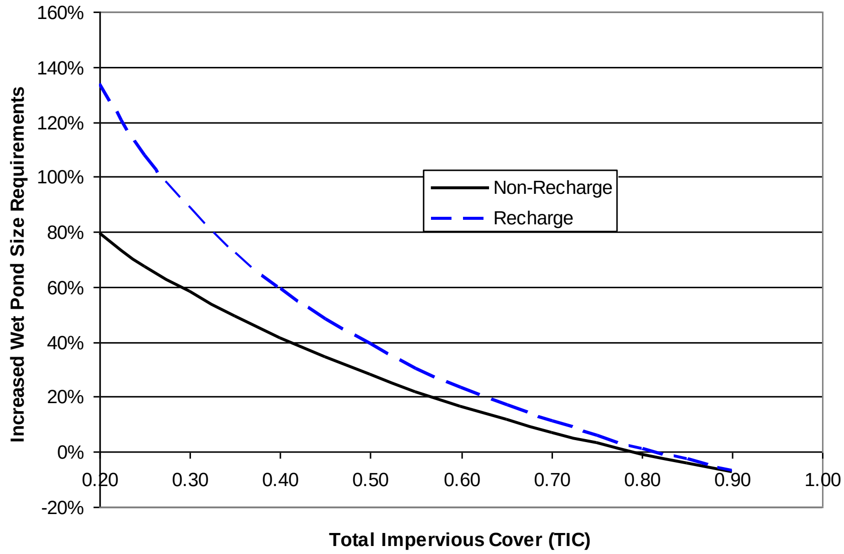

Figure 3.13: Impacts on wet pond sizing using proposed *Rv*-TIC relationships

3.3 Discussion of Water Quantity Analyses

The analyses of long-term *Rv*s indicate that the relationship with TIC is linear and that this provides a better estimation than using DCIA. The estimate for DCIA used in this report was determined using and relationship with TIC and was not directly measured. If a direct measurement of DCIA were available the relationship with runoff might be better. The theory behind disconnecting impervious cover as an LID and using DCIA to estimate runoff is that runoff from impervious areas would have an opportunity to infiltrate before entering a drainage way. Given the soils in the Austin urban area, measuring the difference in runoff after disconnecting impervious cover may be within the margin of error of current measurement techniques.

The relationship between TIC and *Rv* found in this report differs significantly from that found in the COA ECM (COA, 2009). If the relationship found in this report is adopted there would be no change in the capture volume requirements for most BMPs currently in the ECM but wet ponds would be larger for TIC less than 0.80 (Figure 3.13); for example, if TIC is 0.45, the wet pond would need to be 34% larger for non-recharge areas. There may be an impact the design of alternative controls that rely on *Rv* as the basis for design rather than capture volume.

4 Runoff Quality

Predicting stormwater runoff quality in an urban area can be a difficult proposition because many different pollutant sources contribute to the runoff. If a watershed were composed entirely of rooftops, for example, the runoff concentrations might be reasonably predicted, assuming the variability in roofing materials can be taken into account. But actual watersheds are composed of many different sources including rooftops, parking areas, lawns, sidewalks and roadways to name a few; each of these may be managed in different ways as well. All of this results in monitored pollutant concentrations that are highly variable. To address this, Pitt (2003) suggested modeling each source area independently and then combining the results; however, each source also responds differently.

This section will examine runoff quality in three ways. First, the long-term mean concentrations will be examined and how they may be impacted by the characteristics of the site including impervious cover (total and connected) and land use will be explored. Second, the EMCs will be examined to determine if any state variables, like antecedent period, total rainfall, etc., in combination with impervious cover, can explain variations in EMCs. This information may aid planners attempting to develop continuous simulation models. Lastly, the intra-event variability will be examined. This can improve results from short time-step models and may be useful in designing and sizing water quality controls.

In the following analyses of water quality several sites were omitted for various reasons. EHA and EMA were dropped because a prior study (Glick, 2007) indicated that the runoff quality from these two sites was not representative of the land use or impervious cover in those watersheds. ERA was dropped for similar reasons. Cu and COD at GPI were dropped due to possible contamination. Zn was dropped from WBA because a galvanized approach channel was used, thus skewing the results. NH_3 was dropped at ARA because of bad detection limits. Lastly, sites with poor flow conversions that were not used for *Rv* analyses were omitted from all analyses that rely on loads or runoff computations.

4.1 Long-Term Runoff Quality

Three analyses were conducted on the long-term site mean water quality data to test three different hypotheses which were: 1) the runoff concentrations from developed and undeveloped areas are different, 2) the runoff concentrations change with changing impervious cover, and 3) the runoff concentrations change with changing impervious cover and land use. The first hypothesis was tested using analyses of variance (ANOVA), both parametric and non-parametric, the second using linear regression while step-wise multi-linear regression was used to test the last hypothesis.

4.1.1 Analyses of Variance

The primary assumption in requiring water quality controls is that runoff quality from undeveloped areas is different from runoff from developed areas. If increased load due to increased runoff is not considered, the difference between concentrations of runoff from developed and undeveloped areas can be compared using ANOVA tests, which determine if two populations have the same distribution. The mean concentrations listed in Table 2.2 were divided into two groups: developed and undeveloped. Undeveloped catchments are listed in Table 1.1).

Two tests were used to evaluate the data, a standard parametric ANOVA test and the Wilcoxon rank sum test (RST). The parametric test assumes the data are normally distributed and evaluates the differences in the means. The Wilcoxon RST makes no assumptions about the underlying distributions but evaluates the differences in the median of the ranks of the data (Gilbert, 1987). The Wilcoxon RST is a special case of the Kruskal-Wallis test for two datasets.

The results of these tests are presented in Table 4.1. Both tests fail to reject the null hypothesis (data are from the same distribution) for four of the seventeen parameters tested, Cd, FSTR, TOC and TSS. The failure to detect a difference in Cd may be due to poor detection limits for much of the COA data; it has more non-detects than any other standard parameter. FSTR and TOC have been monitored for many years by COA and no discernable trends have been detected in the past. TSS presents a curious case. The undeveloped mean is lower than the

Table 4.1: Results of ANOVA (pr>|z|)

Pollutant	Wilcoxon RST	ANOVA
BOD	0.003	0.018
CD	0.165	0.424
COD	0.014	0.054
CU	0.005	0.043
DP	0.004	0.016
FCOL	0.014	0.053
FSTR	0.298	0.348
NH_3	0.001	0.002
NO_3+NO_2	0.041	0.047
PB	0.001	0.038
TKN	0.029	0.037
TN	0.015	0.020
TOC	0.187	0.323
TP	0.002	0.007
TSS	0.158	0.305
VSS	0.026	0.054
ZN	0.001	0.042

developed mean concentration but the variability is such that the data are not significantly different at the 0.05 level (the level of significance selected for this report). Part of the reason for this may be that many events sampled at undeveloped sites were associated with larger, high-intensity events that have more potential for erosion because these are the only events that generate runoff from those sites. If load were considered rather than concentration alone, there may be a significant difference based on the changes in runoff volume.

Three parameters, COD, FCOL and VSS, produced conflicting results between the parametric and non-parametric test. The parametric test did not indicate a significant difference between the data for these parameters but the Wilcoxon test did. This may be due to the comparison of the medians rather than the means but it may also be related to the distribution of the data. It was originally assumed that the site means would have a normal distribution (COA, 1994); however, when this was tested (see Table 4.2) it appears that the long-term means may be log-normally

Table 4.2: Results of Shapiro-Wilk test for normality on long-term mean concentrations.

Pollutant	Normal		Log-normal	
	W	P>W	W	P>W
BOD	0.871	0.000	0.961	0.261
CD	0.933	0.034	0.948	0.107
COD	0.864	0.000	0.989	0.965
CU	0.831	0.000	0.972	0.427
DP	0.914	0.011	0.964	0.329
FCOL	0.886	0.002	0.889	0.002
FSTR	0.773	0.000	0.987	0.947
NH_3	0.851	0.000	0.934	0.022
NO_3+NO_2	0.992	0.993	0.935	0.024
PB	0.787	0.000	0.985	0.875
TKN	0.928	0.014	0.982	0.765
TN	0.960	0.172	0.975	0.515
TOC	0.906	0.003	0.956	0.119
TP	0.936	0.026	0.950	0.080
TSS	0.912	0.003	0.979	0.632
VSS	0.950	0.123	0.955	0.191
ZN	0.744	0.000	0.978	0.622

distributed. This may be a result of sampling fewer undeveloped sites rather than a truly log-normal distribution. It appears the results of the Wilcoxon RST produce more reliable results.

Several agencies and associations, through the International BMP Database project, have recommended plotting the distribution of influent and effluent EMCs on the same graph (Geosyntec and Wright Water, 2009). This approach, while not a statistical test, can be applied in this study to graphically show the differences between developed and undeveloped runoff. Developed and undeveloped probability plots are shown in Figures 4.1-17. These graphs, log-transformed EMCs on the x-axes and inverse probability on the y-axes, indicate the variance of the data by the slope and the mean where the line crosses the x-axis. The probability plots closely follow the results of the parametric tests. The lines representing the distributions for TSS, Cd, VSS, FSTR, TOC and NO3+NO2 cross, indicating unequal variance. TOC crosses near the mean for both distributions.

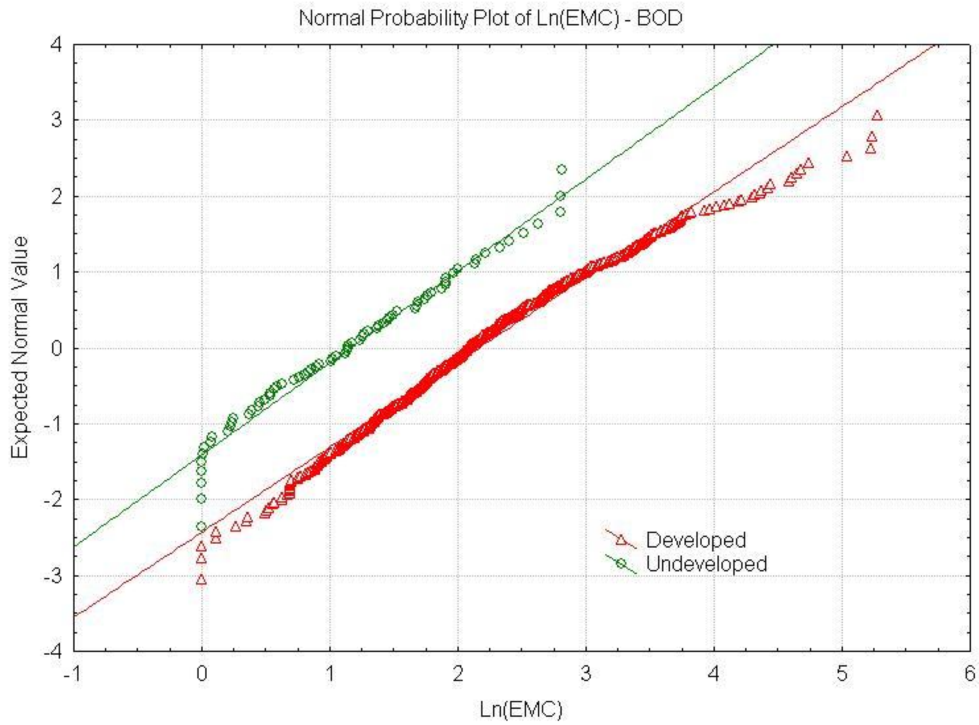

Figure 4.1: Normal probability plots of log-transformed BOD EMCs from developed and undeveloped monitoring sites.

While the lines for FCOL do not cross they are close and it appears the lognormal distribution may not be the best fit for the data.

Based strictly on development condition, there are no statistically significant differences between developed and undeveloped site mean runoff concentrations for Cd, FSTR, TOC and TSS. There are significant differences for BOD, COD, Cu, DP, FCOL, NH_3, NO_3+NO_2, Pb, TKN, TN, TP, VSS and Zn. Further tests will try to determine if those differences may be better explained by additional factors other than development condition alone.

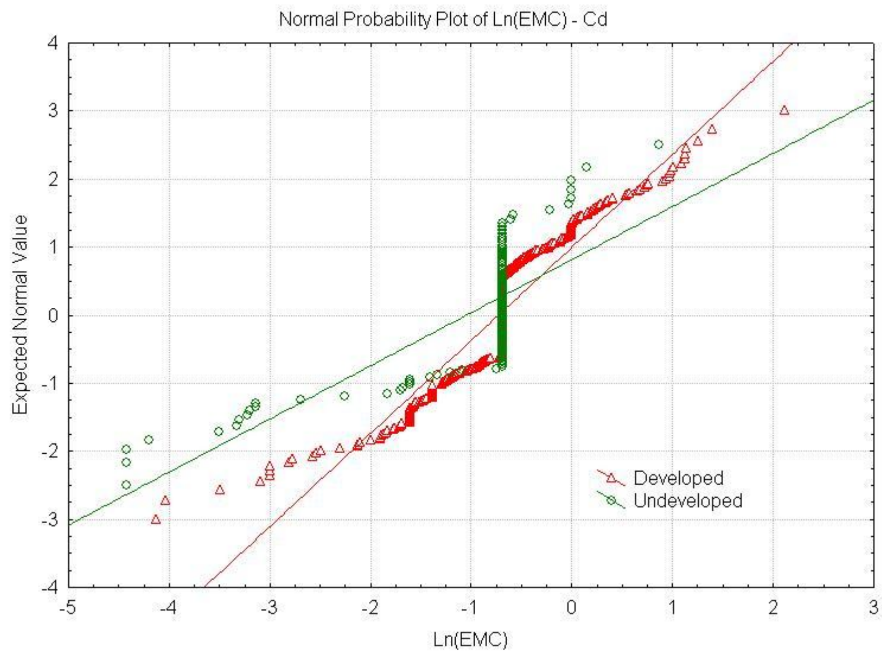

Figure 4.2: Normal probability plots of log-transformed Cd EMCs from developed and undeveloped monitoring sites.

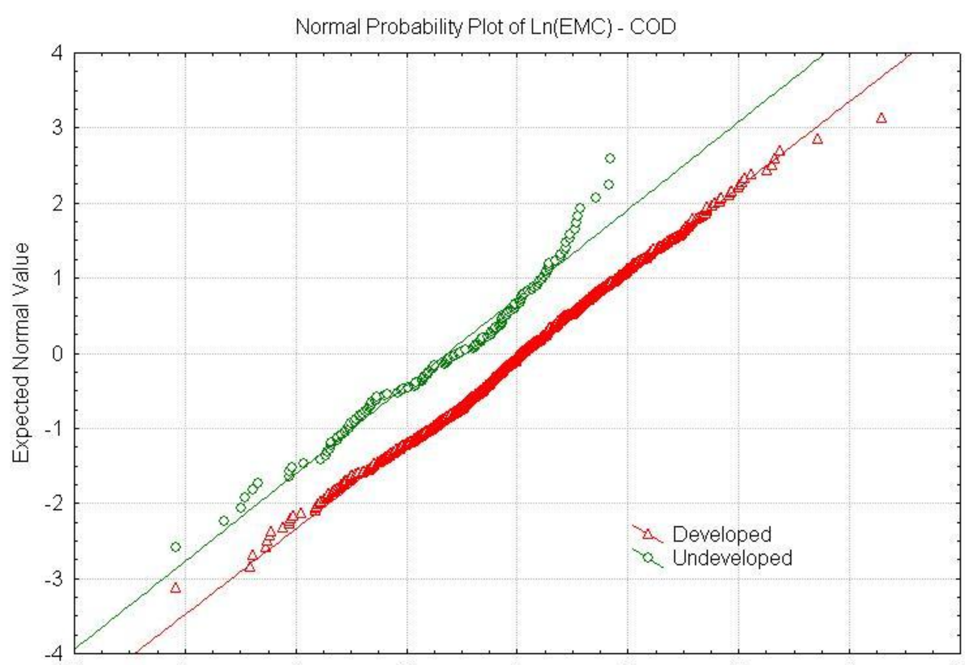

Figure 4.3: Normal probability plots of log-transformed COD EMCs from developed and undeveloped monitoring sites.

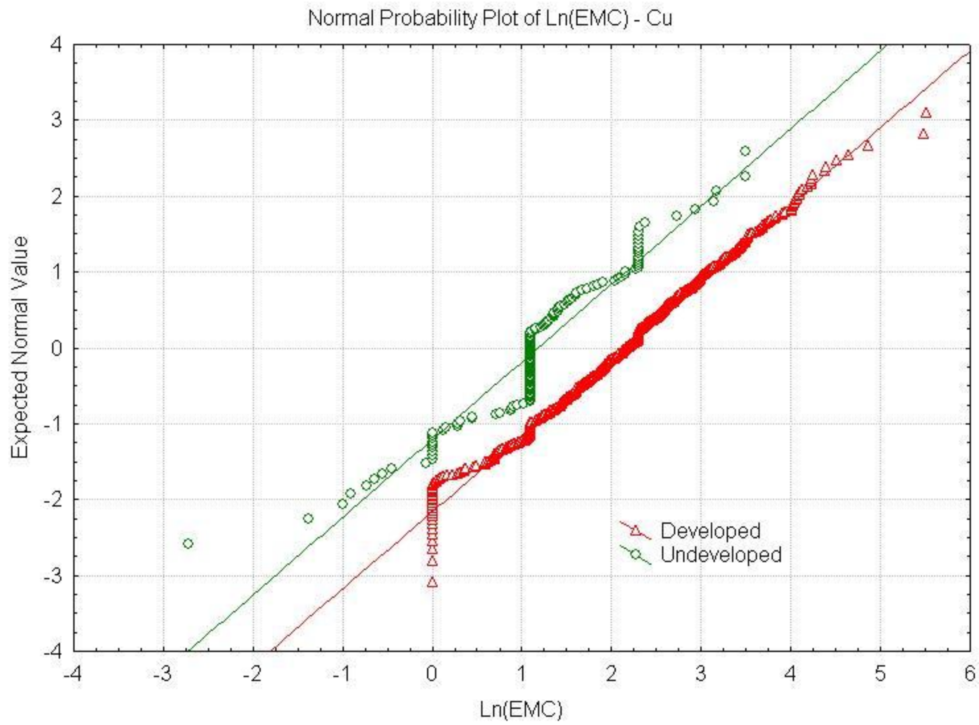

Figure 4.4: Normal probability plots of log-transformed Cu EMCs from developed and undeveloped monitoring sites.

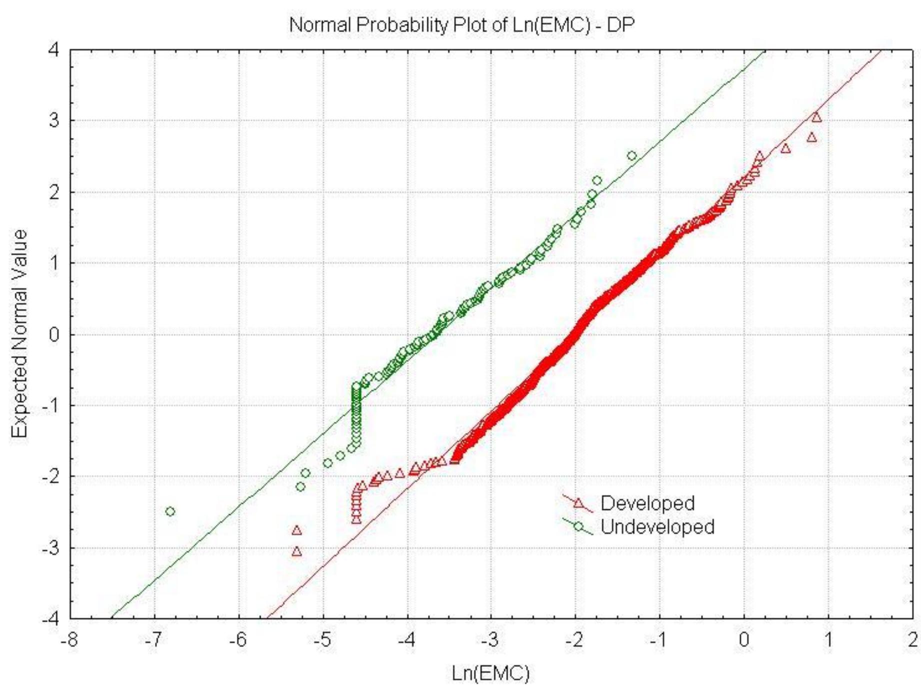

Figure 4.5: Normal probability plots of log-transformed DP EMCs from developed and undeveloped monitoring sites.

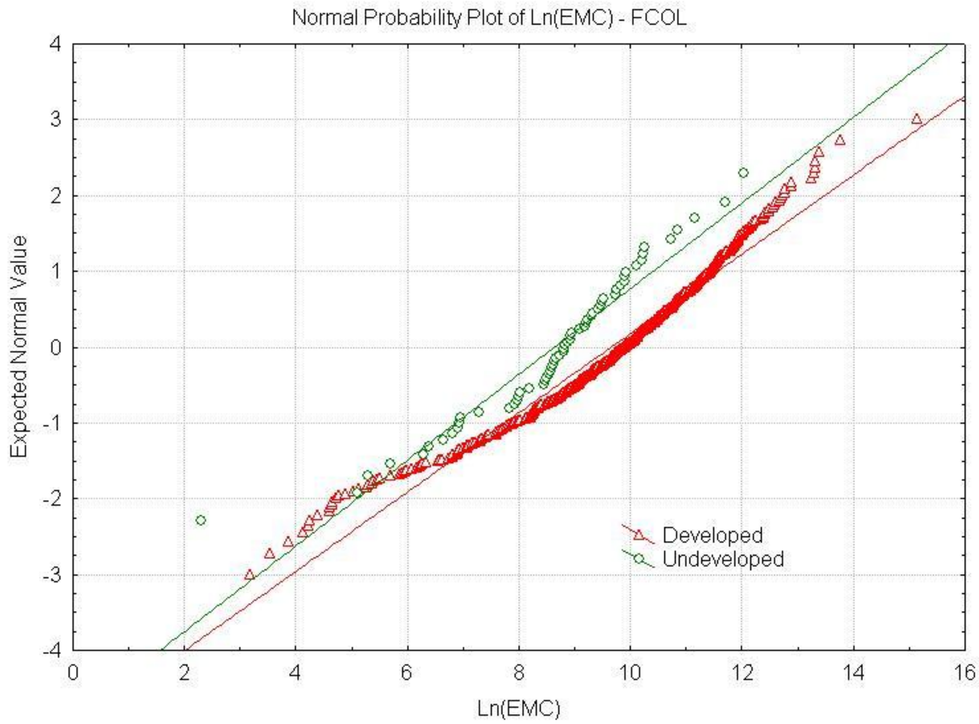

Figure 4.6: Normal probability plots of log-transformed FCOL EMCs from developed and undeveloped monitoring sites.

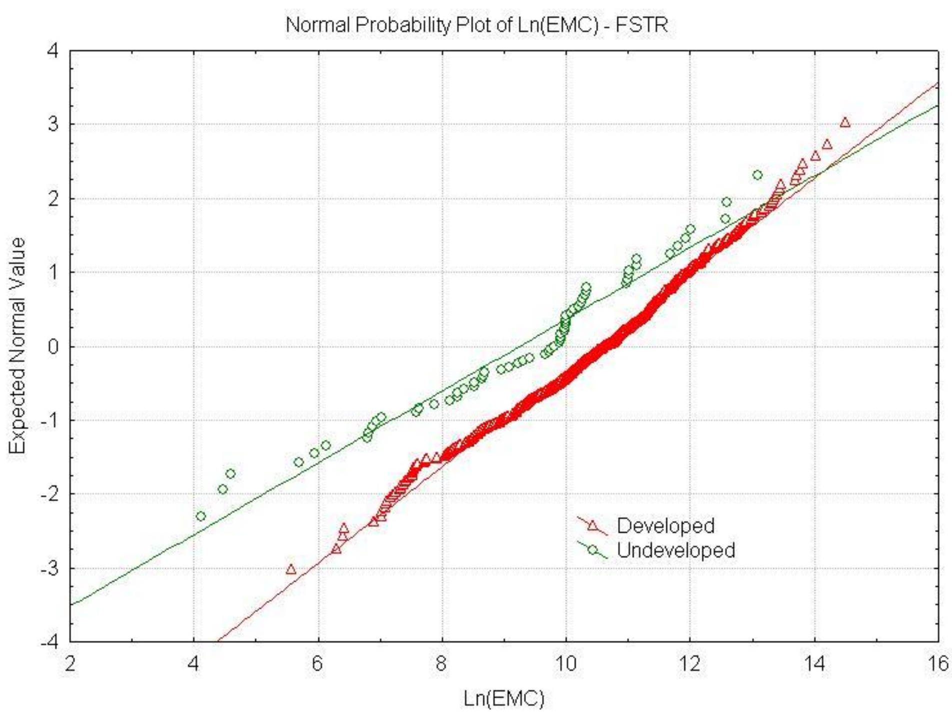

Figure 4.7: Normal probability plots of log-transformed FSTR EMCs from developed and undeveloped monitoring sites.

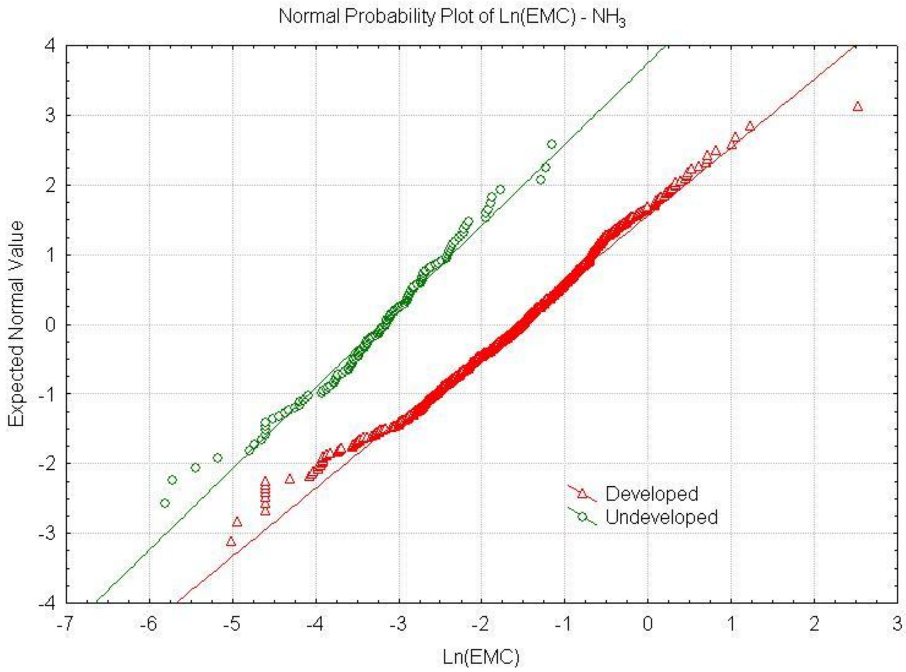

Figure 4.8: Normal probability plots of log-transformed NH_3 EMCs from developed and undeveloped monitoring sites.

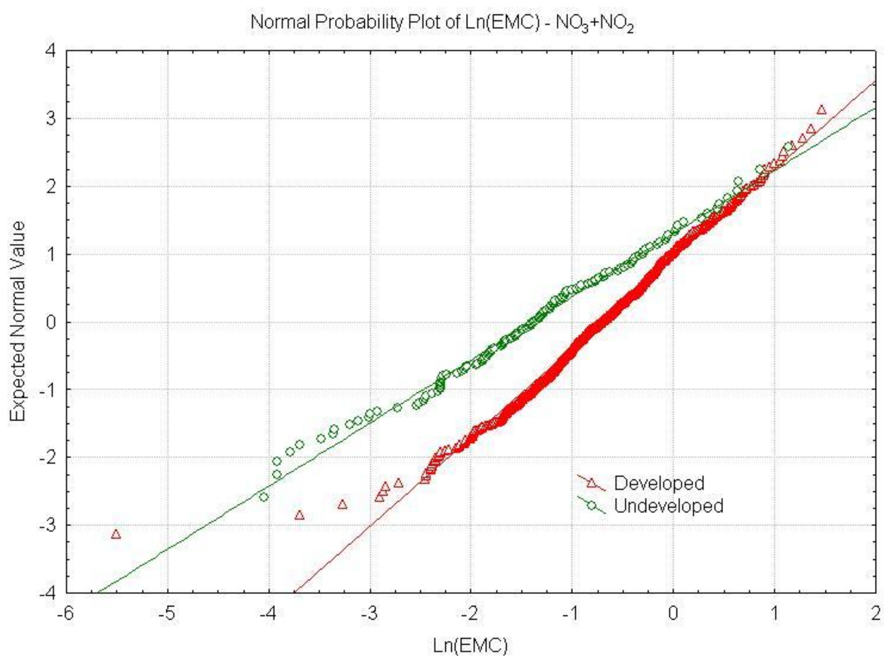

Figure 4.9: Normal probability plots of log-transformed NO^3+NO_2 EMCs from developed and undeveloped monitoring sites.

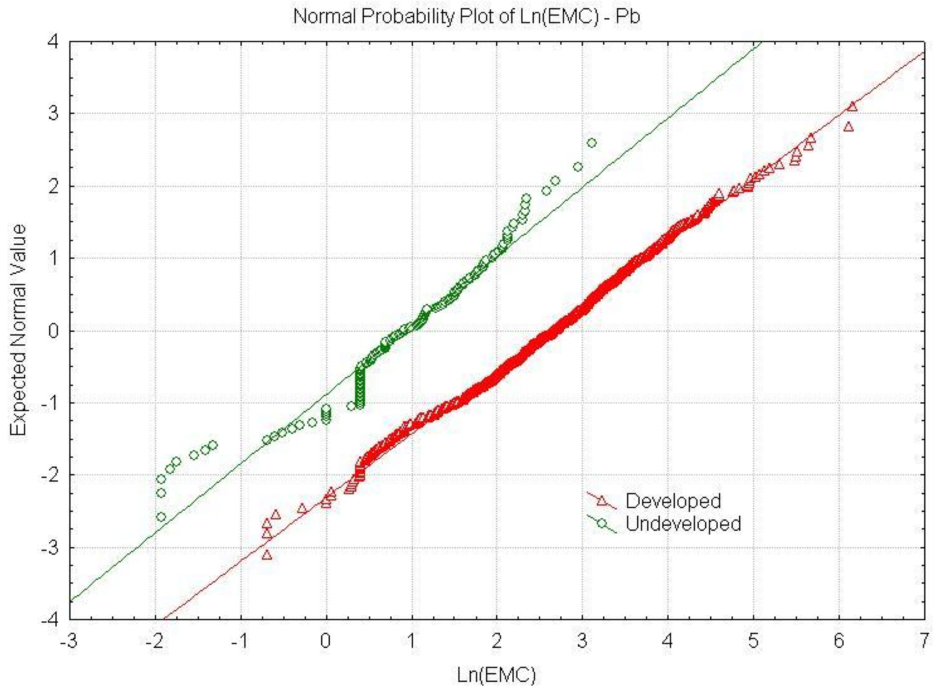

Figure 4.10: Normal probability plots of log-transformed Pb EMCs from developed and undeveloped monitoring sites.

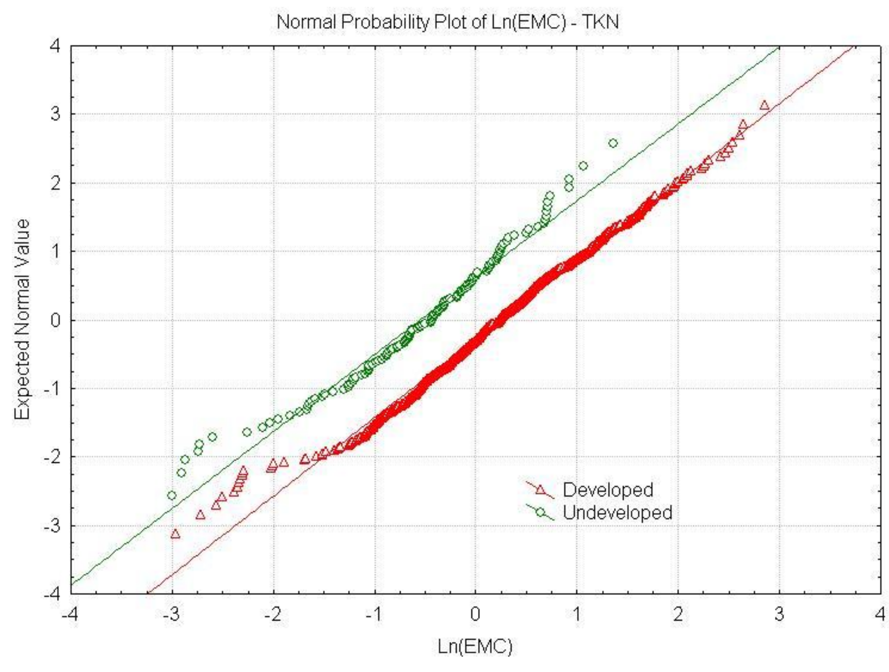

Figure 4.11: Normal probability plots of log-transformed TKN EMCs from developed and undeveloped monitoring sites.

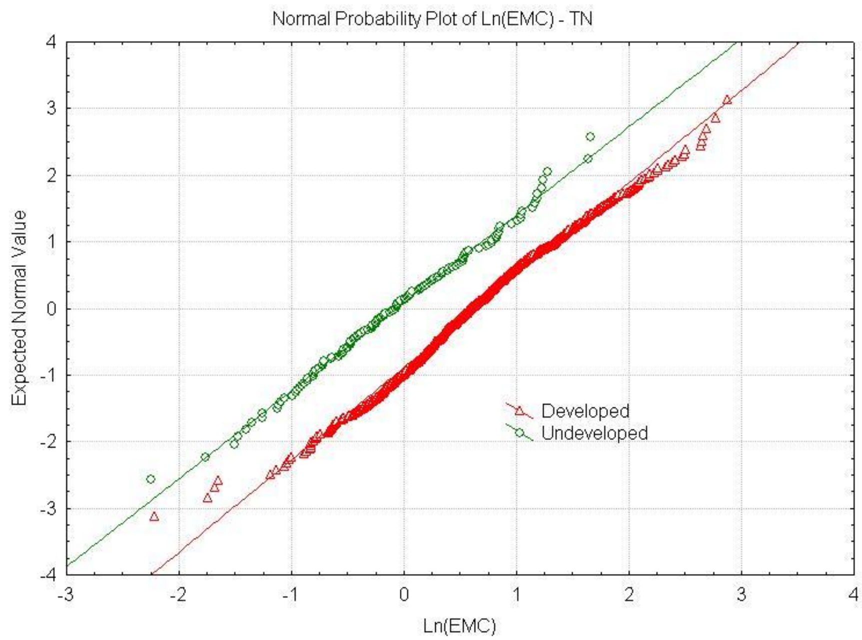

Figure 4.12: Normal probability plots of log-transformed TN EMCs from developed and undeveloped monitoring sites.

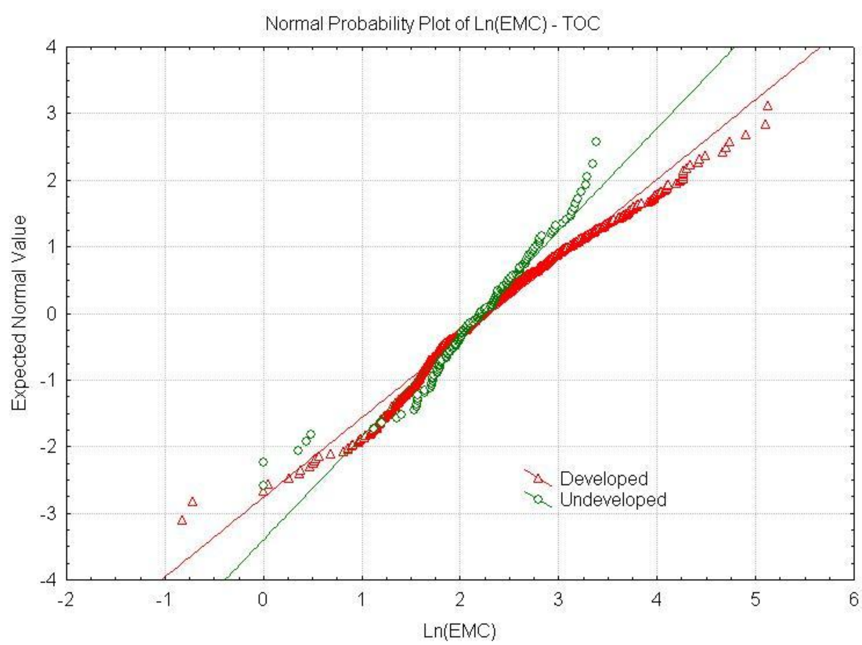

Figure 4.13: Normal probability plots of log-transformed TOC EMCs from developed and undeveloped monitoring sites.

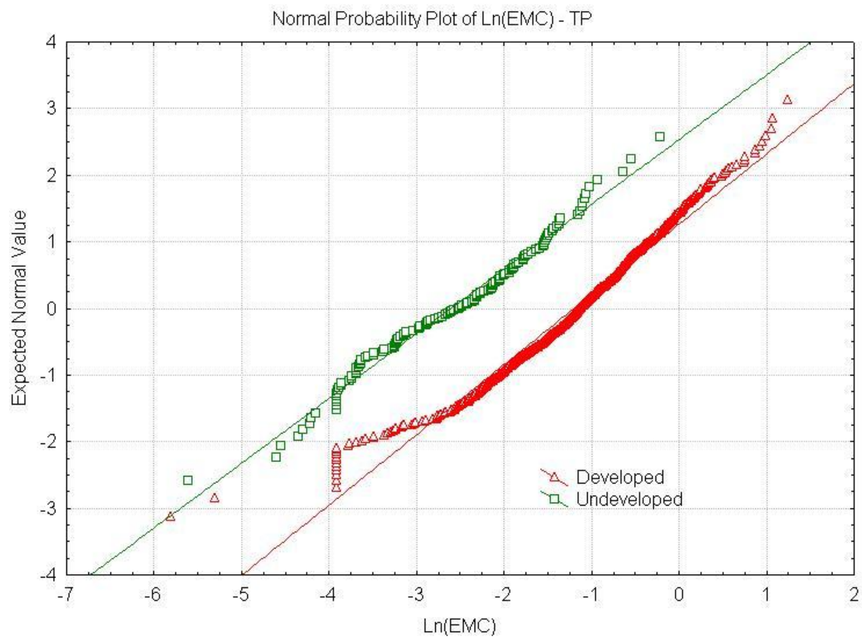

Figure 4.14: Normal probability plots of log-transformed TP EMCs from developed and undeveloped monitoring sites.

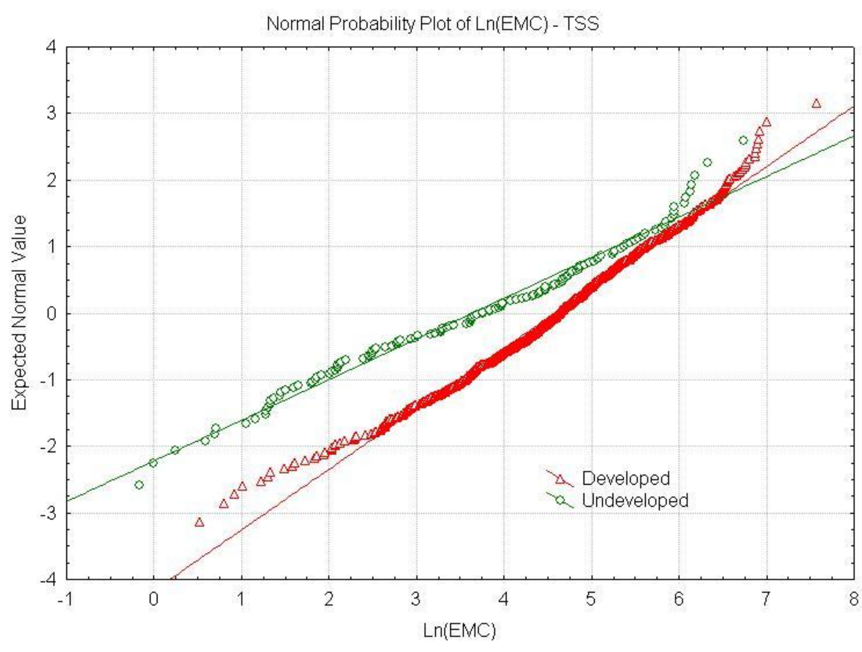

Figure 4.15: Normal probability plots of log-transformed TSS EMCs from developed and undeveloped monitoring sites.

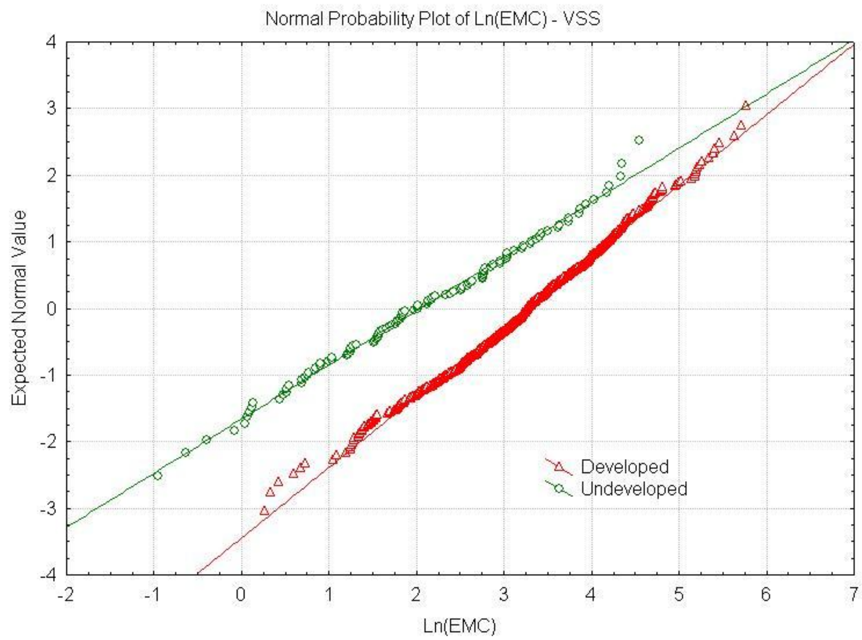

Figure 4.16: Normal probability plots of log-transformed VSS EMCs from developed and undeveloped monitoring sites.

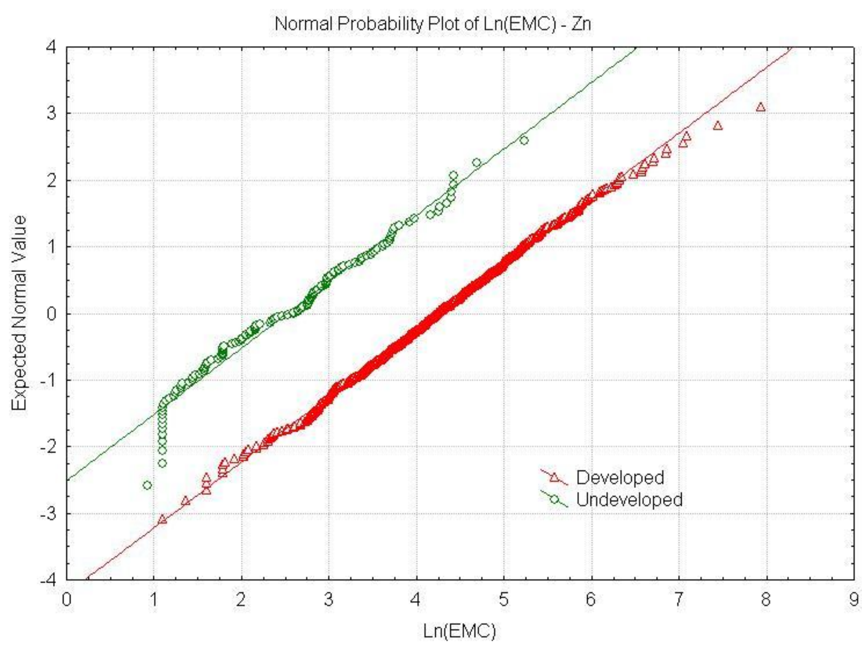

Figure 4.17: Normal probability plots of log-transformed Zn EMCs from developed and undeveloped monitoring sites.

Table 4.3: Results from regression analyses using mean concentration as the dependant variable and TIC or DCIA as the independent variable.

Pollutant	TIC		DCIA	
	P>f	r2	P>f	r2
BOD	0.005	0.214	0.010	0.191
CD	0.001	0.289	0.001	0.310
COD	0.003	0.205	0.003	0.214
CU	0.000	0.331	0.000	0.329
DP	0.058	0.108	0.107	0.082
FCOL	0.926	0.000	0.816	0.002
FSTR	0.354	0.026	0.344	0.028
NH_3	0.000	0.279	0.001	0.265
NO_3+NO_2	0.170	0.049	0.238	0.037
PB	0.000	0.402	0.000	0.400
TKN	0.061	0.089	0.111	0.067
TN	0.068	0.085	0.089	0.076
TOC	0.237	0.036	0.170	0.050
TP	0.091	0.073	0.203	0.043
TSS	0.842	0.001	0.608	0.007
VSS	0.040	0.125	0.050	0.118
ZN	0.000	0.382	0.000	0.394

4.1.2 Relationship with Impervious Cover

In addition to the assumption that stormwater runoff concentrations are different between developed and undeveloped areas, it is also assumed that the concentrations increase with increasing impervious cover. To test this hypothesis, linear regression analyses were performed on each parameter to determine if there was a significant relationship with impervious cover. The analyses were conducted using both TIC and DCIA; results of these analyses are in Table 4.3.

Of the 17 parameters tested, eight exhibited significant relationships to TIC and/or DCIA; BOD, Cd, COD, Cu, NH_3, Pb, VSS, and Zn. There was little or no improvement in the prediction when using DCIA as opposed to TIC. Because there is little improvement in the relationships with impervious cover and the difficulty in measuring DCIA accurately, it is

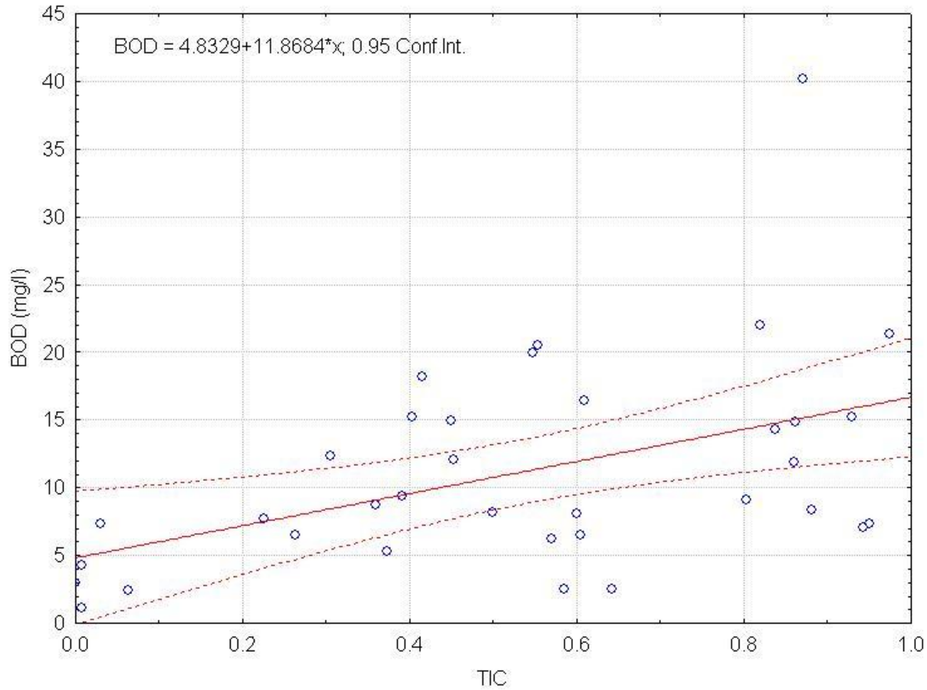

Figure 4.18: Linear regression of BOD v. TIC and the 95% confidence interval.

recommended that TIC be used to predict runoff pollutant concentrations. Further investigations using measured DCIA rather than an estimation might yield better results since the Sutherland equations were not verified for use in the Austin area.

Scatter plots of the eight parameters with significant linear regressions are in Figures 4.18-25. Scatter plots of data without significant regression may be found in the appendix. Coefficients for the linear regression are found in Table 4.4. It can be seen the residuals of the regression tend to increase as impervious cover increases, indicating a higher degree of variability in runoff concentrations as impervious cover increases. This may indicate that other watershed characteristics are influencing mean runoff concentrations and will be explored later in this report.

In an effort to increase the proportion of variability explained by TIC, non-linear regression was performed on the data using an exponential form, $MC=ae^{bTIC}$. Three parameters, NH_3, Pb and Zn, demonstrated significantly improved r^2 using an exponential relationship. For Pb and Zn the exponential estimation is also more reasonable because the linear model would

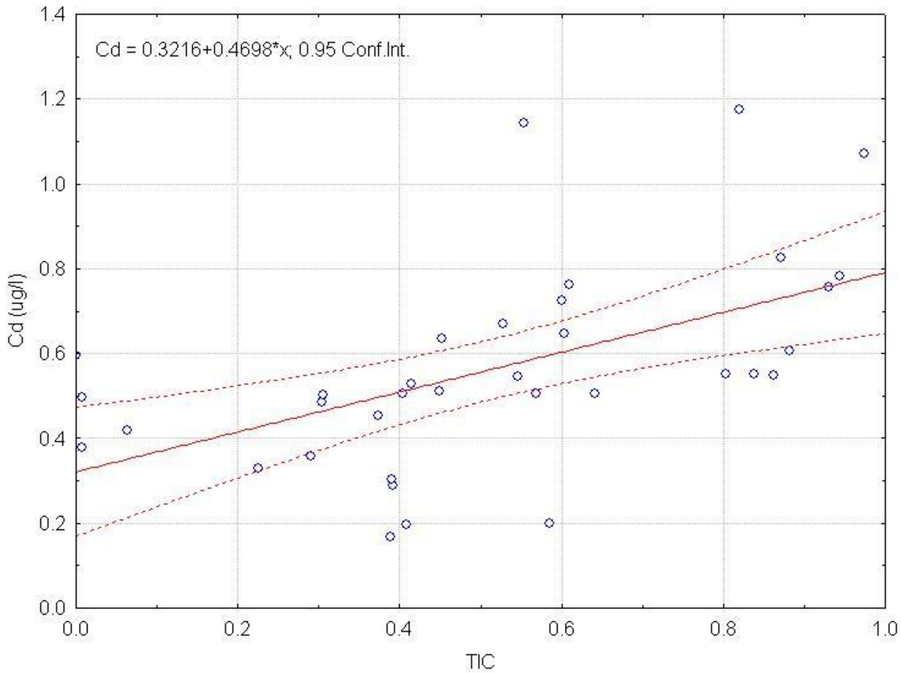

Figure 4.19: Linear regression of Cd EMCs v. TIC and the 95% confidence interval.

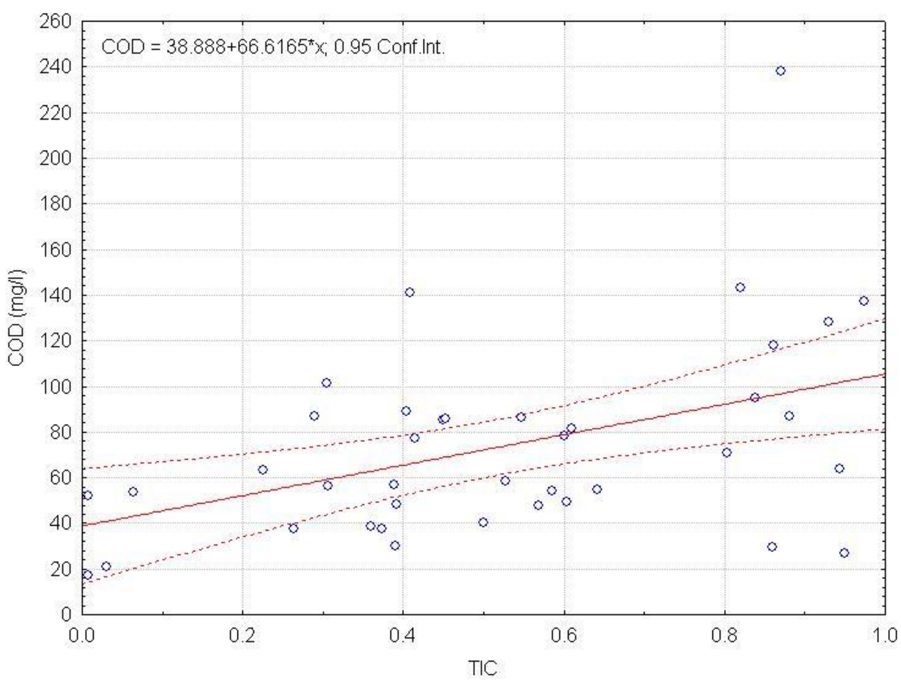

Figure 4.20: Linear regression of COD EMCs v. TIC and the 95% confidence interval.

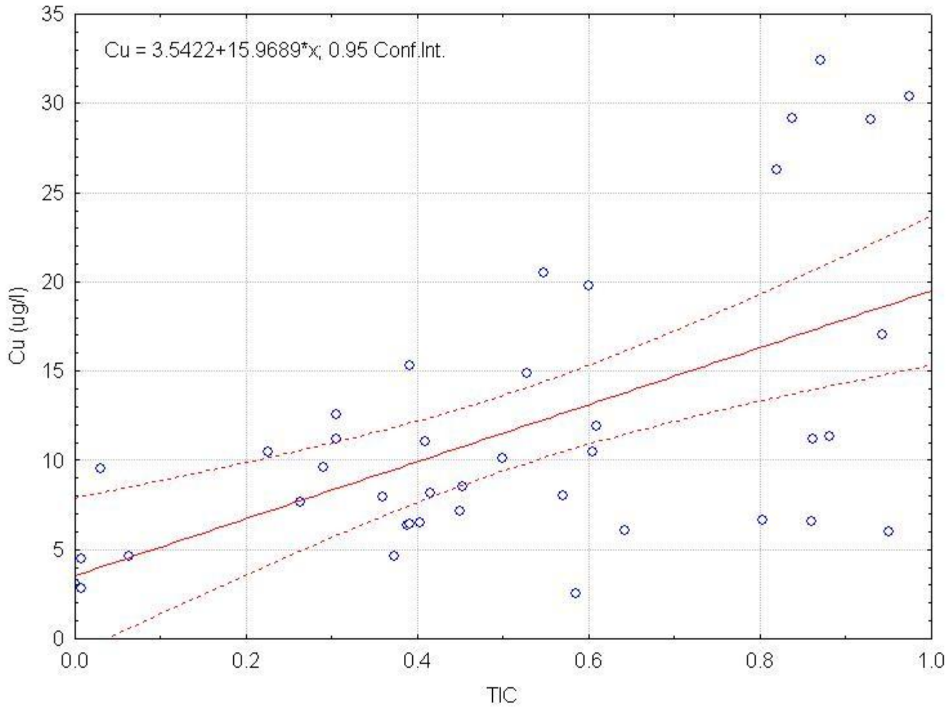

Figure 4.21: Linear regression of Cu EMCs v. TIC and the 95% confidence interval.

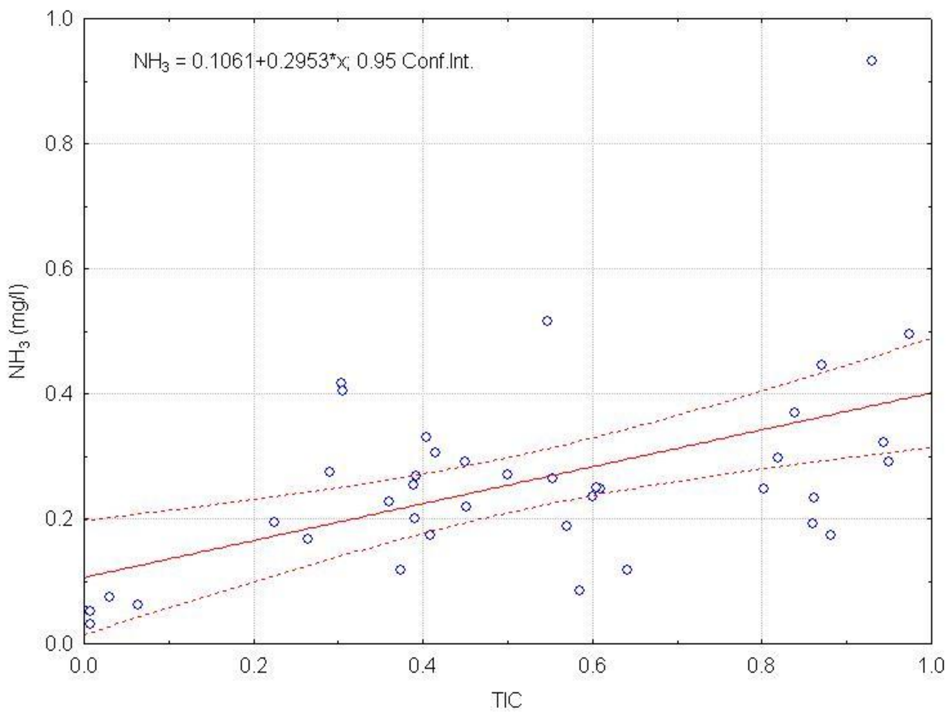

Figure 4.22: Linear regression of NH_3 EMCs v. TIC and the 95% confidence interval.

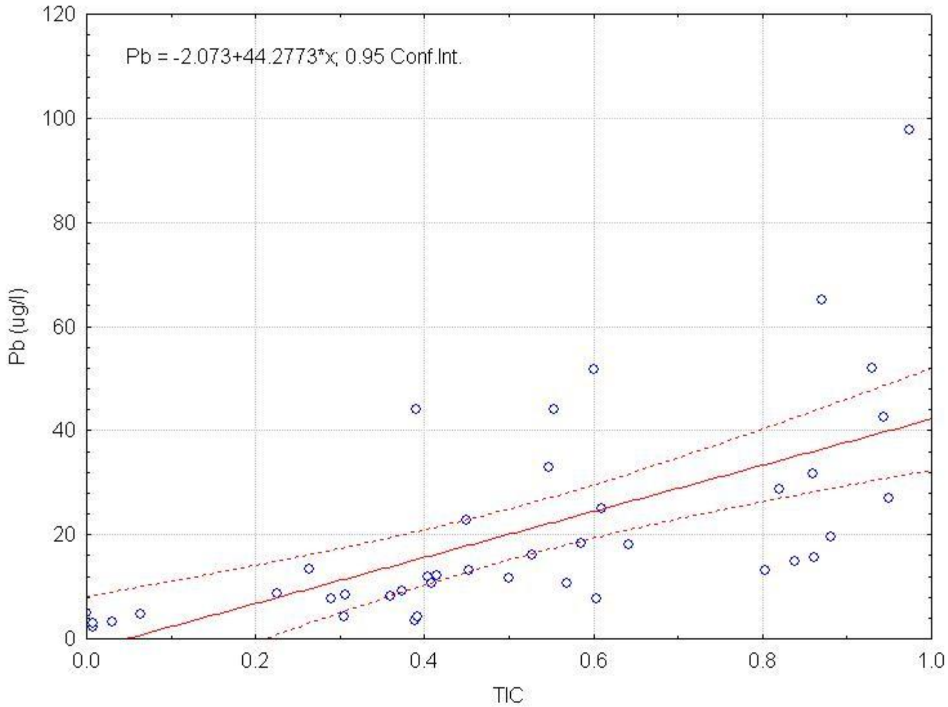

Figure 4.23: Linear regression of Pb EMCs v. TIC and the 95% confidence interval.

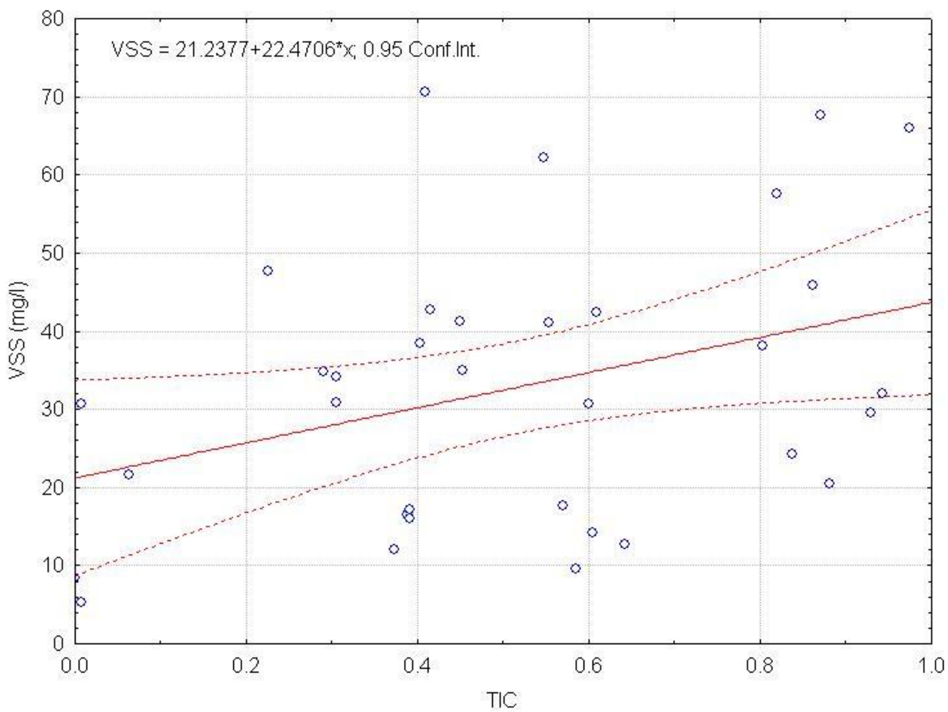

Figure 4.24: Linear regression of VSS EMCs v. TIC and the 95% confidence interval.

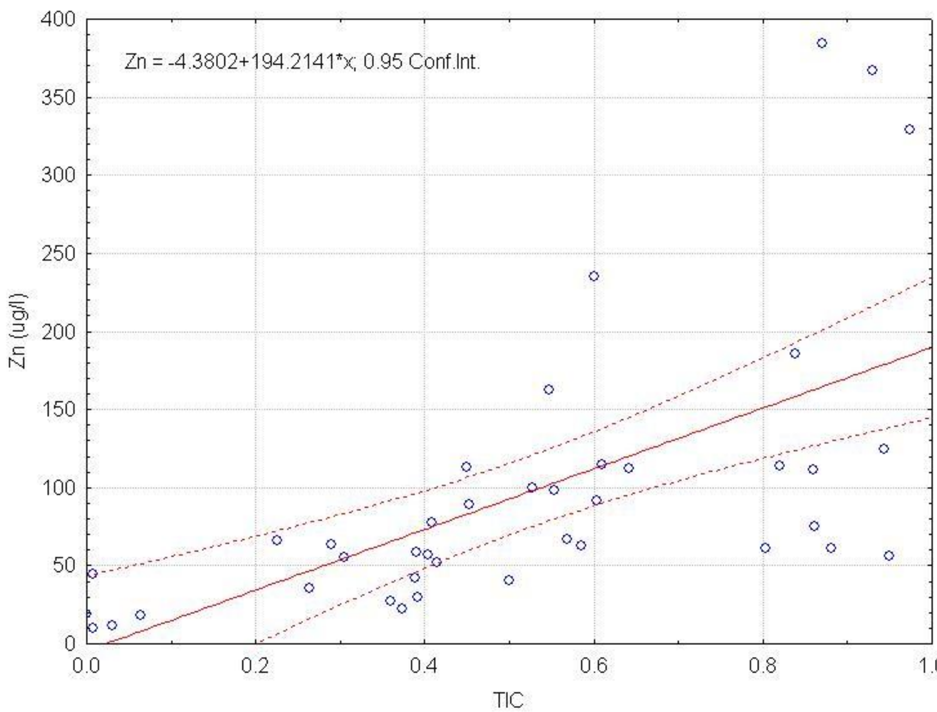

Figure 4.25: Linear regression of Zn EMCs v. TIC and the 95% confidence interval.

Table 4.4: Coefficients for suggested linear relationships to predict concentrations using TIC.

Pollutant	Intercept	Slope
BOD	4.83	11.9
CD	0.322	0.470
COD	38.9	66.6
CU	3.54	16.0
NH_3	0.106	0.295
PB	-2.07	44.28
VSS	21.2	22.5
ZN	-4.4	194.2

predict negative concentrations at low impervious cover. The exponential relationships are included in Figures 4.26-28 respectively. Results and coefficients for the exponential analyses are in Table 4.5

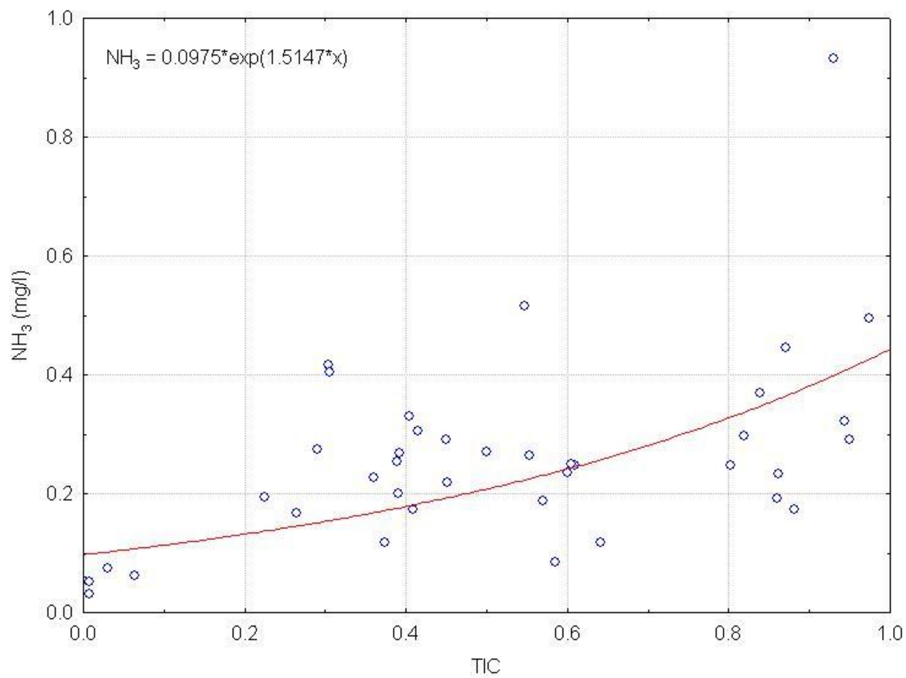

Figure 4.26 Exponential relationship between NH_3 EMCs and TIC.

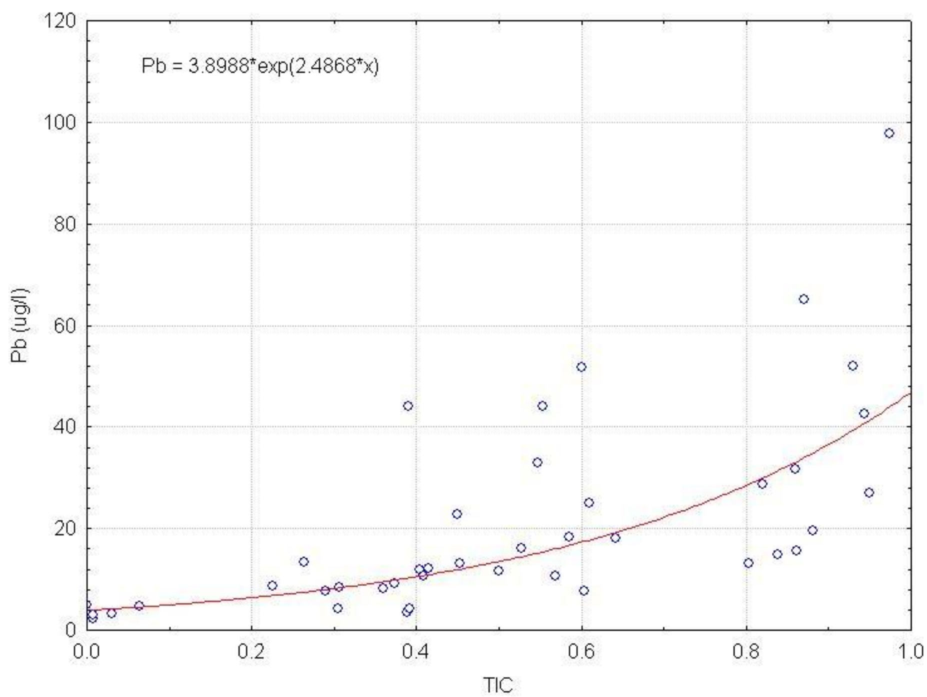

Figure 4.27: Exponential relationship between Pb EMCs and TIC.

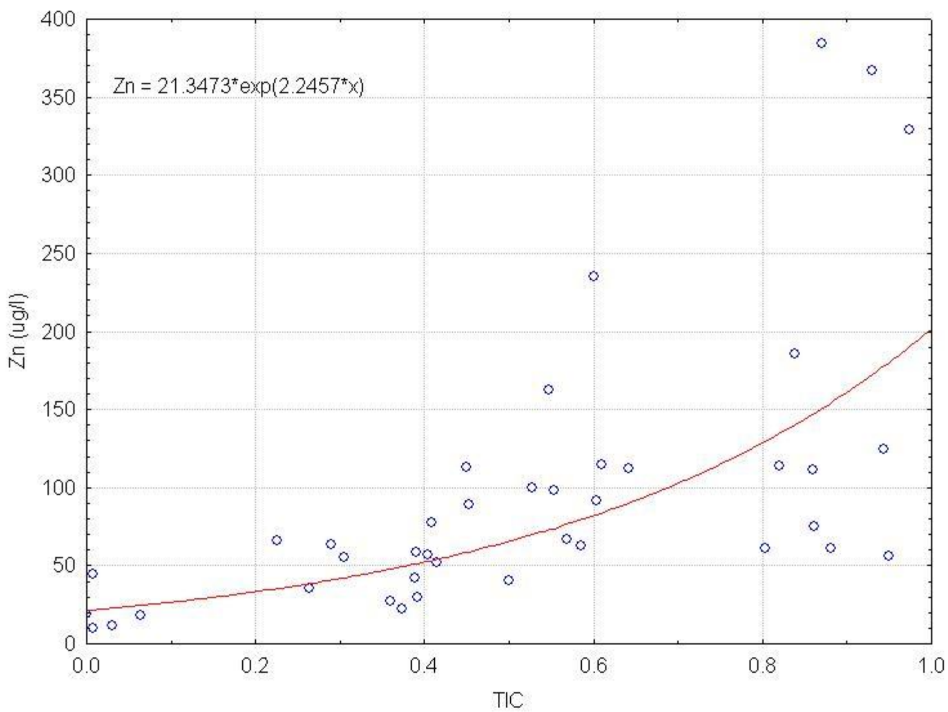

Figure 4.28: Exponential relationship between Zn EMCs and TIC.

Table 4.5: Coefficients for suggested exp. relationships to predict concentrations using TIC.

Pollutant	P>f	r2	a	b
NH_3	0.0004	0.382	0.102	1.487
Pb	0.0000	0.5411	4.283	2.424
Zn	0.0000	0.508	23.565	2.179

4.1.3 Relationship with Impervious Cover and Land use

As mentioned previously, impervious cover may not be the only watershed characteristic influencing the mean runoff concentrations; the type of impervious cover may have as much or more impact in the mean concentration than the total amount of impervious cover. To test this, step-wise multi-linear regression was performed in the seventeen parameters using TIC and fraction of five different land use types (non-urban, single-family residential, commercial, transportation and industrial) as independent variables.

Step-wise regression assesses all potential independent variables that may be included in a model and selects the best single variable for inclusion in the model in the first step. In the second step, it assesses the remaining independent variables for inclusion in the presence of the previously selected variable based on previously selected thresholds. In subsequent steps

variables are also evaluated for removal from the model. These steps continue until no variable meets the criteria for inclusion in or removal from the model. While this is a useful tool, collinearity should be evaluated and the model should be reasonable from a practical standpoint as well. The coefficients in Table 4.6 may be used to predict mean concentrations using the following equation:

$$MC = \beta_0 + \beta_1 TIC + \beta_2 NU + \beta_3 SFR + \beta_4 COM + \beta_5 TRANS + \beta_5 IND \qquad [4.1]$$

where *TIC* is the decimal fraction of total impervious cover, *NU* is the decimal fraction of non-urban land use, SFR is the decimal fraction of single-family residential land use, COM is the decimal fraction of commercial land use, TRANS is the decimal fraction of non-urban land use, and IND is the decimal fraction of industrial land use.

Three parameters, FSTR, NO_3+NO_2 and TOC, could not be significantly related to any of these independent variables. TIC alone was the best predictor for BOD, COD and Cu. Pb and Zn included industrial and transportation land uses respectively, with TIC for an improved model, but the multi-linear model still had a lower r^2 (explaining less of the variability) compared to the exponential model using TIC as the sole predictor. The model for TP included the fraction of non-urban land use as the sole predictor with the runoff concentration decreasing as the fraction of non-urban land increased. Analyses of VSS, TKN, TN, TSS and DP resulted in models with combinations of land use. The model for FCOL included only the fraction of single-family land use with the concentration increasing as the land use increased.

Table 4.6: Significant multivariate regression models for urban pollutants using impervious cover and land use as dependant variables. Coefficients, β_n, are; β_0, intercept; β_1, factor for fraction impervious cover; β_2, undeveloped land use; β_3, SFR land use; β_4, fraction commercial land use; β_5, transportation land use; β_6, industrial land use. Coefficients marked with --- were not significant at the 0.05 level.

Pollutant	P>f	r2	int	TIC	NU	SFR	COM	TRANS	INDU
BOD	0.0051	0.214	4.83	11.87	---	---	---	---	---
CD	0.0010	0.404	0.174	0.559	0.244	---	0.216	---	---
COD	0.0033	0.205	38.89	66.62	---	---	---	---	---
CU	0.0001	0.331	3.54	15.97	---	---	---	---	---
DP	0.0277	0.207	0.201	---	-0.125	---	---	---	-0.118
FCOL	0.0023	0.248	37709	---	---	70274	---	---	---
FSTR*	---	---	---	---	---	---	---	---	---
NH_3	0.0005	0.280	0.106	---	---	---	0.295	---	---
NO_3+NO_2*	---	---	---	---	---	---	---	---	---
Pb	0.0000	0.483	-5.078	61.095	---	---	-13.541	---	-25.021
TKN	0.0392	0.161	0.782	1.120	---	0.745	---	---	---
TN	0.0288	0.222	-0.265	3.058	1.621	1.929	---	---	---
TOC*	---	---	---	---	---	---	---	---	---
TP	0.0458	0.101	0.407	---	-0.200	---	---	---	---
TSS	0.0485	0.094	138.44	---	---	---	---	124.42	---
VSS	0.0016	0.341	21.52	---	---	20.21	36.02	---	---
Zn	0.0000	0.429	-14.32	175.33	---	---	---	84.98	---

The step-wise model for Cd included TIC and fraction of non-urban land use. A further examination of the results indicated that the results were influenced by collinearity and the model was not valid. Once again this could be residual effects of detection limit problems with Cd.

4.1.4 Discussion of Long-Term Runoff Analyses

Of the seventeen mean pollutant concentrations examined, two of them -- FSTR and TOC -- did not exhibit any significant relationship to development condition, impervious cover or land use. FSTR and TOC have been monitored by COA for a number of years (COA, 1984; 1990; 2006; Glick, 2009) and have not shown significant relationships in the past. FSTR was dropped from the COA sampling plan in 2001 due to problems with holding times for sample analyses. TOC may also be dropped from future sampling plans. These pollutants generally had high variability across all ranges of other explanatory variables, therefore the best estimate of the runoff concentration when estimating long-term loading is the mean of the concentrations for all sites (FSTR = 84720 cfu/100ml, TOC = 13.03 mg/l). Even though the concentrations do not change for these pollutants the loading will, due to the increased runoff volume.

The remaining pollutants do vary with urbanization to one degree or another. BOD and COD were significantly related to TIC; as TIC increased these concentrations also increased. This is reasonable because the myriad of constituents in urban runoff will increase the oxygen demand in the runoff. This is an important consideration because the increased demand will result in a lower oxygen environment and be detrimental to aquatic life. Because both concentration and runoff increase with impervious cover, the load will increase following a quadratic function.

Metals are strongly related to TIC. This is reasonable as there are few sources of these metals that are not associated with impervious cover, usually transportation or 'car habitats' and, in the case of zinc, galvanized roofs and other materials. Cu was significantly related to TIC in a linear manner. The multi-linear relationship for Cd, while significant, was not valid due to collinearity problems so the linear relationship to TIC should be used (Table 4.4). Pb and Zn are the most ubiquitous metals found in the monitoring data, rarely below the detection limits. As such, their relationships are much stronger than Cd and Cu. While multi-linear analyses of both metals resulted in significant and improved relationships with TIC and land use, the exponential relationship with TIC alone explained more of the variability (higher r^2). This is not entirely unexpected because as impervious cover increases, more of the impervious area is generally devoted to transportation, an assumed source for Pb and Zn.

Nutrients are an interesting case. The concentrations of all measured nutrients were significantly different between developed and undeveloped conditions but explaining those differences was not the same for all nutrients. NH_3 was the only nutrient that was related to TIC and followed an exponential relationship. When land use was included, NH_3 demonstrated some correlation to commercial land use. A 2005 COA study found that the land use with the highest NH_3 concentration was downtown commercial areas. This could be due to it being an entertainment area, but also, waste from birds and other animals may accumulate on impervious areas and easily be washed off during rain events. DP, TP, TKN and TN were not related to TIC but showed some relationship with the fraction of non-urban land use including parks, undeveloped areas and other open space but not including golf courses or other highly managed turf areas. While nutrients generally decrease as non-urban land use increases, a previous COA study (2005) indicated that nutrient concentrations in runoff from golf courses are elevated above other land uses. While these relationships are significant, there is a significant scatter for watersheds with little or no non-urban land use and the regression explains only about 10% of the variability. Given this, it may be better to use means for developed and undeveloped areas that were found significantly different in the ANOVA test for DP, TP, TKN and TN. NO_3+NO_2, was not significantly related to TIC or land use but there was a significant difference between developed and undeveloped.

FCOL is related to the fraction of single-family residential land use in the watershed. Since pets are one of the biggest sources for FCOL it is reasonable that increases in FCOL are related to areas where pets generally reside. As more people with pets start to reside in the downtown area, an increase in FCOL may be seen. VSS is related to two land uses, commercial and SFR, but there is not a ready explanation as to why. TSS showed a relationship with transportation land use but not TIC. At this time the best recommendation for TSS is to use the mean concentration from all sites assuming a log-normal distribution. It is recommended that for FSTR, TOC and TSS that the mean concentration be used when computing long-term loads. For NH_3, Pb, and Zn, the exponential relationship is used along with the coefficients in Table 4.5. For all other pollutants the long-term mean concentrations should be estimated using Equation 4.1 and the coefficients in Table 4.6

The COA Environmental Criteria Manual (ECM) lists assumed pollutant concentrations for various land uses and impervious covers in Tables 1.10 and 1.11. Those tables were combined to create table 4.7. Results of the analyses in this report for the same pollutants are listed in Table 4.8. In many cases the undeveloped concentrations found in Table 4.8 are greater than developed concentrations in Table 4.7. It is recommended that the ECM be updated to reflect the most recent data analyses. While TP, TN and FCOL did vary with land use, the project team believes that the slight improvement in pollutant loading gained by using those

Table 4.7: Current City of Austin Environmental Criteria Manual pollutant concentration assumptions, Table 1.10 and 1.11.

Pollutant	UND	SFR		MFR		COMM	
		0-15%	>15%	0-15%	>15%	0-15%	>15%
TSS (mg/l)	55	82.5	110	82.5	110	82.5	110
TP (mg/l)	0.04	0.1	0.16	0.1	0.16	0.1	0.16
TN (mg/l)	0.54	1.27	2	0.97	1.4	1.18	1.82
COD (mg/l)	22	28.5	35	28.5	35	50.5	79
BOD (mg/l)	8	8	8	8	8	8	8
Pb (ug/l)	3	12	20	12	20	17	30
FCOL (cfu/100 ml)	4000	6,200	8,400	6,200	8,400	21,500	39,000
FSTR (CFU/100 ml)	3000	7,000	11,000	7,000	11,000	24,500	46,000
TOC (mg/l)	6	7.5	9	7.5	9	12.5	19
Zn (ug/l)	8	24	40	24	40	29	50

Table 4.8: Recommended changes to City of Austin Environmental Criteria Manual, to replace Tables 1.10 and 1.11.

Pollutant	UND	DEV
TSS (mg/l)	166	
TP (mg/l)	0.124	0.396
TN (mg/l)	1.19	2.22
COD (mg/l)	38.9 + 66.6 TIC	
BOD (mg/l)	4.83 + 11.9 TIC	
Pb (ug/l)	4.283 EXP (2.424*TIC)	
FCOL (CFU/100 ml)	17,870	57,055
FSTR (CFU/100 ml)	84,720	
TOC (mg/l)	13.03	
Zn (ug/l)	23.565 EXP (2.179*TIC)	

relationships is offset by the increased complexity of computation and varying definitions of the land use categories and therefore does not recommend using them in the ECM. The main impact of these changes will be in evaluating pollutant removal requirements for alternative controls.

4.2 Event Runoff Quality

While long-term mean concentrations discussed above are usually used for long-term loading, they may be used in event modeling (Glick, 2009) but they would provide only differences in watershed characteristics, not variation in load due to state conditions such as rainfall, antecedent conditions, etc., As can be seen in Table 2.2, EMCs at a site can show a large variation and neglecting these variations will result in a less-than-optimal model. It has been suggested that if state conditions cannot explain the variations, EMCs can be randomly drawn from the distribution of the measured data (Pitt, 2003). This section will investigate whether any state conditions significantly explain the variations in EMCs and, if so, to evaluate the resulting stochastic models.

The initial analyses conducted were analyses of variance (ANOVA) tests to determine which state variables might be used to explain the variation in EMCs. The dependant variable was the natural log of EMC because of the prior analyses indicating EMCs are usually log-normally distributed. Independent variables used were the length of the preceding dry period (days), the peak 15-minute rainfall intensity (in/hr), the total rainfall (in) and the total runoff (ft^2). The natural log of the rainfall and runoff were also used. Rather than using TIC as a continuous independent variable, the sites were grouped into four classes that cover most cases: IC1 for non-SFR with TIC less than 70%, IC2 for non-SFR greater than 70%, SFR and undeveloped (UND). Seventy percent TIC was selected for the non-SFR classes due to a natural break in monitoring data relating to high and low intensity non-residential uses. These analyses indicated that most of the variability could be explained using previous dry period (*Dry*), rainfall intensity (i_{P-15}) and the log of the rainfall depth (I_t). The dry period and rainfall depth correspond to build-up wash-off theory while the intensity is a measure of the energy of the rainfall that may dislodge particulate matter.

After selecting the most likely predictors, regression analyses were conducted to find the significant state variables for each pollutant-group combination and develop a predictive equation for each. The coefficients for the equation based on the regressions are presented in Table 4.9 using the general equation form:

$$EMC = \beta_0 e^{(\beta_1 Dry + \beta_2 i_{P-15})} I_t^{\beta_3} \qquad [4.2]$$

The natural log of the total rainfall is important for most of the pollutants in the developed groups but appears in fewer of the pollutants for UND. But peak intensity is prevalent in UND predictions. This is not unexpected because build-up wash-off processes will dominate in areas with impervious while rainfall energy would be needed in pervious areas. The length of the preceding dry period was less important in commercial areas than was expected. Theoretically, particulate matter builds up on impervious areas and is then washed off during a runoff event; therefore, longer dry period should result in higher EMCs, especially for particulate matter. This is not seen in these data; for groups IC1 and IC2 the parameters that should be most affected by preceding dry period (TSS, metals, TP) were not affected. Of all of the analyses, only four pollutants from undeveloped areas (Cd, Cu, Pb and NH_3) could not be related to these state variables. In these cases the EMC may be randomly drawn from the distribution of the data as previously suggested by Pitt (2003).

While these relationships are statistically significant, they still may not be useful. USGS developed similar regression equations using NURP data (Tasker and Driver, 1990) to predict loads for runoff events rather than concentrations. This was extended to the Dallas-Ft. Worth area by Baldys et al. (1998) using local monitoring data. Because these equations were predicting loads, runoff was also estimated so impervious cover and drainage areas were included as independent variables. Glick (2009) compared the predicted loads using the USGS relationships to those predicted using long-term *Rv*s and mean concentrations and found that the long-term predictions were often better predictors of loads than the USGS relationships. In order to compare the relationships presented in Table 4.7 using Equation 4.2, the Nash-Suttcliffe (Nash and Sutcliffe, 1970) coefficient (NS) was computed for each group and pollutant (Table 4.10).

NS is a coefficient that ranges from 1 to $-\infty$. A value of 1 indicates that the model perfectly predicts the observed data while a value of 0 indicates that the model is no better than using the observed mean and a negative NS means the model is a worse predictor than the mean. Twenty of the models resulted in an NS of more than 0.10. The models for COD showed improvements in all categories. The predictions were better for the non-residential areas compared to SFR and UND. This may be due increased impervious cover and build-up wash-off processes being more important than traditional erosion processes. While twenty models did show a slight improvement over using the mean, the rest were no better than using the mean and represent little or no improvement over using the long-term mean relationships or the USGS

Table 4.9: Significant multivariate regression models for urban pollutants using impervious cover and land use as dependant variables. Coefficients, β_n, are; β_0, constant; β_1, factor for preceding dry period in days (*Dry*); β_2, factor for peak 15-min rainfall intensity (i_{P-15}); β_3, factor for total rainfall in inches (I_t). Coefficients marked with --- were not significant at the 0.05 level.

Group	Pollutant	P>f	r^2	β0	β1	β2	B3
IC1	BOD	0.0000	0.301	5.72	0.022	---	-0.456
IC1	CD	0.0480	0.015	0.545	---	0.110	---
IC1	COD	0.0000	0.243	27.24	0.018	0.265	-0.530
IC1	CU	0.0000	0.088	6.552	---	0.352	-0.528
IC1	DP	0.0021	0.040	0.116	---	---	-0.167
IC1	FCOL	0.0000	0.160	4094	-0.031	1.016	-0.904
IC1	FSTR	0.0000	0.213	20368	-0.040	0.727	-0.610
IC1	NH3	0.0006	0.050	0.160	0.031	---	---
IC1	NO23	0.0000	0.183	0.415	---	---	-0.371
IC1	PB	0.0000	0.150	5.70	---	0.576	-0.573
IC1	TKN	0.0000	0.256	0.521	0.013	0.418	-0.575
IC1	TN	0.0000	0.257	0.940	0.011	0.281	-0.504
IC1	TOC	0.0000	0.415	4.75	0.025	0.135	-0.553
IC1	TP	0.0000	0.121	0.174	---	0.426	-0.431
IC1	TSS	0.0000	0.165	39.52	---	0.647	-0.427
IC1	VSS	0.0000	0.102	12.48	---	0.421	-0.348
IC1	ZN	0.0000	0.166	51.19	---	0.324	-0.577
IC2	BOD	0.0000	0.285	4.89	0.015	0.176	-0.567
IC2	CD	0.0481	0.019	0.540	0.012	---	---
IC2	COD	0.0000	0.285	40.97	---	0.212	-0.592
IC2	CU	0.0000	0.122	9.580	---	---	-0.366
IC2	DP	0.0001	0.089	0.081	0.029	---	-0.200
IC2	FCOL	0.0291	0.015	8834	---	---	-0.277
IC2	FSTR	0.0001	0.079	14633	-0.024	0.423	-0.616
IC2	NH3	0.0000	0.174	0.156	---	0.256	-0.490
IC2	NO23	0.0000	0.271	0.318	0.009	0.156	-0.463
IC2	PB	0.0002	0.044	21.02	---	---	-0.234
IC2	TKN	0.0000	0.269	0.556	0.013	0.373	-0.595
IC2	TN	0.0000	0.325	0.928	0.010	0.308	-0.547
IC2	TOC	0.0000	0.167	6.32	0.016	0.181	-0.417
IC2	TP	0.0000	0.179	0.130	---	0.430	-0.552
IC2	TSS	0.0000	0.087	42.34	---	0.501	-0.412
IC2	VSS	0.0000	0.169	10.99	0.017	0.369	-0.521
IC2	ZN	0.0000	0.224	69.01	0.025	---	-0.396

Table 4.9 (cont): Significant multivariate regression models for urban pollutants using impervious cover and land use as dependant variables. Coefficients, β_n, are; β_0, constant; β_1, factor for preceding dry period in days (*Dry*); β_2, factor for peak 15-min rainfall intensity (i_{P-15}); β_3, factor for total rainfall in inches (I_t). Coefficients marked with --- were not significant at the 0.05 level.

Group	Pollutant	P>f	r^2	β0	β1	β2	β3
SFR	BOD	0.0000	0.211	4.86	0.035	0.192	-0.559
SFR	CD	0.0336	0.012	0.307	---	0.154	-0.117
SFR	COD	0.0000	0.257	30.16	0.027	0.244	-0.538
SFR	CU	0.0000	0.119	4.199	0.023	0.185	-0.278
SFR	DP	0.0000	0.072	0.127	0.025	---	-0.104
SFR	FCOL	0.0070	0.052	19129	-0.032	0.592	-0.460
SFR	FSTR	0.0319	0.026	100730	-0.032	---	-0.151
SFR	NH3	0.0000	0.098	0.091	0.026	0.218	-0.314
SFR	NO23	0.0000	0.108	0.392	0.012	---	-0.246
SFR	PB	0.0000	0.070	4.97	0.022	0.342	-0.330
SFR	TKN	0.0000	0.133	0.789	0.018	0.280	-0.407
SFR	TN	0.0000	0.164	1.276	0.016	0.207	-0.363
SFR	TOC	0.0000	0.269	6.27	0.029	0.147	-0.468
SFR	TP	0.0000	0.086	0.241	0.022	0.223	-0.253
SFR	TSS	0.0000	0.075	55.47	0.015	0.448	-0.289
SFR	VSS	0.0000	0.089	14.41	0.019	0.329	-0.343
SFR	ZN	0.0000	0.111	30.51	0.018	0.228	-0.392
UND	BOD	0.0953	0.024	2.55	---	0.133	---
UND	CD	---	---	---	---	---	---
UND	COD	0.0000	0.146	18.54	---	0.348	-0.320
UND	CU	---	---	---	---	---	---
UND	DP	0.0055	0.055	0.019	---	0.209	---
UND	FCOL	0.0003	0.235	1684	-0.027	0.750	---
UND	FSTR	0.0013	0.181	4524	-0.040	0.686	---
UND	NH3	---	---	---	---	---	---
UND	NO23	0.0132	0.034	0.177	---	0.192	---
UND	PB	---	---	---	---	---	---
UND	TKN	0.0000	0.106	0.381	---	0.273	---
UND	TN	0.0000	0.120	0.625	---	0.302	-0.248
UND	TOC	0.0012	0.062	7.16	---	0.143	---
UND	TP	0.0034	0.050	0.053	---	0.219	---
UND	TSS	0.0000	0.115	17.68	---	0.493	---
UND	VSS	0.0002	0.096	4.43	---	0.359	---
UND	ZN	0.0001	0.104	9.05	---	0.320	-0.481

Table 4.10: Nash-Sutcliffe results for EMC predictions by group and pollutant.

Pollutant	IC1	IC2	SFR	UND
BOD	**0.252**	**0.170**	0.049	0.001
CD	-0.016	-0.037	-0.048	---
COD	**0.314**	**0.205**	**0.164**	**0.115**
CU	-0.001	0.061	0.066	---
DP	0.003	-0.005	0.024	-0.044
FCOL	-0.103	-0.146	-0.041	-0.122
FSTR	-0.044	-0.068	-0.163	-0.044
NH3	-0.046	**0.119**	0.035	---
NO23	**0.142**	**0.192**	**0.100**	-0.090
PB	**0.102**	-0.061	-0.029	---
TKN	**0.193**	**0.230**	0.044	0.022
TN	**0.243**	**0.288**	0.095	**0.100**
TOC	**0.403**	0.009	**0.103**	0.033
TP	0.021	0.091	0.061	-0.067
TSS	0.058	-0.090	-0.051	-0.078
VSS	0.027	0.067	-0.015	-0.045
ZN	**0.139**	**0.160**	0.041	-0.008

equations (Glick, 2009). In these cases, randomly drawing from the distribution may be preferable, but the models are not appreciably worse than using the mean as a prediction.

These relationships based on state variables for concentrations appear to be a slight improvement for event predictions. While these stochastic models may provide improved estimations, a physical model that can be applied under varying conditions is needed to replace the reliance on stochastic relationships. However, any suggested model should be tested against observed data using NS or some other objective criteria.

4.3 Intra-Event Runoff Concentrations

How runoff concentrations change during an event is important to both modeling and BMP design. If the concentration does not change, but is constant throughout the event, the changes in load are solely a function of the change in the runoff rate. If, however, the concentration does change, the change in load is a function of both the change in flow rate and the change in concentration. This could be critical in designing BMPs when determining treatment capacity of the BMP.

An earlier report by COA (1990) indicated that runoff concentrations are higher at the start of the runoff and decrease as the runoff continues, approaching an asymptotic minimum. This effect has been reported in some studies while its presence has been disputed by others. Part of the confusion may be a result of people looking for the 'first flush' in the wrong place. The phenomenon is most prevalent in small catchments with high impervious cover. It is masked in larger watersheds because the runoff from upland areas arrives at different time, serving to smooth the concentration during the runoff and erosion processes may dominate wash-off processes in natural channels. In highly impervious watersheds particulate matter is washed off of the impervious areas fairly rapidly and the pollutant source no longer remains while in highly pervious watersheds it may be more difficult to dislodge and transport particles but the source would be near limitless.

Wash-off processes have been conducted in the past and numerous equations have been proposed for inclusion in water quality models. That is not the purpose of the study; rather, this study will examine existing data and report observed trends, but this may serve as a starting point for further study.

The relationship between instantaneous runoff concentration and intra-event location was examined in three different ways, each providing different information yet similar results. The first method created a series of 'bins,' each representing 0.1 inch runoff. Water quality samples were placed in the bin corresponding to the amount of runoff that had occurred prior to the sample being collected. Multiple samples from a single event that fell into the same bin were averaged to prevent over-weighting an event. The resulting concentrations from each site were then averaged to prevent over-weighting a single site. The sites were then combined into groups as was previously done, IC1 for non-SFR with TIC less than 0.70, IC2 for non-SFR with TIC greater than 0.70, SFR for all single-family residential watersheds and UND for all undeveloped watersheds. These groups were chosen because of the similarity of the sites and to increase the power of the analyses. This method is simple and all samples may be used, even if the EMC does not score well. The drawback is that there is more noise than the other methods and there may be gaps in the data if no samples were collected for a given bin. In the interest of space, the results of these analyses and the other two tests may be found in the appendix of this report.

The second method was based on the percentage of runoff. The total of load and runoff that occurs in each 10%, by runoff, segment of the hydrograph is computed. The concentration in that segment is the load divided by the volume. The resulting concentrations were combined into groups as before. The advantage to this method is that segments of a storm need not be sampled to provide a valid data point; however, the storm must have a passing EMC and sites with less than optimal flow rating may be used. Further, because the size of the storm is factored out, the first part of the event has the same weight as the last part of the event. This advantage also creates a drawback in that the change in concentration is attenuated because small events where the concentration has not changed as much are combined with larger events where the concentration has changed considerably. Normalized concentrations for each segment were also computed in this step, which would allow for varying EMCs to be computed for an event. Then the load could be proportionally distributed across the event following the correct trend.

The third set of analyses followed the procedure outlined in a CalTrans study (Stenstrom and Kayhanian, 2005) and was similar to the analyses used in the 1990 COA study. Load for each 0.1 inch partition of runoff is computed based on the sampling data. This is accomplished in a manner not unlike that which was described for computing loads for EMC computation, except that the start and end times correspond to the start and end times of the partition rather than the start and end of the event. The concentration for the partition is computed by dividing the load in the partition by the volume. These partitions were then combined into groups, as with the previous analyses. In addition, long-term runoff characteristics of the runoff were computed during this step including the percentage of load and volume occurring before the partition (inclusive), the concentration before and after the partition, the mass first-flush ratio (MFF) and the effectiveness factor (EF). MFF is the percent of load to the partition divided by the percent of volume to the partition while EF is the concentration before the partition divided by the concentration after the partition. The last two factors may be used to evaluate BMP capture volumes.

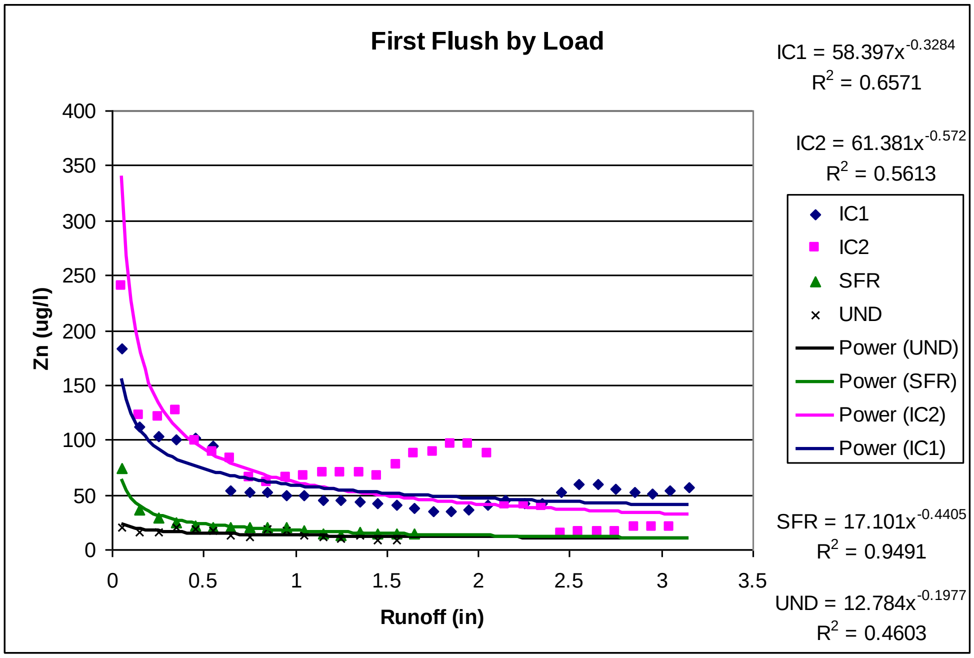

Figure 4.29: First-flush analyses for Zn by load, volume of runoff.

The results of these analyses are not substantially different from those present by others (COA, 1990; Pitt, 2003; Stenstrom and Kayhanian, 2005) in that concentrations tend to decrease as runoff volume increases. However, most of the other studies focused on particulate wash-off from high impervious cover sites. These analyses demonstrate that the first flush is related to impervious cover and land use, but not all pollutants behave in the same manner (see Figures 4.29 and 4.30 and others in the appendix). While outside the scope of this report, further study may be conducted to develop better wash-off models incorporating land use and impervious cover.

The results of all three analyses are similar for each pollutant. BOD and COD demonstrated strong first flush effects for IC1 and IC2 groups and little change in UND. This is expected because much of the oxygen demand is often associated with particulate matter. Cu, Pb and Zn all demonstrated similar trend with strong first flush for IC1 and IC2 groups, with less-pronounced effects on SFR; but UND demonstrated no change in concentration based on storm volume (see Figure 2.49). Cd was the only metal that did not show a significant trend, most likely due to poor detection limits. Solids like TSS and VSS exhibited first flush effects for all groups, stronger with higher impervious cover. The first flush trends for solids generally follow

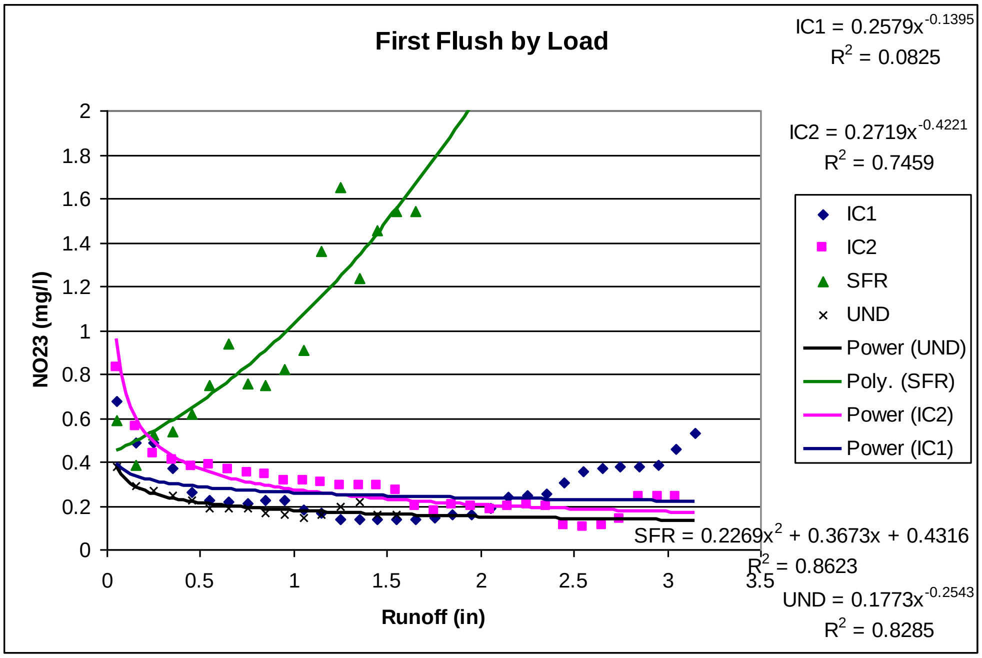

Figure 4.30: First-flush analyses for NO_3+NO_2 by load, volume of runoff.

an exponential decay pattern and do not disagree with the work of Sartor and Boyd (1972). But modifications are needed to account for non-wash-off erosion in pervious areas.

While particulate matter follows traditional trends, the same cannot be said for nutrients, especially dissolved phases. Generally UND, IC1 and IC2 follow similar trends as the particulate pollutants; however, SFR concentrations tend to increase as the runoff increases. This may be due to the initial runoff from SFR areas coming from impervious areas while the latter portion of the runoff is coming from the pervious lawn areas. The presence of a ‘last flush’ in SFR areas may have a profound impact on BMP design for these areas. See Figure 4.30 for an example of a ‘last flush’ trend for nitrate + nitrite.

The presence of the first flush effect has an impact on both modeling and BMP design. If shorter time-step modeling is planned, the model should take into account the change in concentration. The first flush also allows the designers of BMPs to design systems that treat a larger percentage of the load than the volume of runoff captured for treatment. The design capture volume for each developed group and pollutant may be found in Table 4.11 using the

Table 4.11: Results of MFF analyses indicating the capture volume in inches required to treat 90% of the annual load for sites in the IC1, IC2 and SFR classes and the percentage of the load treated using ½"+ sizing requirements.

Pollutant	IC1		IC2		SFR	
	Capture volume (in) for 90% Load	Percent load treated with 1/2"+ capture	Capture volume (in) for 90% Load	Percent load treated with 1/2"+ capture	Capture volume (in) for 90% Load	Percent load treated with 1/2"+ capture
BOD	0.8	91.7	1.6	85.5	0.6	93.1
CD	0.9	90.2	1.4	87.3	1.2	80.4
COD	0.8	92.6	0.8	95.9	0.9	88.1
CU	0.9	91.3	1	92.2	0.7	90.3
DP	1.0	88.9	1.1	92.0	1.9	69.4
FCOL	0.8	92.2	0.8	94.3	1.3	77.7
FSTR	0.7	94.5	1.0	93.8	0.7	90.5
NH3	0.8	92.4	2.4	78.0	1.7	77.1
NO23	0.8	92.8	1.1	90.5	1.8	68.3
PB	0.9	91.2	0.8	94.1	0.6	92.8
TKN	0.9	90.5	1.1	90.5	1.1	83.5
TN	0.9	91.2	1.1	90.8	1.5	78.7
TOC	0.9	91.0	0.6	96.8	1.3	81.6
TP	0.9	90.7	1.0	93.3	1.2	80.0
TSS	1.0	88.7	0.7	94.2	0.7	90.3
VSS	1.2	85.6	0.6	96.9	0.6	94.3
ZN	0.7	93.7	1.0	91.6	0.6	92.8

load partitioned by runoff volume method, assuming the goal is to design a BMP that will capture and treat 90% of the load. By comparison, the COA ½"+ criteria will capture and treat the fractions of load also shown in Table 4.11. It was assumed that IC1 has an impervious cover of 60%, 90% for IC2 and 40% for SFR, corresponding to design capture volumes of 0.9, 1.1 and 0.7 inches respectively. It can readily be seen that nutrients from SFR are the most problematic. One caveat about the data in Table 4.11: this does not take into account instances where a runoff event occurs while the full BMP capture volume is not available due to a previous event. While this is a rare occurrence it will lower the reported percentage of load treated.

5 Conclusions

This report is intended to summarize the runoff quality and quantity data collected by the City of Austin since 1981. During the preceding thirty years, collection techniques, equipment and personnel have changed, all having an impact on data quality. However, the data used in this report represents a unique dataset in both scope and duration. While far from an exhaustive examination of the data, this report does verify some existing hypotheses and also challenges some existing assumptions.

The relationship between TIC and *Rv* found in this report differs significantly from that found in the COA ECM (2009). If the relationship found in this report is adopted there will be no changes in required capture volumes of most BMPs currently in the ECM but the size of wet ponds will increase. There may be an impact on the design of alternative water quality controls. An earlier COA study (2006) found that there was no difference between the runoff from recharge and non-recharge areas; therefore, only one relationship is presented in this report.

It was demonstrated that some mean pollutant concentrations change with development conditions. NH_3, Pb and Zn increased exponentially with impervious cover. TP, DP, TKN and TN increased as the fraction of non-urban land decreased. COD, BOD, Cd and CU increased linearly at total impervious cover increased. FCOL increased as the fraction of SFR land use increased while VSS varied with changes in SFR and Com land uses. NO_3+NO_2 concentrations were different between developed and undeveloped areas but there were no significant relationships with impervious cover or land use. FSTR, TOC and TSS were not significantly related to changes in development condition tested in this report. A table was prepared to replace the existing COA ECM (2009) stormwater concentration assumption in Tables 1.10 and 1.11. This change would have no impact on existing BMP designs but would impact the design of alternative controls.

It was found that using DCIA instead of TIC did not result in improved predictions of mean concentrations or runoff-rainfall ratios, *Rv*. DCIA was estimated in this report based on empirical relationships developed elsewhere. If local relationships are developed or if DCIA were actually measured, this conclusion may be different.

Significant relationships were developed to predict EMCs for the pollutants studied and four classes of development. The models used one or more of the following as predictive variables: preceding dry time, 15-minute peak rainfall intensity and total rainfall. While these models were statistically significant, most models resulted in predictions that were no better than using the mean value. Better physical models are needed to predict EMCs, rather than relying on stochastic relationships.

The analyses confirmed results of earlier studies that indicated runoff concentrations are not constant during a runoff event in small watersheds with moderate to high impervious cover. The first-flush effect was less pronounced (even non-existent for some pollutants) in undeveloped areas. While other studies focused solely on impervious cover, this report also examined the type of land use associated with the impervious cover. If was found that in SFR areas, nutrients, more especially dissolved nutrients, exhibited a 'last-flush' with pollutant concentrations increasing rather than decreasing as runoff volume increased. This effect may have a substantial impact future BMP design.

Testing proposed modifications the NRCS curve number method found a slight improvement but it still under predicts runoff volumes for smaller events, those of most concern for water quality design. While this method may still be used for flood design, models based on physical processes should be employed when attempting to perform continuous simulations for water quality design.

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Appendix A Site Pages

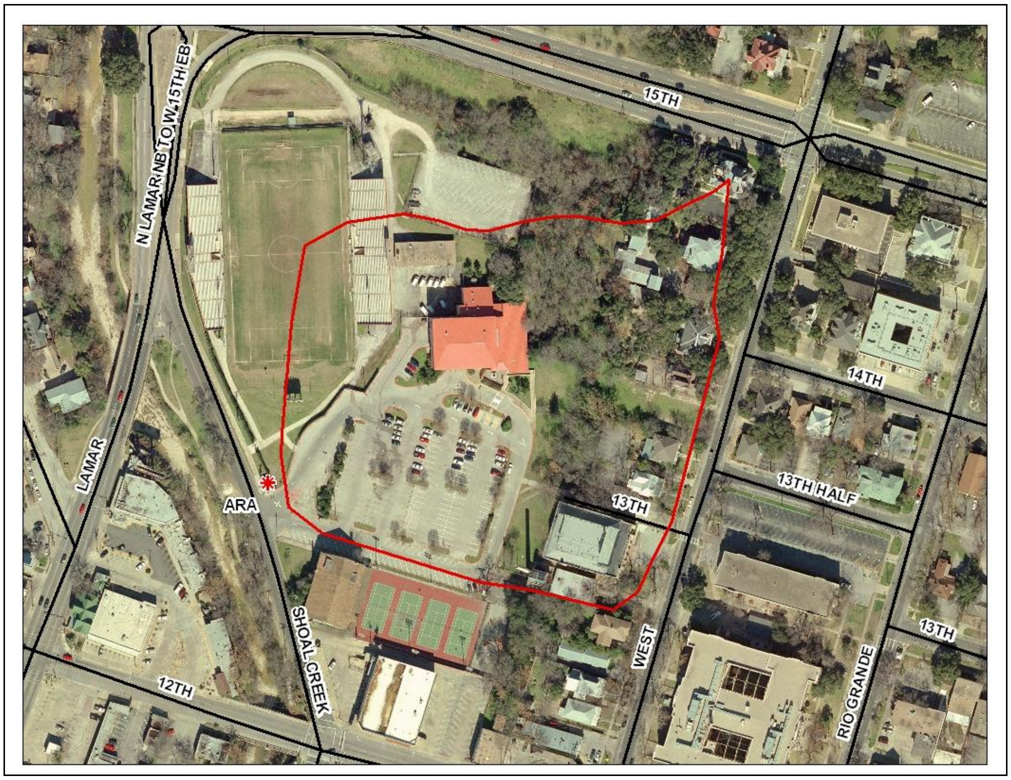
Austin Recreation Center (ARA)

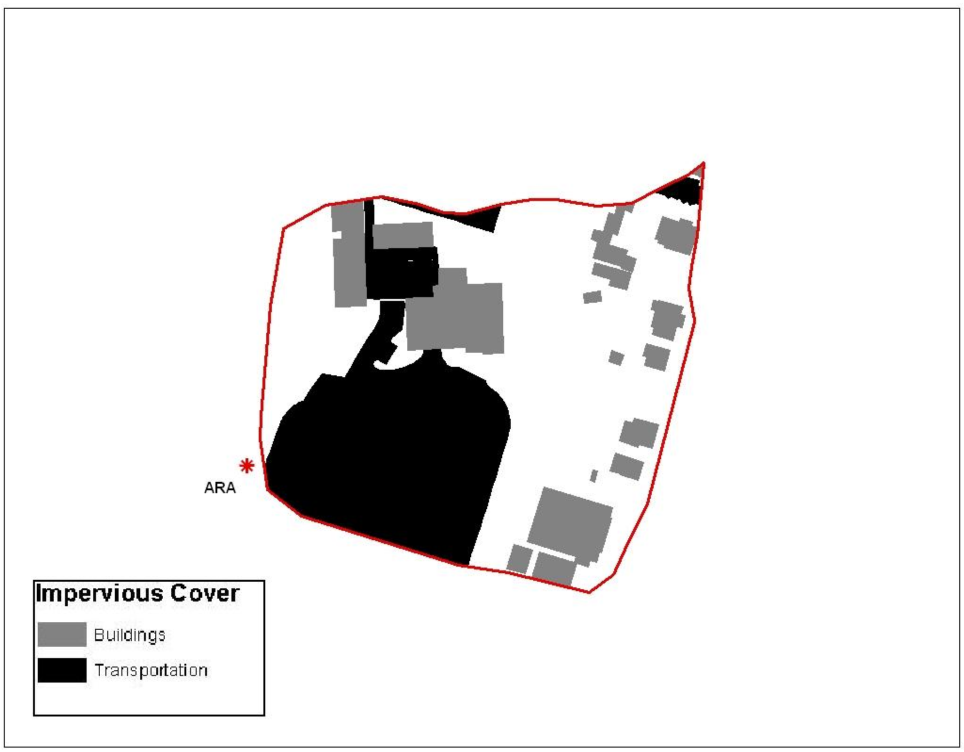
This monitoring station was established at the entrance to the parking lot of Austin Recreation Center located at 12th and Shoal Creek Blvd. and was monitored between 1995 and 1997 and reactivated in 2006-7 as part of a study on PAHs on runoff. The 9.0 ac. watershed in the Shoal Creek watershed is 53% impervious and is classed as a civic land use but more closely resembles an office complex. The station measured the flow into an oil and grit chamber using a flow metering insert. The chamber was designed to capture low flows; when the runoff rate exceeded the capacity of the chamber flows bypassed the station and were not measured. This station was not used for runoff-rainfall analyses for this reason. During very large events flows in Shoal Creek backed up into the chamber and also impacted the monitoring.

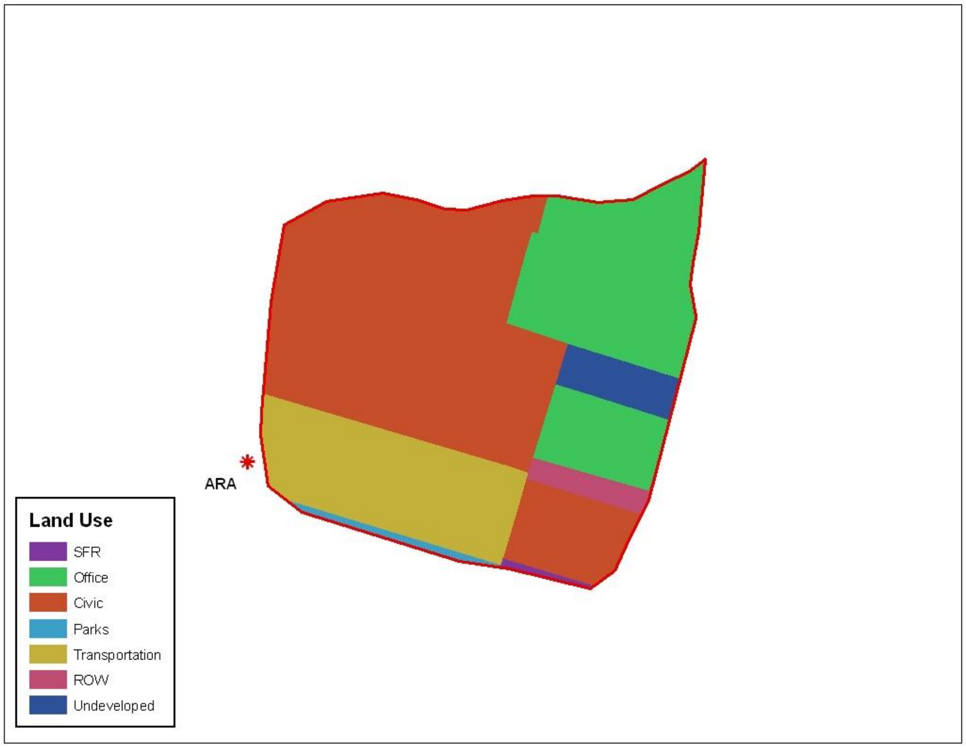
Site Summary

Site ID	ARA	
Site Name	Austin Recreation Center Influent	
Latitude	30.2776	N
Longitude	97.7501	W
Predominate Land Use	Civic	
Drainage Area	9.0	Acres
Impervious Cover	0.5279	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	136.1	mg/L	21
NO_2+NO_3	0.577	mg/L	8
NH_3	2.084	mg/L	9
TKN	4.380	mg/L	8
TN	4.450	mg/L	7
COD	58.50	mg/L	8
TOC	7.93	mg/L	9
Cadmium	0.671	µg/L	7
Copper	14.856	µg/L	9
Lead	16.04	µg/L	7
Zinc	100.05	µg/L	9


15TH
N LAMAR NB TO W 15TH EB
14TH
13TH HALF
13TH
LAMAR
ARA
SHOAL CREEK
WEST
12TH
RIO GRANDE
13TH


ARA
Impervious Cover
Buildings
Transportation


ARA
Land Use
SFR
Office
Civic
Parks
Transportation
ROW
Undeveloped


WRONG
WAY
08.25.2005

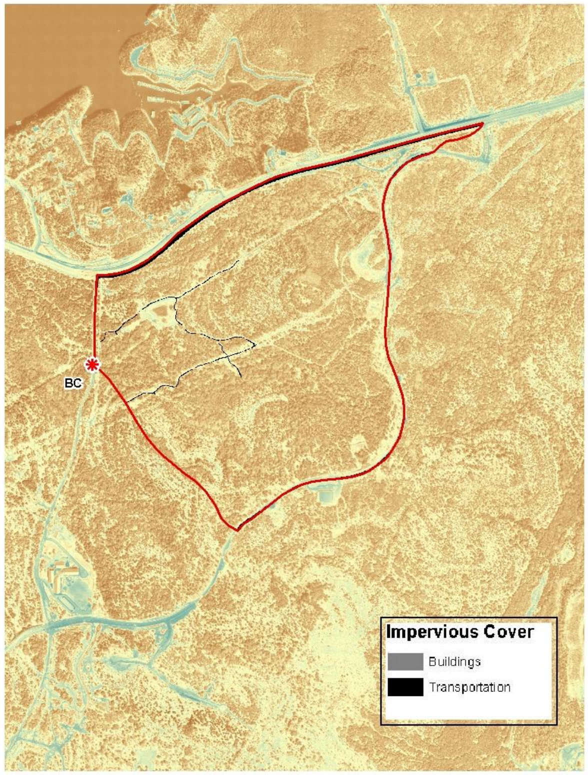
Bear Creek near Lake Travis (BC)

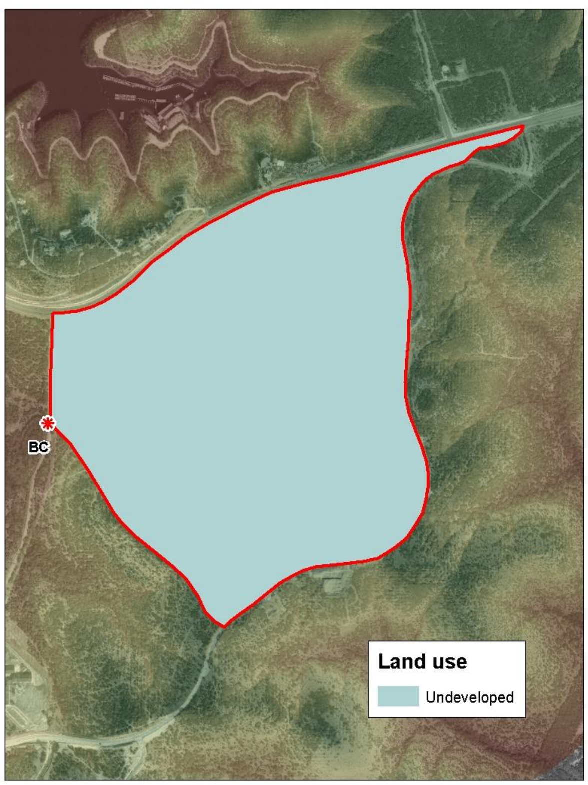
This monitoring station was located on Quinlan Park Road and was operated between 1984 and 1987. The 301 ac. watershed had approximately 3% impervious cover at the time of monitoring. The primary land use at the time of monitoring was undeveloped. Flow was measured using a 2.5 foot HL-flume at the end of a 24 inch pipe that ran under Quinlan Park Rd. There was an existing pond inside the watershed that may have affected the total amount of runoff recorded.

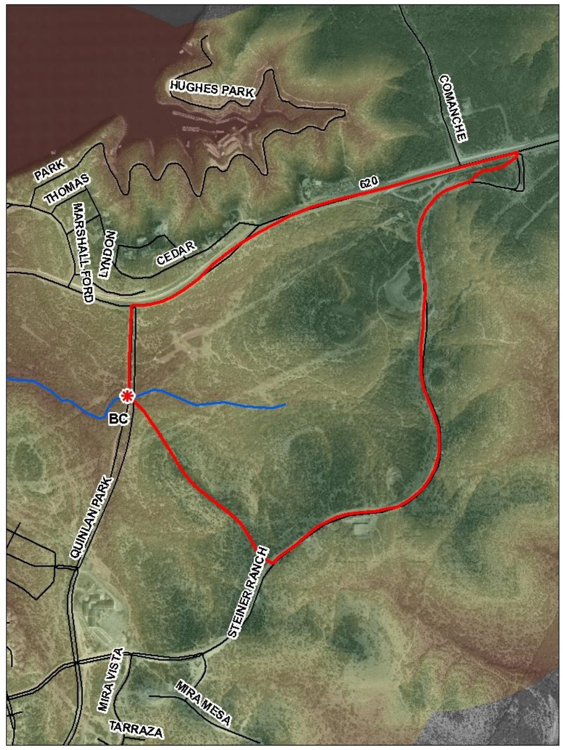
Site Summary

Site ID	BC
Site Name	Bear Creek near Lake Travis
Latitude	30.3867 N
Longitude	97.8826 W
Predominate Land Use	Undeveloped
Drainage Area	301.0 Acres
Impervious Cover	0.03
Runoff-Rainfall Ratio	0.007
Runoff-Rainfall Events	51
Recharge Zone	No

Parameter	**Mean EMC**	**Units**	**Count**
TSS	147.0	mg/L	22
NO_2+NO_3	0.140	mg/L	22
NH_3	0.075	mg/L	22
TKN	0.406	mg/L	19
TN	0.602	mg/L	19
TP	0.066	mg/L	21
BOD	6.69	mg/L	21
COD	20.86	mg/L	21
TOC	8.03	mg/L	21
Copper	9.544	µg/L	22
Lead	3.27	µg/L	22
Zinc	11.25	µg/L	22
F. Coliform	15,281	cfu/100m	22
F. Strep.	8,109	cfu/100m	22


BC
Impervious Cover
Buildings
Transportation


BC
Land use
Undeveloped


HUGHES PARK
COMANCHE
PARK
THOMAS
620
MARSHALL FORD
LYNDON
CEDAR
BC
QUINLAN PARK
STEINER RANCH
MIRA VISTA
MIRA MESA
TARRAZA

Barton Creek Tributary (BCU)

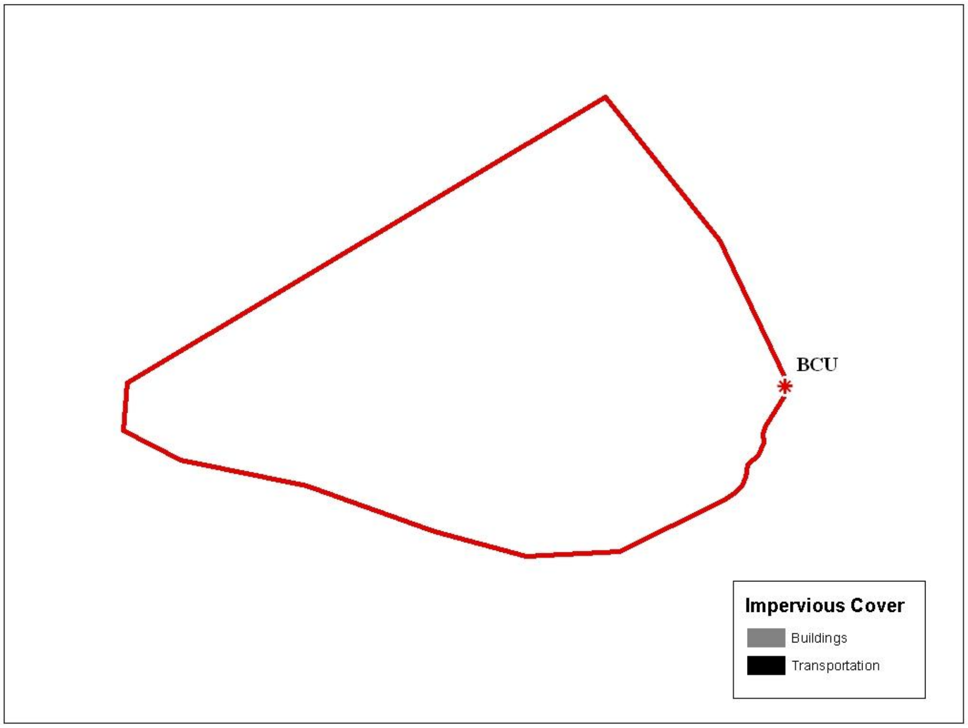
This site is on a tributary to Barton Creek in the Barton Creek Greenbelt in the recharge zone. The drainage area is 17.33 acres with minimal impervious cover (0.007%) with the land use being classified as parks. The monitoring station was operational from 1996 through 2004. The flow was measured by a compound weir with the bottom portion being a 90° V-notch. The weir collapsed three times during the monitoring period during very large runoff events, after 7 inches of rain in 1998 and 6 inches in 2001 and finally 6.75 inches in 2004.

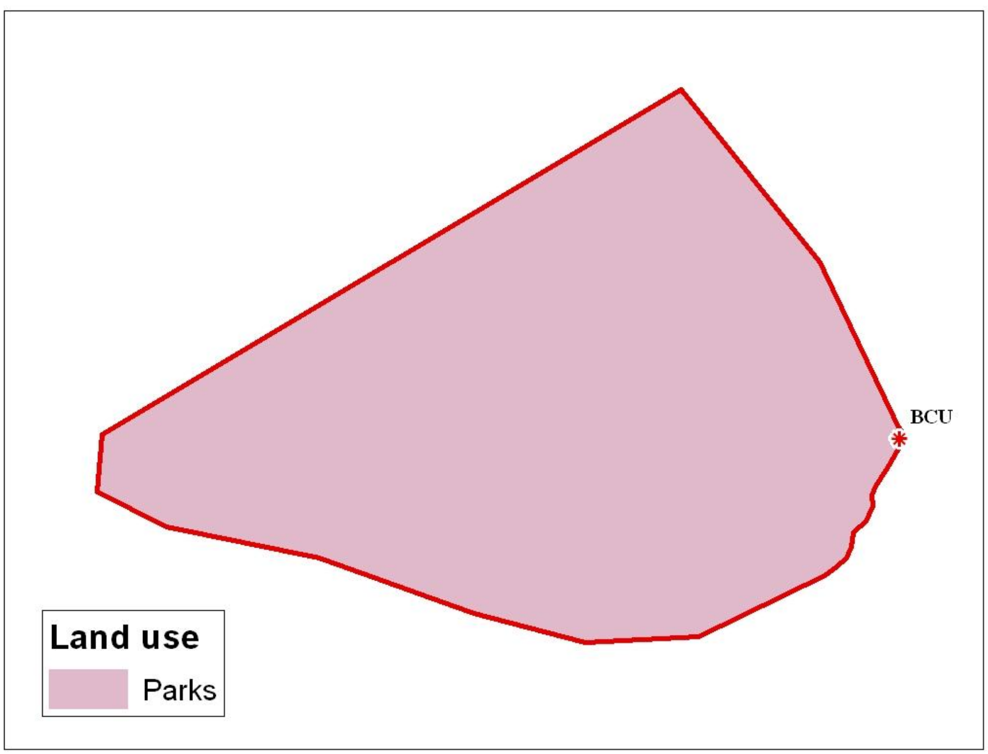
Site Summary

Site ID	BCU	
Site Name	Barton Creek Undeveloped.	
Latitude	30.2603	N
Longitude	97.8271	W
Predominate Land Use	Undeveloped	
Drainage Area	17.33	Acres
Impervious Cover	0.0007	
Runoff-Rainfall Ratio	0.02	
Runoff-Rainfall Events	431	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	27.7	mg/L	24
VSS	8.5	mg/L	24
NO_2+NO_3	0.626	mg/L	24
NH_3	0.053	mg/L	24
TKN	1.002	mg/L	24
TN	1.581	mg/L	24
DP	0.023	mg/L	23
TP	0.070	mg/L	24
BOD	2.98	mg/L	12
COD	52.06	mg/L	24
TOC	17.68	mg/L	24
Cadmium	0.594	µg/L	25
Copper	3.090	µg/L	25
Lead	5.10	µg/L	25
Zinc	18.93	µg/L	25
F. Coliform	20,114	cfu/100m	10
F. Strep.	88,399	cfu/100m	10


BCU
MAGDELENA
MOONSHADOW
MC DADE
SENDERO


BCU
Impervious Cover
Buildings
Transportation


BCU
Land use
Parks

Brodie Oaks Shopping Center (BI)

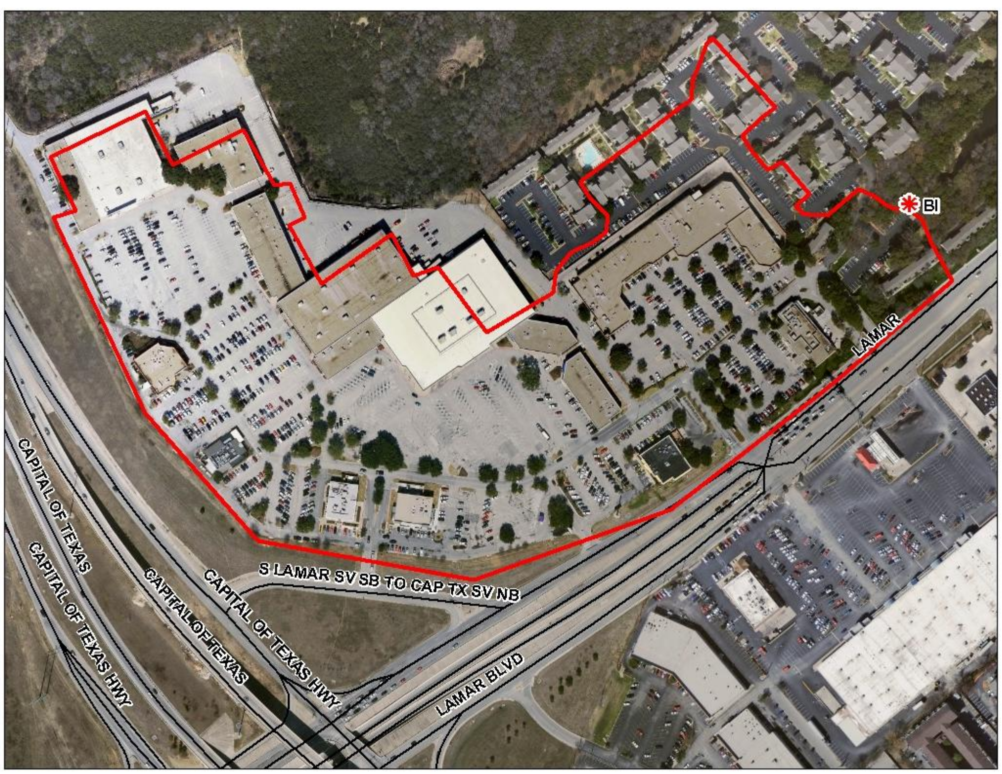
This monitoring station was located at the influent to a water quality control structure in the Brodie Oaks Shopping Center and was operational between 1985 and 1987. The 30.9 acre watershed has 95% impervious cover and a commercial land use. Due to concerns with the accuracy of the flow measurements at this station, data from this station were not used in runoff-rainfall analyses. A portion of the watershed is in the recharge zone and another portion is in the contribution zone east of the recharge zone.

Site Summary

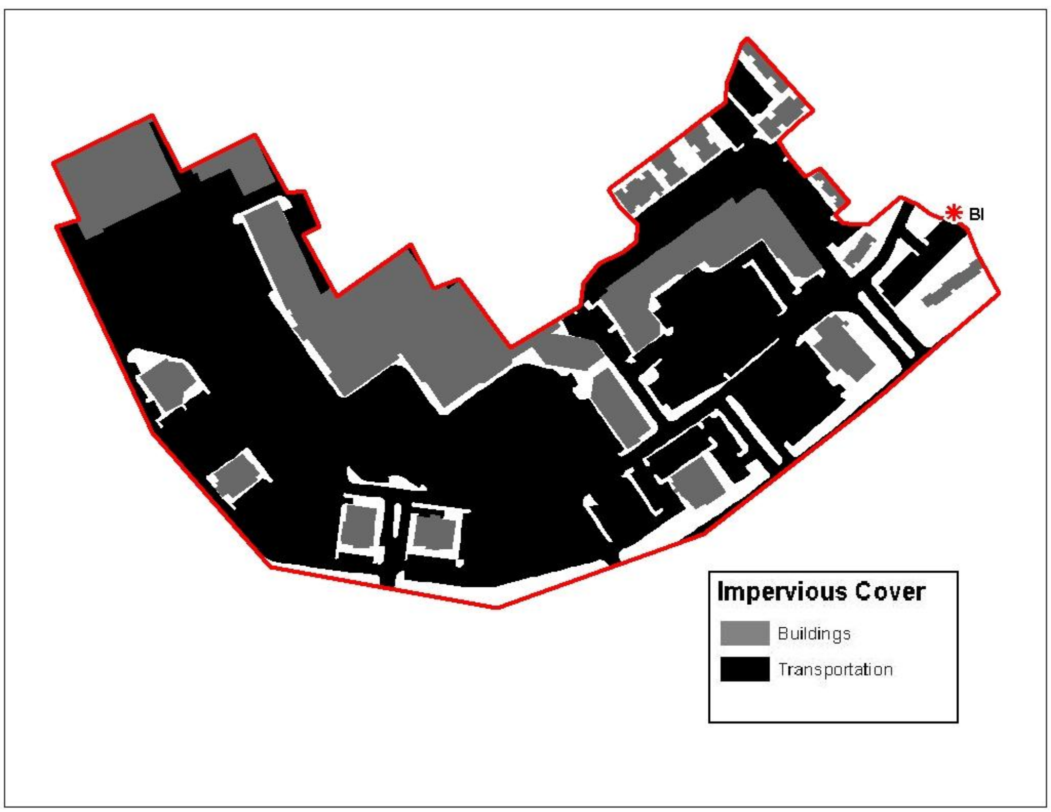
Site ID	BI	
Site Name	Brodie Oaks Influent	
Latitude	30.2380	N
Longitude	97.7914	W
Predominate Land Use	Commercial	
Drainage Area	30.9	Acres
Impervious Cover	0.95	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	64.1	mg/L	12
NO_2+NO_3	0.278	mg/L	12
NH_3	0.249	mg/L	12
TKN	0.663	mg/L	12
TN	0.933	mg/L	12
TP	0.107	mg/L	12
BOD	7.29	mg/L	11
COD	26.83	mg/L	12
TOC	10.27	mg/L	12
Copper	5.992	µg/L	12
Lead	25.48	µg/L	12
Zinc	56.42	µg/L	12
F. Coliform	24,607	cfu/100m	11
F. Strep.	17,617	cfu/100m	12


BI
Land Use
MFR
Commercial
Office
ROW


BI
LAMAR
CAPITAL OF TEXAS
CAPITAL OF TEXAS HWY
CAPITAL OF TEXAS
CAPITAL OF TEXAS HWY
S LAMAR SV SB TO CAP TX SV NB
LAMAR BLVD


08.25.2005


BI
Impervious Cover
Buildings
Transportation

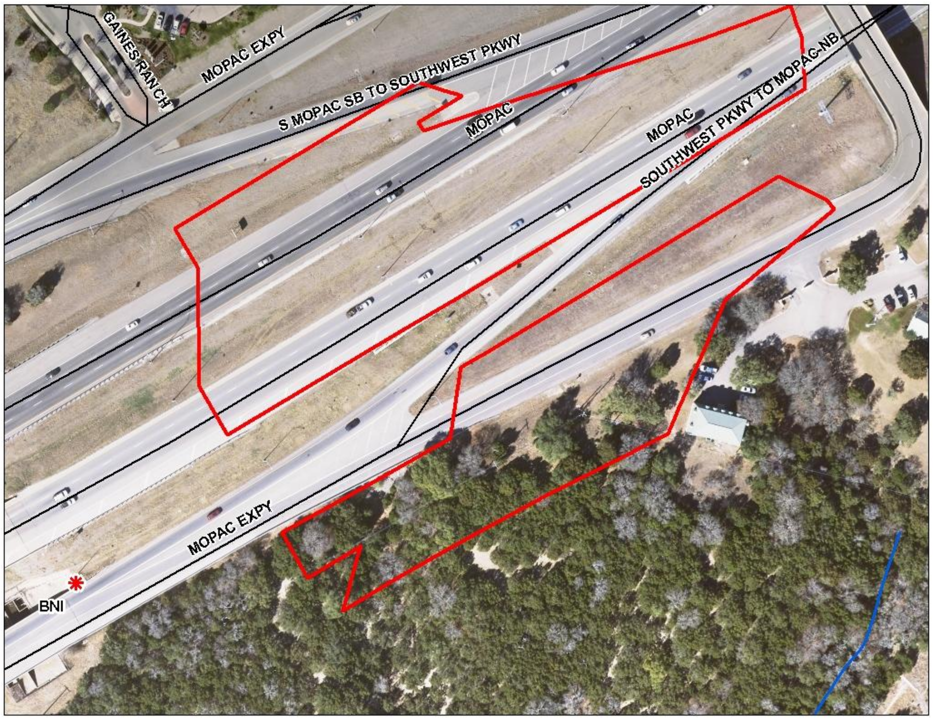
Highway BMP #6 (BNI)

This monitoring site was established as part of a joint effort between Barton Springs Edwards Aquifer Conservation District, Lower Colorado River Authority, Texas Department of Transportation and the City of Austin to evaluate water quality controls on major roadways. The site was located on the north side of Gaines Creek at Loop 1 or MoPac and was monitored from 1994 through 1997. The total drainage area was 4.93 acres with 59% impervious cover with transportation land use. Flow was estimated using the slope-area method however the accuracy was deemed too low for inclusion in runoff-rainfall analyses. The station is part of the Barton Spring recharge zone.

Site Summary

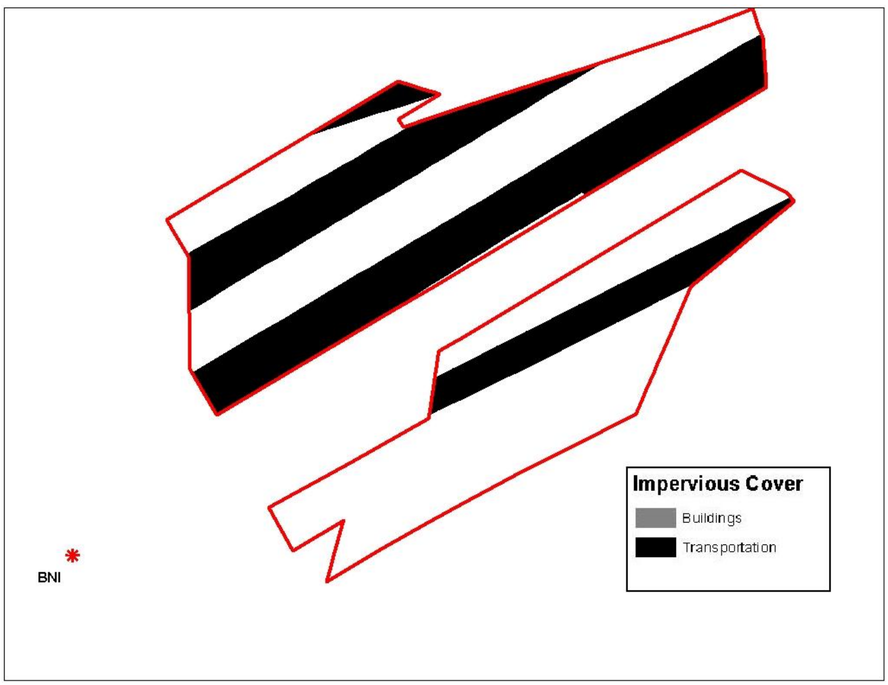
Site ID	BNI
Site Name	Highway BMP #6 Influent
Latitude	30.2389 N
Longitude	97.8180 W
Predominate Land Use	Transportation
Drainage Area	4.93 Acres
Impervious Cover	0.5853
Runoff-Rainfall Ratio	N/A
Runoff-Rainfall Events	N/A
Recharge Zone	Yes

Parameter	Mean EMC	Units	Count
TSS	408.3	mg/L	12
VSS	9.5	mg/L	1
NO_2+NO_3	0.419	mg/L	11
NH_3	0.085	mg/L	1
TKN	1.233	mg/L	11
TN	1.660	mg/L	11
DP	0.072	mg/L	10
TP	0.322	mg/L	10
BOD	2.50	mg/L	1
COD	54.52	mg/L	13
TOC	8.20	mg/L	12
Cadmium	0.200	µg/L	1
Copper	2.505	µg/L	1
Lead	18.24	µg/L	8
Zinc	62.44	µg/L	14
F. Coliform	1,893	cfu/100m	2
F. Strep.	3,170	cfu/100m	2


GAINES RANCH
MOPAC EXPY
S MOPAC SB TO SOUTHWEST PKWY
MOPAC
MOPAC
SOUTHWEST PKWY TO MOPAC NB
MOPAC EXPY
BNI


SPEED LIMIT
65


Land Use
Office
Parks
ROW
Undeveloped
BNI


Impervious Cover
Buildings
Transportation
BNI

Barton Ridge Plaza (BRI)

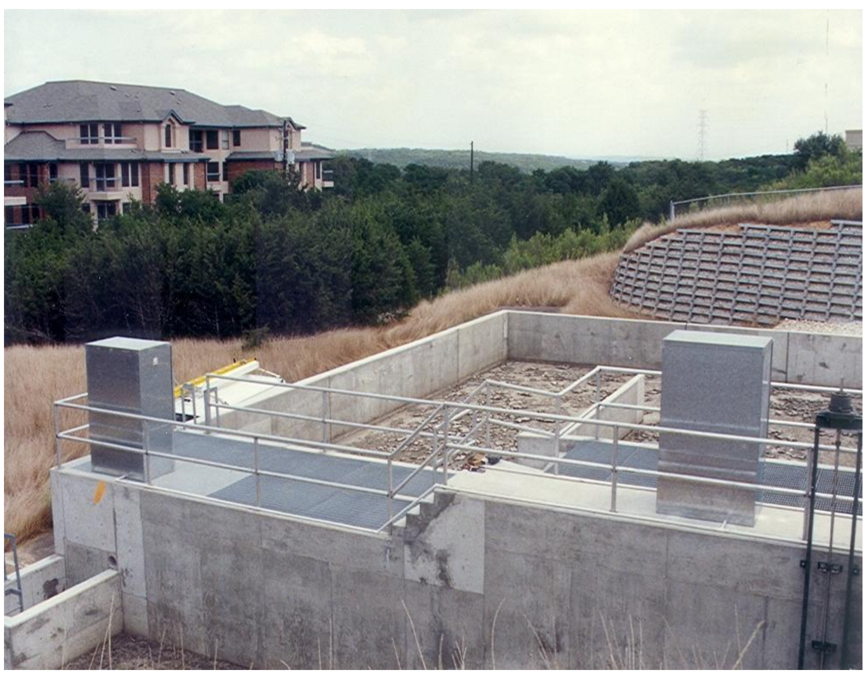
This site was monitored from 1993 until 2002. The Barton Ridge Plaza pond is a water quality control structure on an impervious surface through the use of sedimentation and filtration. This station includes treatment of 3.04 acres of high impervious cover (80%) commercial land. High velocities of incoming flow had to be slowed for accurate measurement in the influent which was measured with a 3 foot H flume. Flow from sedimentation to filtration was regulated by a 12 inch perforated riser pipe and valve. The valve was manually operated by staff to prevent the sand filtration pond from overflowing. A 120 degree V-notch weir was installed to measure effluent flow.

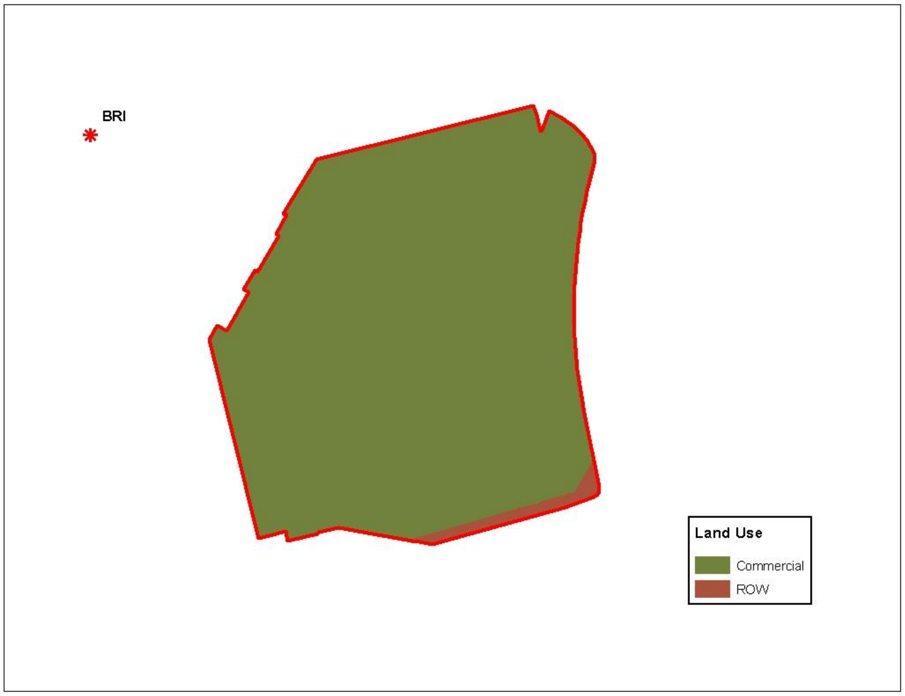
Site Summary

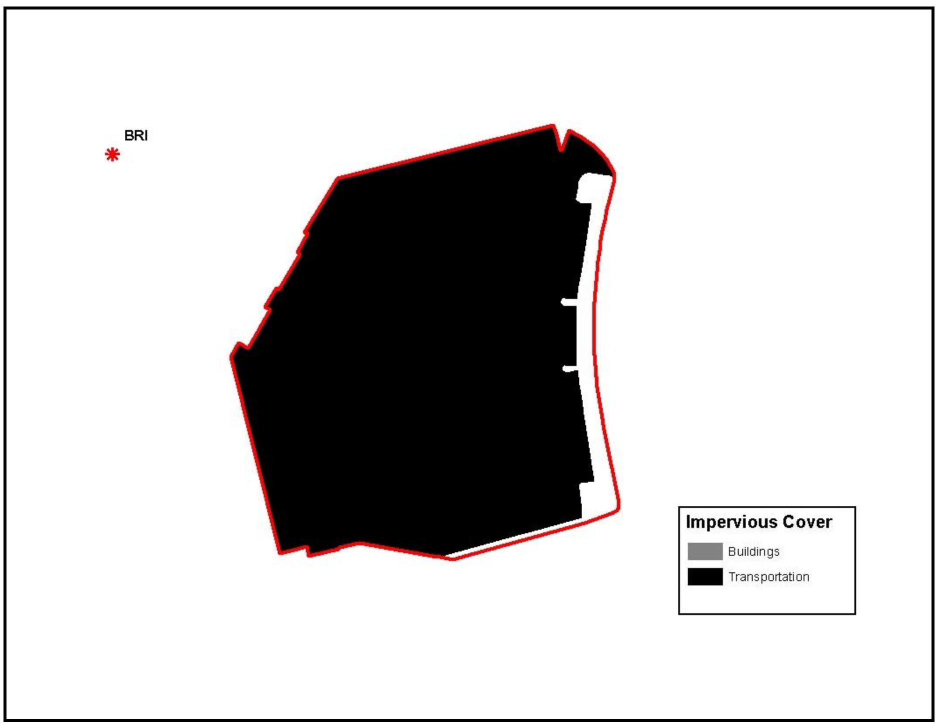
Site ID	BRI	
Site Name	Barton Ridge Plaza Influent	
Latitude	30.2340	N
Longitude	97.8025	W
Predominate Land Use	Commercial	
Drainage Area	3.04	Acres
Impervious Cover	0.8032	
Runoff-Rainfall Ratio	0.758	
Runoff-Rainfall Events	419	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	240.5	mg/L	27
VSS	38.1	mg/L	23
NO_2+NO_3	0.574	mg/L	24
NH_3	0.253	mg/L	24
TKN	1.767	mg/L	24
TN	2.341	mg/L	24
DP	0.133	mg/L	20
TP	0.348	mg/L	24
BOD	9.06	mg/L	24
COD	70.64	mg/L	24
TOC	8.00	mg/L	19
Cadmium	0.551	µg/L	14
Copper	6.660	µg/L	14
Lead	11.14	µg/L	14
Zinc	58.69	µg/L	15
F. Coliform	29,313	cfu/100m	19
F. Strep.	7,687	cfu/100m	19


BRI
LAMAR BLVD
LAMAR
WESTGATE
BEN WHITE




BRI
Land Use
Commercial
ROW


BRI
Impervious Cover
Buildings
Transportation

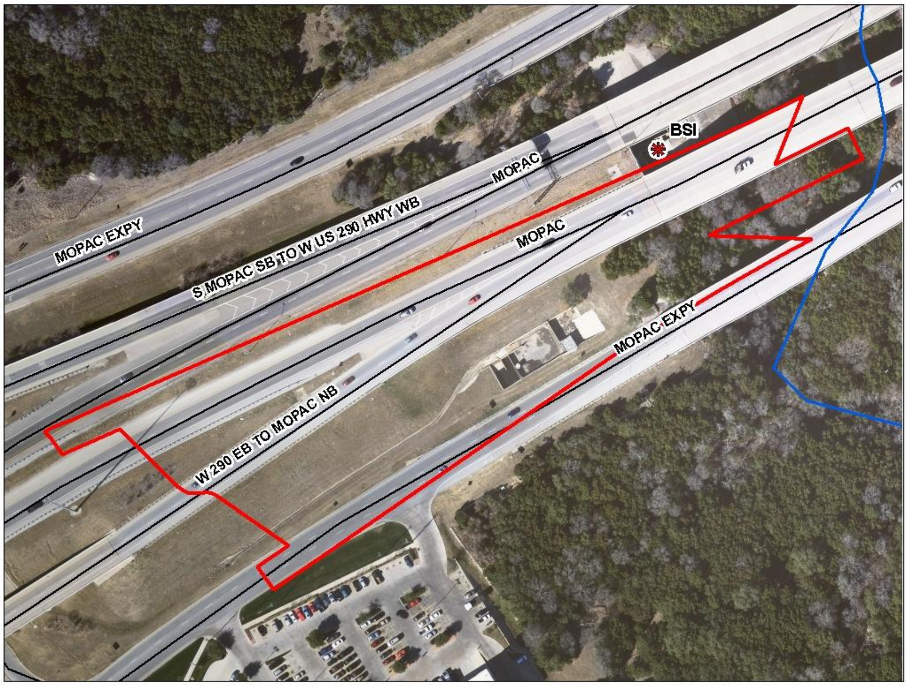
Highway BMP # 5 (BSI)

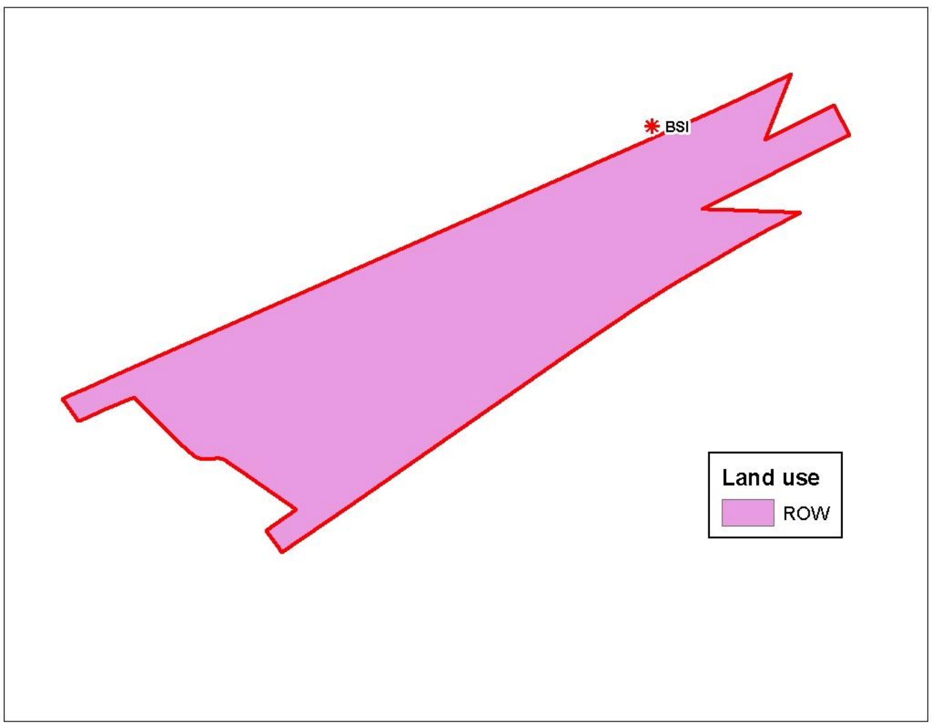
This monitoring site was established as part of a joint effort between Barton Springs Edwards Aquifer Conservation District, Lower Colorado River Authority, Texas Department of Transportation and the City of Austin to evaluate water quality controls on major roadways. The site was located on the south side of Gaines Creek at Loop 1 or MoPac and was monitored from 1994 through 1997. The total drainage area was 4.63 acres with 64% impervious cover in transportation land use. This monitoring site is in the Barton Springs recharge zone. Flow was measured using a 90° V-notch weir.

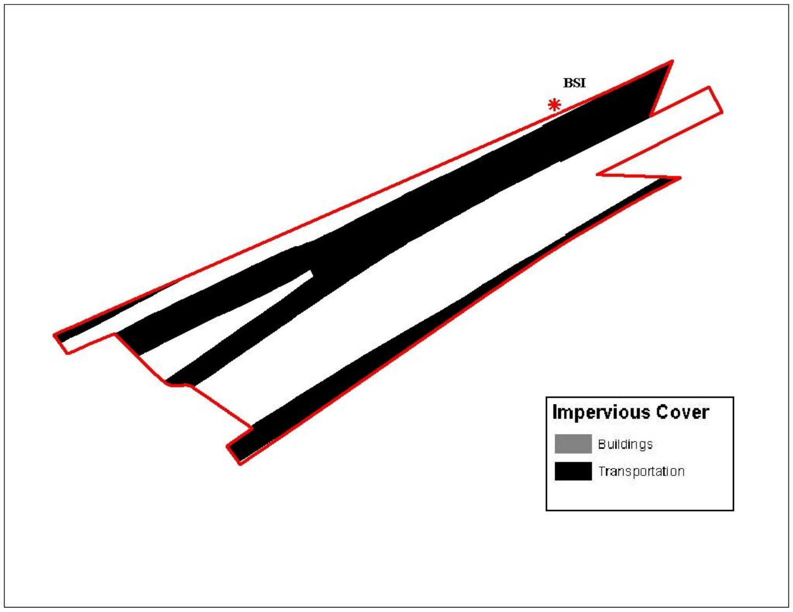
Site Summary

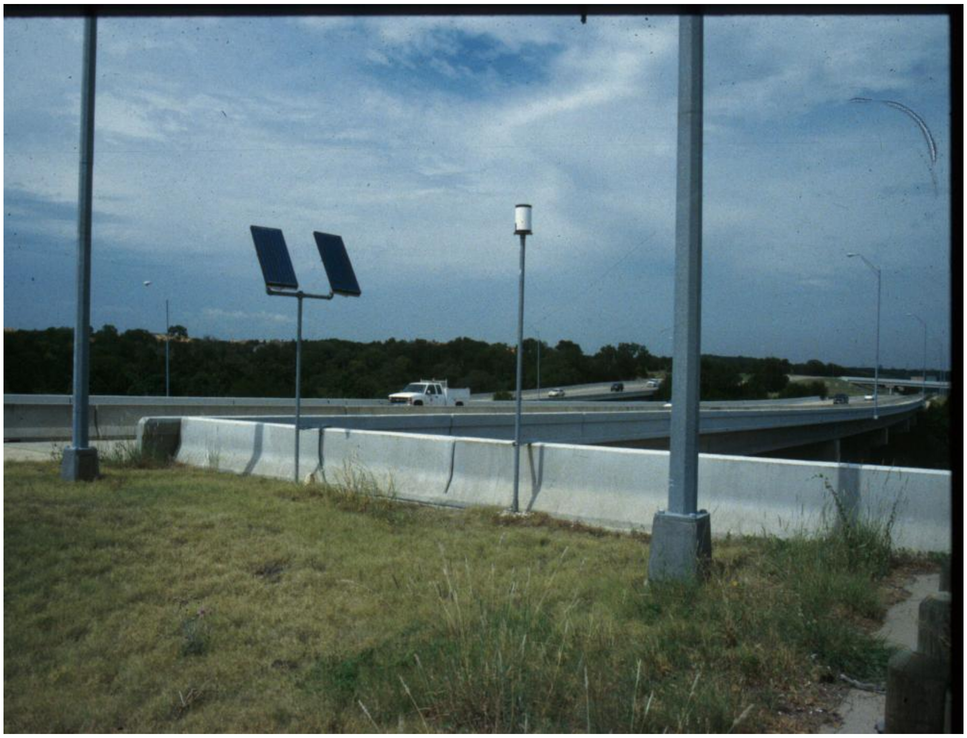
Site ID	BSI	
Site Name	Highway BMP #5 Influent	
Latitude	30.2386	N
Longitude	97.8199	W
Predominate Land Use	Transportation	
Drainage Area	4.63	Acres
Impervious Cover	0.642	
Runoff-Rainfall Ratio	0.716	
Runoff-Rainfall Events	125	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	86.2	mg/L	10
VSS	12.8	mg/L	2
NO_2+NO_3	0.335	mg/L	6
NH_3	0.118	mg/L	2
TKN	0.703	mg/L	7
TN	1.098	mg/L	6
DP	0.055	mg/L	7
TP	0.161	mg/L	7
BOD	2.50	mg/L	2
COD	54.61	mg/L	10
TOC	6.35	mg/L	10
Cadmium	0.508	µg/L	2
Copper	6.057	µg/L	2
Lead	16.32	µg/L	6
Zinc	111.94	µg/L	12
F. Coliform	3,213	cfu/100m	3
F. Strep.	8,050	cfu/100m	3


BSI
MOPAC
MOPAC EXPY
S MOPAC SB TO W US 290 HWY WB
MOPAC
W 290 EB TO MOPAC NB
MOPAC EXPY


BSI
Land use
ROW


BSI
Impervious Cover
Buildings
Transportation



Burton Site (BUA)

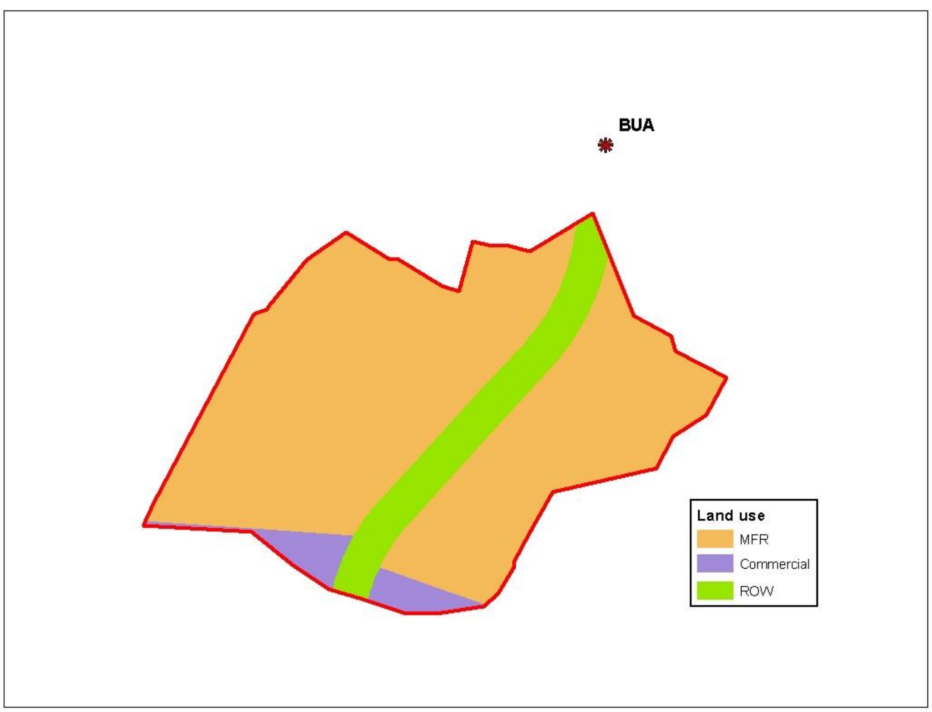
The Burton site was located on Burton Road between Oltorf Street and Mariposa Drive and was monitored between 1992 and 1996. The 11.59 acres watershed has 82% impervious cover and is predominantly a multi-family residential land use. Sensors were placed in 30 inch storm sewer but it was determined that the velocities in the pipe were too great for accurate flow measurements. Various attempts were made to reduce the velocities by placing baffles in the pipe or pouring concrete in the bottom of the pipe to reduce the slope. None of these were completely successful so the flow data were not used for runoff-rainfall analyses

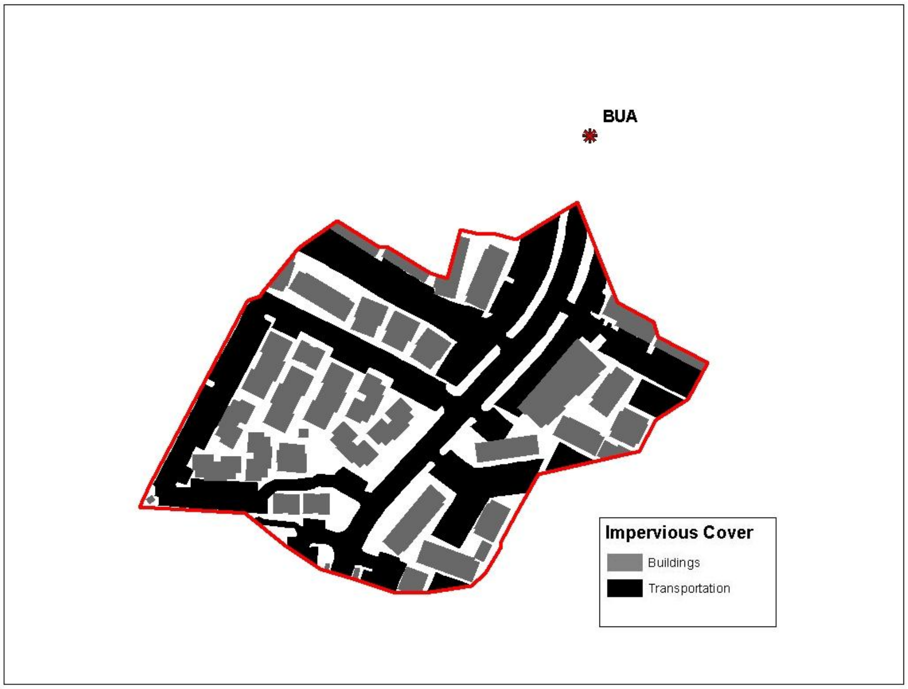
Site Summary

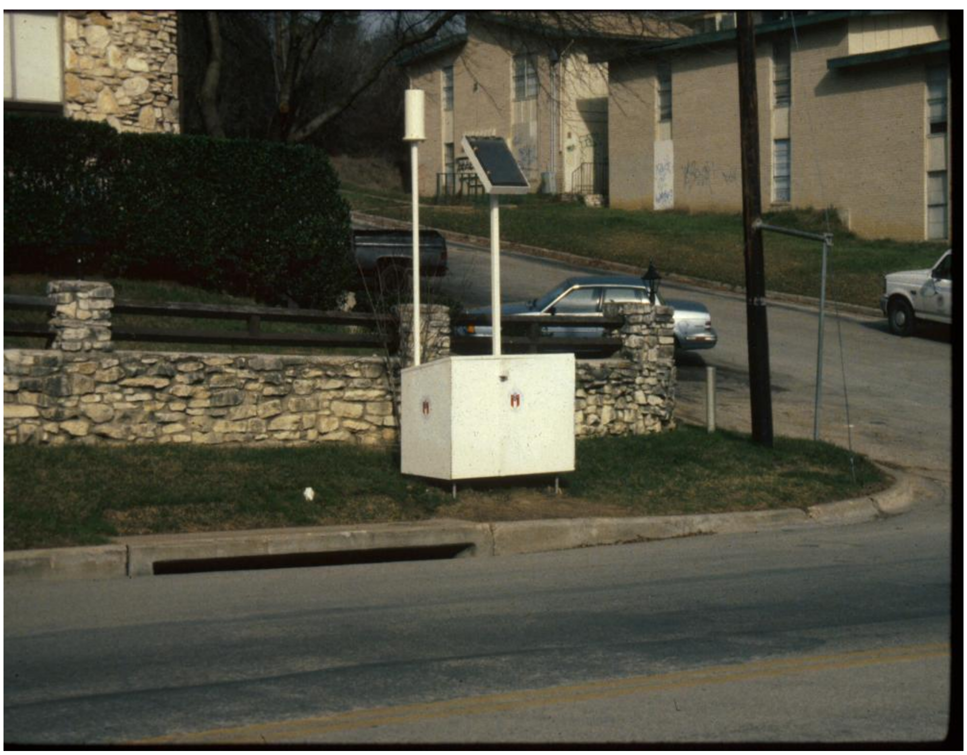
Site ID	BUA	
Site Name	Burton Road	
Latitude	30.2336	N
Longitude	97.7320	W
Predominate Land Use	Multi-Family	
Drainage Area	11.59 Acres	
Impervious Cover	0.82	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	290.8	mg/L	21
VSS	57.6	mg/L	16
NO_2+NO_3	1.090	mg/L	20
NH_3	0.297	mg/L	16
TKN	2.630	mg/L	21
TN	3.593	mg/L	19
DP	0.318	mg/L	18
TP	0.656	mg/L	21
BOD	22.01	mg/L	20
COD	142.93	mg/L	21
TOC	14.97	mg/L	15
Cadmium	1.175	µg/L	11
Copper	26.137	µg/L	13
Lead	28.77	µg/L	13
Zinc	114.17	µg/L	14
F. Coliform	53,894	cfu/100m	15
F. Strep.	59,559	cfu/100m	16


MARIPOSA
BUA
BURTON
OLTORF


BUA
Land use
MFR
Commercial
ROW


BUA
Impervious Cover
Buildings
Transportation



Central Market Wet Pond Influent (CMI)

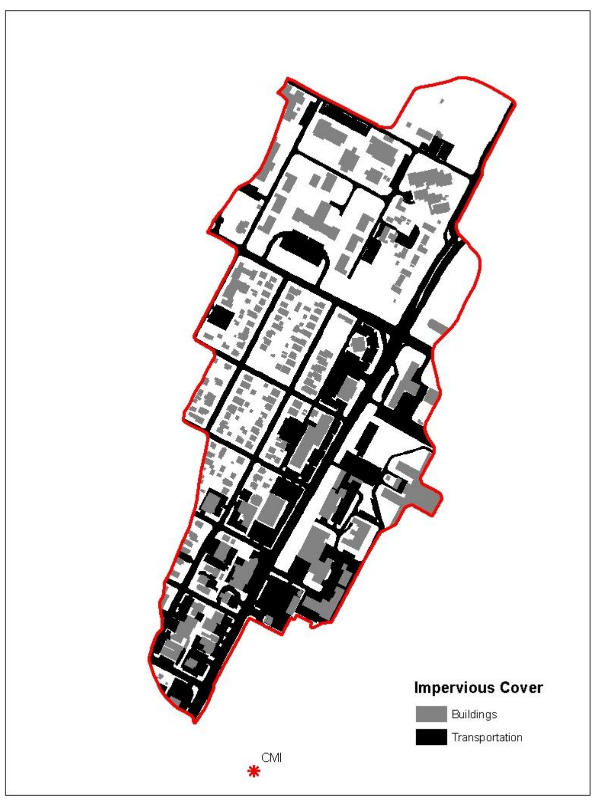
This monitoring site was located near 38th Street and Lamar Boulevard, and was the influent to the Central Park wet pond. The 100.03 acres watershed had 55% impervious cover and the land use was mixed urban. This station was monitored from 1996-2002. Flow was measured in a 42 in. storm sewer using Manning's Eqn. The pond had three main influent pipes, right pipe was from the building rooftops and the loading area, the center pipe was from customer parking and the left pipe was from the upstream neighborhood. Only the left influent pipe was monitored.

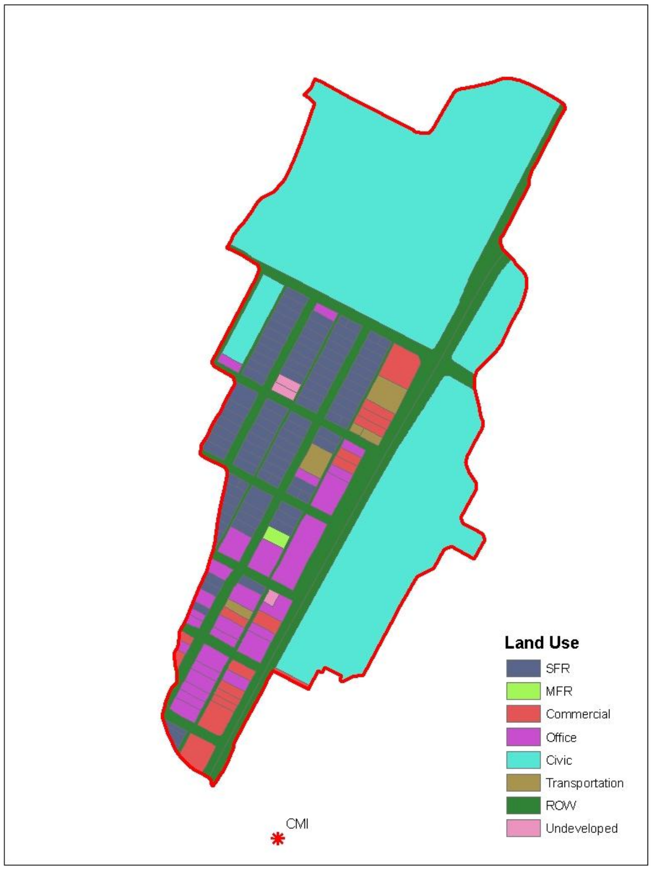
Site Summary

Site ID	CMI	
Site Name	Central Market Influent	
Latitude	30.3065	N
Longitude	97.7405	W
Predominate Land Use	Mixed Urban	
Drainage Area	100.03 Acres	
Impervious Cover	0.5468	
Runoff-Rainfall Ratio	0.302	
Runoff-Rainfall Events	291	
Recharge Zone	No	

Parameter	Mean EMC	Units	Count
TSS	210.5	mg/L	24
VSS	62.2	mg/L	15
NO_2+NO_3	0.626	mg/L	24
NH_3	0.516	mg/L	22
TKN	2.282	mg/L	24
TN	2.904	mg/L	24
DP	0.238	mg/L	16
TP	0.619	mg/L	16
BOD	19.98	mg/L	11
COD	86.24	mg/L	24
TOC	16.84	mg/L	21
Cadmium	0.547	µg/L	24
Copper	20.466	µg/L	24
Lead	32.97	µg/L	24
Zinc	162.69	µg/L	24
F. Coliform	109,759	cfu/100m	9
F. Strep.	79,035	cfu/100m	10


CMI


Impervious Cover
Buildings
Transportation
CMI


Land Use
SFR
MFR
Commercial
Office
Civic
Transportation
ROW
Undeveloped
CMI

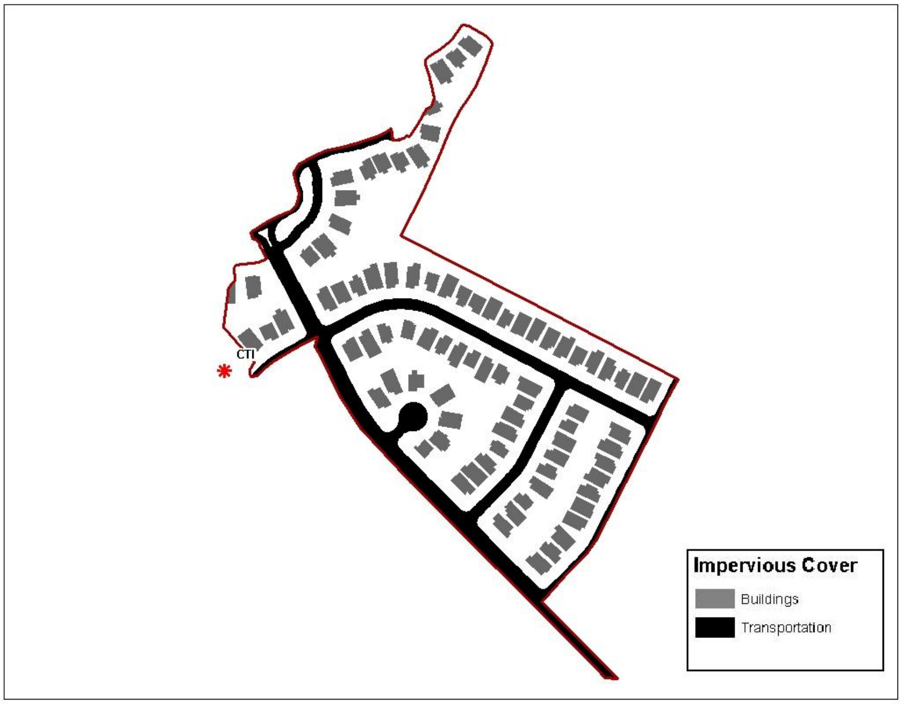
Ceylon Tea (CTI)

This station is located at 13815 ½ Ceylon Tea Circle and was operational from 2005 through 2007. Total drainage area to the monitoring site is 17.89 acres with an impervious cover of 39%. The primary land use is single-family residential. This station is one of three influents for a wet pond, the others being CTJ and CTK. Manning equation was used to calculate runoff. During large storm events water from the wet pond would back up into the pipe and would make data from those events unusable.

Site Summary

Site ID	CTI	
Site Name	Ceylon Tea Influent East	
Latitude	30.4184	N
Longitude	97.6396	W
Predominate Land Use	Single-Family	
Drainage Area	17.89	Acres
Impervious Cover	0.3885	
Runoff-Rainfall Ratio	0.66	
Runoff-Rainfall Events	148	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	129.7	mg/L	17
VSS	16.5	mg/L	17
NO_2+NO_3	0.569	mg/L	17
NH_3	0.253	mg/L	17
TKN	1.048	mg/L	17
TN	1.616	mg/L	17
DP	0.131	mg/L	17
TP	0.286	mg/L	17
COD	56.83	mg/L	17
TOC	11.50	mg/L	17
Cadmium	0.168	µg/L	15
Copper	6.329	µg/L	17
Lead	3.47	µg/L	17
Zinc	41.99	µg/L	17


CTI
Impervious Cover
Buildings
Transportation


CTI
Land Use
SFR
ROW
Undeveloped


DARJEELING
JASMINE TEA
OCHA
ENGLISH ROSE
BRUNO
OOLONG
HONEY BLOSSOM
BATTENBURG
VANILLA BEAN
TUDOR HOUSE
SWEET LEAF
CTI
NESTLE
TEACUP
HARCOURT HOUSE
SLEEPYTIME
ALDERMINSTER
CEYLON TEA
LEMONGRASS

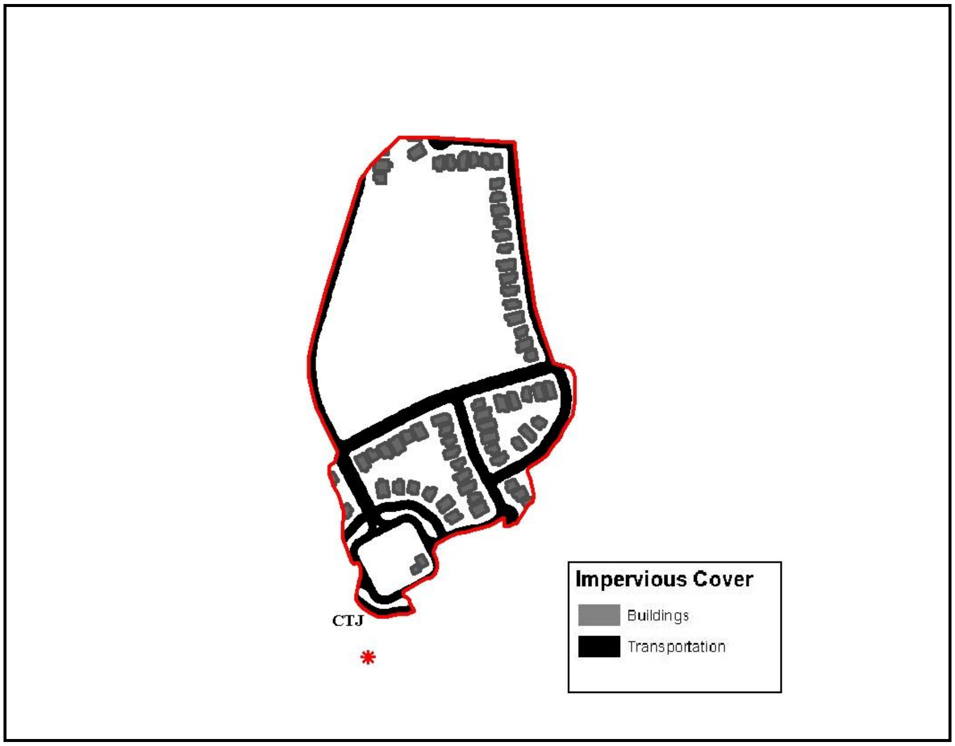
Ceylon Tea (CTJ)

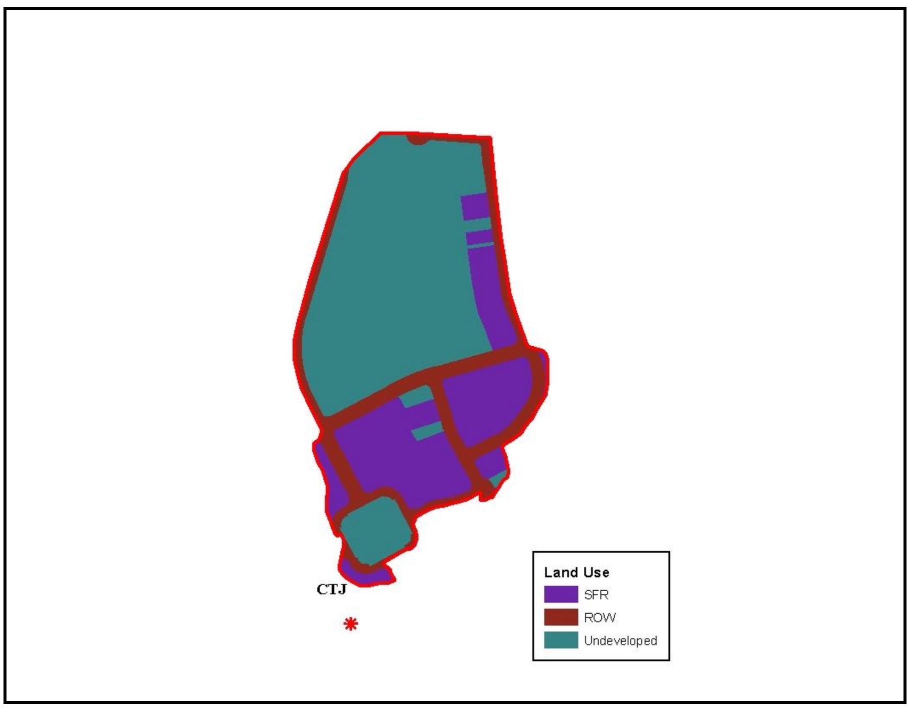
This station is located directly behind 1105 Tudor House Road and was operational from 2005 thru 2007. Total drainage area for the watershed is 28.99 acres with an impervious cover of 29%; the primary land use is single family residential. This station is one of three influents for a wet pond, the others being CTI and CTK. Manning's eqn. was used to calculate flow. A large portion of this watershed was undeveloped at the time of monitoring, a future school site.

Site Summary

Site ID	CTJ	
Site Name	Ceylon Tea Influent North	
Latitude	30.4188	N
Longitude	97.6398	W
Predominate Land Use	Single-Family	
Drainage Area	28.99	Acres
Impervious Cover	0.2899	
Runoff-Rainfall Ratio	0.374	
Runoff-Rainfall Events	156	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	489.1	mg/L	24
VSS	34.7	mg/L	24
NO_2+NO_3	0.568	mg/L	24
NH_3	0.274	mg/L	24
TKN	1.425	mg/L	24
TN	1.992	mg/L	24
DP	0.123	mg/L	24
TP	0.404	mg/L	24
COD	87.07	mg/L	24
TOC	11.62	mg/L	24
Cadmium	0.358	µg/L	17
Copper	9.621	µg/L	24
Lead	7.74	µg/L	24
Zinc	63.52	µg/L	24


CTJ
Impervious Cover
Buildings
Transportation


CTJ
Land Use
SFR
ROW
Undeveloped


EARL GREY
ORANGE SPICE
ST CROIX
LADY GREY
MANDARIN
GREY CASTLE
DARJEELING
HYSON
TUDOR HOUSE
TEAPOT
GINSENG
SWEET LEAF
FALLING STONE
MORNING MIST
EVENING MIST
TEA LEAF
ORANGE PEKOE
OCHA
JASMINE TEA
ENGLISH ROSE
HARCOURT HOUSE
HONEY BLOSSOM
OOLONG
BRUNO
BATTENBURG
CTJ
VANILLA BEAN
CEYLON TEA
SLEEPYTIME


17 11:45AM

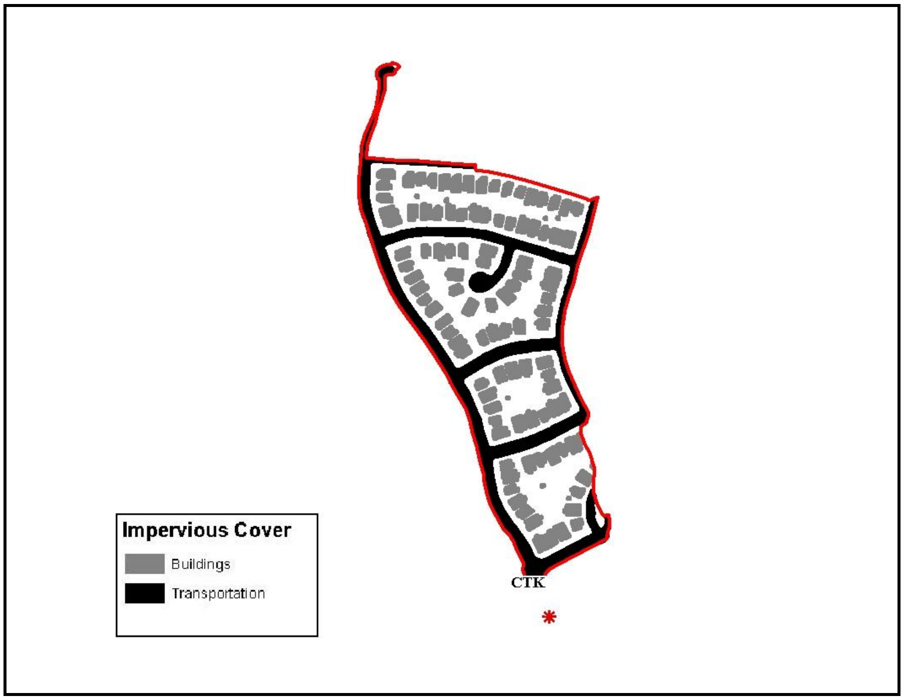
Ceylon Tea (CTK)

This station was located directly behind 1201 Battenburg Trail and was operational from 2005 through 2007. Total drainage area for the monitoring site is 23.82 acres with an impervious cover of 39%. The primary land use is single-family residential. This station is one of three influents for a wet pond, the others being CTI and CTJ. Manning's eqn. was used to calculate flow. Construction was taking place during the monitoring period but was completed before monitoring at the site was finished.

Site Summary

Site ID	CTK	
Site Name	Ceylon Tea Influent W	
Latitude	30.4186	N
Longitude	97.6407	W
Predominate Land Use	Single-Family	
Drainage Area	23.82	Acres
Impervious Cover	0.3917	
Runoff-Rainfall Ratio	0.569	
Runoff-Rainfall Events	154	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	135.3	mg/L	22
VSS	16.0	mg/L	22
NO_2+NO_3	0.659	mg/L	22
NH_3	0.266	mg/L	22
TKN	1.034	mg/L	22
TN	1.702	mg/L	22
DP	0.129	mg/L	22
TP	0.247	mg/L	22
COD	48.37	mg/L	22
TOC	9.42	mg/L	22
Cadmium	0.289	µg/L	16
Copper	6.399	µg/L	22
Lead	4.21	µg/L	22
Zinc	29.70	µg/L	22


Impervious Cover
Buildings
Transportation
CTK


Land Use
SFR
ROW
CTK


SALLY LUNN
EARL GREY
GREY CASTLE
TEAPOT
GINSENG
TUDOR HOUSE
BATTENBURG
ORANGE PEKOE
EMILY DICKENSON
CHARLES DICKENS
SEBASTIAN
JANE AUSTEN
HARRIS RIDGE
MERSEYSIDE
CTK
MANDARIN
HYSON
CORONATION
GINGER SPICE
ORANGE SPICE
LADY GREY
DARJEELING
TEA LEAF
SWEET LEAF
JASMINE TEA
OCHA
ENGLISH ROSE
OOLONG
CEYLON TEA
NESTLE
TEACUP
SLEEPYTIME

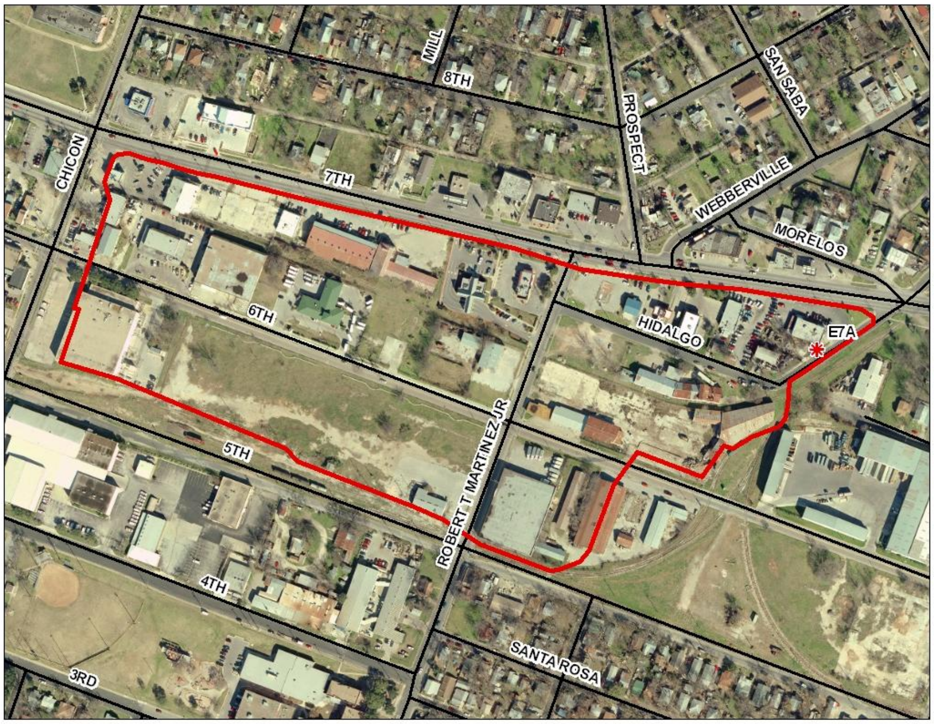
7th Street (E7A)

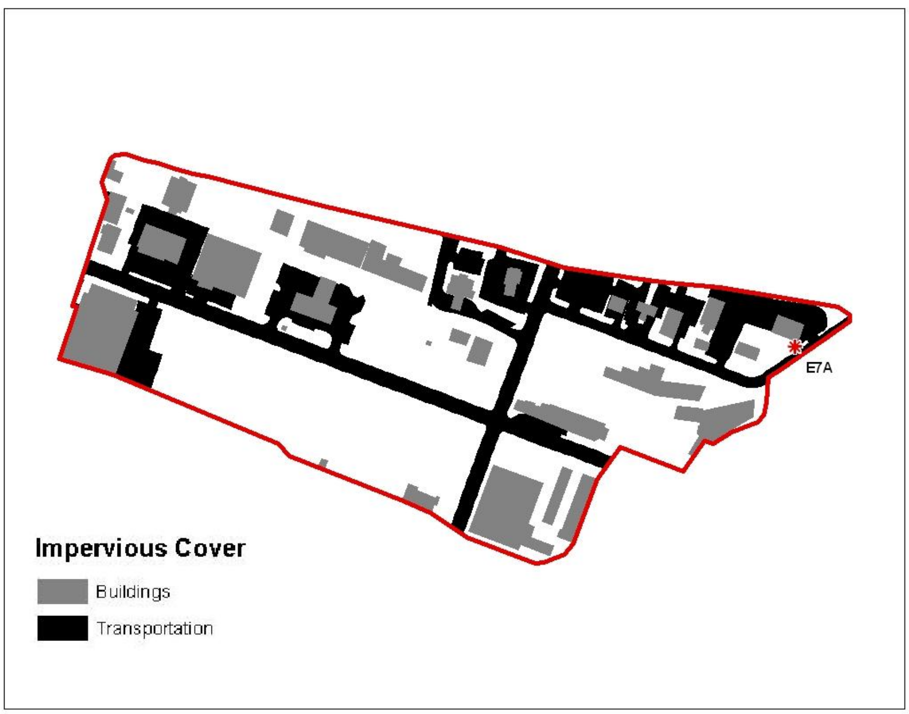
This monitoring station was established in 1995 and operated until1999. The station was located at Northwestern Ave. and 7th Street and operated between 1995 and 1999. The 29.3 acre drainage area has 60% impervious cover and was primarily industrial land use at the time of monitoring. Flow was measured in a 48 inch storm sewer using Manning's equation.

Site Summary

Site ID	E7A	
Site Name	East Austin at East 7th	
Latitude	30.2608	N
Longitude	97.7160	W
Predominate Land Use	Industrial	
Drainage Area	29.28	Acres
Impervious Cover	0.6007	
Runoff-Rainfall Ratio	0.38	
Runoff-Rainfall Events	258	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	181.8	mg/L	26
VSS	30.7	mg/L	26
NO_2+NO_3	0.767	mg/L	26
NH_3	0.236	mg/L	26
TKN	1.256	mg/L	26
TN	2.021	mg/L	26
DP	0.192	mg/L	25
TP	0.698	mg/L	25
BOD	8.05	mg/L	25
COD	77.50	mg/L	26
TOC	8.67	mg/L	25
Cadmium	0.726	µg/L	26
Copper	19.750	µg/L	26
Lead	51.73	µg/L	26
Zinc	235.17	µg/L	26
F. Coliform	84,823	cfu/100m	24
F. Strep.	128,270	cfu/100m	24


MILL
8TH
SAN SABA
PROSPECT
CHICON
7TH
WEBBERVILLE
MORELOS
HIDALGO
E7A
6TH
5TH
ROBERT T MARTINEZ JR
4TH
SANTA ROSA
3RD


E7A
Impervious Cover
Buildings
Transportation


E7A
Land Use
Commercial
Office
Industrial
Civic
Transportation
ROW
Undeveloped


PAWN

Belfast Street (EBA)

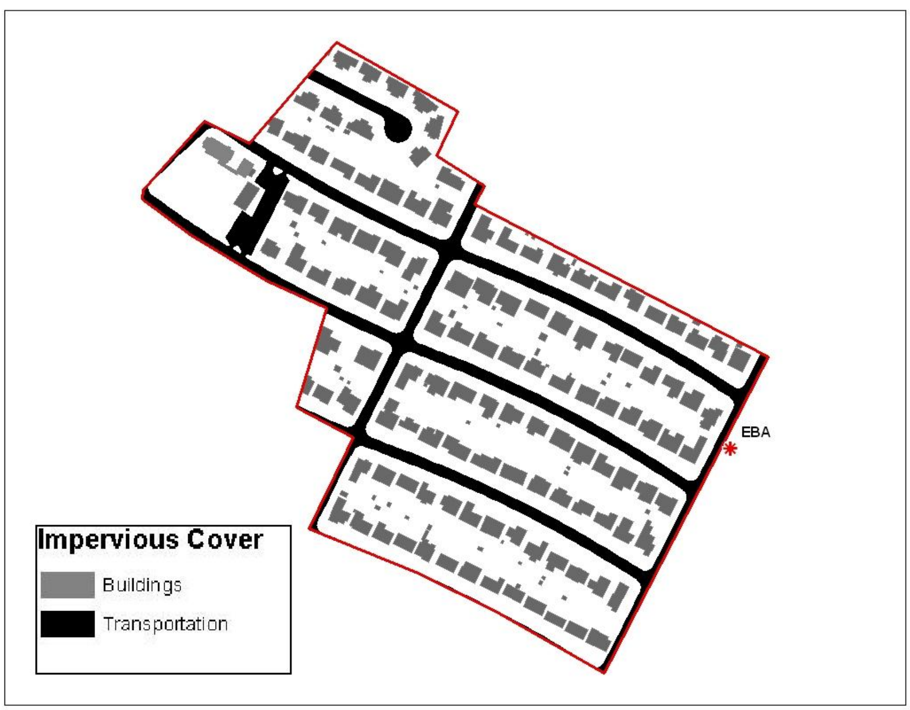
This station was located near the corner of Belfast Drive and Ridgehaven Drive and was operational from 1999 through 2003. The 35.2 acres watershed has an impervious cover of 40% with single-family residential being the primary land use. It was determined during monitoring that the velocities were too high for bubbler meters to operate properly so a weir was installed in the storm sewer and an area-velocity meter was used to develop a stage discharge relationship.

Site Summary

Site ID	EBA	
Site Name	East Austin at Belfast	
Latitude	30.3130	N
Longitude	97.6967	W
Predominate Land Use	Single-Family	
Drainage Area	35.24	Acres
Impervious Cover	0.4036	
Runoff-Rainfall Ratio	0.105	
Runoff-Rainfall Events	230	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	85.1	mg/L	37
VSS	38.5	mg/L	37
NO_2+NO_3	0.595	mg/L	37
NH_3	0.331	mg/L	37
TKN	2.709	mg/L	37
TN	3.292	mg/L	37
DP	0.271	mg/L	37
TP	0.601	mg/L	37
BOD	15.20	mg/L	23
COD	88.82	mg/L	37
TOC	19.69	mg/L	37
Cadmium	0.506	µg/L	35
Copper	6.512	µg/L	35
Lead	12.02	µg/L	35
Zinc	56.70	µg/L	35
F. Coliform	102,561	cfu/100m	19
F. Strep.	188,829	cfu/100m	20


REINLI
CAMERON
DANBURY
BRIARCLIFF
YORKSHIRE
BRAES RIDGE
NORTHRIDGE
BELFAST
NASSAU
EBA
RIDGEHAVEN
LARKWOOD
RIDGEMONT
CLOVERLEAF
CORONA


EBA
Impervious Cover
Buildings
Transportation


EBA
Land Use
SFR
Civic
ROW

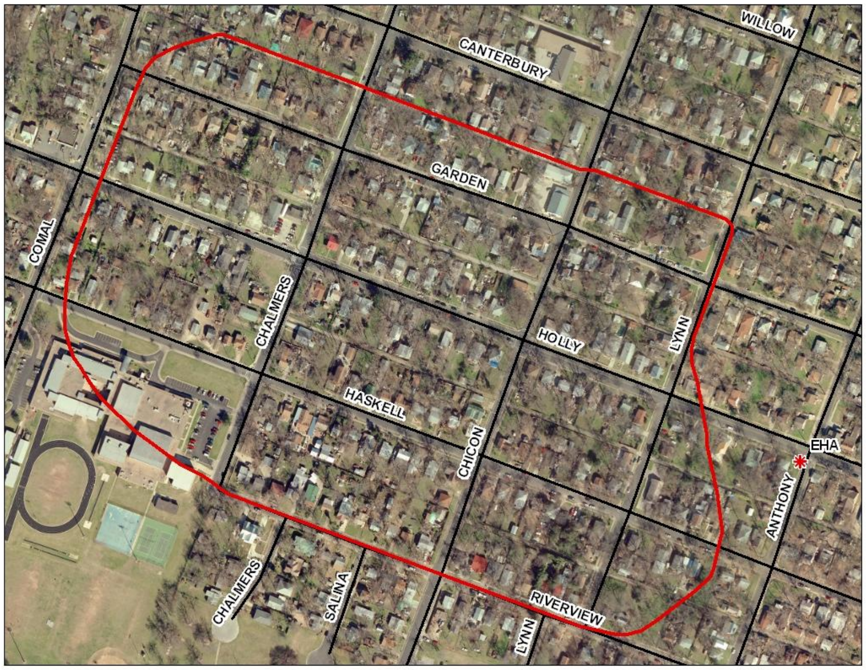
Holly and Anthony Street (EHA)

This monitoring station was located at the intersection of Holly & Anthony Street and was active between 1994 and 2003. The 51.34 acre watershed has 43% impervious cover and is primarily single-family residential. Monitoring at the site is conducted in the 54-inch diameter storm sewer pipe underneath Holly Street. Large amounts of sediment were noted in the storm sewer during monitoring. Sediment depths of up to 7 inches in sections of the pipe upstream from one depth sensor created difficulties in measuring flow and collecting water quality samples.

Site Summary

Site ID	EHA	
Site Name	Holly & Anthony	
Latitude	30.2525	N
Longitude	97.7238	W
Predominate Land Use	Single-Family	
Drainage Area	51.34	Acres
Impervious Cover	0.4342	
Runoff-Rainfall Ratio	0.416	
Runoff-Rainfall Events	449	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	291.2	mg/L	37
VSS	77.3	mg/L	37
NO_2+NO_3	0.744	mg/L	36
NH_3	0.380	mg/L	36
TKN	3.987	mg/L	36
TN	4.701	mg/L	35
DP	0.349	mg/L	36
TP	1.476	mg/L	37
BOD	29.66	mg/L	36
COD	150.45	mg/L	37
TOC	25.49	mg/L	37
Cadmium	0.701	µg/L	34
Copper	15.461	µg/L	34
Lead	50.88	µg/L	34
Zinc	181.60	µg/L	34
F. Coliform	130,553	cfu/100m	25
F. Strep.	426,878	cfu/100m	30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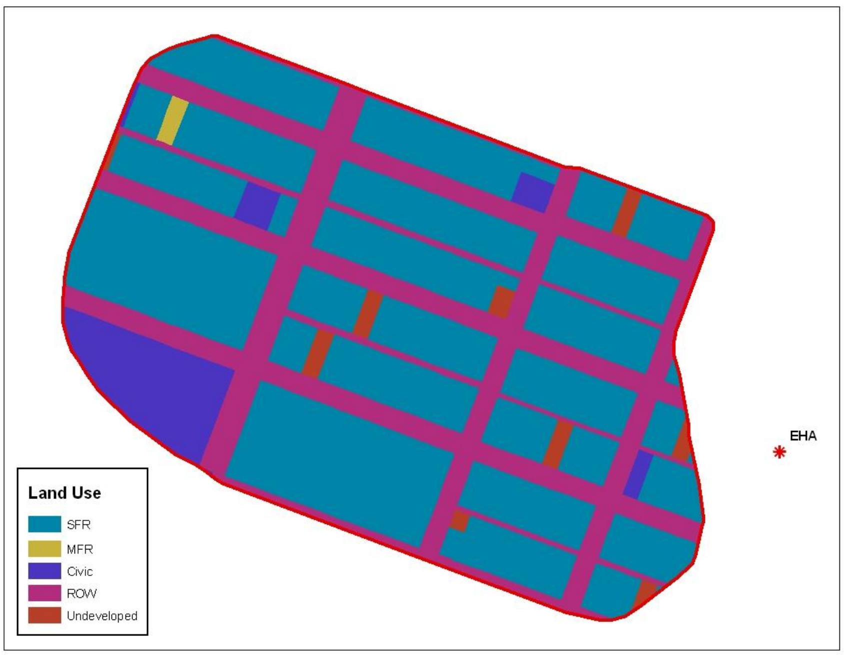
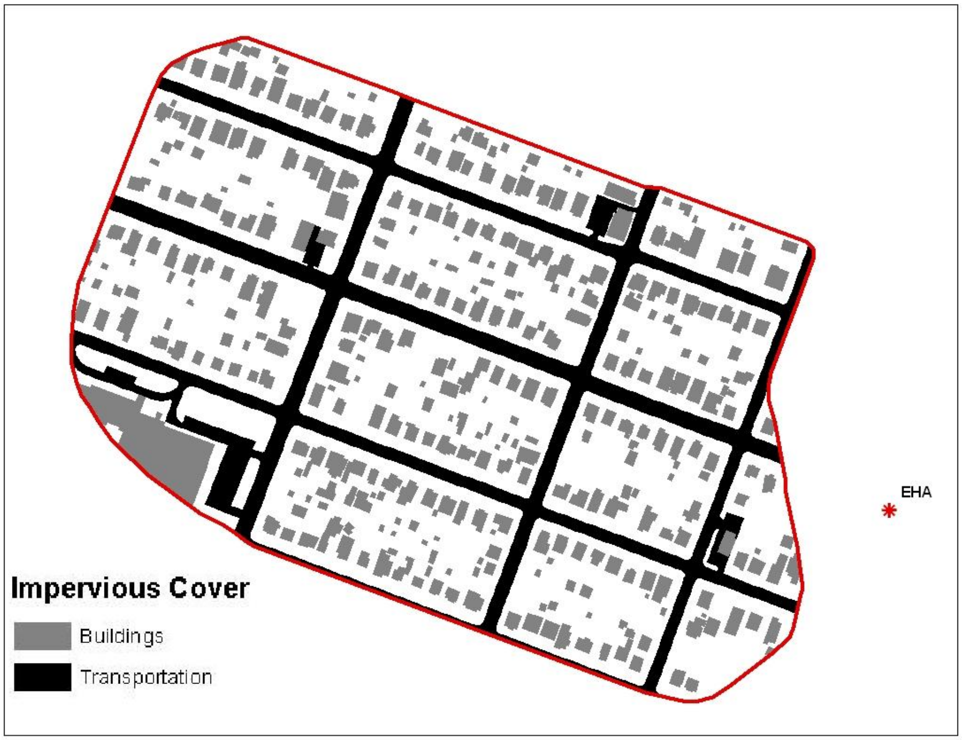
CANTERBURY
GARDEN
COMAL
CHALMERS
HOLLY
LYNN
HASKELL
CHICON
EHA
ANTHONY
CHALMERS
SALINA
RIVERVIEW
LYNN


EHA
Land Use
SFR
MFR
Civic
ROW
Undeveloped


EHA
Impervious Cover
Buildings
Transportation


STOP

Mansell site (EMA)

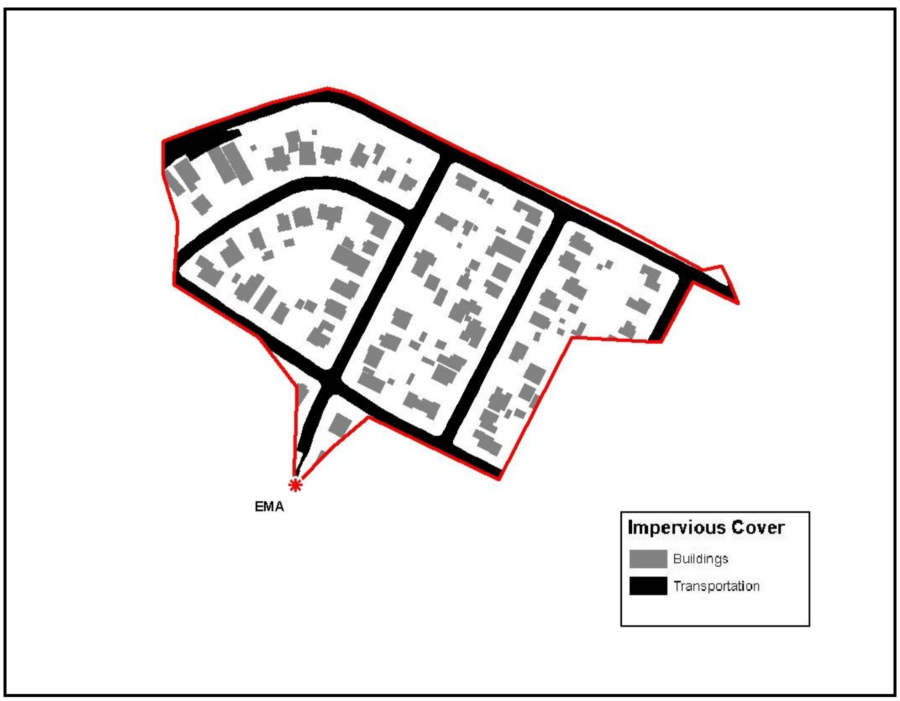
This station was located at the end of Mansell Ave on the north bank of Boggy Creek and was operated between 1999 through 2003. The drainage area was 15.73 acres with 42% being impervious cover. Flow was measured using Manning's equation in a 30 inch storm sewer. This station was installed to collect additional data on runoff from single-family residential areas in East Austin.

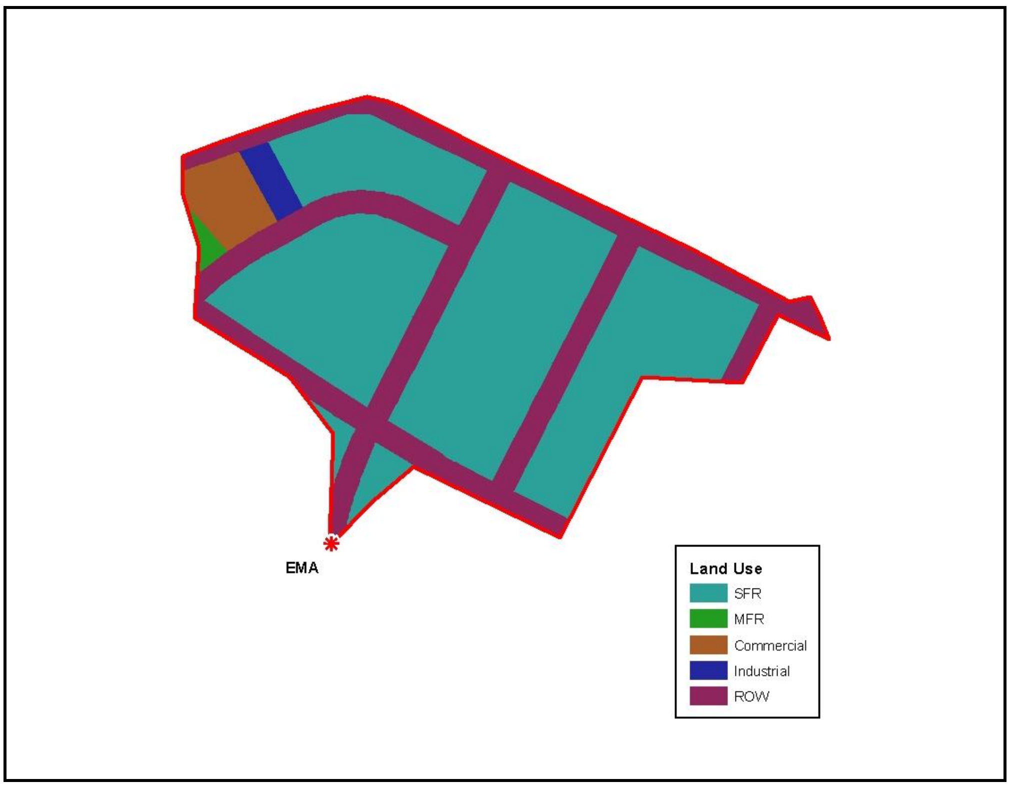
Site Summary

Site ID	EMA	
Site Name	Mansell at Boggy Creek	
Latitude	30.2590	N
Longitude	97.6973	W
Predominate Land Use	Single-Family	
Drainage Area	15.73 Acres	
Impervious Cover	0.4204	
Runoff-Rainfall Ratio	0.503	
Runoff-Rainfall Events	232	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	305.0	mg/L	48
VSS	72.9	mg/L	48
NO_2+NO_3	0.545	mg/L	48
NH_3	0.288	mg/L	48
TKN	3.521	mg/L	47
TN	4.003	mg/L	47
DP	0.351	mg/L	48
TP	0.917	mg/L	48
BOD	92.45	mg/L	27
COD	180.22	mg/L	48
TOC	39.69	mg/L	48
Cadmium	0.563	µg/L	48
Copper	14.551	µg/L	48
Lead	27.24	µg/L	48
Zinc	154.97	µg/L	48
F. Coliform	92,722	cfu/100m	22
F. Strep.	506,729	cfu/100m	25


BOLM
CHOTE
SPRINGDALE
MANSELL
LYONS
CALLE LIMON
GULLETT
AIRPORT
SHADY
EMA
MILBURN
GLISSMAN
MANSELL


EMA
Impervious Cover
Buildings
Transportation


EMA
Land Use
SFR
MFR
Commercial
Industrial
ROW

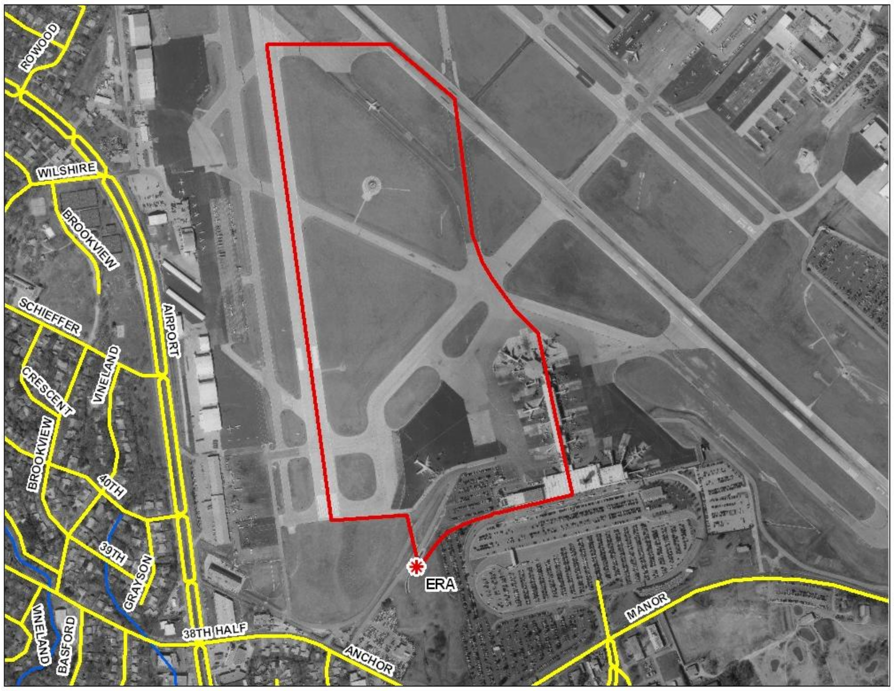
East Austin Robert Muller Municipal Airport (ERA)

This station was located at the former Robert Mueller Airport in the Tannehill Creek watershed and monitored between 1994 and 1999. The drainage area is 99.79 acres with 46% impervious cover. Stormwater is conveyed from the runway into storm sewers into a trapezoidal concrete channel where flow was monitored. A compound v-notch weir was used to measure flow. A large shallow depression in the grassy area of the watershed acts as an unintended detention pond, creating an extended drainage period after rainfall has ceased.

Site Summary

Site ID	ERA	
Site Name	Robert Mueller Airport	
Latitude	30.2905	N
Longitude	97.7026	W
Predominate Land Use	Transportation	
Drainage Area	99.79	Acres
Impervious Cover	0.46	
Runoff-Rainfall Ratio	0.355	
Runoff-Rainfall Events	268	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	54.4	mg/L	21
VSS	17.5	mg/L	21
NO_2+NO_3	0.651	mg/L	20
NH_3	0.199	mg/L	21
TKN	1.415	mg/L	21
TN	2.076	mg/L	20
DP	0.186	mg/L	17
TP	0.633	mg/L	20
BOD	11.45	mg/L	17
COD	80.06	mg/L	21
TOC	12.17	mg/L	20
Cadmium	3.005	µg/L	20
Copper	64.002	µg/L	20
Lead	17.31	µg/L	20
Zinc	105.63	µg/L	20
F. Coliform	32,384	cfu/100m	13
F. Strep.	60,163	cfu/100m	13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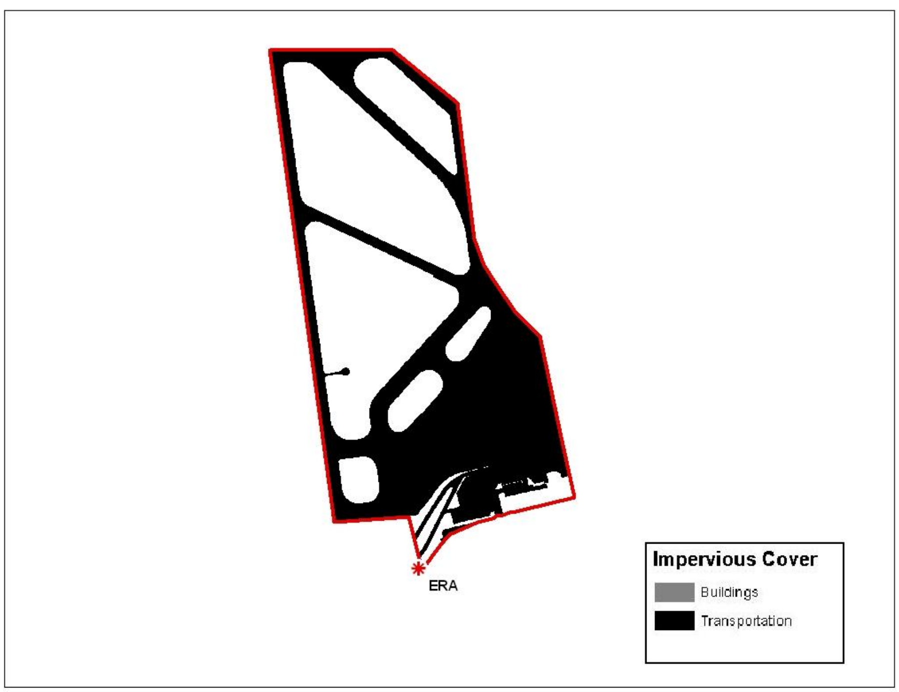
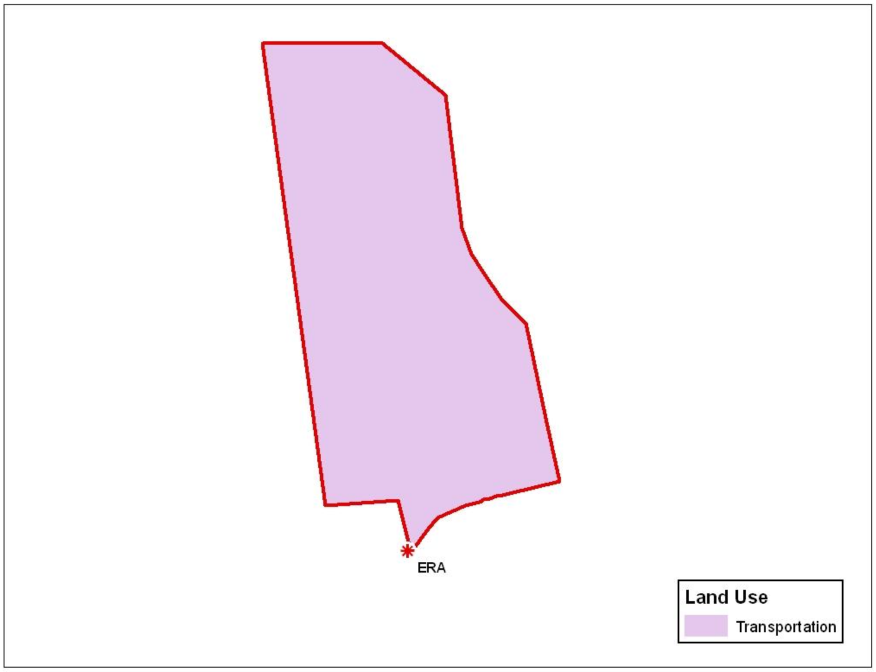
WILSHIRE
BROOKVIEW
SCHIEFFER
AIRPORT
VINELAND
CRESCENT
BROOKVIEW
40TH
39TH
GRAYSON
VINELAND
BASFORD
38TH HALF
ANCHOR
MANOR
ERA


ERA
Impervious Cover
Buildings
Transportation


ERA
Land Use
Transportation

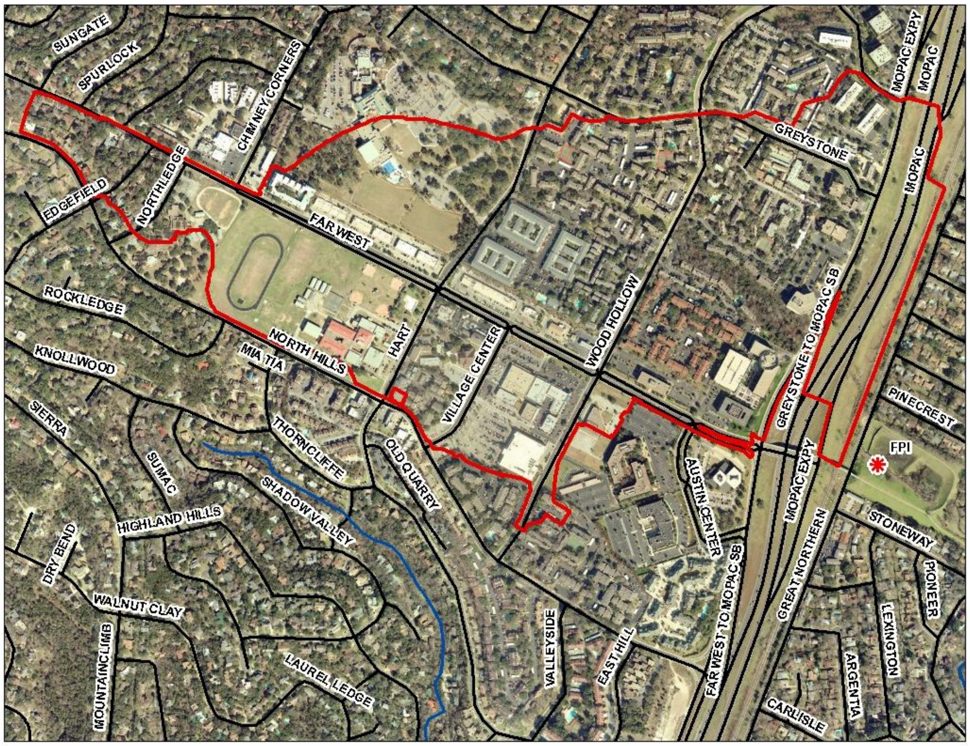
Far West Blvd (FPI)

This station was located at the end of Far West Blvd just east of Loop 1/MoPac and was operational from 1997 through 1999. Total drainage area to the station is 240.01 acres with an impervious cover of 57%. The primary land use was mixed urban. Flow measurements were done using a cutthroat flume. This station is at the influent to a retrofit sedimentation pond/wetland BMP. The flow measurements at this station were not used in runoff-rainfall analyses because runoff would bypass the influent flume and enter the sedimentation basin without being measured.

Site Summary

Site ID	FPI	
Site Name	Far West Pond Influent	
Latitude	30.3515	N
Longitude	97.7470	W
Predominate Land Use	Mixed Urban	
Drainage Area	240.01 Acres	
Impervious Cover	0.5694	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	94.5	mg/L	15
VSS	17.6	mg/L	15
NO_2+NO_3	0.344	mg/L	15
NH_3	0.188	mg/L	15
TKN	0.784	mg/L	15
TN	1.129	mg/L	15
DP	0.083	mg/L	15
TP	0.179	mg/L	15
BOD	6.20	mg/L	15
COD	47.55	mg/L	15
TOC	5.74	mg/L	15
Cadmium	0.504	µg/L	15
Copper	8.018	µg/L	15
Lead	10.66	µg/L	15
Zinc	66.74	µg/L	15
F. Coliform	23,019	cfu/100m	14
F. Strep.	88,320	cfu/100m	15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SPURLOCK
CHIMNEY CORNERS
MOPAC EXPY
MOPAC
GREYSTONE
EDGEFIELD
NORTHLEDGE
FAR WEST
MOPAC
ROCKLEDGE
GREYSTONE TO MOPAC SB
KNOLLWOOD
NORTH HILLS
MIA TIA
HART
VILLAGE CENTER
WOOD HOLLOW
PINECREST
SIERRA
THORNCLIFFE
OLD QUARRY
FPI
SUMAC
MOPAC EXPY
AUSTIN CENTER
SHADOW VALLEY
HIGHLAND HILLS
STONEWAY
DRY BEND
GREAT NORTHERN
PIONEER
WALNUT CLAY
LEXINGTON
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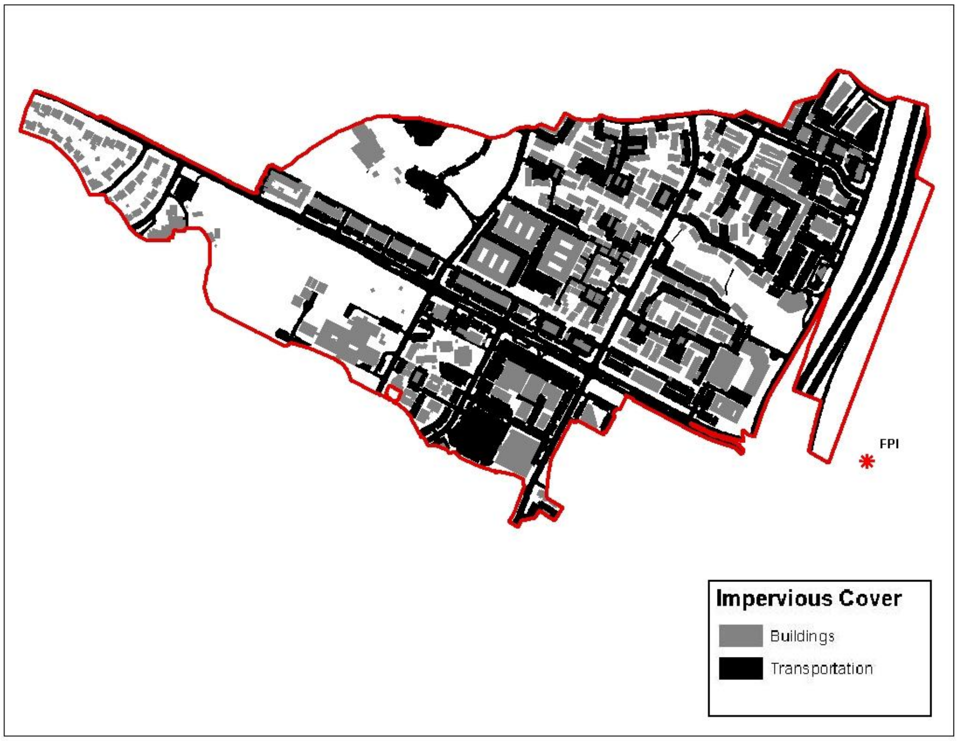
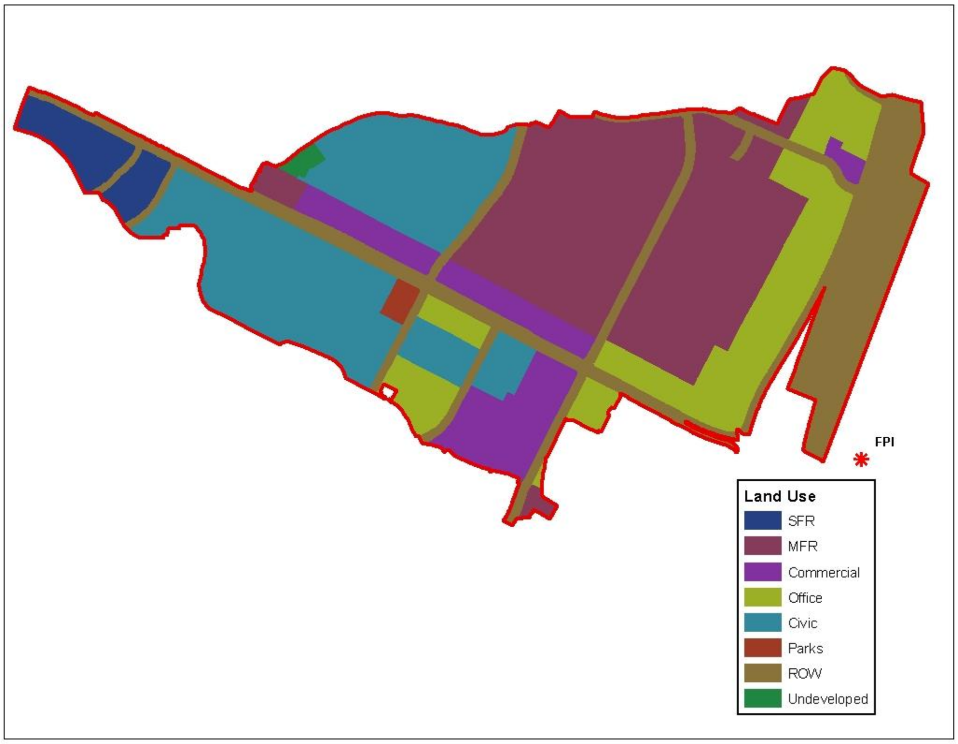
MOUNTAINCLIMB
VALLEYSIDE
EAST HILL
ARGENTIA
LAUREL LEDGE
CARLISLE


FPI
Impervious Cover
Buildings
Transportation


FPI
Land Use
SFR
MFR
Commercial
Office
Civic
Parks
ROW
Undeveloped

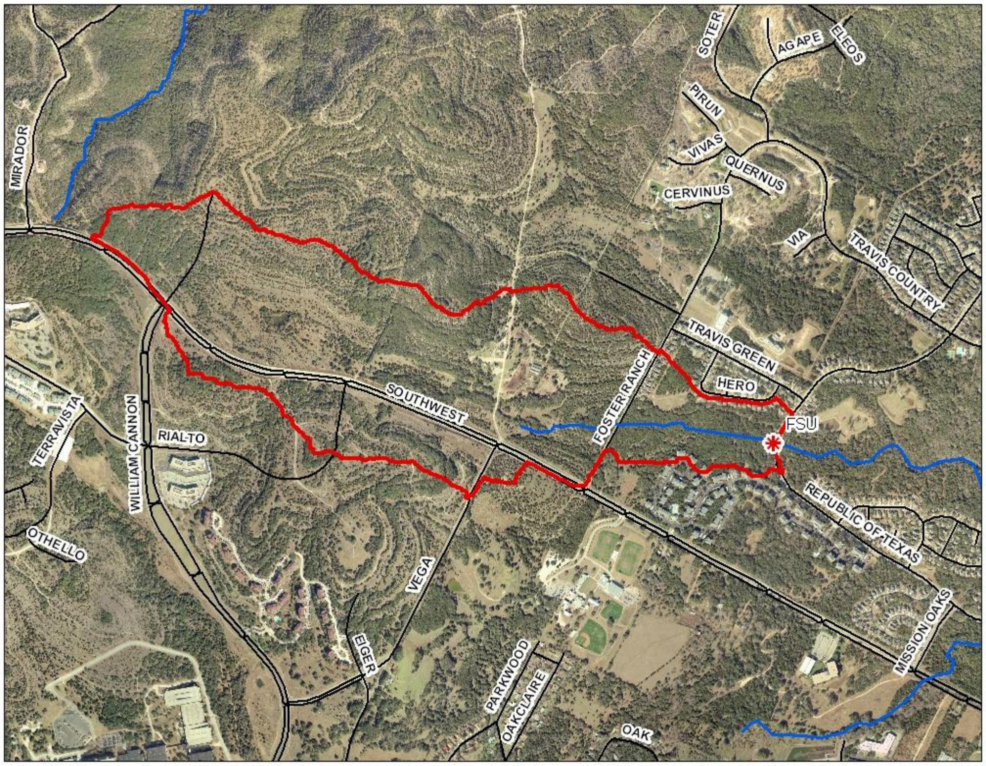
Foster Ranch Site (FSU)

The Foster Ranch station was installed in 1994 and is still in operation. It is located on Sycamore Creek at 4902 Republic of Texas Blvd in Travis Country Subdivision. The 329.75 acre watershed has 6% impervious cover and is mostly undeveloped at this time. The lower portion of the watershed is in the Barton Springs recharge zone. The flow is estimated at this site using stage-discharge relationships based on open channel flow and calibrated using a velocity meter. The purpose of this station is to track changes as land use patterns change.

Site Summary

Site ID	FSU	
Site Name	Sycamore Creek @ Republic of Texas Blvd.	
Latitude	30.2494	N
Longitude	97.8424	W
Predominate Land Use	Single-Family	
Drainage Area	329.75 Acres	
Impervious Cover	0.064	
Runoff-Rainfall Ratio	0.06	
Runoff-Rainfall Events	618	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	131.2	mg/L	31
VSS	21.6	mg/L	31
NO_2+NO_3	0.504	mg/L	31
NH_3	0.063	mg/L	31
TKN	1.089	mg/L	31
TN	1.589	mg/L	31
DP	0.076	mg/L	31
TP	0.223	mg/L	31
BOD	2.46	mg/L	6
COD	53.70	mg/L	31
TOC	11.95	mg/L	31
Cadmium	0.418	µg/L	29
Copper	4.651	µg/L	31
Lead	4.77	µg/L	31
Zinc	17.39	µg/L	31
F. Coliform	28,700	cfu/100m	3
F. Strep.	80,995	cfu/100m	6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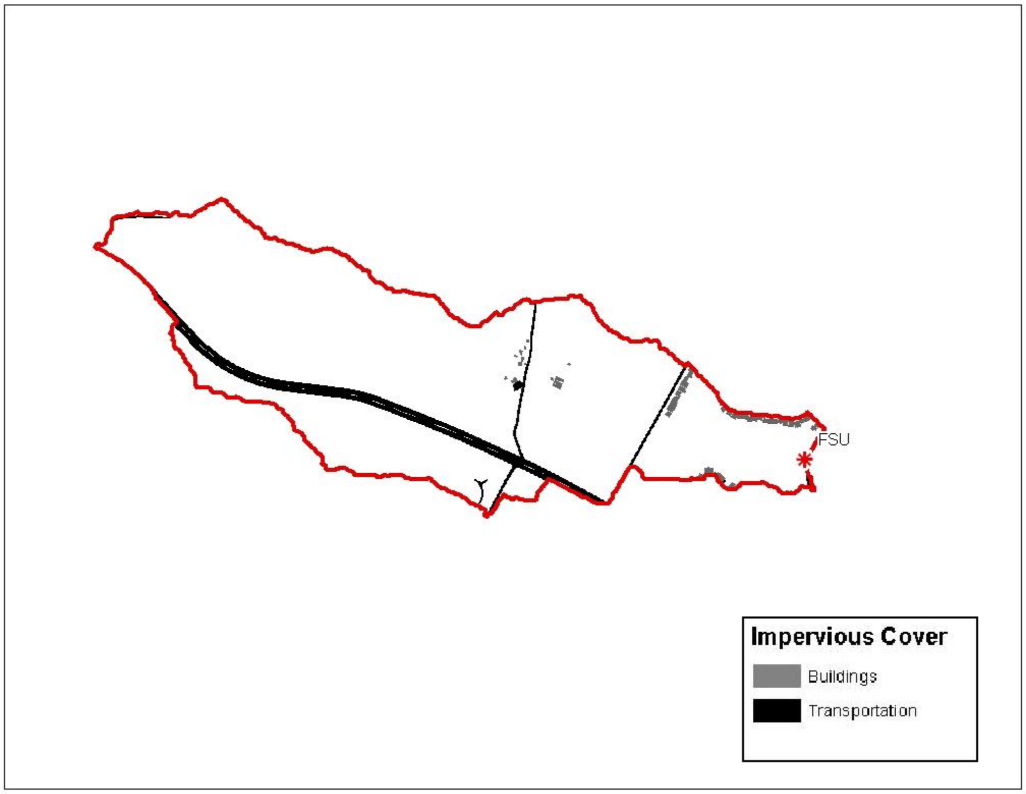
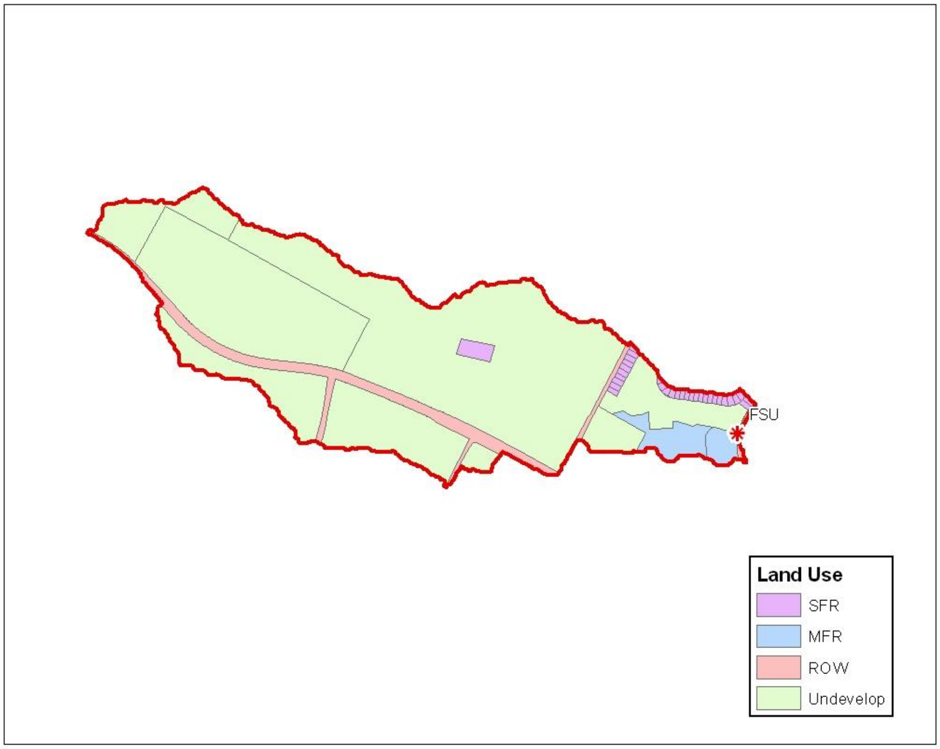
SOTER
AGAPE
ELEOS
PIRUN
VIVAS
QUERNUS
CERVINUS
VIA
TRAVIS COUNTRY
TRAVIS GREEN
HERO
FOSTER RANCH
FSU
SOUTHWEST
TERRAVISTA
WILLIAM CANNON
RIALTO
REPUBLIC OF TEXAS
OTHELLO
VEGA
MISSION OAKS
EIGER
PARKWOOD
OAKCLAIRE
OAK


FSU
Impervious Cover
Buildings
Transportation


FSU
Land Use
SFR
MFR
ROW
Undevelop

Windago (FWU)

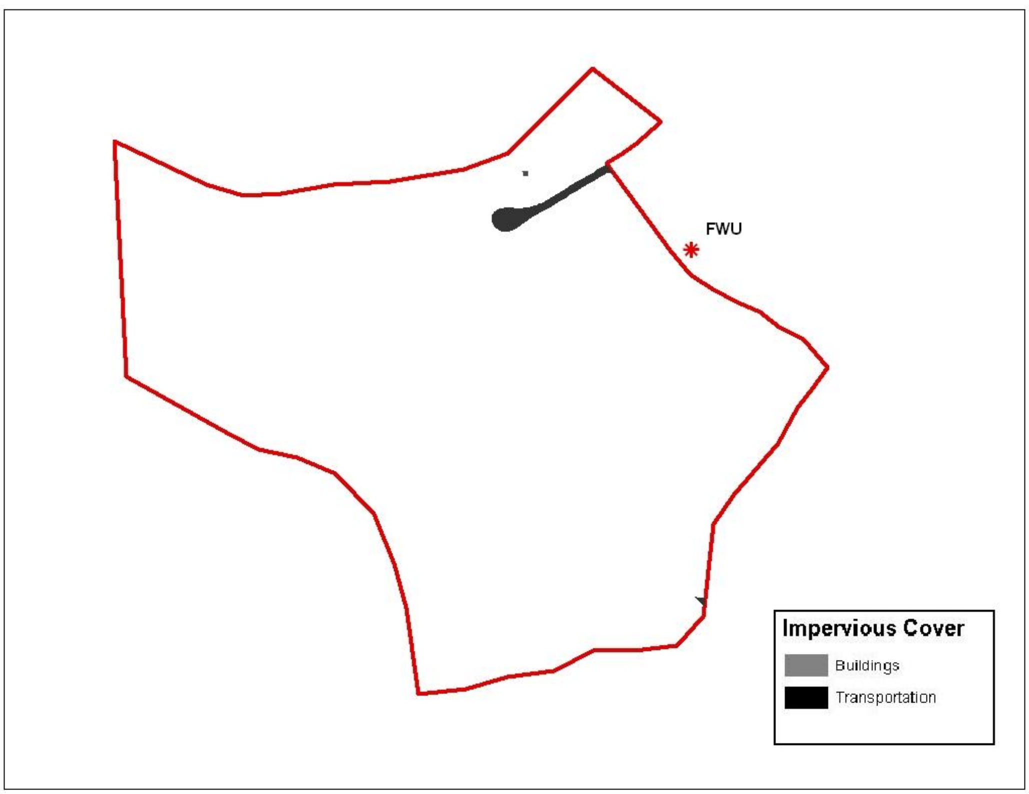
This monitoring station was operational from 1994-2001 and was located on Windago Way off of Highway 71 near the confluence of Little Barton Creek and Barton Creek. At the time of monitoring the undeveloped watershed was 45.9 acres with 1% impervious cover. Flow was estimated using open channel relationships and was calibrated using a velocity meter. Toward the end on monitoring construction in the watershed impacted TSS concentrations and those EMCs were omitted from analyses. The station was abandoned in 2001 due to the construction and a new station (SOA) was installed in roughly the same location after road construction was completed.

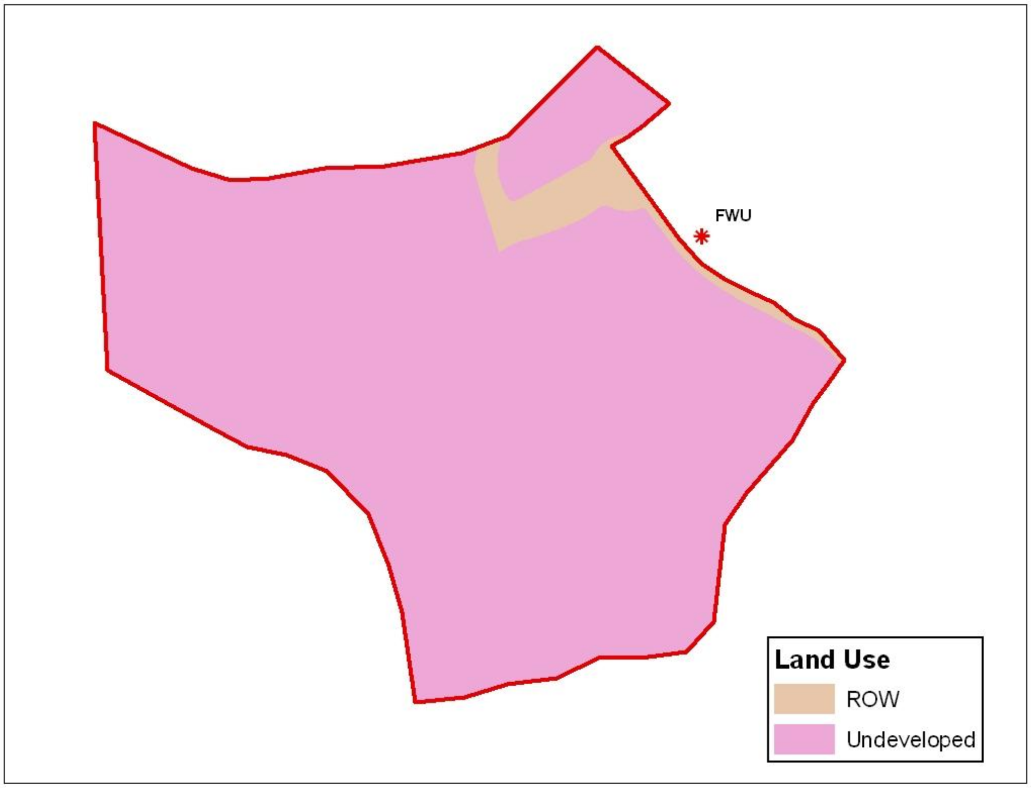
Site Summary

Site ID	FWU	
Site Name	Windago Undeveloped	
Latitude	30.2914	N
Longitude	97.9329	W
Predominate Land Use	Undeveloped	
Drainage Area	45.9	Acres
Impervious Cover	0.008	
Runoff-Rainfall Ratio	0.045	
Runoff-Rainfall Events	369	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	273.9	mg/L	24
VSS	30.7	mg/L	23
NO_2+NO_3	0.436	mg/L	24
NH_3	0.052	mg/L	23
TKN	1.060	mg/L	24
TN	1.556	mg/L	23
DP	0.039	mg/L	20
TP	0.207	mg/L	23
BOD	4.30	mg/L	21
COD	51.88	mg/L	24
TOC	8.82	mg/L	23
Cadmium	0.497	µg/L	22
Copper	4.480	µg/L	23
Lead	2.35	µg/L	22
Zinc	44.22	µg/L	23
F. Coliform	24,051	cfu/100m	17
F. Strep.	51,957	cfu/100m	17


FANDANGO
FANDANGO
FANDANGO
FANDANGO
FANDANGO
FWU
WINDAGO
OVERLOOK
OVERLOOK


FWU
Impervious Cover
Buildings
Transportation


FWU
Land Use
ROW
Undeveloped

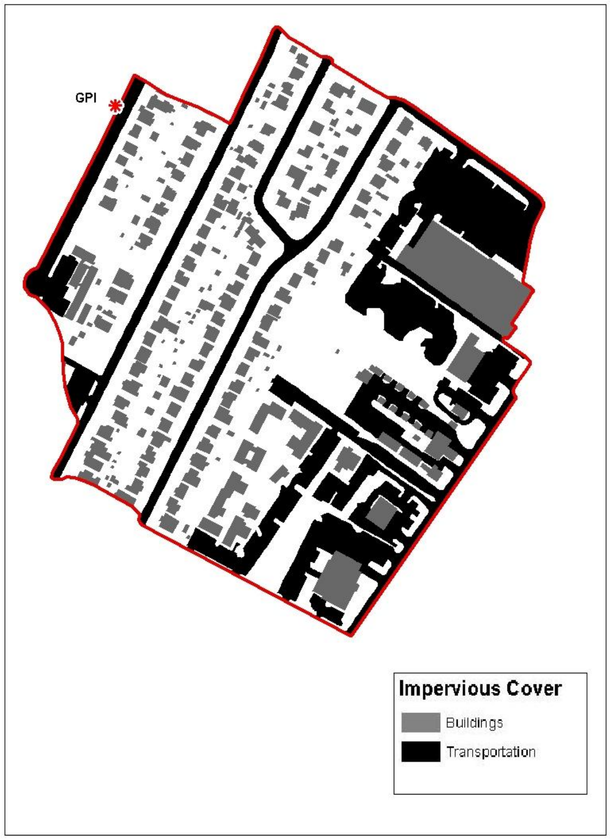
Gillis Park (GPI)

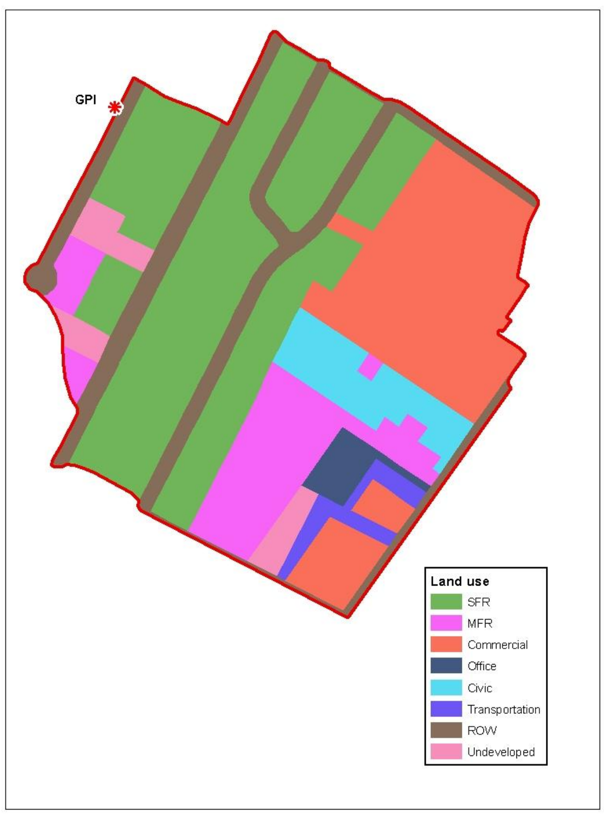
This monitoring station, located at 2504 Durwood Dr., was operational from 1994-1997. It is the influent to a sediment and trash trap BMP which treats a drainage area of 64.2 acres with 55% impervious cover. The land use is a mixed urban. Flow measurements at this site were problematic so those data were not used for runoff-rainfall analyses.

Site Summary

Site ID	GPI	
Site Name	Gillis Park O/G Chamber	
Latitude	30.2404	N
Longitude	97.7602	W
Predominate Land Use	Mixed Urban	
Drainage Area	64.17	Acres
Impervious Cover	0.5537	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	225.7	mg/L	18
VSS	41.0	mg/L	18
NO_2+NO_3	0.873	mg/L	18
NH_3	0.265	mg/L	18
TKN	2.337	mg/L	18
TN	3.226	mg/L	18
DP	0.166	mg/L	18
TP	0.629	mg/L	17
BOD	20.50	mg/L	17
COD	145.21	mg/L	18
TOC	23.06	mg/L	17
Cadmium	1.145	µg/L	18
Copper	99.325	µg/L	18
Lead	43.45	µg/L	18
Zinc	98.60	µg/L	18
F. Coliform	81,818	cfu/100m	15
F. Strep.	169,618	cfu/100m	16


GPI
Impervious Cover
Buildings
Transportation


GPI
Land use
SFR
MFR
Commercial
Office
Civic
Transportation
ROW
Undeveloped


GPI
DURWOOD
WILSON
FOREST
OLTORF
EUCLID
LONG BOW
CONGRESS
CUMBERLAND
BEN HOWELL
EDENS
EL PASO
BREWSTER


08.25.2005

Highwood Apartments (HI)

This monitoring station was operated from 1985-1987. It is located at Great Hills Trail and Agate Cove. The drainage area 3 acres with 50% impervious cover. The watershed is in the northern Edwards recharge zone and the land use is multi-family residential. Flow rate was measured at the station using a 150° V-notch weir. This station was the influent to an early sedimentation/filtration basin.

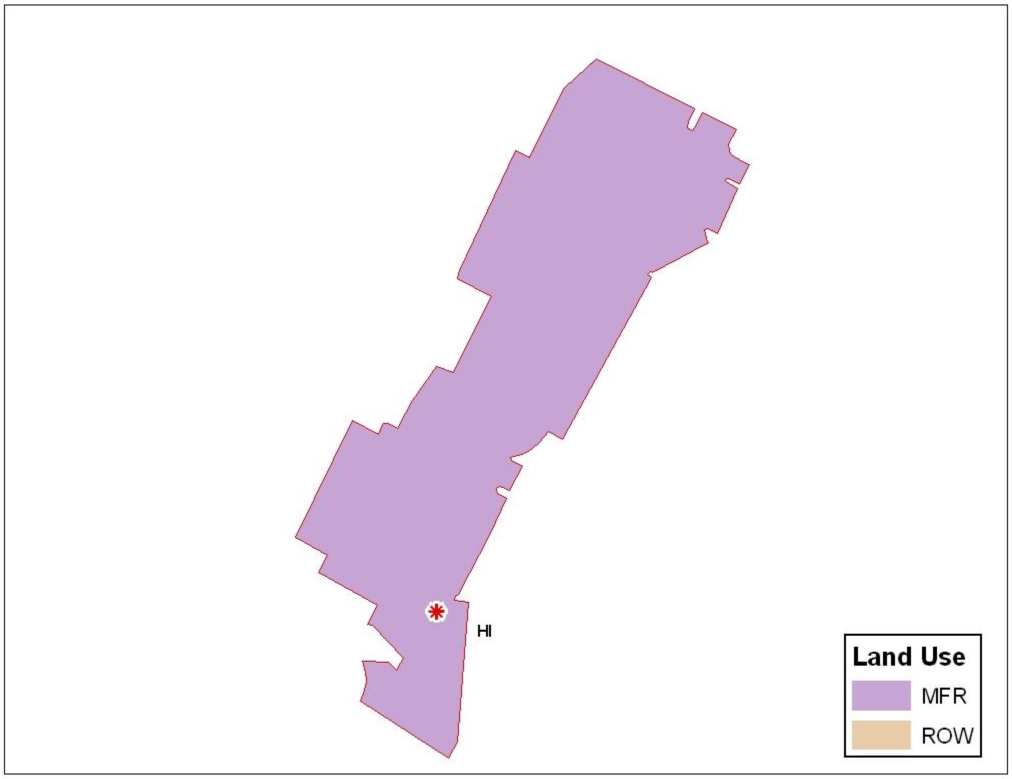
Site Summary

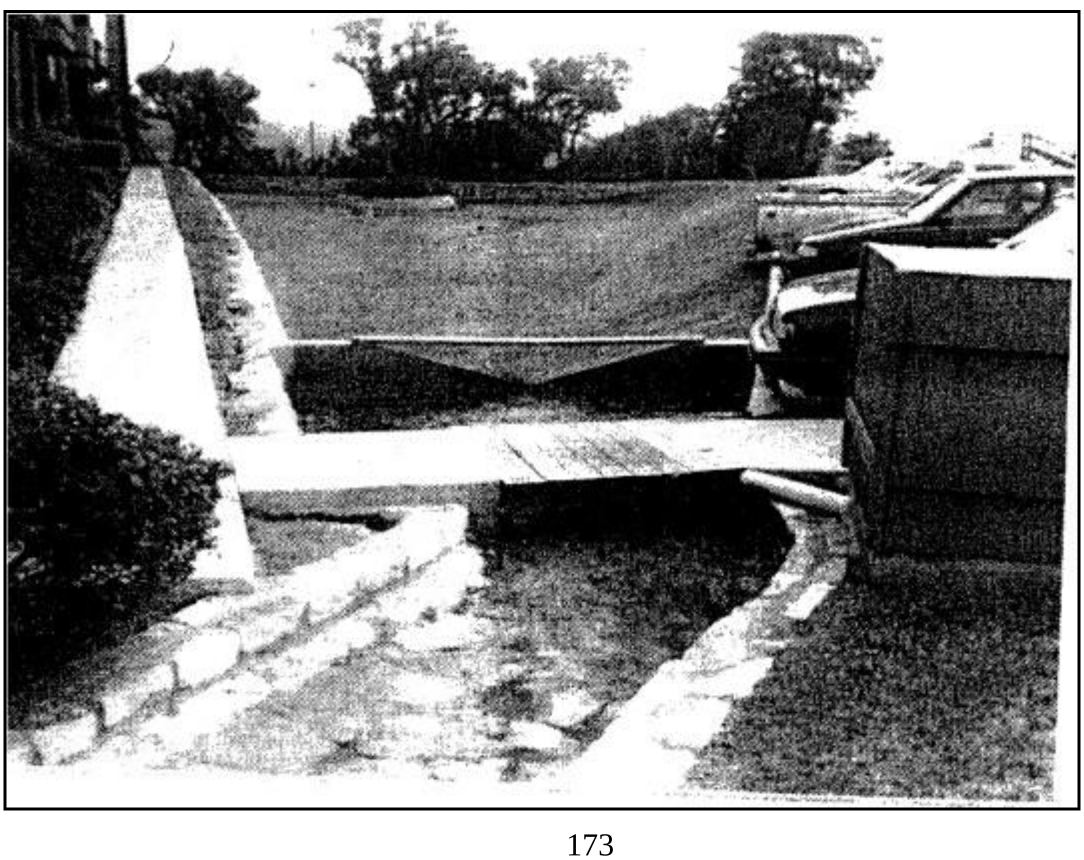
Site ID	HI	
Site Name	Highwood Apartments Influent	
Latitude	30.3916	N
Longitude	97.7554	W
Predominate Land Use	Multi-Family	
Drainage Area	3.0	Acres
Impervious Cover	0.5	
Runoff-Rainfall Ratio	0.565	
Runoff-Rainfall Events	59	
Recharge Zone	Yes	

Parameter	Mean EMC	Units	Count
TSS	127.1	mg/L	19
NO_2+NO_3	0.252	mg/L	19
NH_3	0.271	mg/L	19
TKN	0.606	mg/L	17
TN	0.858	mg/L	17
TP	0.168	mg/L	18
BOD	8.22	mg/L	18
COD	40.08	mg/L	19
TOC	7.68	mg/L	19
Copper	10.094	µg/L	19
Lead	11.68	µg/L	19
Zinc	40.67	µg/L	19
F. Coliform	22,326	cfu/100m	17
F. Strep.	25,866	cfu/100m	18


GREAT HILLS
AGATE
HI


HI
Impervious Cover
Buildings
Transportation


HI
Land Use
MFR
ROW



Hart Lane (HLA)

Monitoring at this site started from 1984-1987 under the name (HL). Monitoring resumed from 1995-1997 under the name (HLA). This monitoring station is located at 7560 Hart Lane. The total drainage area is 329.14 acres with 39% impervious cover. The watershed is in the northern Edwards recharge zone and is primarily single-family residential. Flow measurement at this station was problematic and the data were not use in runoff-rainfall analyses. This station was also used as the influent for the Wood Hollow wet pond.

Site Summary

Site ID	HLA	
Site Name	Hart Lane	
Latitude	30.3607	N
Longitude	97.7528	W
Predominate Land Use	Single-Family	
Drainage Area	336.07 Acres	
Impervious Cover	0.3909	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	162.9	mg/L	21
VSS	17.2	mg/L	2
NO_2+NO_3	0.702	mg/L	21
NH_3	0.201	mg/L	21
TKN	0.704	mg/L	21
TN	1.405	mg/L	21
DP	0.065	mg/L	2
TP	0.222	mg/L	21
BOD	9.38	mg/L	21
COD	30.22	mg/L	21
TOC	6.94	mg/L	20
Cadmium	0.303	µg/L	1
Copper	15.268	µg/L	19
Lead	44.07	µg/L	19
Zinc	58.77	µg/L	19
F. Coliform	94,416	cfu/100m	20
F. Strep.	34,464	cfu/100m	20

LONG POINT
WEST RIM
TALLOWOOD
BAMFORD
LOSTRIDGE
RUSTLING
PAINT ROCK
TABLEROCK
RIDGELINE
BURNEY
MESA TRAILS
MYRICK
COMFORT
SHADYROCK
STONEYWOOD
MORITZ
PETRA
GREENSLOPE
CARDIN
WILLIAMSBURG
SPICEWOOD SPRINGS
ORRELL
WOODWAY
DEEPWOODS
PEBBLE
SIDEHILL
GREEN TRAILS
LINDENWOOD
CAT HOLLOW
GNARL
HONEYCOMB ROCK
ROCKPOINT
CHIMNEY CORNERS
STONEHAVEN
PRICKLY PEAR
ENCLAVE MESA
GREYSTONE
EDGEROCK
HIDDEN
VENADO
WATERLINE
CIRCLETREE
KNOX
RUNNING ROPE
STONECLIFF
HART
HLA
MESA
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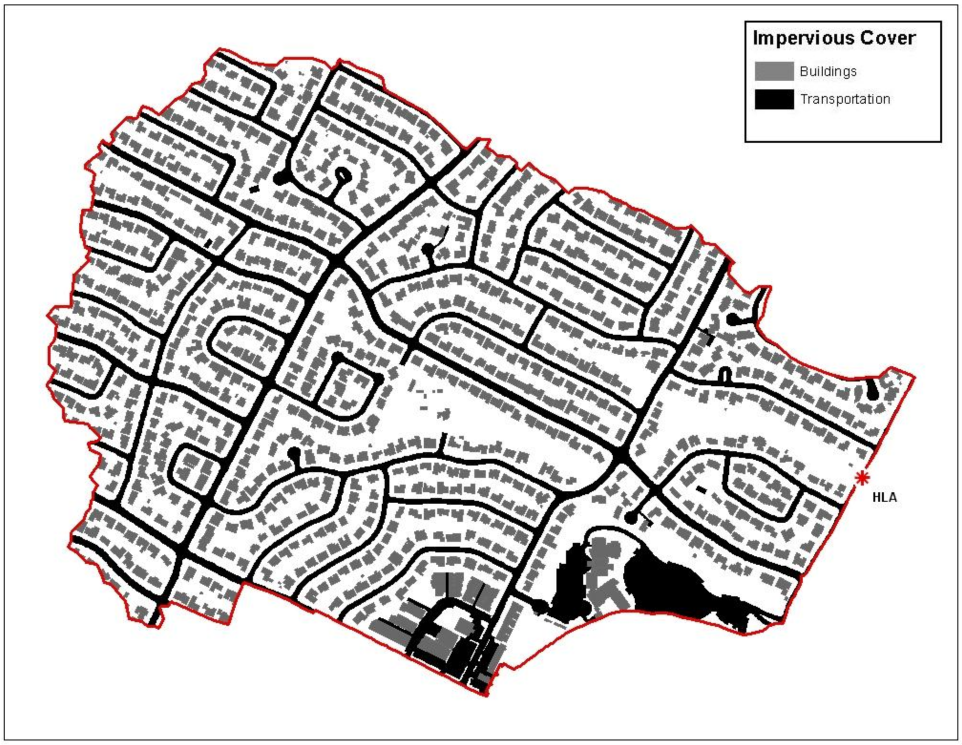
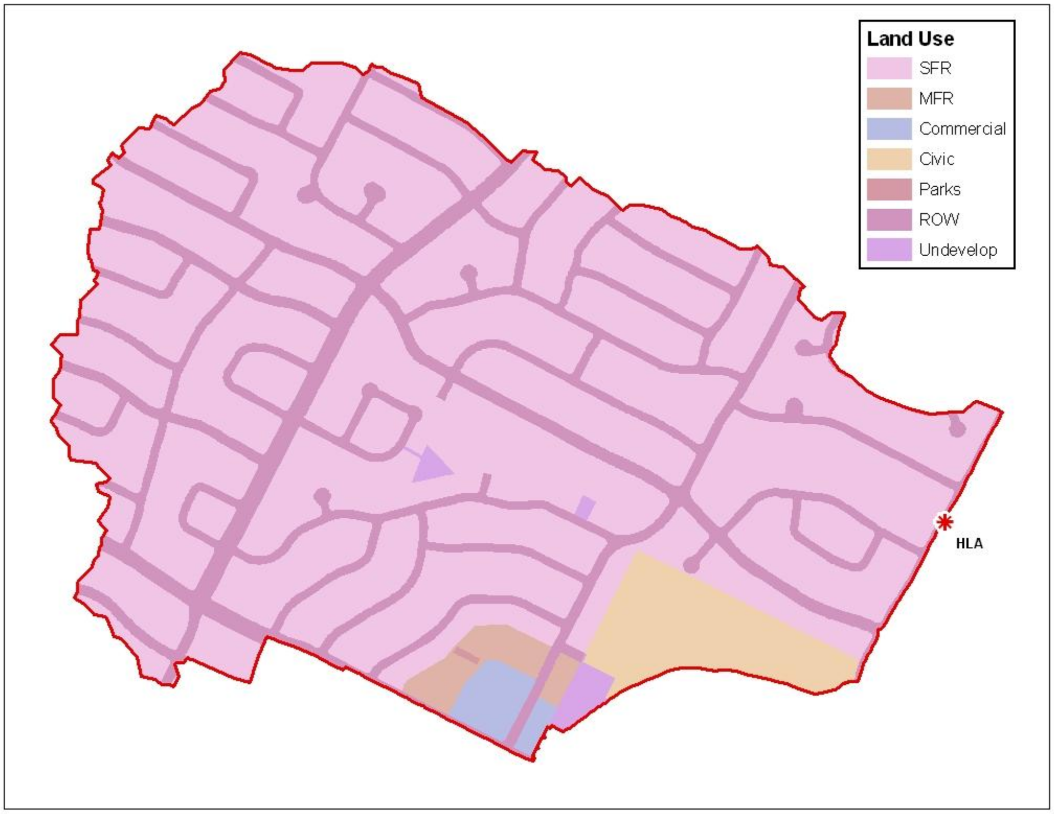
SPURLOCK
MONTANA NORTE
FARHILLS
NORTH HILLS
NORTHLEDGE
EDGEFIELD
FAR WEST



Impervious Cover
Buildings
Transportation
HLA


Land Use
SFR
MFR
Commercial
Civic
Parks
ROW
Undevelop
HLA


17 10:23 AM

Hyde Park (HPA)

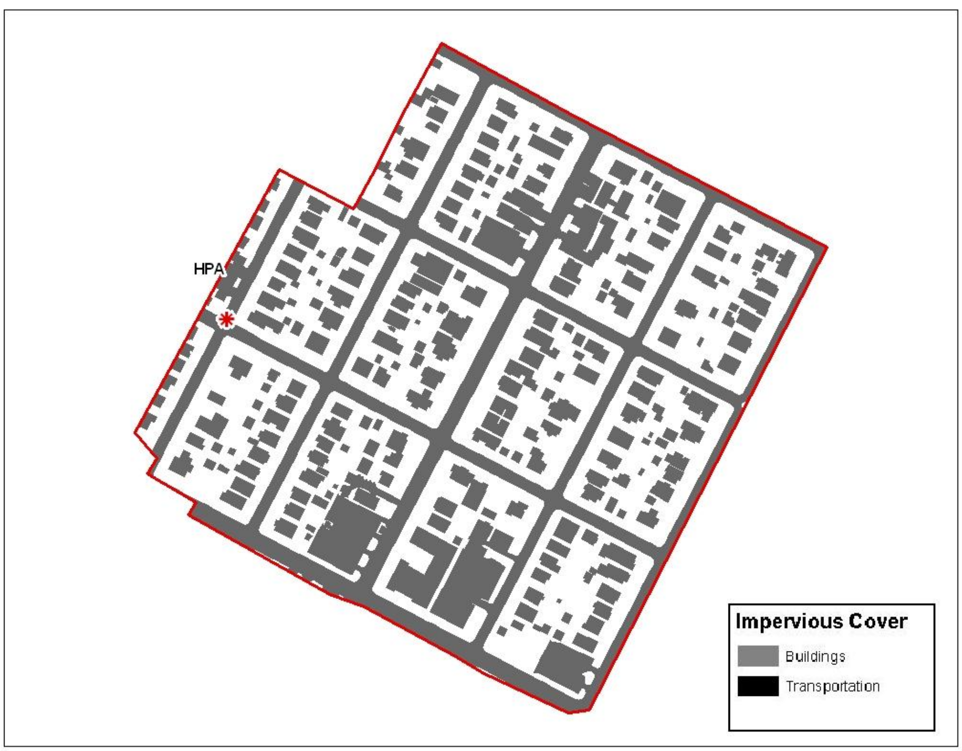
This station was located at the corner of Avenue C and 41st Street in Hyde Park and was operational from 2000 thru 2003. The total drainage area for HPA is 42.6 acres with an impervious cover of 53%. The primary land use is single family residential. Flow was primarily estimated in the 54-inch storm sewer using Manning's Eqn. but validated using an area-velocity meter. The bubbler line at this site occasionally became partially clogged by travertine deposits, requiring frequent maintenance. Also affecting data at this site was an unexpected sustained baseflow, probably due to leaking water lines.

Site Summary

Site ID	HPA	
Site Name	Hyde Park at 41st St.	
Latitude	30.3051	N
Longitude	97.7330	W
Predominate Land Use	Single-Family	
Drainage Area	43.04	Acres
Impervious Cover	0.4495	
Runoff-Rainfall Ratio	0.43	
Runoff-Rainfall Events	215	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	113.3	mg/L	28
VSS	41.2	mg/L	26
NO_2+NO_3	0.586	mg/L	28
NH_3	0.291	mg/L	25
TKN	2.151	mg/L	28
TN	2.717	mg/L	28
DP	0.264	mg/L	28
TP	0.537	mg/L	28
BOD	14.99	mg/L	18
COD	85.53	mg/L	28
TOC	18.29	mg/L	25
Cadmium	0.512	µg/L	27
Copper	7.126	µg/L	27
Lead	22.73	µg/L	27
Zinc	112.51	µg/L	27
F. Coliform	128,496	cfu/100m	11
F. Strep.	254,987	cfu/100m	13

44TH
AVENUE A
AVENUE B
AVENUE F
SPEEDWAY
43RD
HPA
AVENUE H
AVENUE D
42ND
41ST
AVENUE C
40TH
AVENUE G
DUVAL
39TH
41ST



HPA
Impervious Cover
Buildings
Transportation


HPA
Land Use
SFR
MFR
Office
Civic
Transportation
ROW

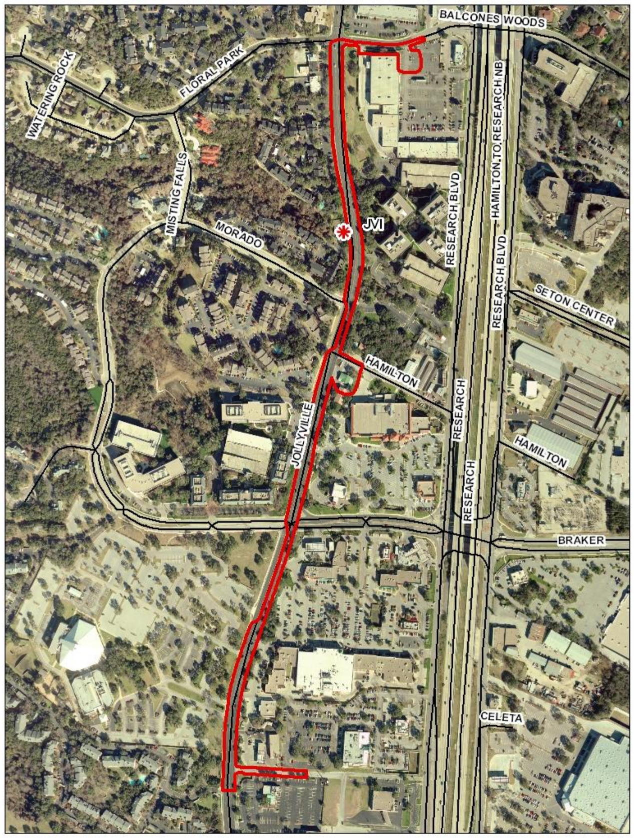
Jollyville Road (JVI)

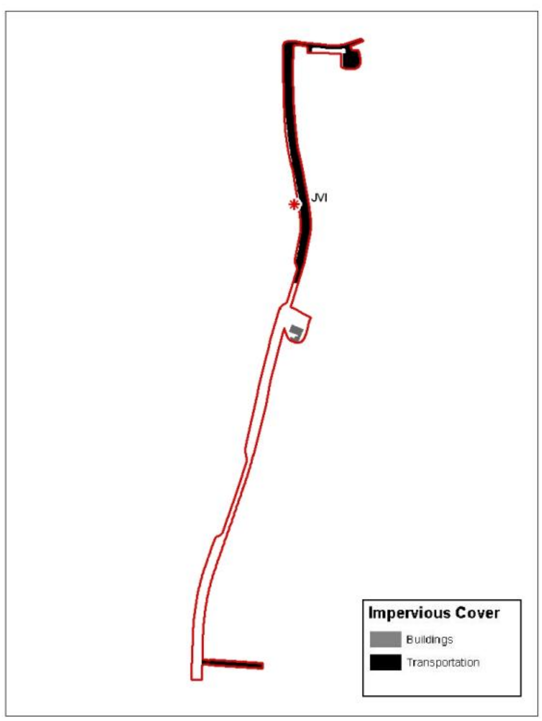
Monitoring at this station started from 1988-1991 under the name (JA). Monitoring resumed from 1994-2002 under the name (JVI). This monitoring station is located at 1100 Jollyville Road. The total drainage area is 7.02 acres with 94% impervious cover and is primarily road right-of-way. An H-flume was used to measure the flow rate. The site is in the north Edwards Aquifer recharge zone. The station is the influent for a sand filter water quality control basin.

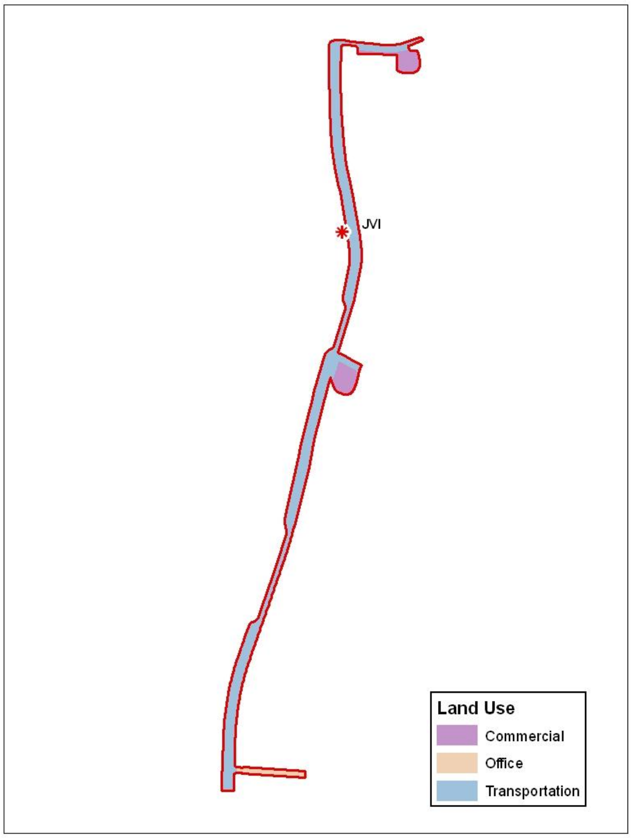
Site Summary

Site ID	JVI	
Site Name	Jollyville Road Pond Influent	
Latitude	30.4050	N
Longitude	97.7478	W
Predominate Land Use	Transportation	
Drainage Area	7.02	Acres
Impervious Cover	0.9436	
Runoff-Rainfall Ratio	0.69	
Runoff-Rainfall Events	510	
Recharge Zone	Yes	

Parameter	Mean EMC	Units	Count
TSS	260.9	mg/L	34
VSS	32.1	mg/L	16
NO_2+NO_3	0.472	mg/L	30
NH_3	0.322	mg/L	32
TKN	0.980	mg/L	31
TN	1.405	mg/L	30
DP	0.092	mg/L	15
TP	0.221	mg/L	33
BOD	7.09	mg/L	30
COD	63.88	mg/L	33
TOC	14.61	mg/L	29
Cadmium	0.783	µg/L	17
Copper	17.031	µg/L	33
Lead	42.50	µg/L	33
Zinc	124.78	µg/L	33
F. Coliform	4,538	cfu/100m	27
F. Strep.	14,706	cfu/100m	30


BALCONES WOODS
FLORAL PARK
WATERING ROCK
MISTING FALLS
MORADO
JVI
RESEARCH BLVD
HAMILTON TO RESEARCH NB
RESEARCH BLVD
SETON CENTER
HAMILTON
JOLLYVILLE
RESEARCH
RESEARCH
HAMILTON
BRAKER
CELETA


JVI
Impervious Cover
Buildings
Transportation


JVI
Land Use
Commercial
Office
Transportation

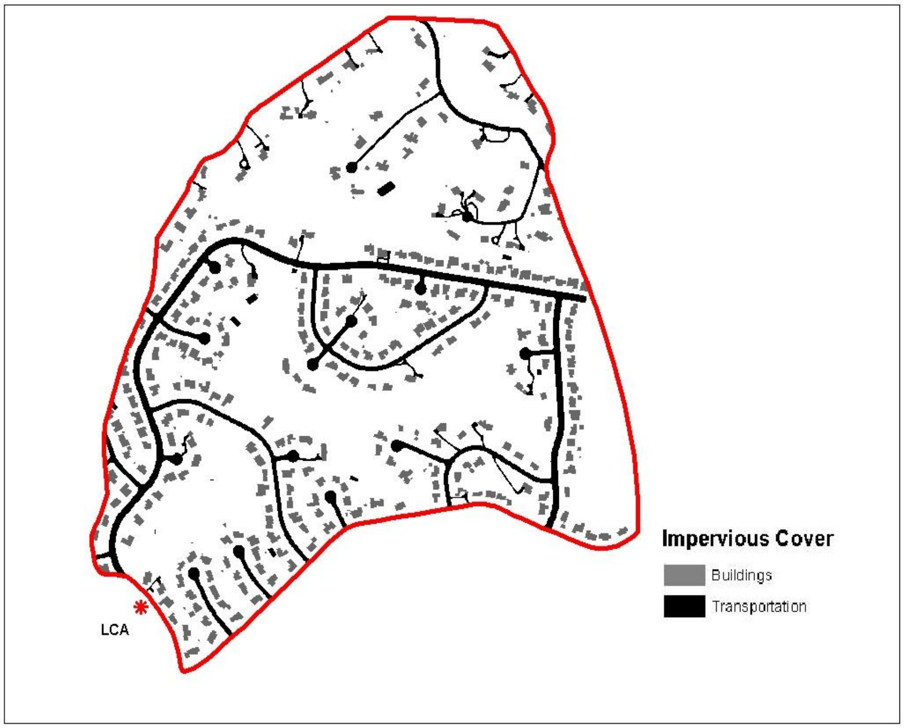
Lost Creek Monitoring Site (LCA)

This monitoring station was located at Whitemarsh Valley Way in the Barton Creek Watershed. The 209.87 acres watershed has 23% impervious cover and the land use is single-family residential. This site was monitored between 1992 and 1999. Flow was measured using Manning's Eqn. in a 72 inch re-enforced concrete pipe and verified using an area-velocity meter.

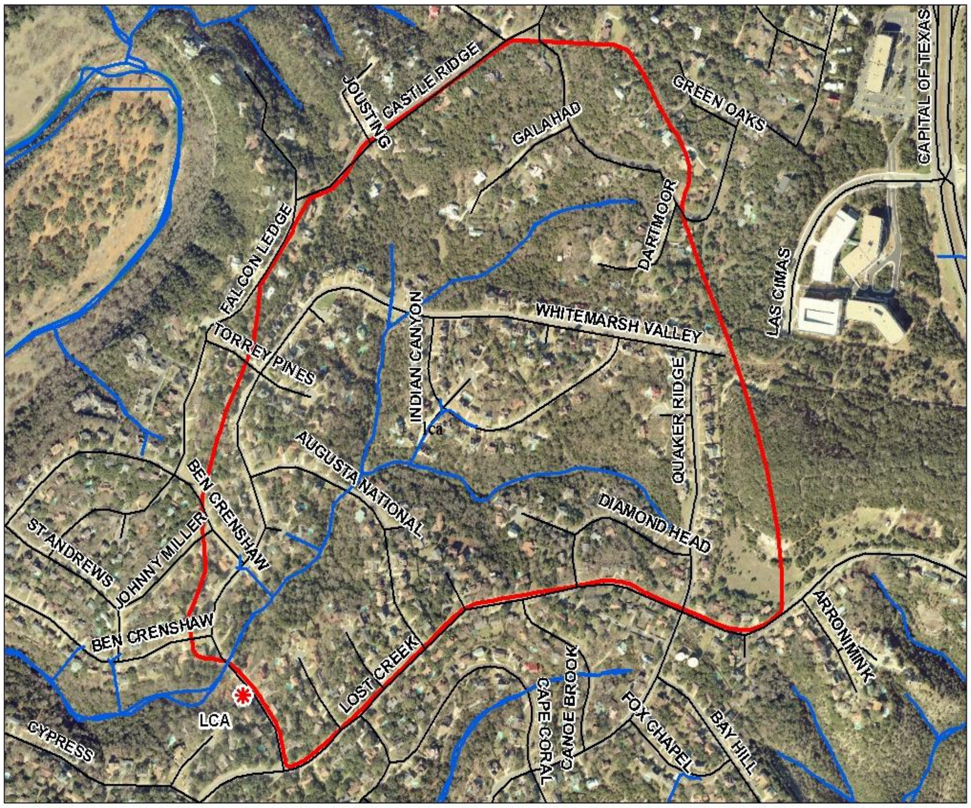
Site Summary

Site ID	LCA	
Site Name	Lost Creek Subdivision	
Latitude	30.2831	N
Longitude	97.8420	W
Predominate Land Use	Single-Family	
Drainage Area	209.87 Acres	
Impervious Cover	0.225	
Runoff-Rainfall Ratio	0.127	
Runoff-Rainfall Events	279	
Recharge Zone	No	

Parameter	Mean EMC	Units	Count
TSS	171.3	mg/L	24
VSS	43.3	mg/L	17
NO_2+NO_3	0.675	mg/L	26
NH_3	0.193	mg/L	21
TKN	1.642	mg/L	28
TN	2.342	mg/L	26
DP	0.114	mg/L	25
TP	0.330	mg/L	28
BOD	7.68	mg/L	25
COD	63.38	mg/L	28
TOC	9.09	mg/L	21
Cadmium	0.330	µg/L	12
Copper	10.486	µg/L	20
Lead	8.62	µg/L	20
Zinc	66.18	µg/L	21
F. Coliform	88,279	cfu/100m	23
F. Strep.	46,258	cfu/100m	21


LCA
Impervious Cover
Buildings
Transportation


17 9:42 AM


JOUSTING
CASTLE RIDGE
GREEN OAKS
CAPITAL OF TEXAS
GALAHAD
DARTMOOR
FALCON LEDGE
LAS CIMAS
INDIAN CANYON
WHITEMARSH VALLEY
TORREY PINES
QUAKER RIDGE
AUGUSTA NATIONAL
BEN CRENSHAW
DIAMOND HEAD
ST ANDREWS
JOHNNY MILLER
ARRONIMINK
BEN CRENSHAW
LOST CREEK
CANOE BROOK
CAPE CORAL
FOX CHAPEL
BAY HILL
LCA
CYPRESS


Land use
SFR
Parks
ROW
Undeveloped
LCA

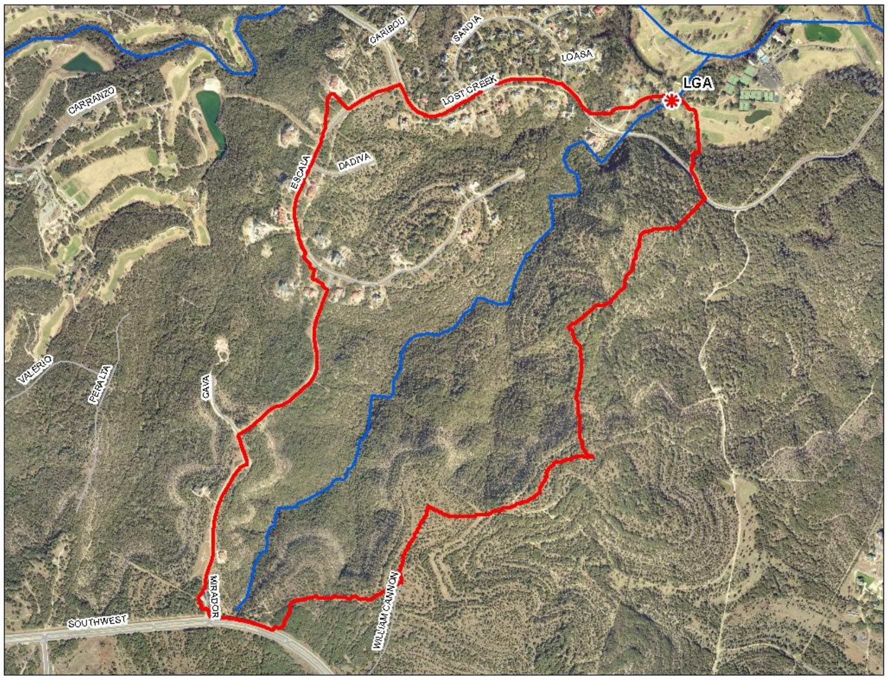
Lost Creek Golf Course (LGA)

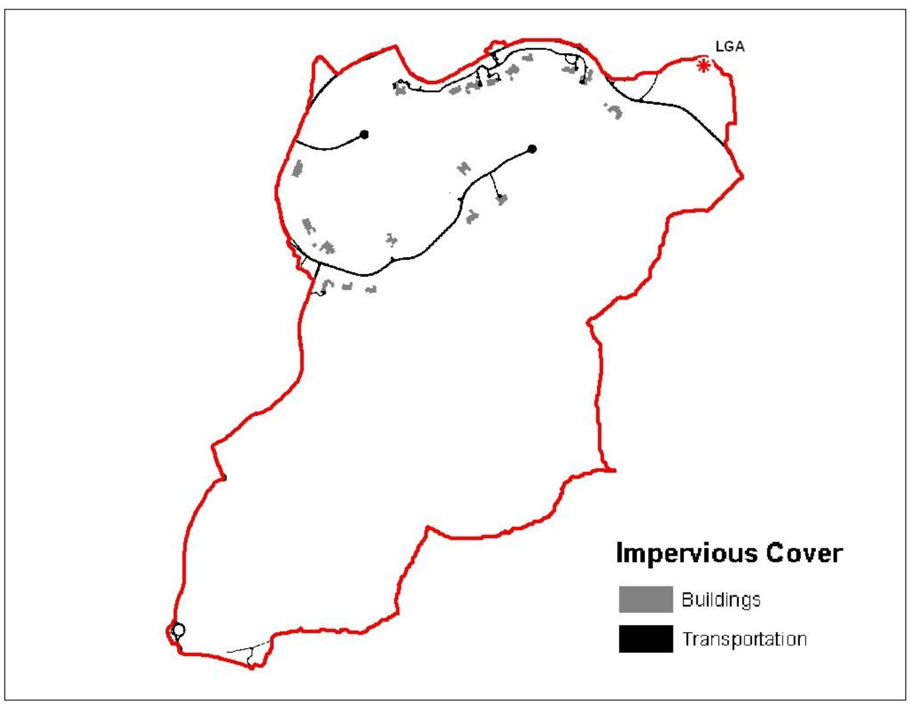
This monitoring station is located on the Lost Creek Golf Course in Barton Creek watershed and measures runoff from an area that is primarily undeveloped. The drainage area covers 481 acres and has ~1% impervious cover. A sharp crested rectangular weir is used as measurement structure. The monitoring station was established in 1999 and monitoring continues in an effort to track changes in the watershed as it developed.

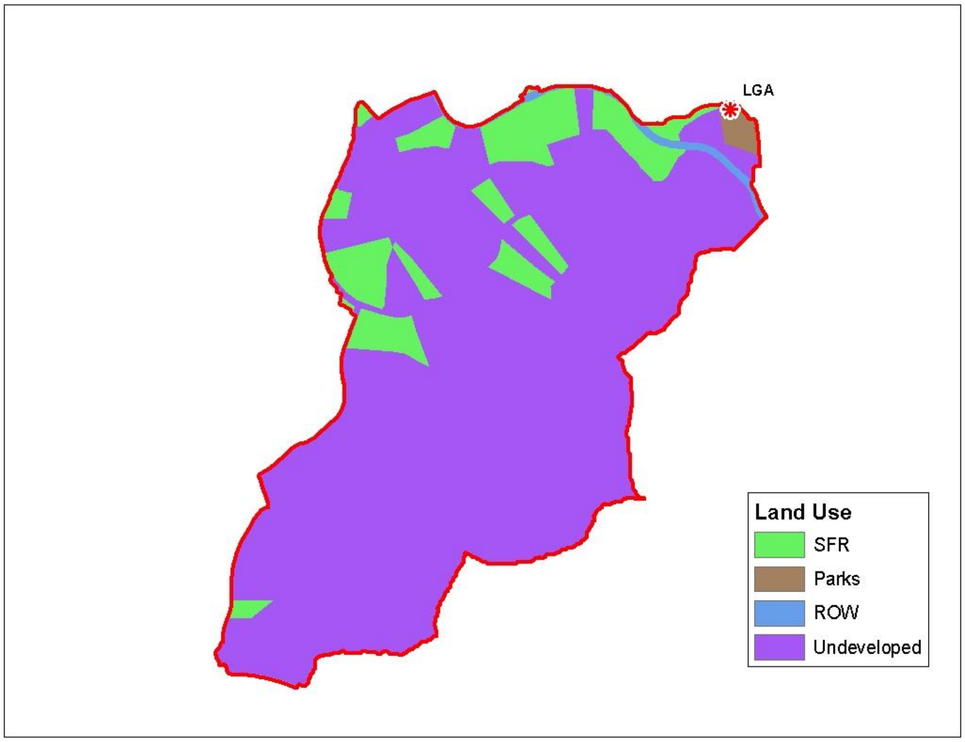
Site Summary

Site ID	LGA	
Site Name	Lost Creek Golf Course	
Latitude	30.2734	N
Longitude	97.8533	W
Predominate Land Use	Undeveloped	
Drainage Area	481.07 Acres	
Impervious Cover	0.0072	
Runoff-Rainfall Ratio	0.079	
Runoff-Rainfall Events	544	
Recharge Zone	No	

Parameter	Mean EMC	Units	Count
TSS	48.0	mg/L	31
VSS	5.3	mg/L	31
NO_2+NO_3	0.366	mg/L	31
NH_3	0.031	mg/L	31
TKN	0.369	mg/L	31
TN	0.753	mg/L	31
DP	0.024	mg/L	30
TP	0.052	mg/L	31
BOD	1.17	mg/L	7
COD	17.25	mg/L	31
TOC	6.57	mg/L	31
Cadmium	0.379	µg/L	30
Copper	2.815	µg/L	31
Lead	3.01	µg/L	31
Zinc	10.03	µg/L	31
F. Coliform	3,488	cfu/100m	6
F. Strep.	18,887	cfu/100m	6


LGA
CARRANZO
CARIBOU
SANDIA
LOASA
LOST CREEK
ESCALA
DADIVA
VALERIO
PERALTA
GAVA
MIRADOR
SOUTHWEST
WILLIAM CANNON


LGA
Impervious Cover
Buildings
Transportation


LGA
Land Use
SFR
Parks
ROW
Undeveloped

Lavaca Street (LUA)

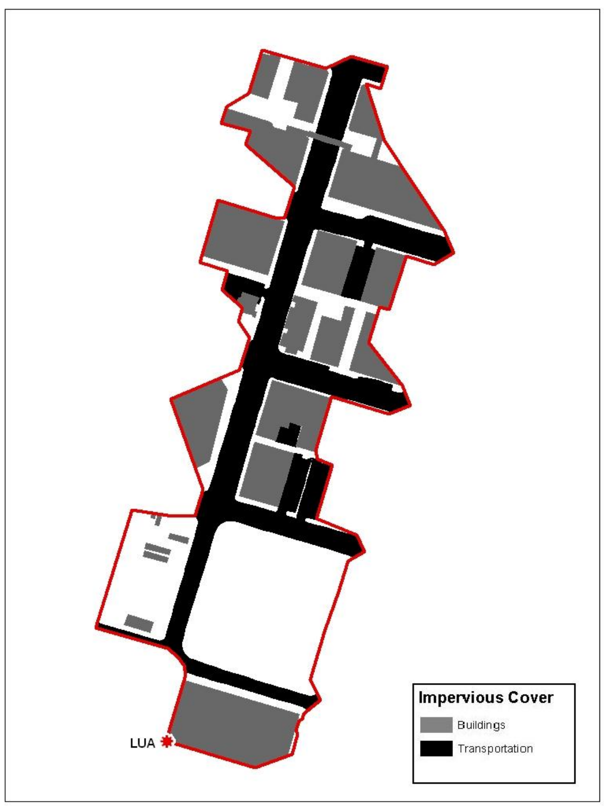
This monitoring station was located at the corner of Lavaca and 2nd Street. The 13.65 acres watershed had 97% impervious cover and a downtown commercial land. The 42-in re-enforced concrete storm sewer pipe had some un-even sections and shifting due to its age which was significant to flow measurement by creating hydraulic jump. Therefore, staff modified the pipe by smoothing the area. This station was monitored from 1992-1998 and was part of the City's preliminary NPDES data collection.

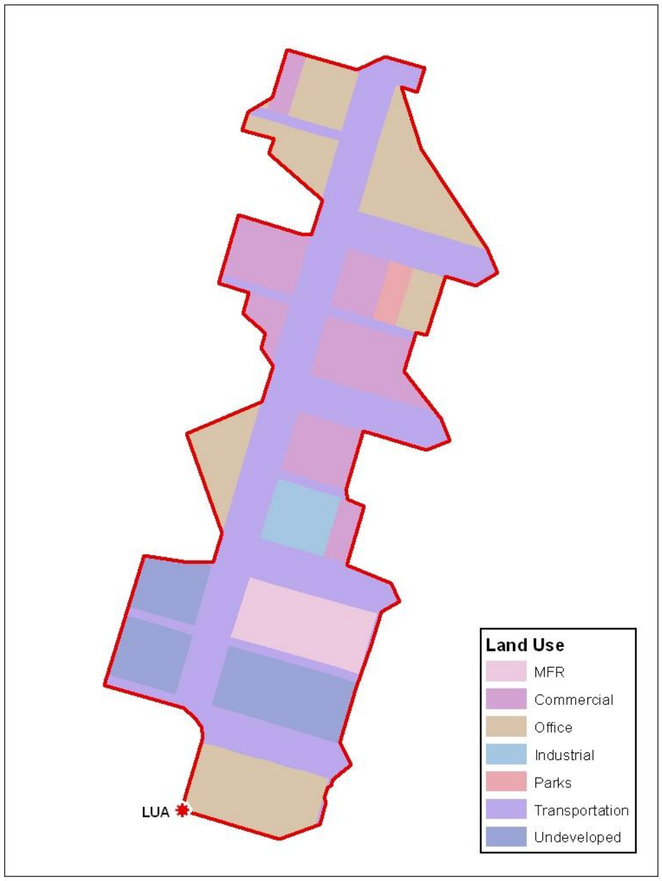
Site Summary

Site ID	LUA	
Site Name	Lavaca Urban	
Latitude	30.2645	N
Longitude	97.7466	W
Predominate Land Use	Mixed Urban	
Drainage Area	13.65 Acres	
Impervious Cover	0.9742	
Runoff-Rainfall Ratio	0.627	
Runoff-Rainfall Events	247	
Recharge Zone	No	

Parameter	Mean EMC	Units	Count
TSS	187.4	mg/L	31
VSS	66.0	mg/L	17
NO_2+NO_3	0.746	mg/L	31
NH_3	0.495	mg/L	25
TKN	2.488	mg/L	31
TN	3.240	mg/L	30
DP	0.442	mg/L	25
TP	0.564	mg/L	31
BOD	21.39	mg/L	30
COD	137.05	mg/L	31
TOC	17.58	mg/L	25
Cadmium	1.072	µg/L	7
Copper	30.399	µg/L	24
Lead	97.88	µg/L	23
Zinc	328.92	µg/L	23
F. Coliform	56,477	cfu/100m	24
F. Strep.	105,485	cfu/100m	28


7TH
COLORADO
LAVACA
6TH
SAN ANTONIO
5TH
GUADALUPE
4TH
CONGRESS
3RD
2ND
LUA
CESAR CHAVEZ


Impervious Cover
Buildings
Transportation
LUA


Land Use
MFR
Commercial
Office
Industrial
Parks
Transportation
Undeveloped
LUA


ONE WAY

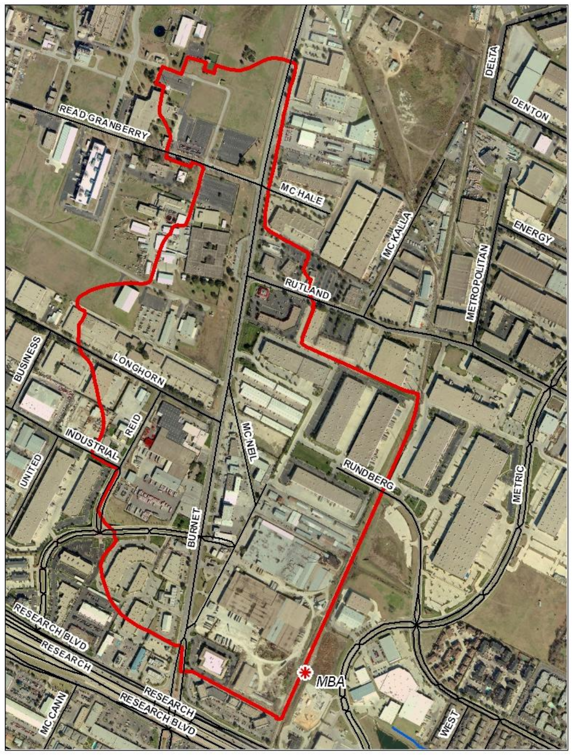
Metric Blvd. (MBA)

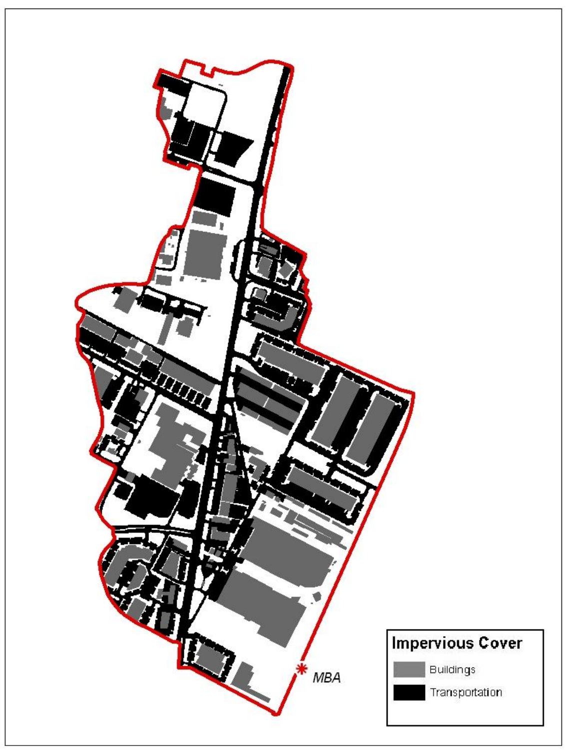
This monitoring station was operational from 1992-1995 and was located at Metric Blvd in Little Walnut Creek watershed. The drainage area is 202.94 acres with 60% impervious cover and is primarily industrial land use. A 10 -foot rectangular weir without end contractions was used for flow rate measurement.

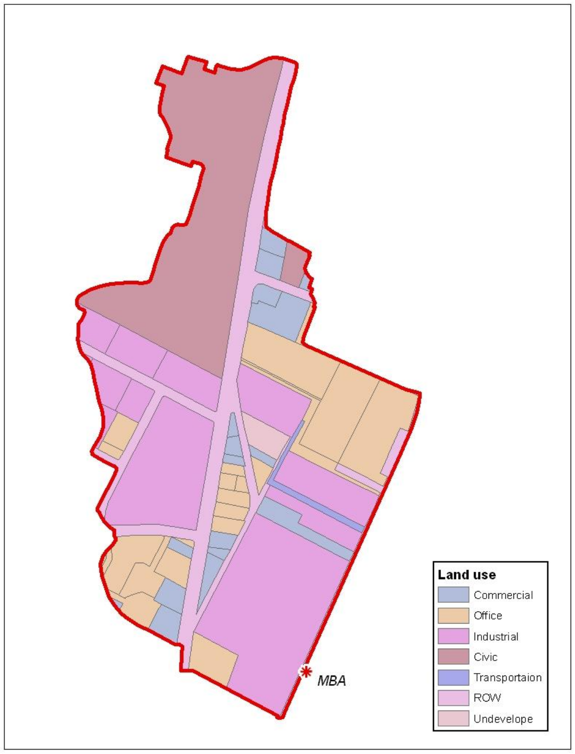
Site Summary

Site ID	MBA	
Site Name	Metric Blvd. Industrial	
Latitude	30.3741	N
Longitude	97.7227	W
Predominate Land Use	Industrial	
Drainage Area	202.94 Acres	
Impervious Cover	0.6093	
Runoff-Rainfall Ratio	0.415	
Runoff-Rainfall Events	178	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	252.3	mg/L	26
VSS	42.4	mg/L	24
NO_2+NO_3	0.655	mg/L	27
NH_3	0.247	mg/L	25
TKN	1.712	mg/L	27
TN	2.366	mg/L	27
DP	0.189	mg/L	27
TP	0.494	mg/L	27
BOD	16.47	mg/L	27
COD	81.55	mg/L	27
TOC	12.83	mg/L	25
Cadmium	0.764	µg/L	15
Copper	11.889	µg/L	18
Lead	24.93	µg/L	18
Zinc	115.01	µg/L	18
F. Coliform	43,349	cfu/100m	19
F. Strep.	50,319	cfu/100m	20


READ GRANBERRY
MC HALE
DELTA
DENTON
ENERGY
MC KALLA
METROPOLITAN
RUTLAND
BUSINESS
LONGHORN
REID
INDUSTRIAL
UNITED
MC NEIL
RUNDBERG
METRIC
BURNET
RESEARCH BLVD
RESEARCH
RESEARCH BLVD
MC CANN
MBA
WEST


MBA
Impervious Cover
Buildings
Transportation


Land use
Commercial
Office
Industrial
Civic
Transportaion
ROW
Undevelope
MBA

Maple Run (MI)

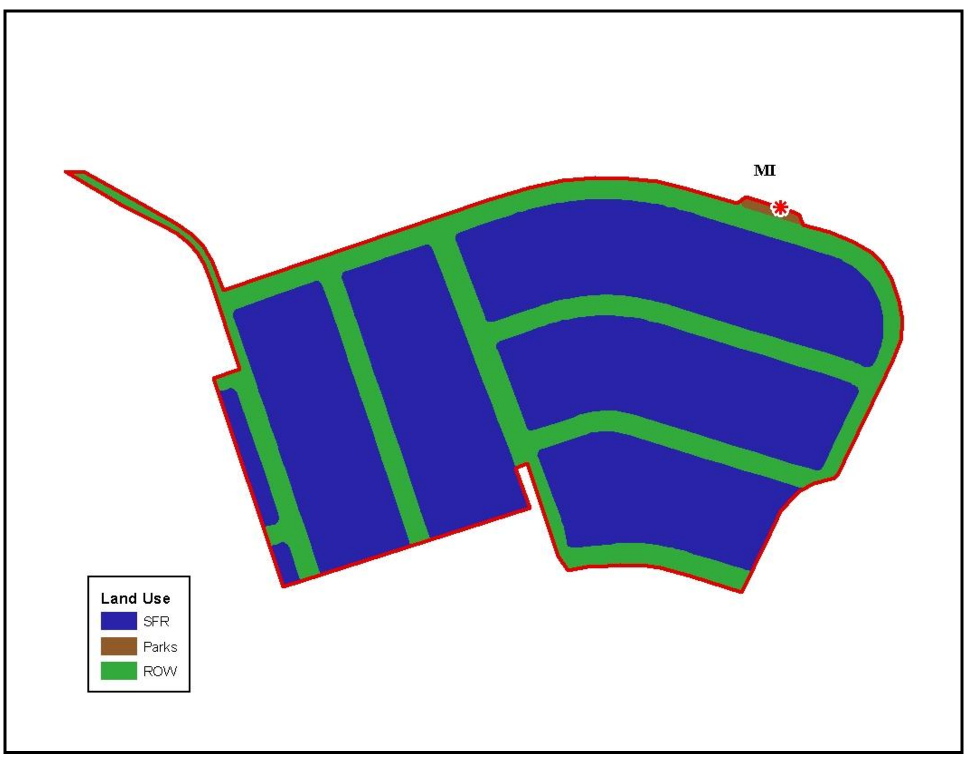
This monitoring station was operational 1984-1986. It is located at 4323 Clarno Drive in the Maple Run Subdivision. The total drainage area is 27.8 acres with an impervious cover of 36% in a primarily single family land use. The historical flow data from this station was lost at some point so EMCs are computed as arithmetic averages.

Site Summary

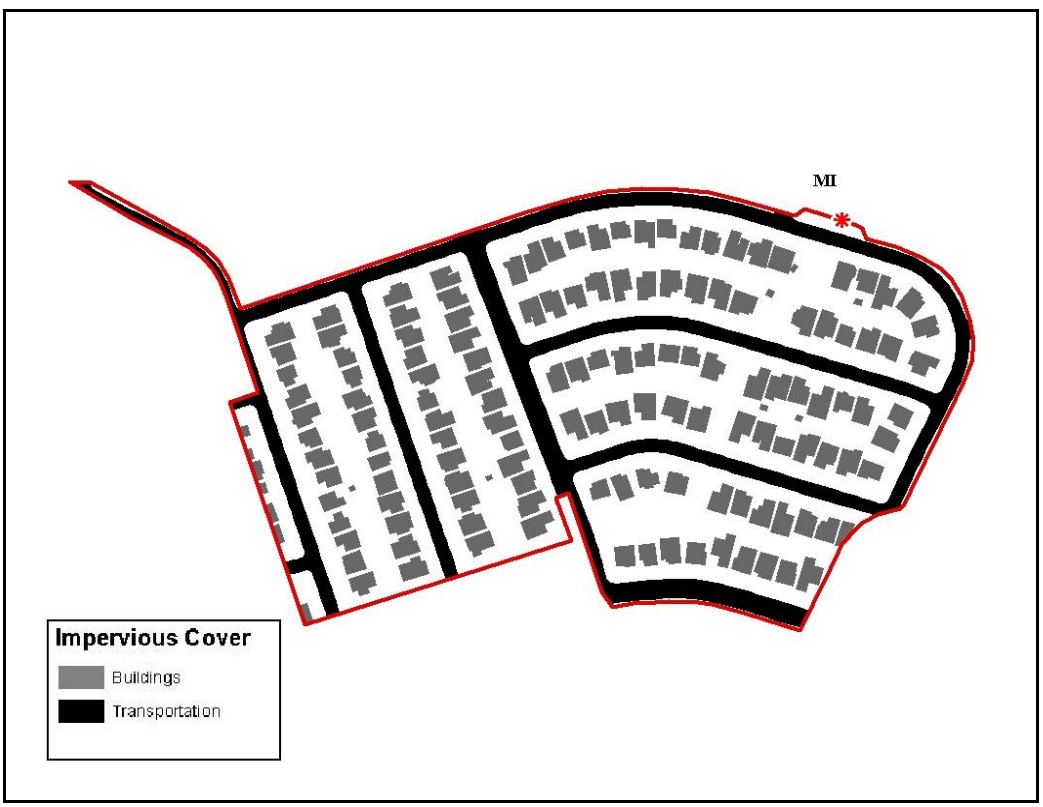
Site ID	MI	
Site Name	Maple Run Pond Influent	
Latitude	30.2116	N
Longitude	97.8471	W
Predominate Land Use	Single-Family	
Drainage Area	27.8	Acres
Impervious Cover	0.36	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	296.3	mg/L	26
NO_2+NO_3	0.450	mg/L	26
NH_3	0.228	mg/L	26
TKN	1.028	mg/L	26
TN	1.417	mg/L	26
TP	0.257	mg/L	26
BOD	8.68	mg/L	25
COD	38.48	mg/L	26
TOC	13.57	mg/L	26
Copper	7.921	µg/L	26
Lead	8.10	µg/L	26
Zinc	27.30	µg/L	26
F. Coliform	52,624	cfu/100m	25
F. Strep.	40,039	cfu/100m	25


08.25.2005


MI
Land Use
SFR
Parks
ROW


NAIRN
COPPERAS
LATTA
NAVARRO
ISLANDER
MI
TIFFANY
CLARNO
TOBAGO
SARASOTA
MANZANILLO
MOLOKAI
SALOMA
SAN SIMEON
COPANO
PALACIOS
KALAMA
ESKEW
VELASCO


MI
Impervious Cover
Buildings
Transportation

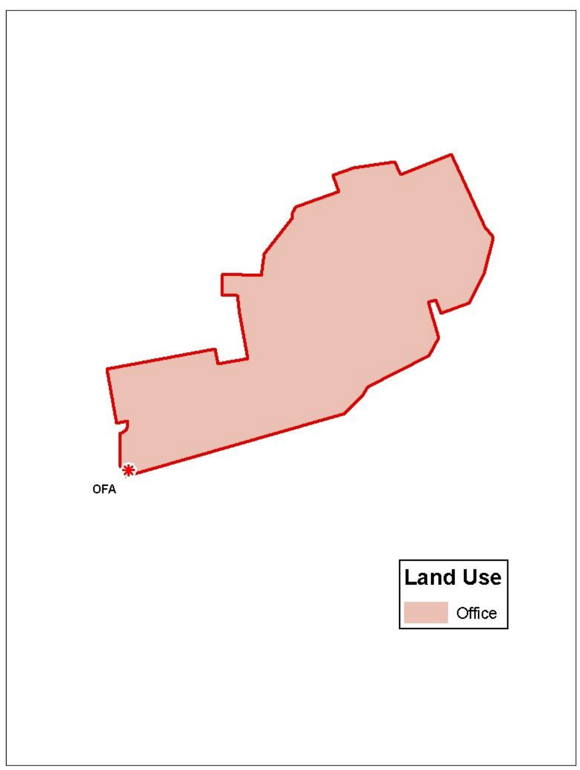
Spyglass Office Park (OFA)

This monitoring site was located at Timberline Office Park off of Spyglass Parkway in the Barton Creek recharge zone. The site was operated in 1993-1997. The 1.54 acre watershed is 86% impervious and the land use is classified as commercial/office. Flow was measured using a 2 ft trapezoidal weir. This station was reactivated between 2005-2008 to collect PAH data from a parking area sealed with coal tar sealant.

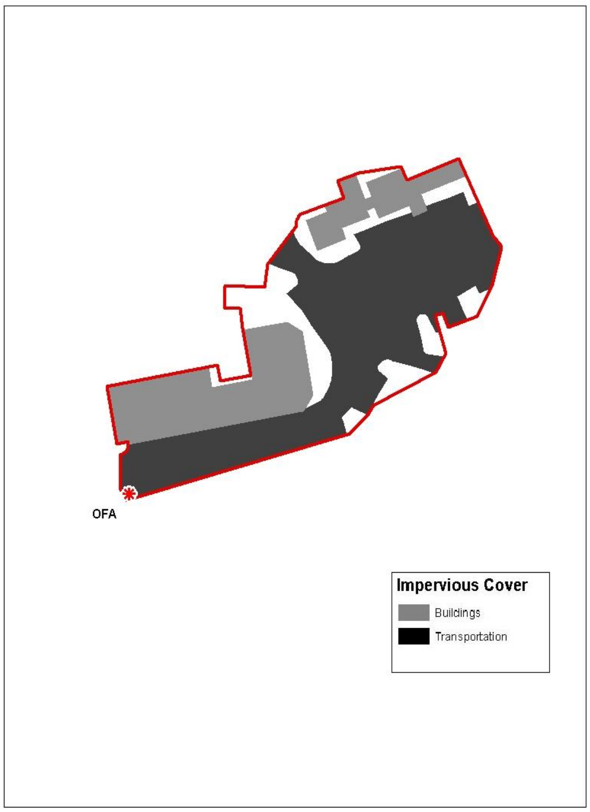
Site Summary

Site ID	OFA	
Site Name	Spyglass Office Site	
Latitude	30.2627	N
Longitude	97.7851	W
Predominate Land Use	Office	
Drainage Area	1.54	Acres
Impervious Cover	0.862	
Runoff-Rainfall Ratio	0.746	
Runoff-Rainfall Events	304	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	73.8	mg/L	27
VSS	45.9	mg/L	17
NO_2+NO_3	0.788	mg/L	18
NH_3	0.231	mg/L	18
TKN	1.998	mg/L	18
TN	2.791	mg/L	18
DP	0.138	mg/L	17
TP	0.293	mg/L	18
BOD	14.84	mg/L	18
COD	117.92	mg/L	18
TOC	18.49	mg/L	16
Cadmium	0.549	µg/L	11
Copper	11.175	µg/L	13
Lead	15.68	µg/L	13
Zinc	74.81	µg/L	13
F. Coliform	30,282	cfu/100m	9
F. Strep.	20,171	cfu/100m	12


OFA
Land Use
Office


WALLINGWOOD
SPYGLASS
OFA


OFA
Impervious Cover
Buildings
Transportation

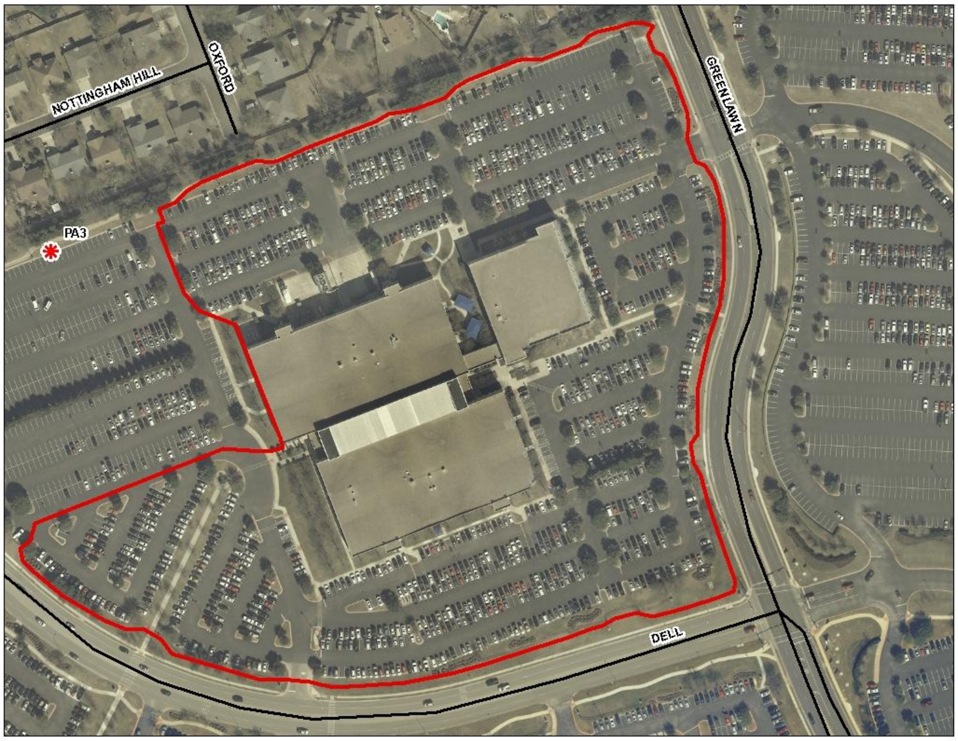
Dell Building #3 (PA3)

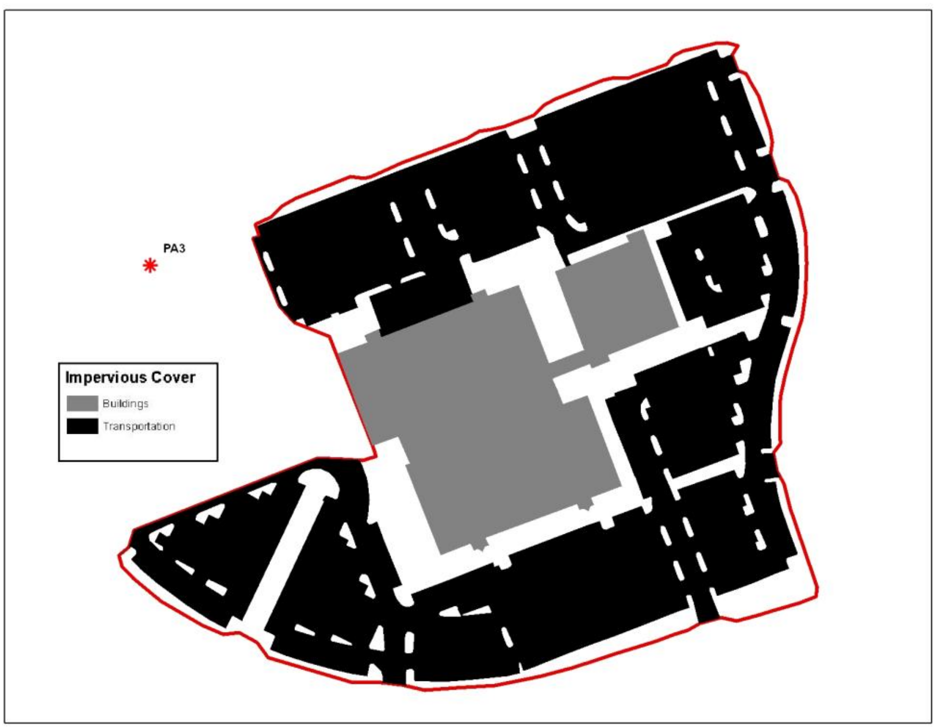
This station was located in the parking lot Of Dell Building #3 in Round Rock and was monitored between 2007 and 2008. The purpose of monitoring this location was to collect runoff samples before and after the parking lot was sealed with an asphalt sealant to evaluate the levels of PAH. The watershed is 18.13 acres and has an impervious cover of 78%. The primary land use is commercial. Flow was calculated using the Manning equation and samples were collected in a galvanized pipe which ran under the parking lot.

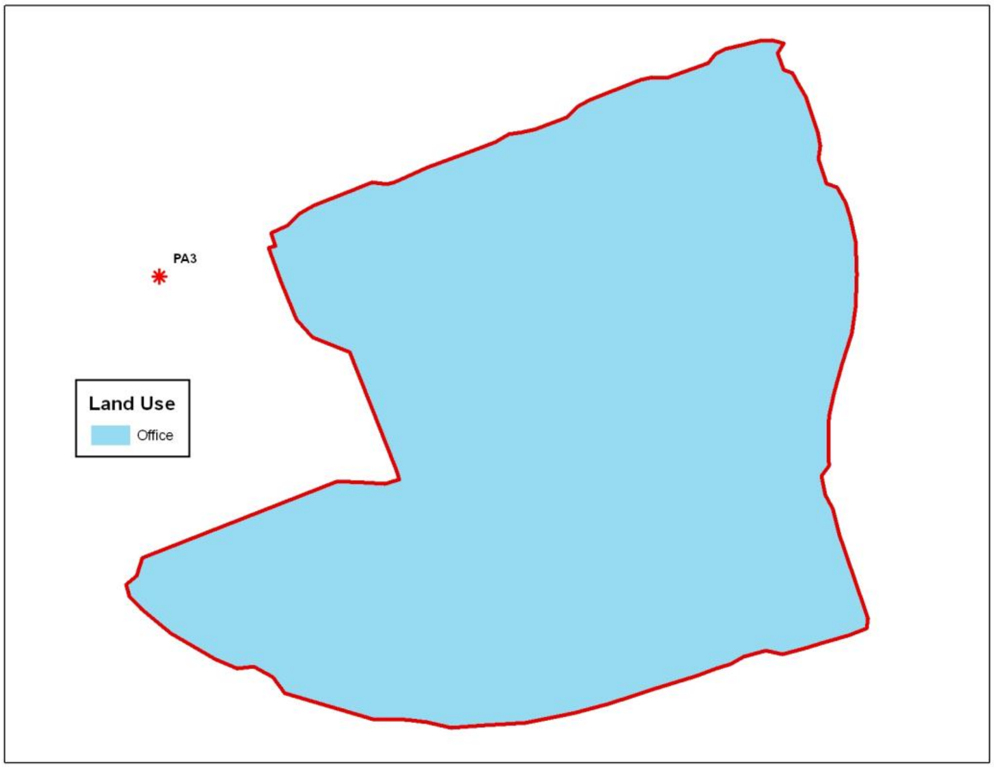
Site Summary

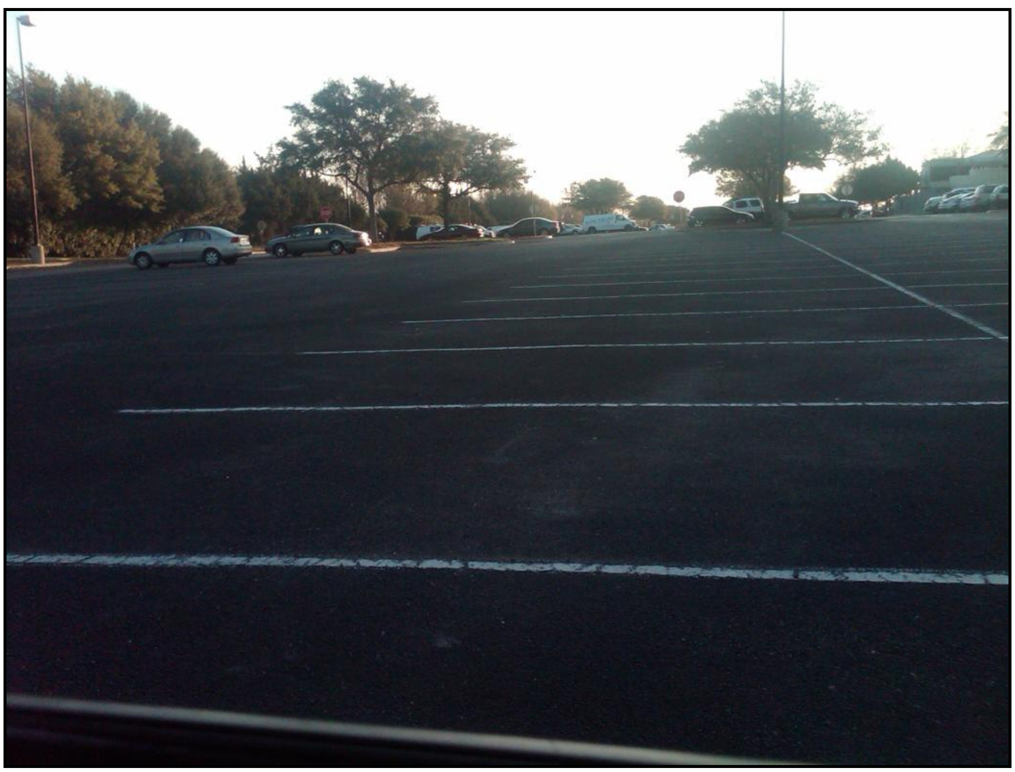
Site ID	PA3	
Site Name	Parking Area 3 at Dell - PAH	
Latitude	30.4875	N
Longitude	97.6654	W
Predominate Land Use	Office	
Drainage Area	18.13	Acres
Impervious Cover	0.7828	
Runoff-Rainfall Ratio	0.485	
Runoff-Rainfall Events	80	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	46.8	mg/L	15


NOTTINGHAM HILL
OXFORD
GREENLAWN
PA3
DELL


PA3
Impervious Cover
Buildings
Transportation


PA3
Land Use
Office



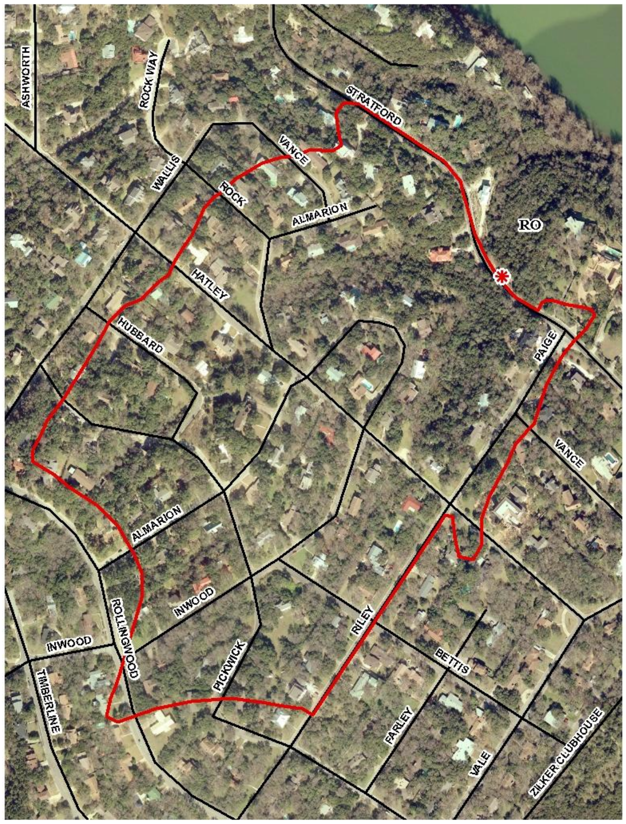
Rollingwood Monitoring Site (RO)

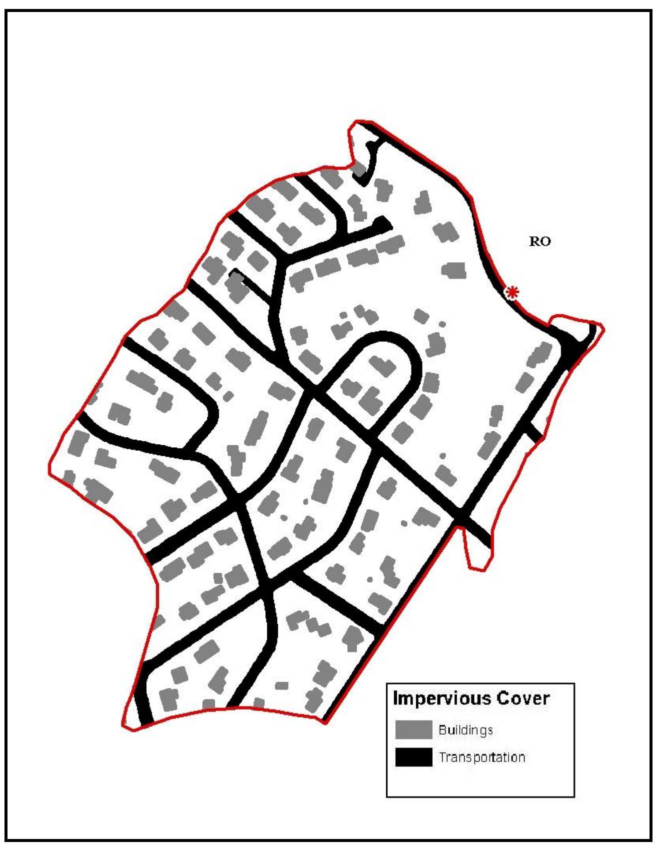
This station was located at 2623 Stratford Dr. and was operational from 1984 through 1988. Total drainage area is 62.9 acres with an impervious cover of 26%. The primary land use is single-family residential. The flow measurements collected at this site were made using an H-flume but were not used for rainfall-runoff calculations. This site was used as part of the National Urban Runoff Program (NURP) study.

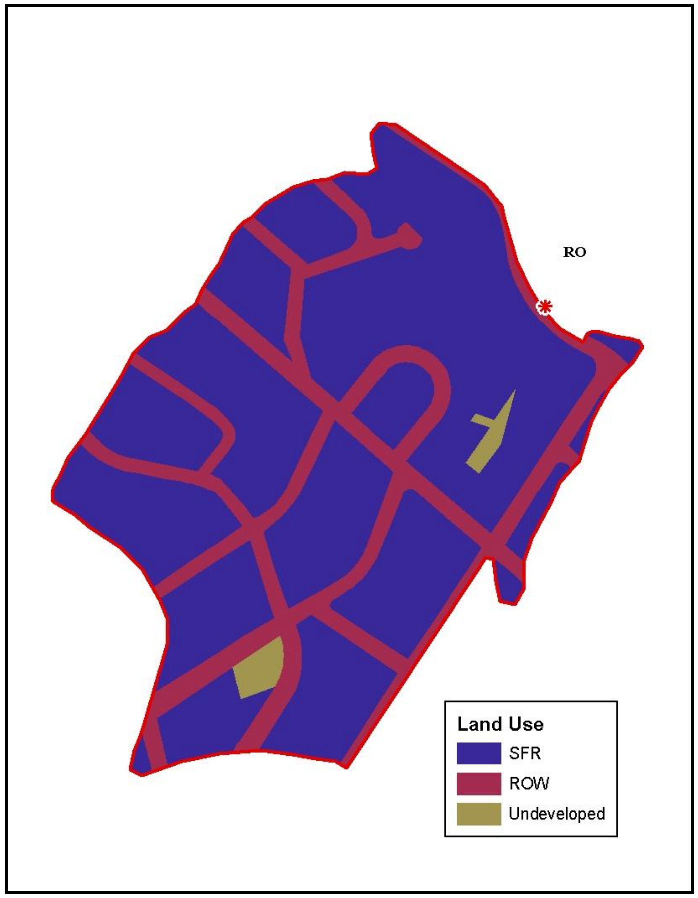
Site Summary

Site ID	RO	
Site Name	Rollingwood	
Latitude	30.2765	N
Longitude	97.7794	W
Predominate Land Use	Single-Family	
Drainage Area	62.9	Acres
Impervious Cover	0.2639	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	222.8	mg/L	16
NO_2+NO_3	0.762	mg/L	16
NH_3	0.167	mg/L	16
TKN	0.943	mg/L	16
TN	1.718	mg/L	16
TP	0.236	mg/L	16
BOD	6.48	mg/L	15
COD	37.65	mg/L	16
TOC	17.13	mg/L	16
Copper	7.646	µg/L	15
Lead	15.02	µg/L	15
Zinc	35.94	µg/L	15
F. Coliform	16,891	cfu/100m	15
F. Strep.	46,605	cfu/100m	16


ASHWORTH
ROCK WAY
STRATFORD
VANCE
WALLIS
ROCK
ALMARION
RO
HATLEY
HUBBARD
PAIGE
VANCE
ALMARION
INWOOD
ROLLINGWOOD
INWOOD
TIMBERLINE
PICKWICK
RILEY
BETTIS
FARLEY
VALE
ZILKER CLUBHOUSE


RO
Impervious Cover
Buildings
Transportation


RO
Land Use
SFR
ROW
Undeveloped


17 10:04 AM

Ross Road (RRI)

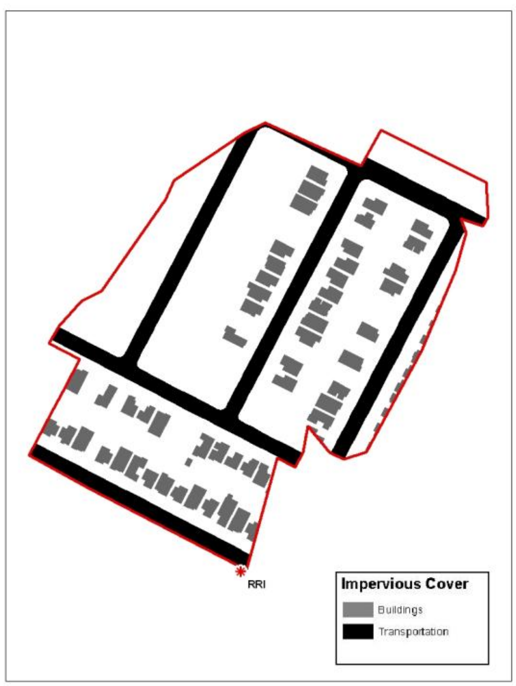
This monitoring station was located at 13605 Alysheba Drive and is the influent for a wet pond in the Berdoll Farms subdivision and was active between 2003 and 2007. The drainage area is 15.72 acres with 30% impervious cover and a single-family resident land use. Flow was measured in a 48 inch storm sewer pipe using Manning's Eqn. An area-velocity meter was also installed to verify the stage-discharge relationship.

Site Summary

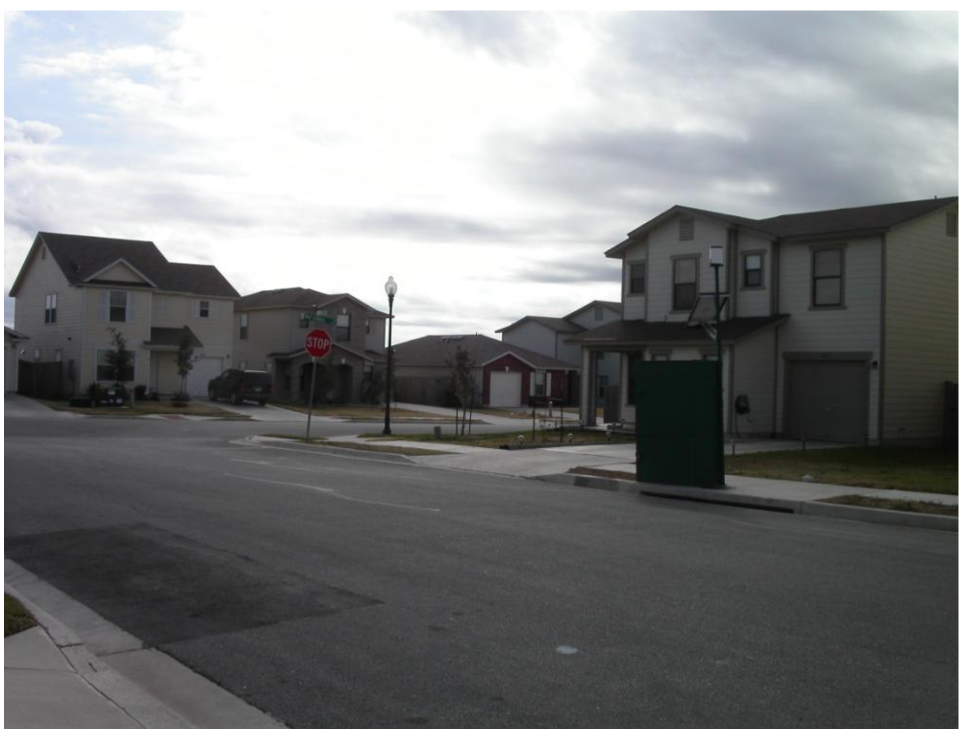
Site ID	RRI	
Site Name	Berdoll Farms Wet Pond	
Latitude	30.1705	N
Longitude	97.6102	W
Predominate Land Use	Single-Family	
Drainage Area	15.72	Acres
Impervious Cover	0.3047	
Runoff-Rainfall Ratio	0.362	
Runoff-Rainfall Events	270	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	268.3	mg/L	32
VSS	30.9	mg/L	32
NO_2+NO_3	0.967	mg/L	32
NH_3	0.417	mg/L	32
TKN	1.632	mg/L	32
TN	2.577	mg/L	32
DP	0.240	mg/L	32
TP	0.538	mg/L	32
COD	101.12	mg/L	32
TOC	22.35	mg/L	32
Cadmium	0.485	µg/L	24
Copper	11.220	µg/L	33
Lead	4.34	µg/L	33
Zinc	54.93	µg/L	33


AFFIRMED
GILWELL
THUNDER GULCH
SUNDAY SILENCE
VICTORY GALLOP
WAR ADMIRAL
SEA BISCUIT
ALYSHEBA
RRI
COOMES


RRI
Impervious Cover
Buildings
Transportation


RRI
Land Use
SFR
ROW
Undeveloped


STOP

Hargrave (S1M)

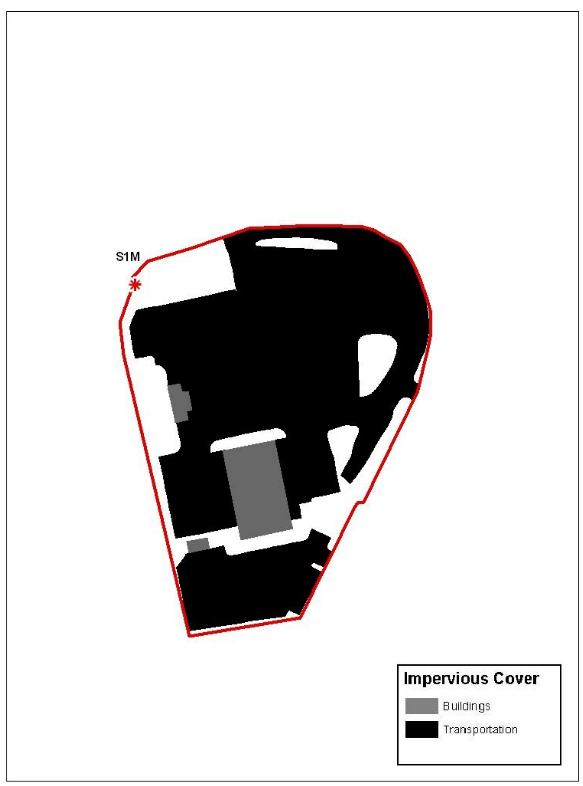
This station monitored runoff from a 5.87 acre industrial site (the City's Fleet Service Center) with 88% impervious cover. The station was active between 1995 and 1999. The station was mounted on a trailer that housed all of the monitoring equipment which could be used elsewhere. A 90° V-notch weir served as a flow measurement structure.

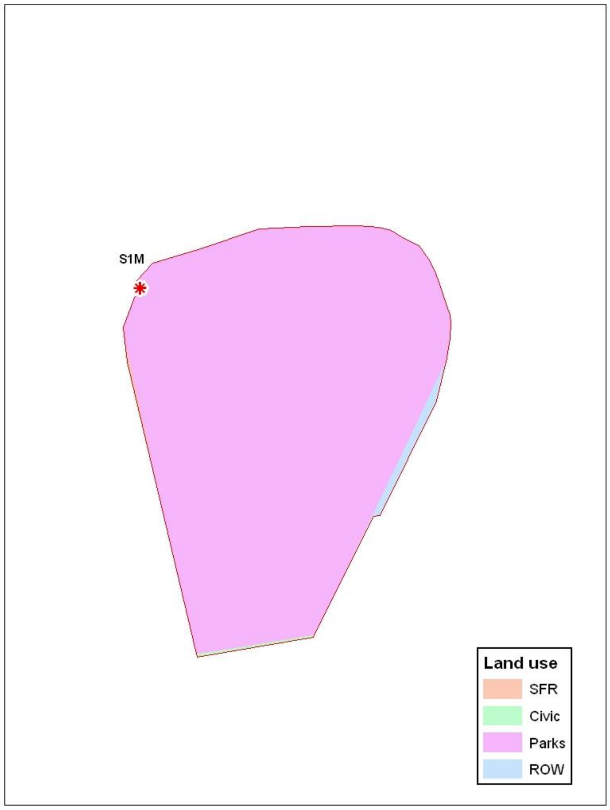
Site Summary

Site ID	S1M	
Site Name	Hargraves Service Center	
Latitude	30.2749	N
Longitude	97.7100	W
Predominate Land Use	Industrial	
Drainage Area	5.87	Acres
Impervious Cover	0.8818	
Runoff-Rainfall Ratio	0.484	
Runoff-Rainfall Events	186	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	86.7	mg/L	29
VSS	20.5	mg/L	29
NO_2+NO_3	0.543	mg/L	28
NH_3	0.173	mg/L	29
TKN	1.047	mg/L	29
TN	1.563	mg/L	28
DP	0.120	mg/L	29
TP	0.255	mg/L	28
BOD	8.38	mg/L	28
COD	87.01	mg/L	29
TOC	14.84	mg/L	29
Cadmium	0.607	µg/L	29
Copper	11.347	µg/L	29
Lead	19.49	µg/L	29
Zinc	61.36	µg/L	29
F. Coliform	39,119	cfu/100m	27
F. Strep.	263,503	cfu/100m	27


12TH
ALEXANDER
WHEAT
S1M
HARGRAVE
BEDFORD
EUNEVA
GRAHAM
SOL WILSON
WALNUT
BEDFORD


S1M
Impervious Cover
Buildings
Transportation


S1M
Land use
SFR
Civic
Parks
ROW

StormCeptor Influent (SCA)

This station was installed at 40th Street and Burnet Road to measure the influent to a StormCeptor BMP. The station was active 2006-2010. The 5.56 acre watershed has 41% impervious cover and a single-family residential land use. A two foot Palmer-Boulus flume was installed in the storm sewer to measure flow.

Site Summary

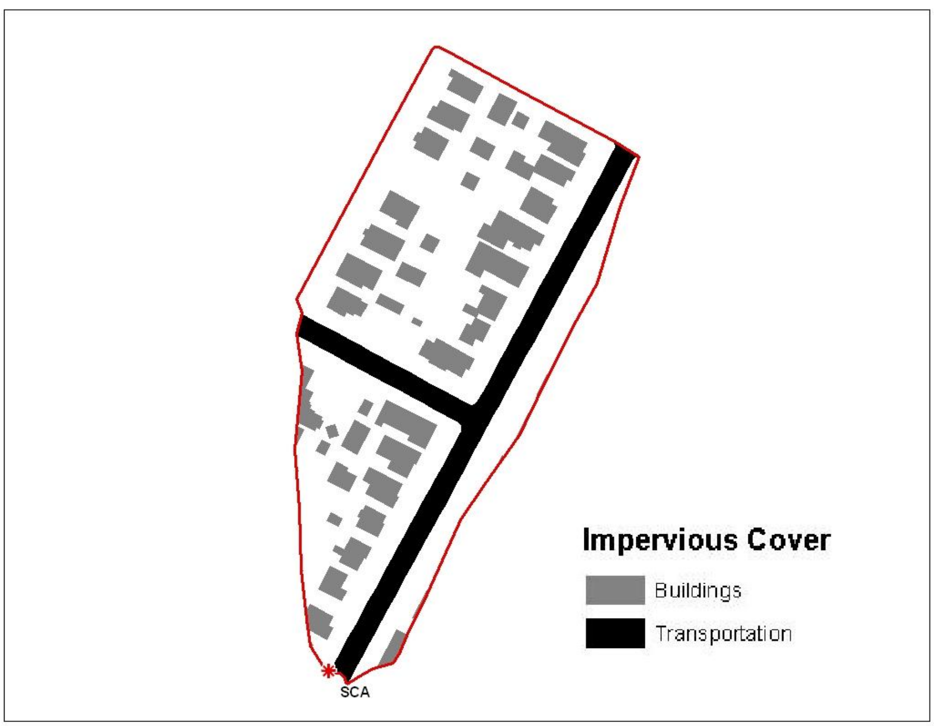
Site ID	SCA
Site Name	StormCeptor BMP Influent
Latitude	30.3097 N
Longitude	97.7452 W
Predominate Land Use	Single-Family
Drainage Area	5.56 Acres
Impervious Cover	0.4088
Runoff-Rainfall Ratio	0.224
Runoff-Rainfall Events	130
Recharge Zone	

Parameter	Mean EMC	Units	Count
TSS	148.6	mg/L	27
VSS	67.7	mg/L	27
NO_2+NO_3	0.336	mg/L	27
NH_3	0.172	mg/L	27
TKN	3.735	mg/L	27
TN	4.050	mg/L	27
DP	0.414	mg/L	27
TP	0.884	mg/L	27
COD	141.49	mg/L	27
TOC	28.52	mg/L	27
Cadmium	0.197	µg/L	27
Copper	11.026	µg/L	27
Lead	10.76	µg/L	27
Zinc	77.44	µg/L	27


RAMSEY
ROSEDALE
42ND
41ST
BURNET
LEWIS
MEDICAL
40TH
SCA


STOP


Land Use
SFR
ROW
SCA


Impervious Cover
Buildings
Transportation
SCA

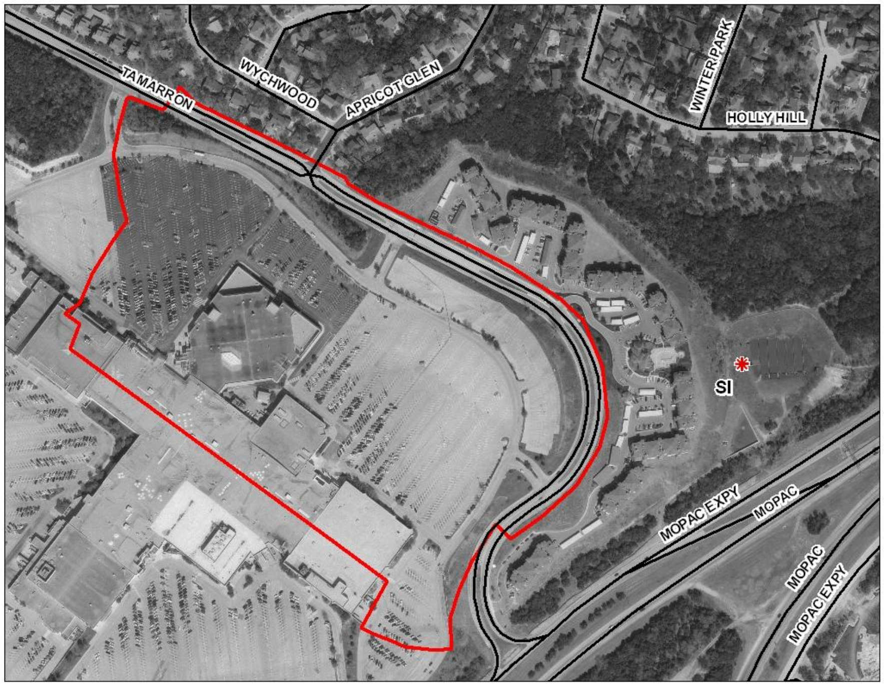
Barton Creek Square Mall (SI)

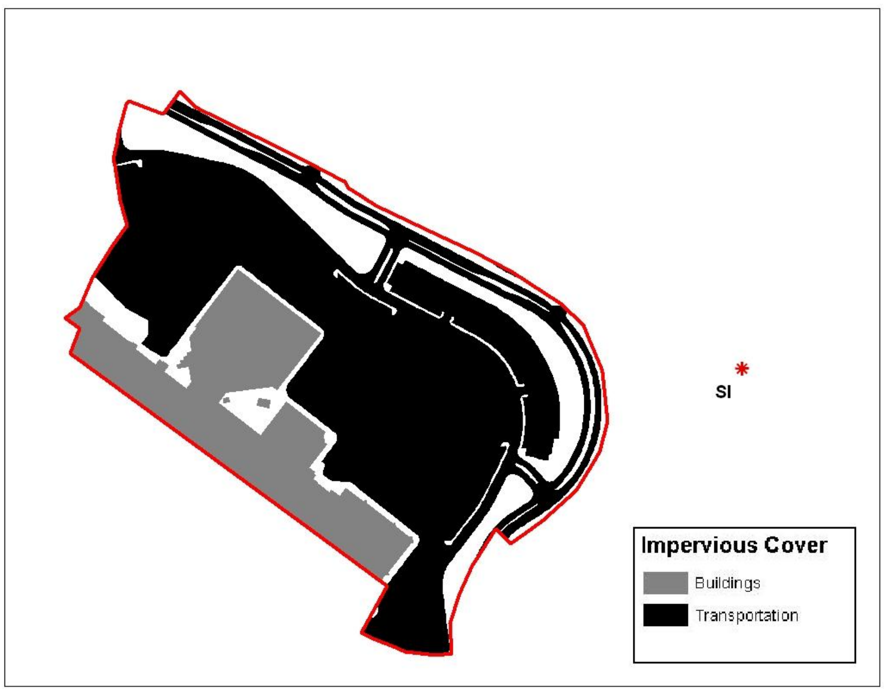
This monitoring station was operated during 1985-1987 and is the influent for a sand filter treating runoff from Barton Creek Square Mall. The 37 acre watershed is 86% impervious, is predominantly commercial land use and is in the recharge zone. The flow rate was estimated using open channel flow relationships but the accuracy was not sufficient for these data to be used for runoff-rainfall analyses.

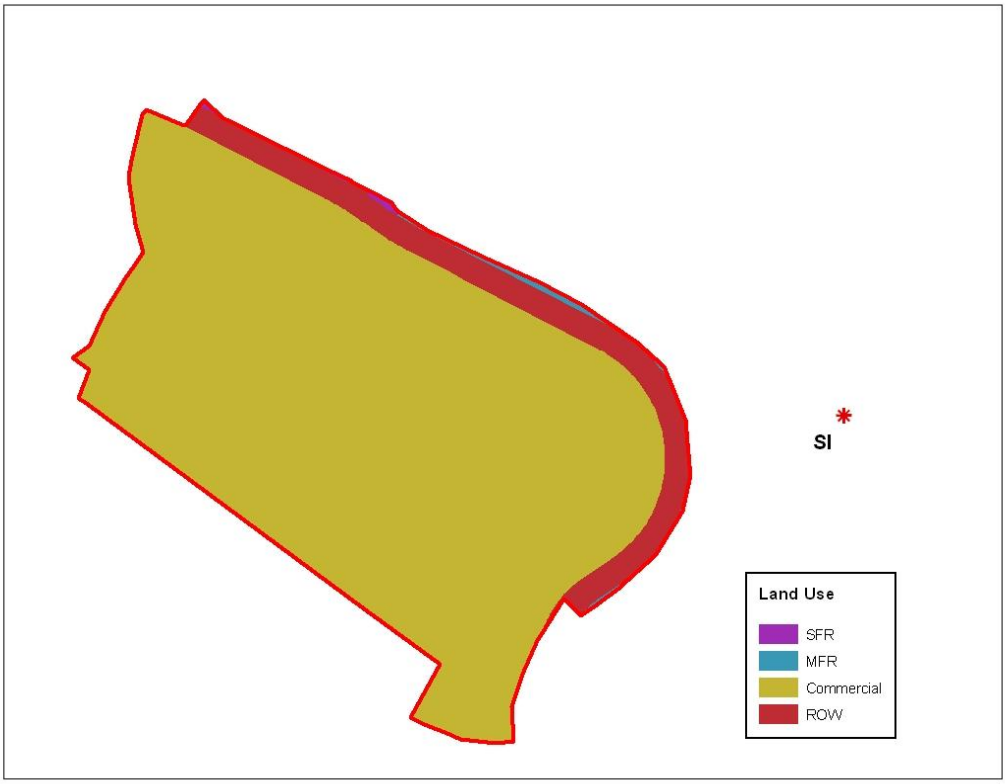
Site Summary

Site ID	SI	
Site Name	Barton Creek Square Mall	
Latitude	30.2584	N
Longitude	97.8009	W
Predominate Land Use	Commercial	
Drainage Area	47	Acres
Impervious Cover	0.86	
Runoff-Rainfall Ratio	0.781	
Runoff-Rainfall Events	33	
Recharge Zone	Yes	

Parameter	Mean EMC	Units	Count
TSS	59.5	mg/L	22
NO_2+NO_3	0.335	mg/L	22
NH_3	0.192	mg/L	22
TKN	0.708	mg/L	20
TN	1.039	mg/L	20
TP	0.116	mg/L	22
BOD	11.92	mg/L	21
COD	29.32	mg/L	22
TOC	9.23	mg/L	22
Copper	6.559	µg/L	22
Lead	31.61	µg/L	22
Zinc	110.99	µg/L	22
F. Coliform	16,530	cfu/100m	21
F. Strep.	14,205	cfu/100m	21


TAMARRON
WYCHWOOD
APRICOT GLEN
WINTER PARK
HOLLY HILL
SI
MOPAC EXPY
MOPAC
MOPAC
MOPAC EXPY


SI
Impervious Cover
Buildings
Transportation


SI
Land Use
SFR
MFR
Commercial
ROW

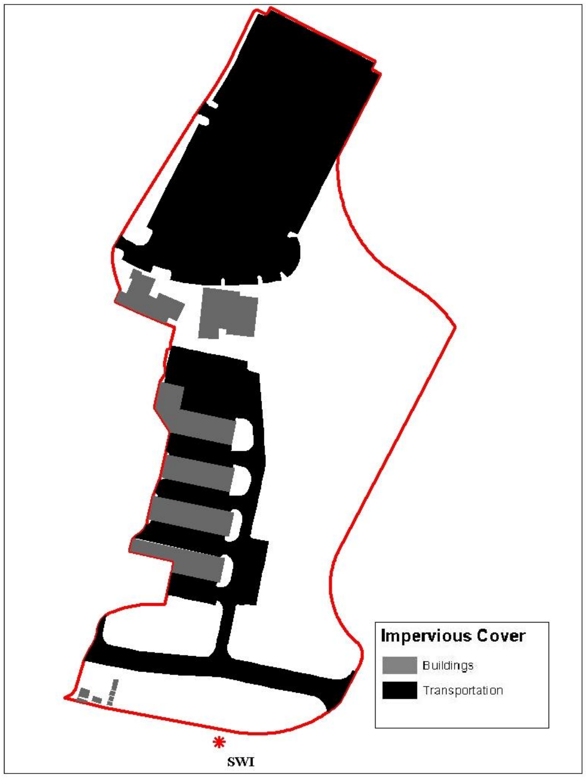
St. Elmo Wet Pond – East Influent (SWI)

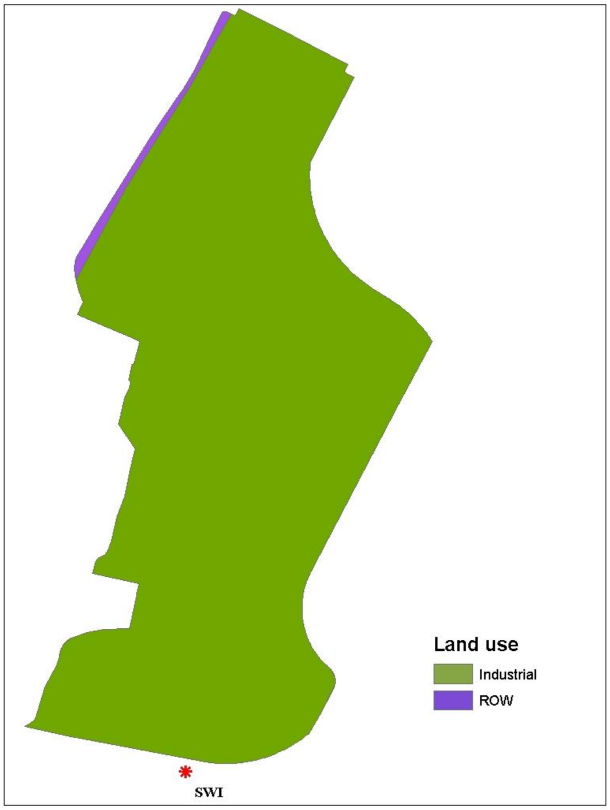
This station was located at the east influent of the wet pond at the St. Elmo Service Center and was monitored between 1995 and 1997. The 16.41 acre watershed has 60% impervious cover and the land use is industrial. Flow was measured by trapezoidal flume. The other influent to the wet pond is SWJ.

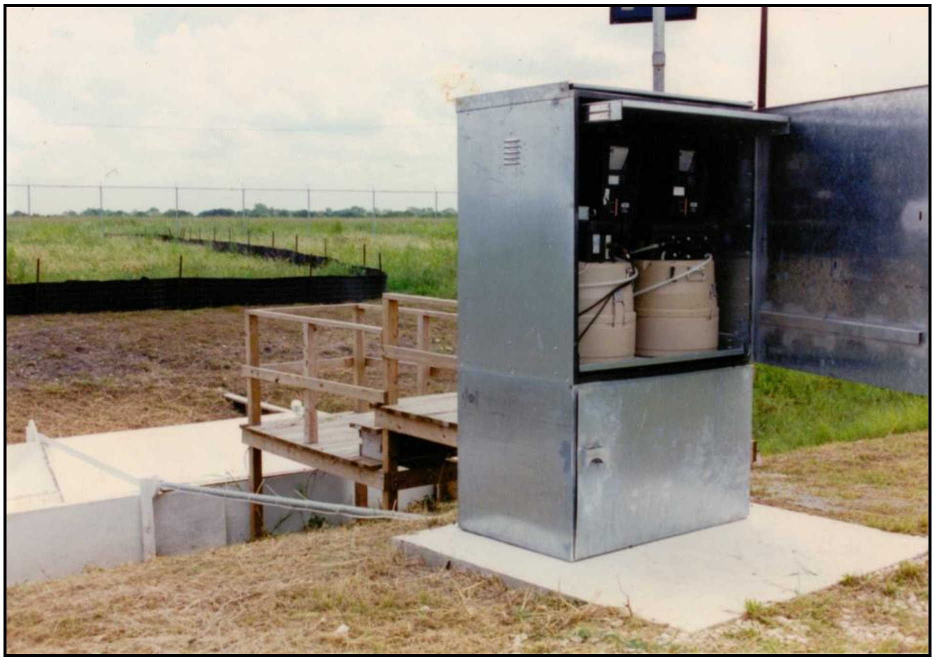
Site Summary

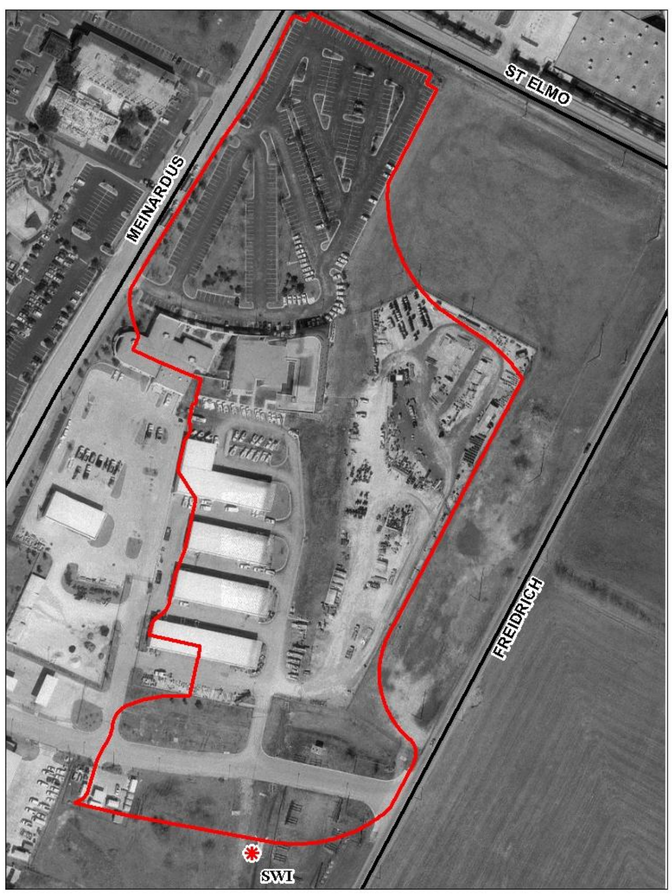
Site ID	SWI
Site Name	St. Elmo Wet Pond East
Latitude	30.2076 N
Longitude	97.7519 W
Predominate Land Use	Industrial
Drainage	16.41 Acres
Impervious Cover	0.604
Runoff-Rainfall Ratio	0.5407
Runoff-Rainfall Events	100
Recharge Zone	No

Parameter	Mean EMC	Units	Count
TSS	122.6	mg/L	13
VSS	14.3	mg/L	13
NO_2+NO_3	0.559	mg/L	12
NH_3	0.235	mg/L	13
TKN	0.981	mg/L	13
TN	1.542	mg/L	12
DP	0.071	mg/L	10
TP	0.245	mg/L	13
BOD	6.49	mg/L	12
COD	49.26	mg/L	13
TOC	8.64	mg/L	12
Cadmium	0.646	ug/L	13
Copper	10.498	ug/L	13
Lead	7.72	ug/L	13
Zinc	91.09	ug/L	13
F. Coliform	44,974	cfu/100m	6
F. Strep.	64,599	cfu/100m	7


Impervious Cover
Buildings
Transportation
SWI


Land use
Industrial
ROW
SWI




ST ELMO
MEINARDUS
FRIEDRICH
SWI

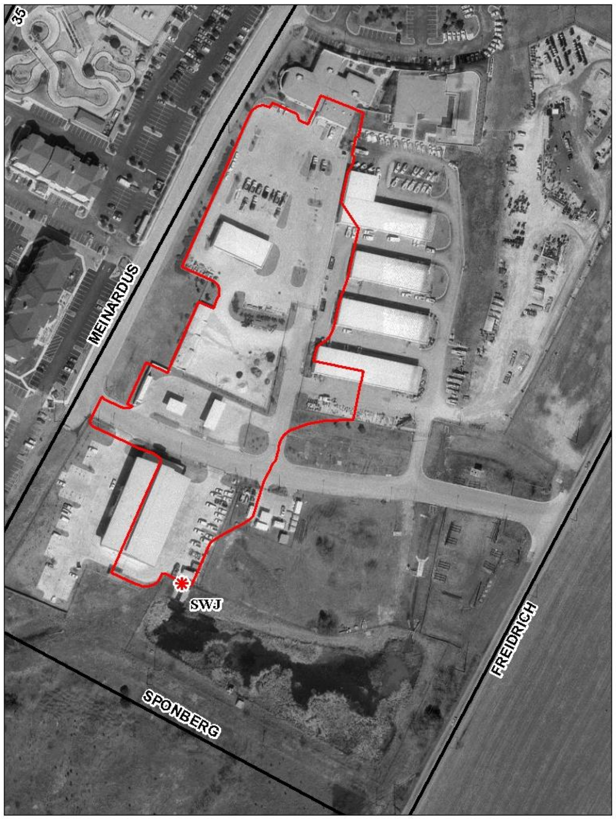
St. Elmo Wet Pond - West Influent (SWJ)

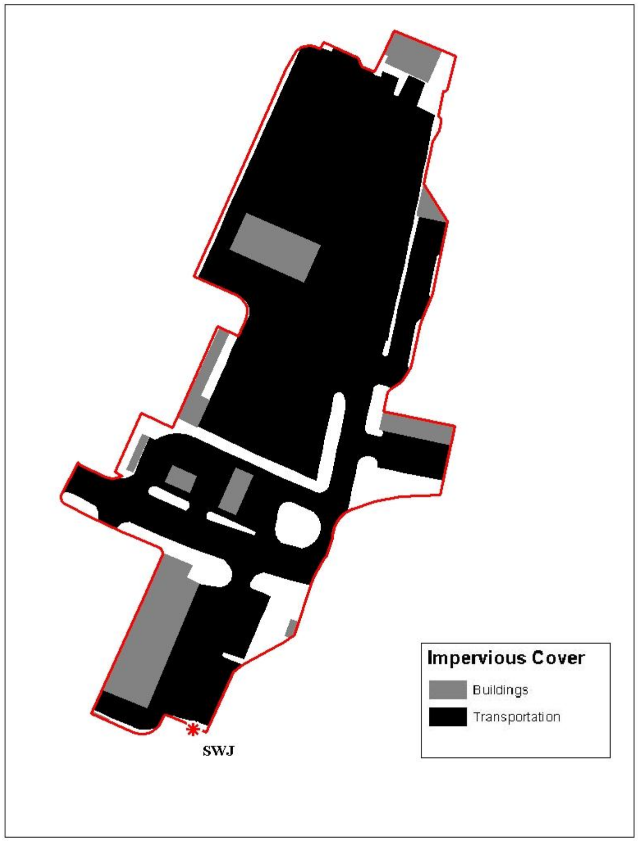
This station was located at the west influent of the wet pond at the St. Elmo Service Center and was monitored between 1995 and 1997. The 5.82 acre watershed has 84% impervious cover and the land use is industrial. Flow was measured in the 48 inch round pipe using Manning's Eqn. Because water in the pond submerged the pipe an attempt was made to use an area-velocity meter but this was not successful. Data from this station were not used for runoff-rainfall analyses.

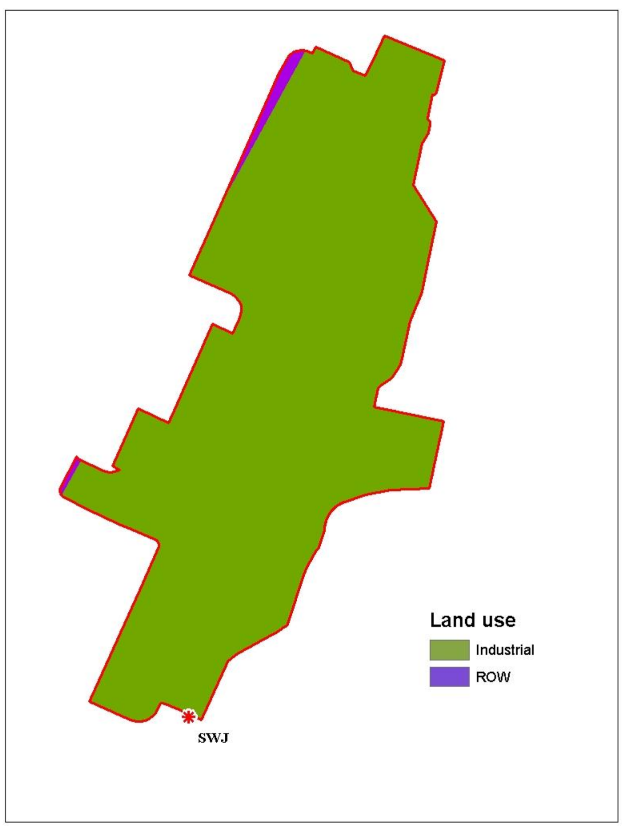
Site Summary

Site ID	SWJ	
Site Name	St. Elmo Wet Pond West	
Latitude	30.2076	N
Longitude	97.7534	W
Predominate Land Use	Industrial	
Drainage Area	5.82	Acres
Impervious Cover	0.8384	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	150.2	mg/L	13
VSS	24.3	mg/L	13
NO_2+NO_3	0.872	mg/L	12
NH_3	0.370	mg/L	13
TKN	2.005	mg/L	13
TN	2.498	mg/L	12
DP	0.036	mg/L	12
TP	0.270	mg/L	13
BOD	13.55	mg/L	11
COD	86.96	mg/L	13
TOC	11.99	mg/L	12
Cadmium	0.551	µg/L	13
Copper	29.191	µg/L	13
Lead	14.74	µg/L	13
Zinc	183.44	µg/L	13
F. Coliform	35,064	cfu/100m	11
F. Strep.	50,485	cfu/100m	10


35
MEINARDUS
SWJ
SPONBERG
FREIDRICH


Impervious Cover
Buildings
Transportation
SWJ


Land use
Industrial
ROW
SWJ

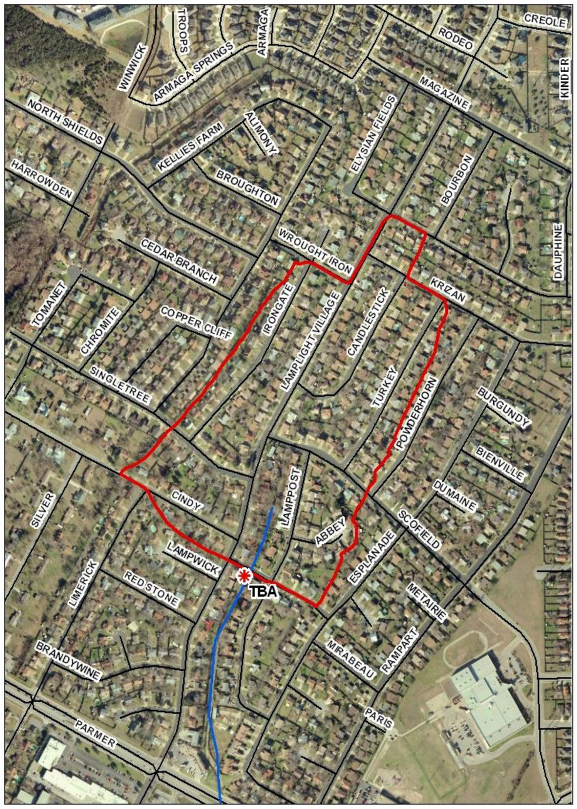
Tar Branch (TBA)

Tar Branch monitoring station was located at 2105 ½ Carriage Park Lane in the Walnut Creek watershed and was monitored 1996 to 2000. Total drainage to the station is 49.4 acres with and impervious cover of 45%, the land use is in single-family resident. Flow was measured using a compound weir consisting of a 90° V-notch weir and a larger rectangular weir without end contractions.

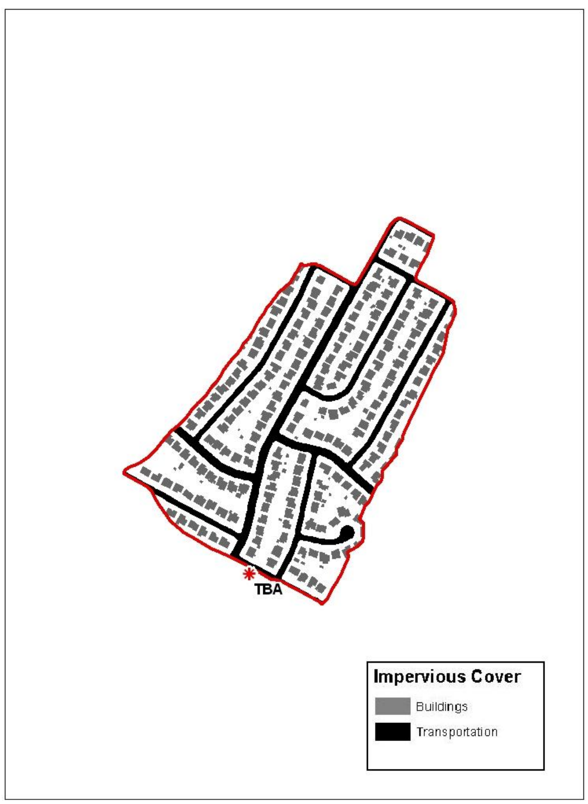
Site Summary

Site ID	TBA	
Site Name	Tar Branch	
Latitude	30.4189	N
Longitude	97.6941	W
Predominate Land Use	Single-Family	
Drainage Area	49.42	Acres
Impervious Cover	0.4521	
Runoff-Rainfall Ratio	0.191	
Runoff-Rainfall Events	210	
Recharge Zone	No	

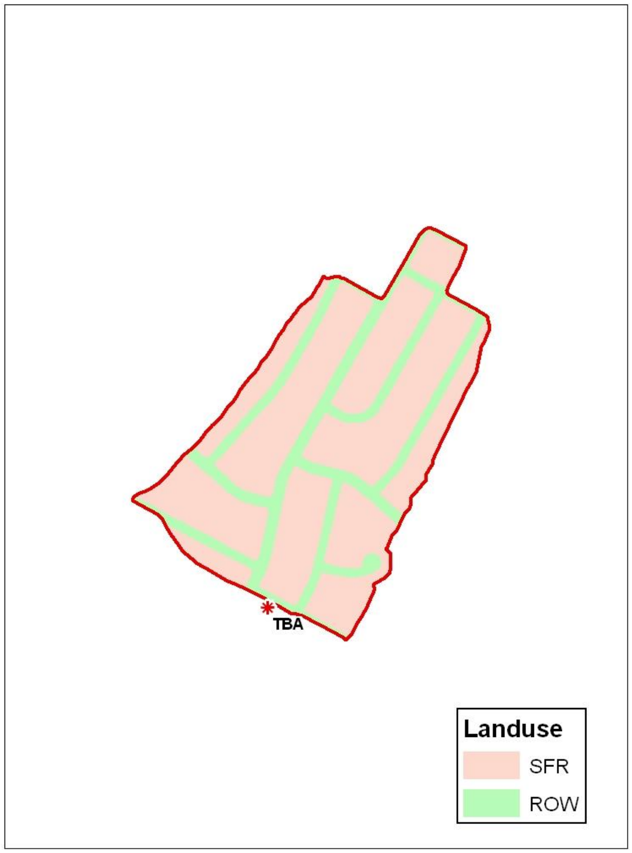
Parameter	**Mean EMC**	**Units**	**Count**
TSS	195.8	mg/L	30
VSS	34.9	mg/L	28
NO_2+NO_3	0.602	mg/L	28
NH_3	0.218	mg/L	28
TKN	1.536	mg/L	30
TN	2.158	mg/L	28
DP	0.146	mg/L	29
TP	0.417	mg/L	28
BOD	12.04	mg/L	30
COD	85.74	mg/L	30
TOC	7.81	mg/L	27
Cadmium	0.636	µg/L	31
Copper	8.499	µg/L	31
Lead	13.22	µg/L	31
Zinc	88.94	µg/L	31
F. Coliform	55,847	cfu/100m	27
F. Strep.	102,733	cfu/100m	25



CREOLE
RODEO
TROOPS
ARMAGA
WINWICK
ARMAGA SPRINGS
KINDER
MAGAZINE
NORTH SHIELDS
KELLIES FARM
ALIMONY
ELYSIAN FIELDS
HARROWDEN
BROUGHTON
BOURBON
DAUPHINE
WROUGHT IRON
CEDAR BRANCH
KRIZAN
TOMANET
CHROMITE
COPPER CLIFF
IRONGATE
LAMPLIGHT VILLAGE
CANDLESTICK
SINGLETREE
TURKEY
POWDERHORN
BURGUNDY
BIENVILLE
DUMAINE
CINDY
LAMPPOST
SILVER
ABBEY
SCOFIELD
ESPLANADE
LAMPWICK
LIMERICK
RED STONE
TBA
METAIRIE
BRANDYWINE
MIRABEAU
RAMPART
PARIS
PARMER



TBA
Impervious Cover
Buildings
Transportation


TBA
Landuse
SFR
ROW

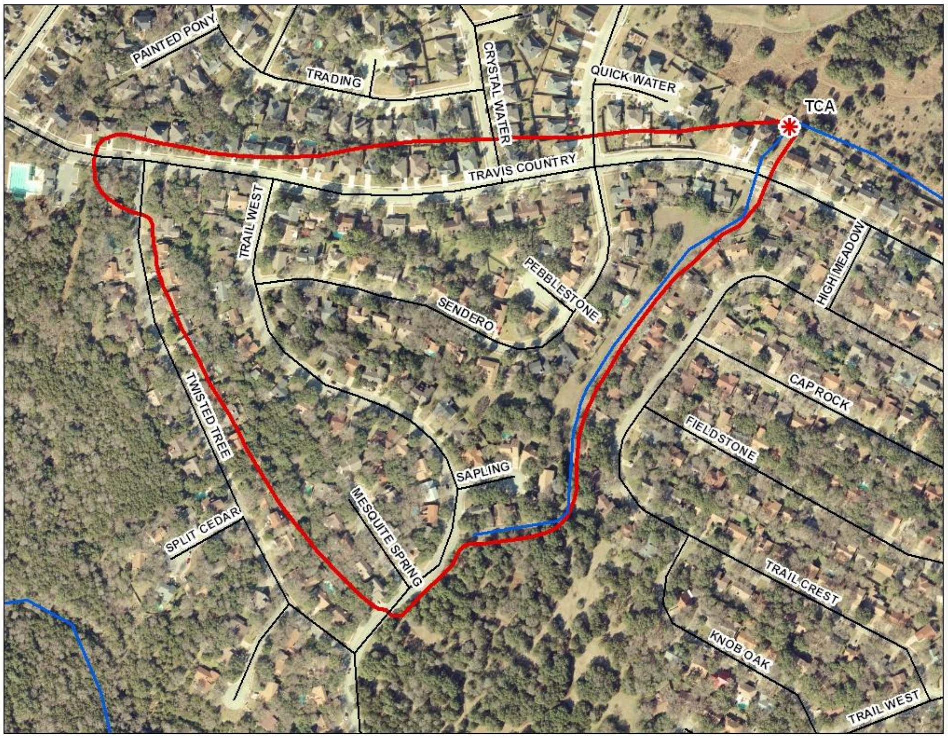
Travis Country Channel (TCA)

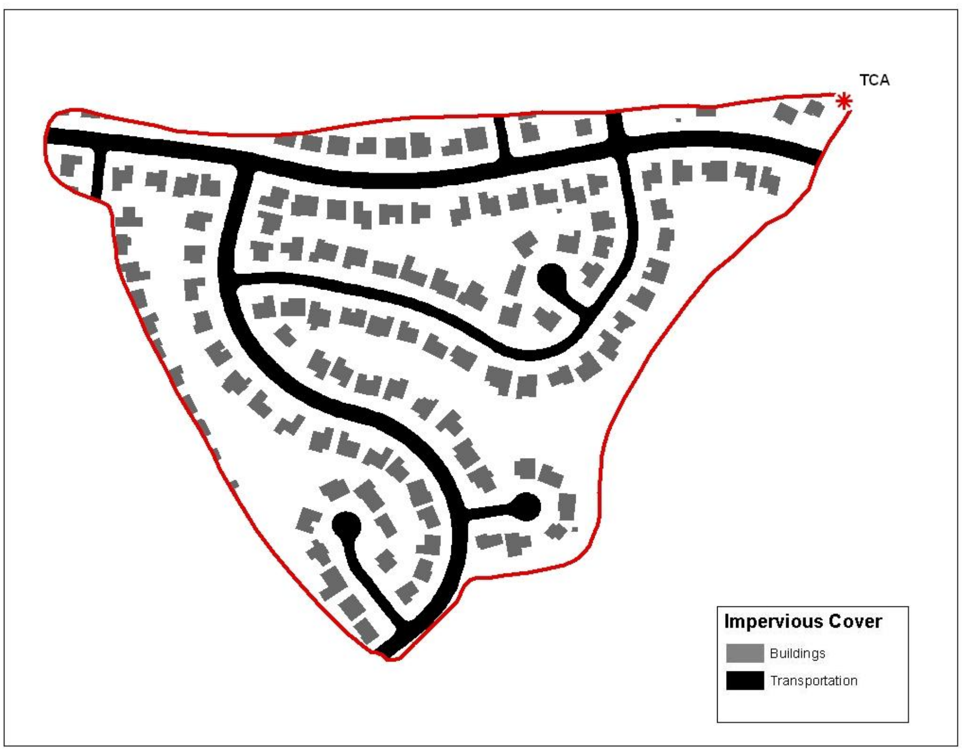
This monitoring station was located at 4157 ½ Travis County Circle in Barton Creek recharge zone and was operated during 1993-1997. The watershed is 40.71 acres with an impervious cover of 37%. The land use is single-family residential. Flow was measured using 90° V-Notch Weir & Rectangular Weir with End Contractions.

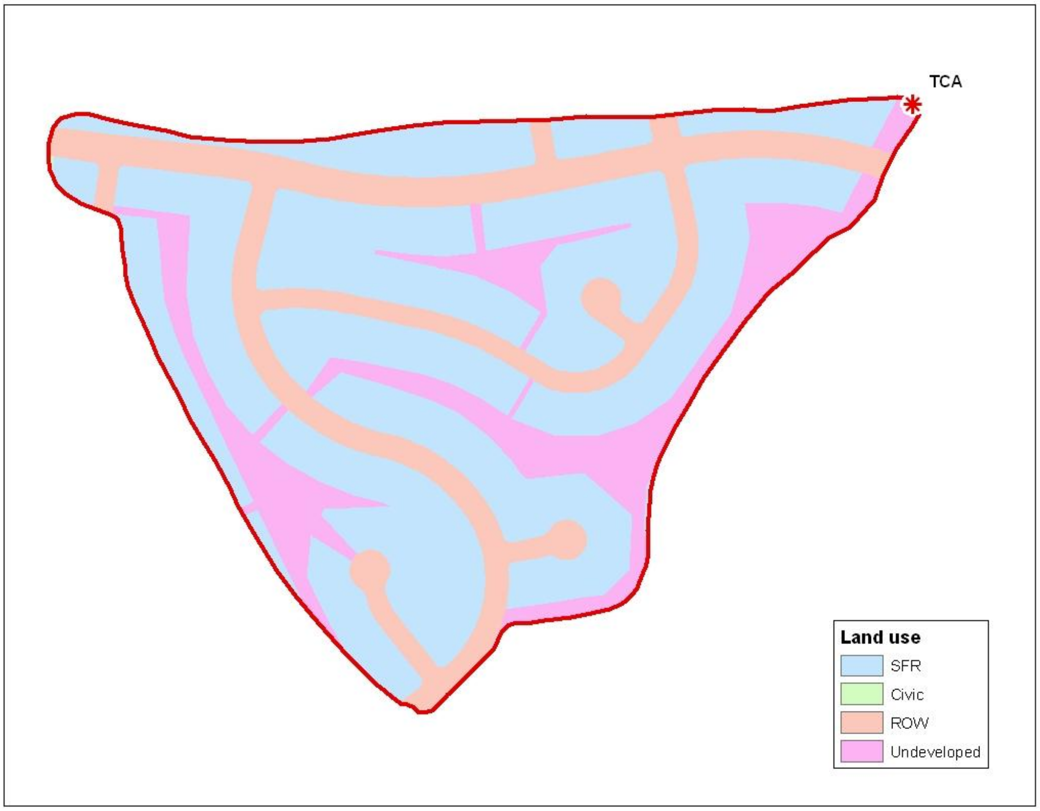
Site Summary

Site ID	TCA	
Site Name	Travis Country Channel	
Latitude	30.2526	N
Longitude	97.8277	W
Predominate Land Use	Single-Family	
Drainage Area	40.71	Acres
Impervious Cover	0.3736	
Runoff-Rainfall Ratio	0.213	
Runoff-Rainfall Events	189	
Recharge Zone	Yes	

Parameter	Mean EMC	Units	Count
TSS	60.5	mg/L	26
VSS	12.1	mg/L	25
NO_2+NO_3	0.448	mg/L	25
NH_3	0.118	mg/L	26
TKN	0.979	mg/L	27
TN	1.467	mg/L	25
DP	0.140	mg/L	19
TP	0.240	mg/L	27
BOD	5.31	mg/L	21
COD	37.05	mg/L	27
TOC	8.10	mg/L	23
Cadmium	0.453	µg/L	20
Copper	4.644	µg/L	21
Lead	9.29	µg/L	21
Zinc	22.45	µg/L	20
F. Coliform	87,292	cfu/100m	15
F. Strep.	47,373	cfu/100m	15


PAINTED PONY
TRADING
CRYSTAL WATER
QUICK WATER
TCA
TRAVIS COUNTRY
TRAIL WEST
PEBBLESTONE
SENDERO
HIGH MEADOW
CAP ROCK
FIELDSTONE
TWISTED TREE
SAPLING
MESQUITE SPRING
SPLIT CEDAR
TRAIL CREST
KNOB OAK
TRAIL WEST


TCA
Impervious Cover
Buildings
Transportation


TCA
Land use
SFR
Civic
ROW
Undeveloped

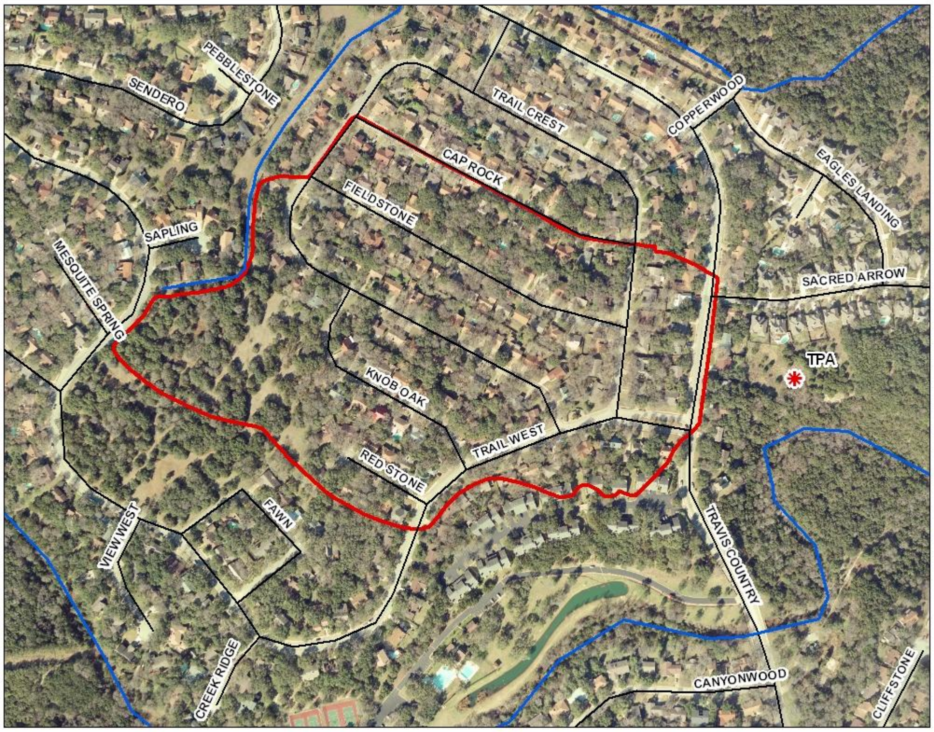
Travis Country Pipe (TPA)

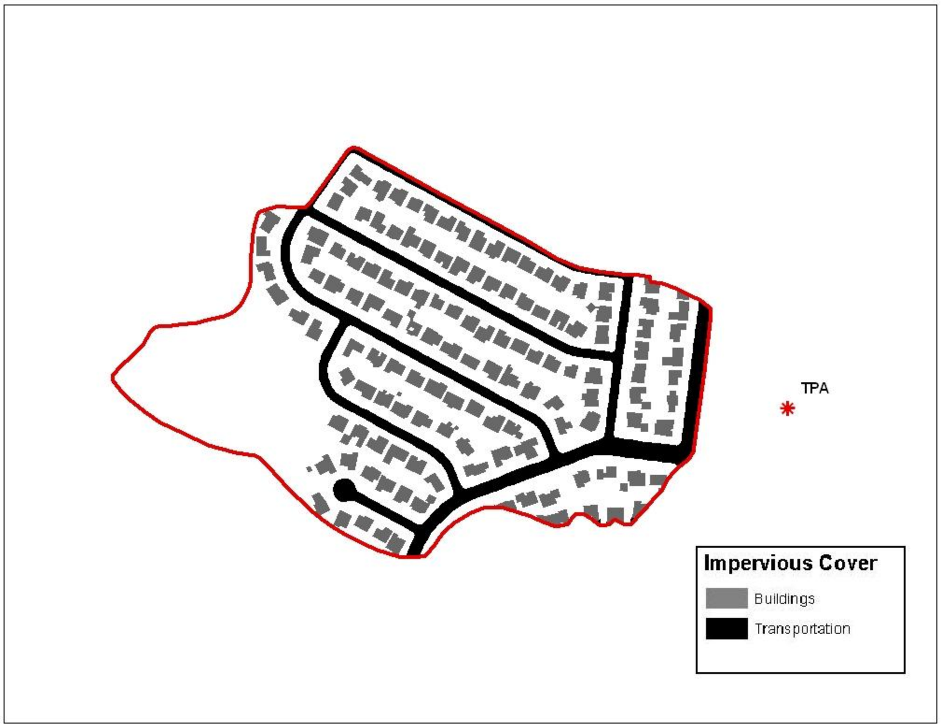
This monitoring station was located at 4009 ½ Gaines Ranch Road in the Barton Creek recharge zone and was operated during 1993-1997. The 41.6 acre watershed has 41.4% impervious cover and is predominantly single-family residential. Flow was measured using a 4 ft rectangular weir without end contractions.

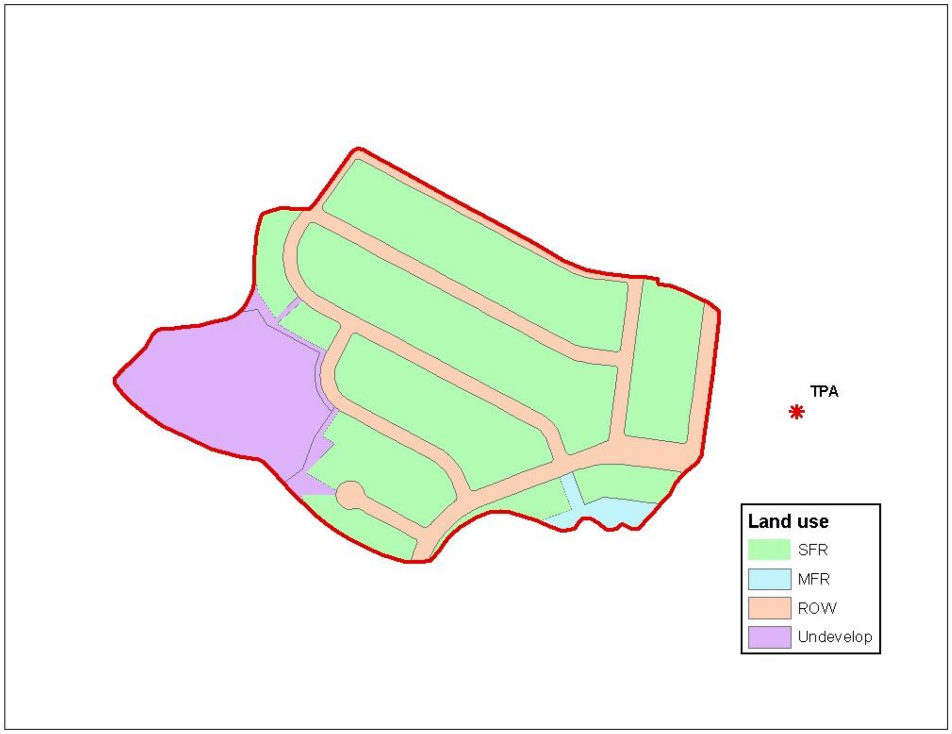
Site Summary

Site ID	TPA	
Site Name	Travis Country Pipe	
Latitude	30.2482	N
Longitude	97.8238	W
Predominate Land Use	Single-Family	
Drainage Area	41.6	Acres
Impervious Cover	0.4145	
Runoff-Rainfall Ratio	0.221	
Runoff-Rainfall Events	193	
Recharge Zone	Yes	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	134.7	mg/L	25
VSS	42.8	mg/L	24
NO_2+NO_3	0.726	mg/L	24
NH_3	0.305	mg/L	23
TKN	2.209	mg/L	24
TN	2.989	mg/L	22
DP	0.212	mg/L	20
TP	0.444	mg/L	24
BOD	18.18	mg/L	24
COD	77.44	mg/L	24
TOC	11.48	mg/L	23
Cadmium	0.530	µg/L	18
Copper	8.188	µg/L	20
Lead	12.08	µg/L	20
Zinc	51.77	µg/L	21
F. Coliform	174,751	cfu/100m	14
F. Strep.	191,033	cfu/100m	16


PEBBLESTONE
SENDERO
TRAIL CREST
COPPERWOOD
CAP ROCK
EAGLES LANDING
FIELDSTONE
SAPLING
MESQUITE SPRING
SACRED ARROW
TPA
KNOB OAK
TRAIL WEST
RED STONE
FAWN
VIEW WEST
TRAVIS COUNTRY
CANYONWOOD
CLIFFSTONE
CREEK RIDGE


TPA
Impervious Cover
Buildings
Transportation


TPA
Land use
SFR
MFR
ROW
Undevelop

5^{th} Street and Red River (W5A)

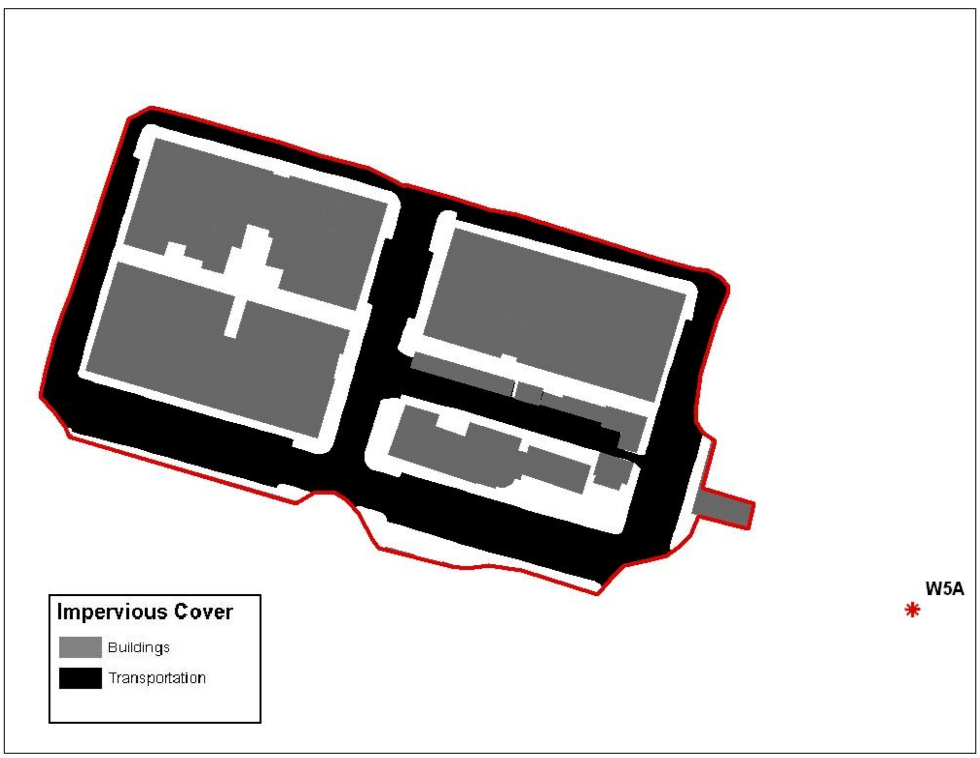
This monitoring station was located at 5^{th} Street and Red River in Waller Creek Watershed and was operated during 1993-1999. The watershed is 6.66 acres with 87% impervious cover. The land use is downtown commercial and covers a portion of the East 6^{th} Street entertainment area. Flow was estimated in the storm sewer using Manning's Eqn.

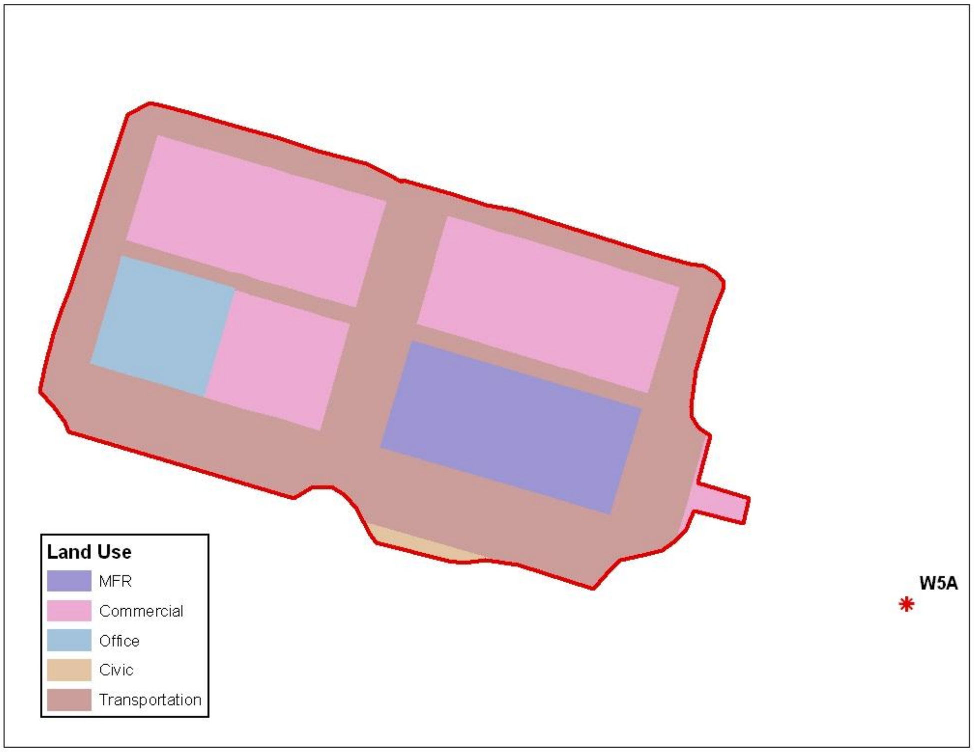
Site Summary

Site ID	W5A
Site Name	5th St. @ Red River
Latitude	30.2657 N
Longitude	97.7376 W
Predominate Land Use	Commercial
Drainage Area	6.66 Acres
Impervious Cover	0.8708
Runoff-Rainfall Ratio	0.741
Runoff-Rainfall Events	320
Recharge Zone	No

Parameter	Mean EMC	Units	Count
TSS	182.4	mg/L	28
VSS	67.7	mg/L	28
NO_2+NO_3	0.796	mg/L	30
NH_3	0.446	mg/L	29
TKN	3.453	mg/L	30
TN	4.180	mg/L	30
DP	0.313	mg/L	26
TP	0.887	mg/L	30
BOD	40.17	mg/L	29
COD	238.06	mg/L	30
TOC	26.12	mg/L	30
Cadmium	0.823	µg/L	18
Copper	32.391	µg/L	20
Lead	65.14	µg/L	20
Zinc	384.23	µg/L	20
F. Coliform	141,388	cfu/100m	24
F. Strep.	428,726	cfu/100m	22


SAN JACINTO
6TH
NECHES
5TH
TRINITY
W5A
4TH
RED RIVER


W5A
Impervious Cover
Buildings
Transportation


Land Use
MFR
Commercial
Office
Civic
Transportation
W5A


03/31/2011 17:00

Wells Branch (WBA)

This station was located at the Wells Branch Community Center at 2106 Klattenhoff Dr. and was operational from 1999 thru 2003. The total drainage area for WBA is 0.93 acre and has an impervious cover of 31%. The primary land use for WBA is office. Flow was measured using a Parshall flume and an approach channel. The original purpose of this monitoring station was to evaluate rainwater harvesting as a stormwater control. During the monitoring period a rainwater harvesting system was installed but no difference in the runoff ratios were noted probably due to the relatively small portion of the watershed affected by the system.

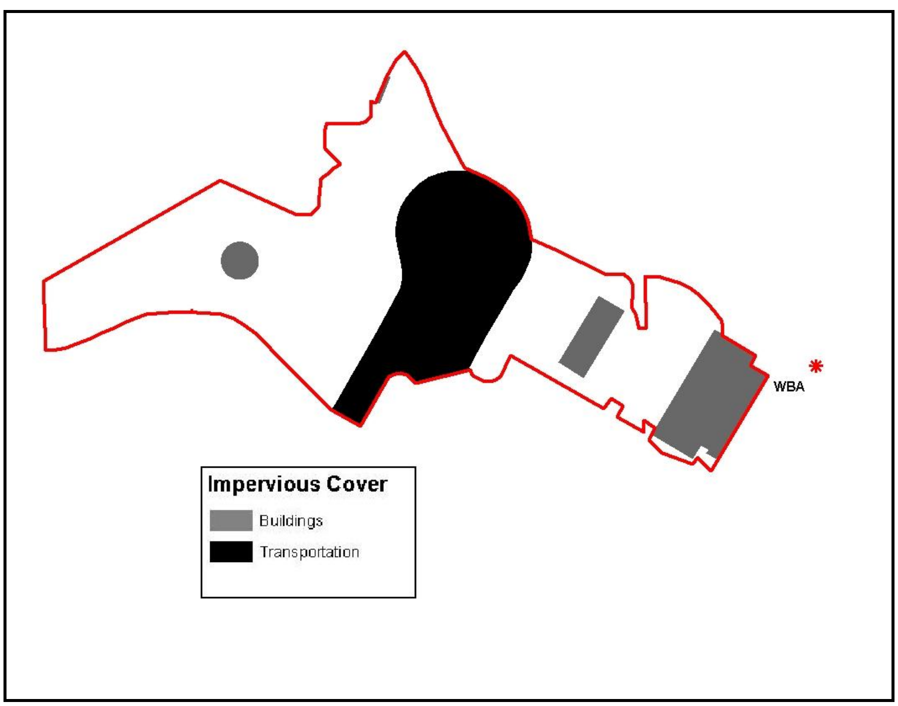
Zinc was omitted from water quality analyses for this site due to possible zinc contamination from the galvanized approach channel.

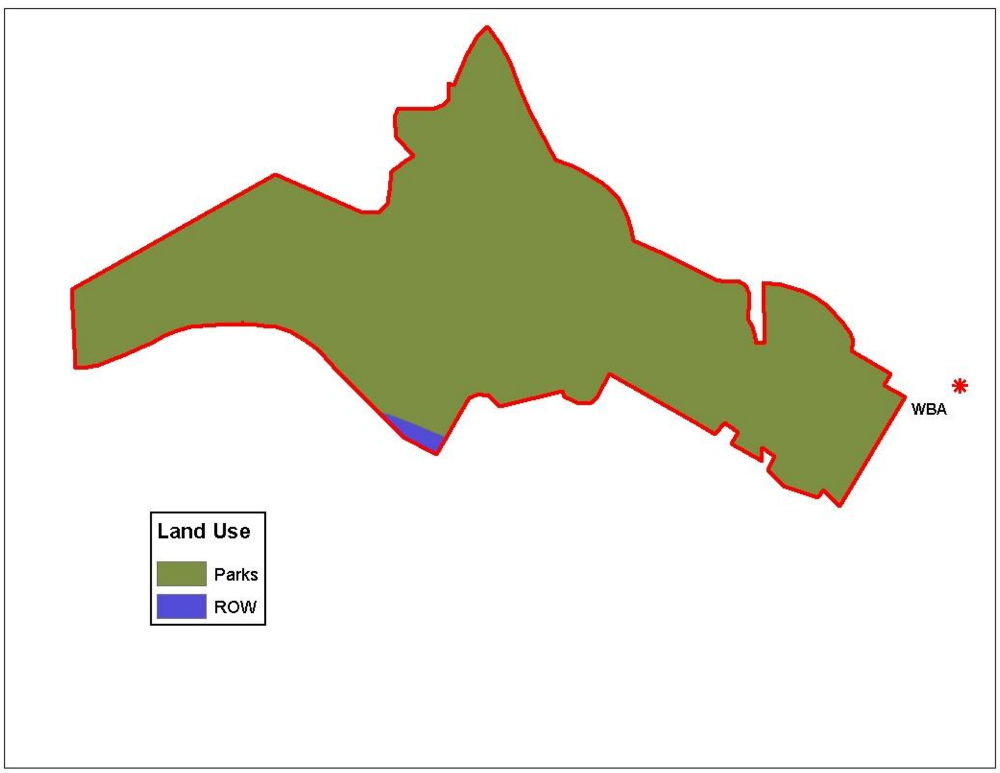
Site Summary

Site ID	WBA	
Site Name	Wells Branch	
Latitude	30.4423	N
Longitude	97.6787	W
Predominate Land Use	Civic	
Drainage Area	0.93	Acres
Impervious Cover	0.3059	
Runoff-Rainfall Ratio	0.548	
Runoff-Rainfall Events	201	
Recharge Zone	No	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	97.7	mg/L	33
VSS	34.2	mg/L	33
NO_2+NO_3	0.818	mg/L	32
NH_3	0.405	mg/L	33
TKN	1.992	mg/L	33
TN	2.831	mg/L	32
DP	0.168	mg/L	34
TP	0.413	mg/L	33
BOD	12.32	mg/L	22
COD	56.10	mg/L	33
TOC	12.02	mg/L	33
Cadmium	0.502	µg/L	33
Copper	12.579	µg/L	33
Lead	8.53	µg/L	33
Zinc	181.98	µg/L	33
F. Coliform	27,683	cfu/100m	19
F. Strep.	52,184	cfu/100m	19


WBA
KLATTENHOFF


WBA
Impervious Cover
Buildings
Transportation


WBA
Land Use
Parks
ROW

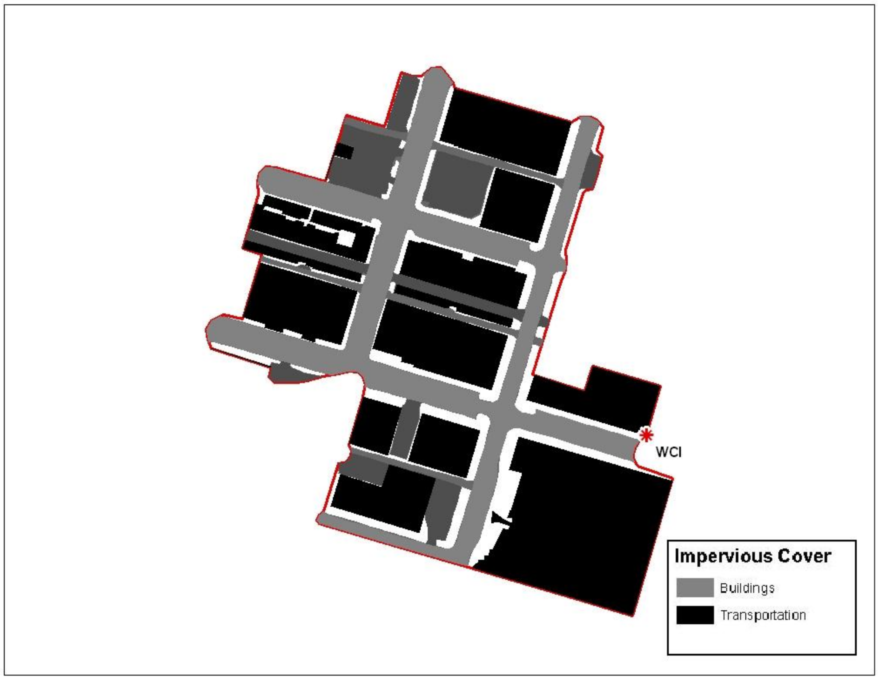
3rd Street Convention Center (WCI)

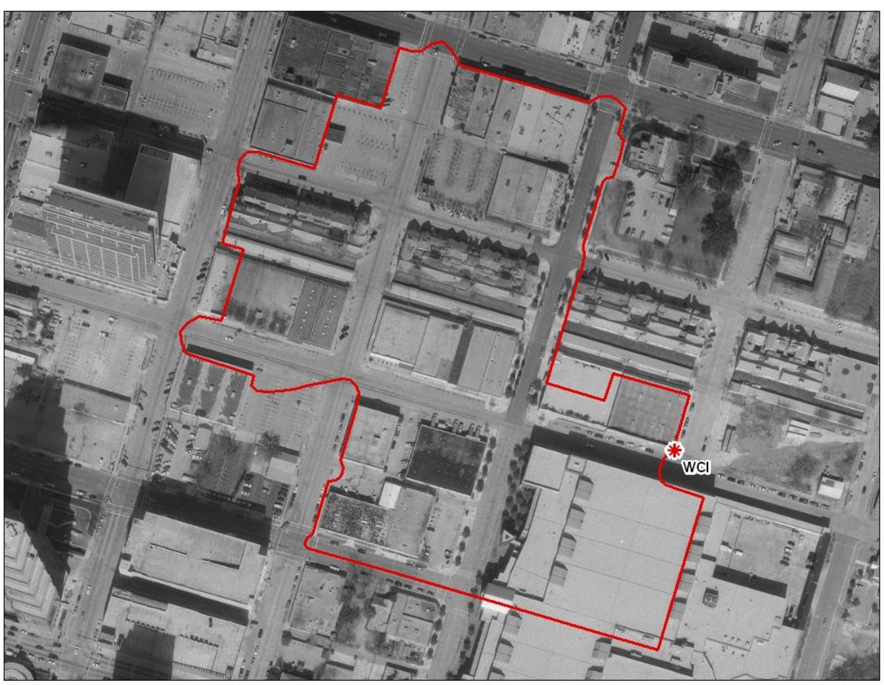
This monitoring station was located at the corner of Neches Street and 3rd Street in Waller Creek watershed. The 16.83 acre watershed had 93% impervious cover with a downtown commercial land use. The period of monitoring was 1999 though 2003, monitoring ended when the Austin Convention Center was expanded and the watershed was altered. This station was the influent for a BMP designed to treat runoff from the Convention Center area. Flow was estimated using Manning's equation in the 27 inch storm sewer.

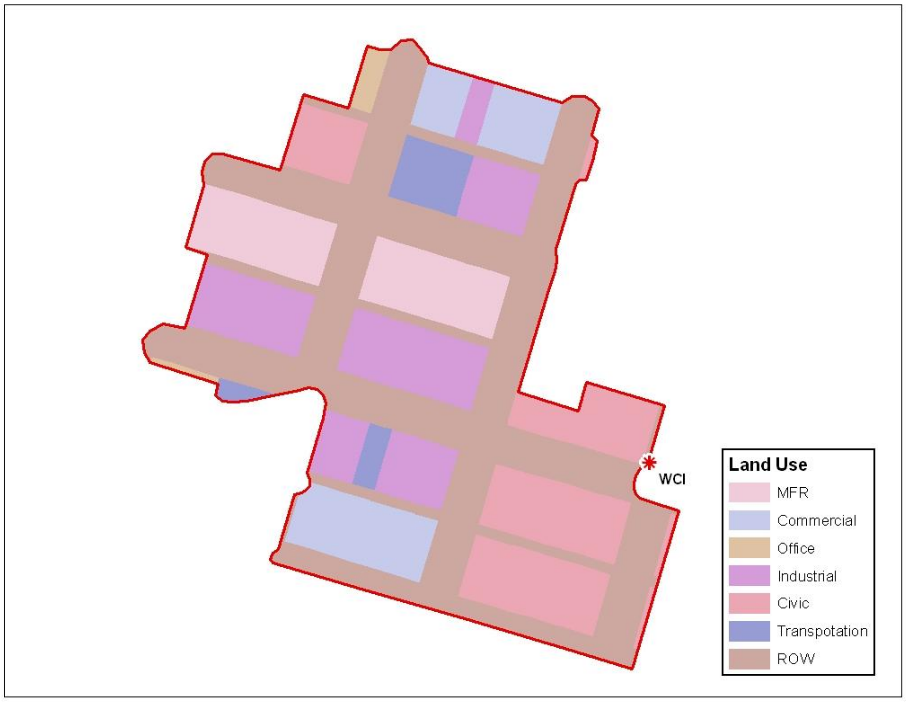
Site Summary

Site ID	WCI	
Site Name	3rd Street @ Neches	
Latitude	30.2641	N
Longitude	97.7393	W
Predominate Land Use	Commercial	
Drainage Area	16.85	Acres
Impervious Cover	0.9298	
Runoff-Rainfall Ratio	0.869	
Runoff-Rainfall Events	247	
Recharge Zone	No	

Parameter	Mean EMC	Units	Count
TSS	123.3	mg/L	36
VSS	29.6	mg/L	35
NO_2+NO_3	0.847	mg/L	33
NH_3	0.932	mg/L	34
TKN	2.376	mg/L	35
TN	3.029	mg/L	33
DP	0.137	mg/L	31
TP	0.544	mg/L	35
BOD	15.19	mg/L	32
COD	127.98	mg/L	34
TOC	21.67	mg/L	32
Cadmium	0.756	µg/L	36
Copper	29.084	µg/L	36
Lead	52.06	µg/L	36
Zinc	367.28	µg/L	37
F. Coliform	35,834	cfu/100m	26
F. Strep.	113,458	cfu/100m	28


WCI
Impervious Cover
Buildings
Transportation


WCI


WCI
Land Use
MFR
Commercial
Office
Industrial
Civic
Transpotation
ROW

45th Street at Duval (WDI)

This monitoring station was operated during 1994-1995. It is located at the intersection of 45th street and Duval in the Waller Creek watershed. It was intended to measure the runoff from a small auto repair facility as part of an evaluation of an oil and grit separator. The total drainage area is approximately 0.10 acre with 95 % impervious cover. Due to inaccuracies in the flow measurements, this station was not used for runoff-rainfall analyses.

Site Summary

Site ID	WDI	
Site Name	45th & Duval O/G Chamber	
Latitude	30.3073	N
Longitude	97.7249	W
Predominate Land Use	Industrial	
Drainage Area	0.1	Acres
Impervious Cover	0.95	
Runoff-Rainfall Ratio	N/A	
Runoff-Rainfall Events	N/A	
Recharge Zone	N/A	

Parameter	**Mean EMC**	**Units**	**Count**
TSS	89.44	mg/L	14
VSS	47.47	mg/L	14
NO_2+NO_3	1.51	mg/L	14
NH_3	0.48	mg/L	14
TKN	2.45	mg/L	14
TN	3.96	mg/L	14
DP	0.24	mg/L	12
TP	0.69	mg/L	14
BOD	32.07	mg/L	14
COD	168.46	mg/L	14
TOC	27.11	mg/L	13
CD	1.52	µg /L	14
CU	46.11	µg /L	14
PB	51.54	µg /L	14
ZN	186.53	µg /L	14
FCOL	10,872	cfu/100mL	10
FSTR	69,710	cfu/100mL	11


Service Center

Appendix B Scatter plots for TIC v MC

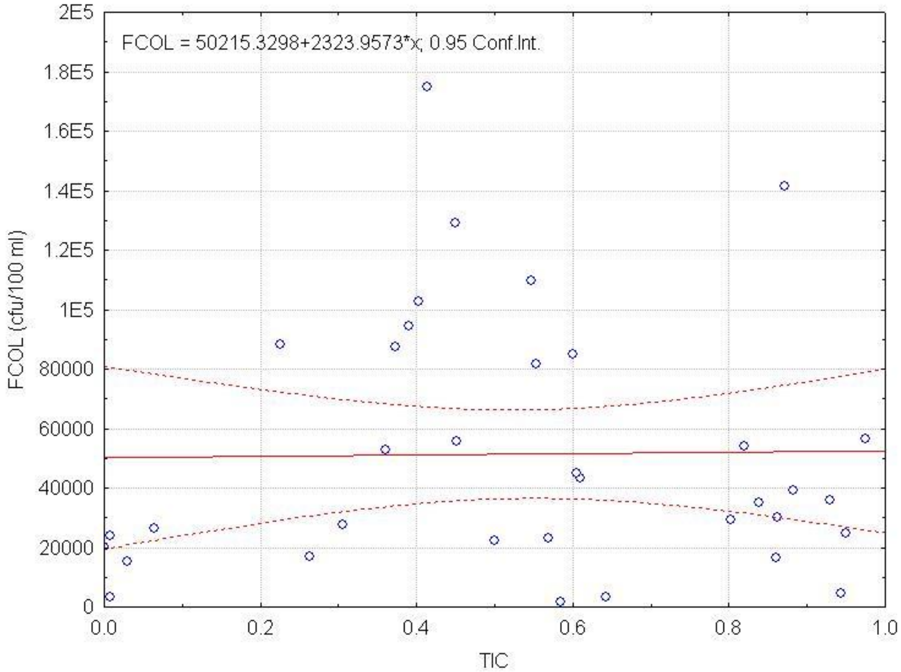


Figure B.1: Linear regression of FCOL v. TIC and the 95% confidence interval.

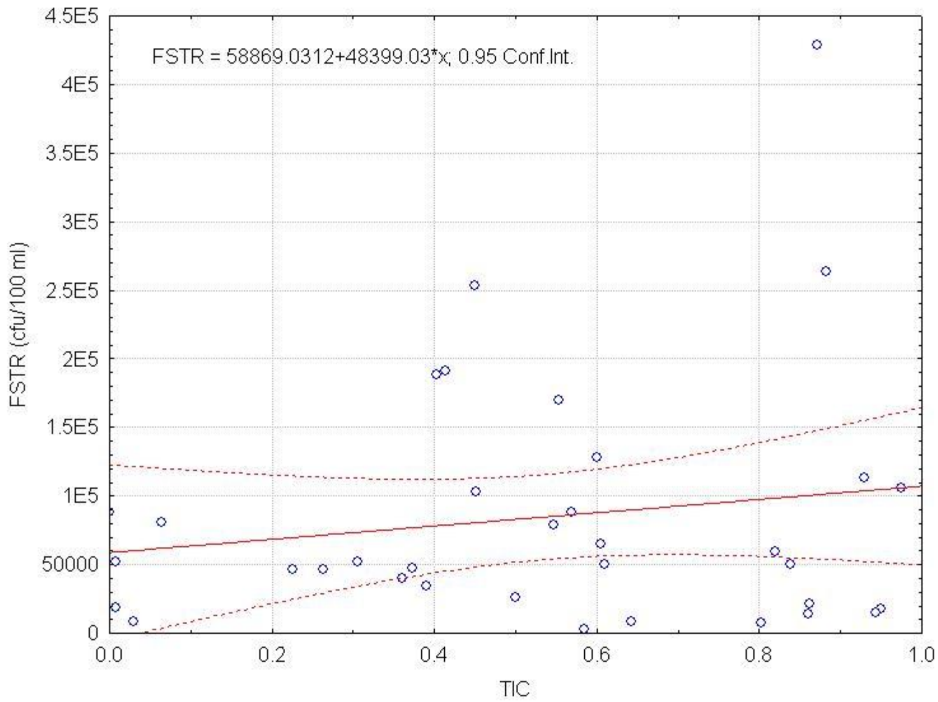


Figure B.2: Linear regression of FSTR v. TIC and the 95% confidence interval.

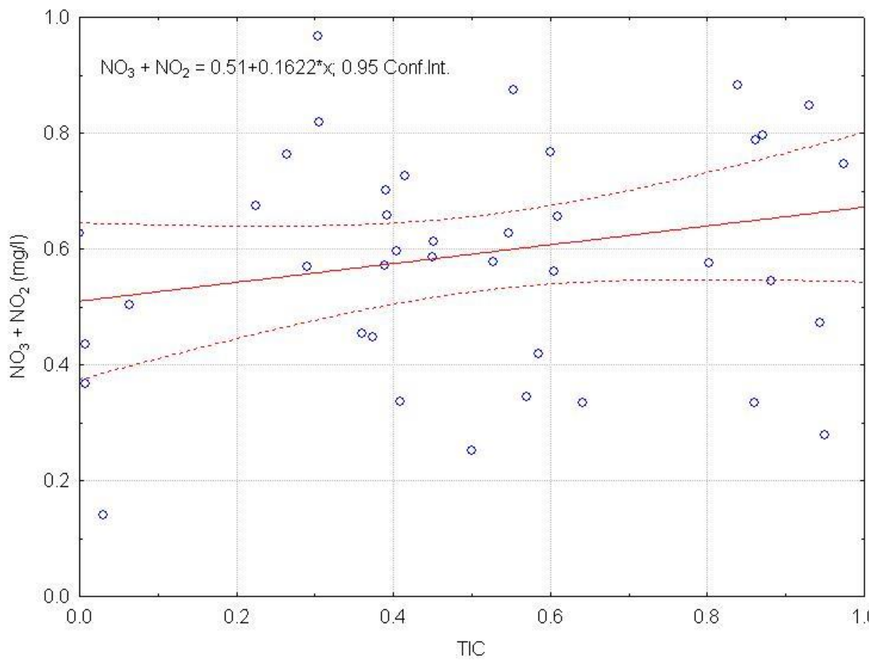


Figure B.3: Linear regression of NO_3+NO_2 v. TIC and the 95% confidence interval.

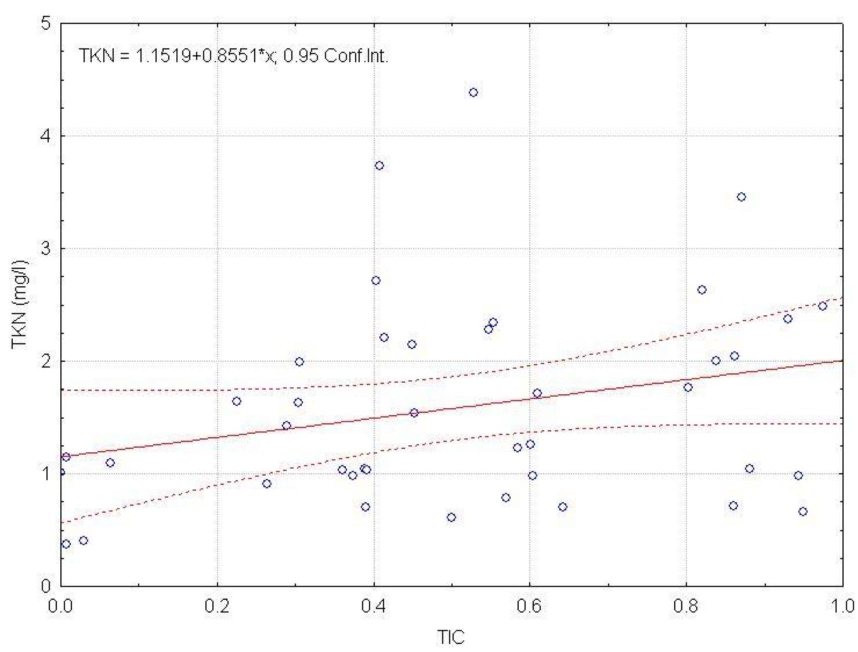


Figure B.4: Linear regression of TKN v. TIC and the 95% confidence interval.

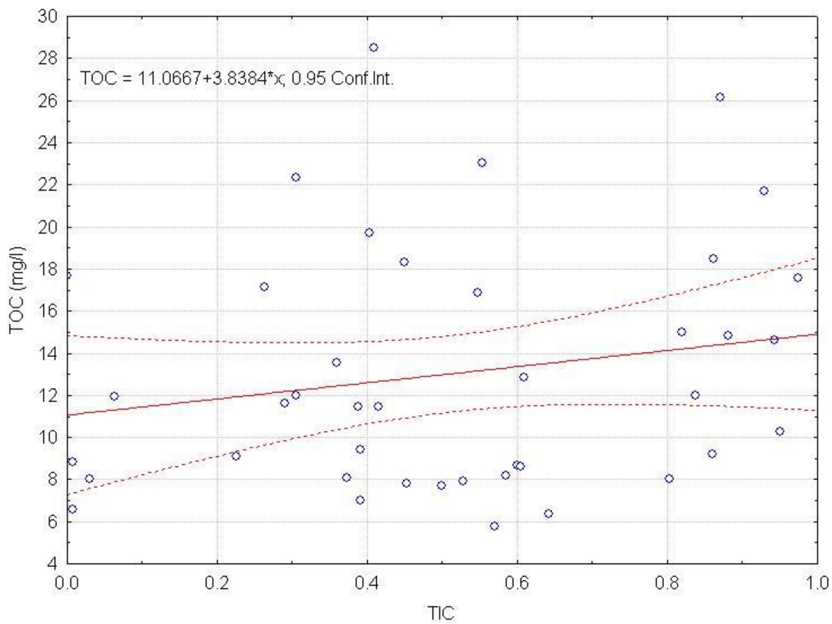


Figure B.5: Linear regression of TOC v. TIC and the 95% confidence interval.

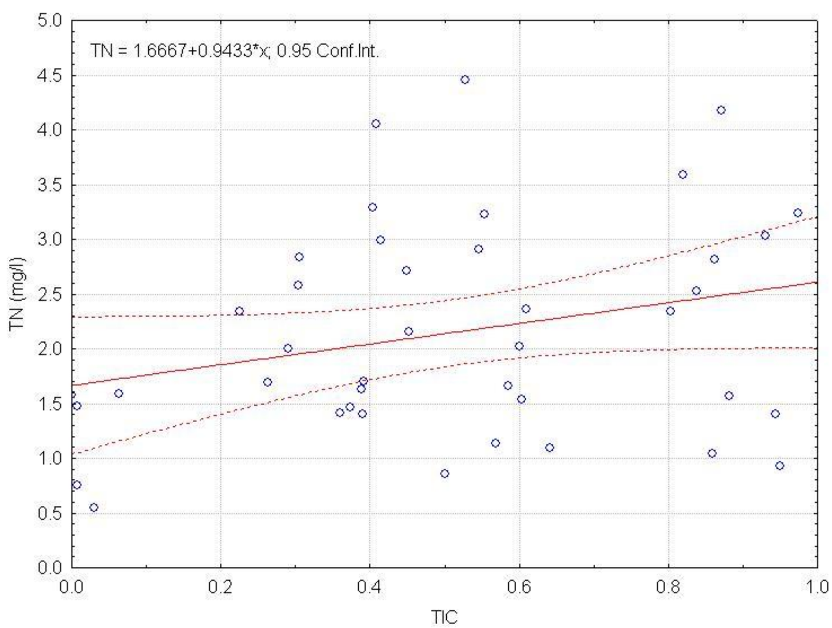


Figure B.6: Linear regression of TN v. TIC and the 95% confidence interval.

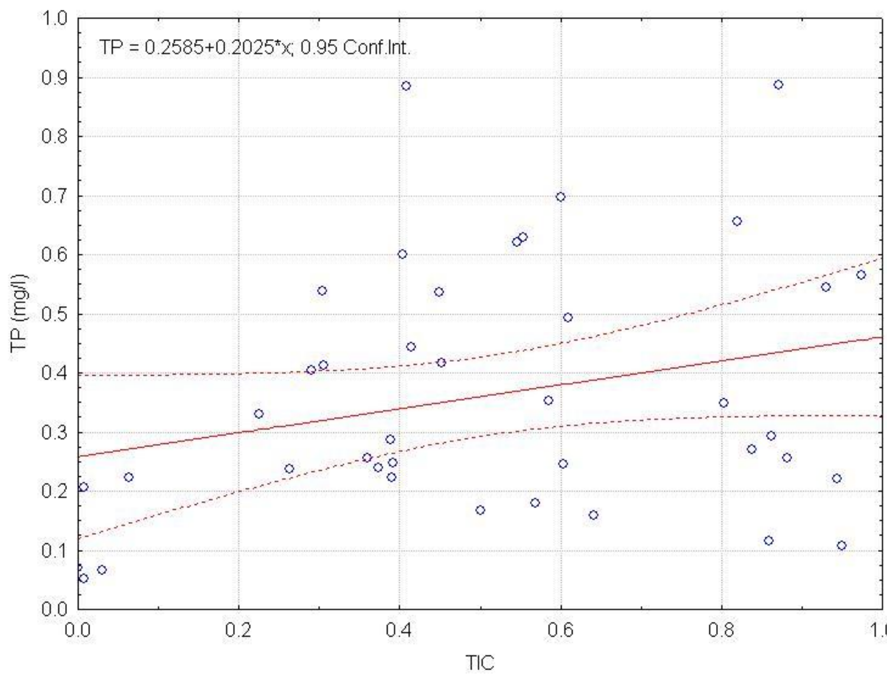


Figure B.7: Linear regression of TP v. TIC and the 95% confidence interval.

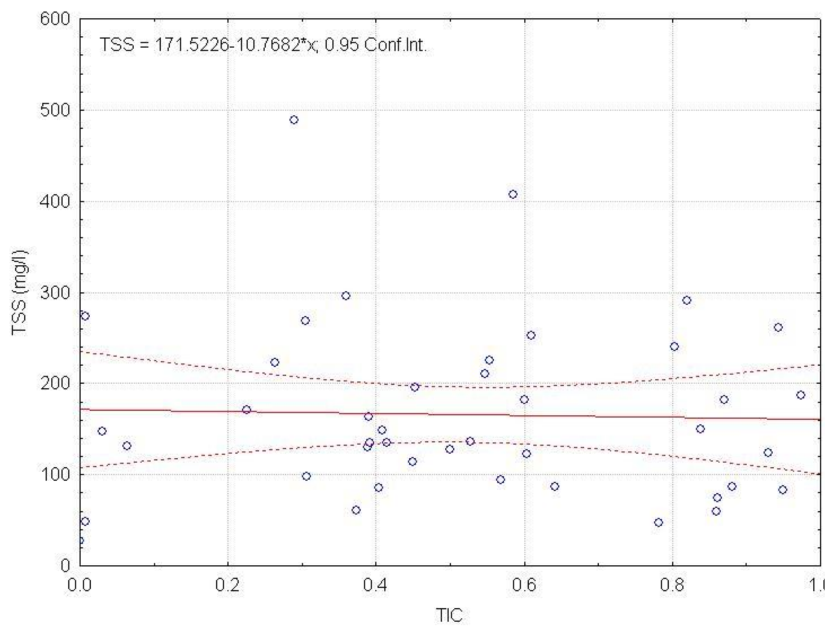
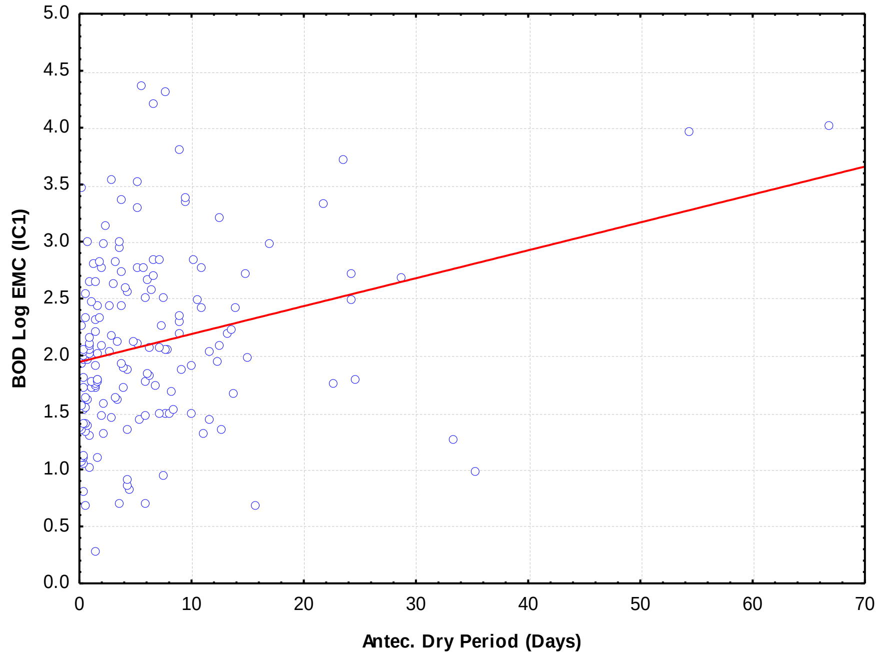
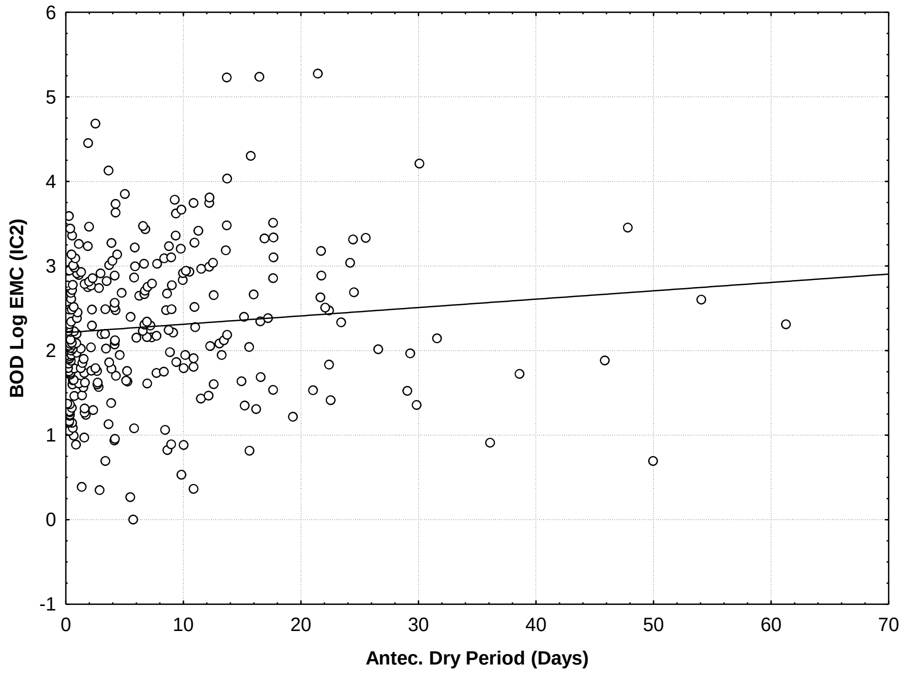


Figure B.8: Linear regression of TSS v. TIC and the 95% confidence interval.

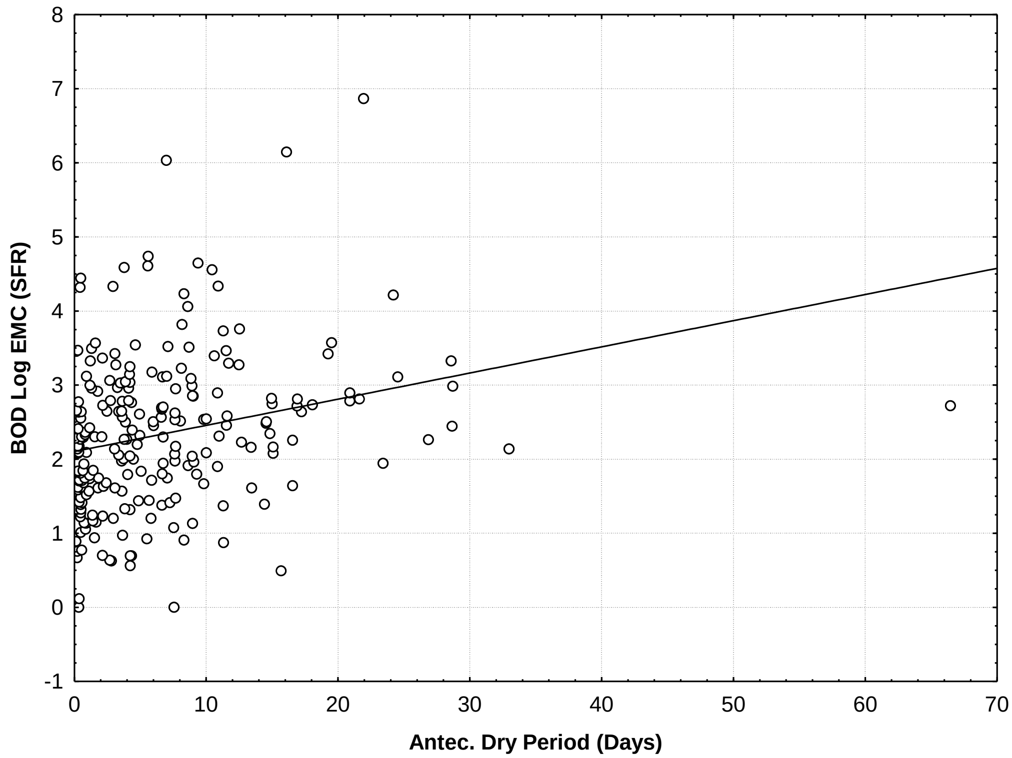
Appendix C Ln(EMC) v. Antecedent Dry Period



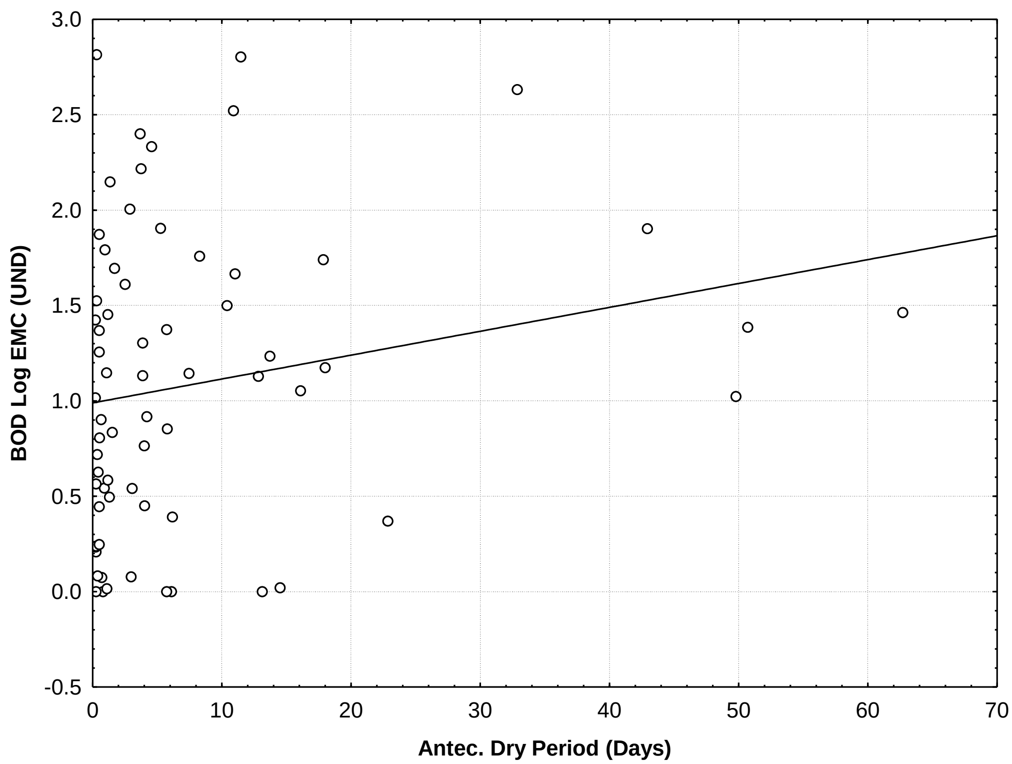
Graph C1. Scatterplot of Antecedent Dry Period vs. Log of EMC for BOD Group IC1



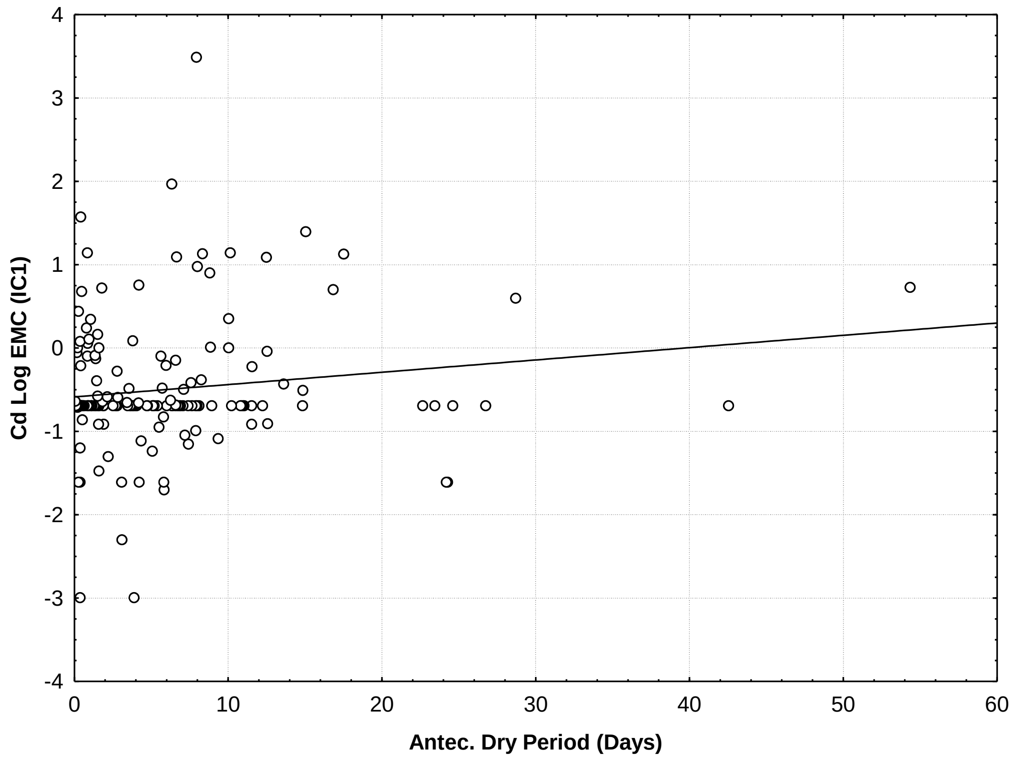
Graph C2. Scatterplot of Antecedent Dry Period vs. Log of EMC for BOD Group IC2



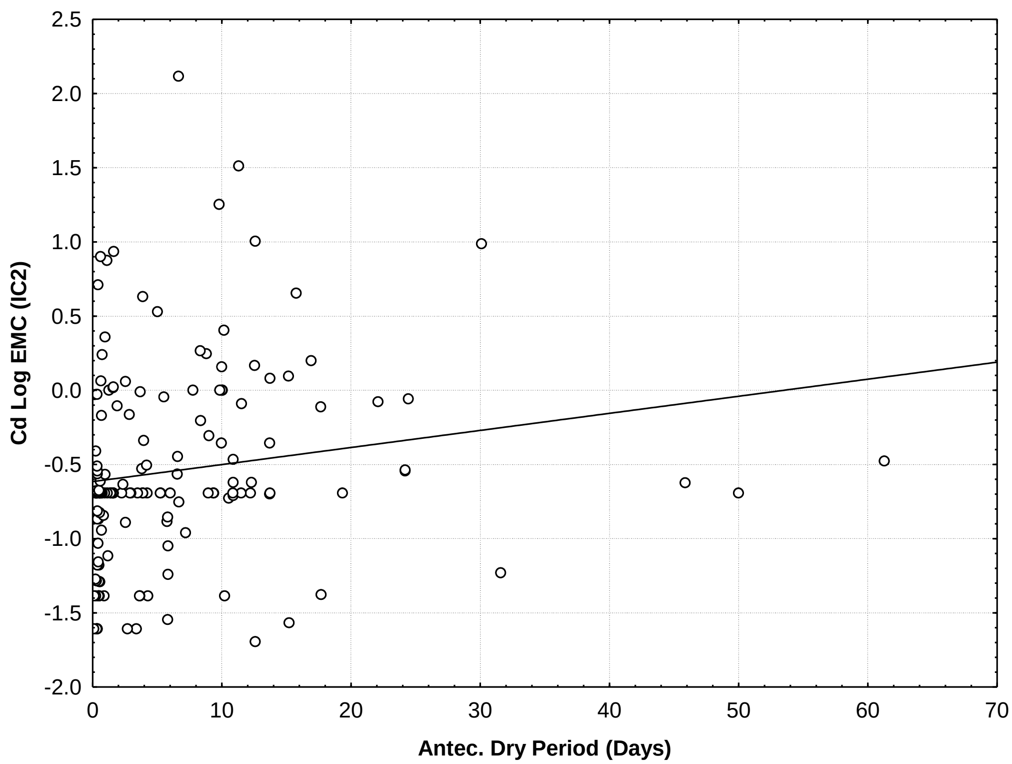
Graph C3. Scatterplot of Antecedent Dry Period vs. Log of EMC for BOD Group SFR



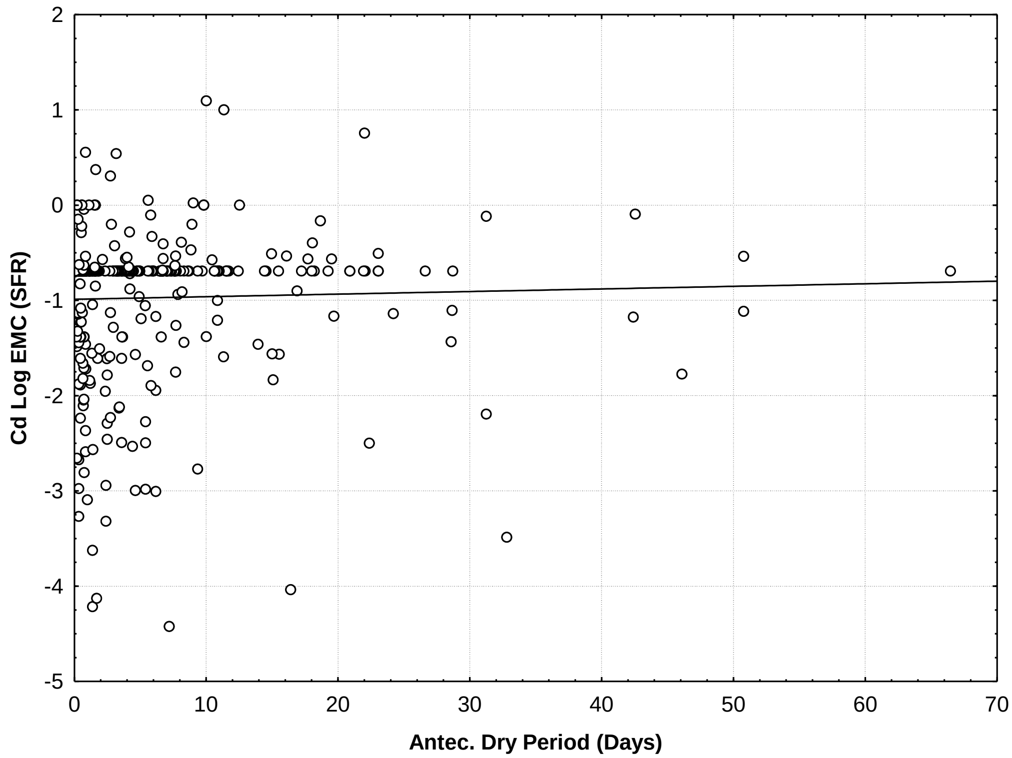
Graph C4. Scatterplot of Antecedent Dry Period vs. Log of EMC for BOD Group UND



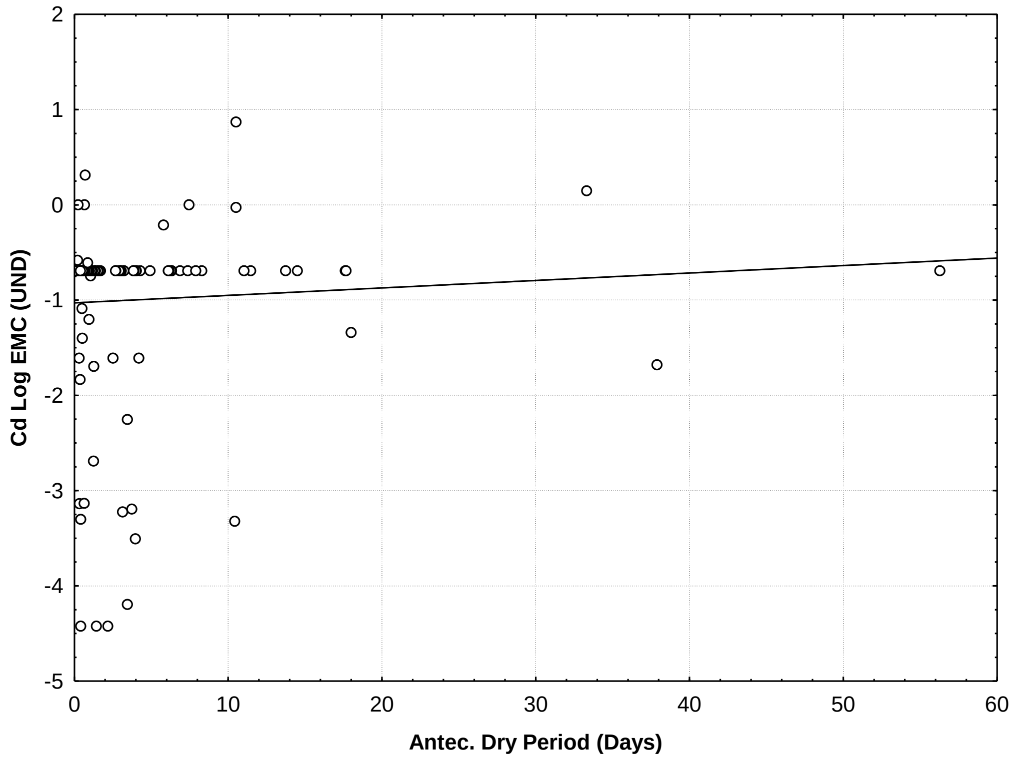
Graph C5. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cd Group IC1



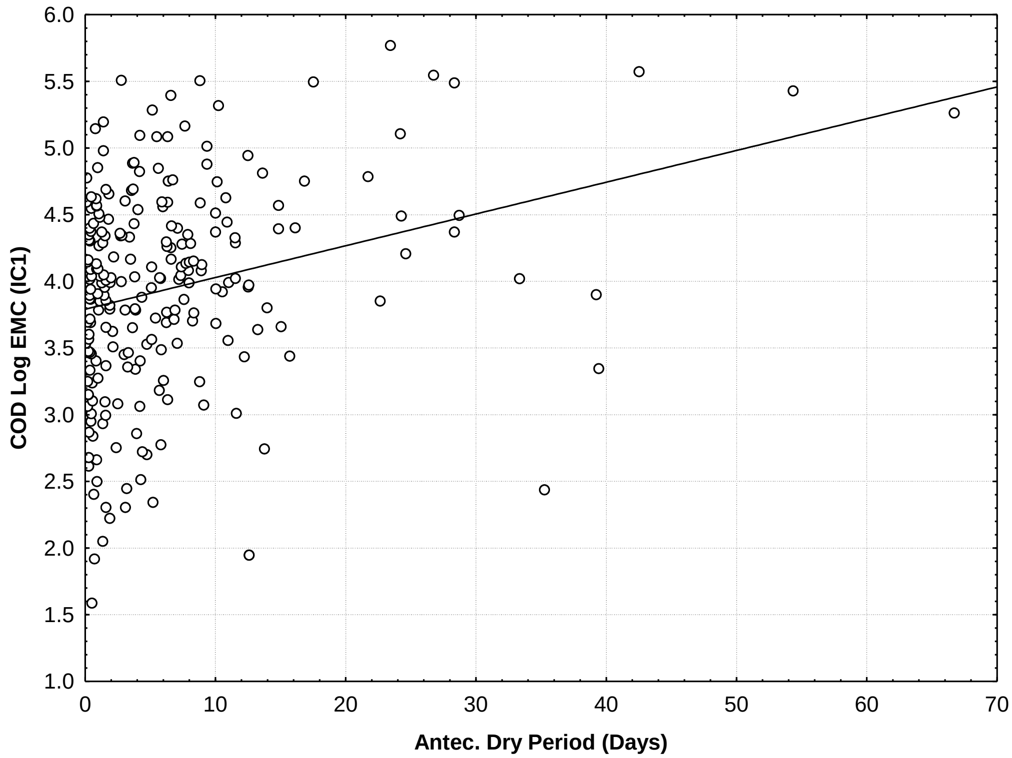
Graph C6. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cd Group IC2



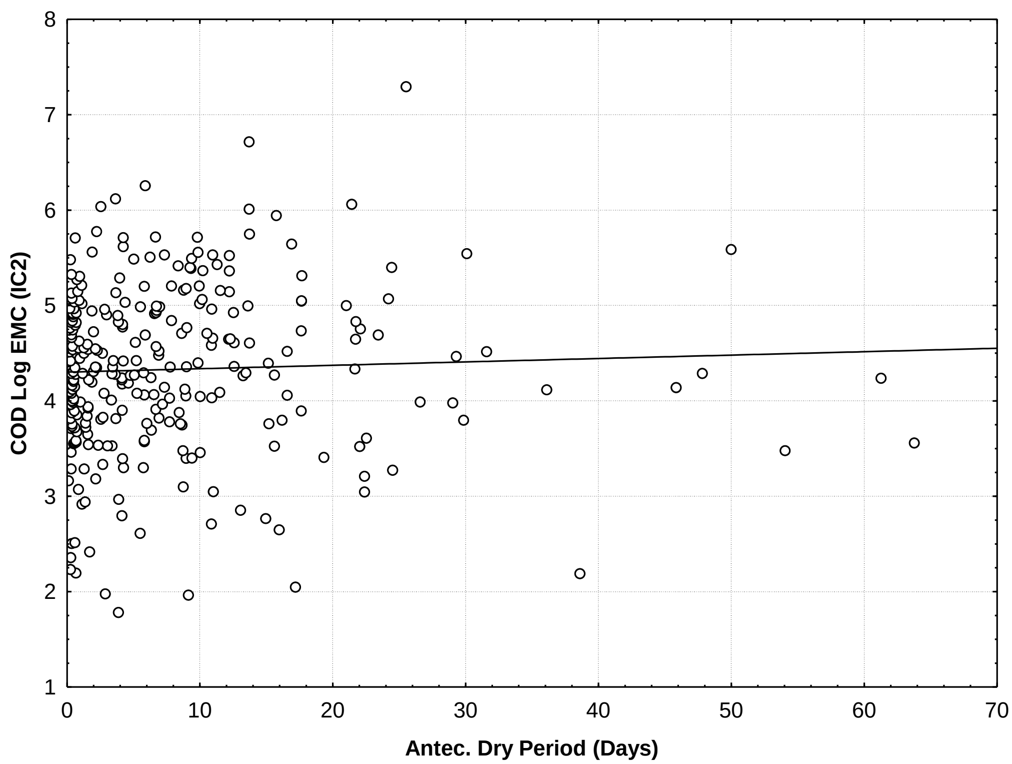
Graph C7. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cd Group SFR



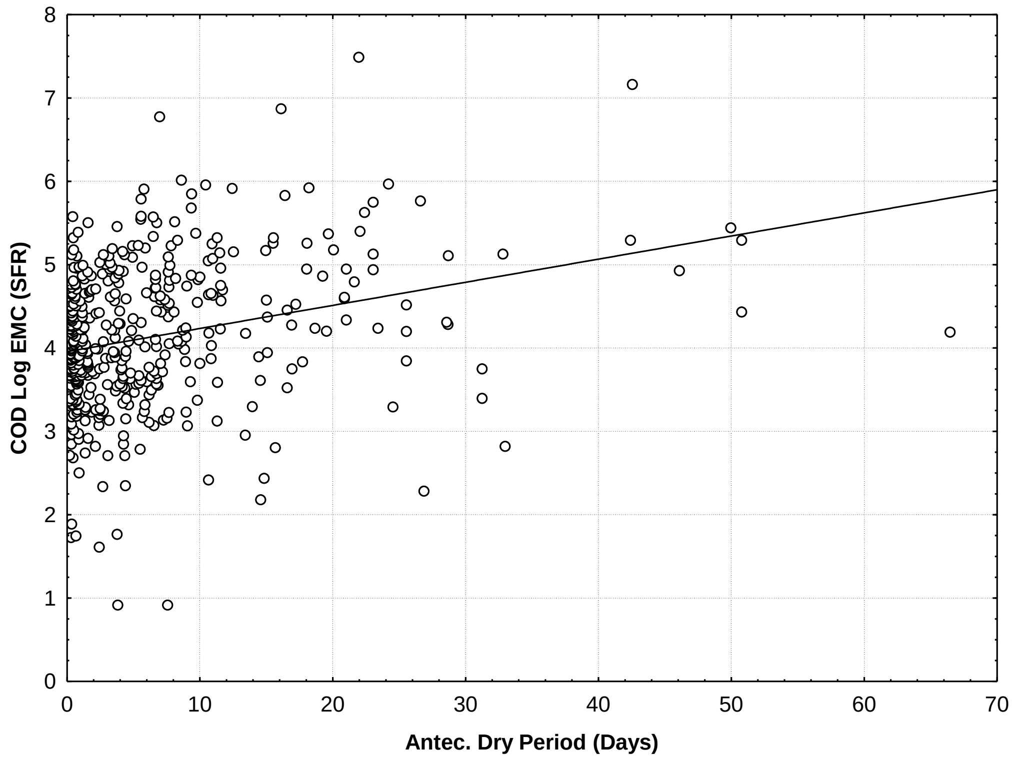
Graph C8. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cd Group UND



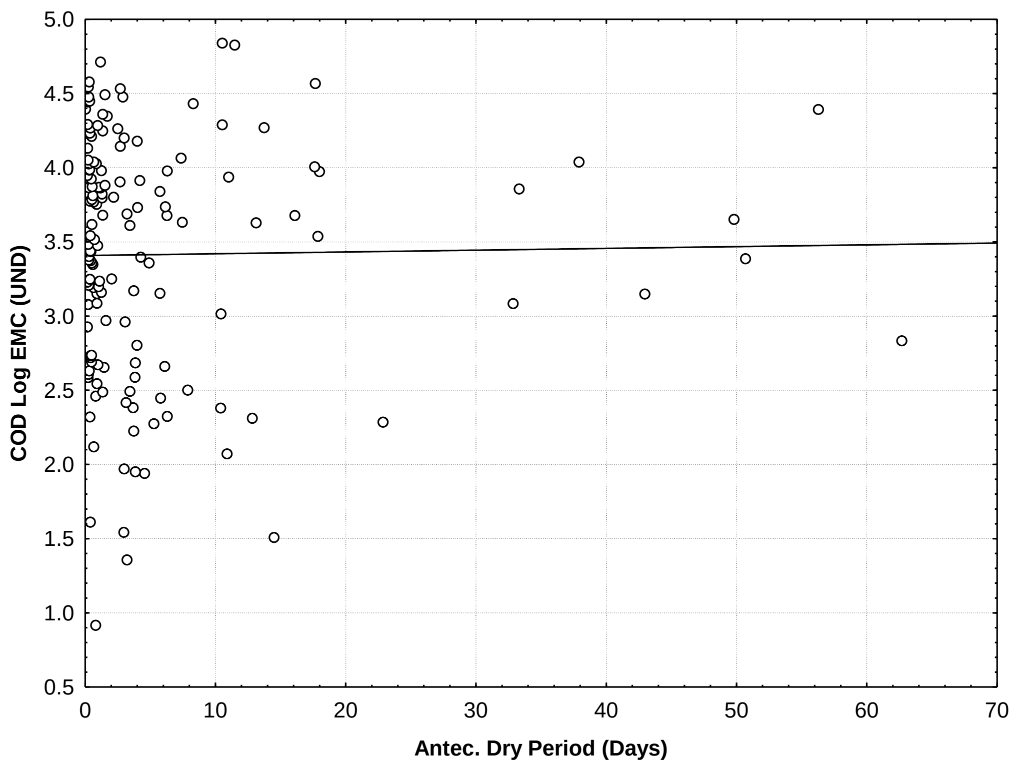
Graph C9. Scatterplot of Antecedent Dry Period vs. Log of EMC for COD Group IC1



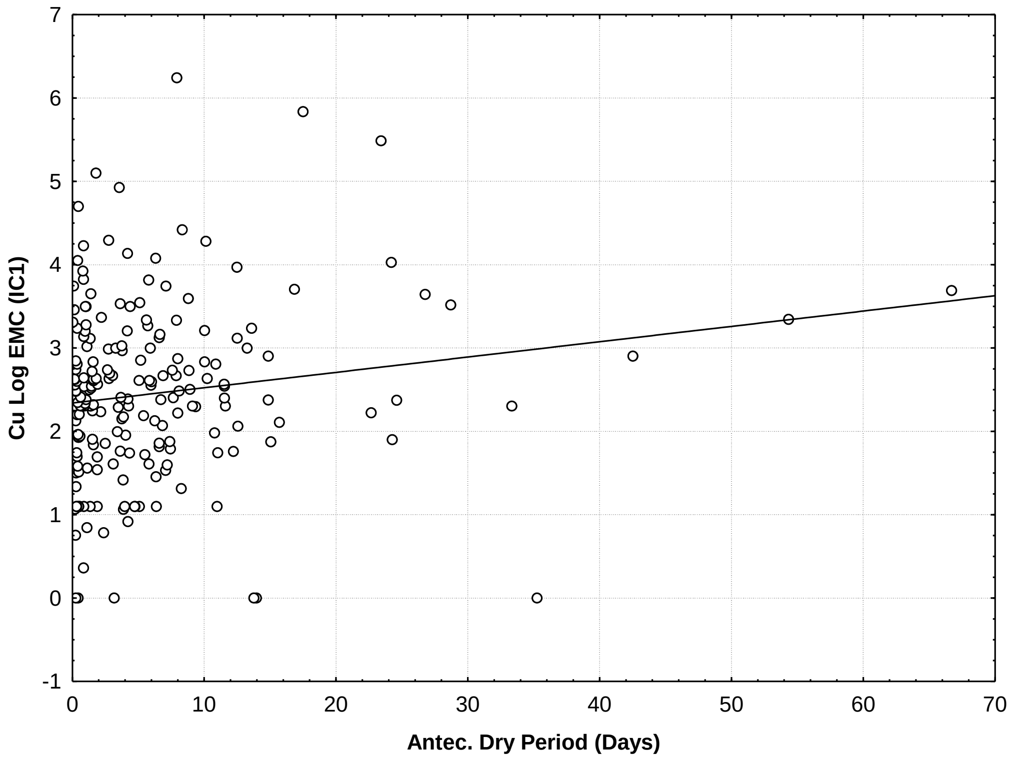
Graph C10. Scatterplot of Antecedent Dry Period vs. Log of EMC for COD Group IC2



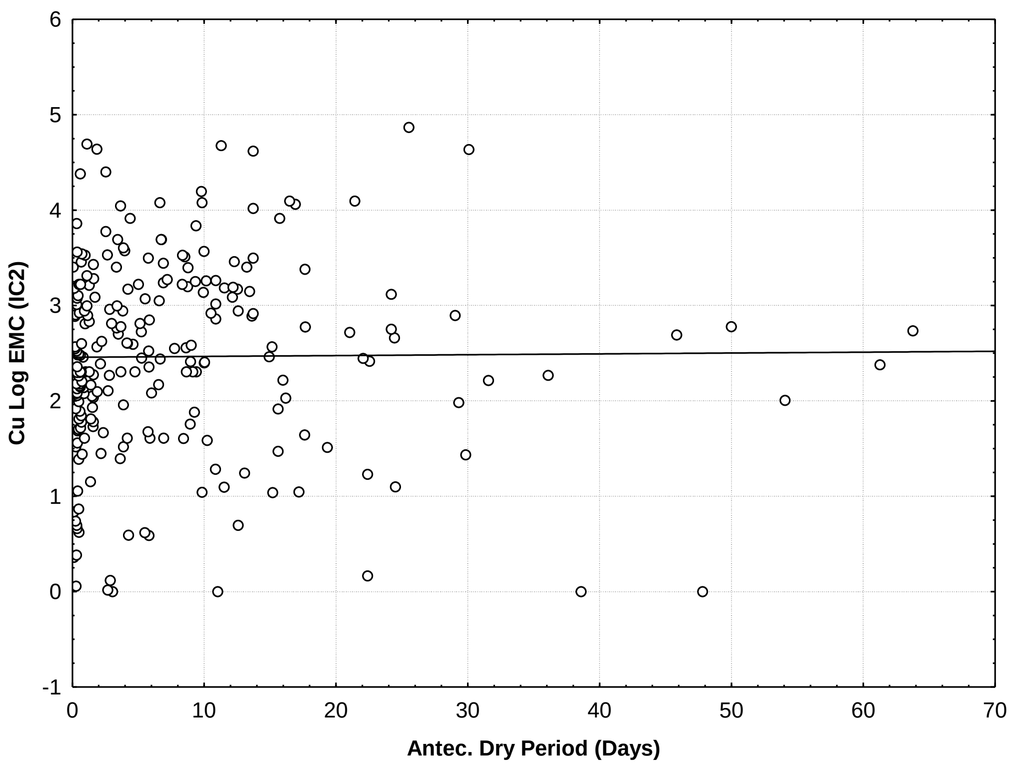
Graph C11. Scatterplot of Antecedent Dry Period vs. Log of EMC for COD Group SFR



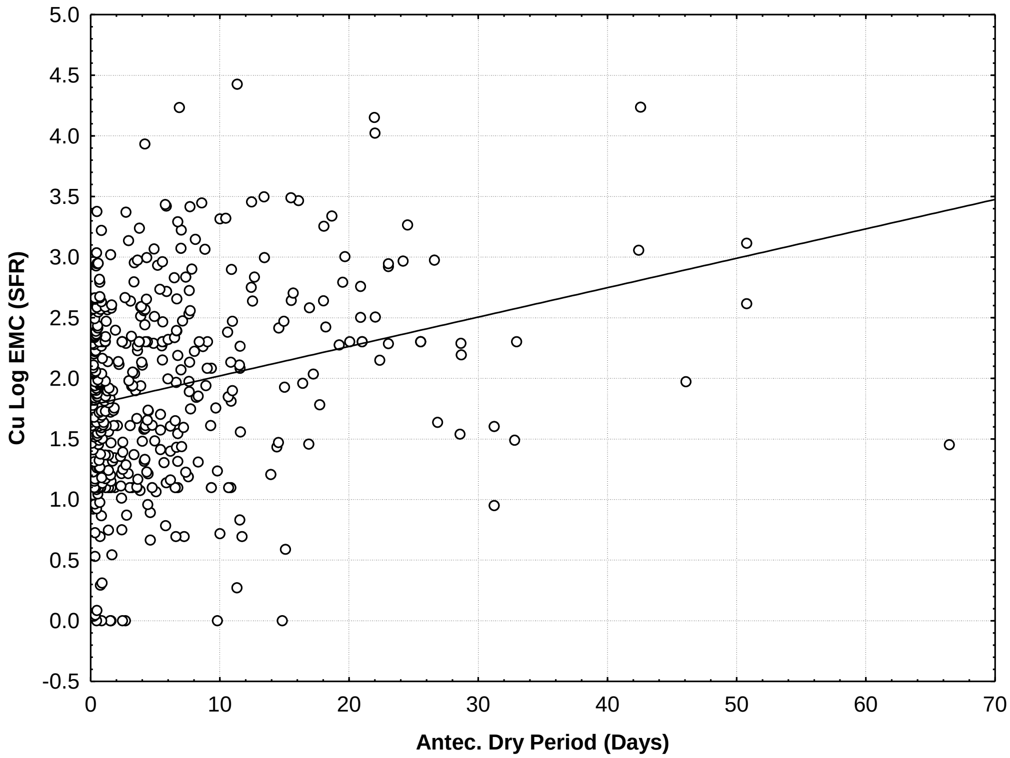
Graph C12. Scatterplot of Antecedent Dry Period vs. Log of EMC for COD Group UND



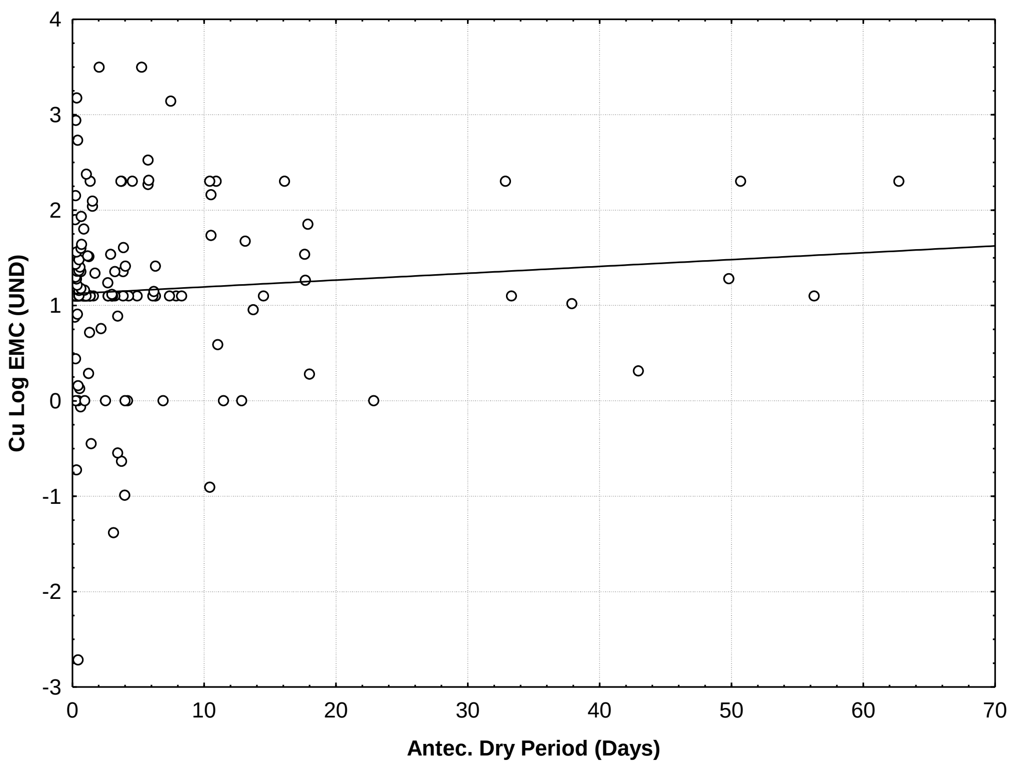
Graph C13. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cu Group IC1



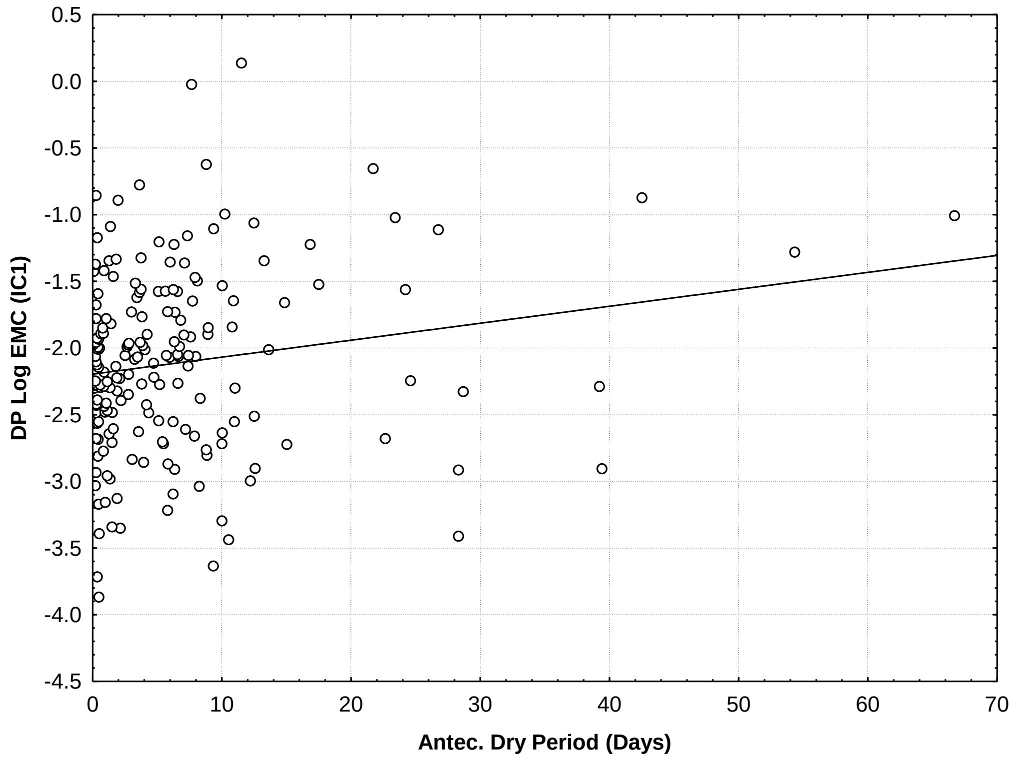
Graph C14. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cu Group IC2



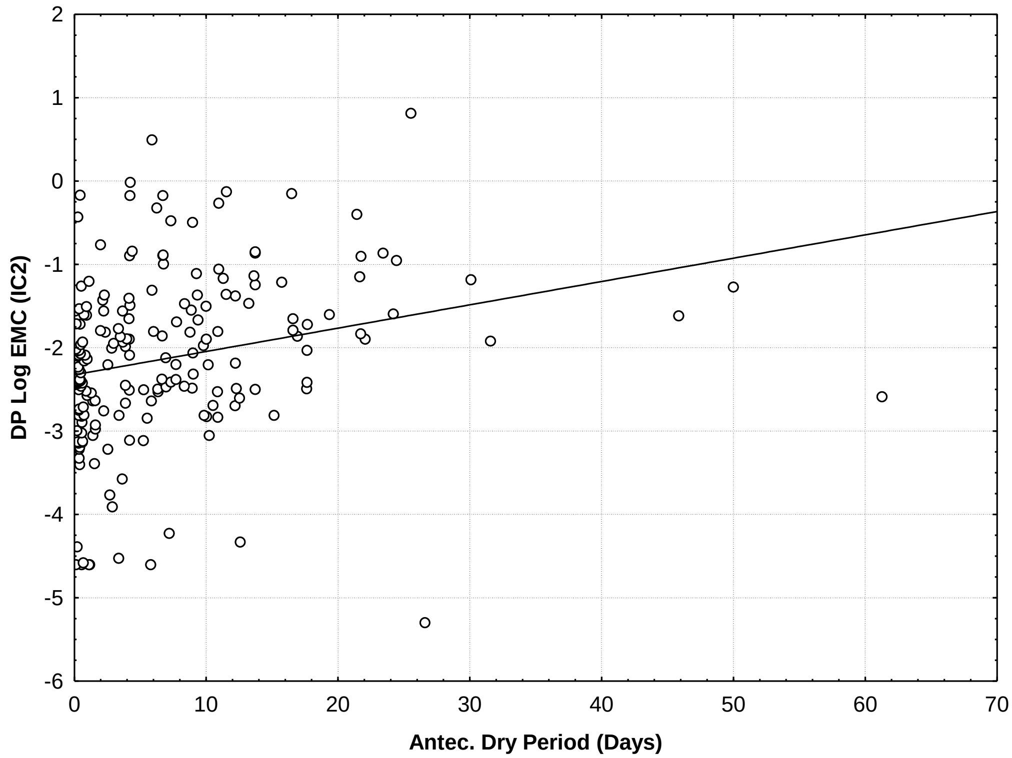
Graph C15. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cu Group SFR



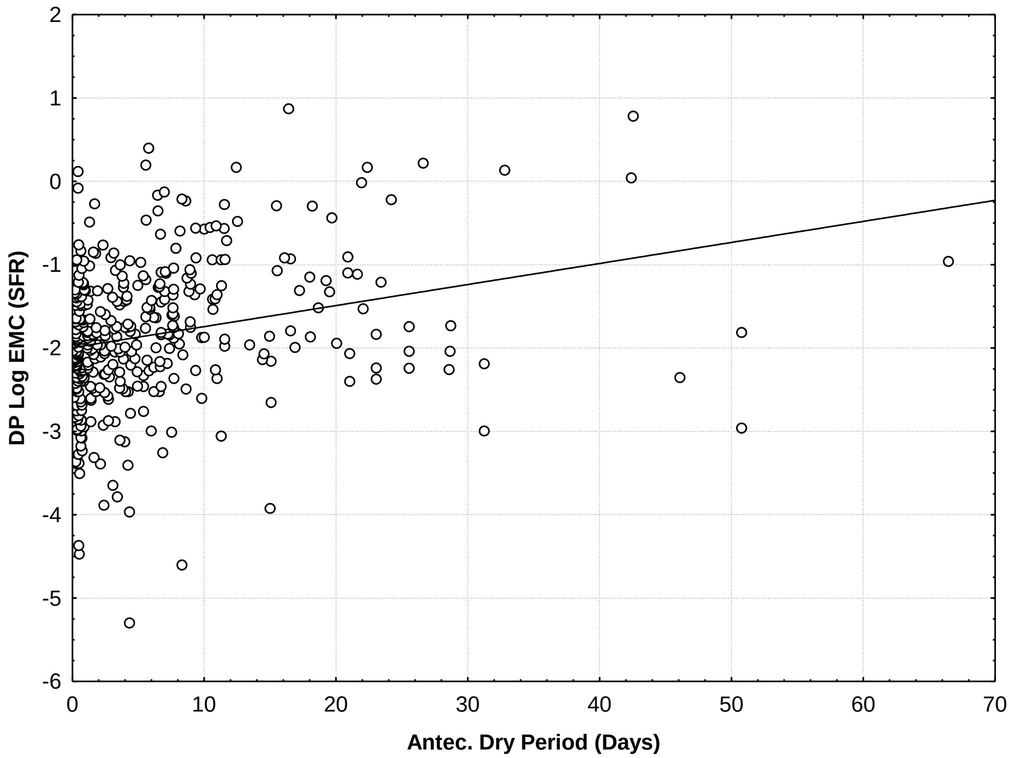
Graph C16. Scatterplot of Antecedent Dry Period vs. Log of EMC for Cu Group UND



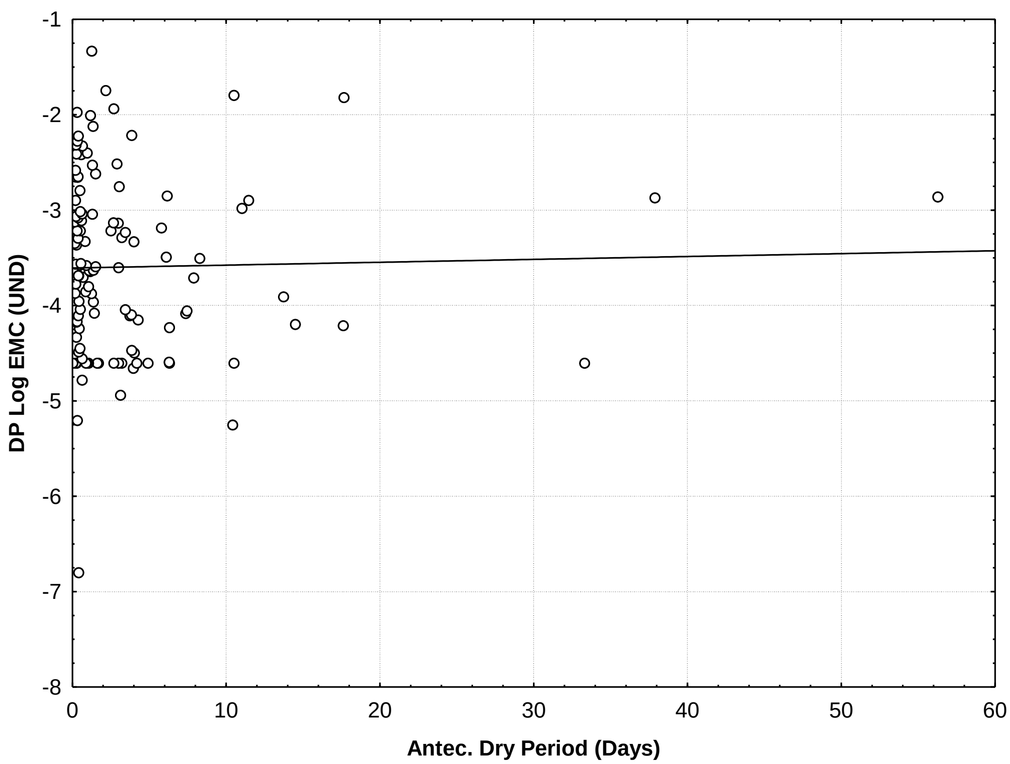
Graph C17. Scatterplot of Antecedent Dry Period vs. Log of EMC for DP Group IC1



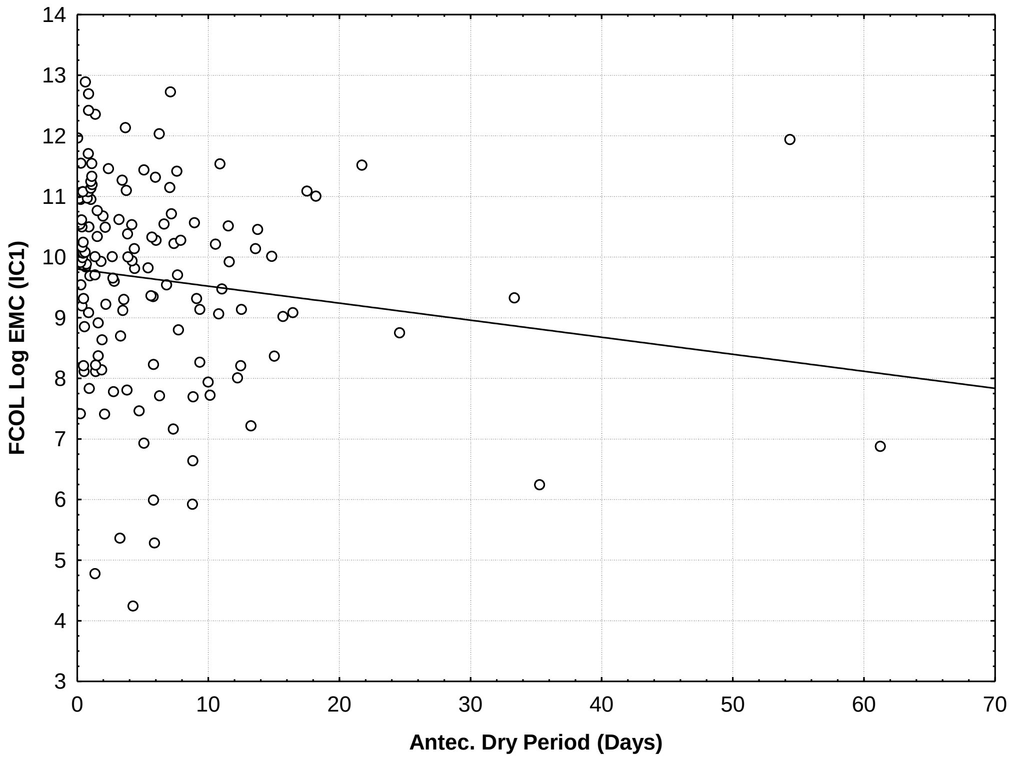
Graph C18. Scatterplot of Antecedent Dry Period vs. Log of EMC for DP Group IC2



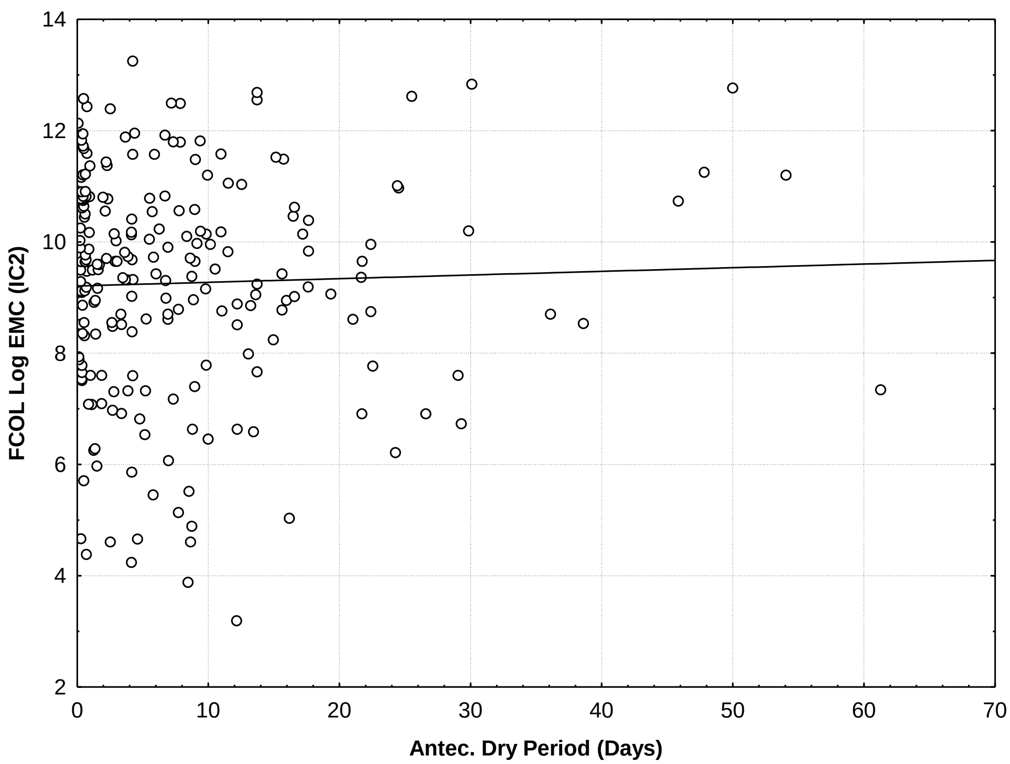
Graph C19. Scatterplot of Antecedent Dry Period vs. Log of EMC for DP Group SFR



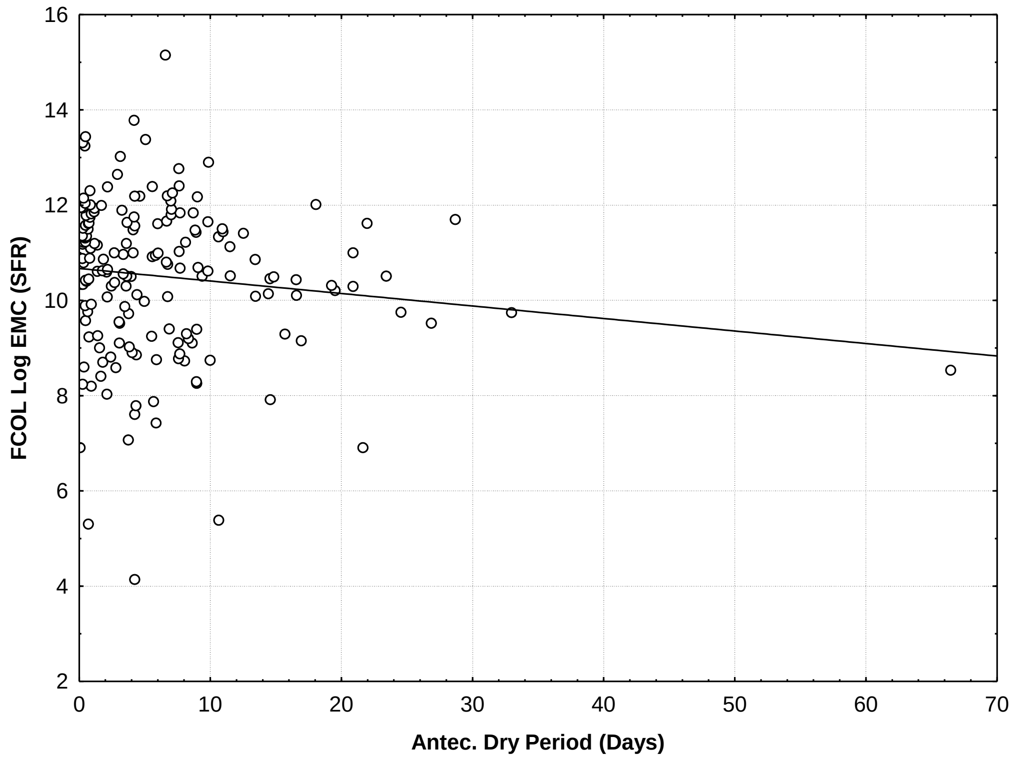
Graph C20. Scatterplot of Antecedent Dry Period vs. Log of EMC for DP Group UND



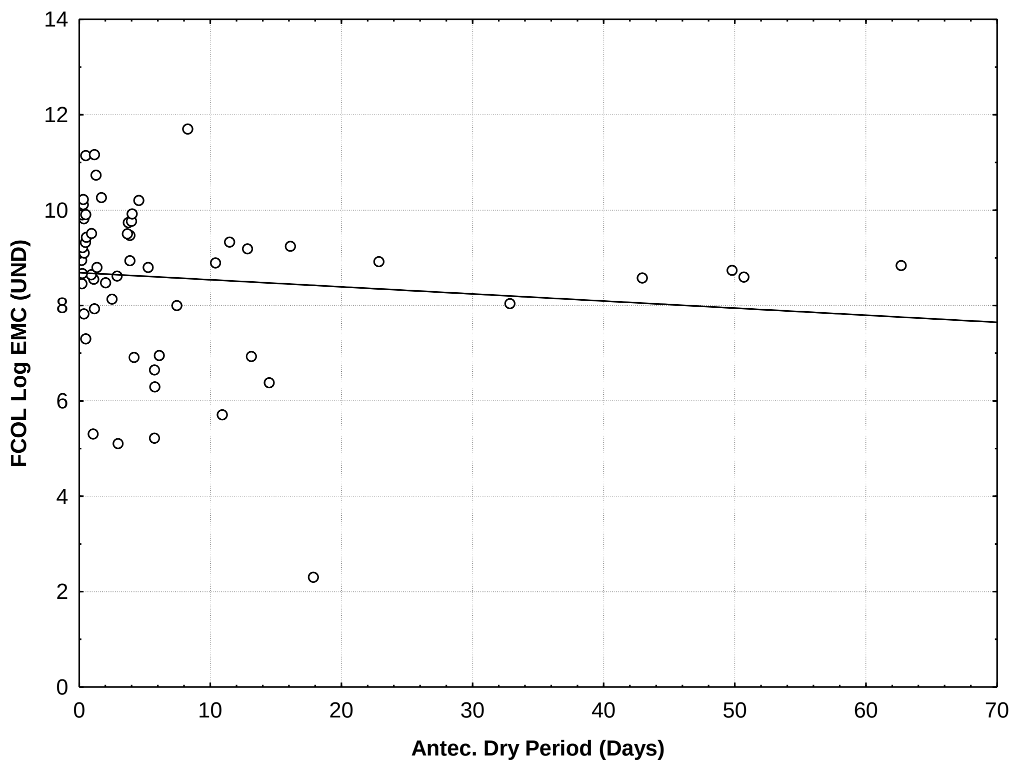
Graph C21. Scatterplot of Antecedent Dry Period vs. Log of EMC for FCOL Group IC1



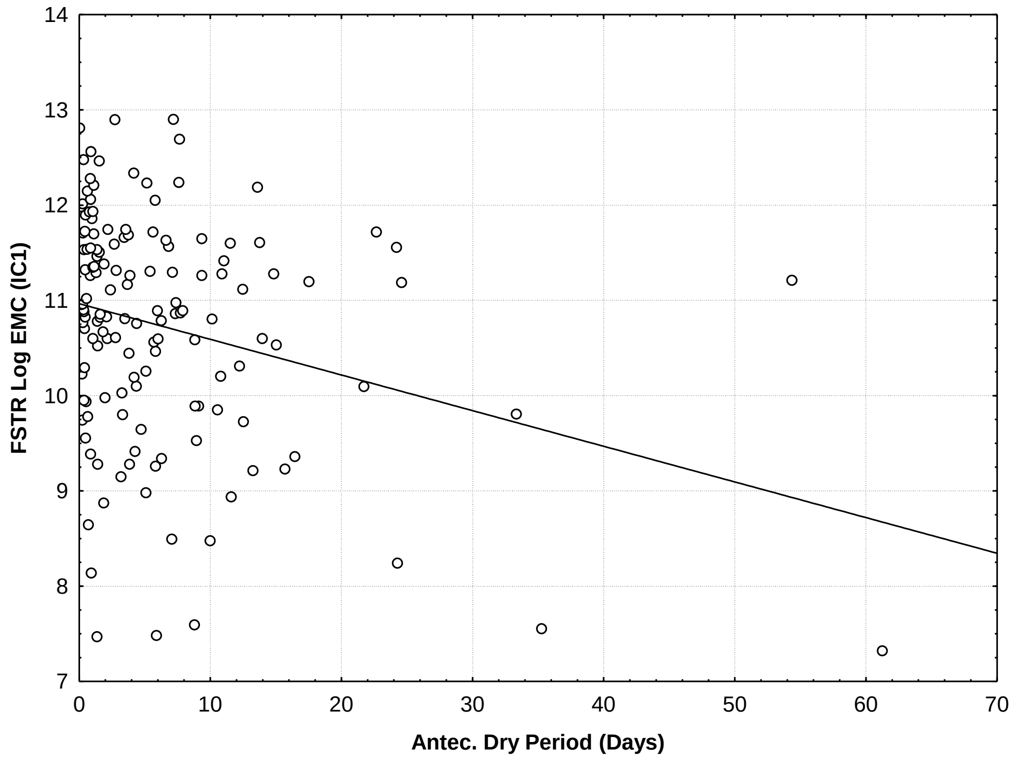
Graph C22. Scatterplot of Antecedent Dry Period vs. Log of EMC for FCOL Group IC2



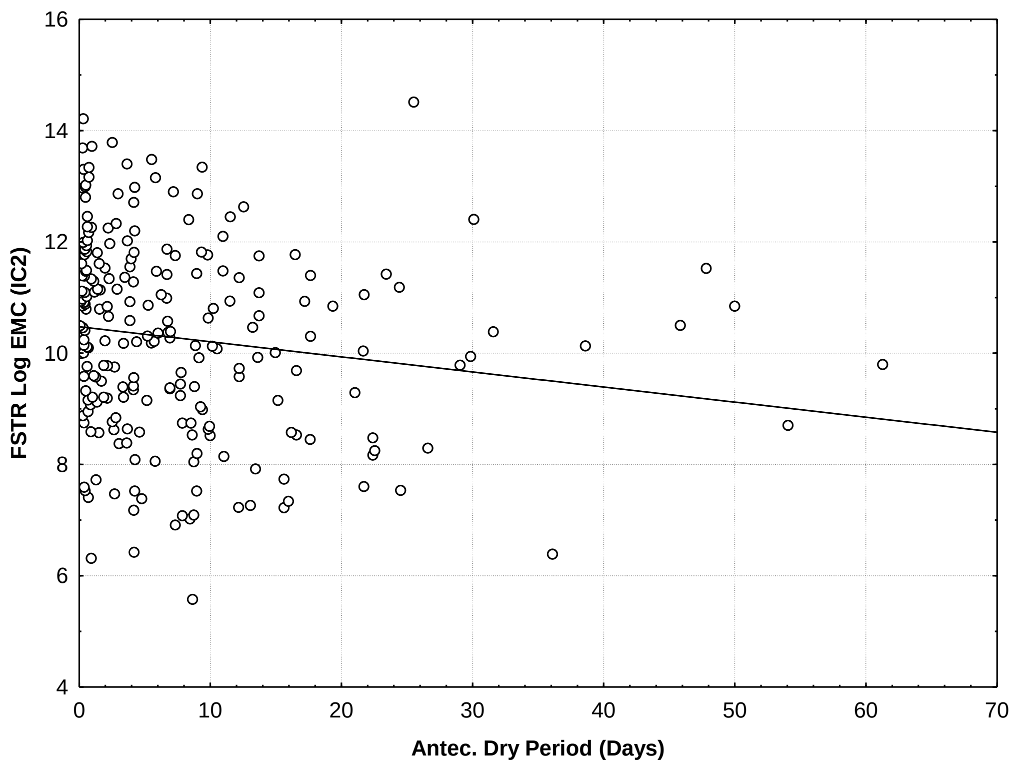
Graph C23. Scatterplot of Antecedent Dry Period vs. Log of EMC for FCOL Group SFR



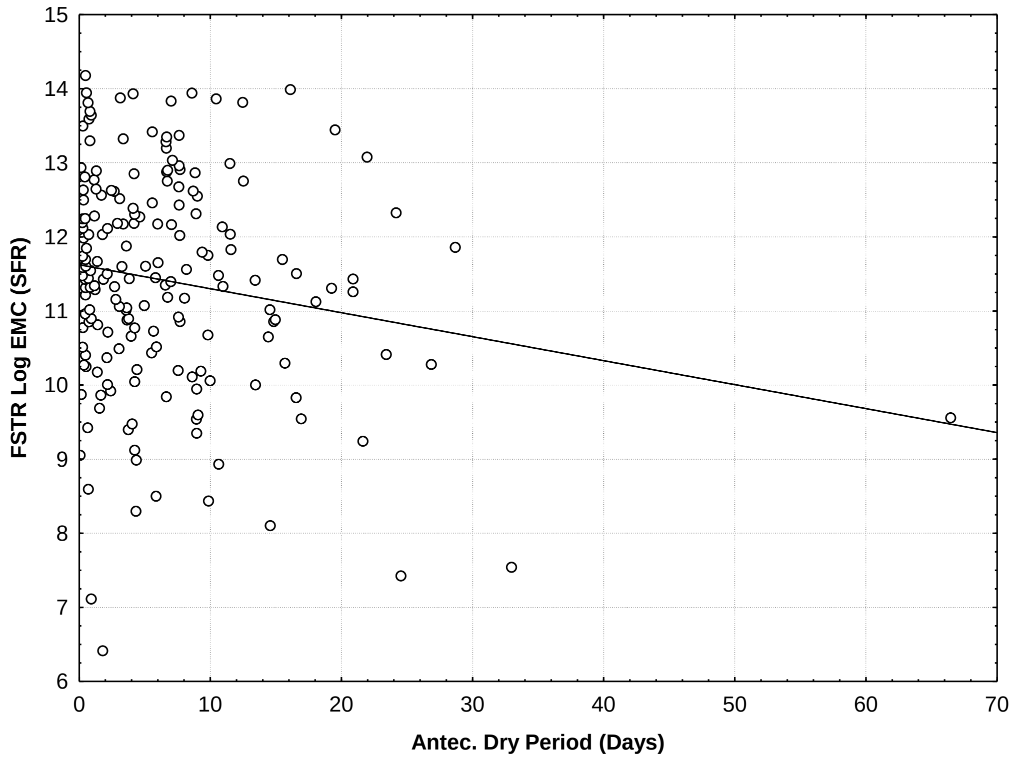
Graph C24. Scatterplot of Antecedent Dry Period vs. Log of EMC for FCOL Group UND



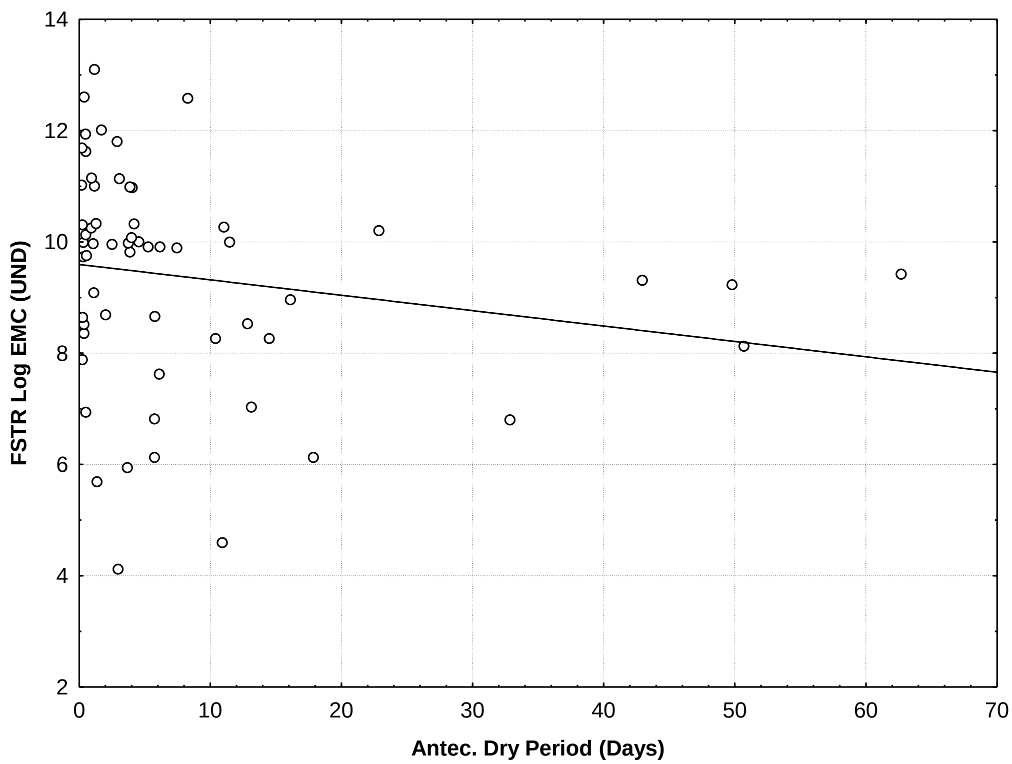
Graph C25. Scatterplot of Antecedent Dry Period vs. Log of EMC for FSTR Group IC1



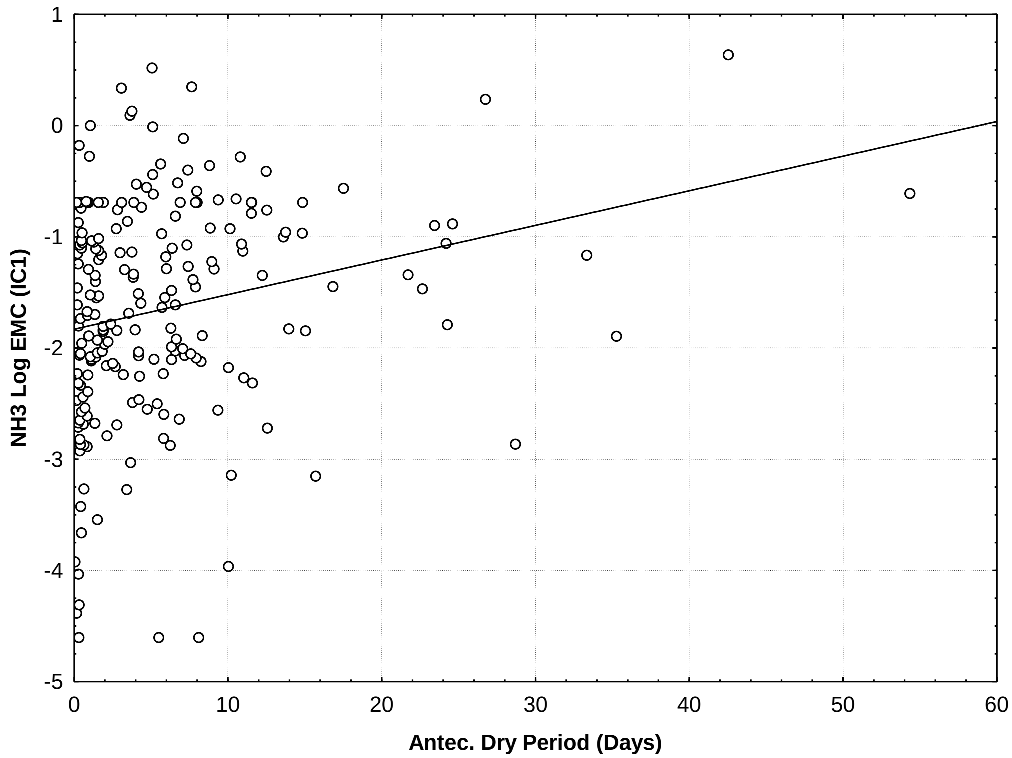
Graph C26. Scatterplot of Antecedent Dry Period vs. Log of EMC for FSTR Group IC2



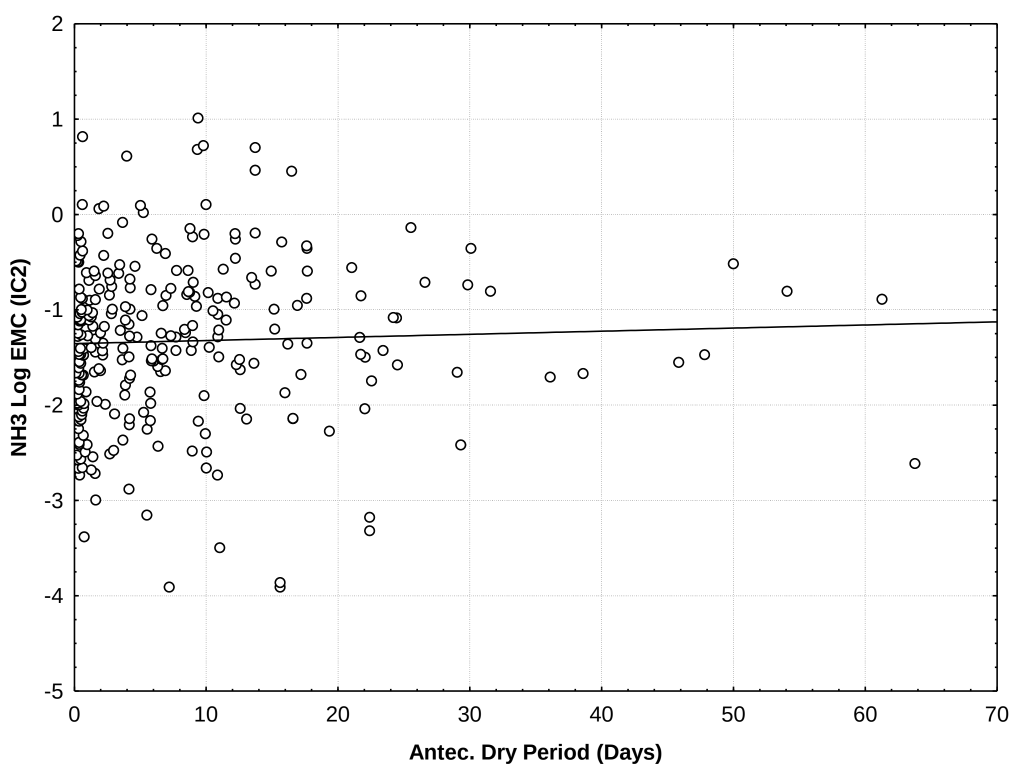
Graph C27. Scatterplot of Antecedent Dry Period vs. Log of EMC for FSTR Group SFR



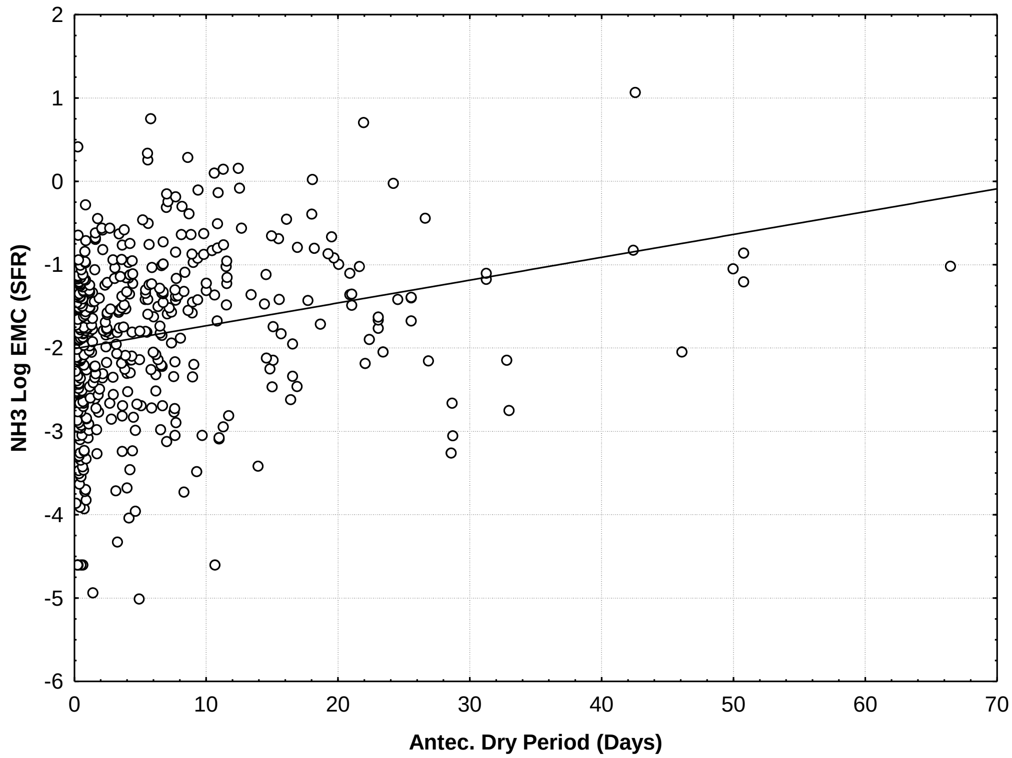
Graph C28. Scatterplot of Antecedent Dry Period vs. Log of EMC for FSTR Group UND



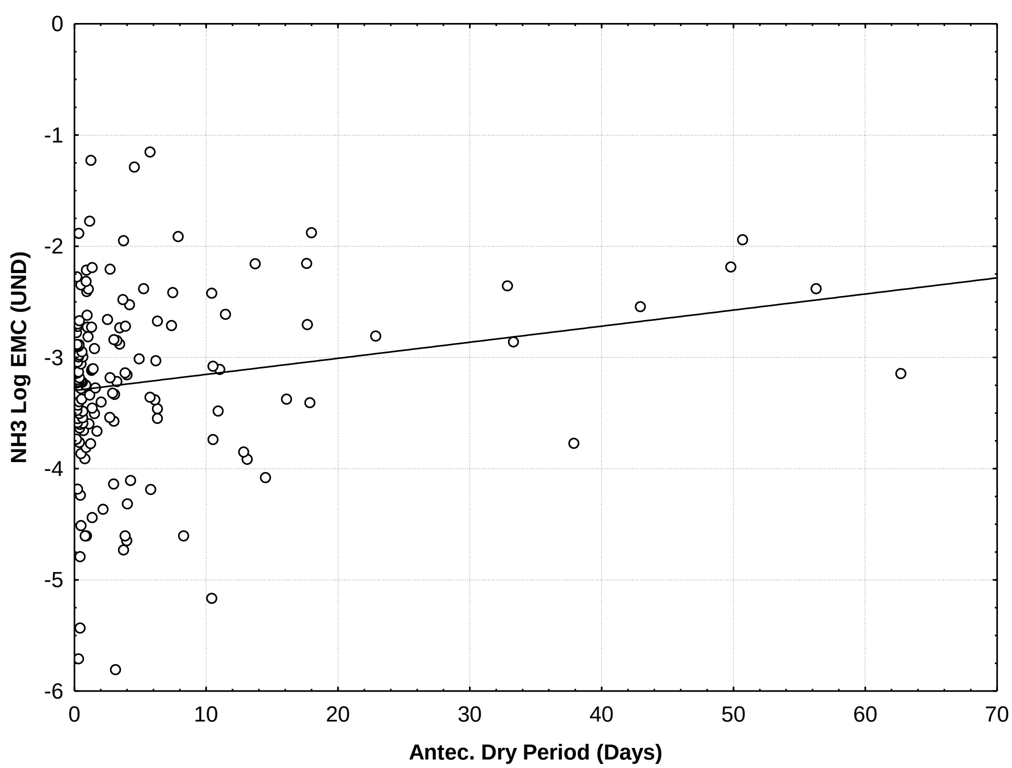
Graph C29. Scatterplot of Antecedent Dry Period vs. Log of EMC for NH3 Group IC1



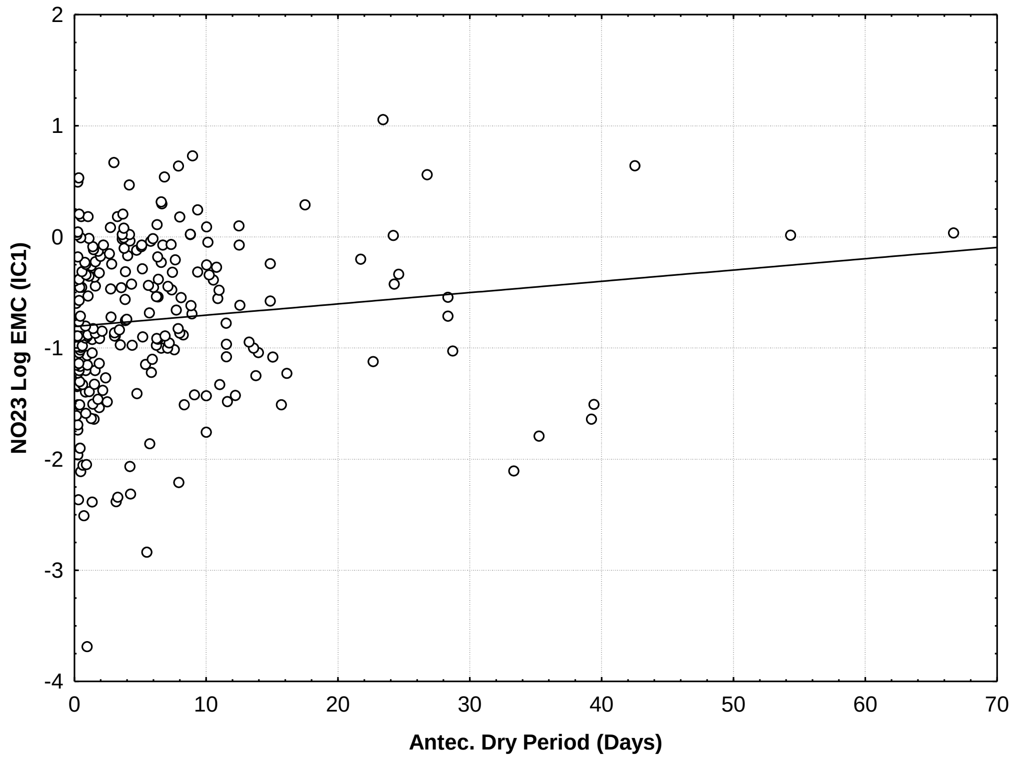
Graph C30. Scatterplot of Antecedent Dry Period vs. Log of EMC for NH3 Group IC2



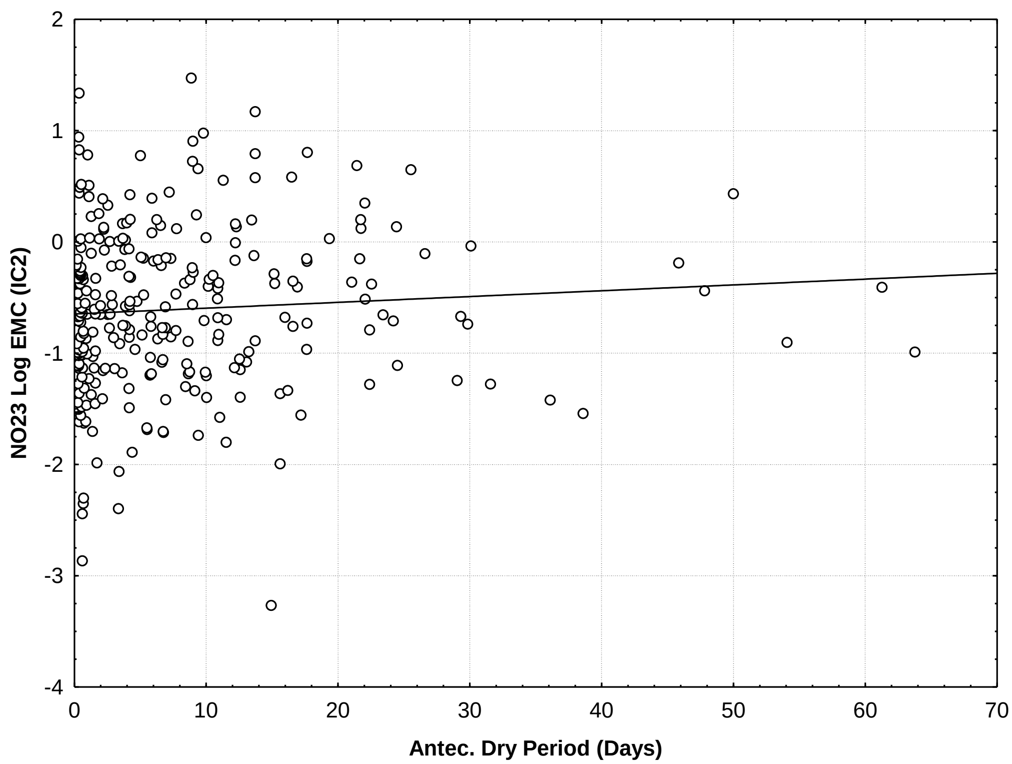
Graph C31. Scatterplot of Antecedent Dry Period vs. Log of EMC for NH3 Group SFR



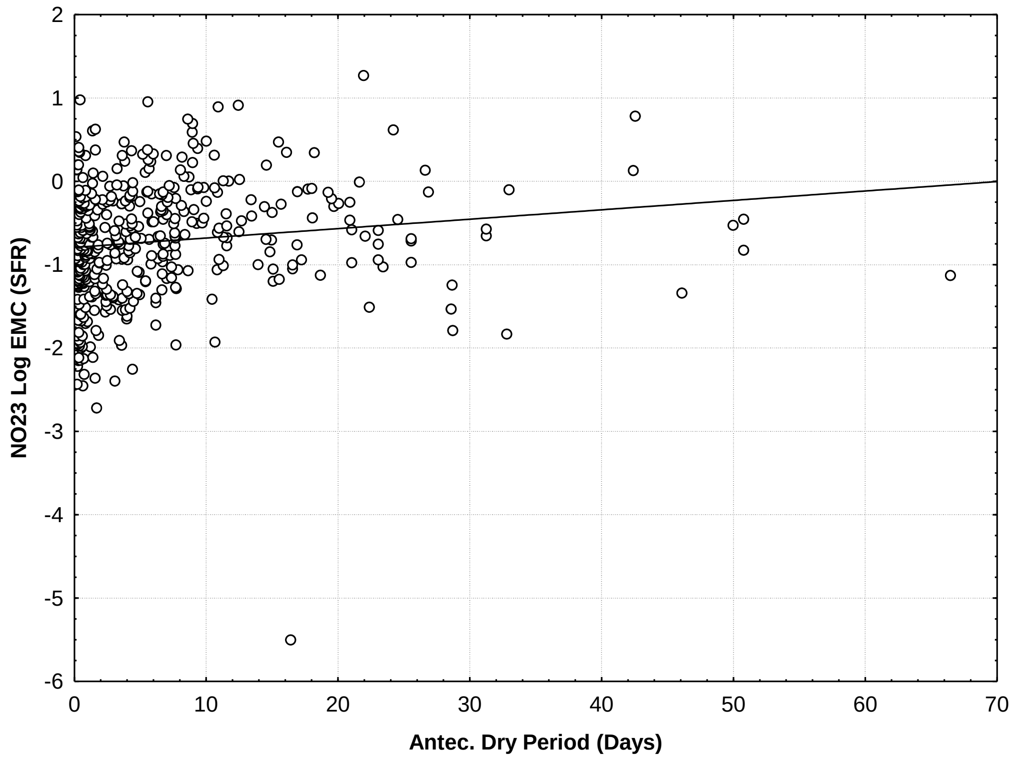
Graph C32. Scatterplot of Antecedent Dry Period vs. Log of EMC for NH3 Group UND



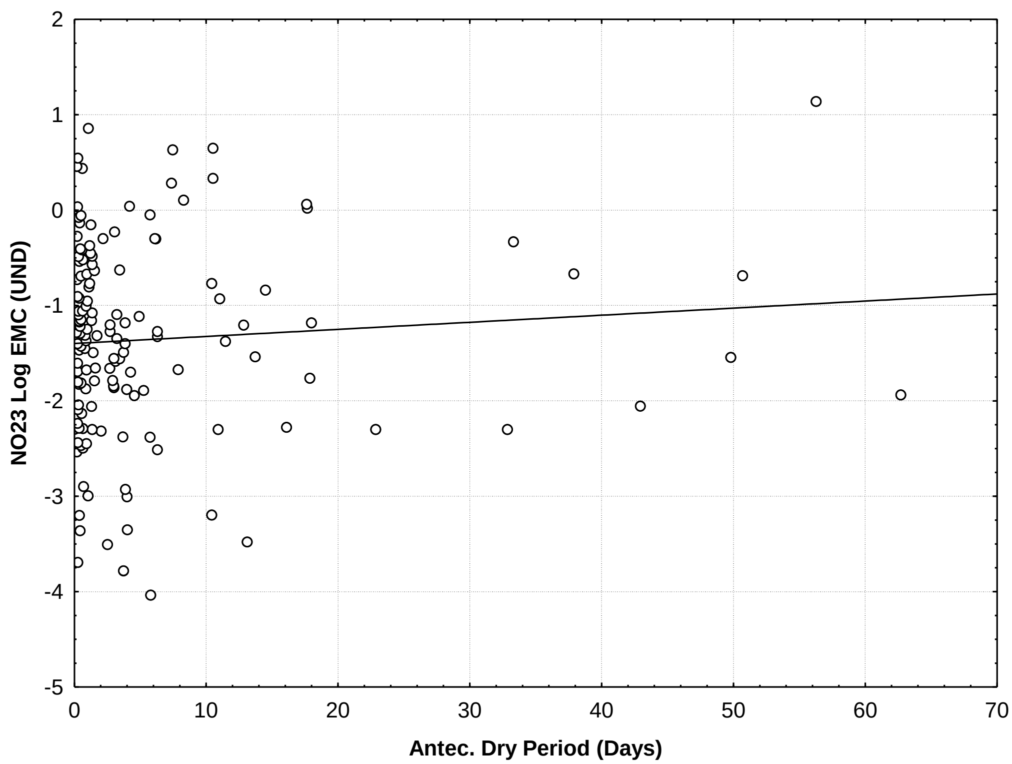
Graph C33. Scatterplot of Antecedent Dry Period vs. Log of EMC for NO23 Group IC1



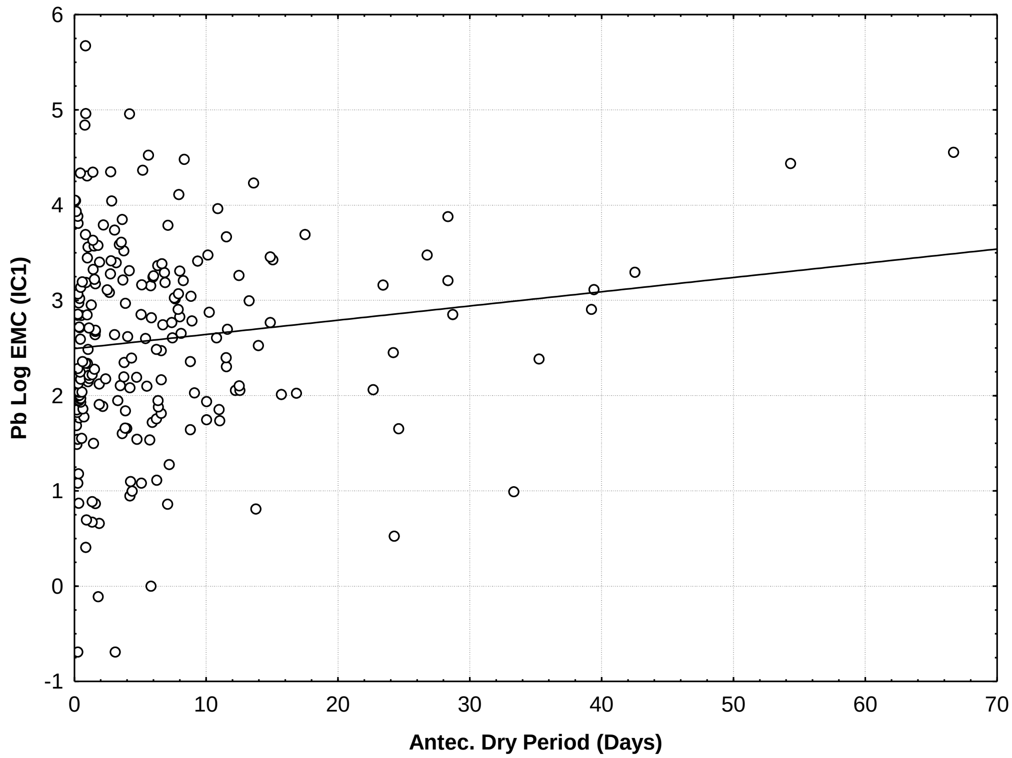
Graph C34. Scatterplot of Antecedent Dry Period vs. Log of EMC for NO23 Group IC2



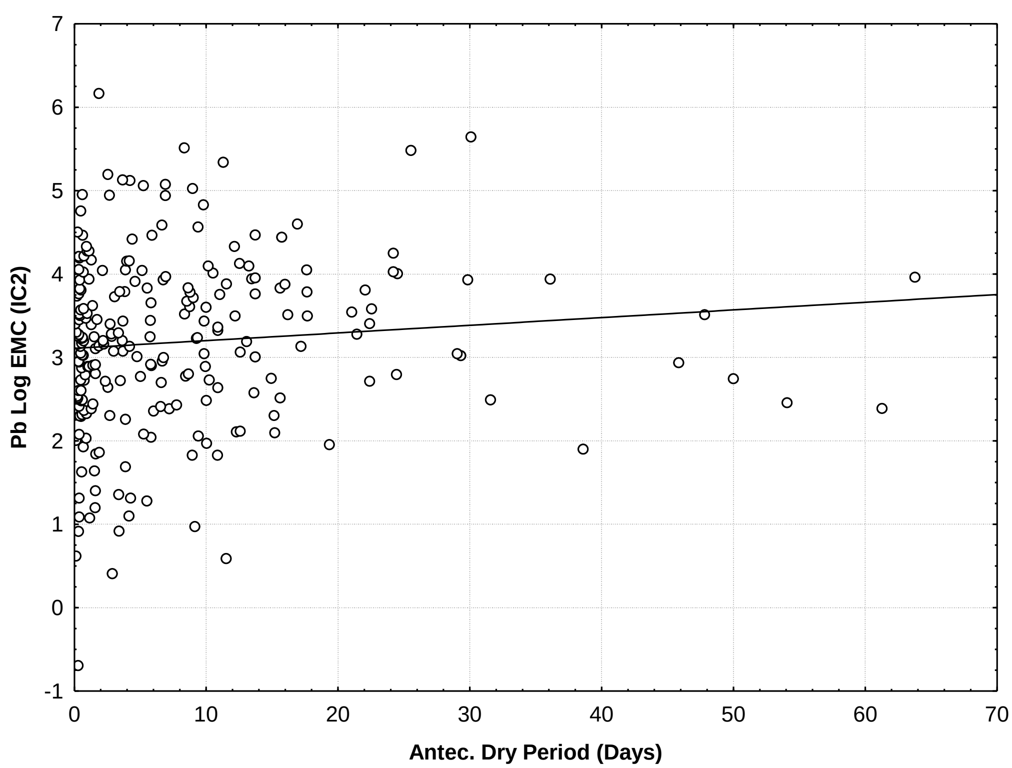
Graph C35. Scatterplot of Antecedent Dry Period vs. Log of EMC for NO23 Group SFR



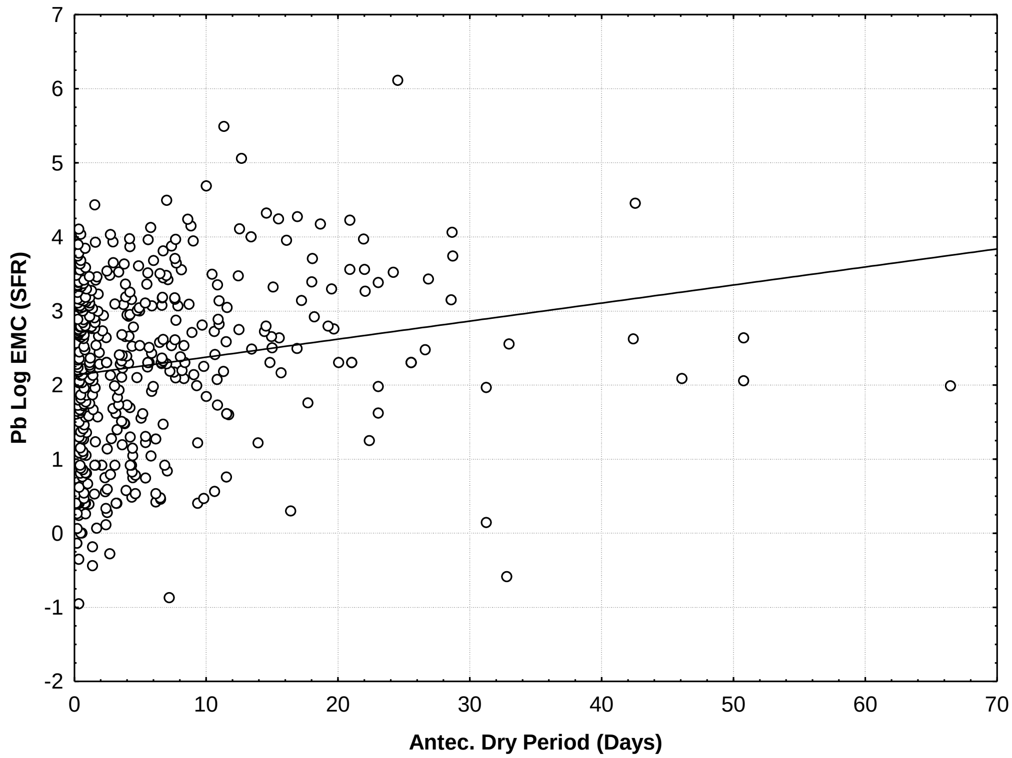
Graph C36. Scatterplot of Antecedent Dry Period vs. Log of EMC for NO23 Group UND



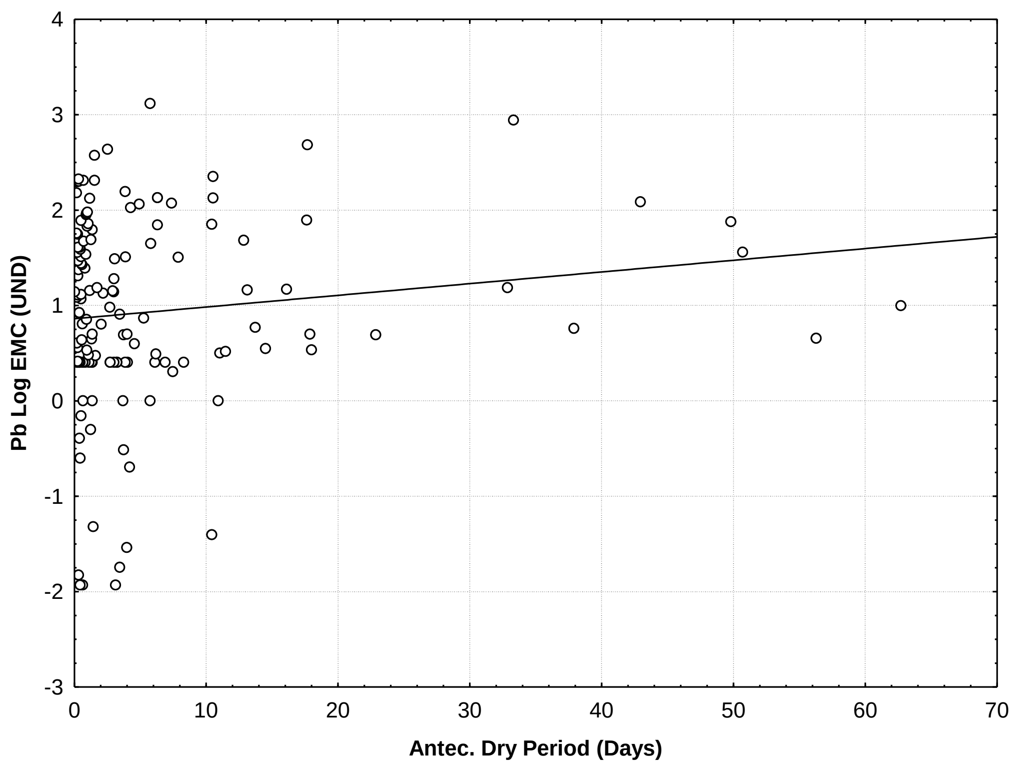
Graph C37. Scatterplot of Antecedent Dry Period vs. Log of EMC for Pb Group IC1



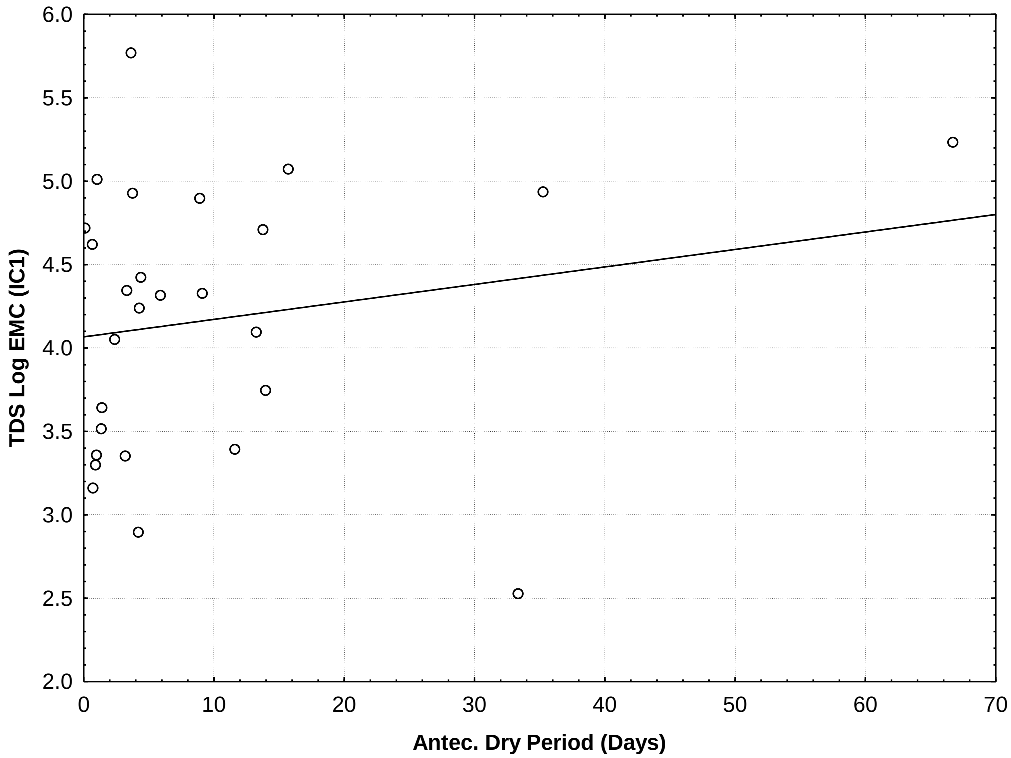
Graph C38. Scatterplot of Antecedent Dry Period vs. Log of EMC for Pb Group IC2



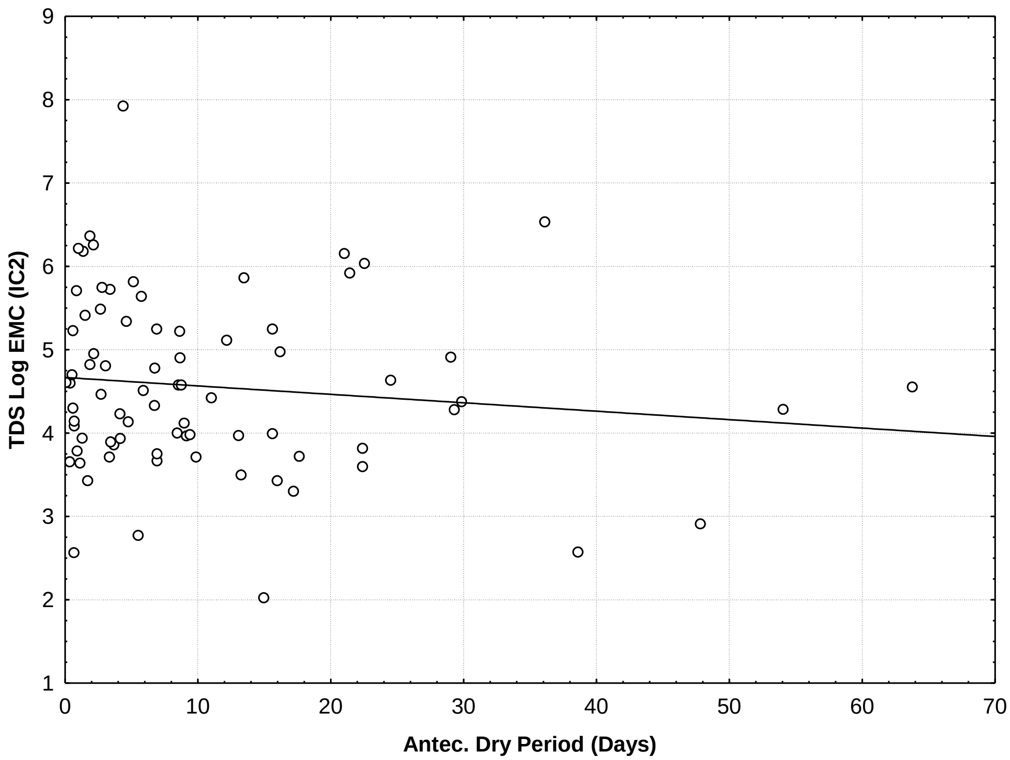
Graph C39. Scatterplot of Antecedent Dry Period vs. Log of EMC for Pb Group SFR



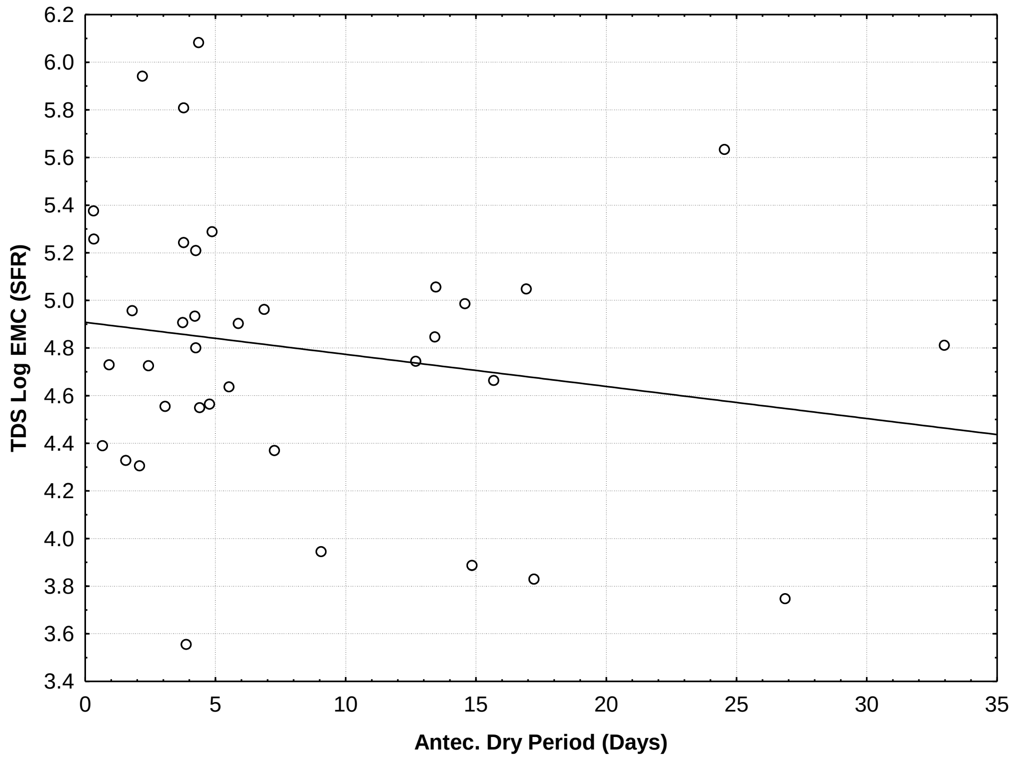
Graph C40. Scatterplot of Antecedent Dry Period vs. Log of EMC for Pb Group UND



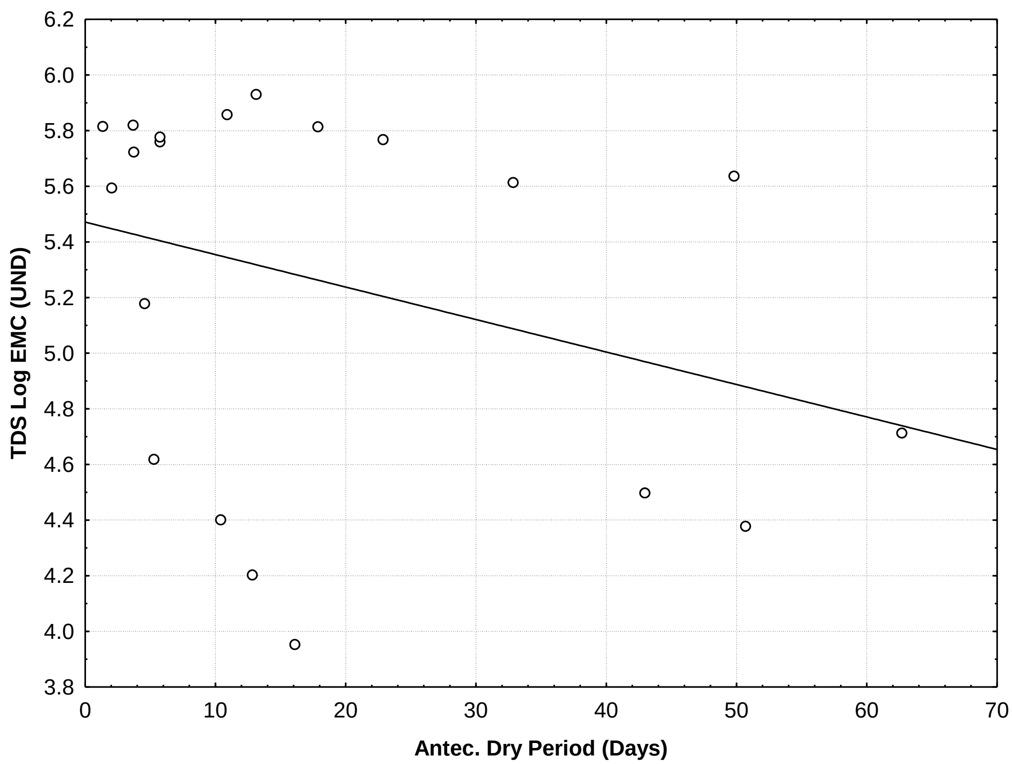
Graph C41. Scatterplot of Antecedent Dry Period vs. Log of EMC for TDS Group IC1



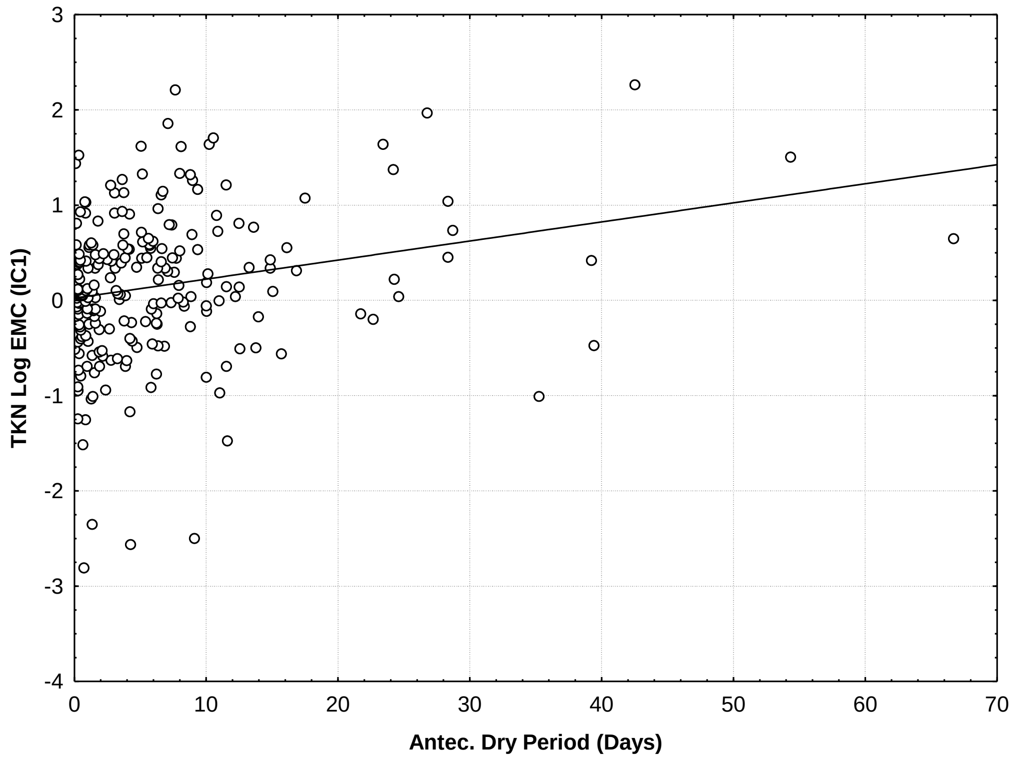
Graph C42. Scatterplot of Antecedent Dry Period vs. Log of EMC for TDS Group IC2



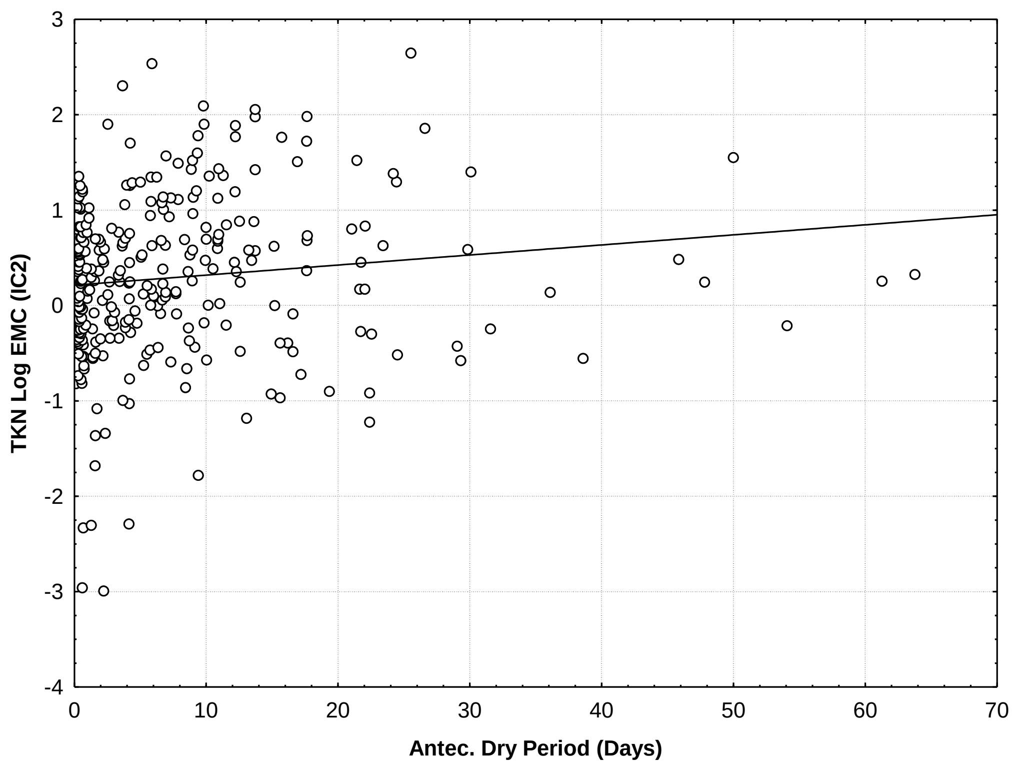
Graph C43. Scatterplot of Antecedent Dry Period vs. Log of EMC for TDS Group SFR



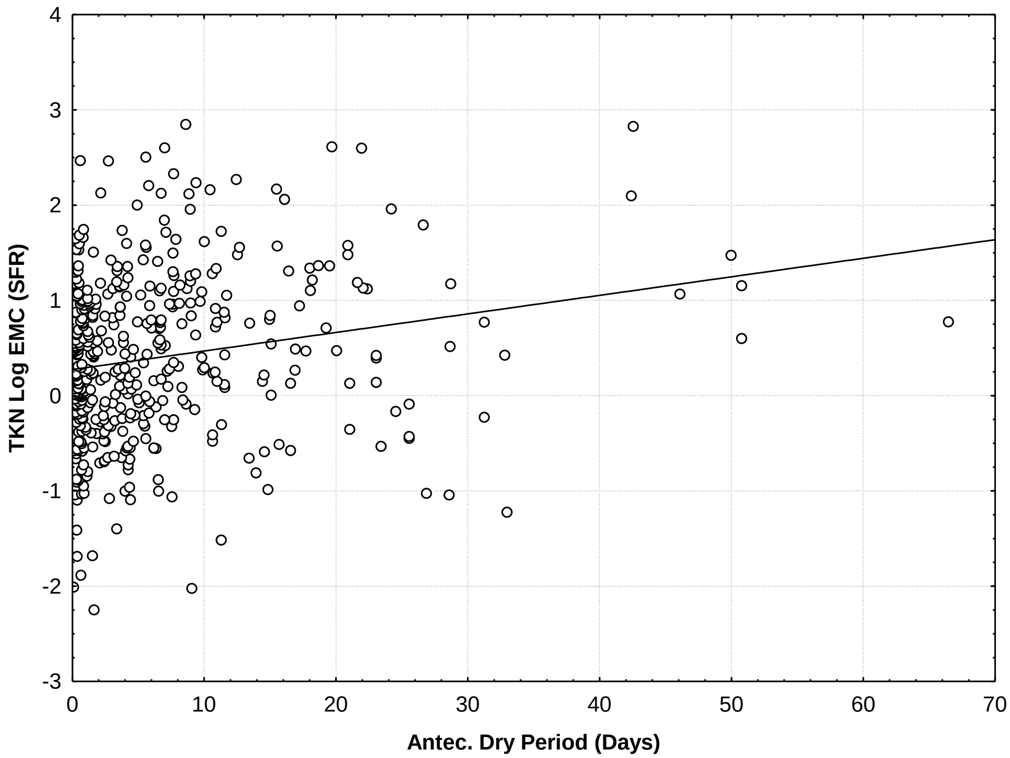
Graph C44. Scatterplot of Antecedent Dry Period vs. Log of EMC for TDS Group UND



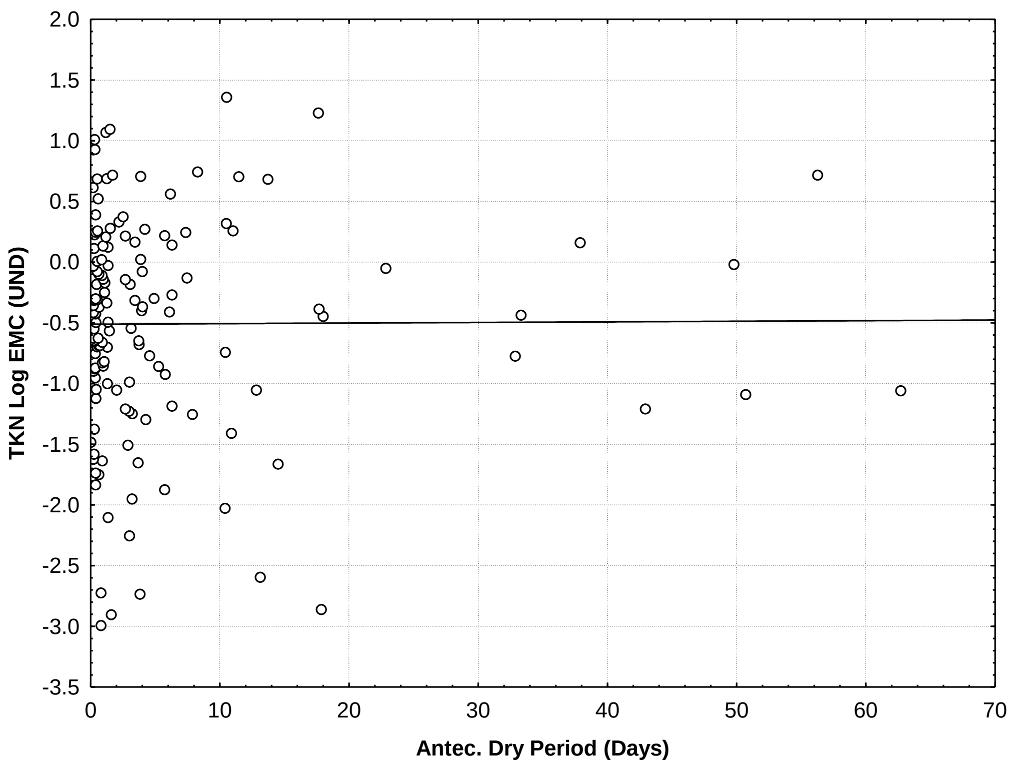
Graph C45. Scatterplot of Antecedent Dry Period vs. Log of EMC for TKN Group IC1



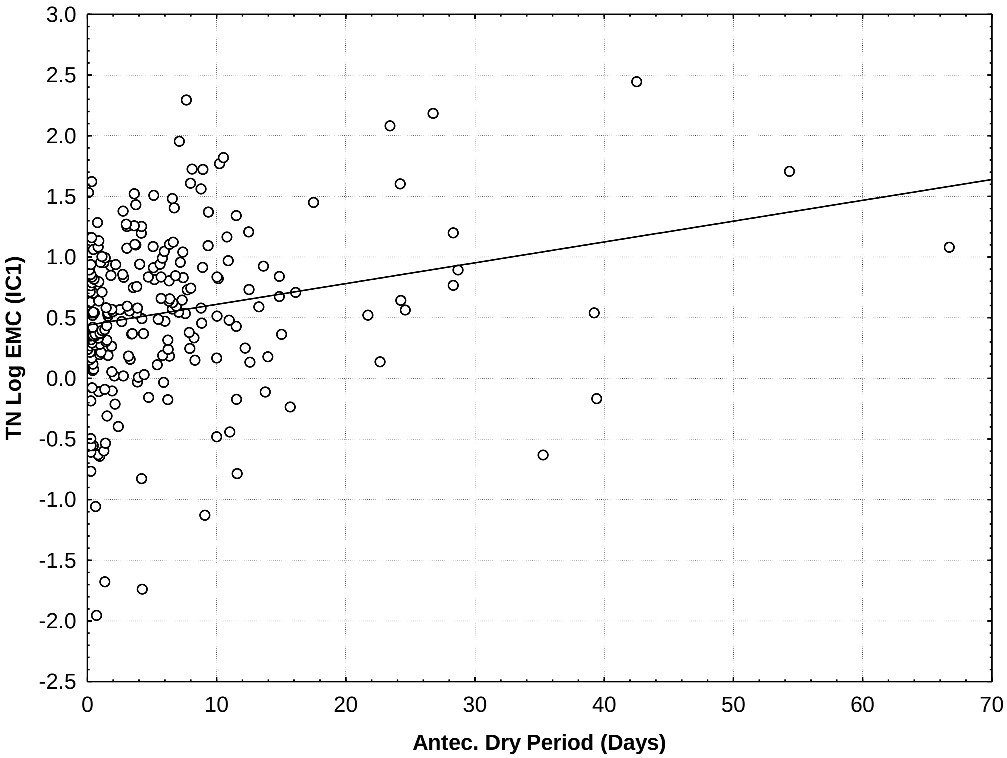
Graph C46. Scatterplot of Antecedent Dry Period vs. Log of EMC for TKN Group IC2



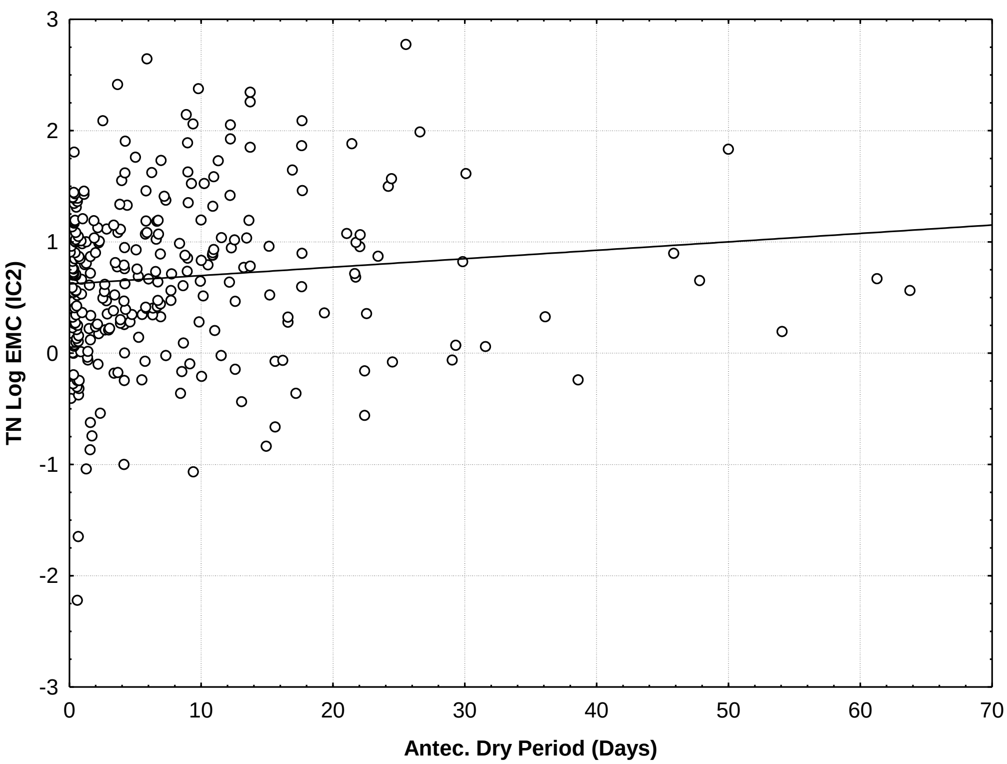
Graph C47. Scatterplot of Antecedent Dry Period vs. Log of EMC for TKN Group SFR



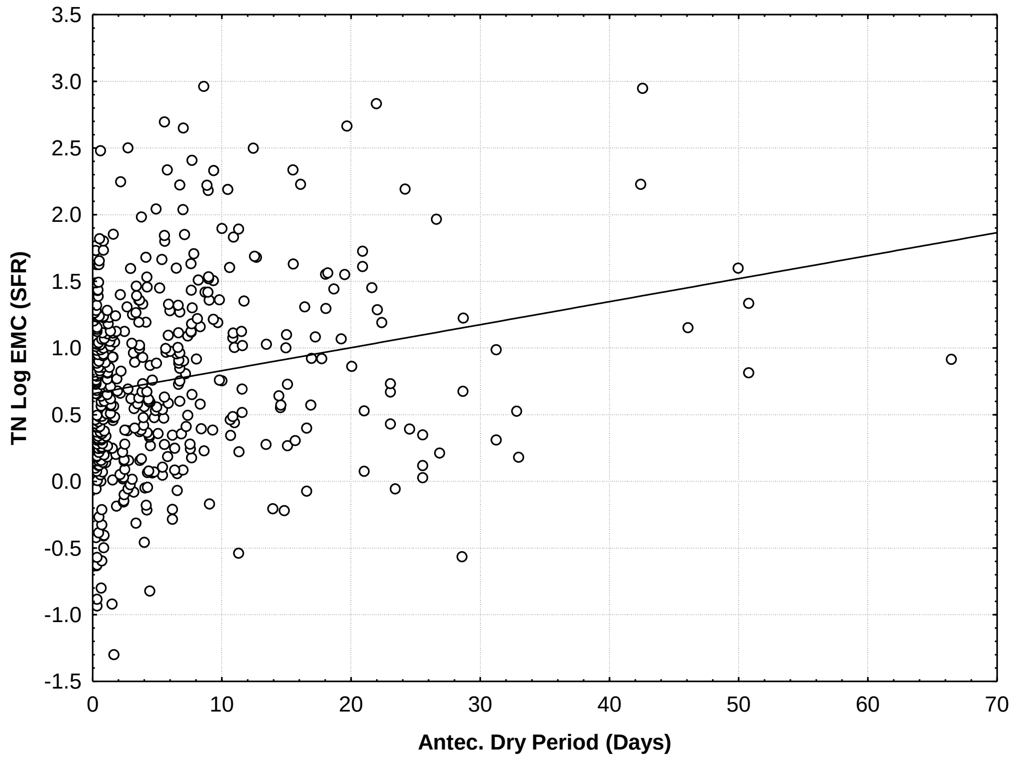
Graph C48. Scatterplot of Antecedent Dry Period vs. Log of EMC for TKN Group UND



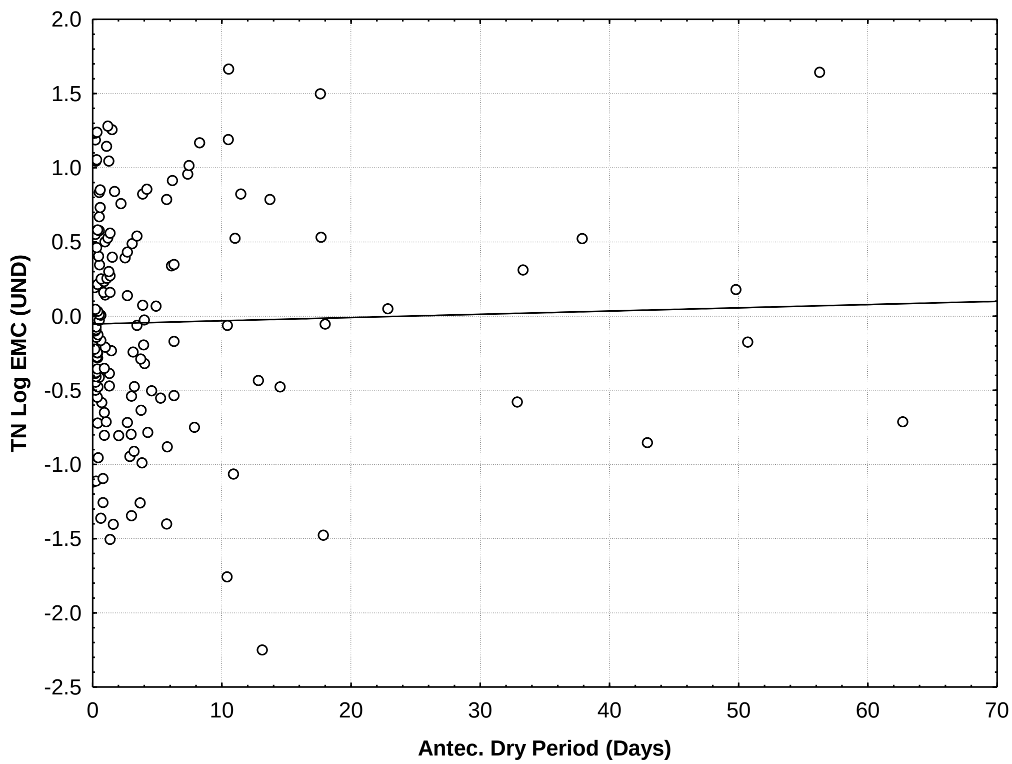
Graph C49. Scatterplot of Antecedent Dry Period vs. Log of EMC for TN Group IC1



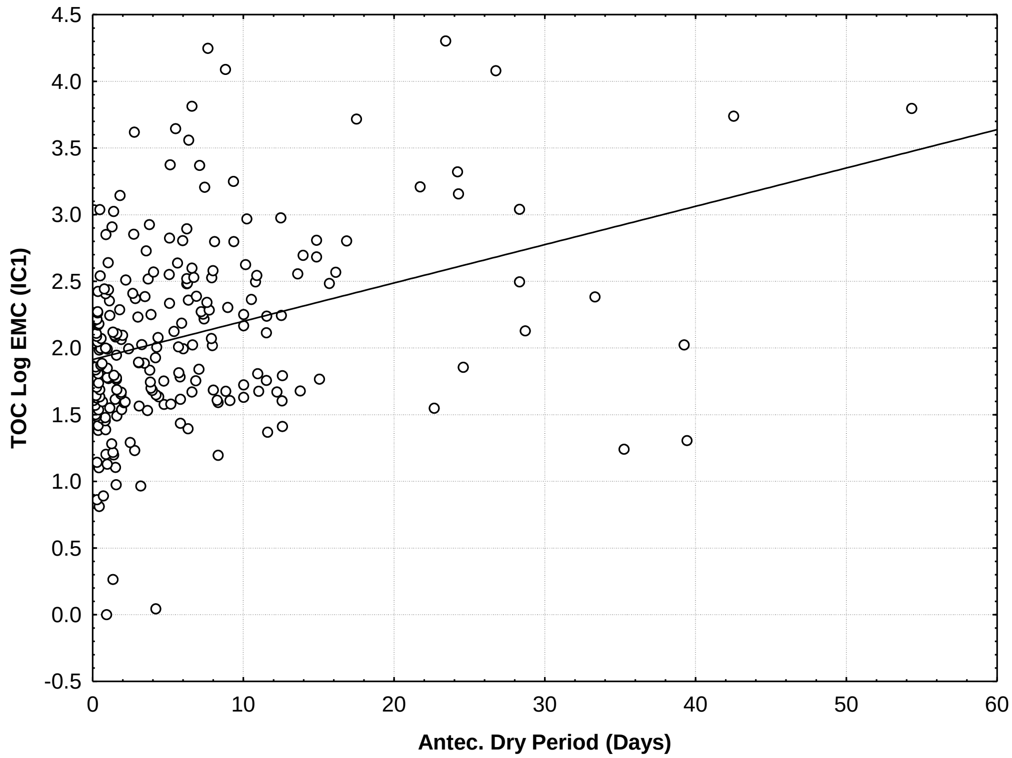
Graph C50. Scatterplot of Antecedent Dry Period vs. Log of EMC for TN Group IC2



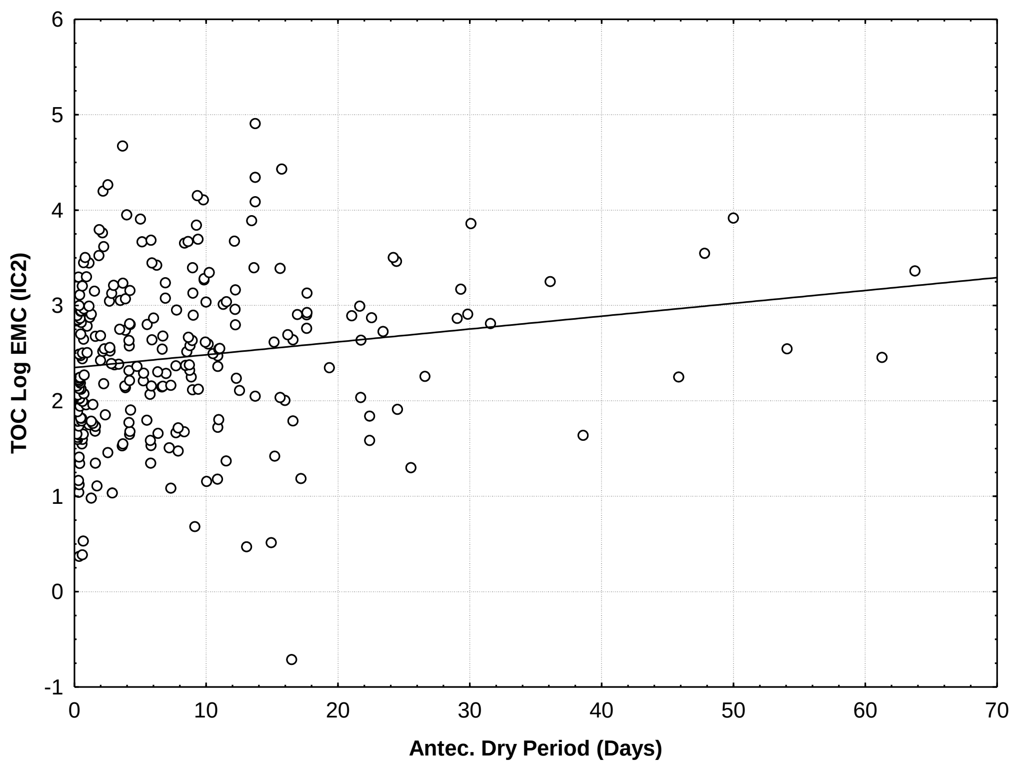
Graph C51. Scatterplot of Antecedent Dry Period vs. Log of EMC for TN Group SFR



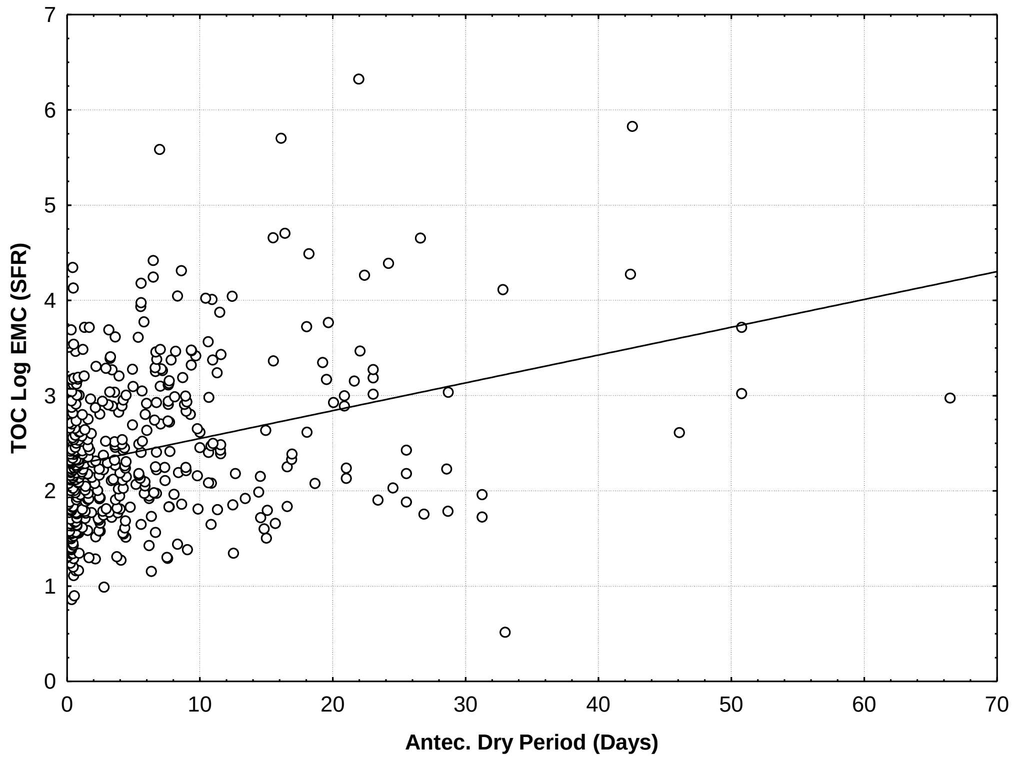
Graph C52. Scatterplot of Antecedent Dry Period vs. Log of EMC for TN Group UND



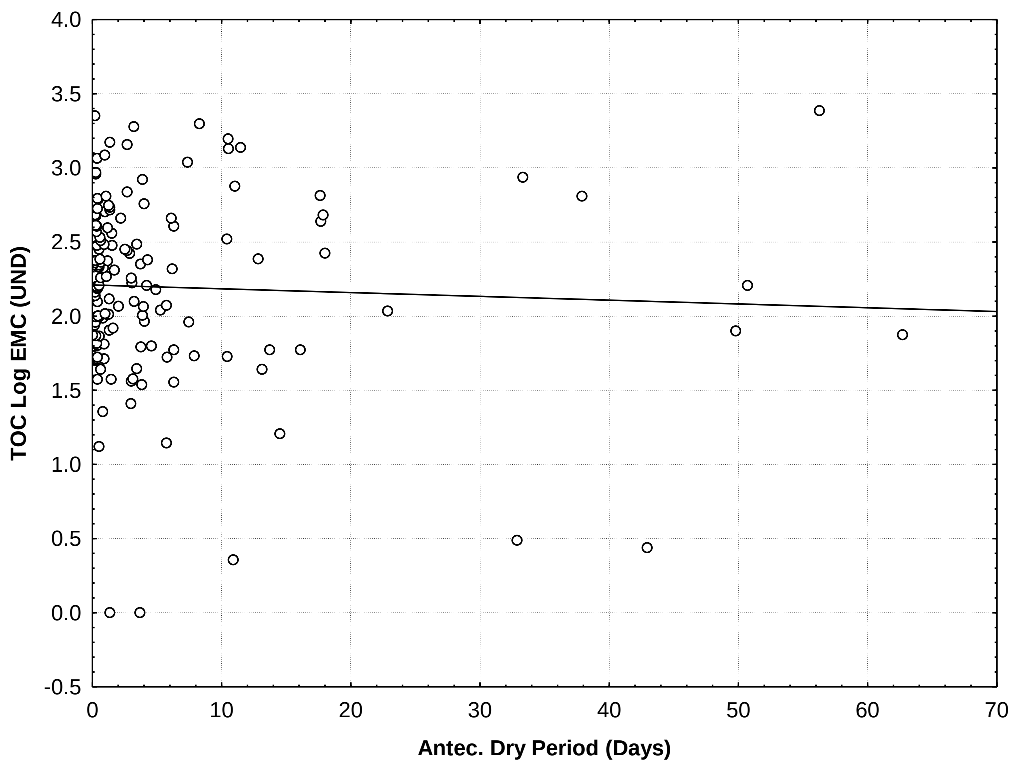
Graph C53. Scatterplot of Antecedent Dry Period vs. Log of EMC for TOC Group IC1



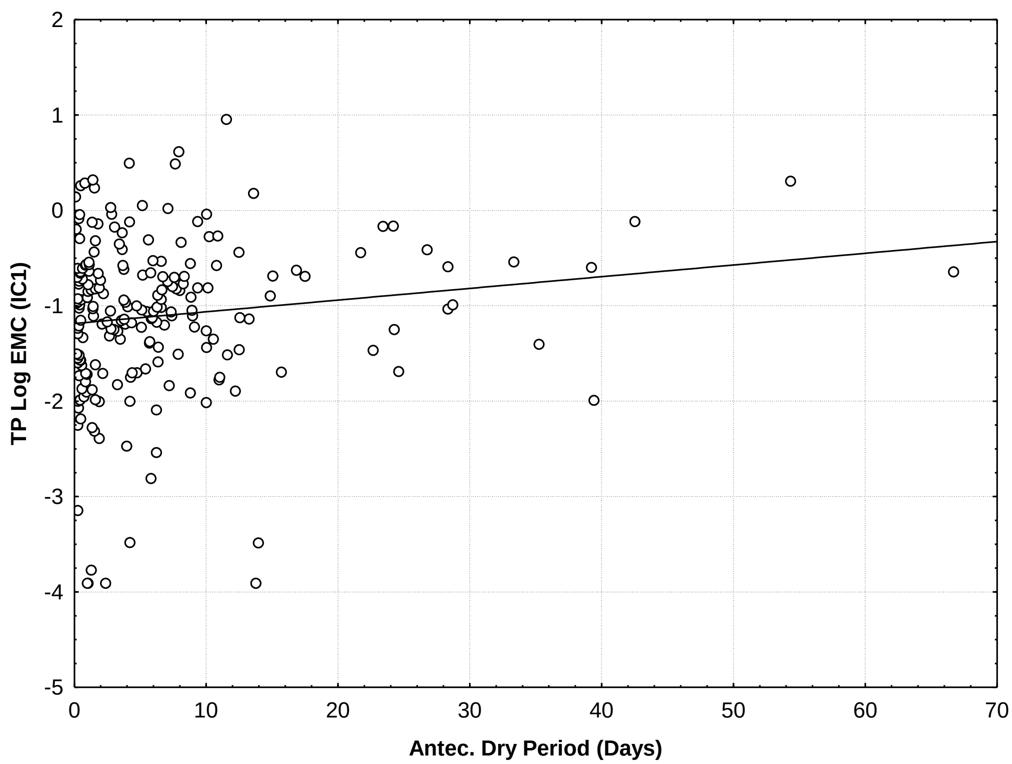
Graph C54. Scatterplot of Antecedent Dry Period vs. Log of EMC for TOC Group IC2



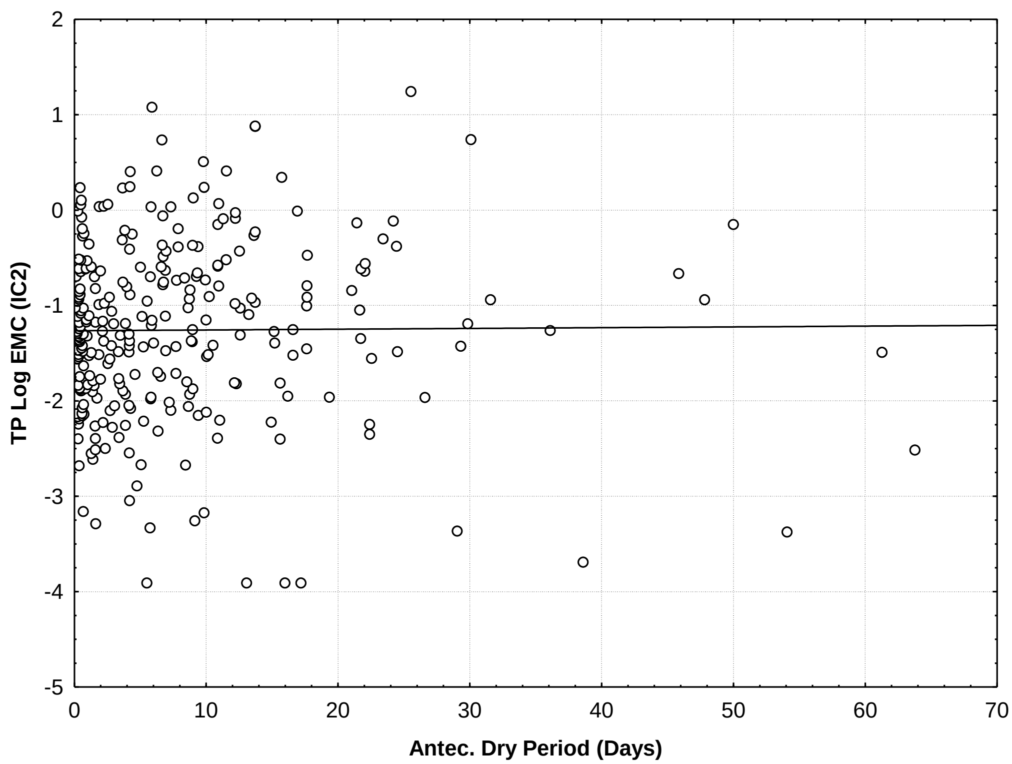
Graph C55. Scatterplot of Antecedent Dry Period vs. Log of EMC for TOC Group SFR



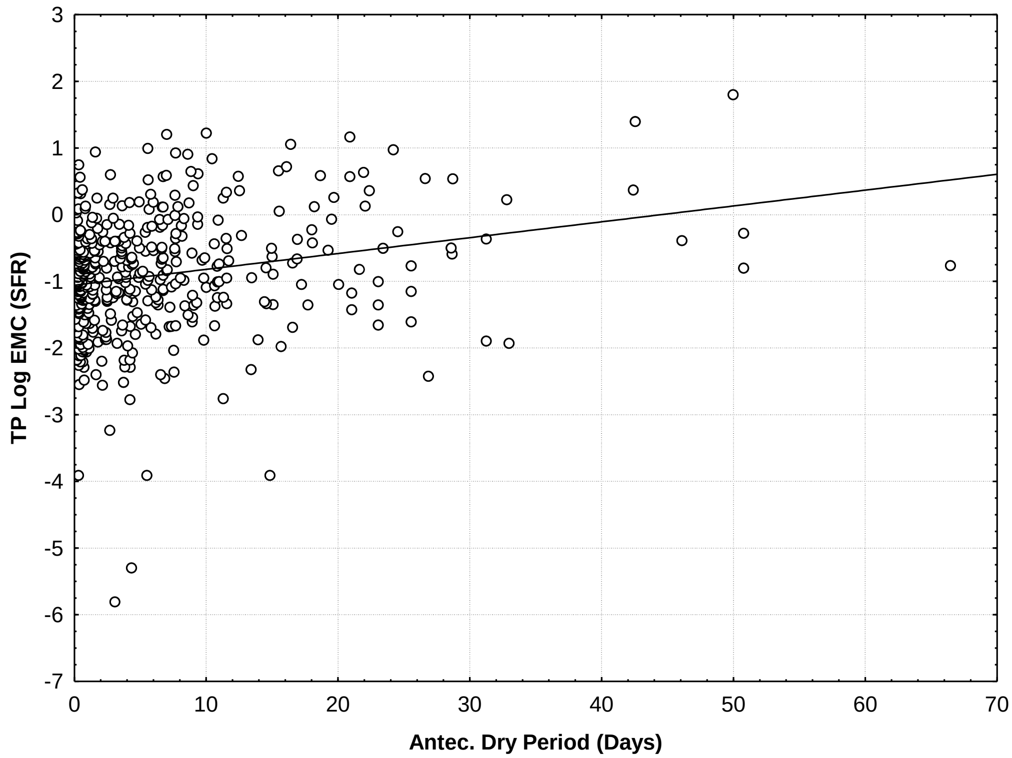
Graph C56. Scatterplot of Antecedent Dry Period vs. Log of EMC for TOC Group UND



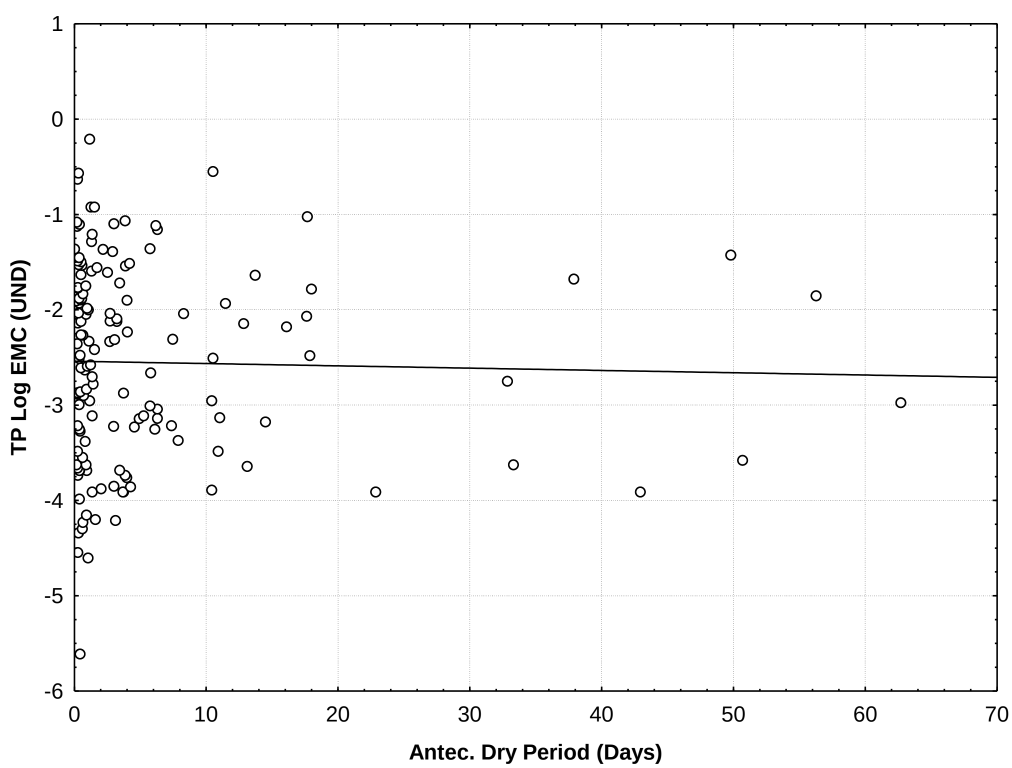
Graph C57. Scatterplot of Antecedent Dry Period vs. Log of EMC for TP Group IC1



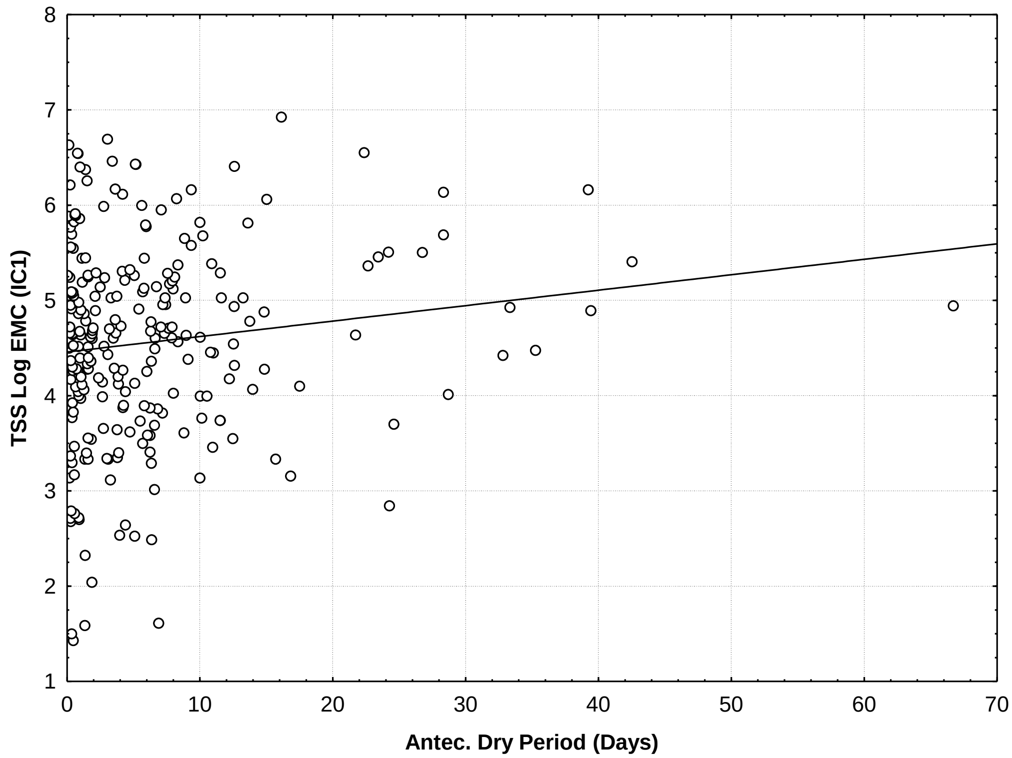
Graph C58. Scatterplot of Antecedent Dry Period vs. Log of EMC for TP Group IC2



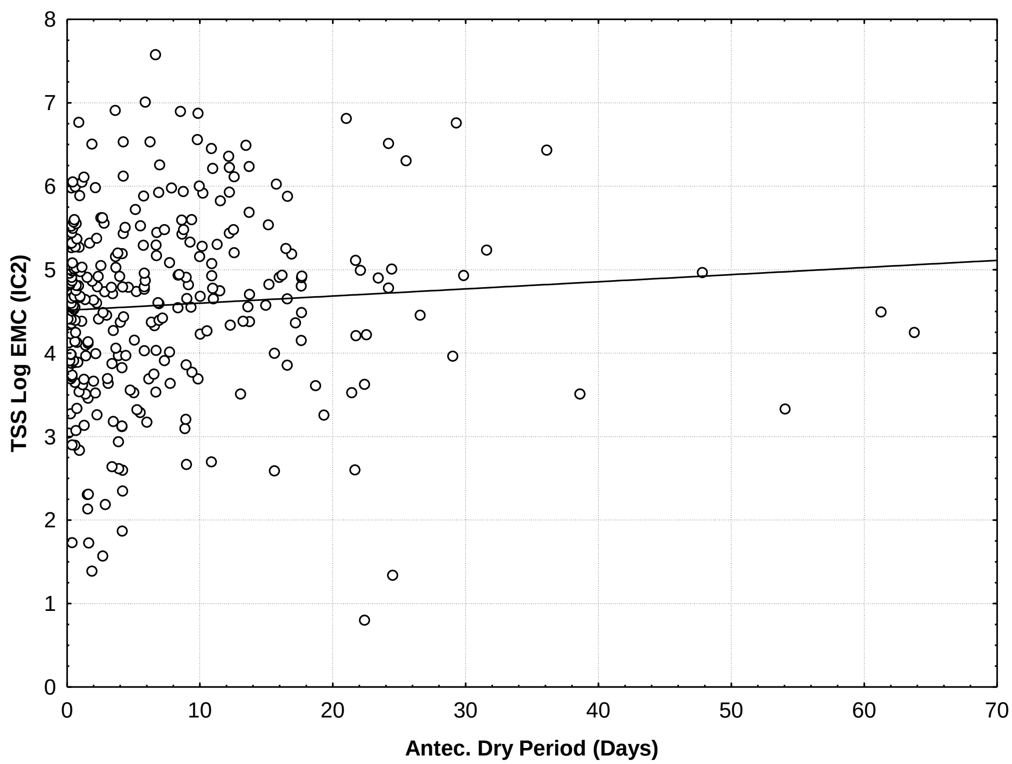
Graph C59. Scatterplot of Antecedent Dry Period vs. Log of EMC for TP Group SFR



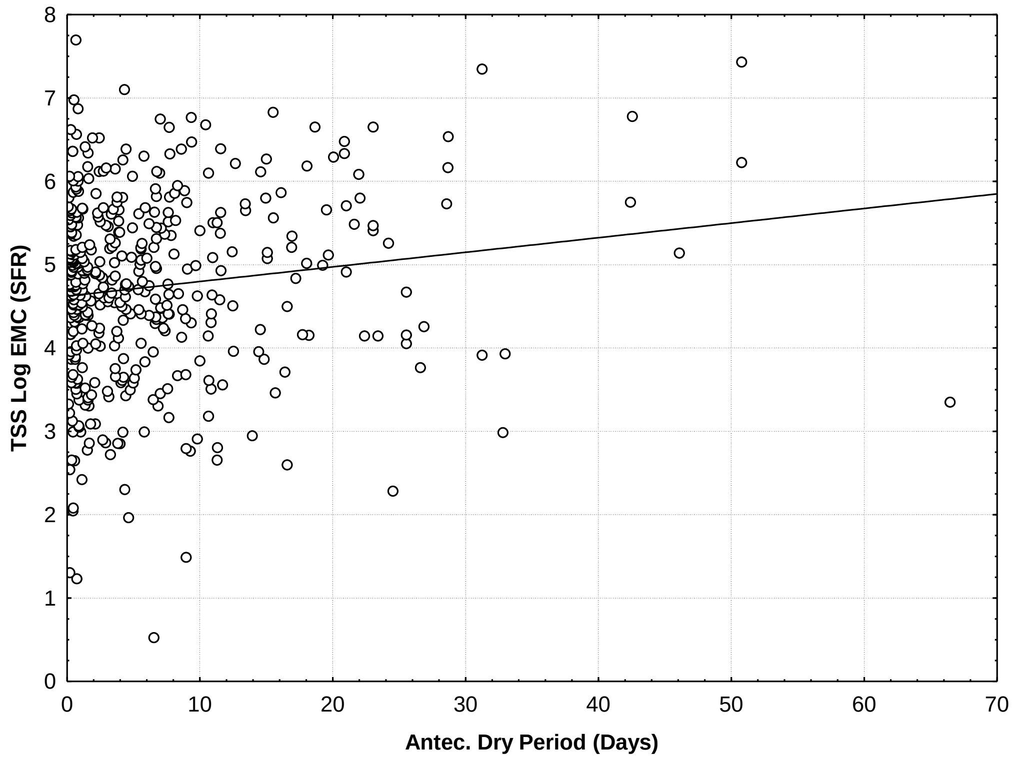
Graph C60. Scatterplot of Antecedent Dry Period vs. Log of EMC for TP Group UND



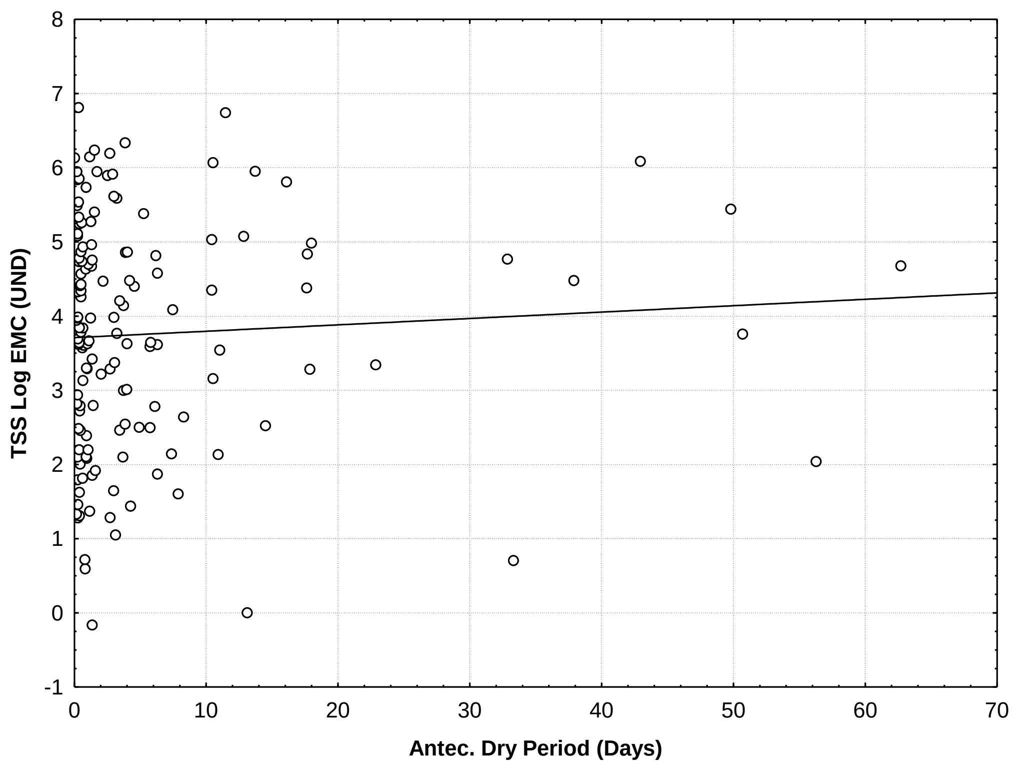
Graph C61. Scatterplot of Antecedent Dry Period vs. Log of EMC for TSS Group IC1



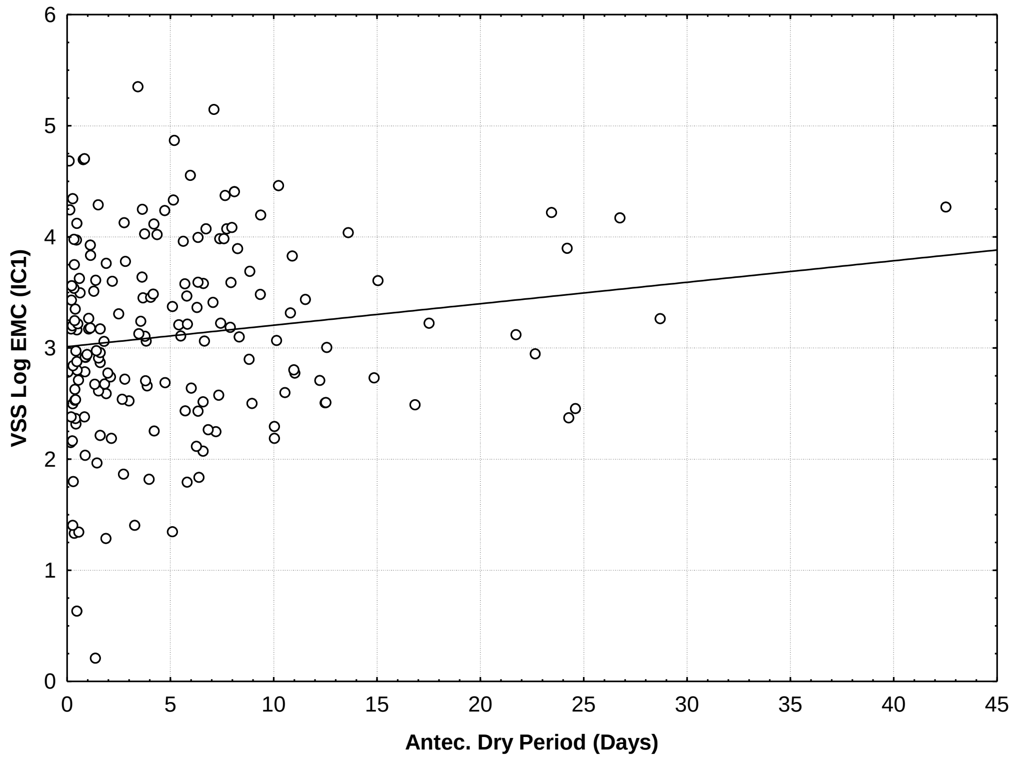
Graph C62. Scatterplot of Antecedent Dry Period vs. Log of EMC for TSS Group IC2



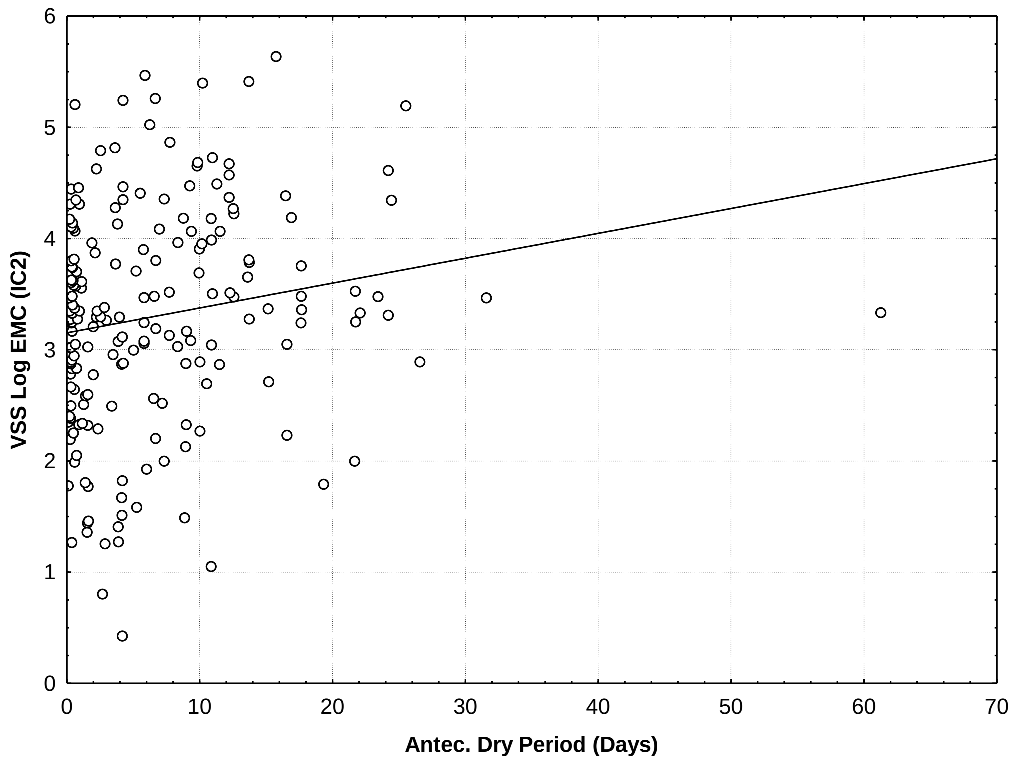
Graph C63. Scatterplot of Antecedent Dry Period vs. Log of EMC for TSS Group SFR



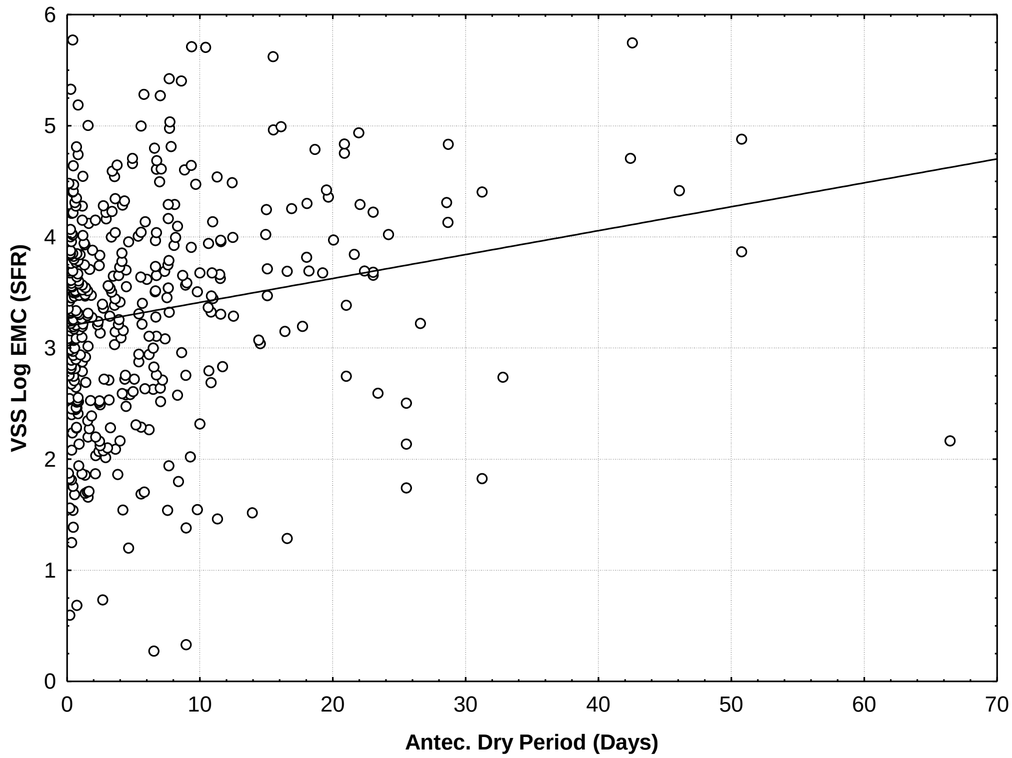
Graph C64. Scatterplot of Antecedent Dry Period vs. Log of EMC for TSS Group UND



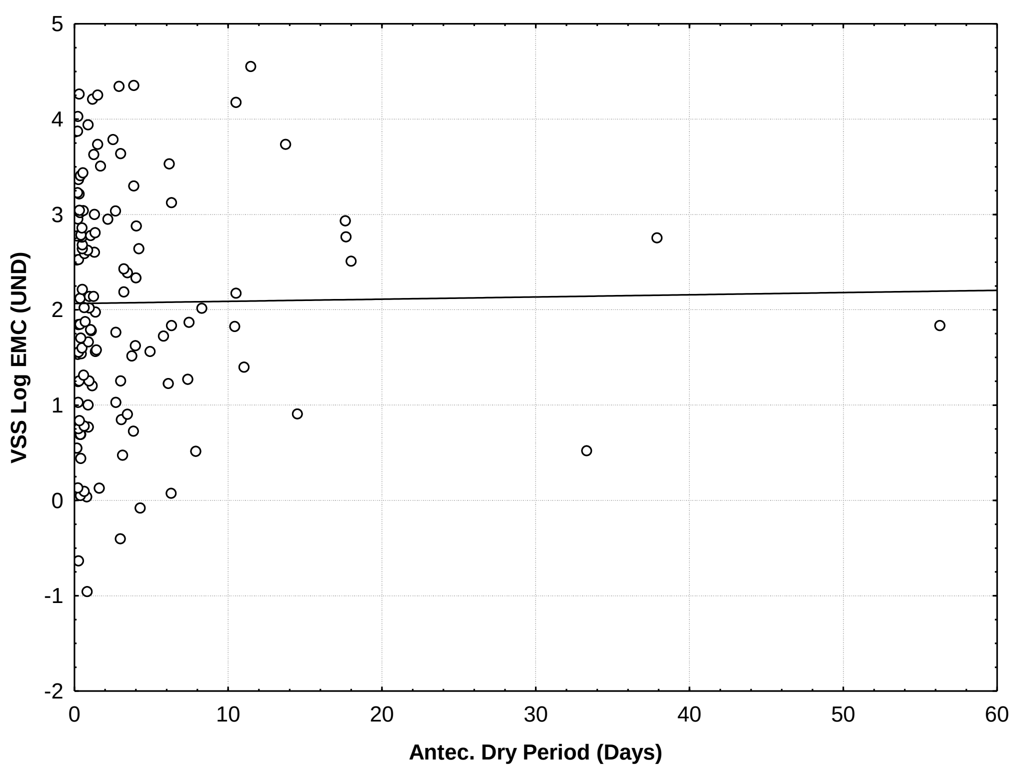
Graph C65. Scatterplot of Antecedent Dry Period vs. Log of EMC for VSS Group IC1



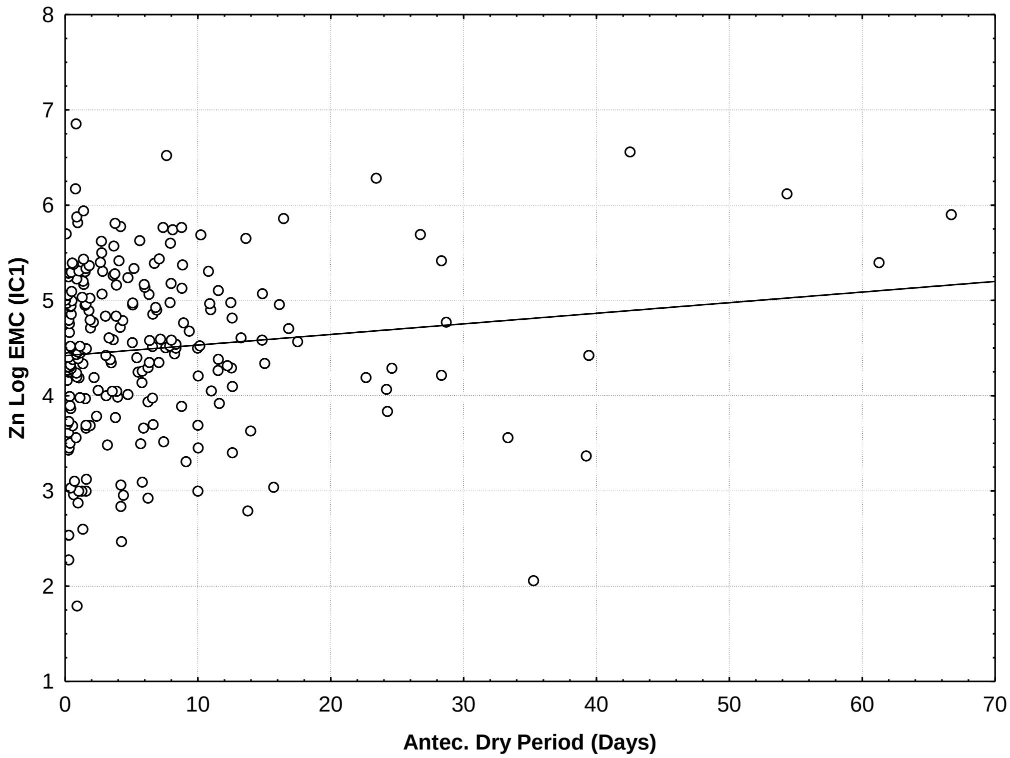
Graph C66. Scatterplot of Antecedent Dry Period vs. Log of EMC for VSS Group IC2



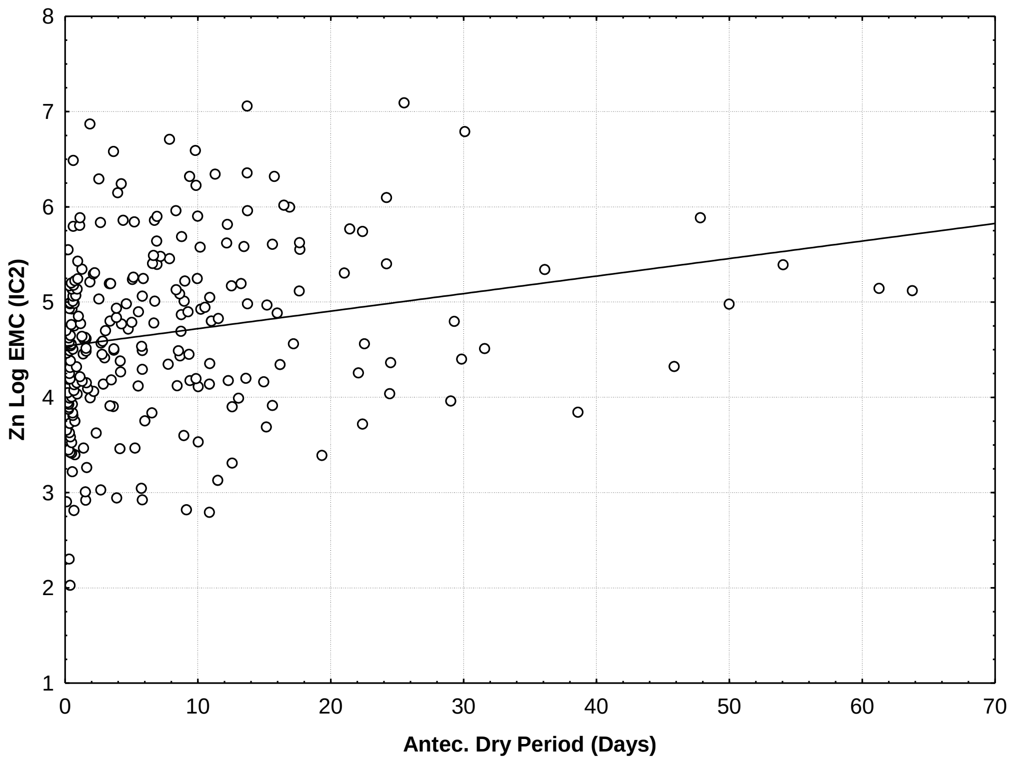
Graph C67. Scatterplot of Antecedent Dry Period vs. Log of EMC for VSS Group SFR



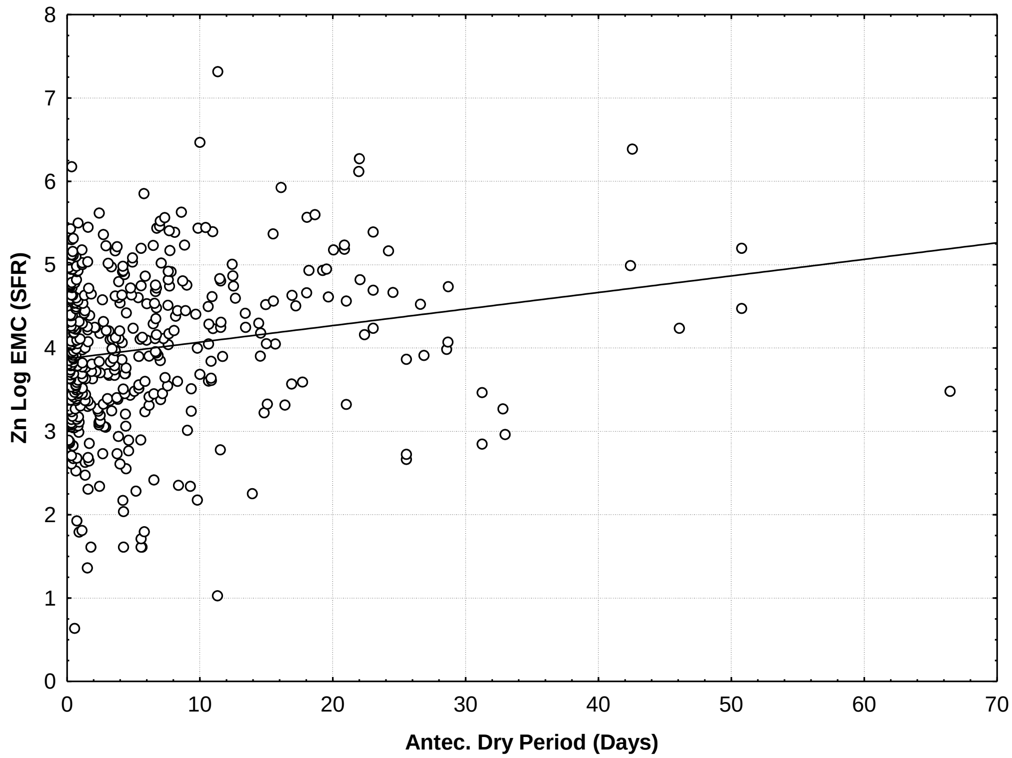
Graph C68. Scatterplot of Antecedent Dry Period vs. Log of EMC for VSS Group UND



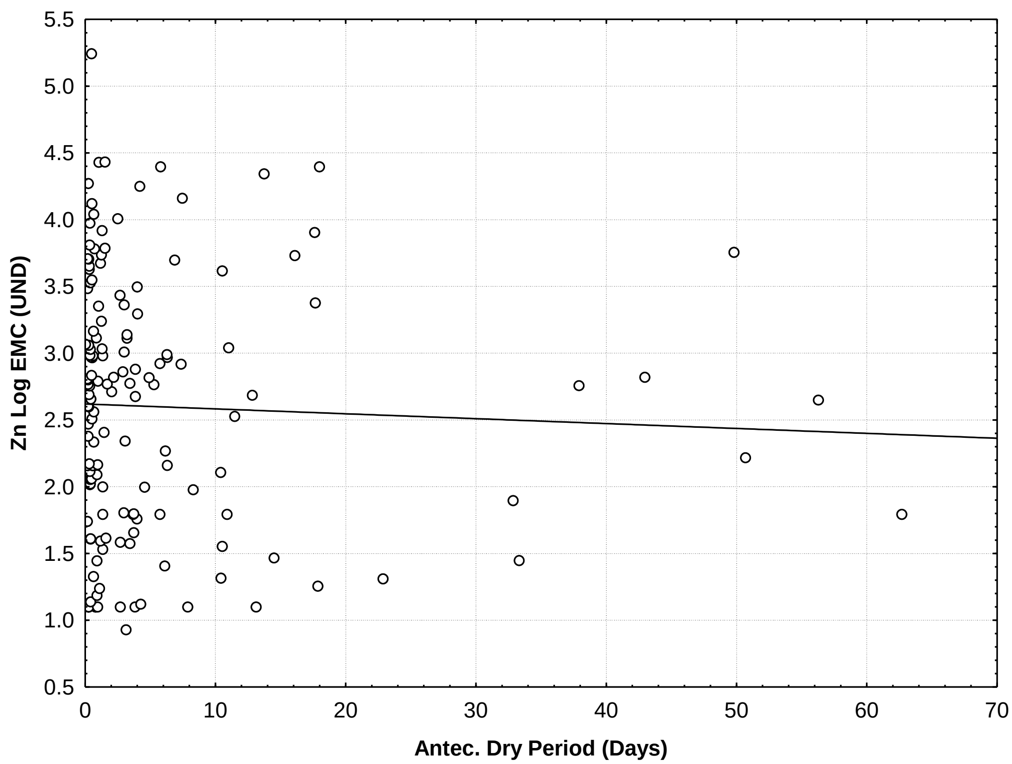
Graph C69. Scatterplot of Antecedent Dry Period vs. Log of EMC for Zn Group IC1



Graph C70. Scatterplot of Antecedent Dry Period vs. Log of EMC for Zn Group IC2

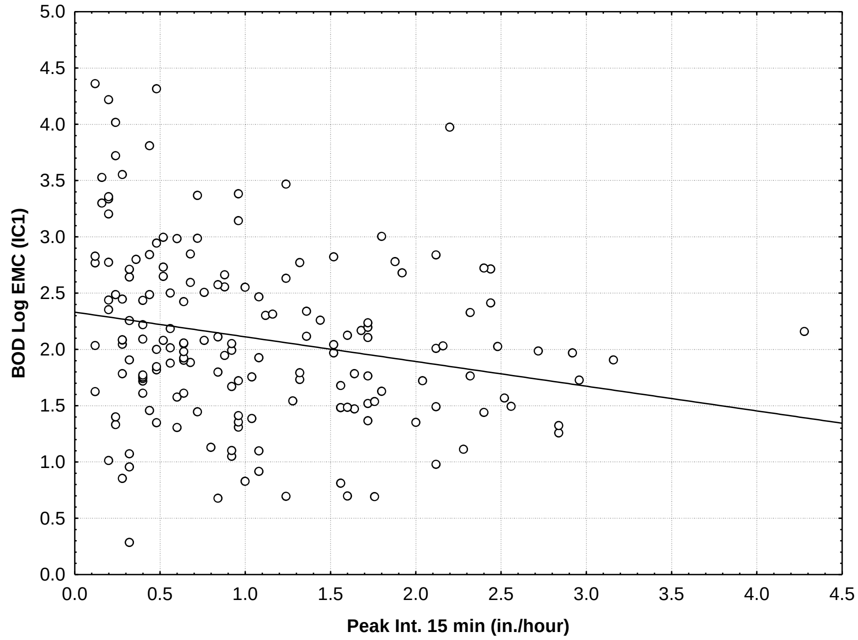


Graph C71. Scatterplot of Antecedent Dry Period vs. Log of EMC for Zn Group SFR

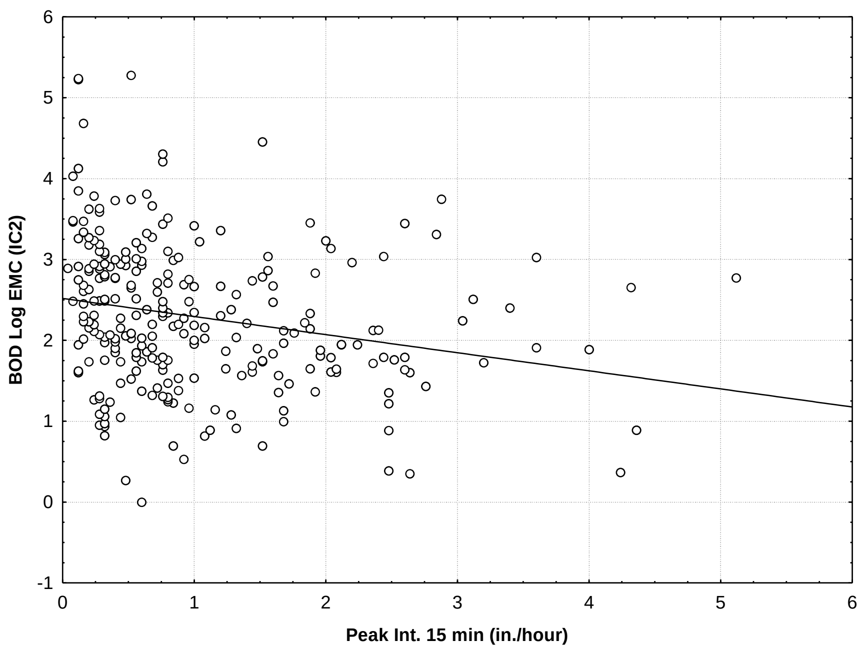


Graph C72. Scatterplot of Antecedent Dry Period vs. Log of EMC for Zn Group UND

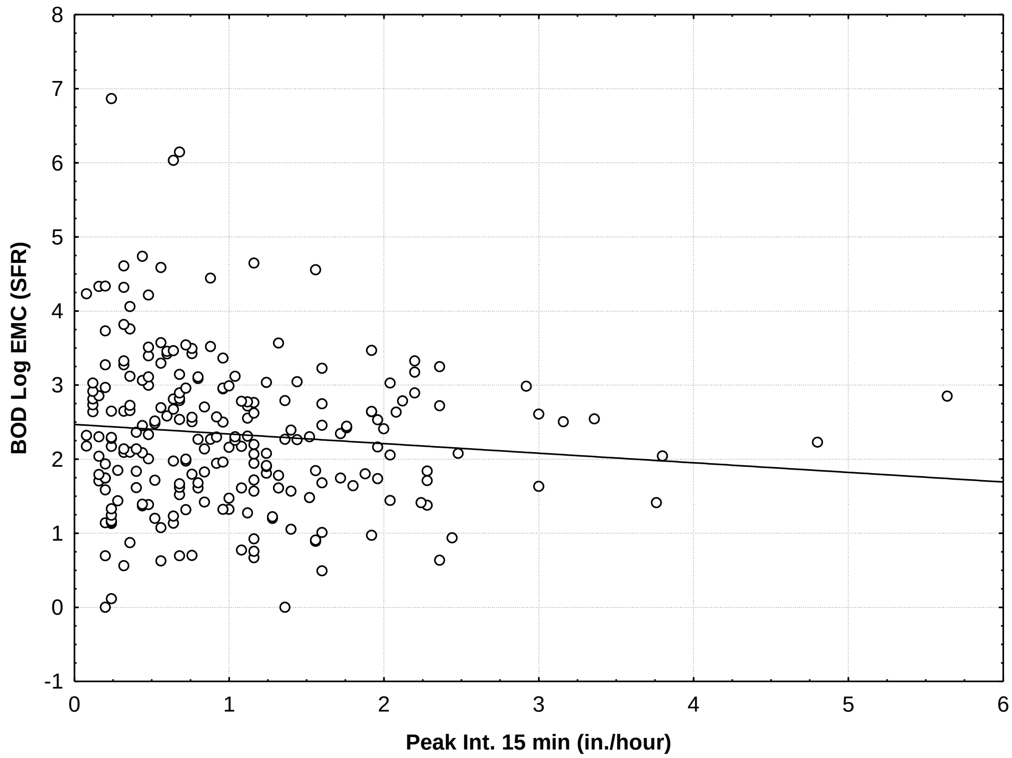
Appendix D Ln(EMC) vs. 15-minute Peak Rainfall Intensity



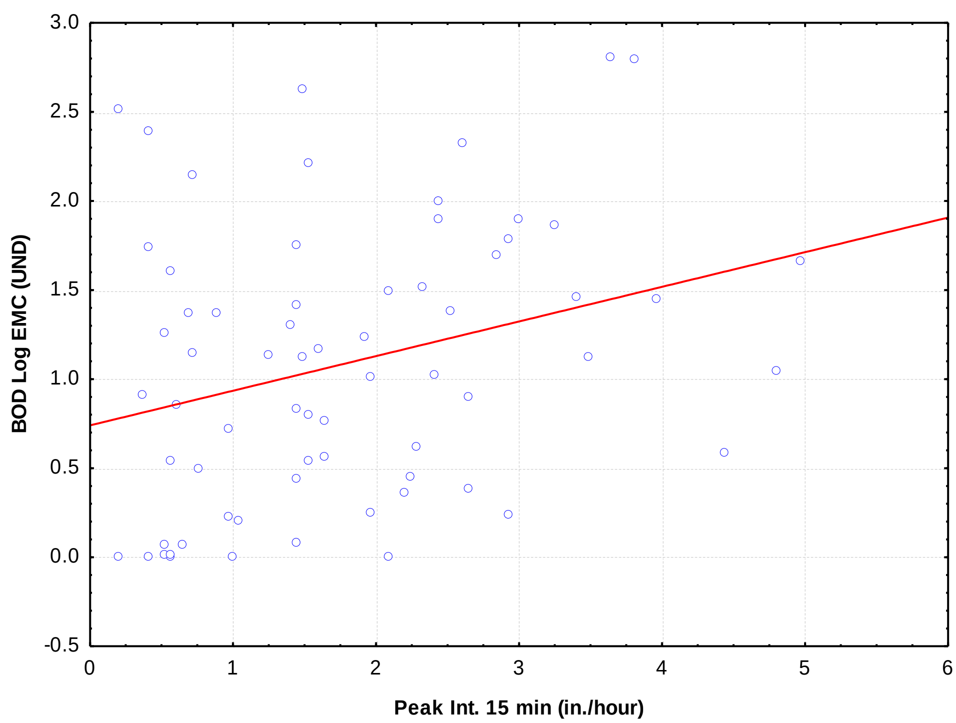
Graph D1. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for BOD Group IC1



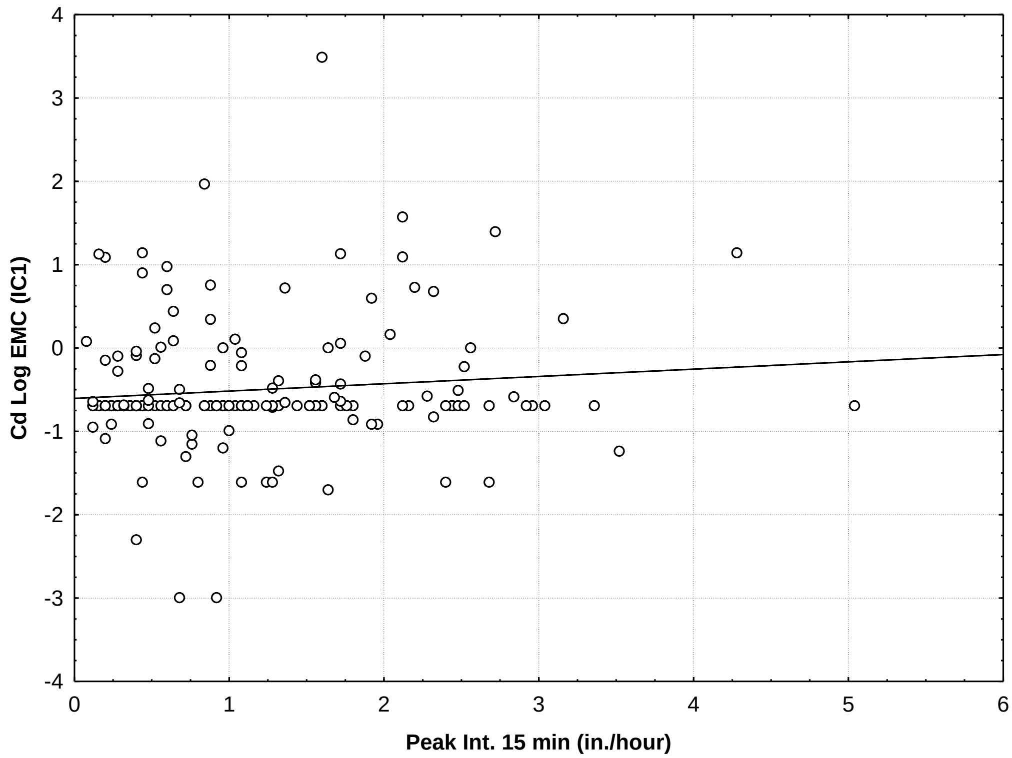
Graph D2. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for BOD Group IC2



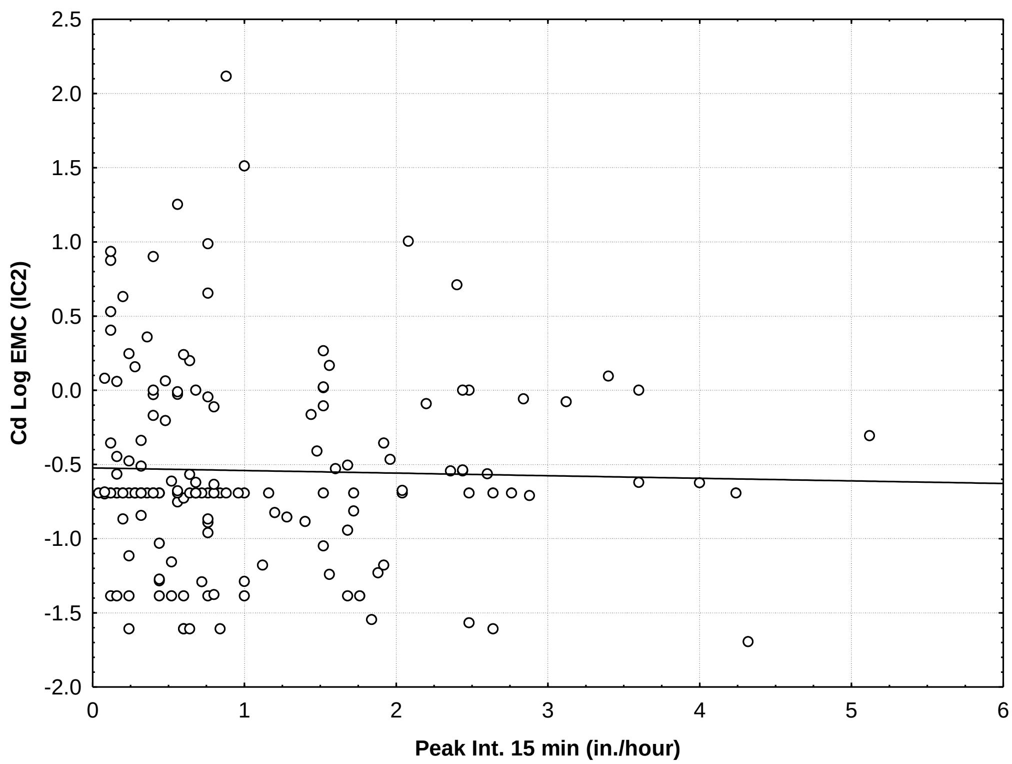
Graph D3. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for BOD Group SFR



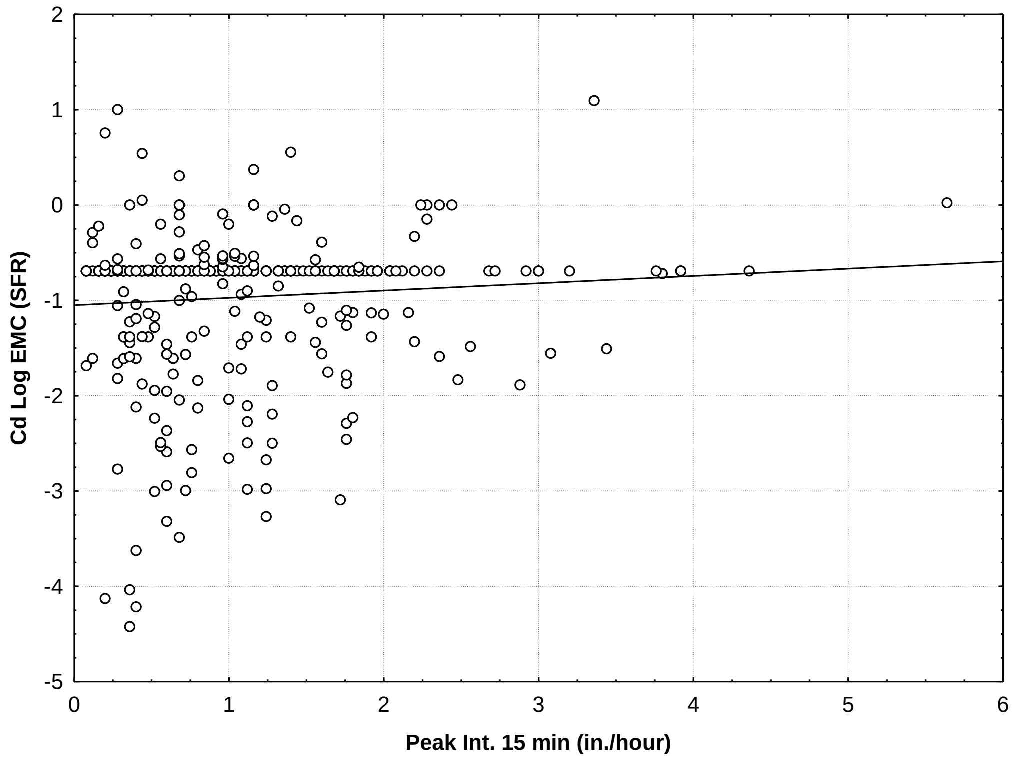
Graph D4. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for BOD Group UND



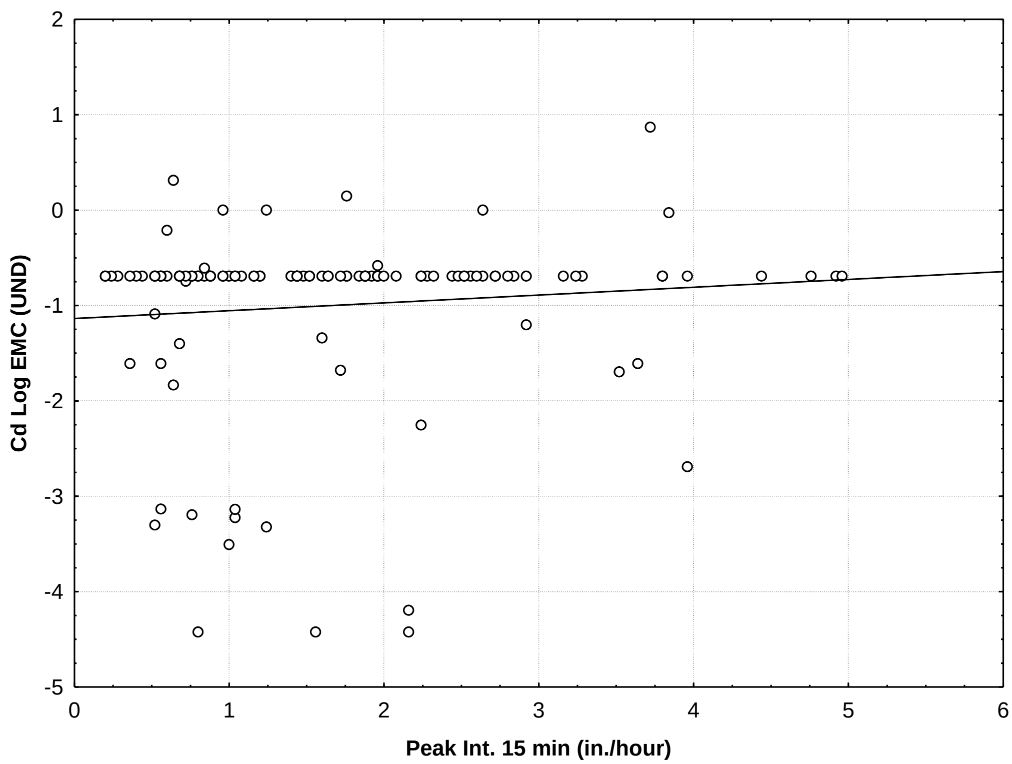
Graph D5. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cd Group IC1



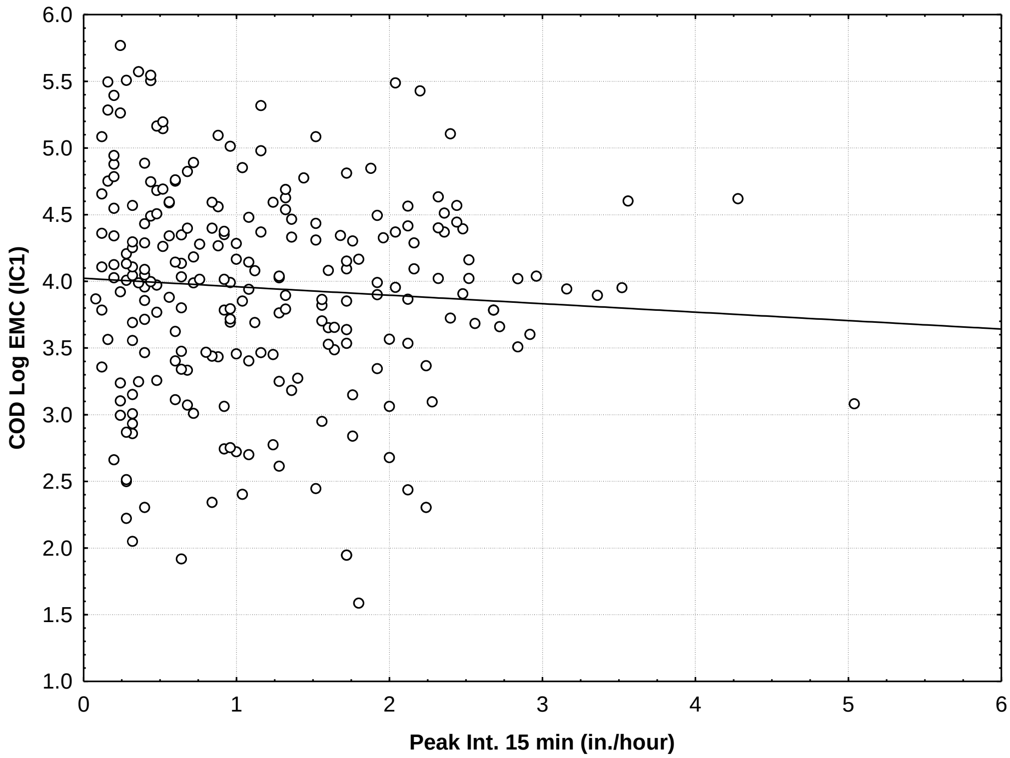
Graph D6. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cd Group IC2



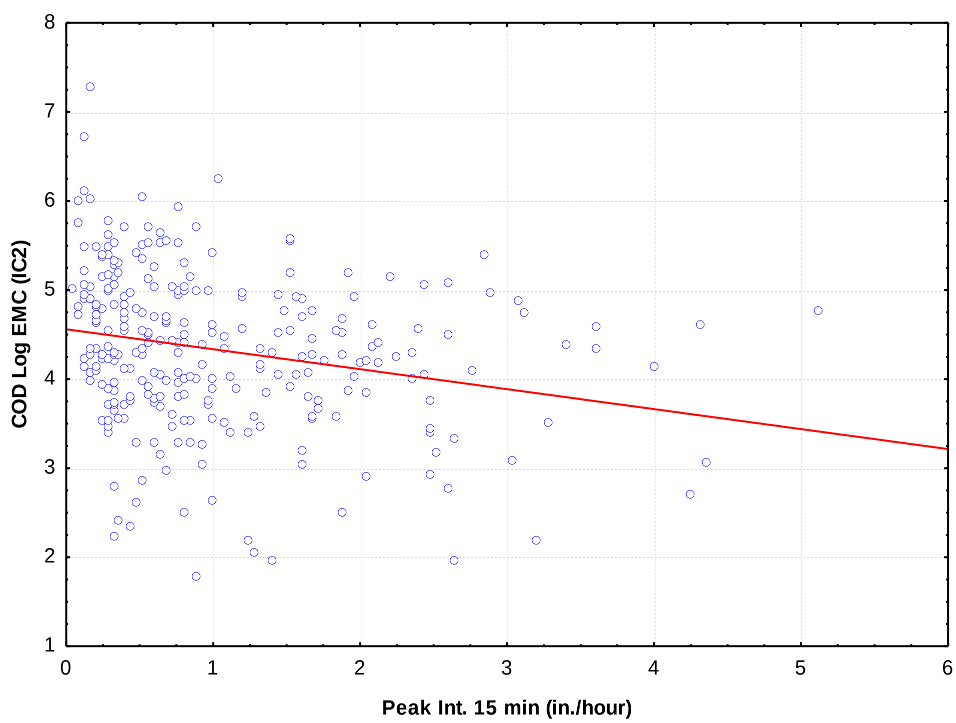
Graph D7. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cd Group SFR



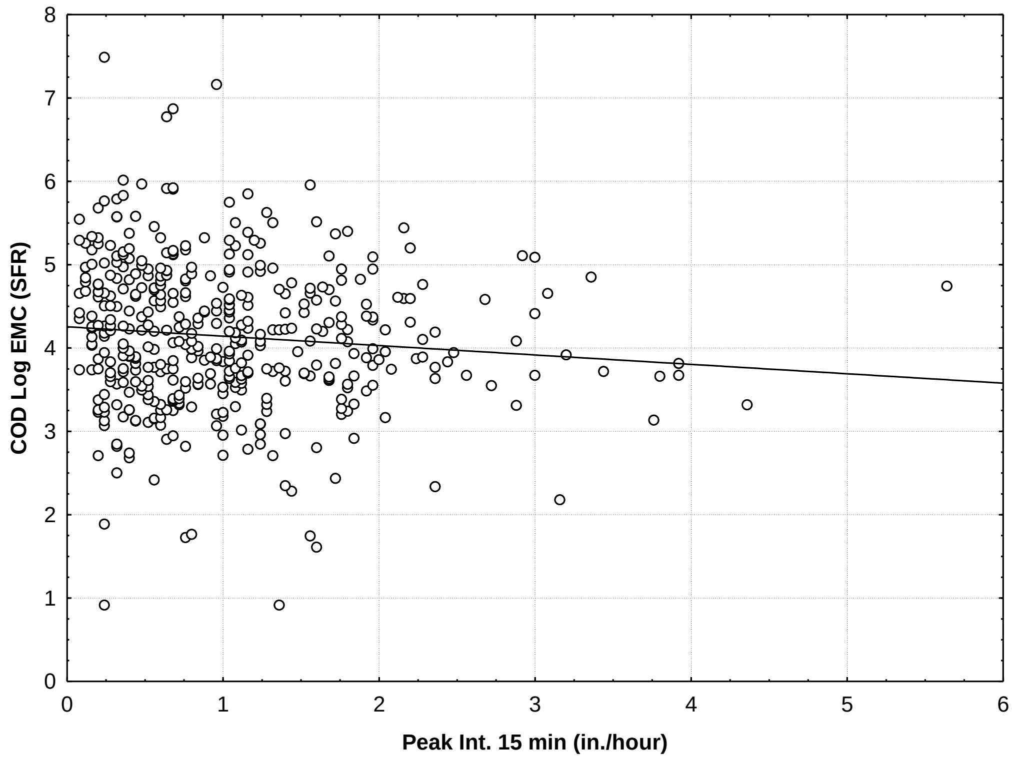
Graph D8. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cd Group UND



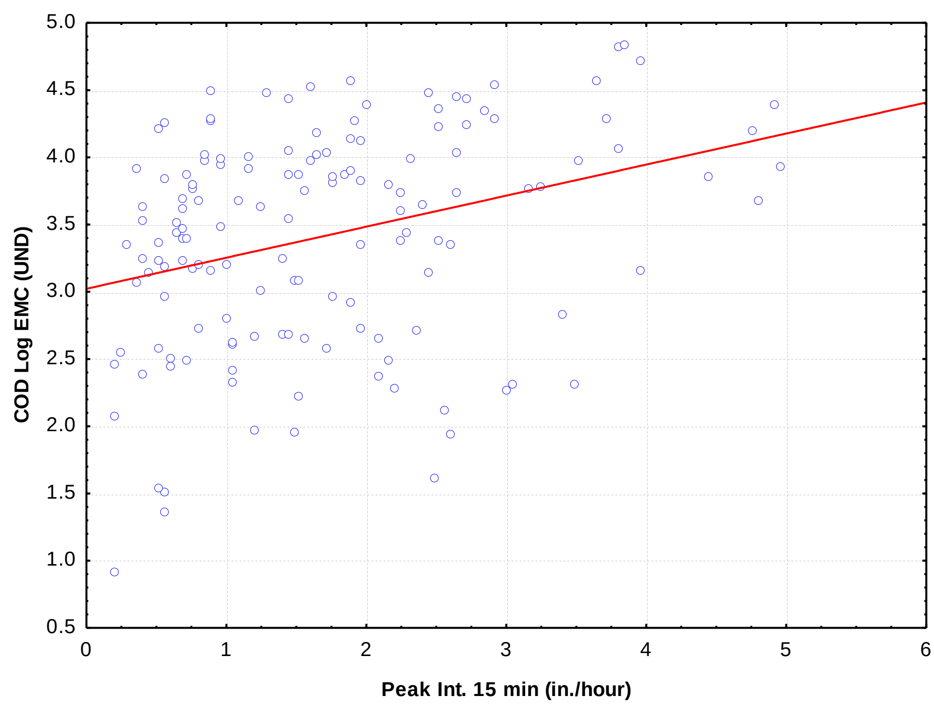
Graph D9. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for COD Group IC1



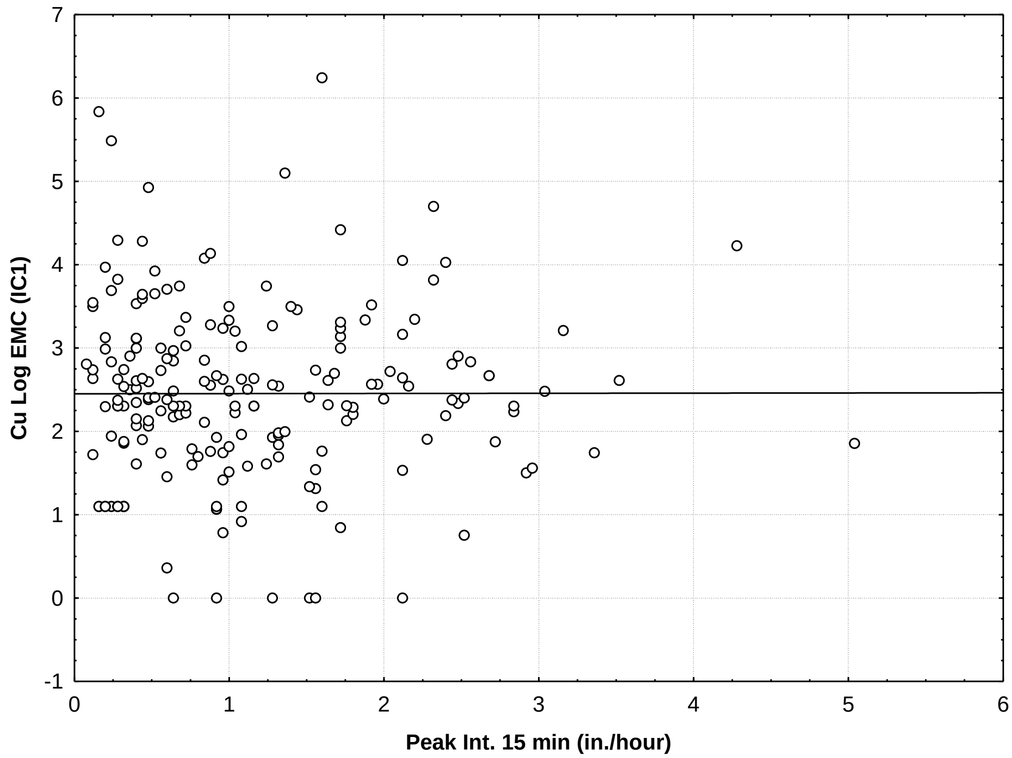
Graph D10. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for COD Group IC2



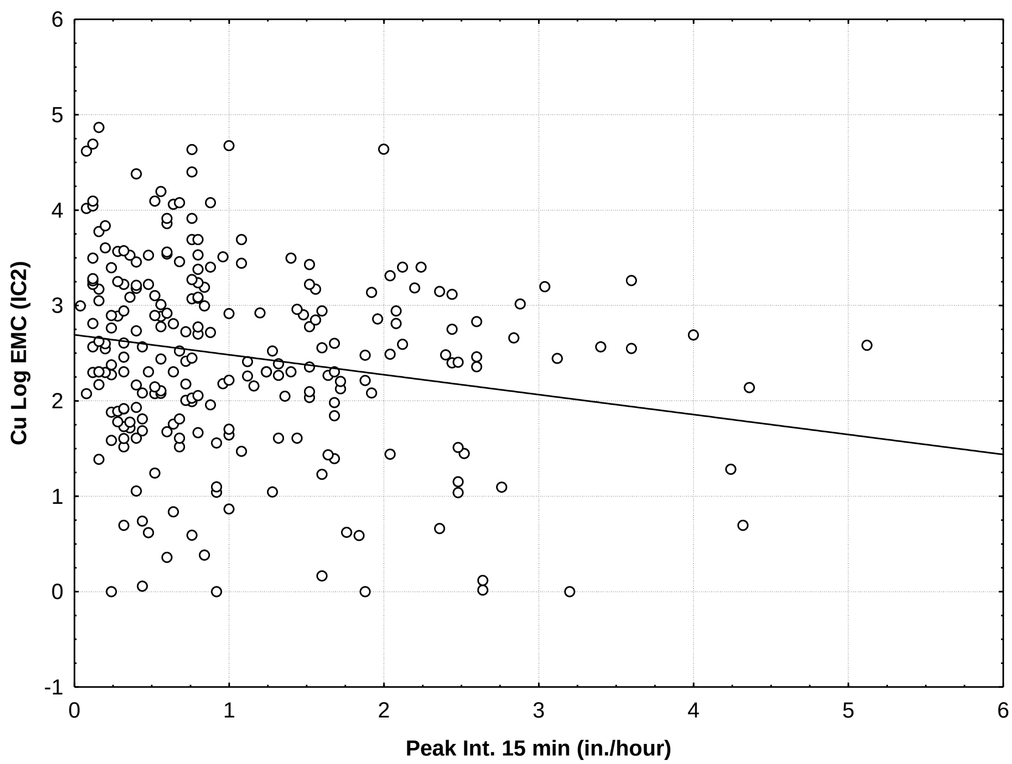
Graph D11. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for COD Group SFR



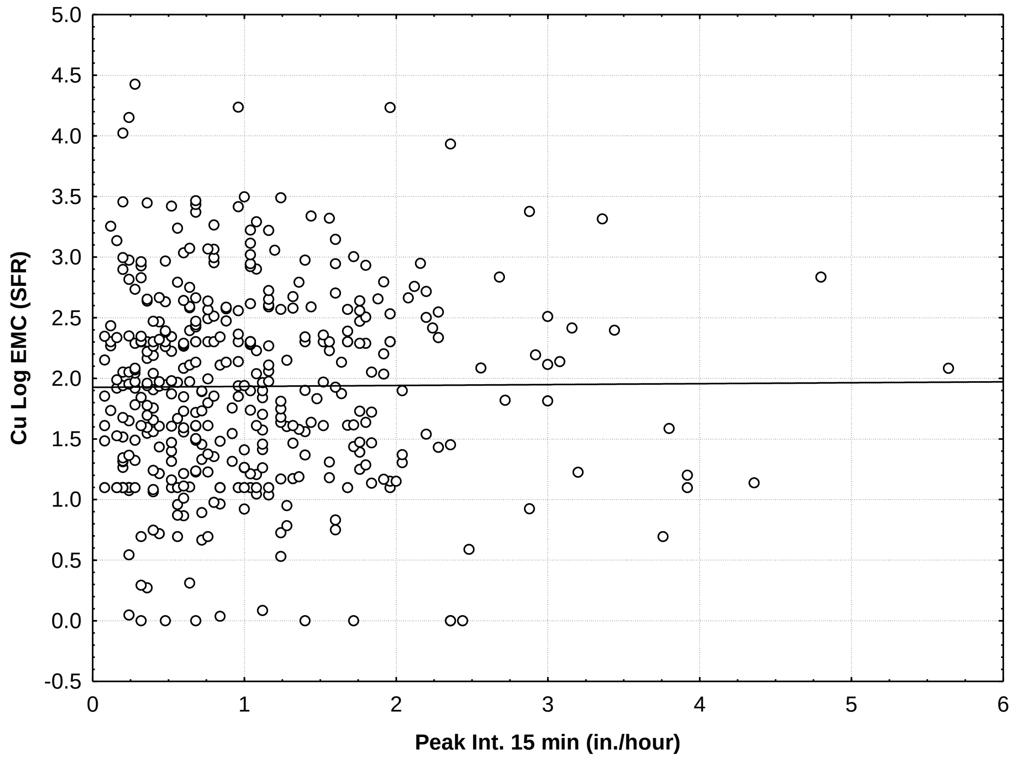
Graph D12. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for COD Group UND



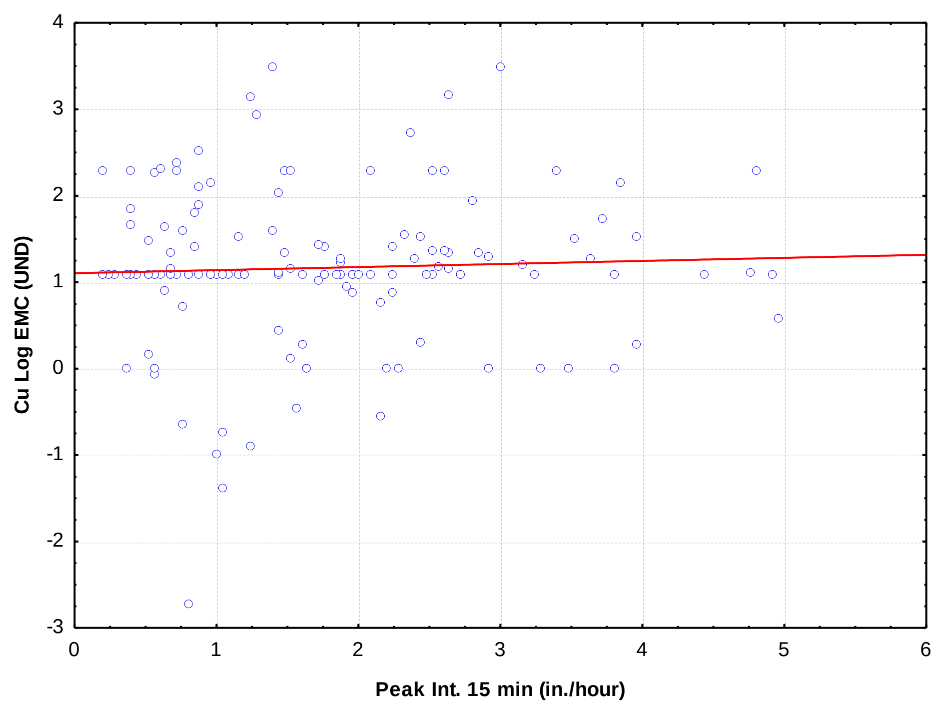
Graph D13. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cu Group IC1



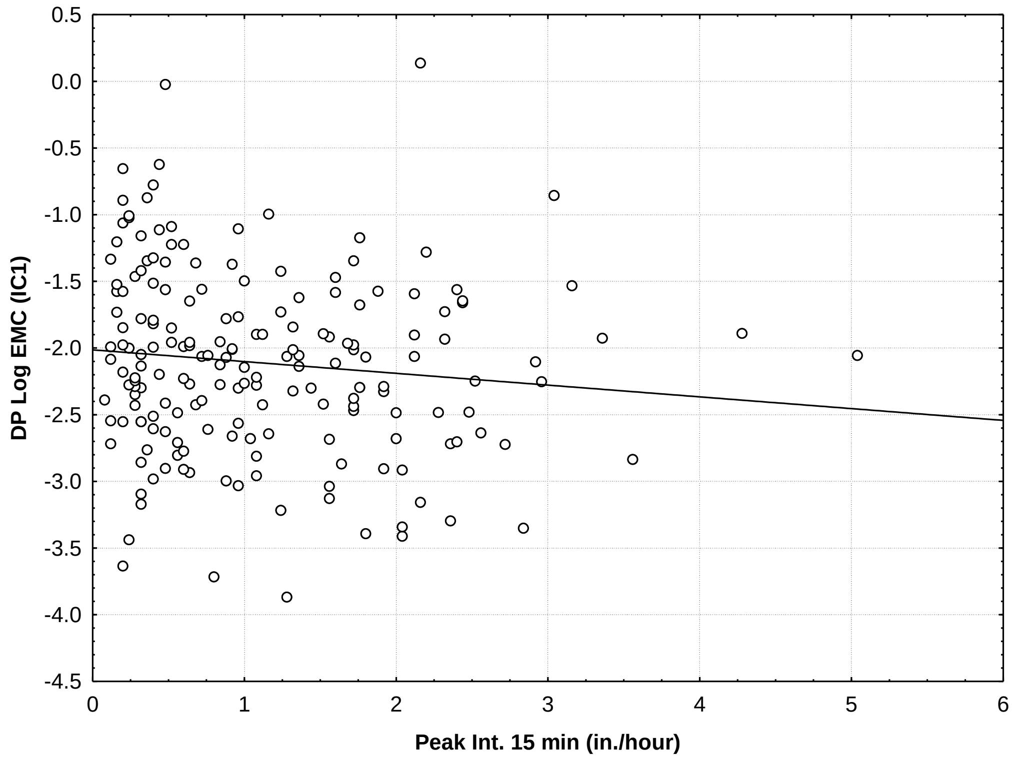
Graph D14. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cu Group IC2



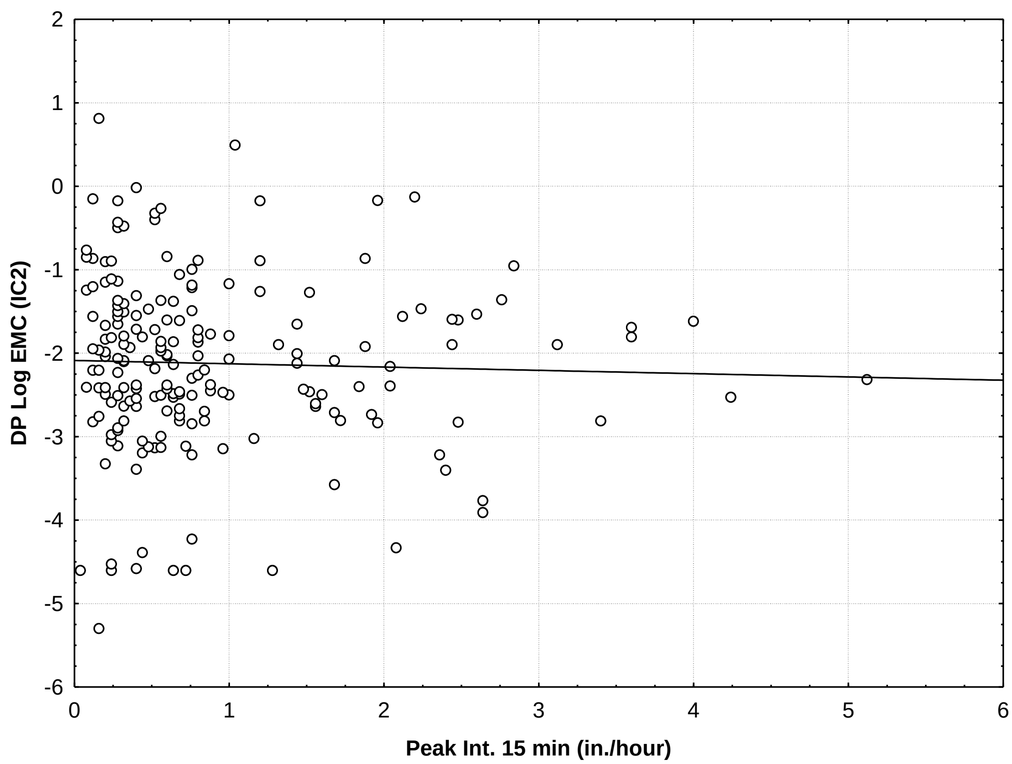
Graph D15. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cu Group SFR



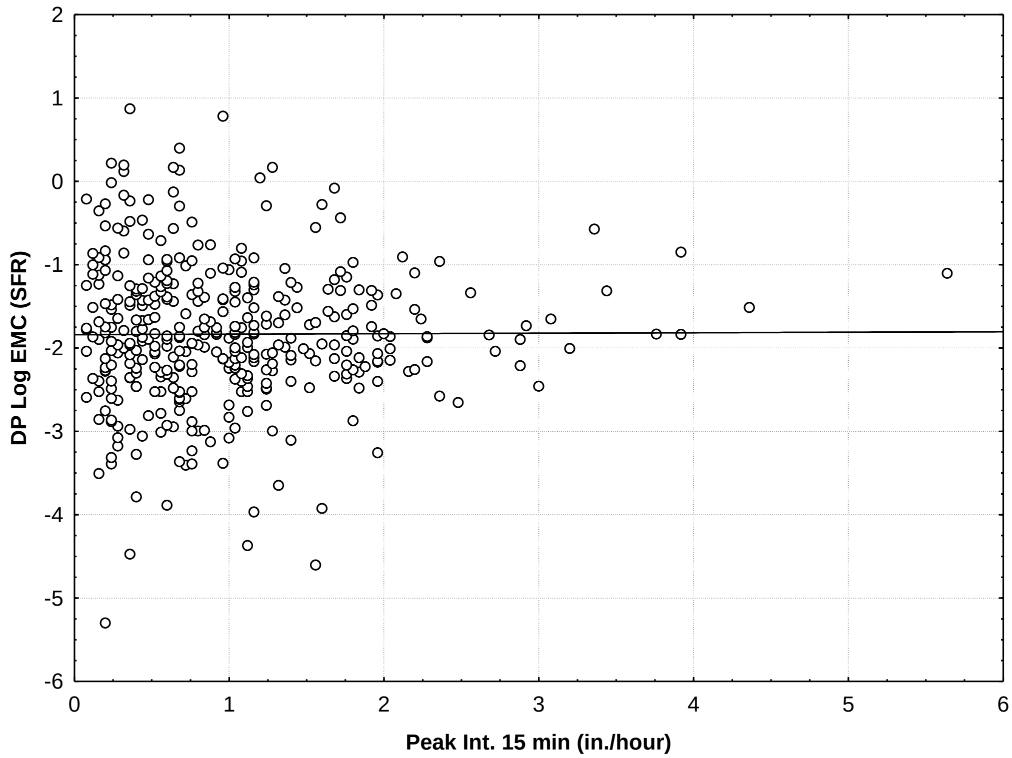
Graph D16. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Cu Group UND



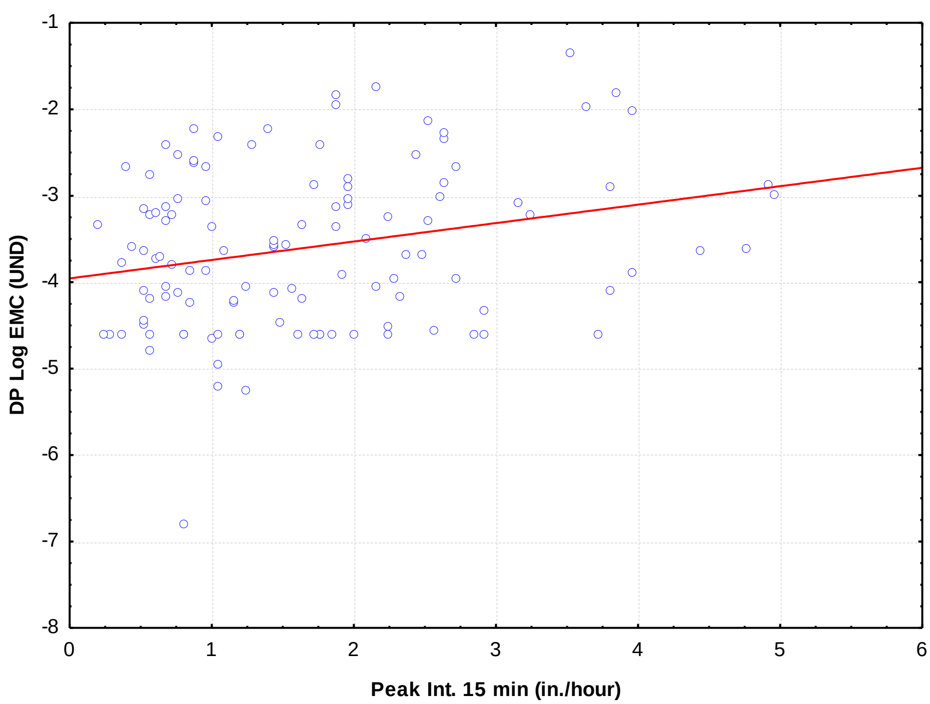
Graph D17. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for DP Group IC1



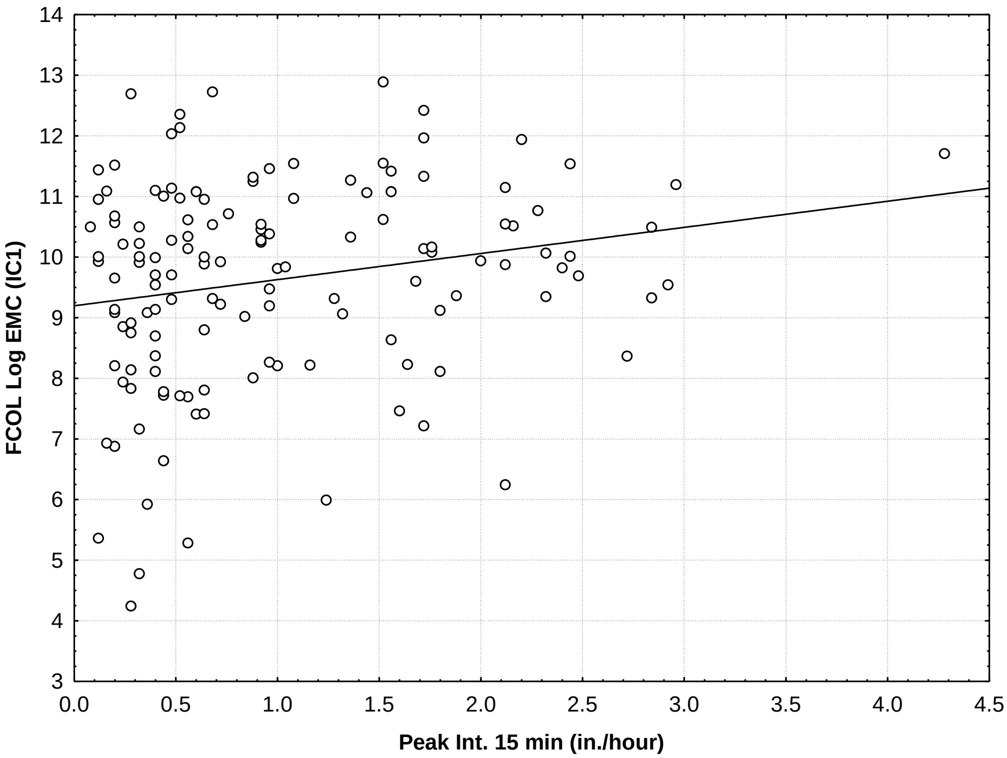
Graph D18. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for DP Group IC2



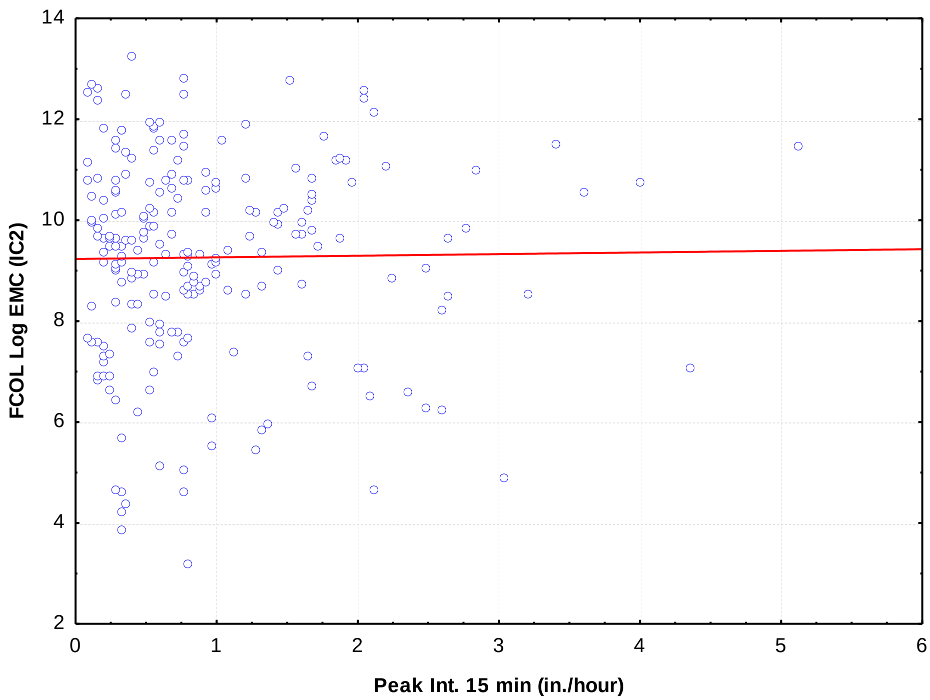
Graph D19. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for DP Group SFR



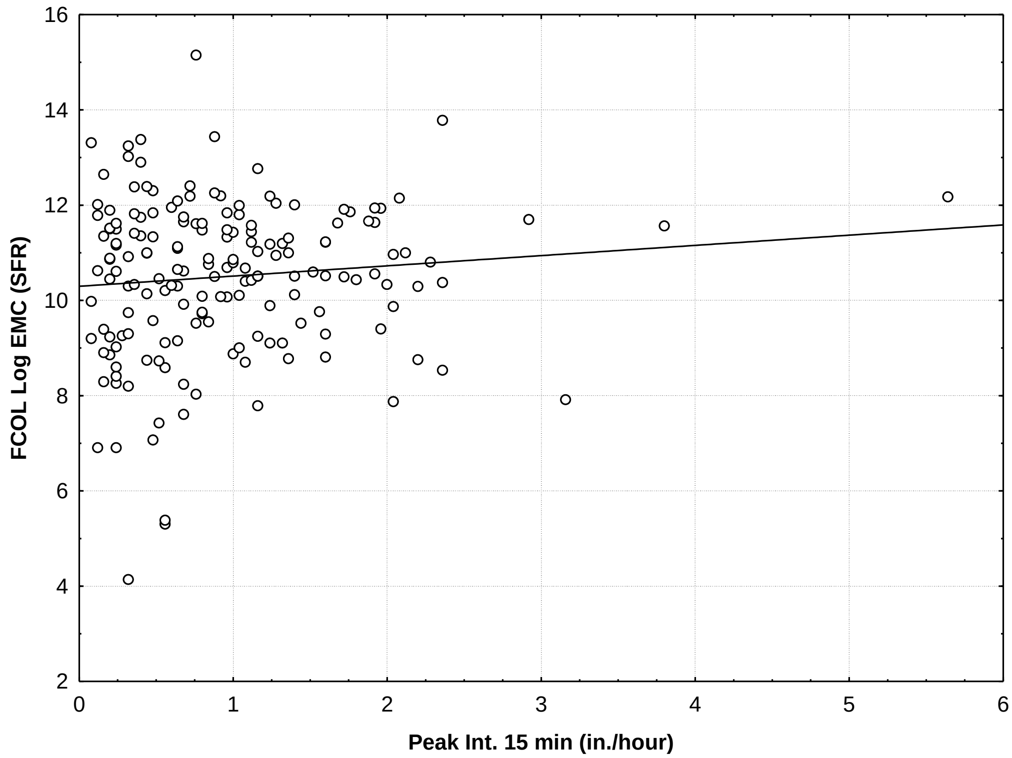
Graph D20. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for DP Group UND



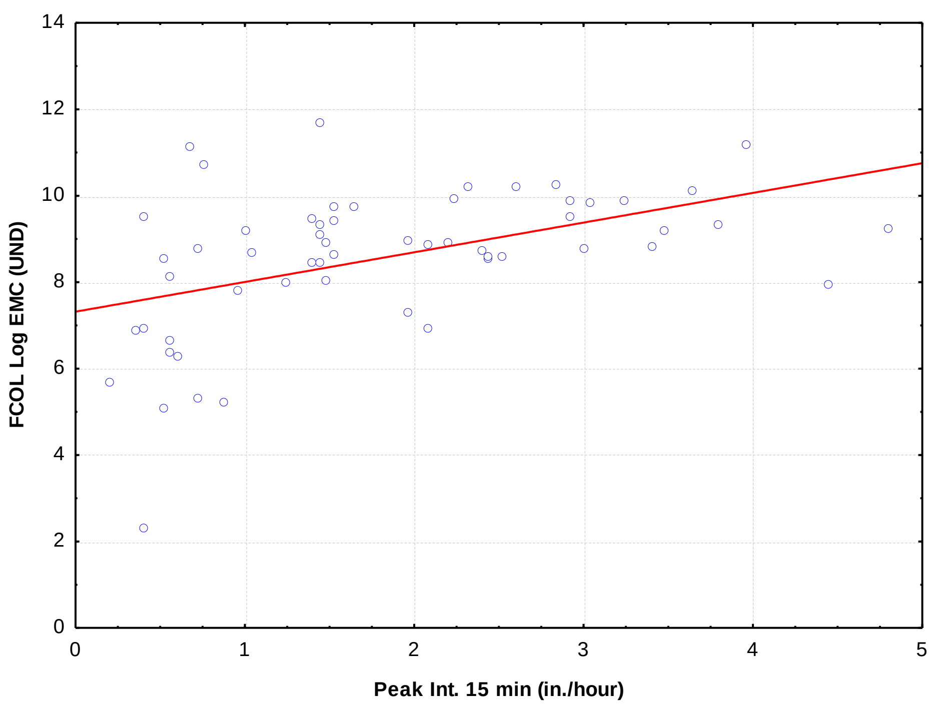
Graph D21. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FCOL Group IC1



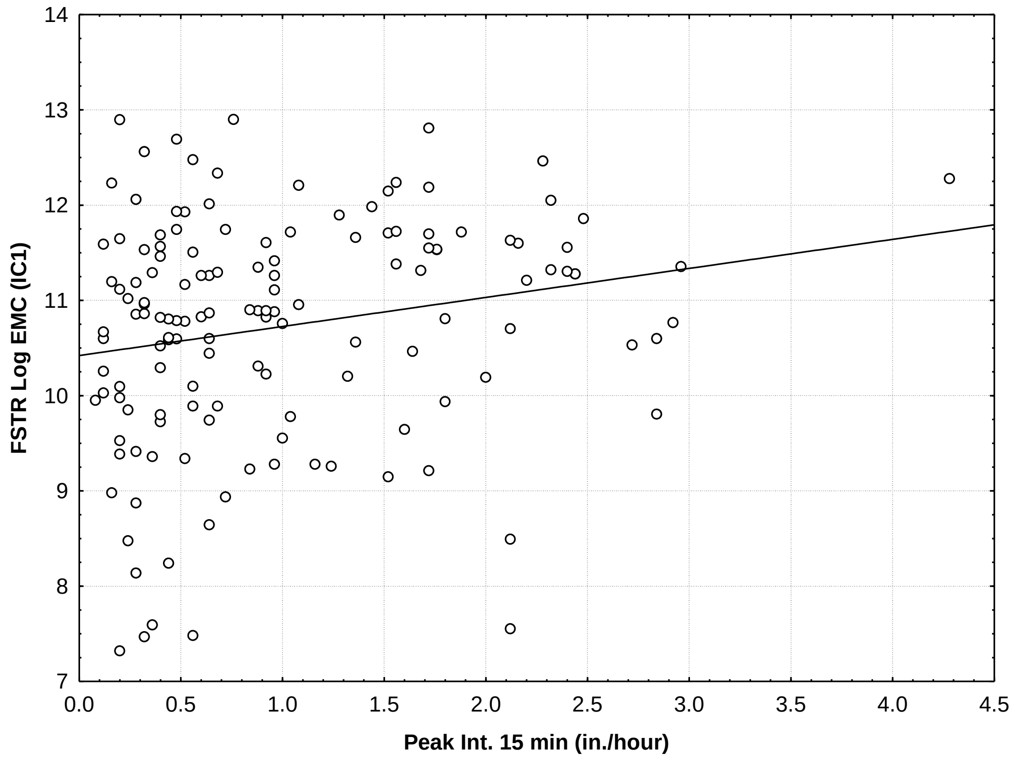
Graph D22. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FCOL Group IC2



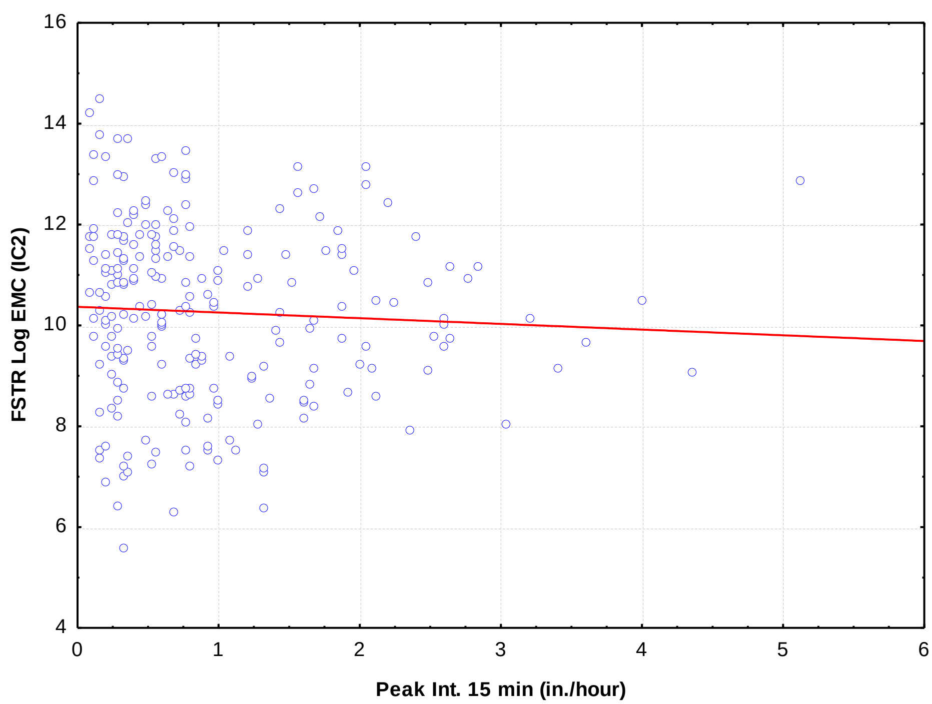
Graph D23. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FCOL Group SFR



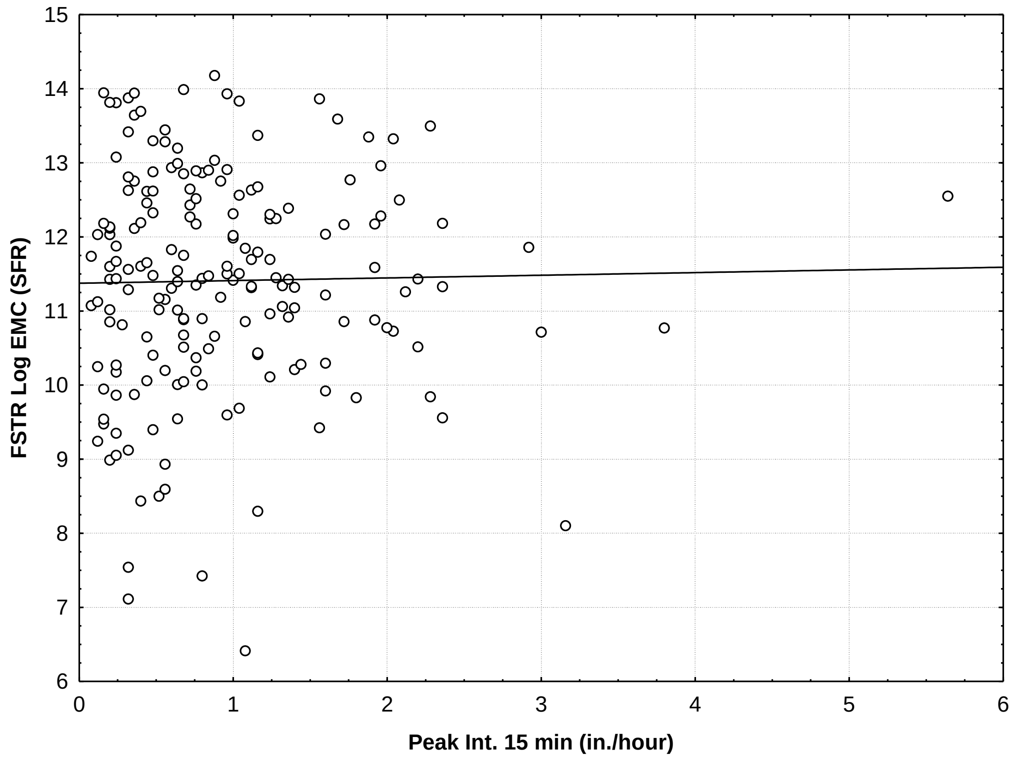
Graph D24. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FCOL Group UND



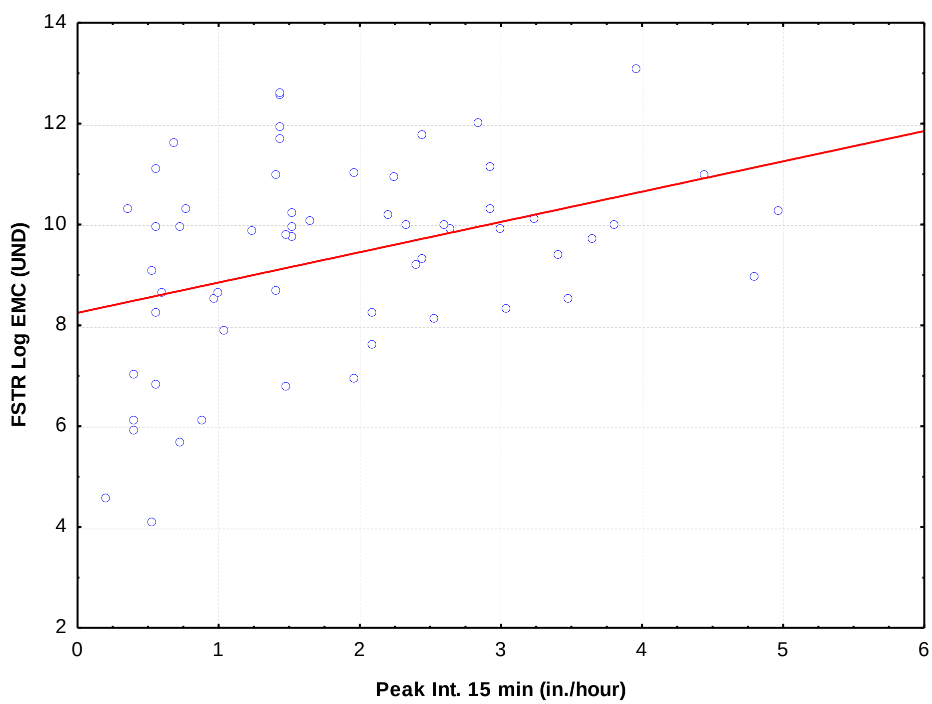
Graph D25. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FSTR Group IC1



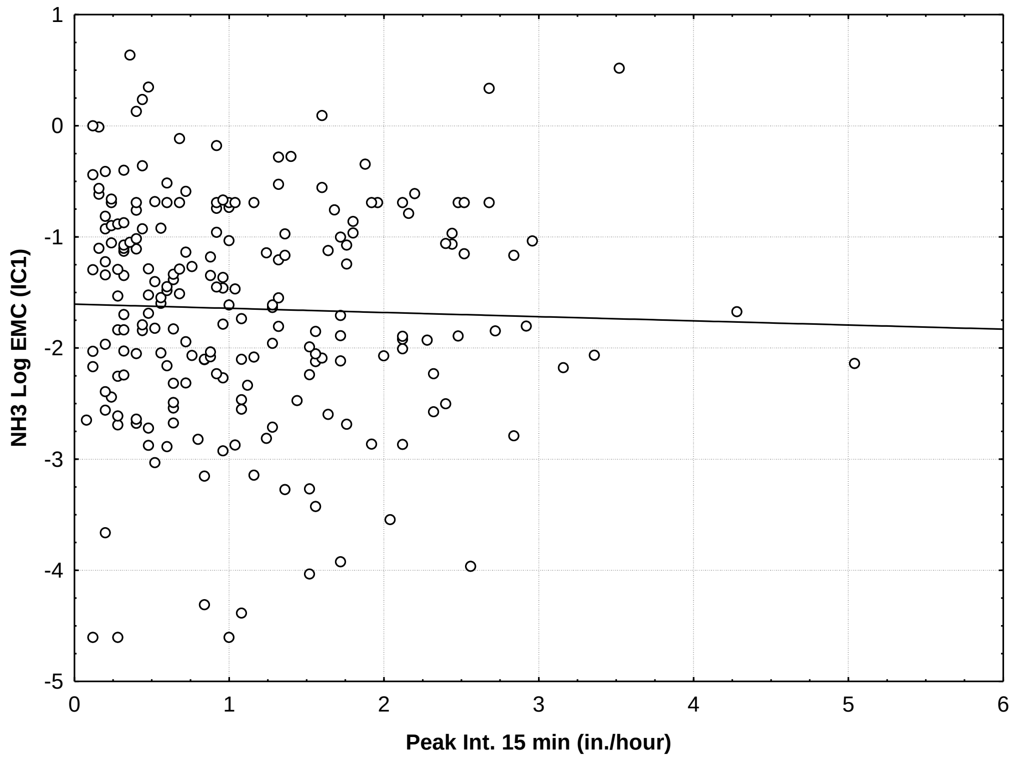
Graph D26. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FSTR Group IC2



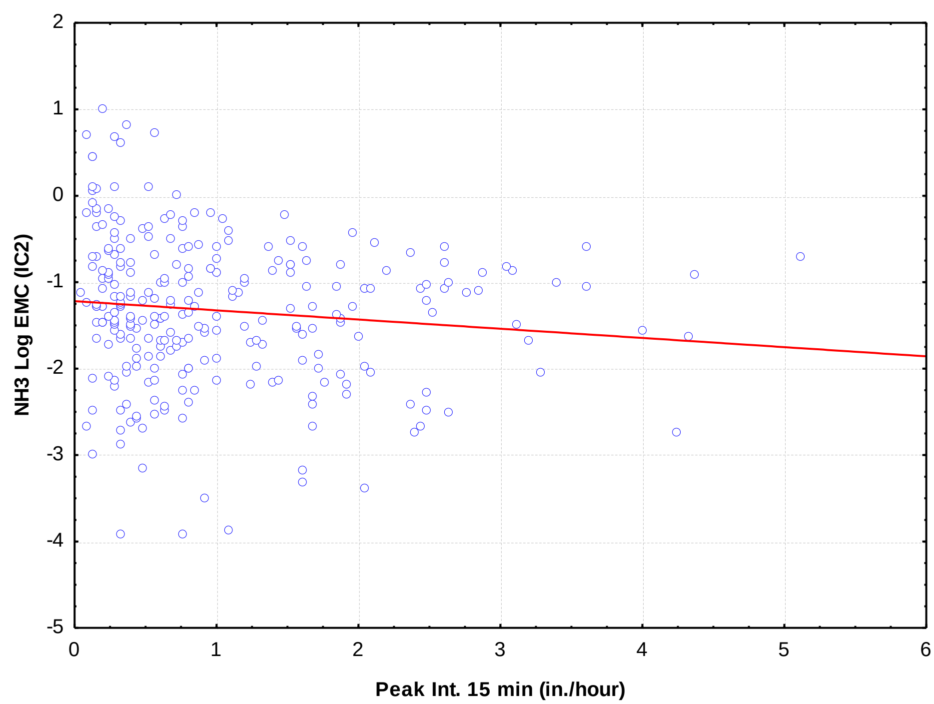
Graph D27. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FSTR Group SFR



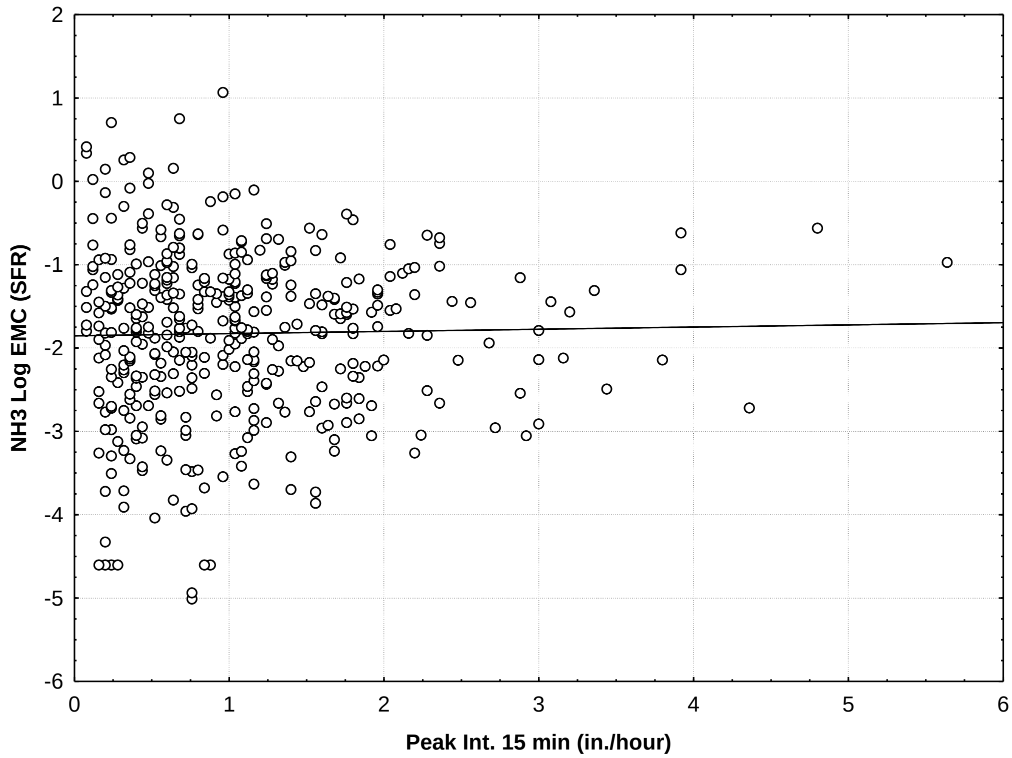
Graph D28. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for FSTR Group UND



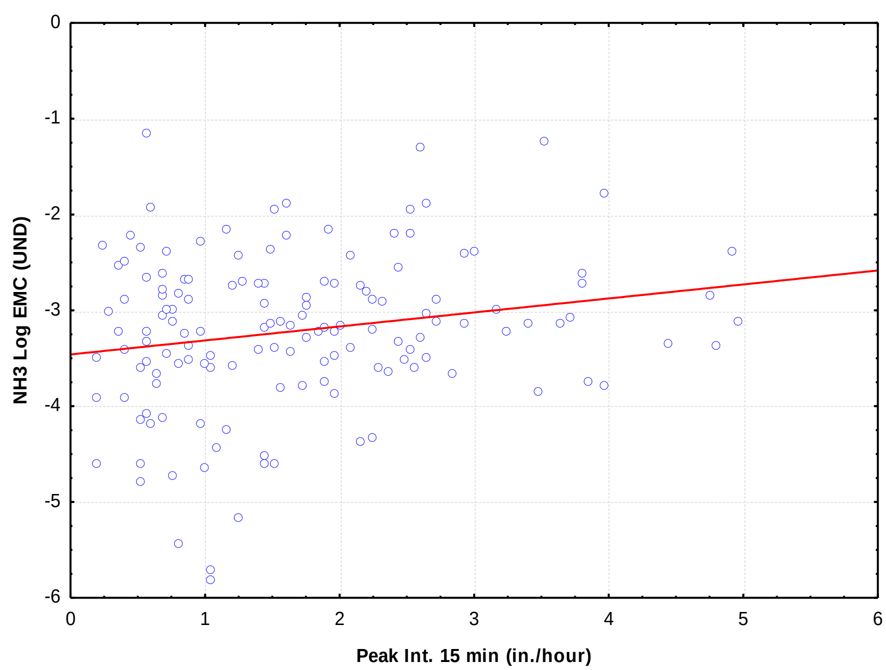
Graph D29. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NH3 Group IC1



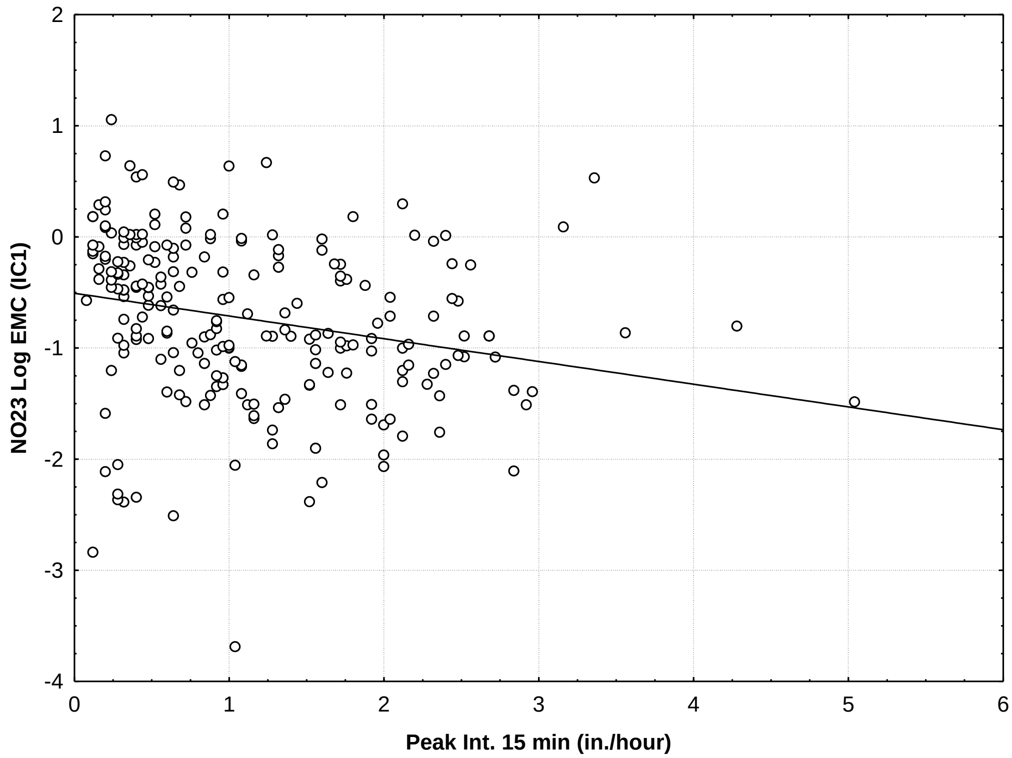
Graph D30. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NH3 Group IC2



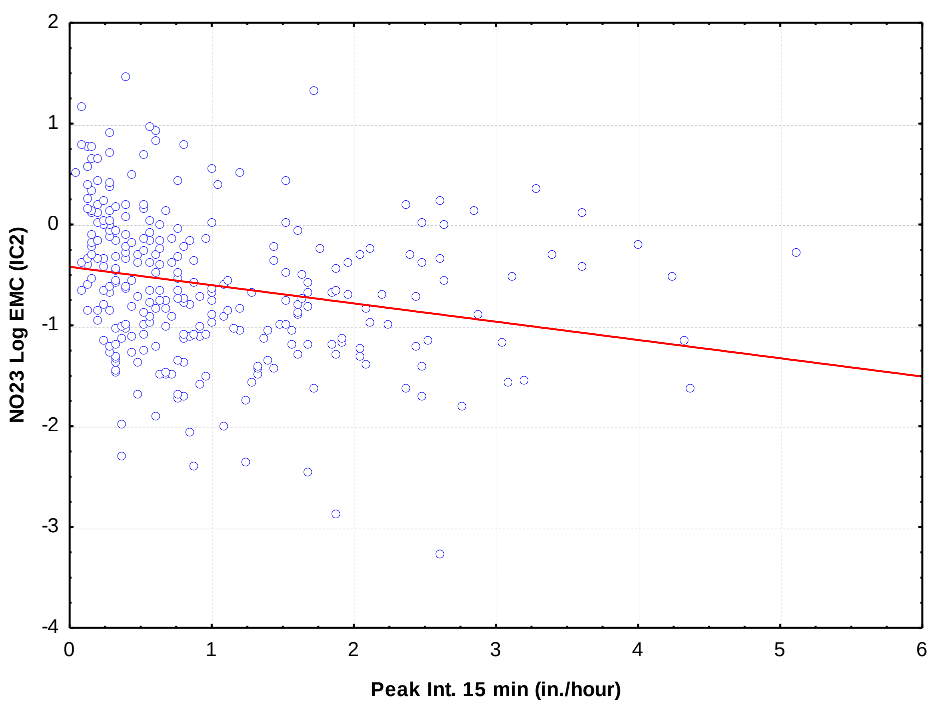
Graph D31. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NH3 Group SFR



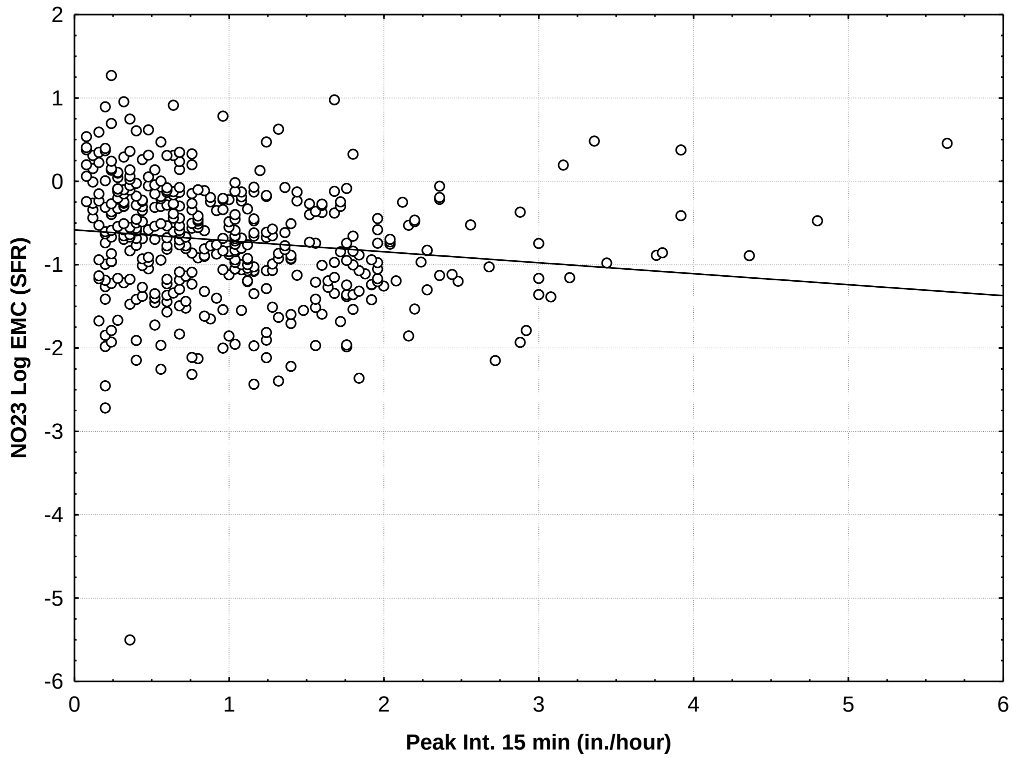
Graph D32. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NH3 Group UND



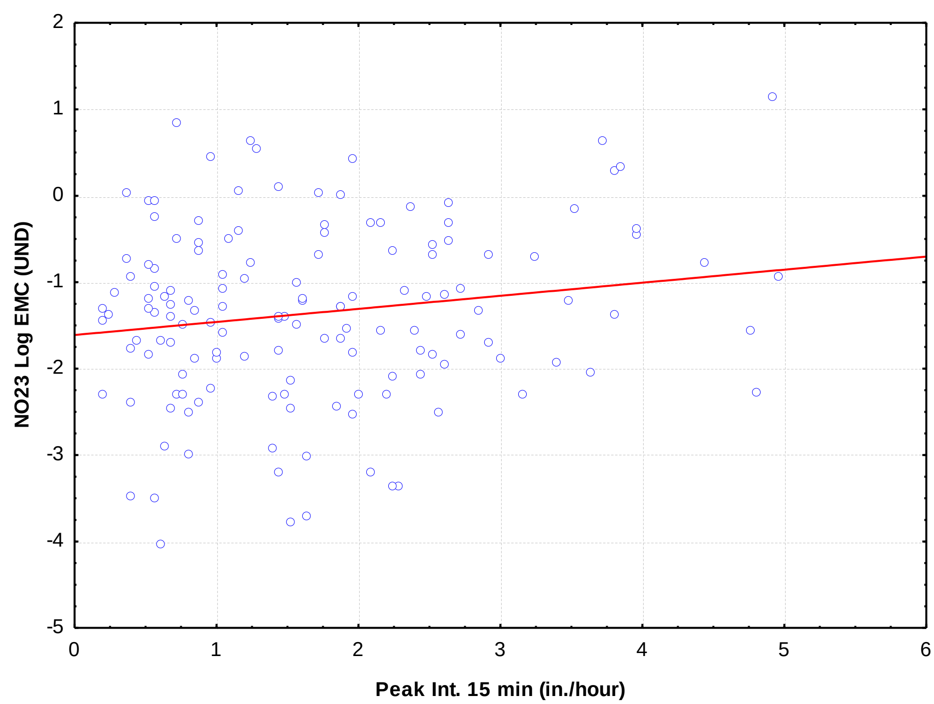
Graph D33. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NO23 Group IC1



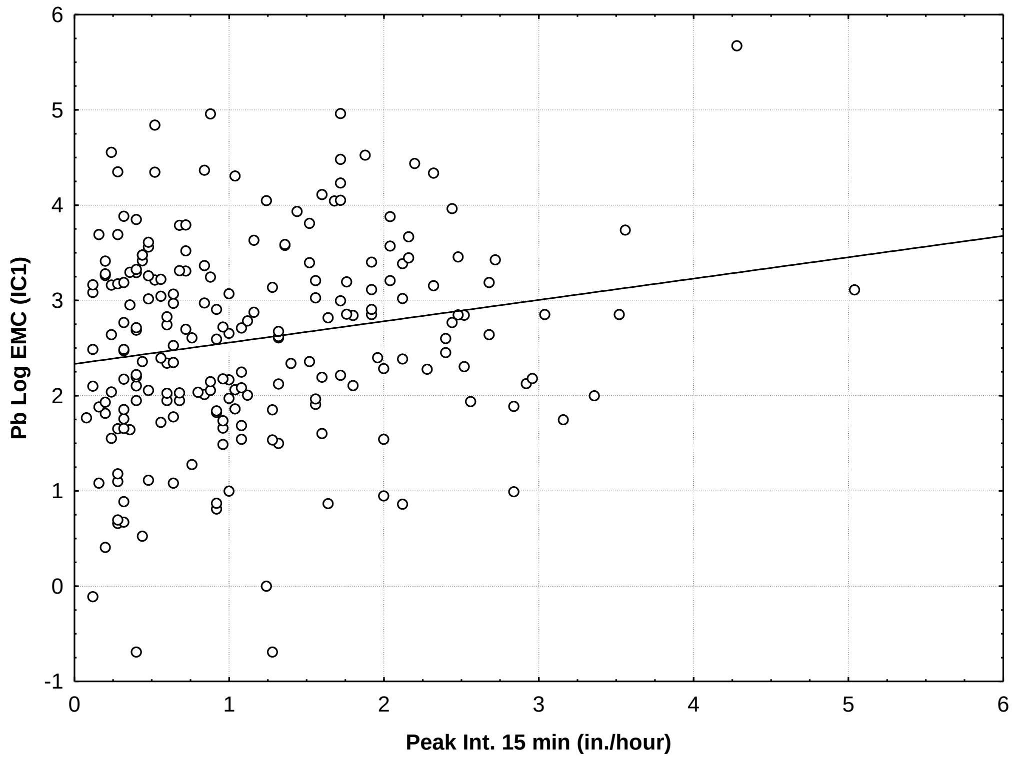
Graph D34. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NO23 Group IC2



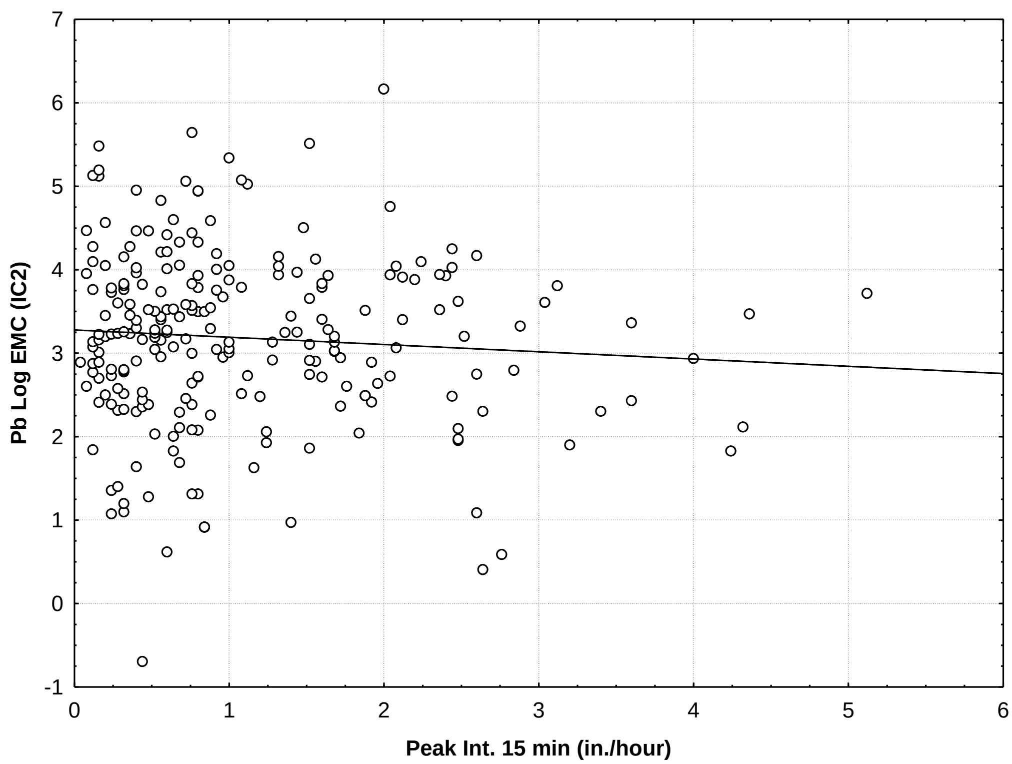
Graph D35. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NO23 Group SFR



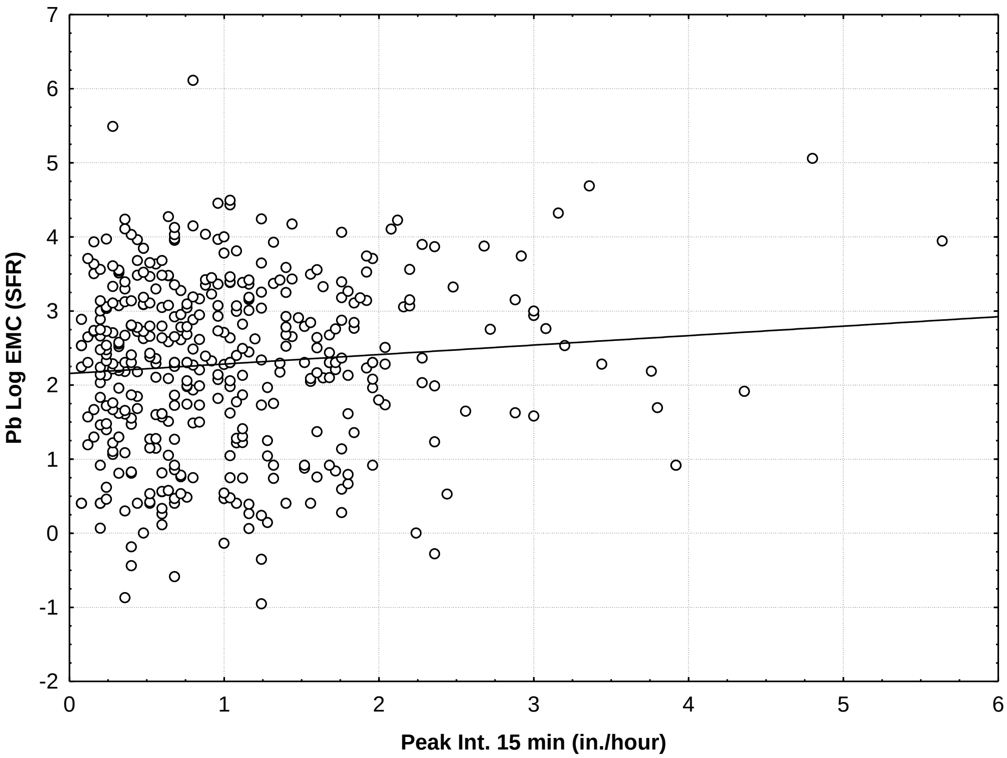
Graph D36. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for NO23 Group UND



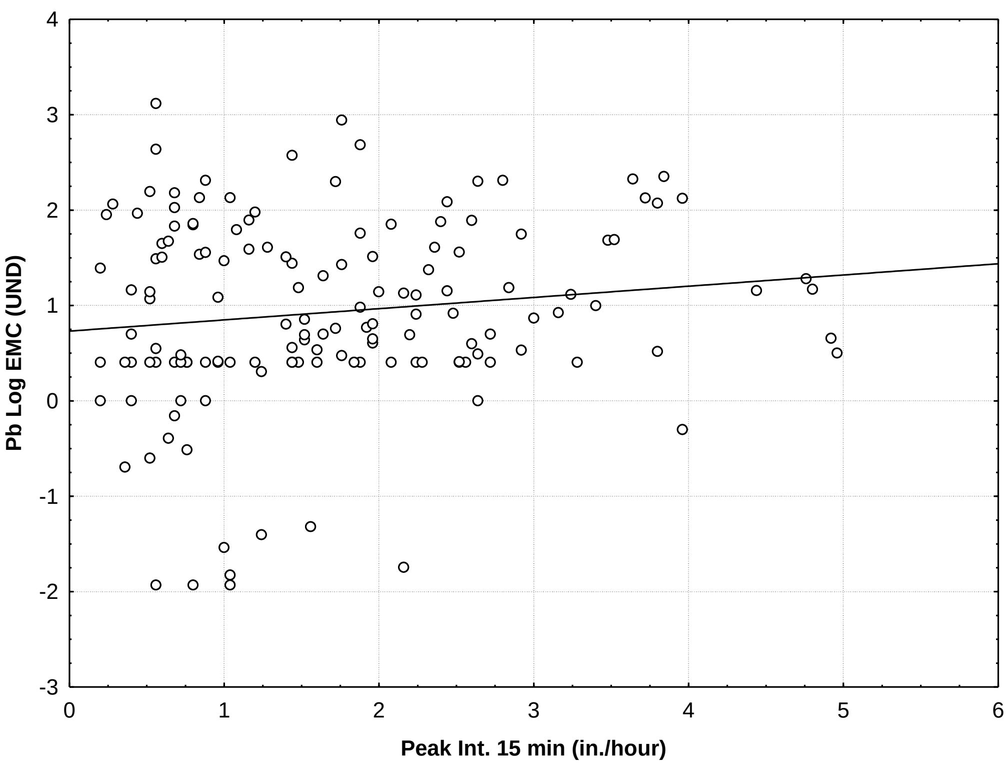
Graph D37. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Pb Group IC1



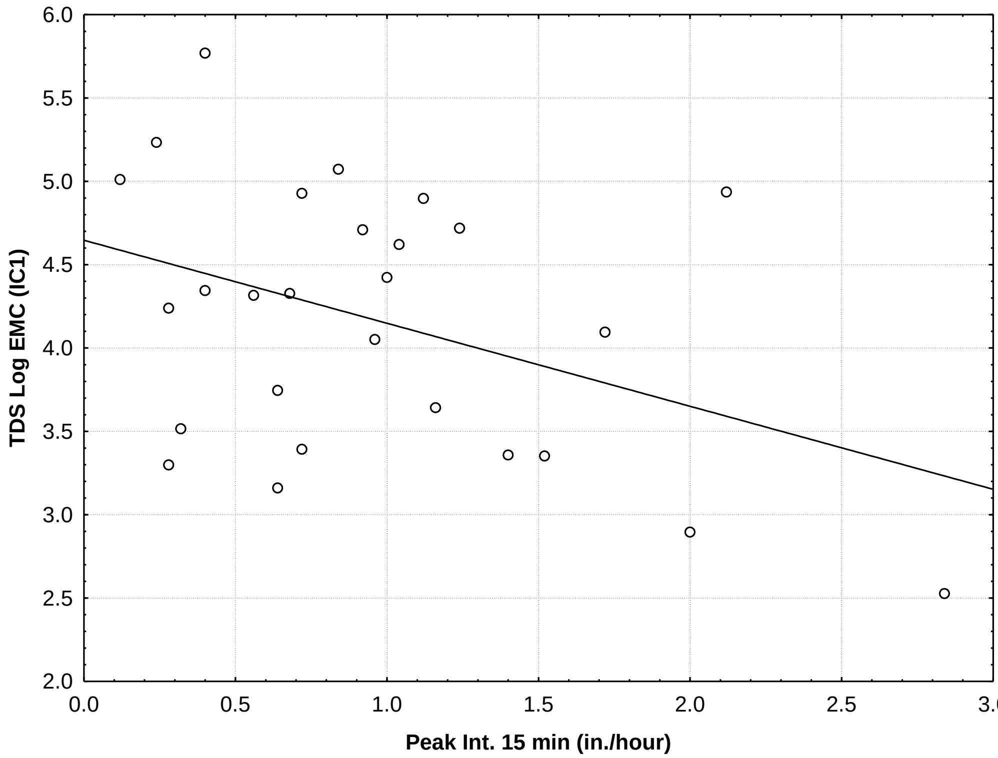
Graph D38. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Pb Group IC2



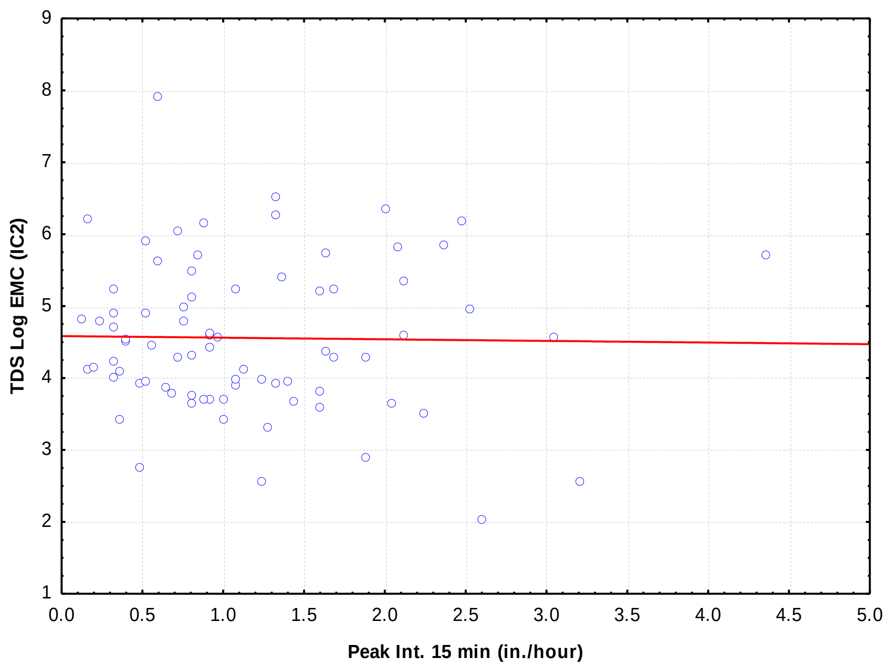
Graph D39. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Pb Group SFR



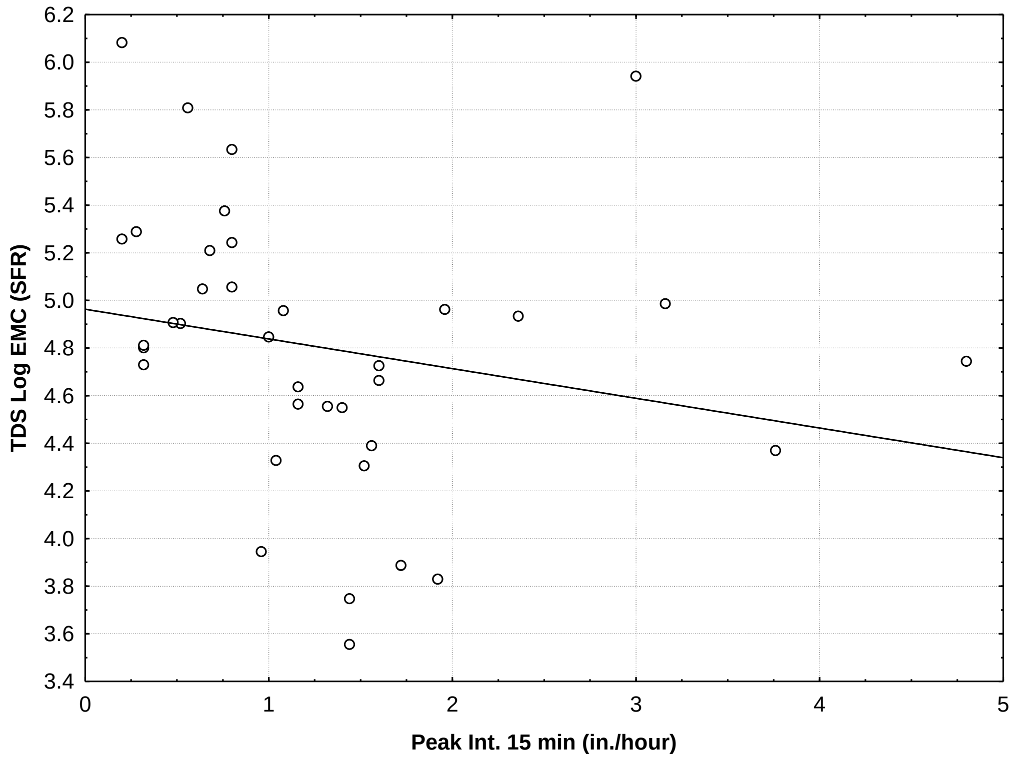
Graph D40. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Pb Group UND



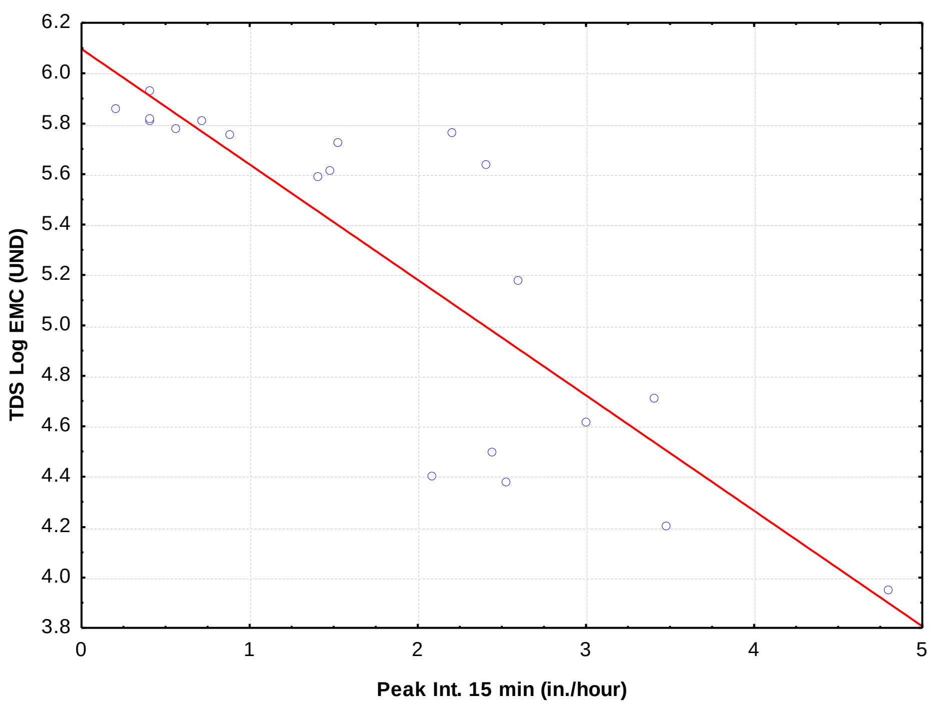
Graph D41. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TDS Group IC1



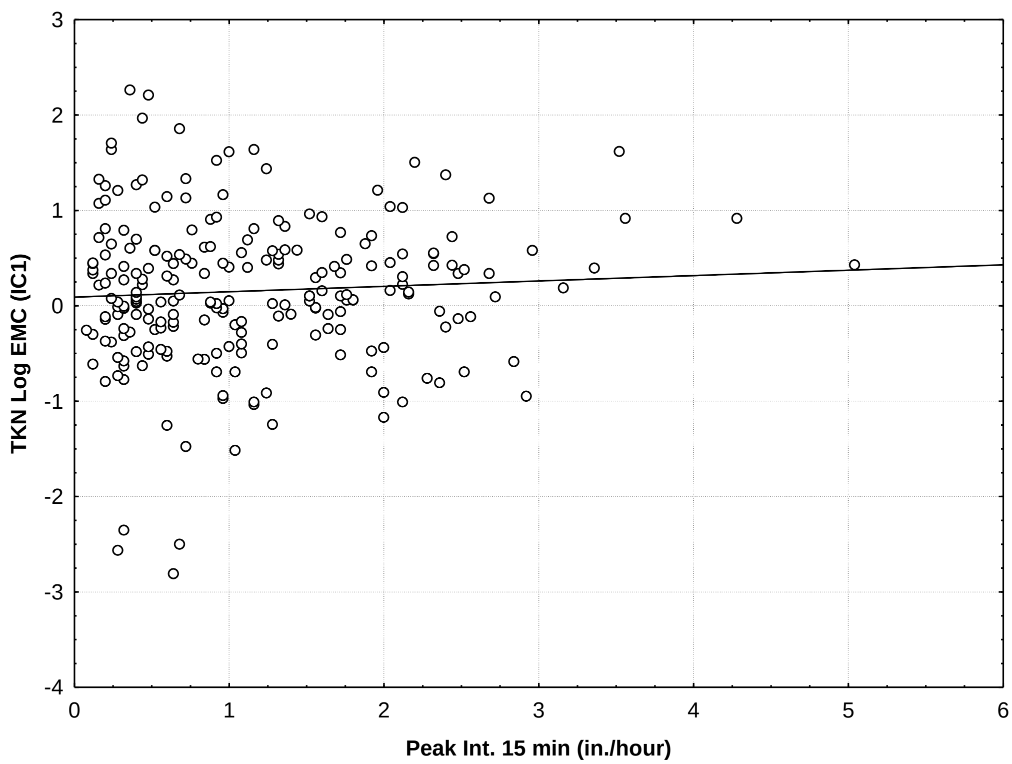
Graph D42. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TDS Group IC2



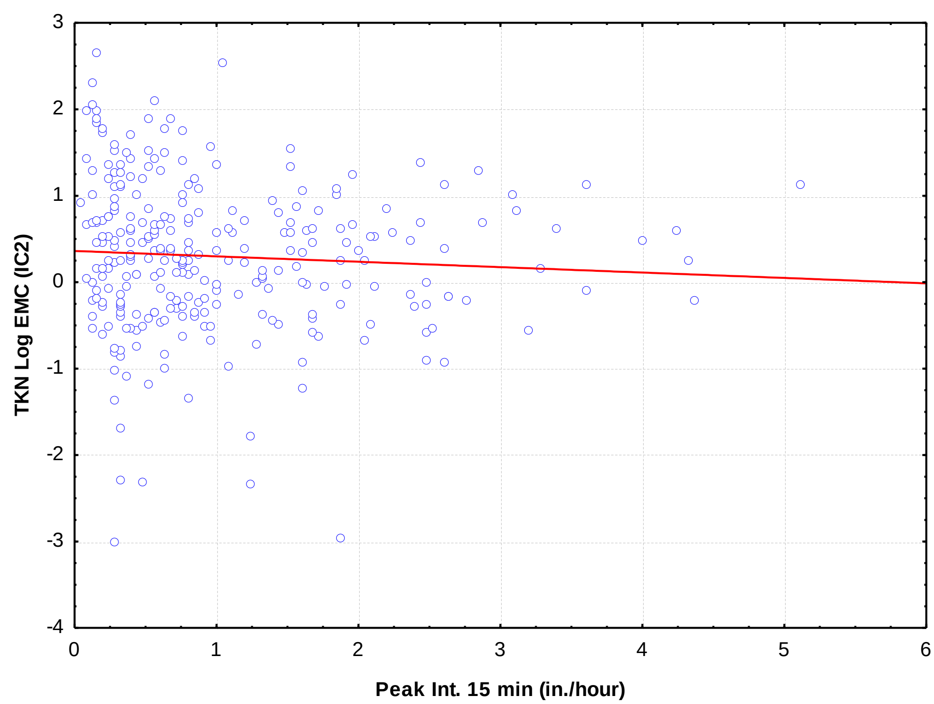
Graph D43. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TDS Group SFR



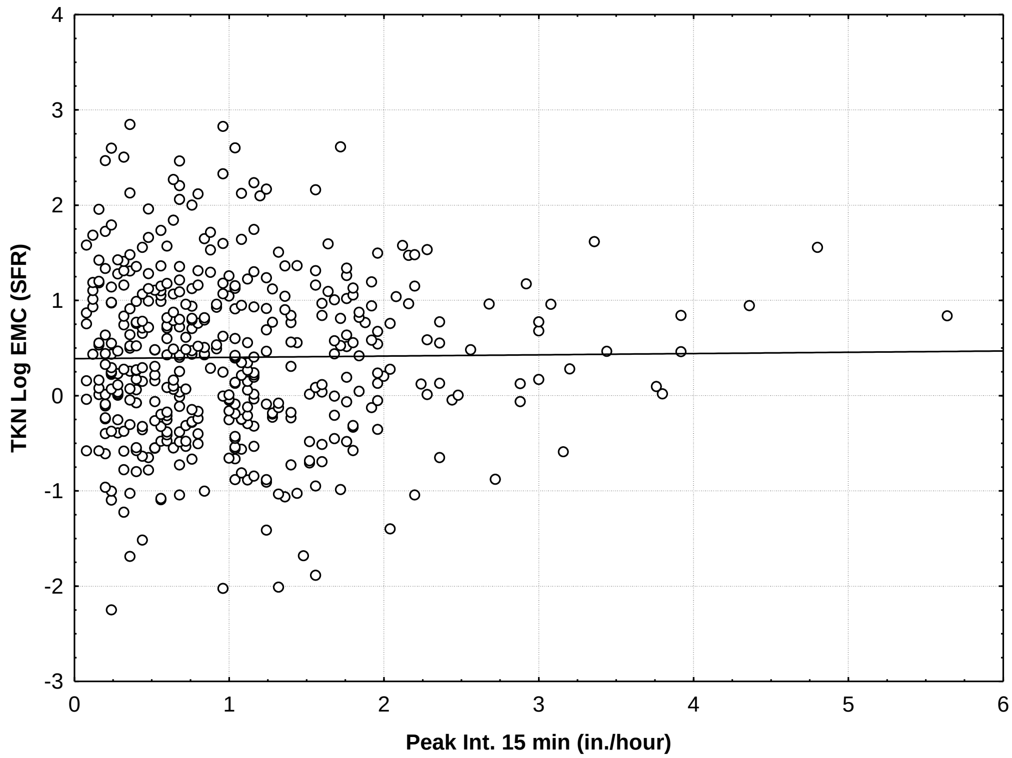
Graph D44. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TDS Group UND



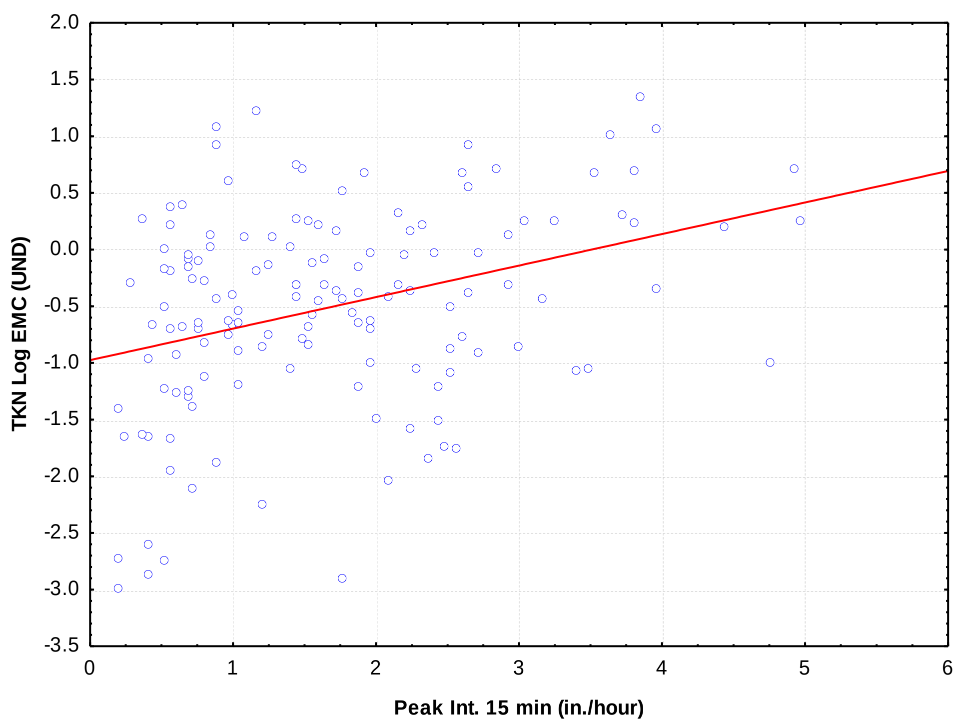
Graph D45. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TKN Group IC1



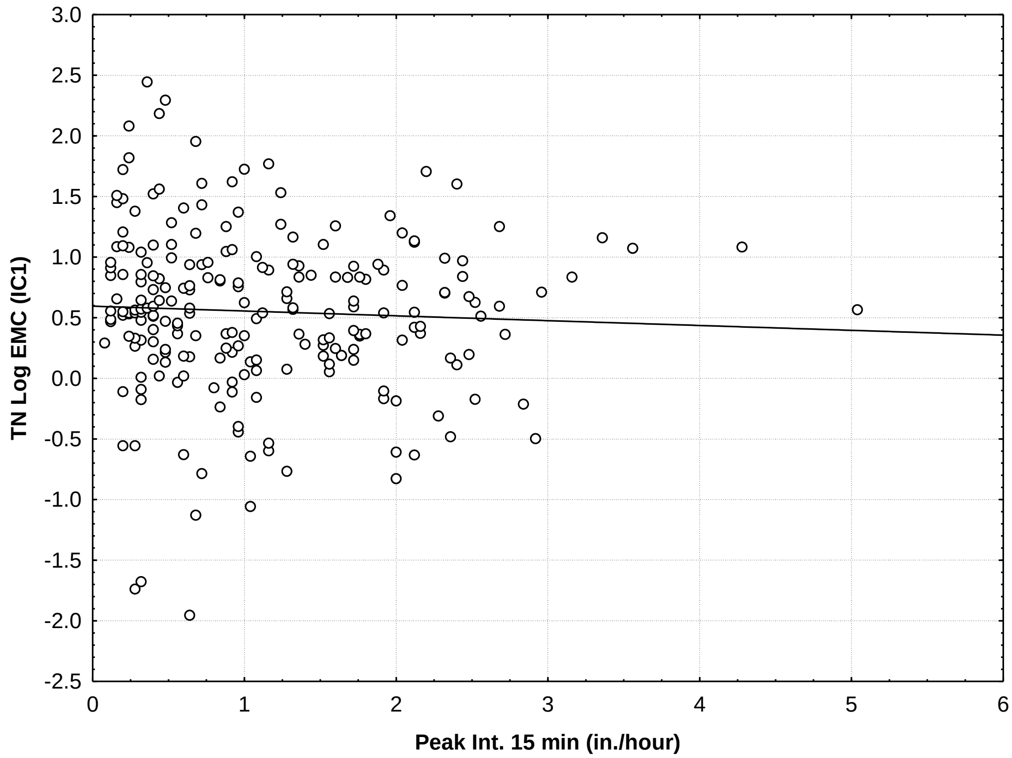
Graph D46. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TKN Group IC2



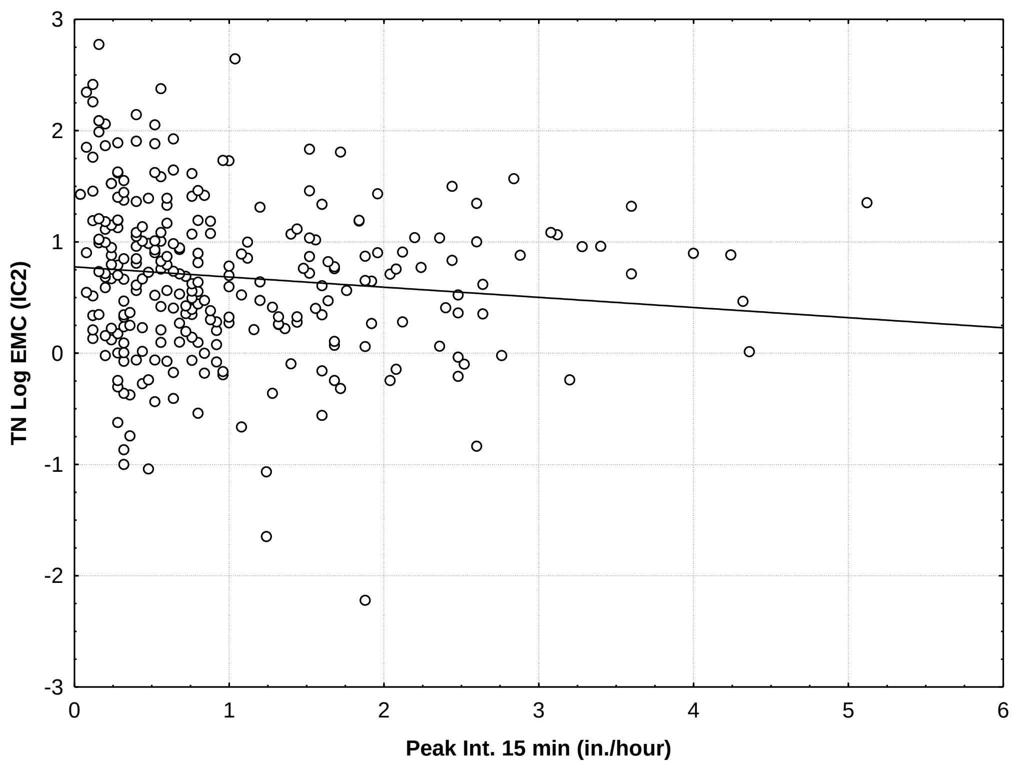
Graph D47. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TKN Group SFR



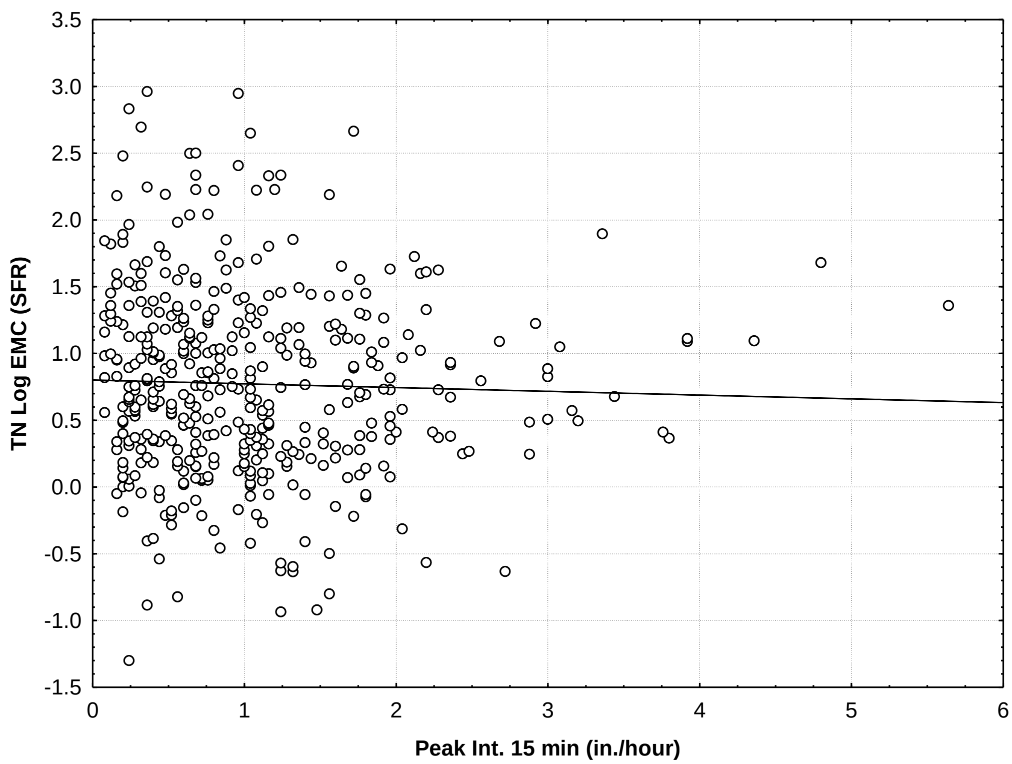
Graph D48. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TKN Group UND



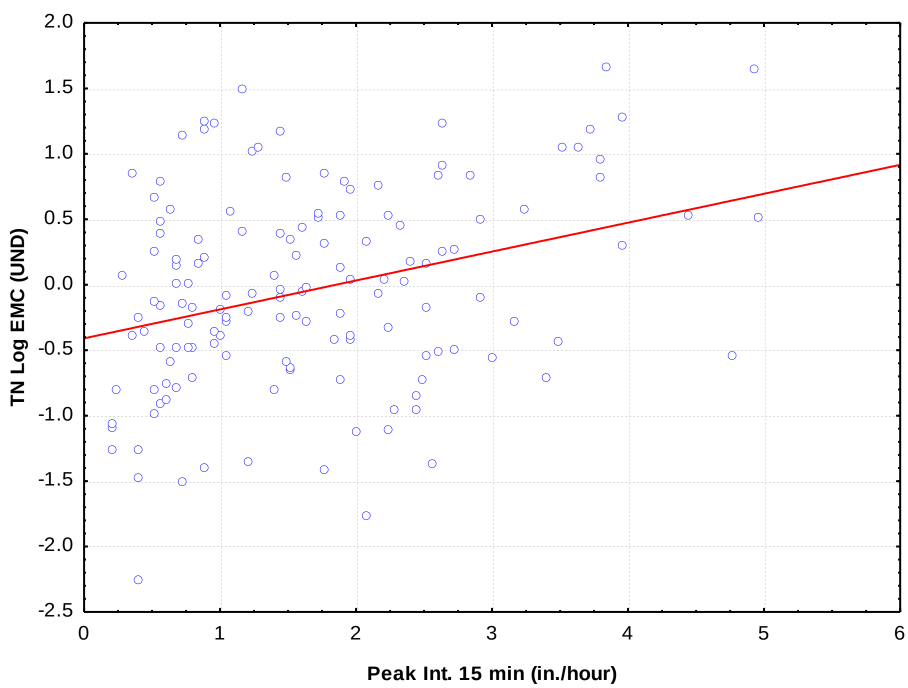
Graph D49. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TN Group IC1



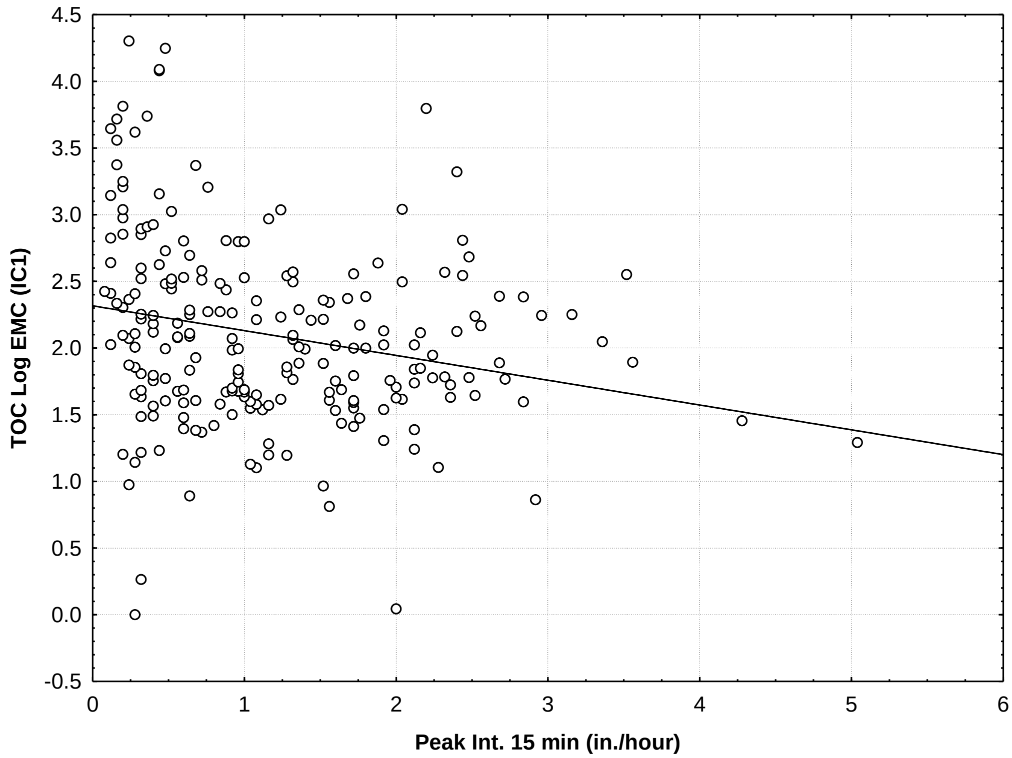
Graph D50. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TN Group IC2



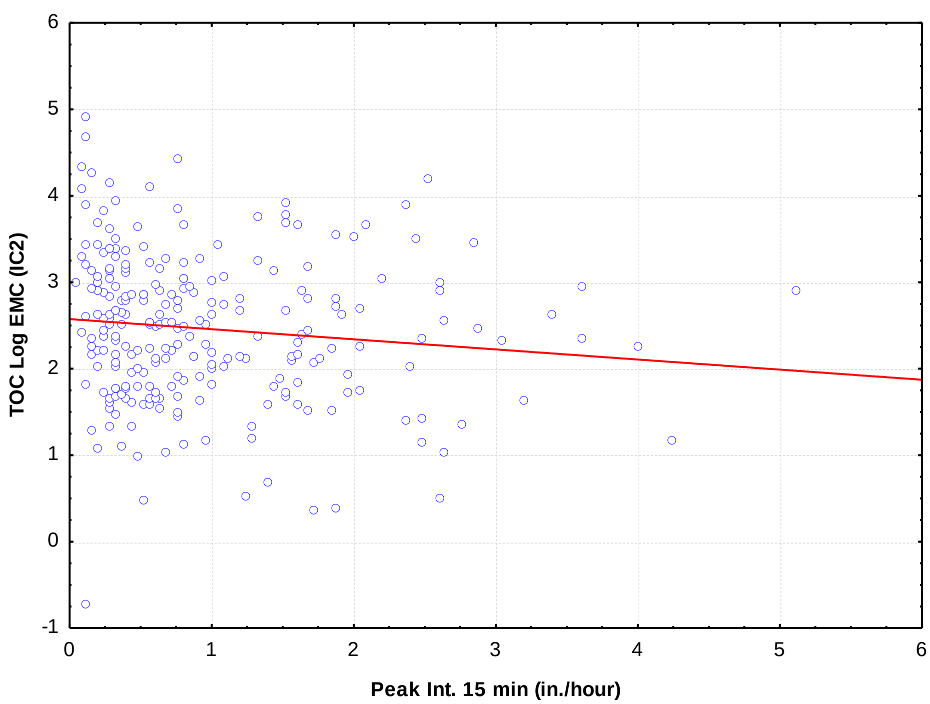
Graph D51. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TN Group SFR



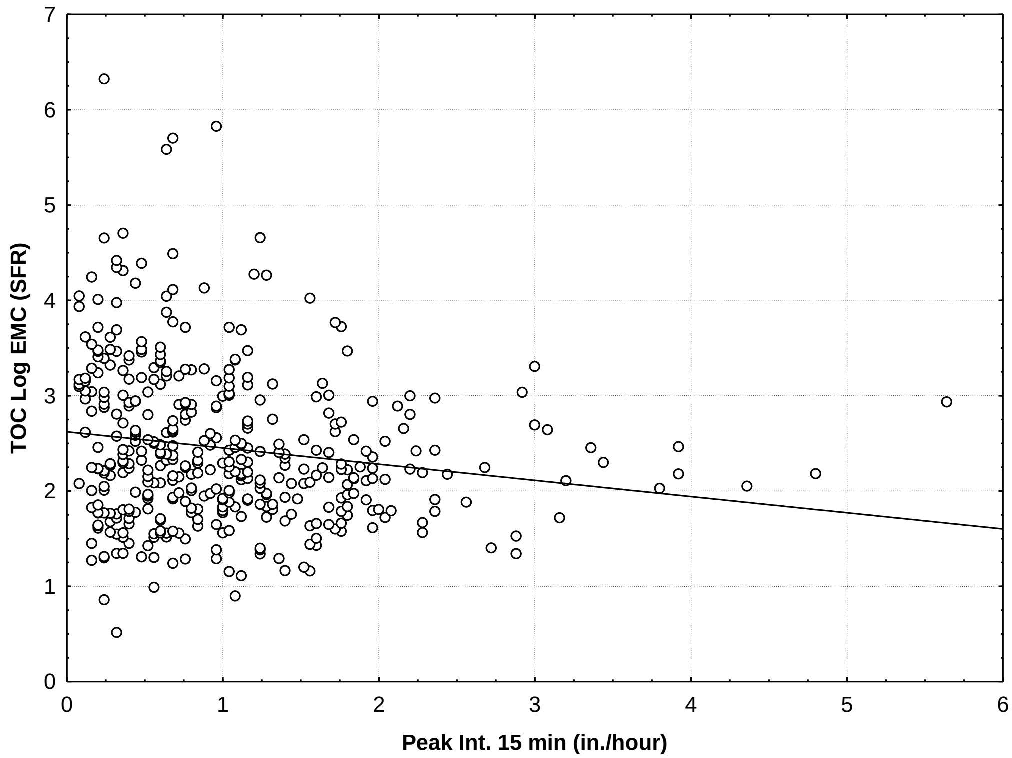
Graph D52. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TN Group UND



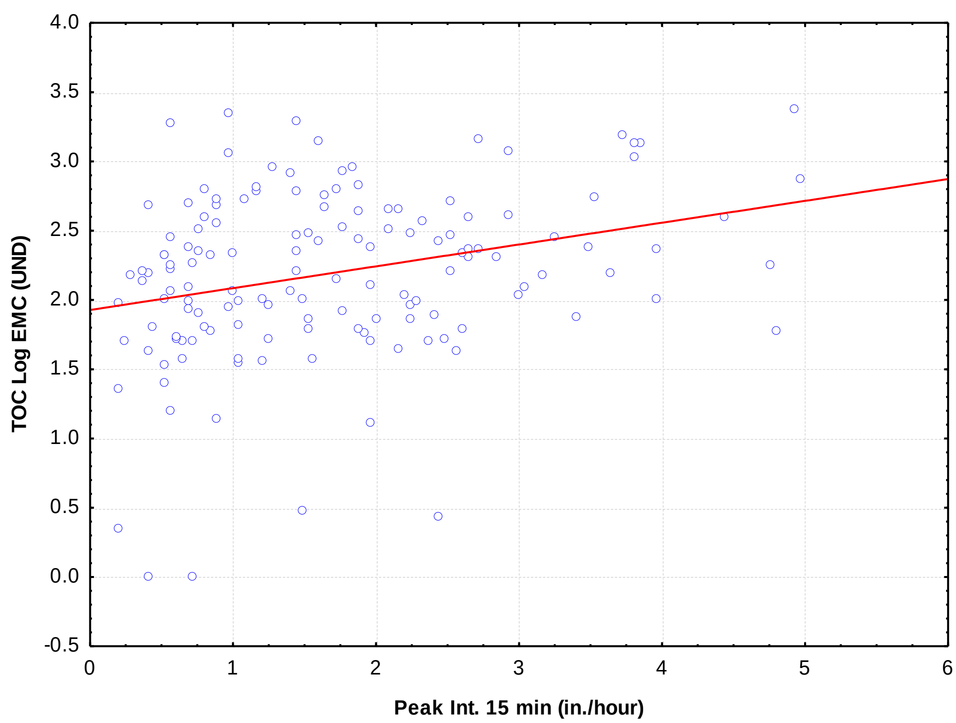
Graph D53. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TOC Group IC1



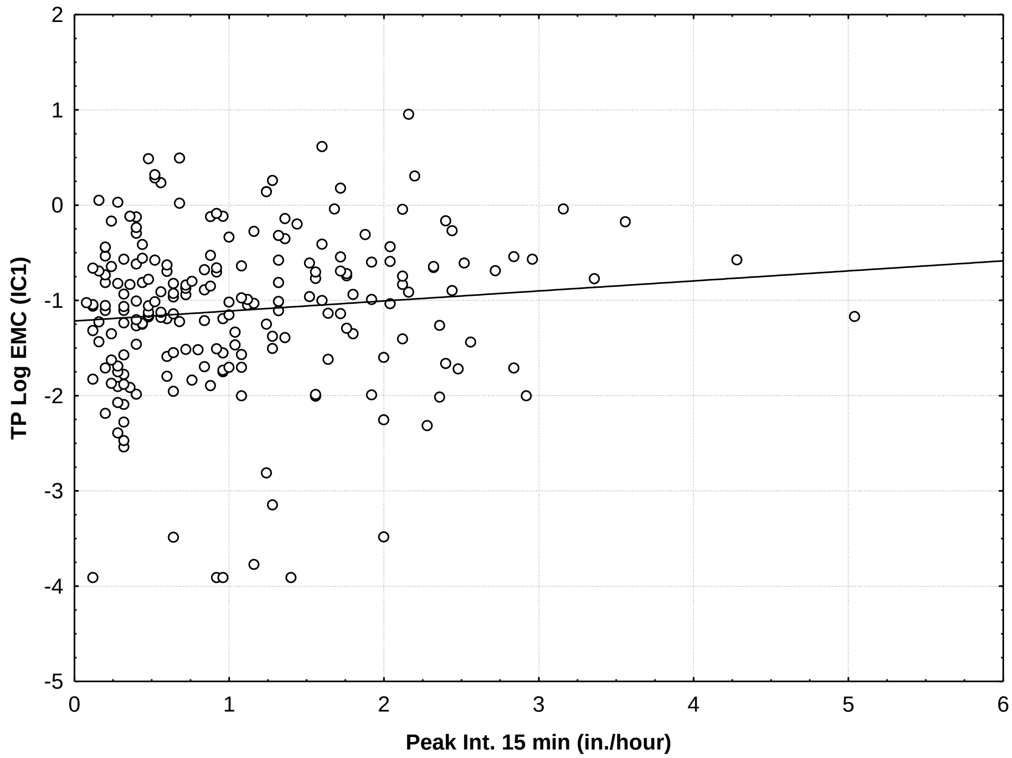
Graph D54. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TOC Group IC2



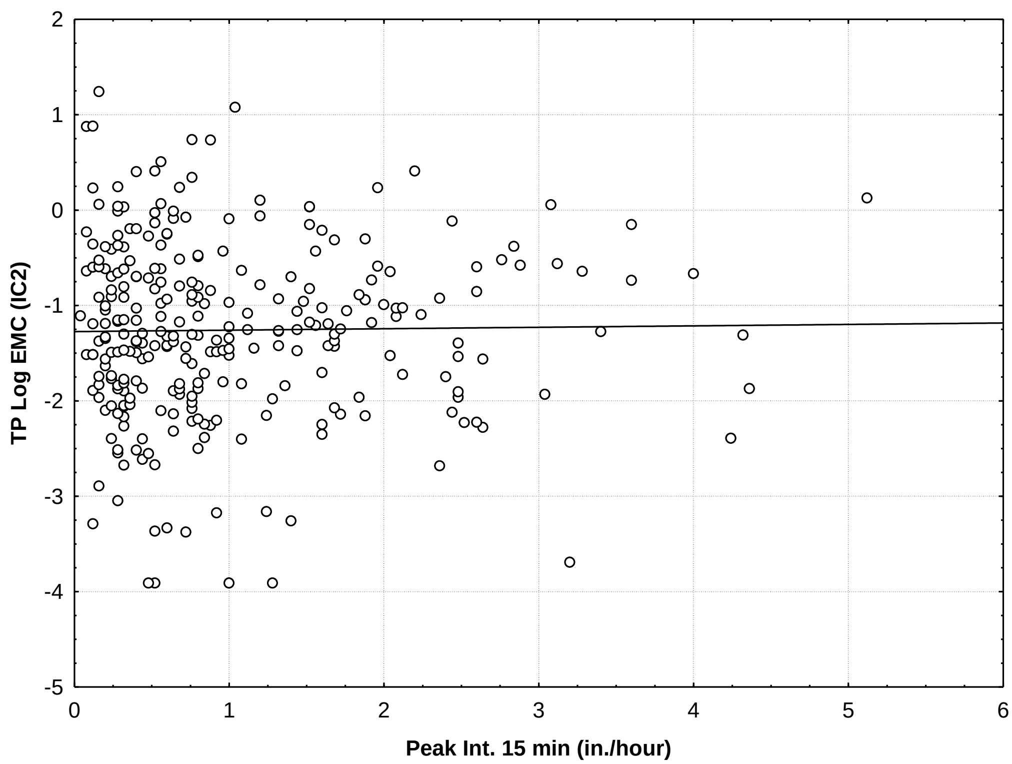
Graph D55. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TOC Group SFR



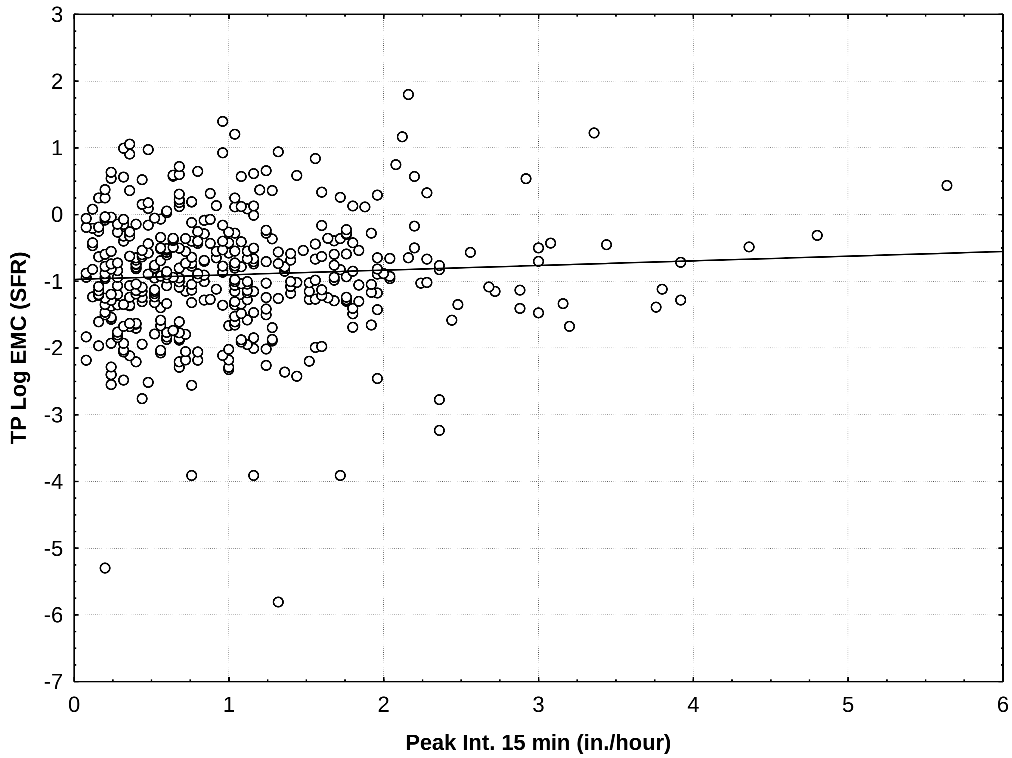
Graph D56. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TOC Group UND



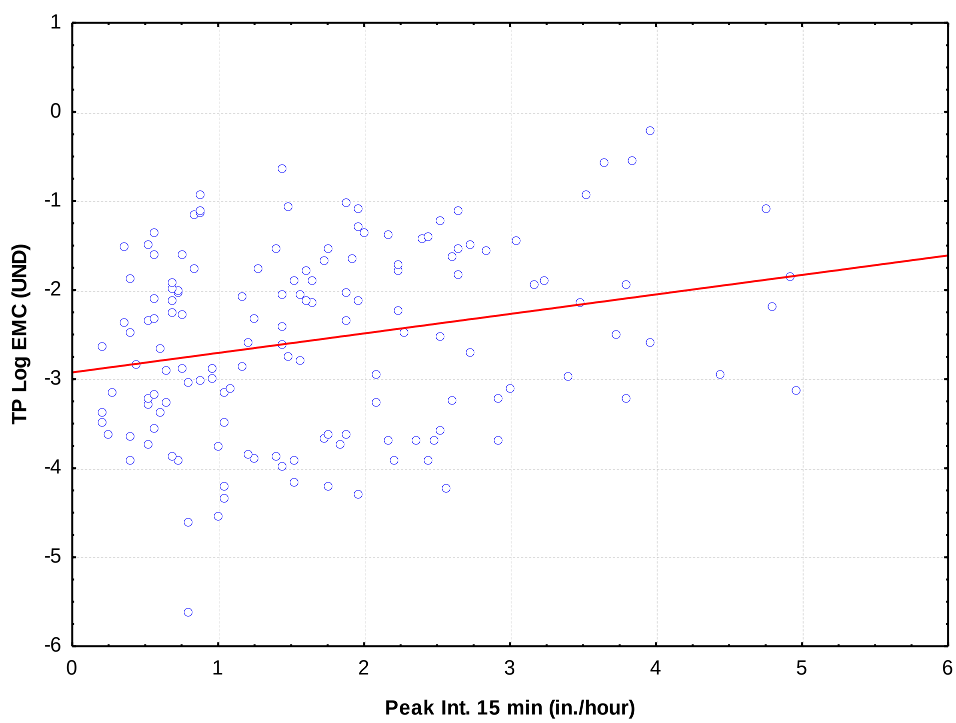
Graph D57. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TP Group IC1



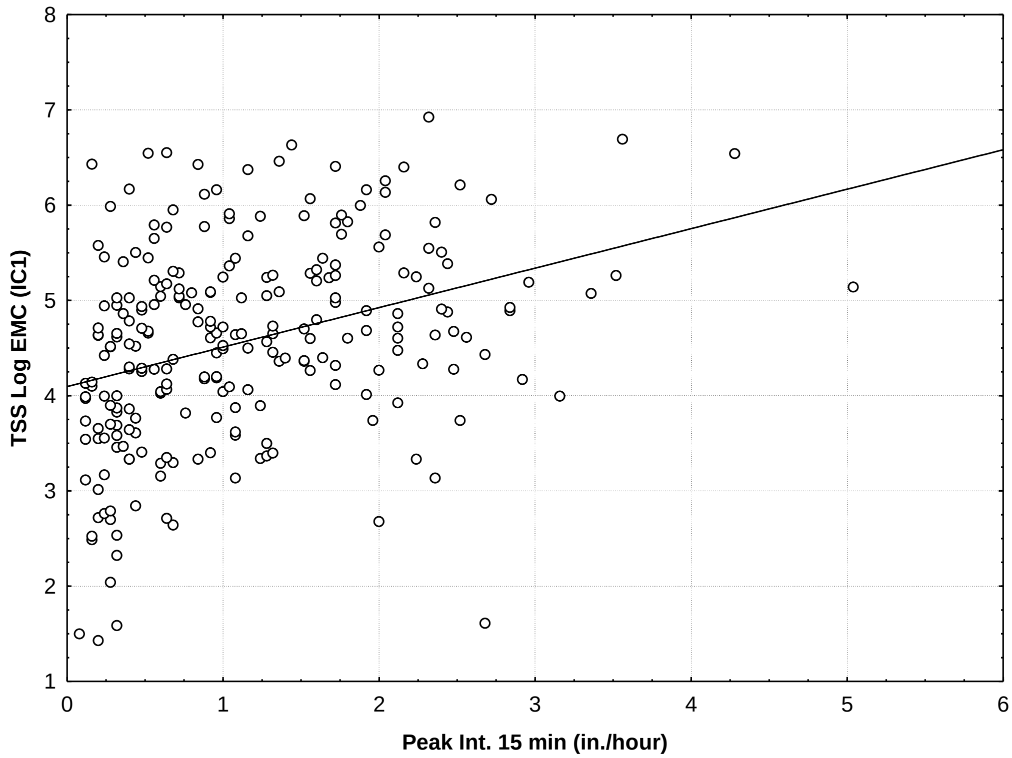
Graph D58. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TP Group IC2



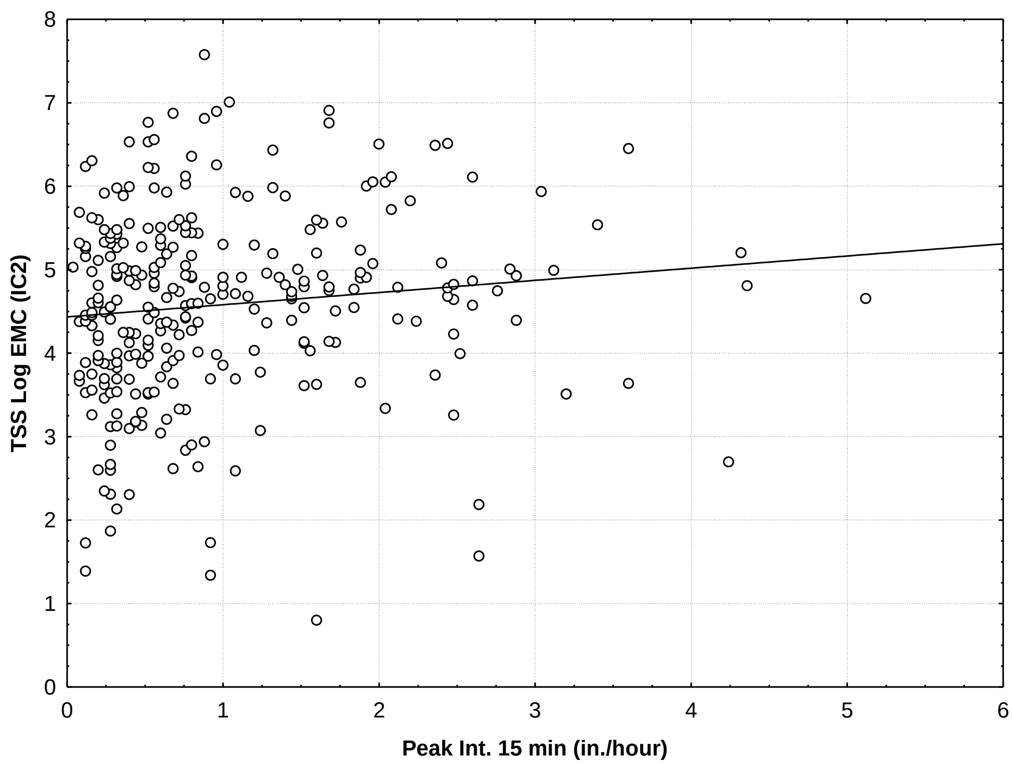
Graph D59. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TP Group SFR



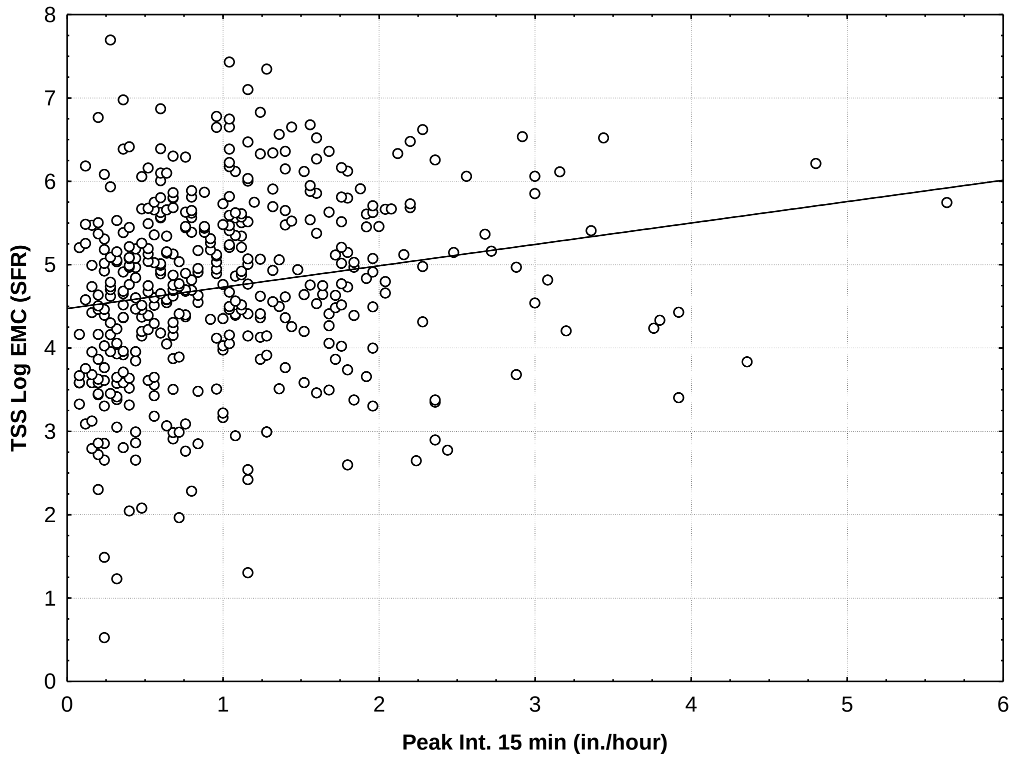
Graph D60. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TP Group UND



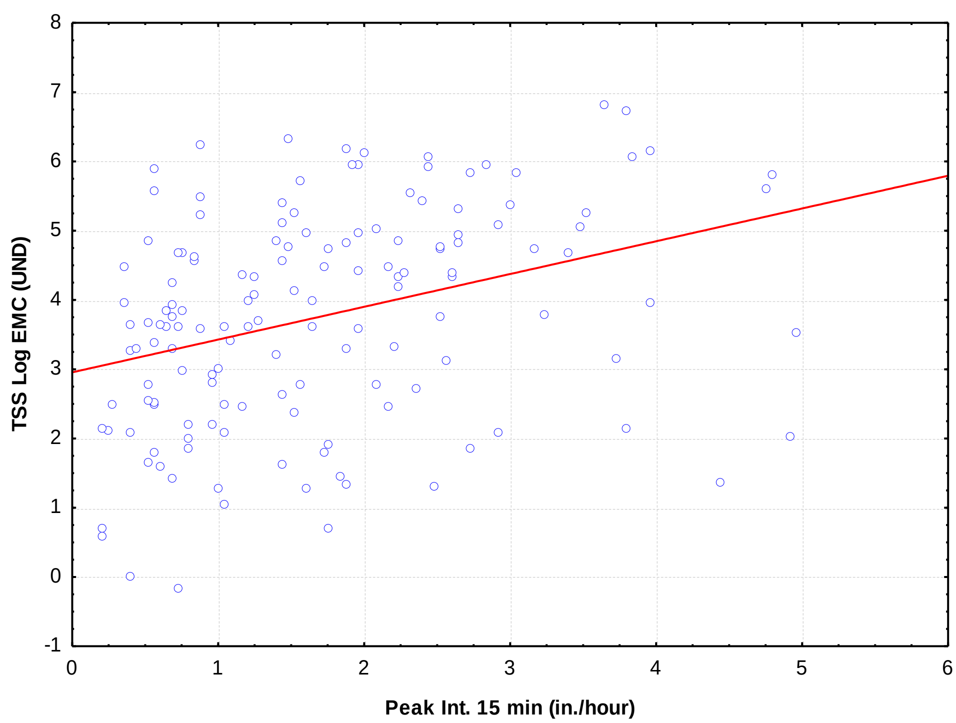
Graph D61. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TSS Group IC1



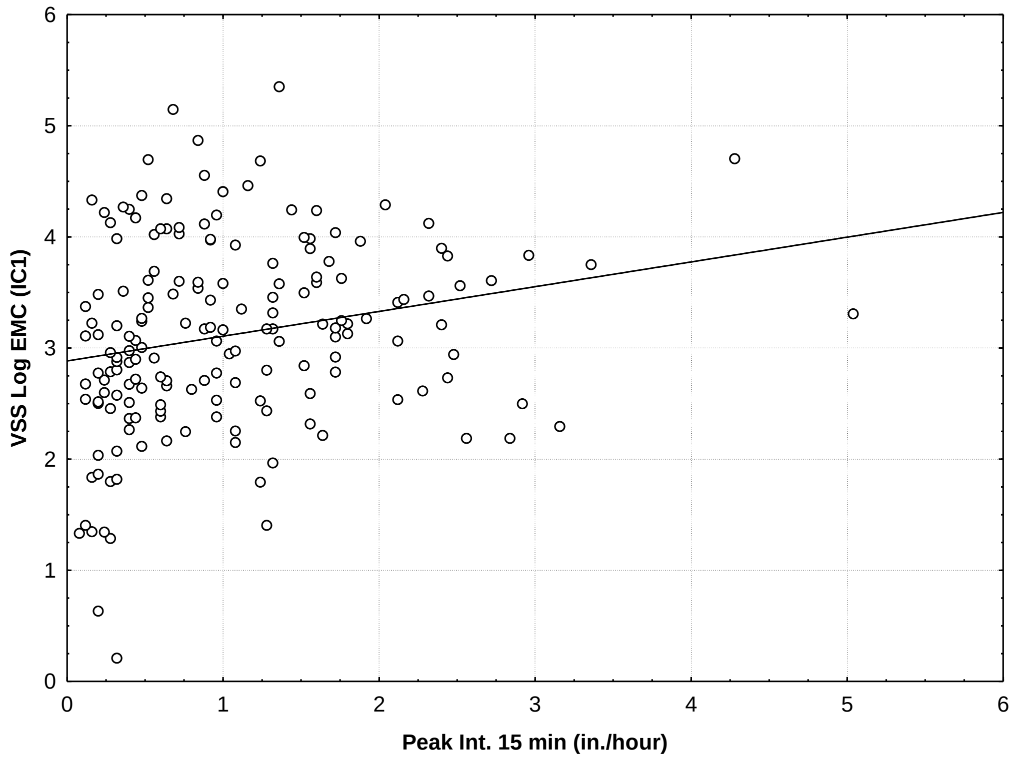
Graph D62. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TSS Group IC2



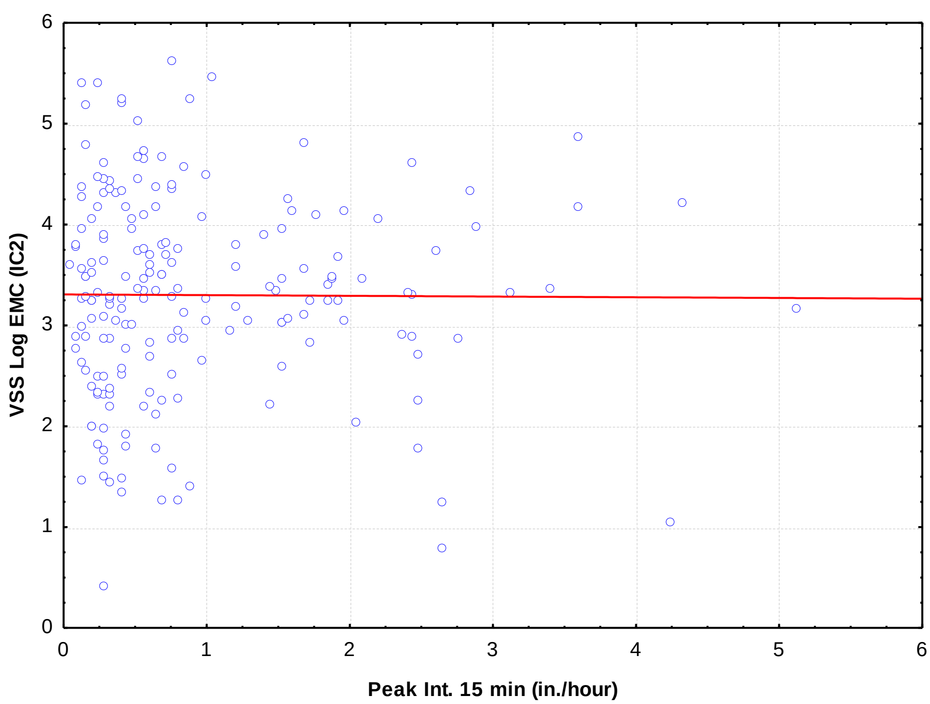
Graph D63. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TSS Group SFR



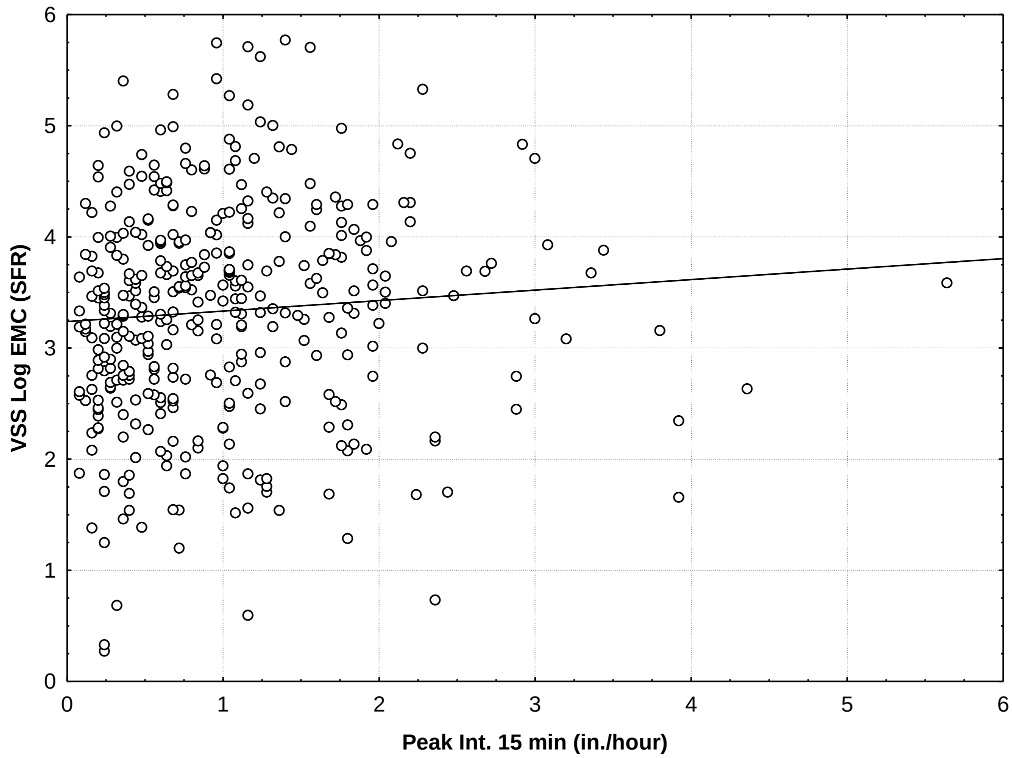
Graph D64. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for TSS Group UND



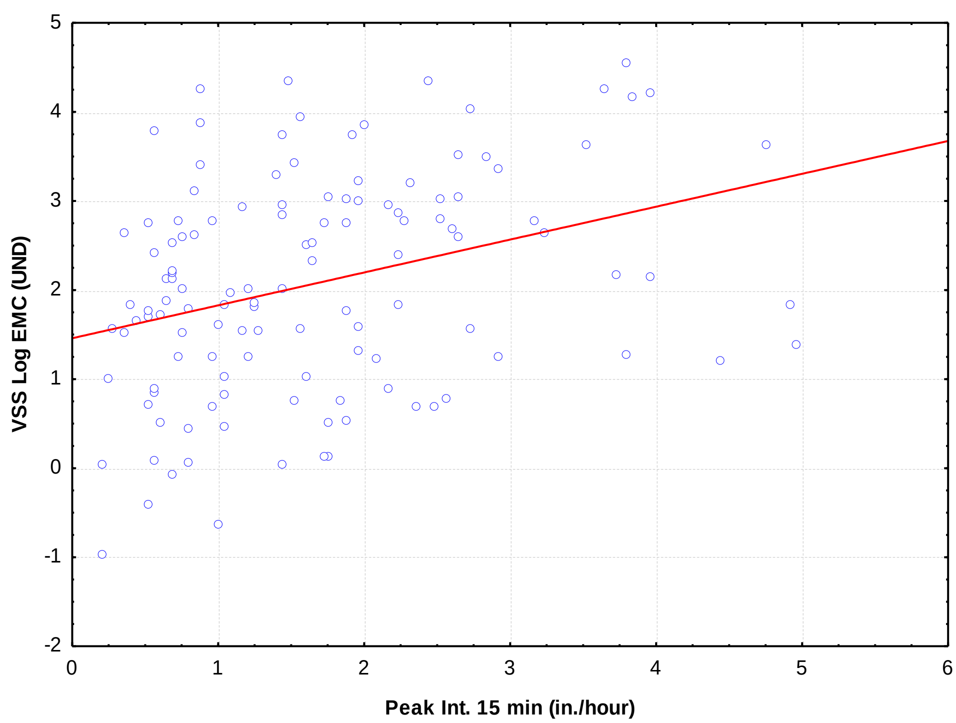
Graph D65. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for VSS Group IC1



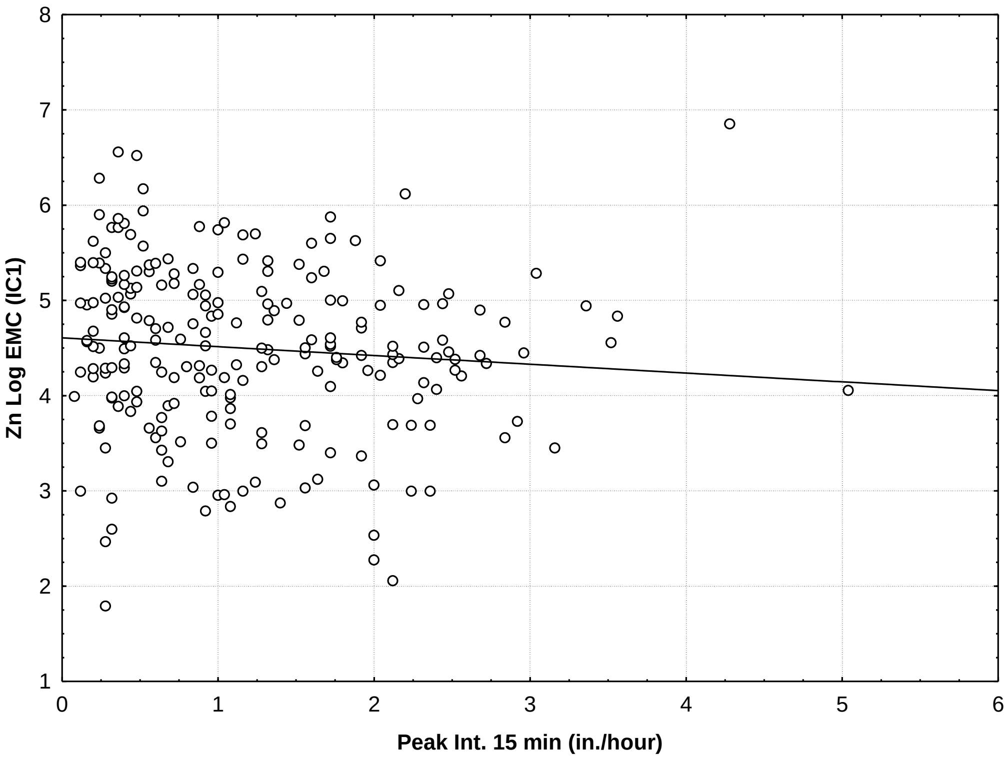
Graph D66. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for VSS Group IC2



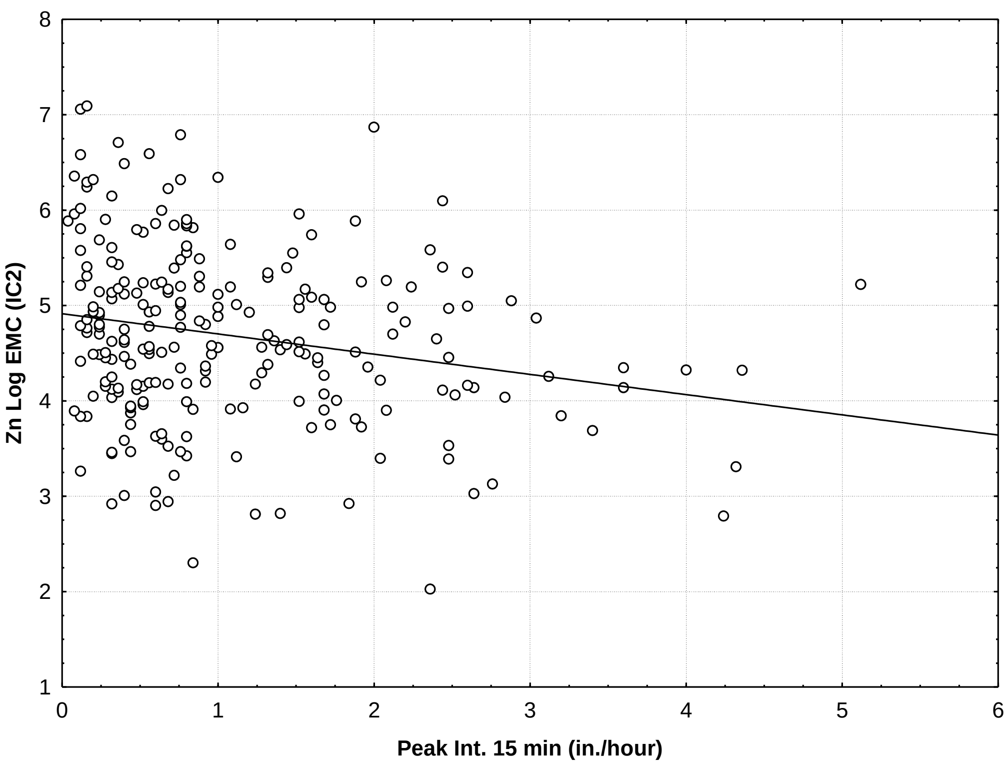
Graph D67. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for VSS Group SFR



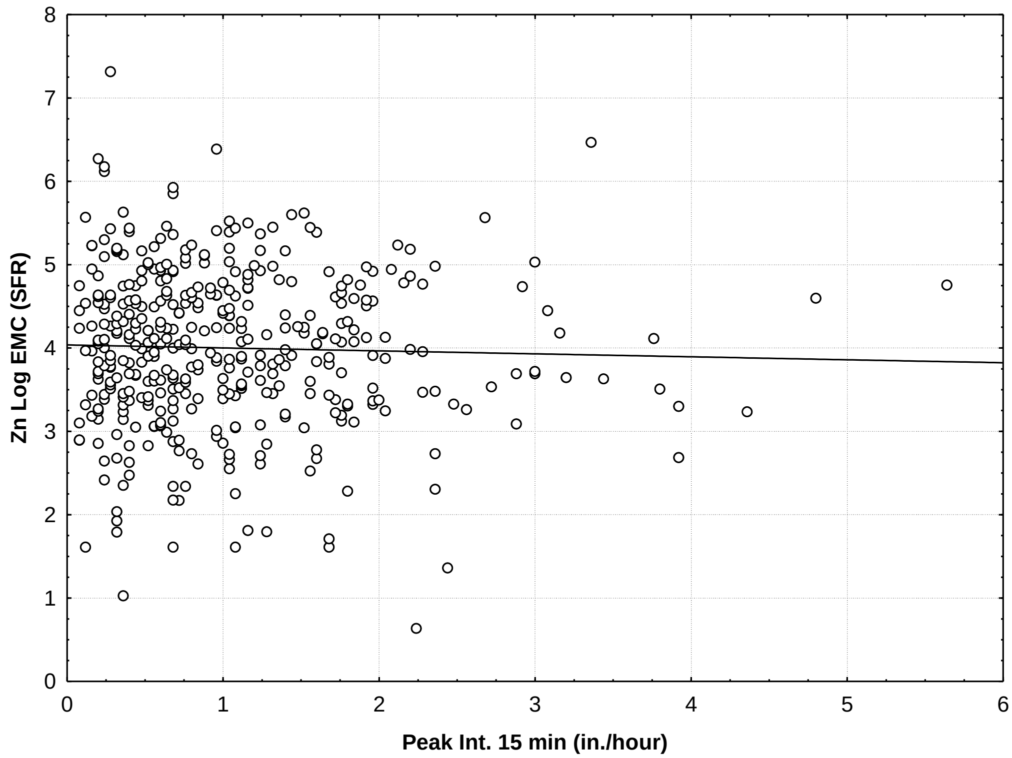
Graph D68. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for VSS Group UND



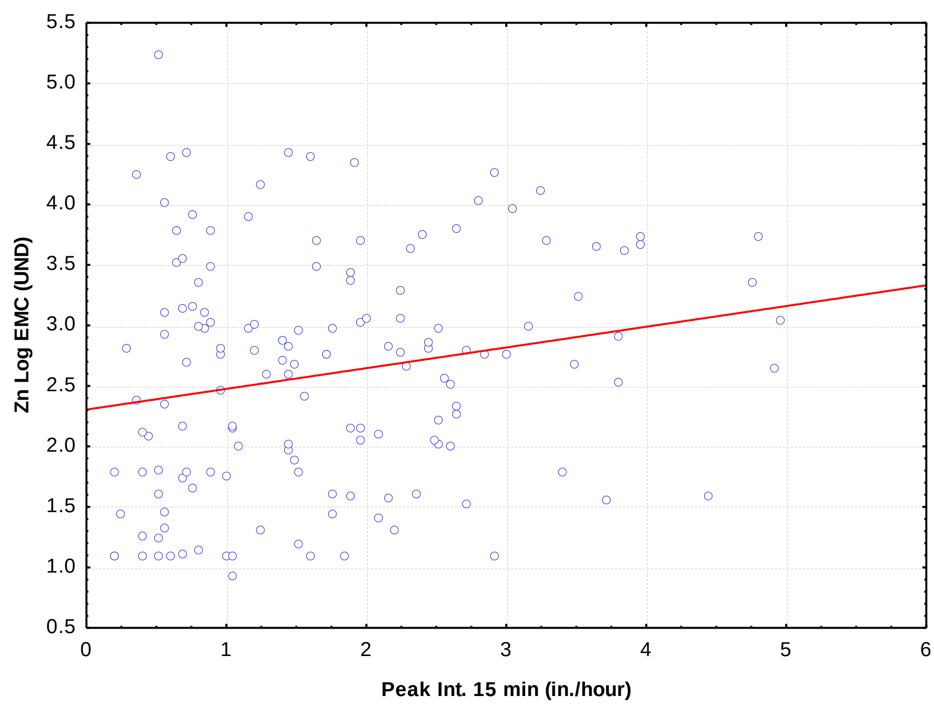
Graph D69. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Zn Group IC1



Graph D70. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Zn Group IC2

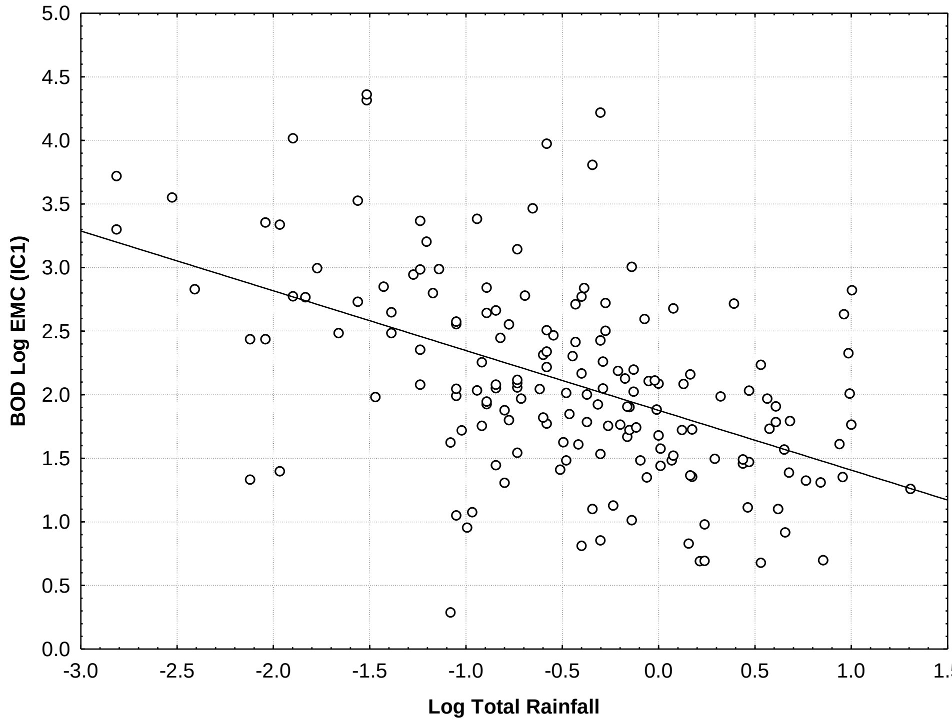


Graph D71. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Zn Group SFR

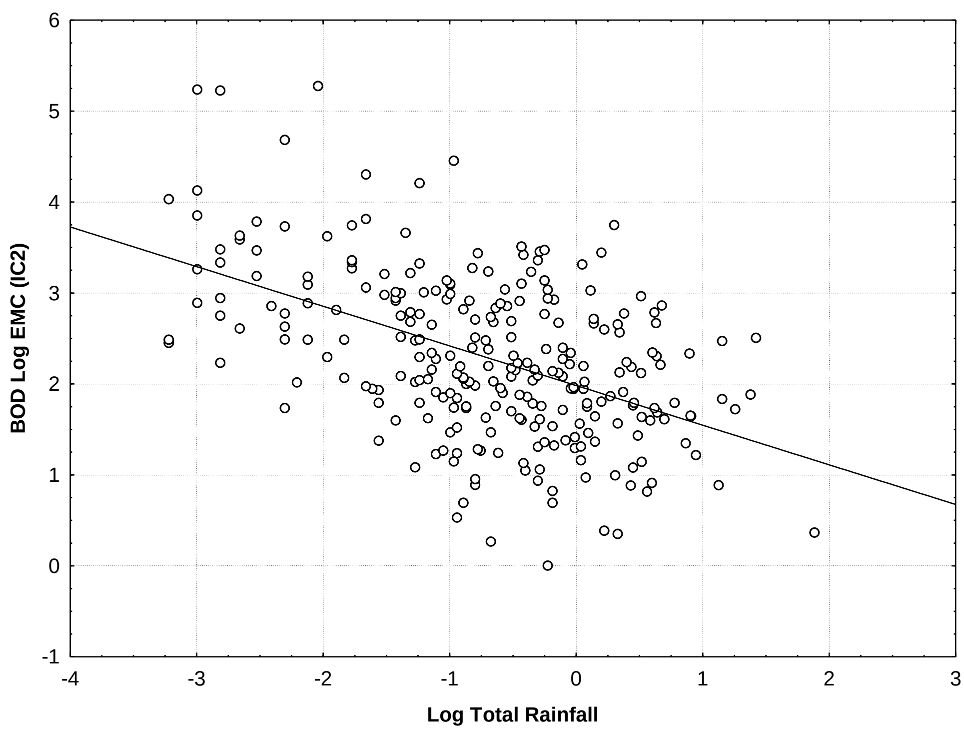


Graph D72. Scatterplot of 15-Minute Peak Rainfall Intensity vs. Log of EMC for Zn Group UND

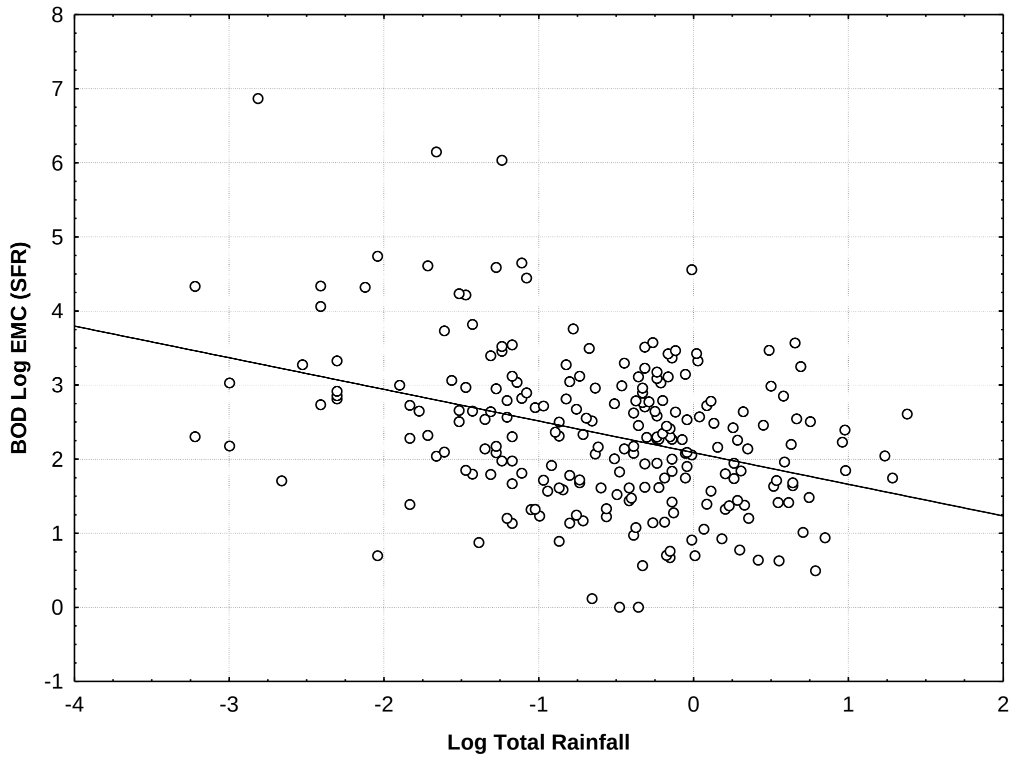
Appendix E Ln(EMC) vs. Ln(Total Rainfall)



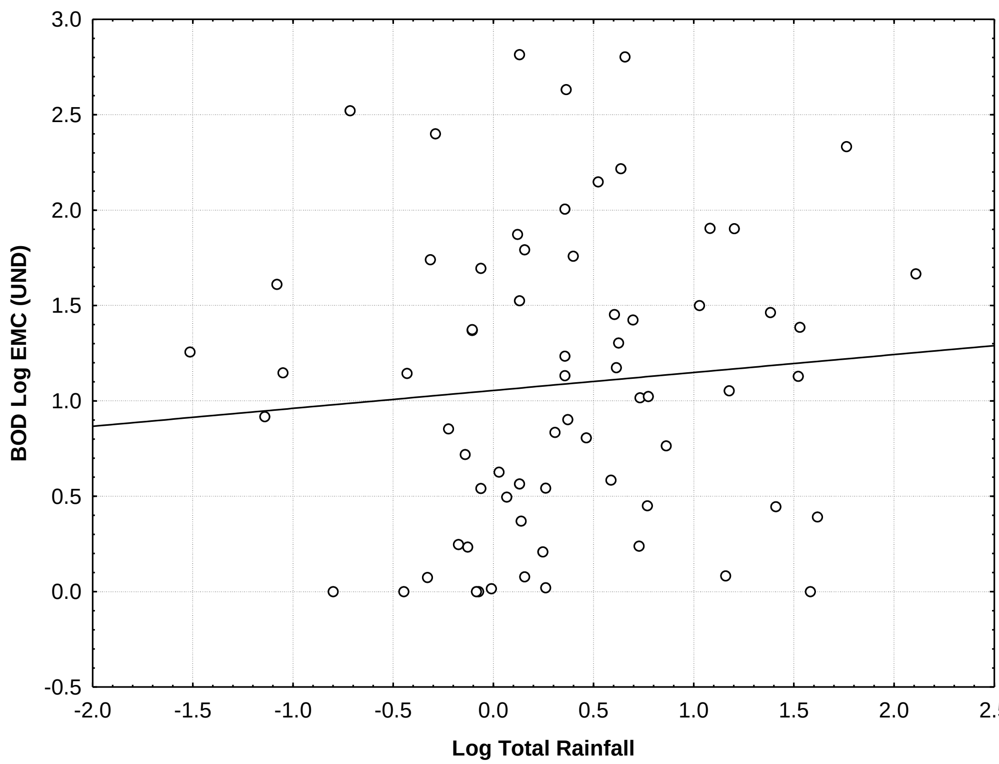
Graph E1. Scatterplot of Log of Total Rainfall vs. Log of EMC for BOD Group IC1



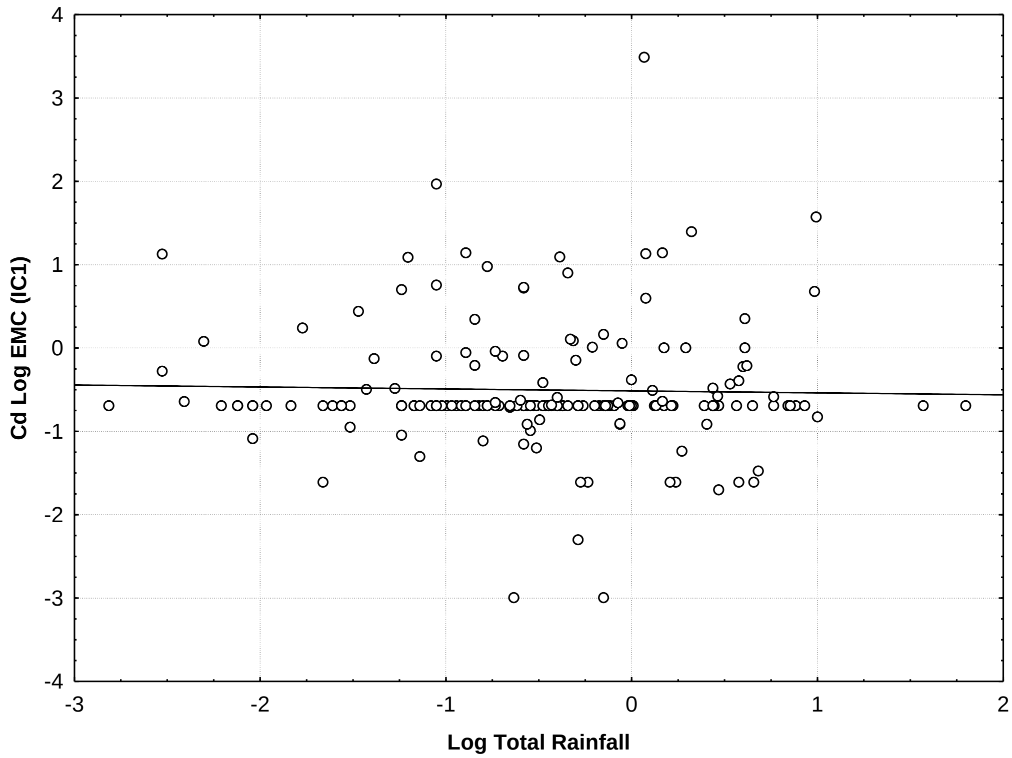
Graph E2. Scatterplot of Log of Total Rainfall vs. Log of EMC for BOD Group IC2



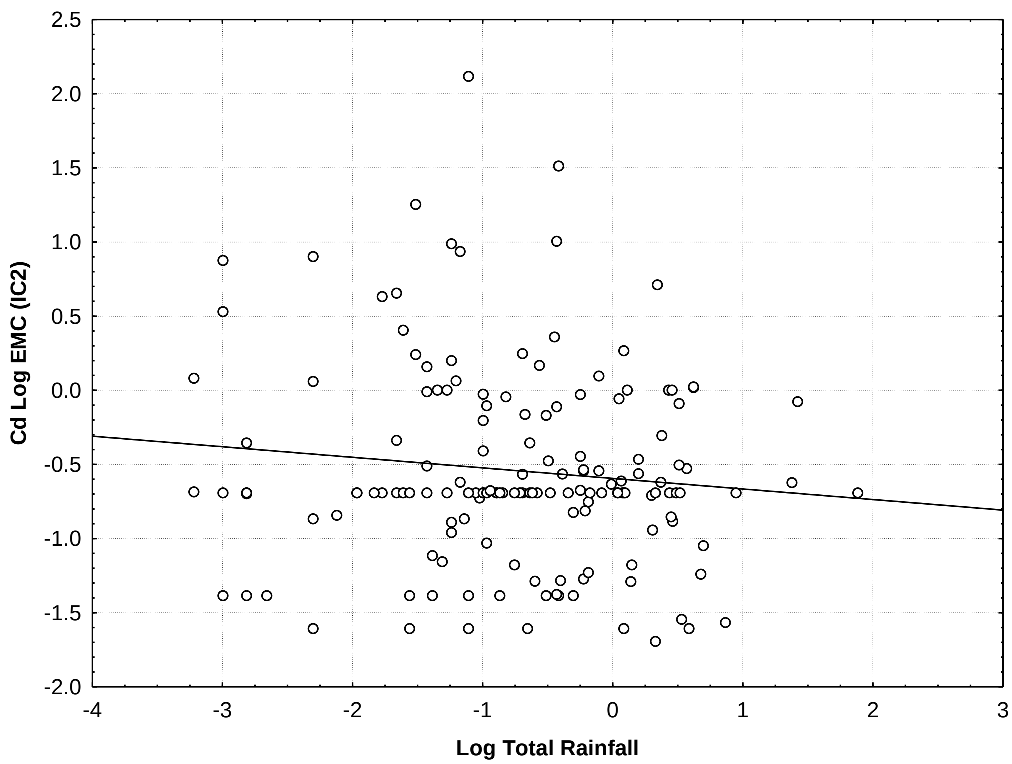
Graph E3. Scatterplot of Log of Total Rainfall vs. Log of EMC for BOD Group SFR



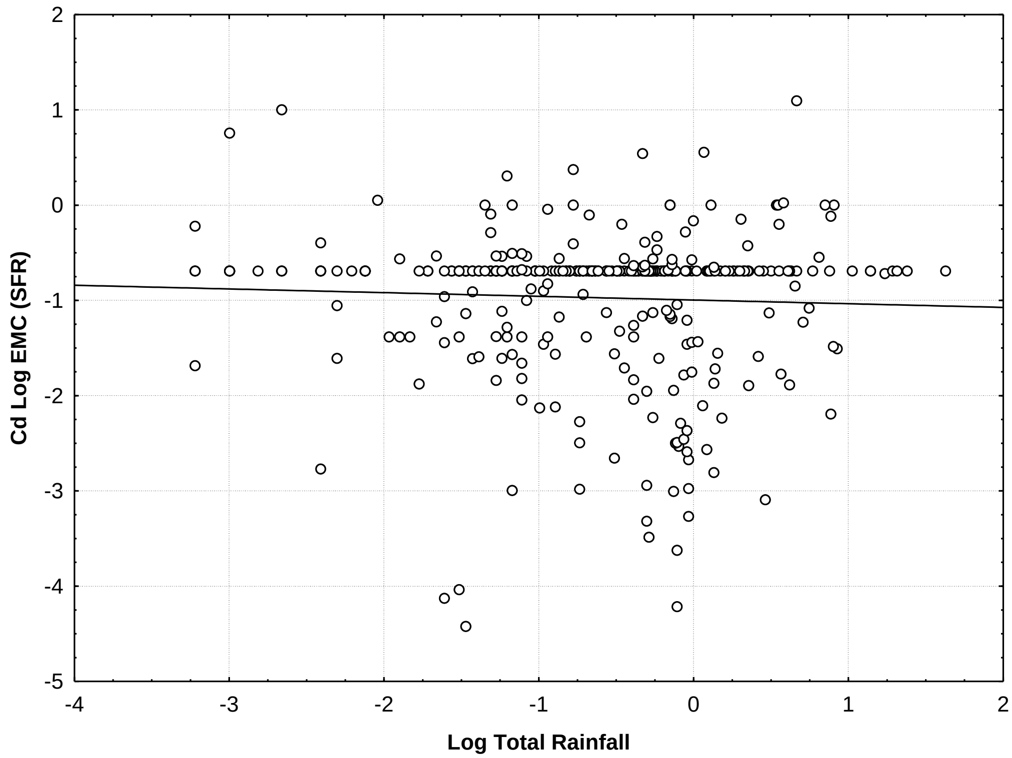
Graph E4. Scatterplot of Log of Total Rainfall vs. Log of EMC for BOD Group UND



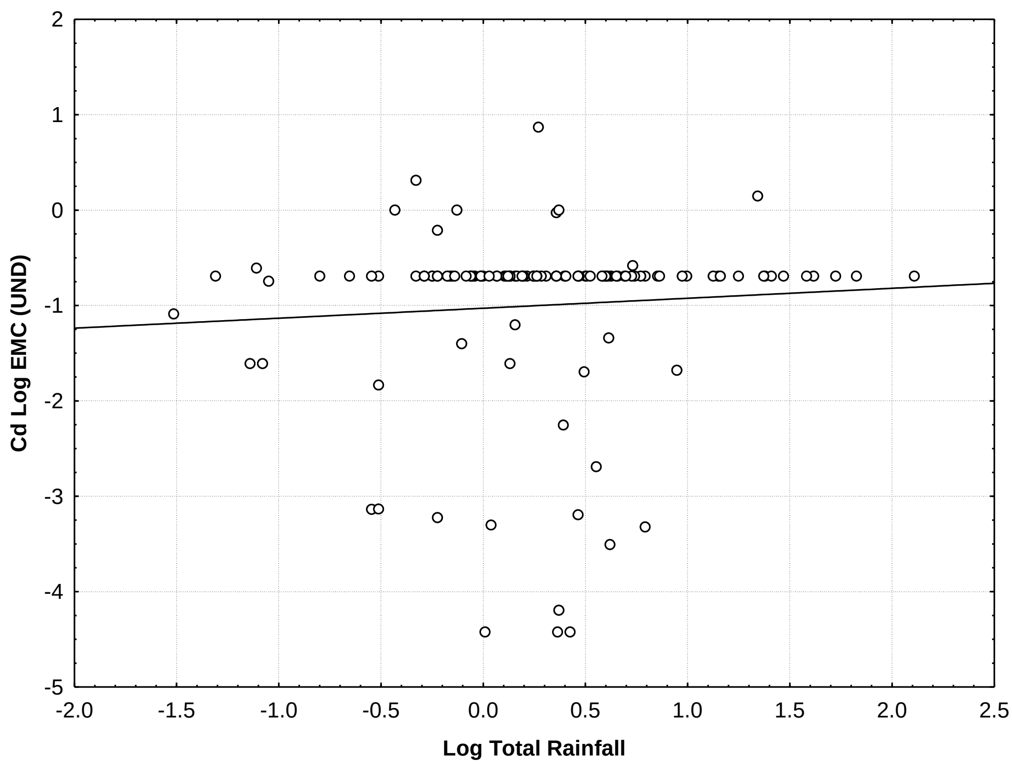
Graph E5. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cd Group IC1



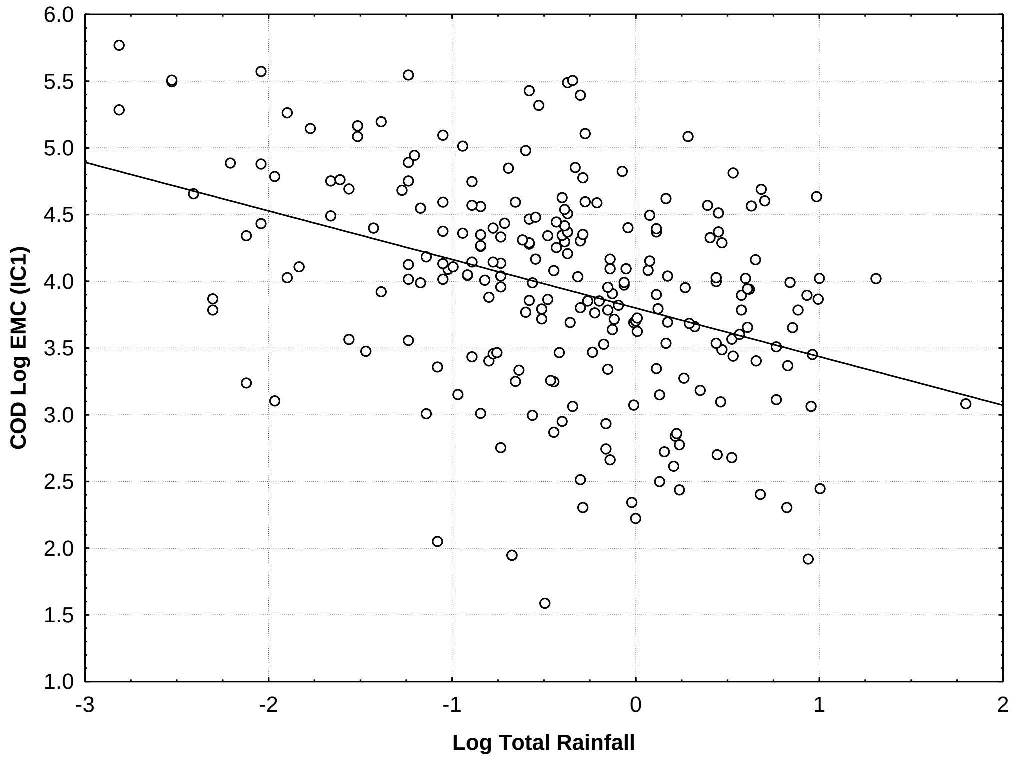
Graph E6. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cd Group IC2



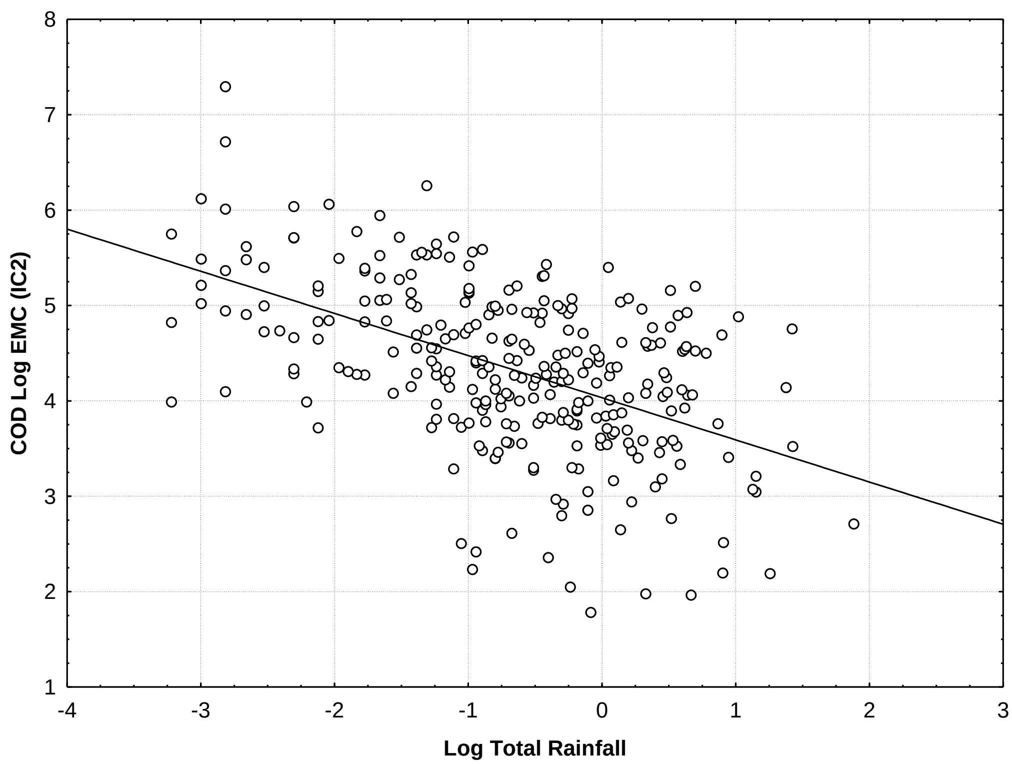
Graph E7. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cd Group SFR



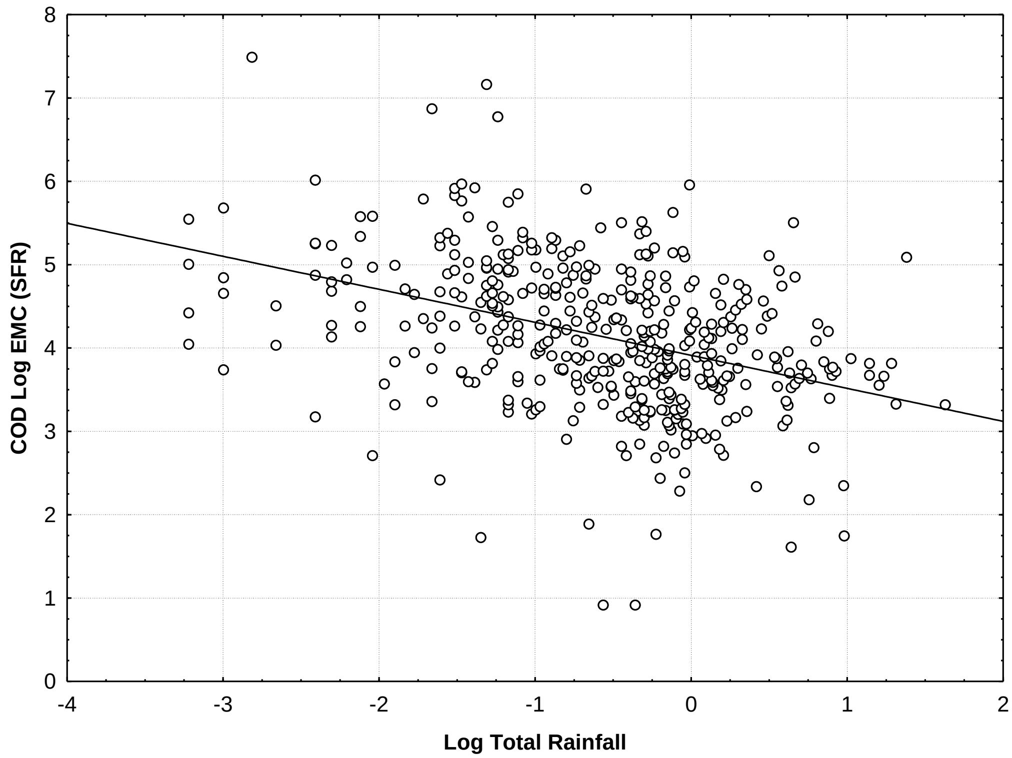
Graph E8. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cd Group UND



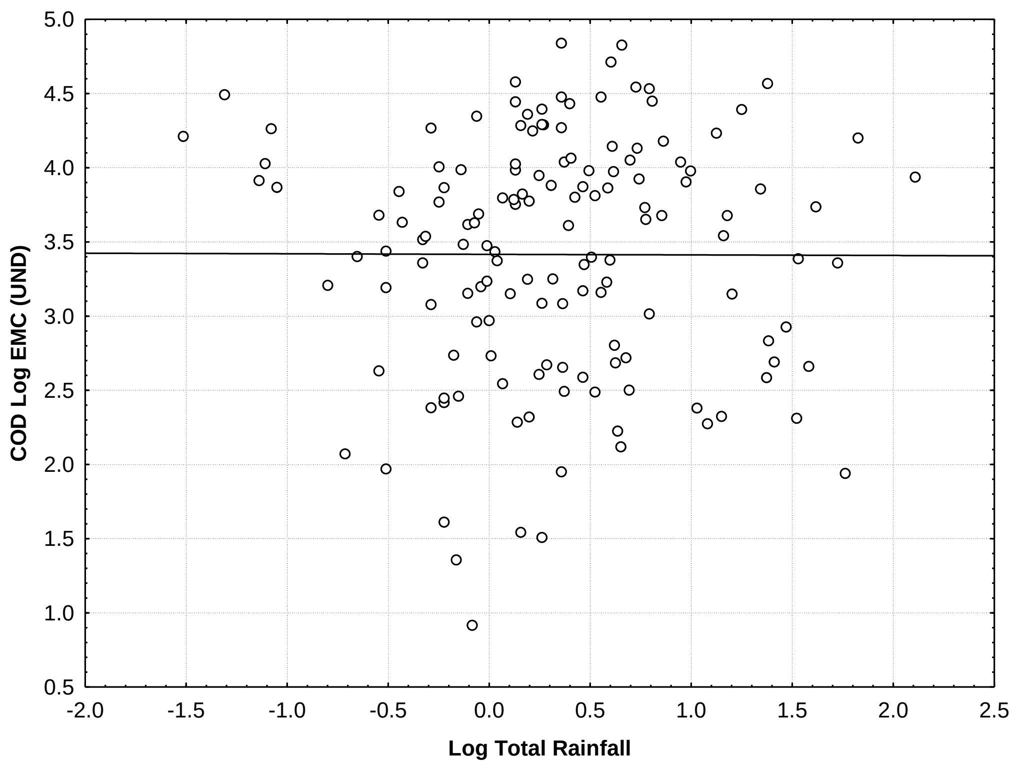
Graph E9. Scatterplot of Log of Total Rainfall vs. Log of EMC for COD Group IC1



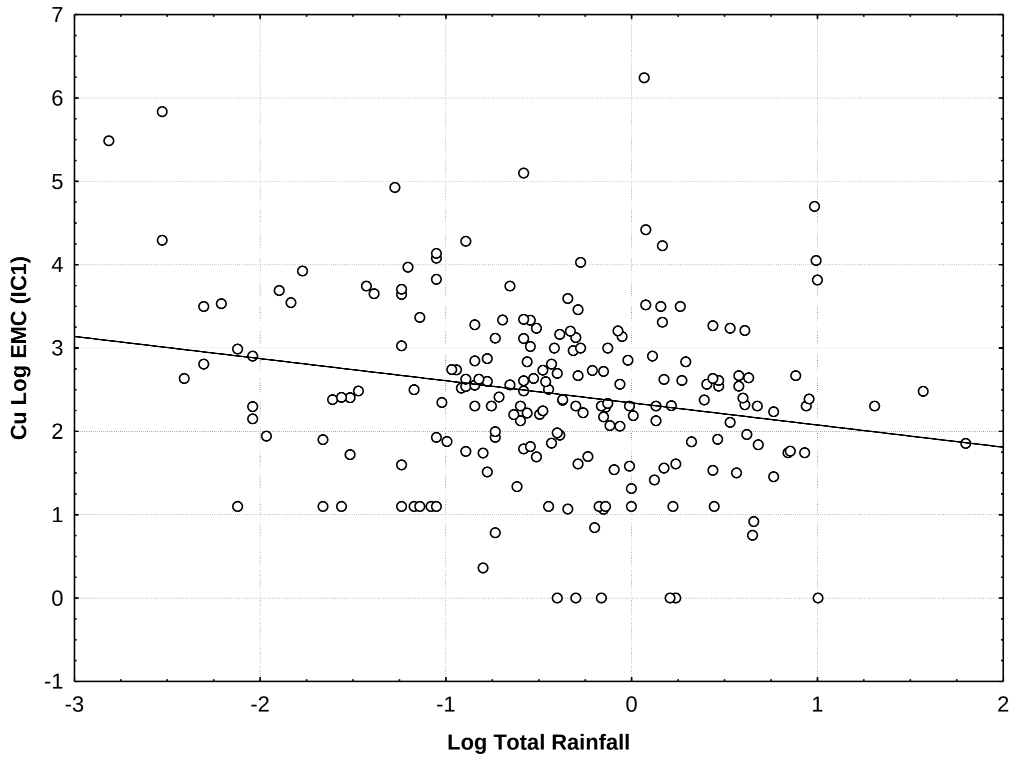
Graph E10. Scatterplot of Log of Total Rainfall vs. Log of EMC for COD Group IC2



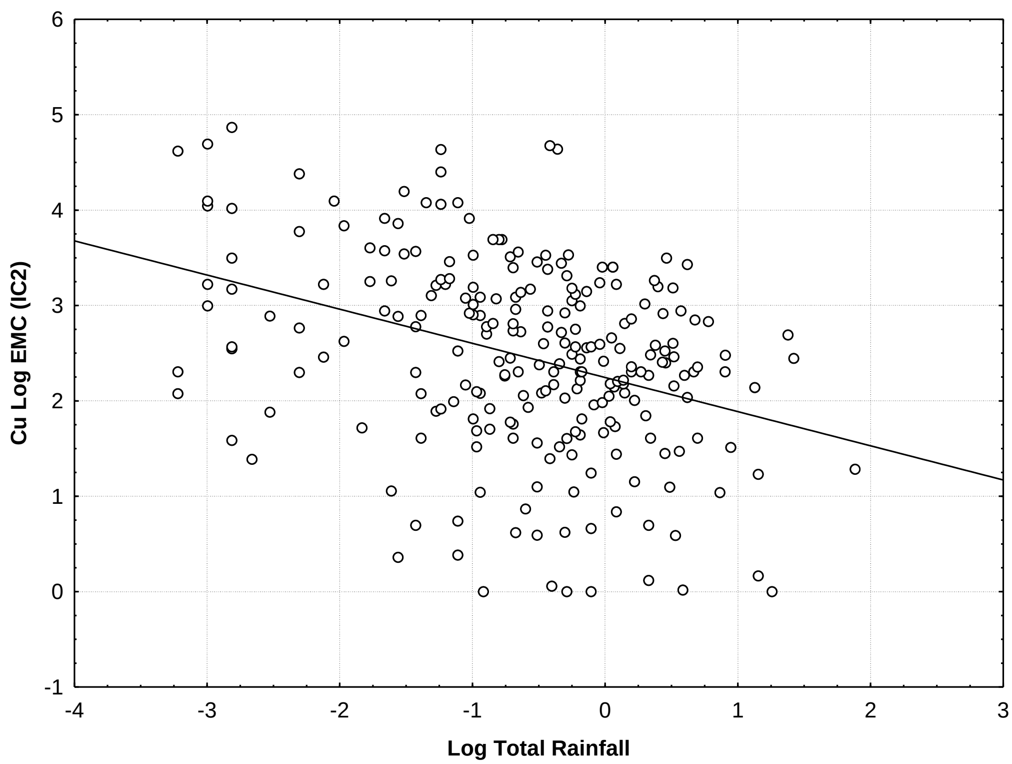
Graph E11. Scatterplot of Log of Total Rainfall vs. Log of EMC for COD Group SFR



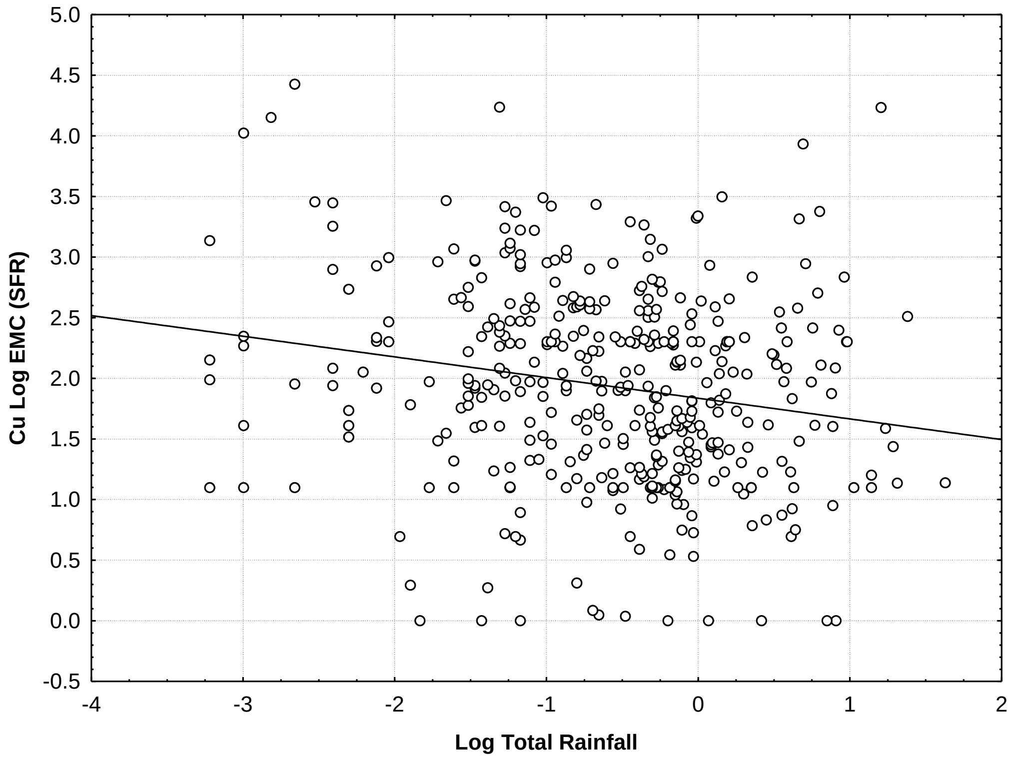
Graph E12. Scatterplot of Log of Total Rainfall vs. Log of EMC for COD Group UND



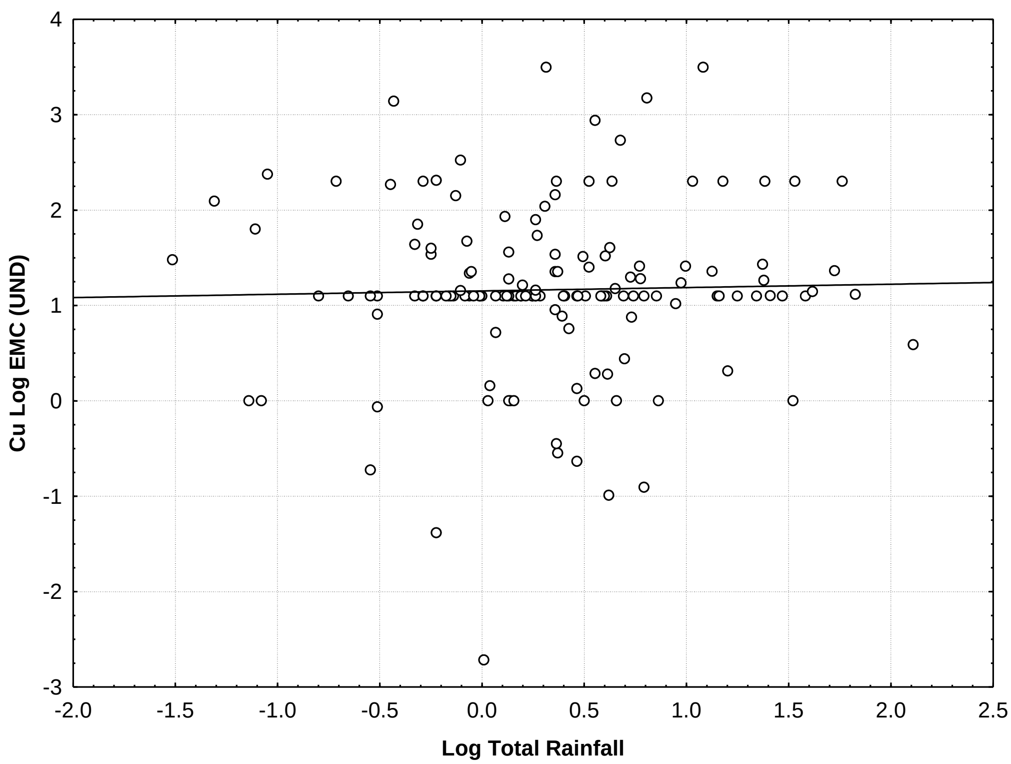
Graph E13. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cu Group IC1



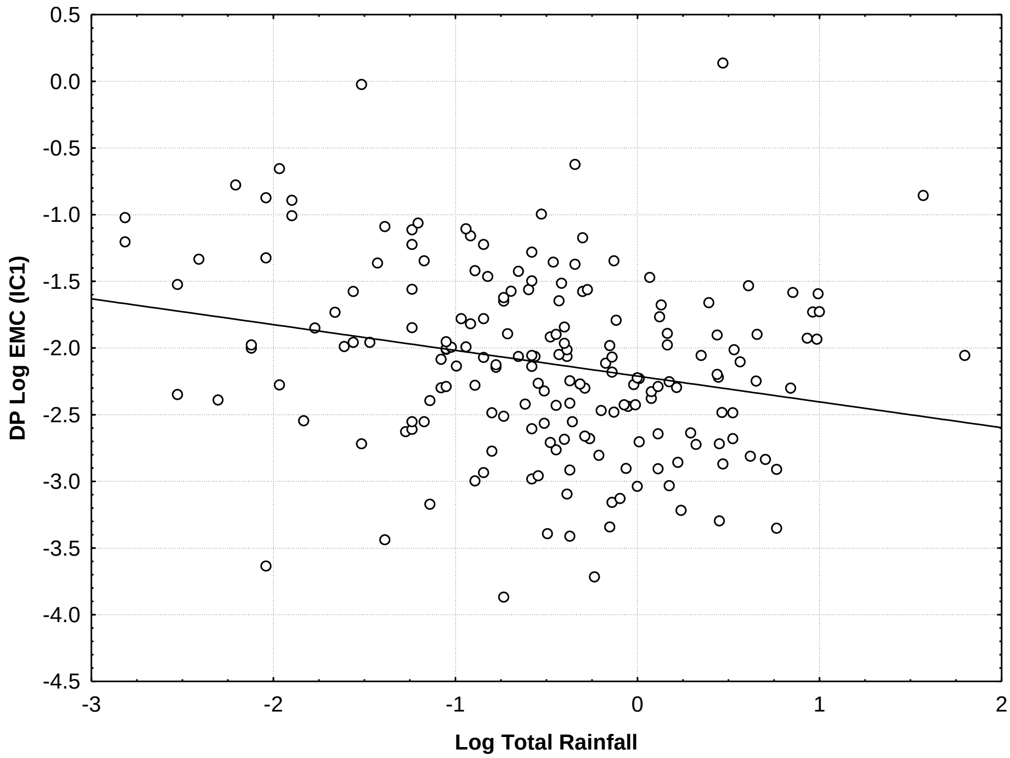
Graph E14. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cu Group IC2



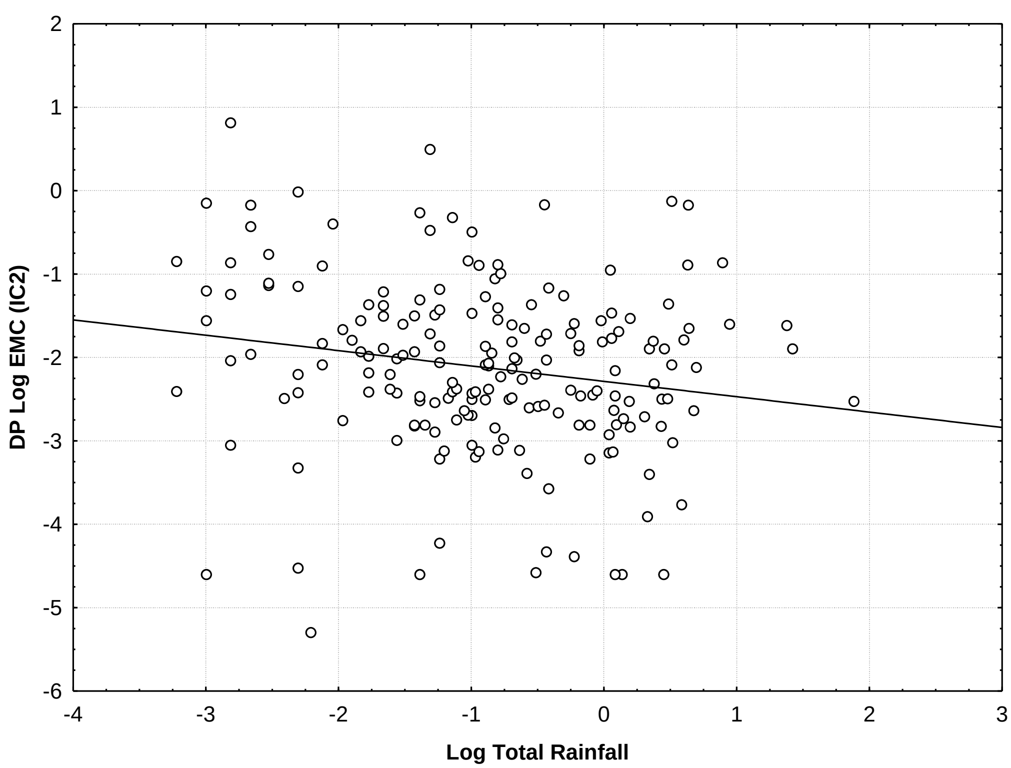
Graph E15. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cu Group SFR



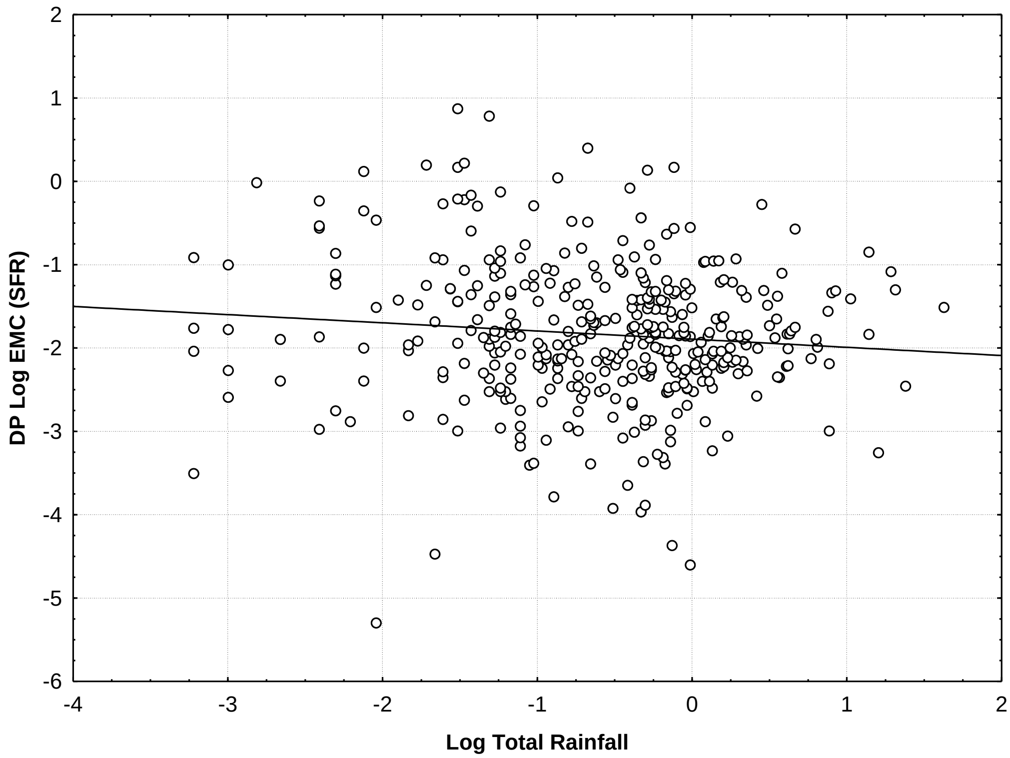
Graph E16. Scatterplot of Log of Total Rainfall vs. Log of EMC for Cu Group UND



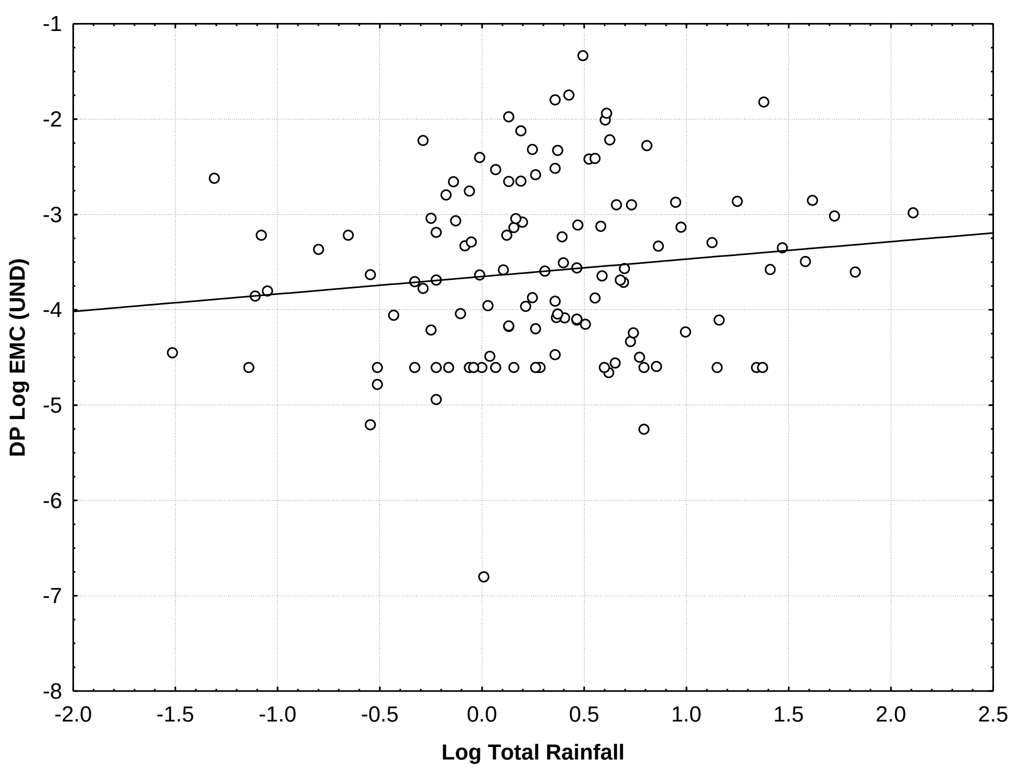
Graph E17. Scatterplot of Log of Total Rainfall vs. Log of EMC for DP Group IC1



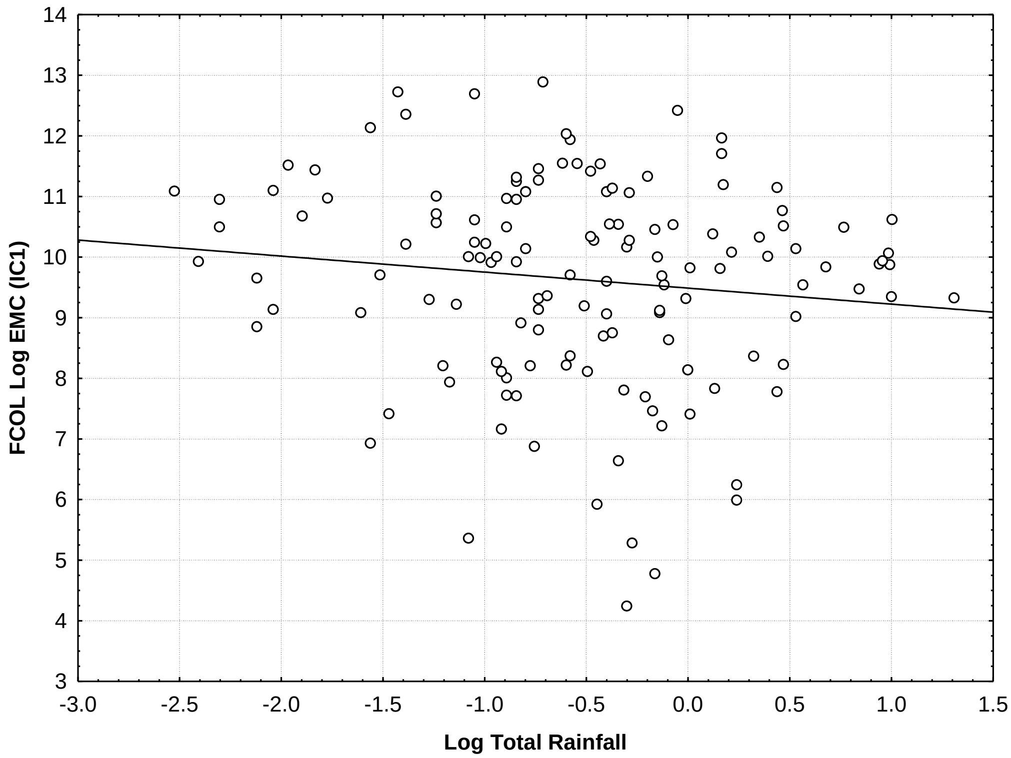
Graph E18. Scatterplot of Log of Total Rainfall vs. Log of EMC for DP Group IC2



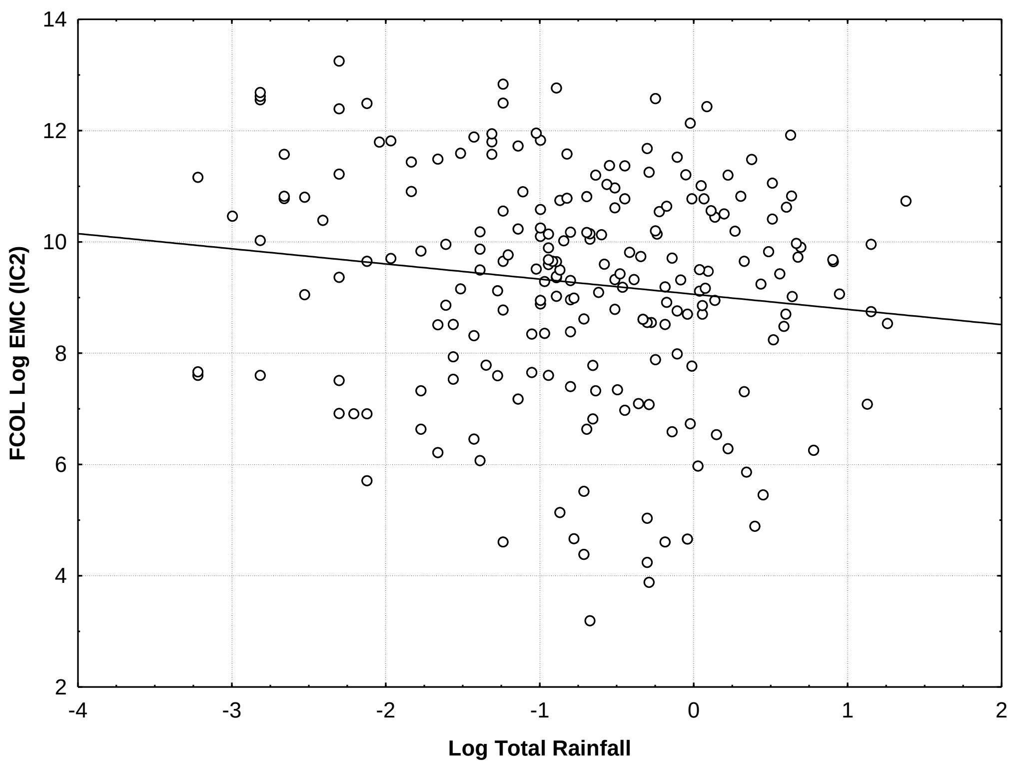
Graph E19. Scatterplot of Log of Total Rainfall vs. Log of EMC for DP Group SFR



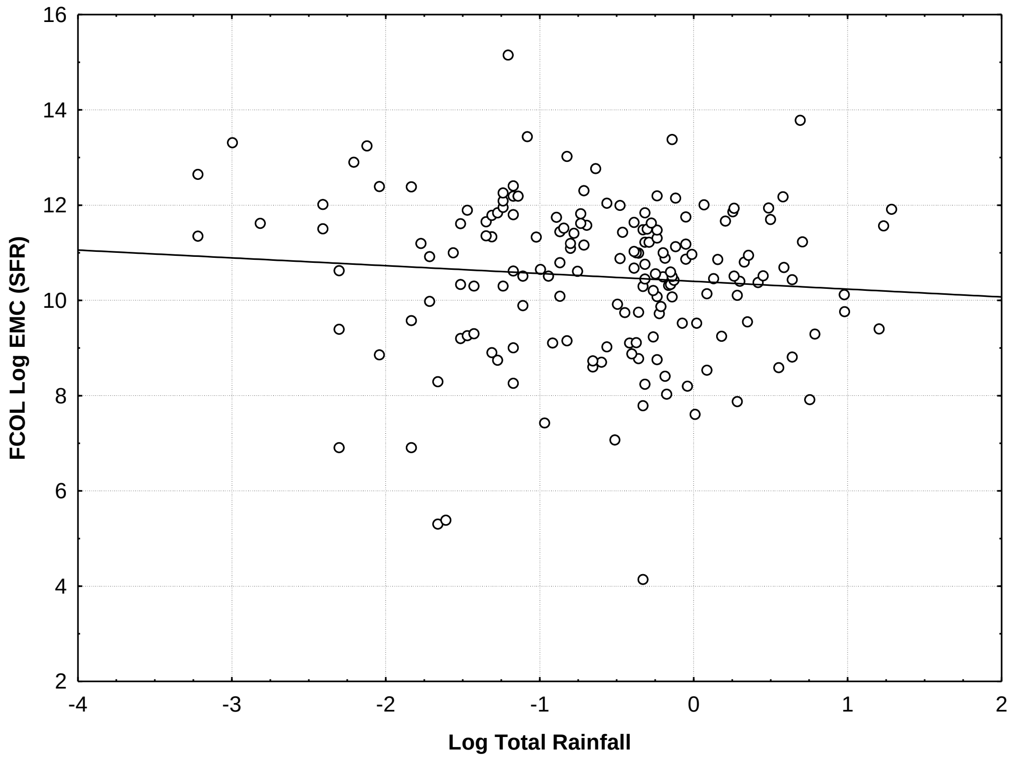
Graph E20. Scatterplot of Log of Total Rainfall vs. Log of EMC for DP Group UND



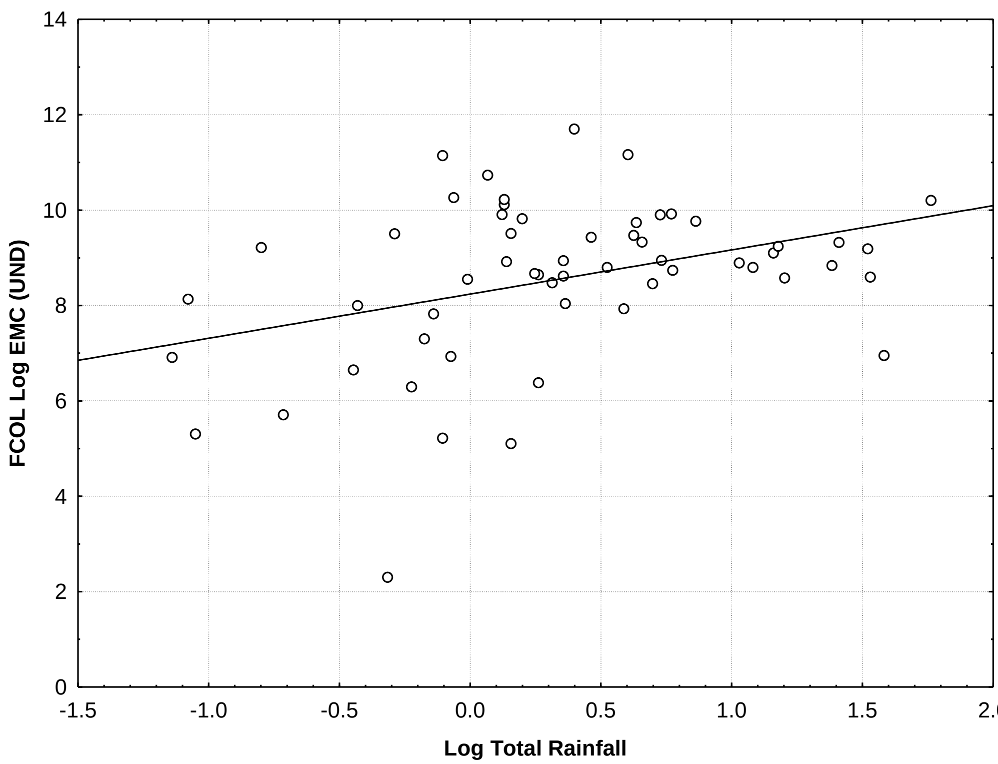
Graph E21. Scatterplot of Log of Total Rainfall vs. Log of EMC for FCOL Group IC1



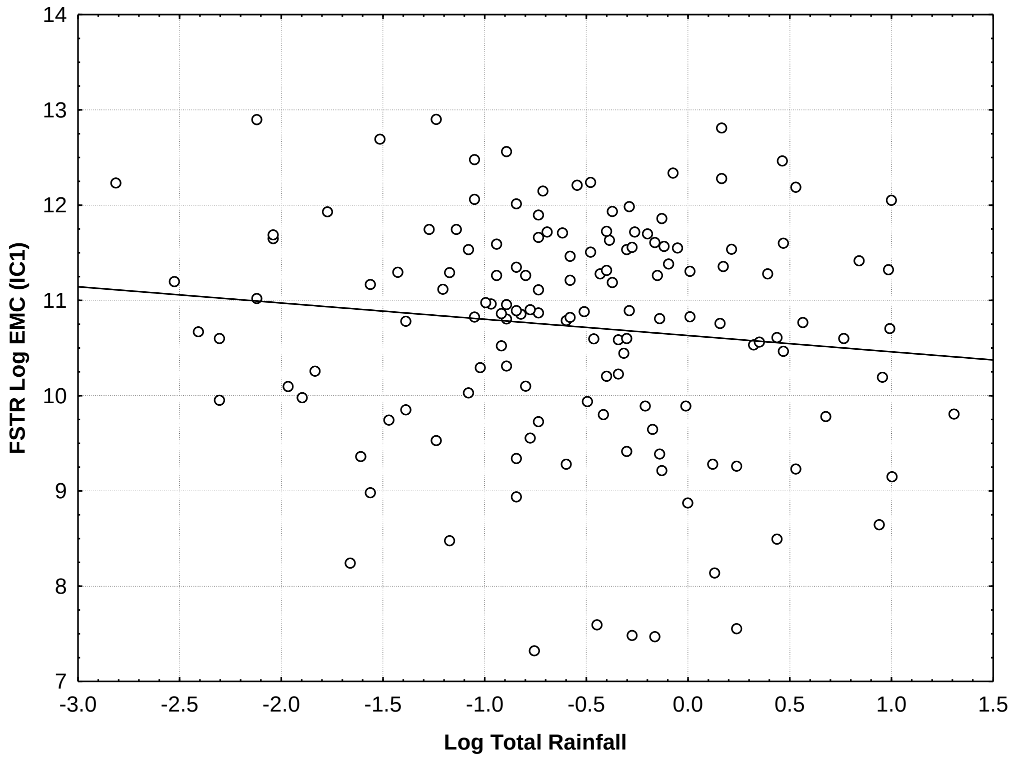
Graph E22. Scatterplot of Log of Total Rainfall vs. Log of EMC for FCOL Group IC2



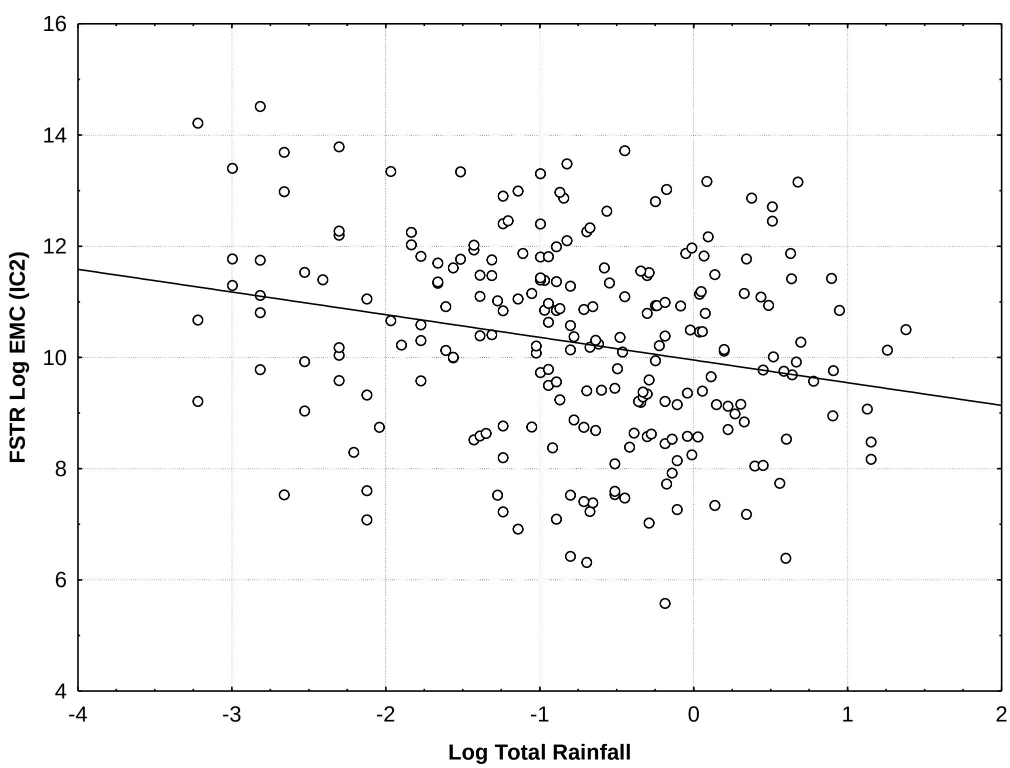
Graph E23. Scatterplot of Log of Total Rainfall vs. Log of EMC for FCOL Group SFR



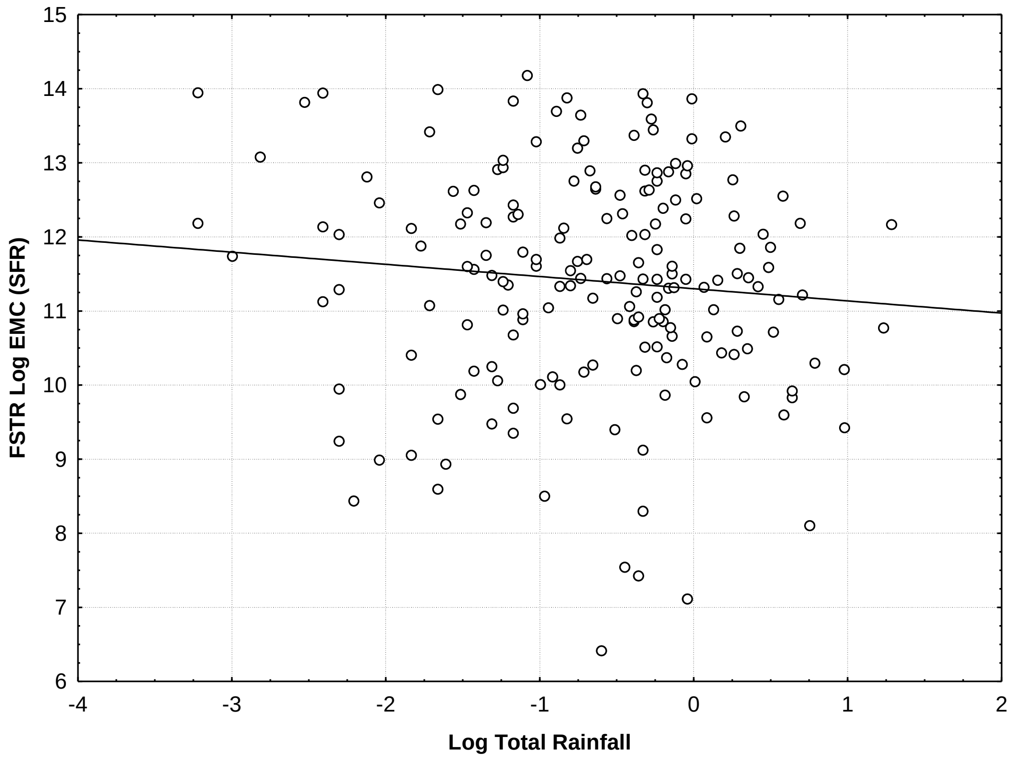
Graph E24. Scatterplot of Log of Total Rainfall vs. Log of EMC for FCOL Group UND



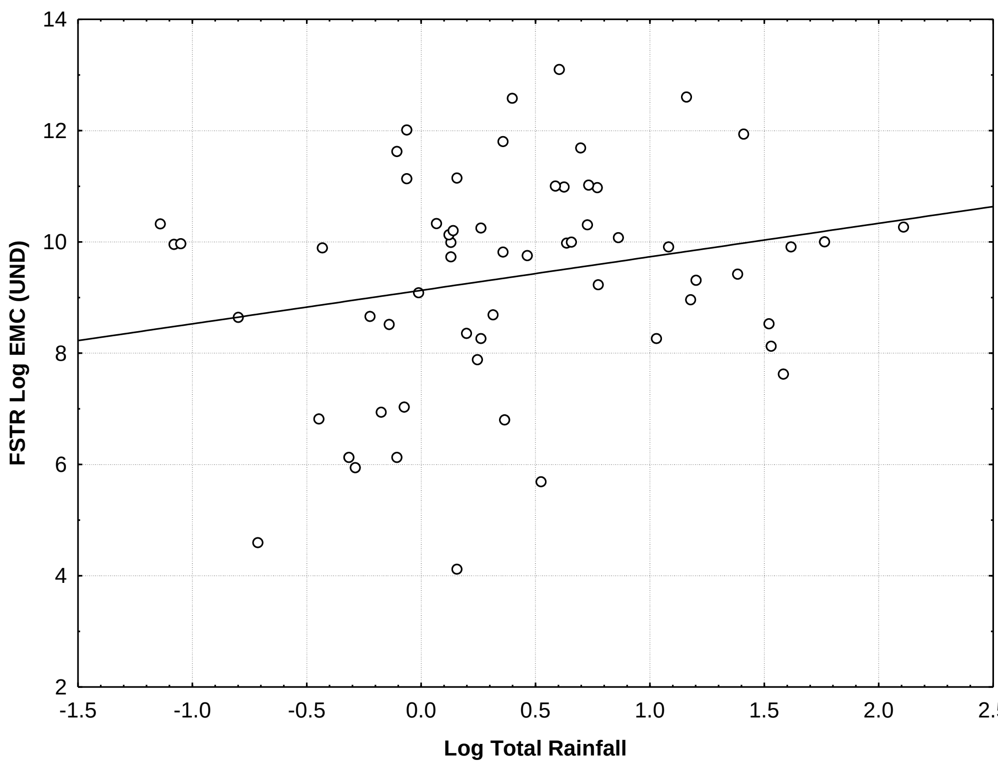
Graph E25. Scatterplot of Log of Total Rainfall vs. Log of EMC for FSTR Group IC1



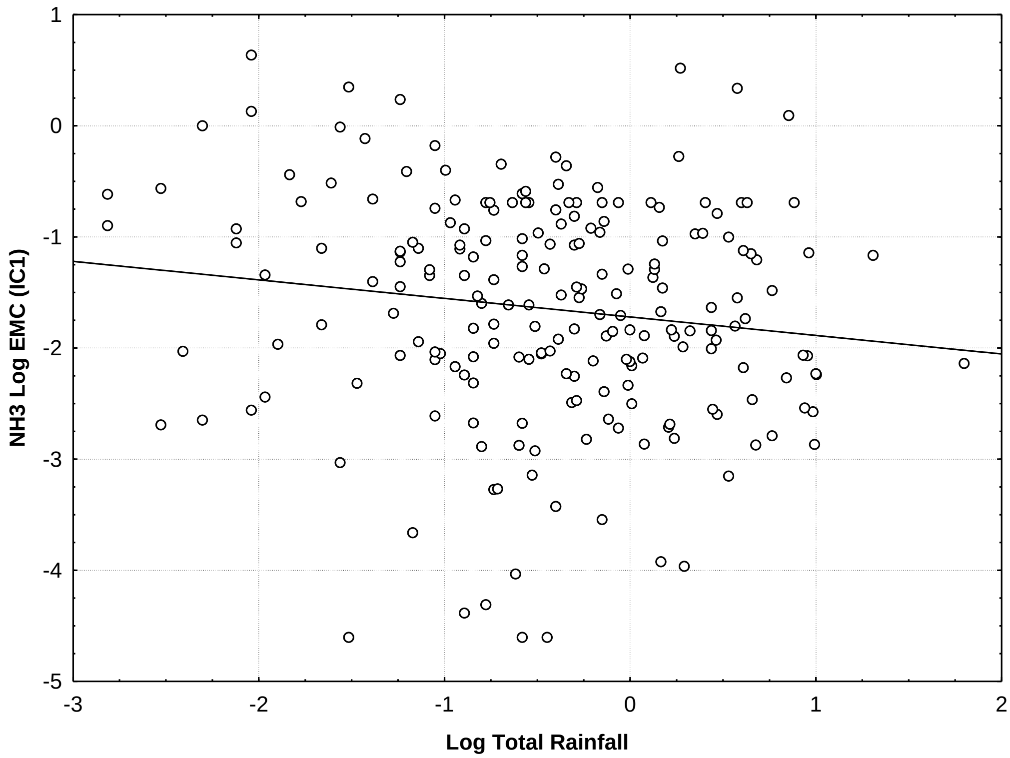
Graph E26. Scatterplot of Log of Total Rainfall vs. Log of EMC for FSTR Group IC2



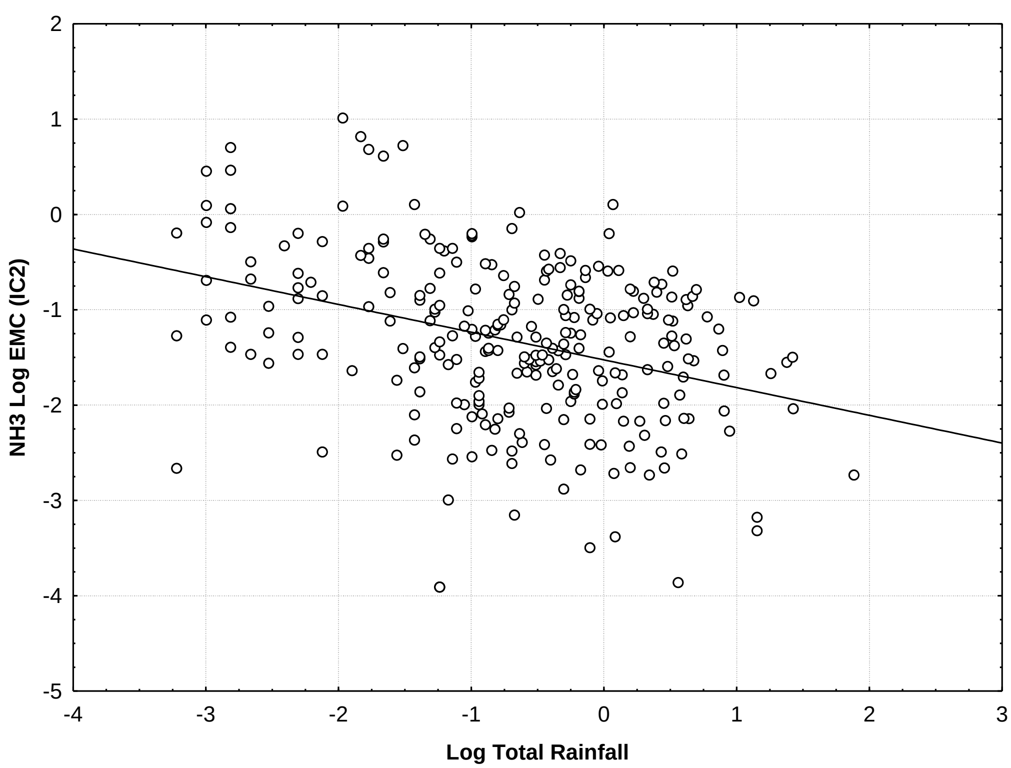
Graph E27. Scatterplot of Log of Total Rainfall vs. Log of EMC for FSTR Group SFR



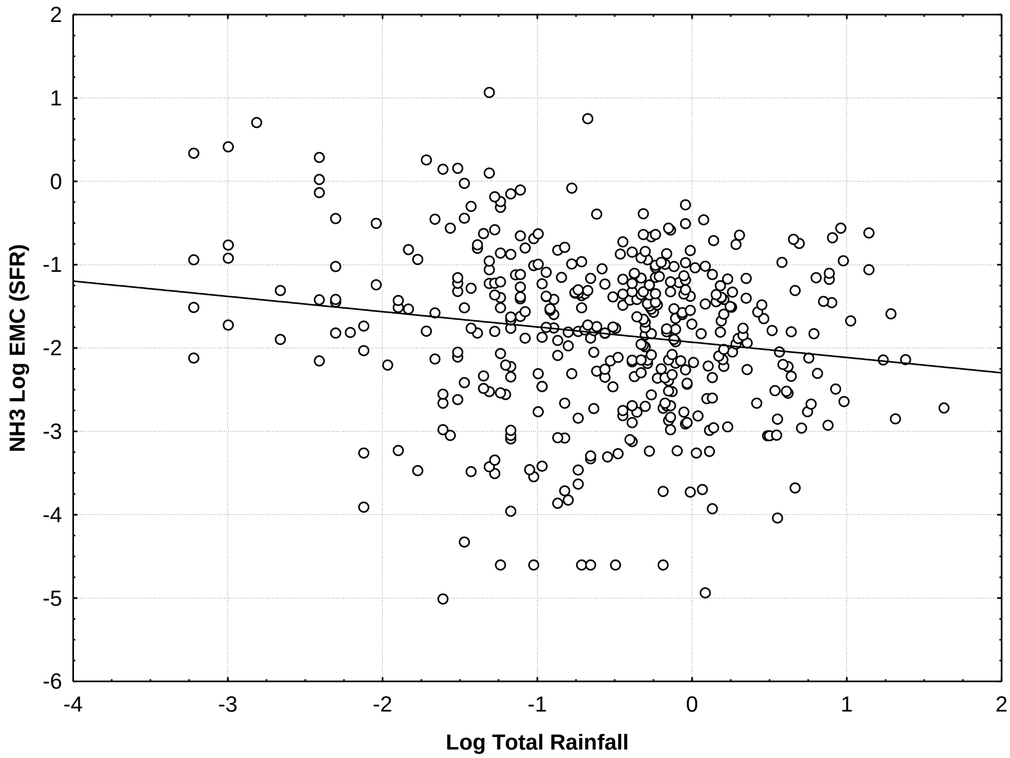
Graph E28. Scatterplot of Log of Total Rainfall vs. Log of EMC for FSTR Group UND



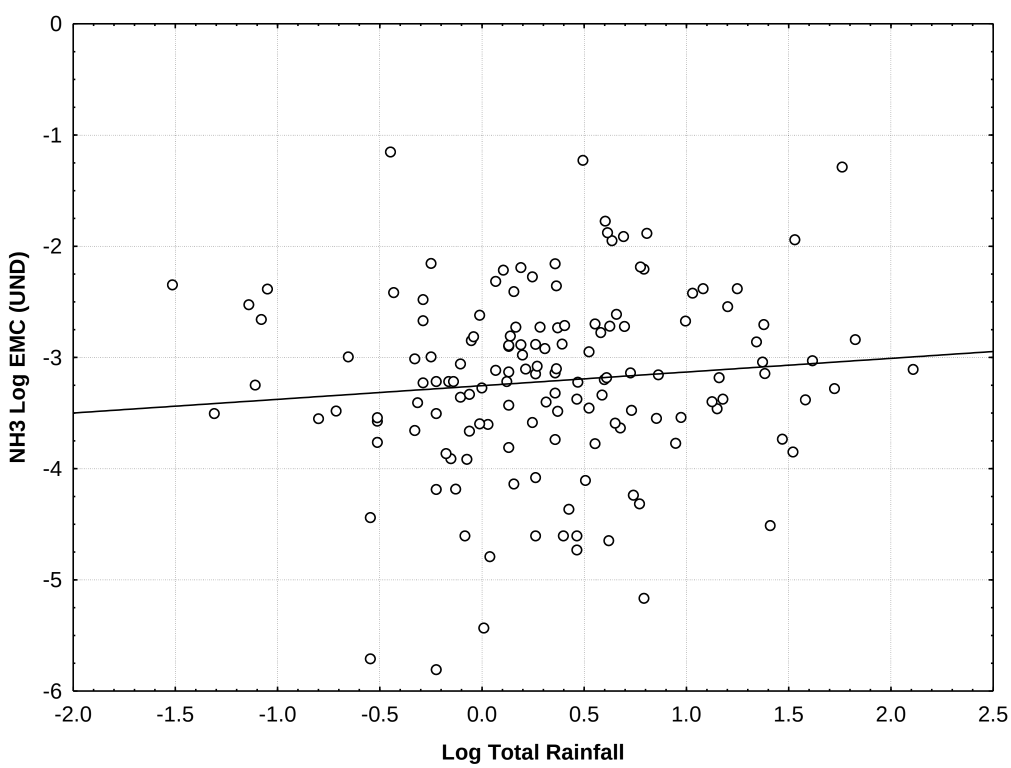
Graph E29. Scatterplot of Log of Total Rainfall vs. Log of EMC for NH3 Group IC1



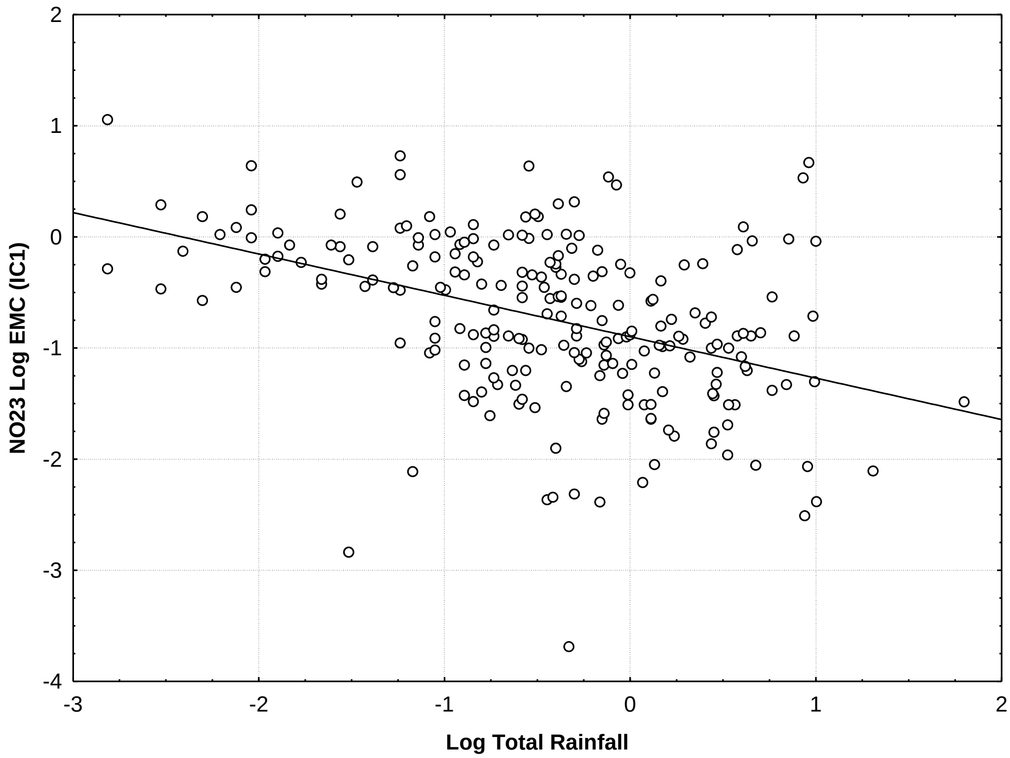
Graph E30. Scatterplot of Log of Total Rainfall vs. Log of EMC for NH3 Group IC2



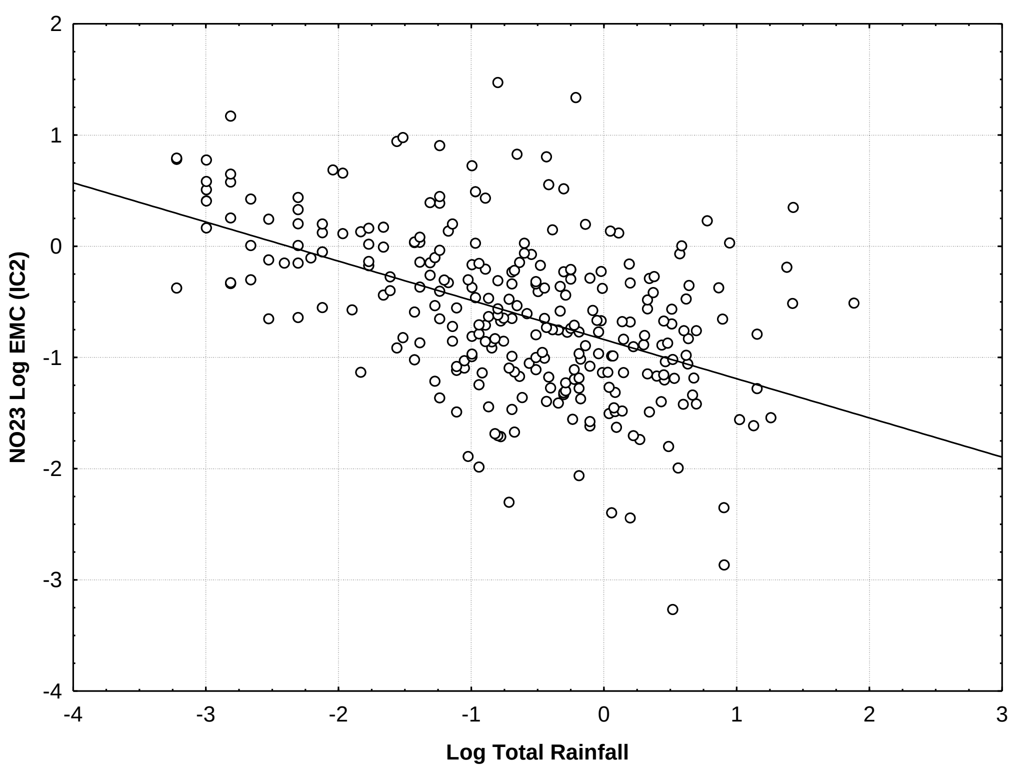
Graph E31. Scatterplot of Log of Total Rainfall vs. Log of EMC for NH3 Group SFR



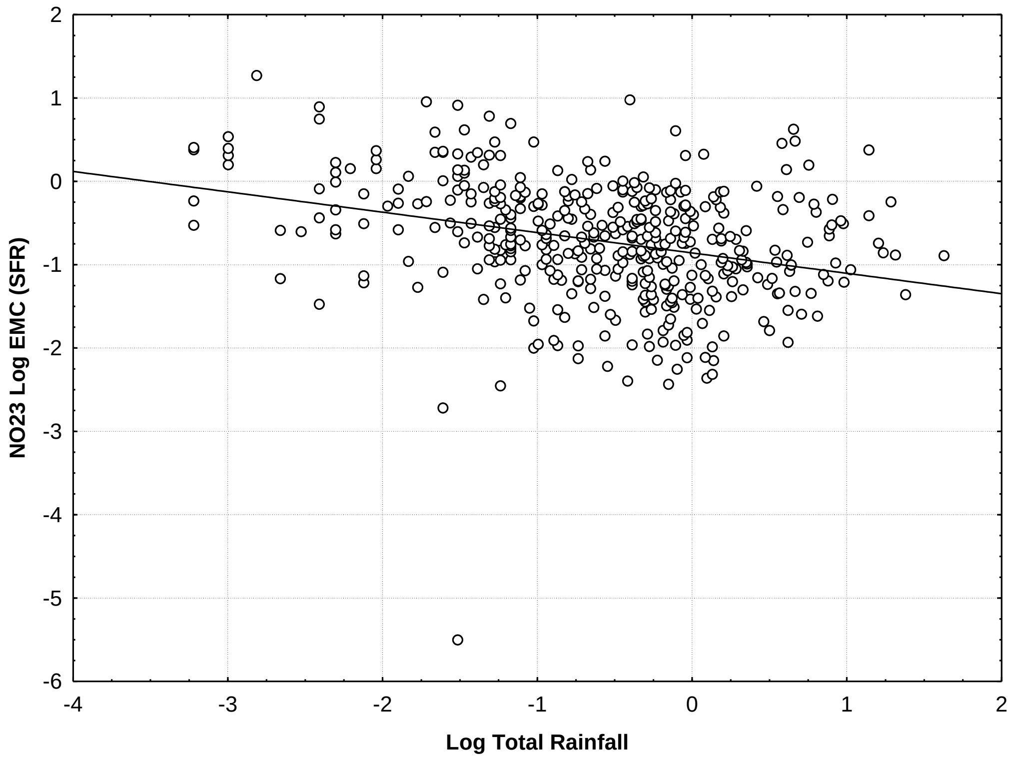
Graph E32. Scatterplot of Log of Total Rainfall vs. Log of EMC for NH3 Group UND



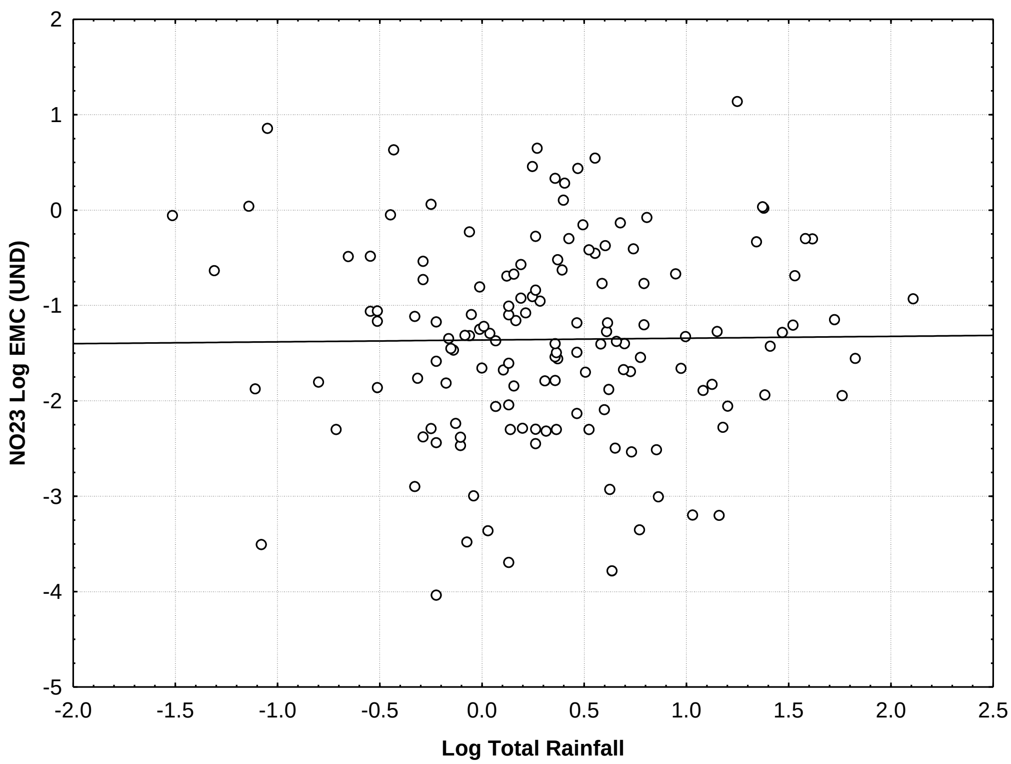
Graph E33. Scatterplot of Log of Total Rainfall vs. Log of EMC for NO23 Group IC1



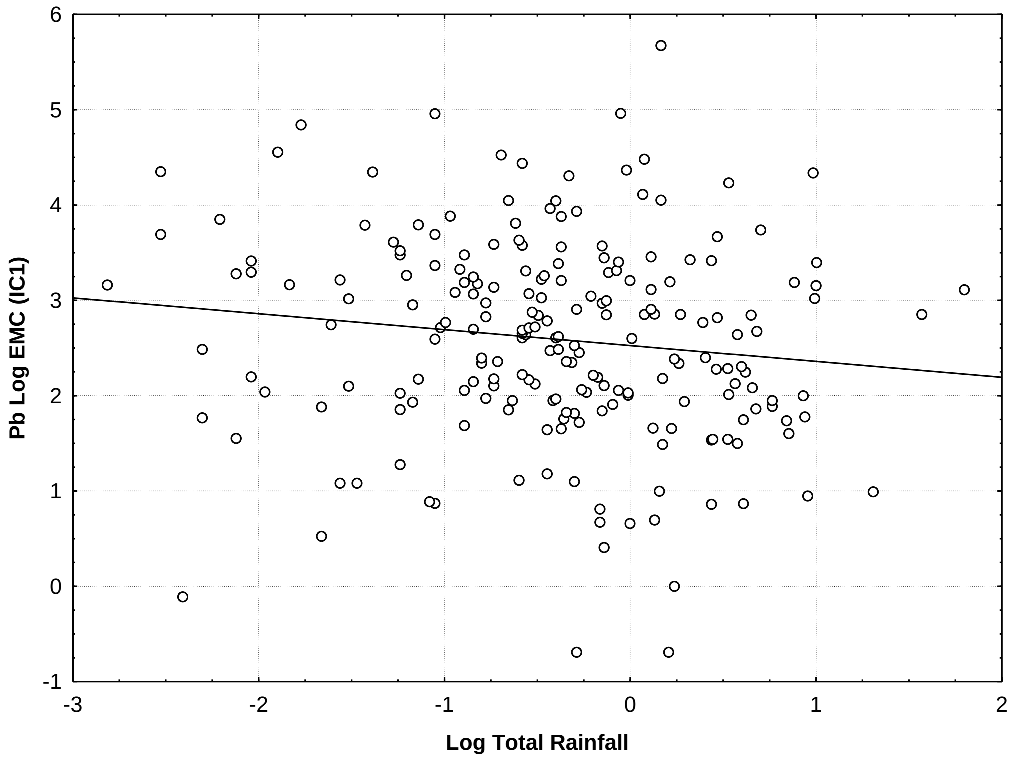
Graph E34. Scatterplot of Log of Total Rainfall vs. Log of EMC for NO23 Group IC2



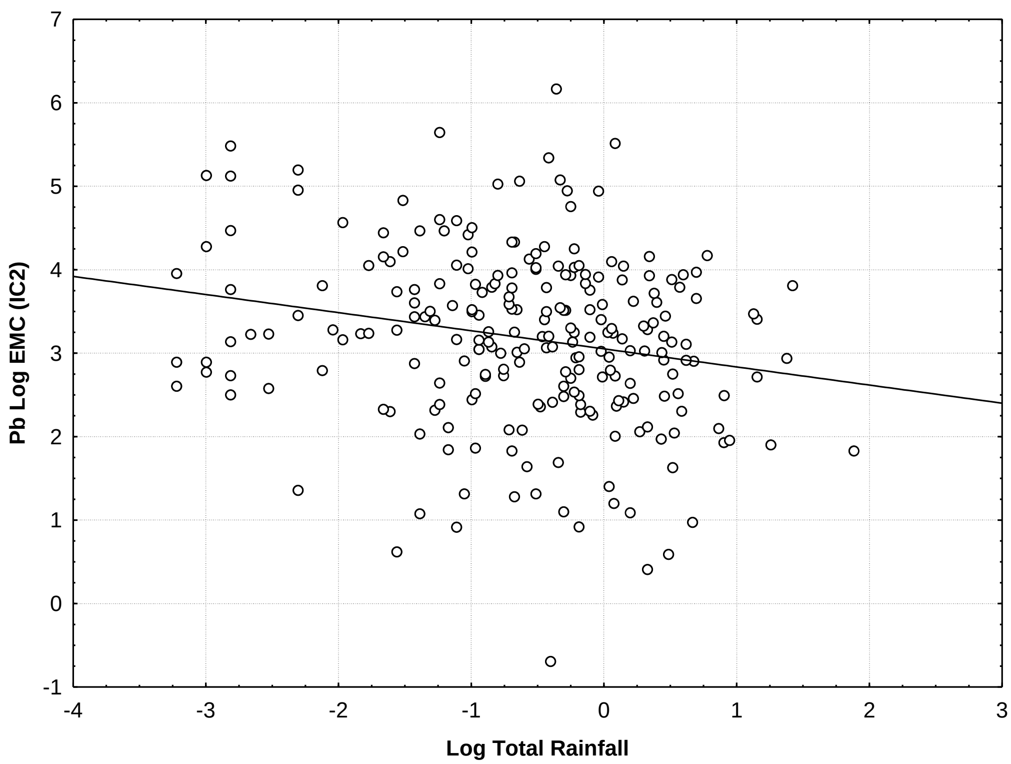
Graph E35. Scatterplot of Log of Total Rainfall vs. Log of EMC for NO23 Group SFR



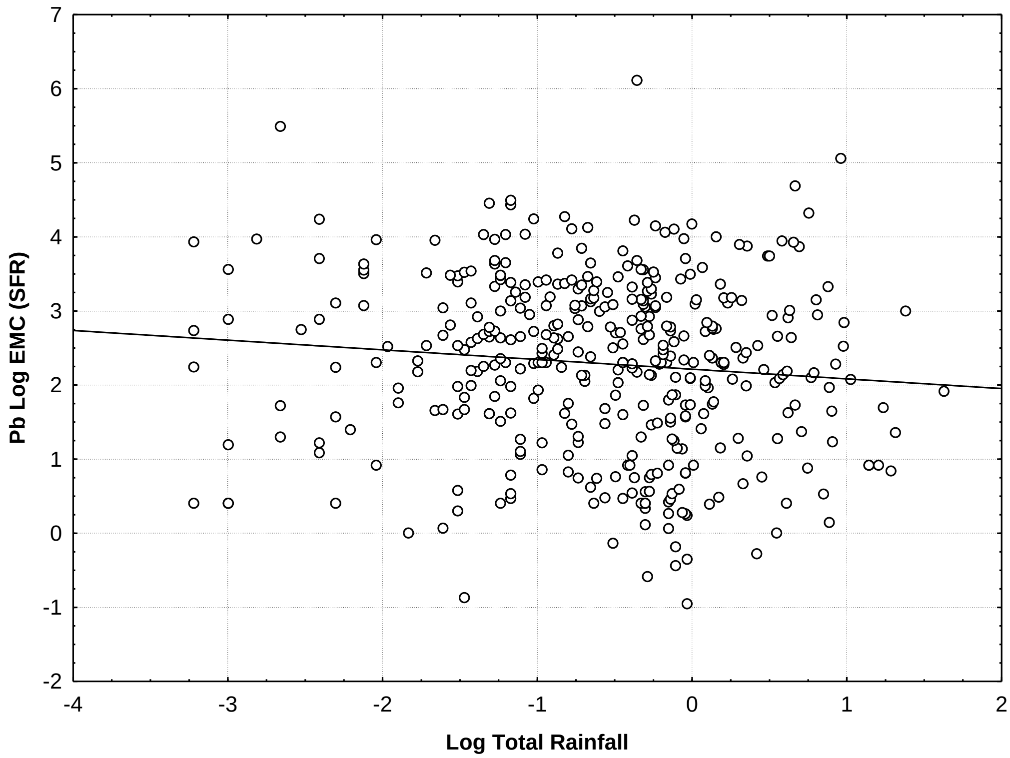
Graph E36. Scatterplot of Log of Total Rainfall vs. Log of EMC for NO23 Group UND



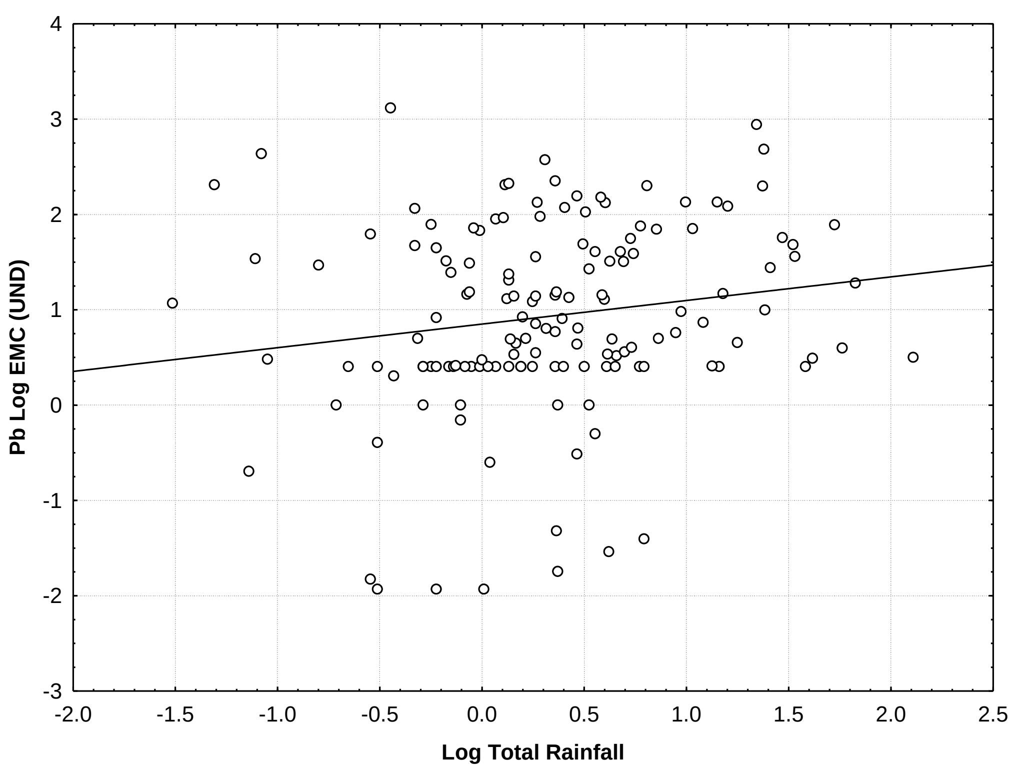
Graph E37. Scatterplot of Log of Total Rainfall vs. Log of EMC for Pb Group IC1



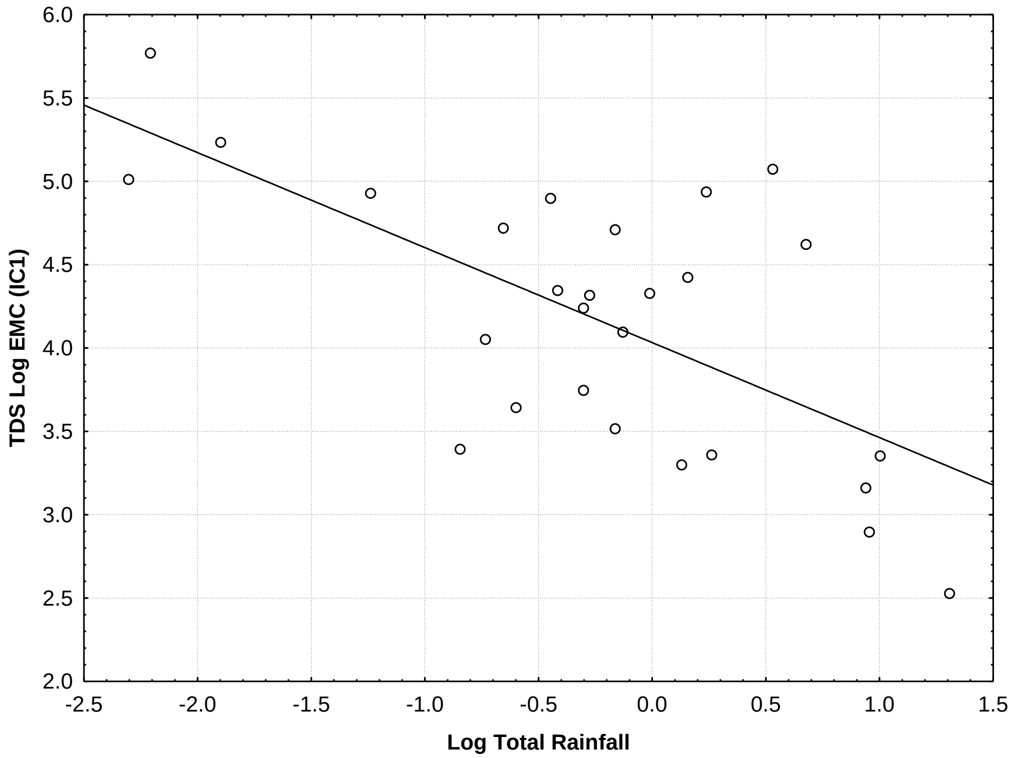
Graph E38. Scatterplot of Log of Total Rainfall vs. Log of EMC for Pb Group IC2



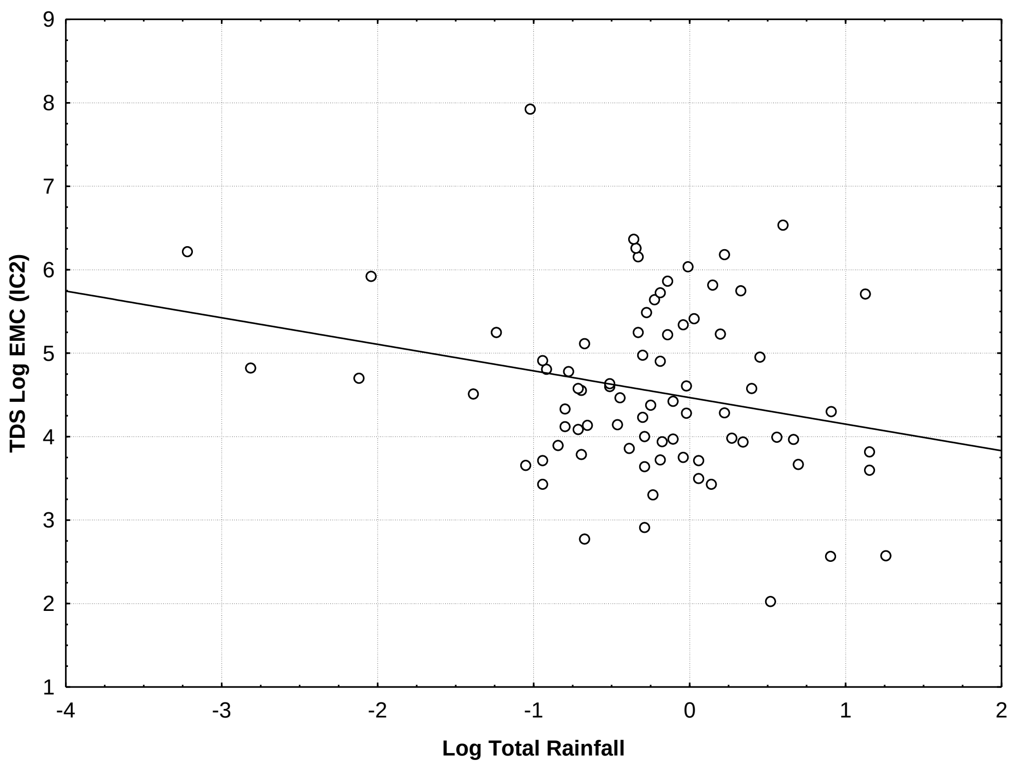
Graph E39. Scatterplot of Log of Total Rainfall vs. Log of EMC for Pb Group SFR



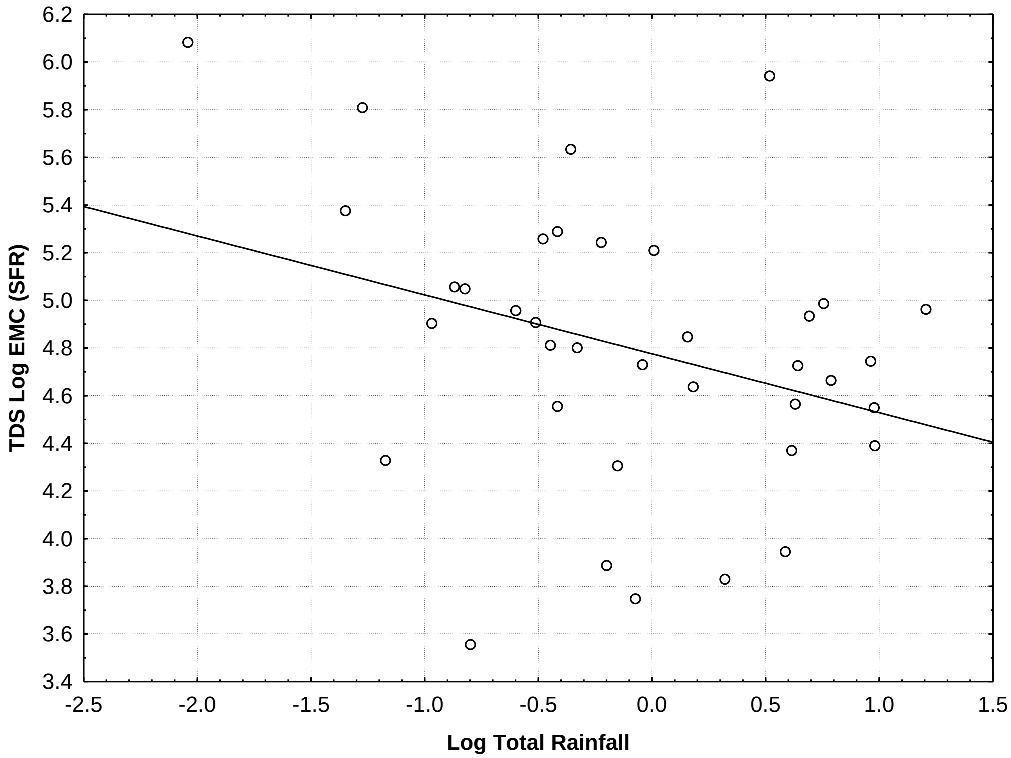
Graph E40. Scatterplot of Log of Total Rainfall vs. Log of EMC for Pb Group UND



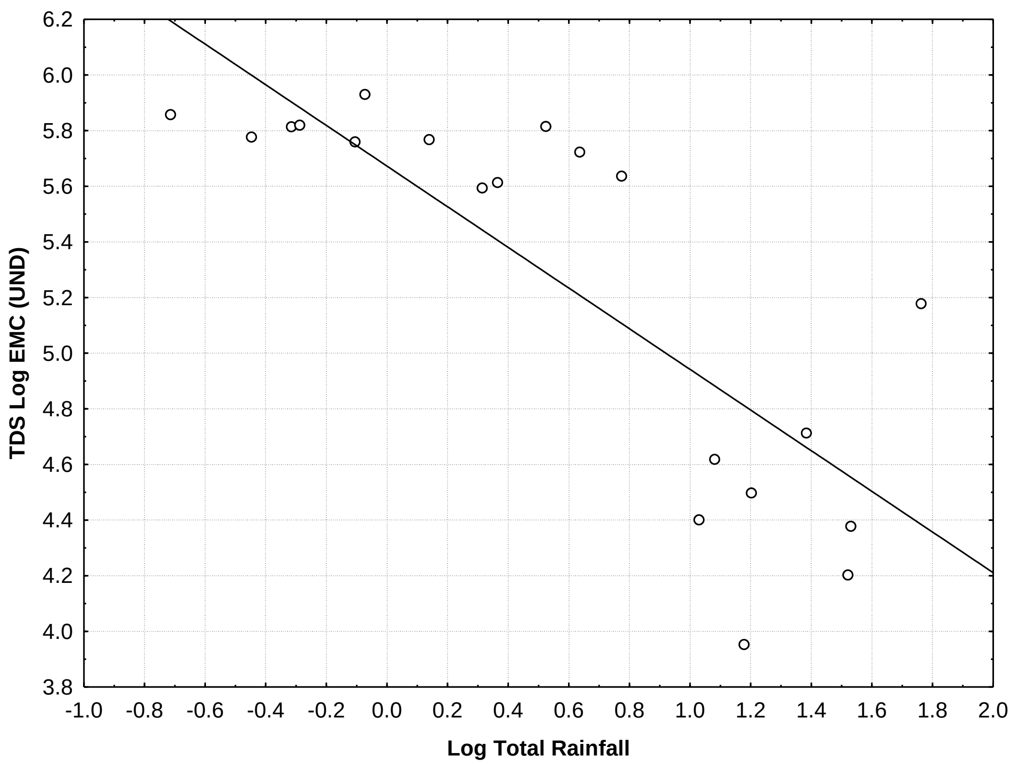
Graph E41. Scatterplot of Log of Total Rainfall vs. Log of EMC for TDS Group IC1



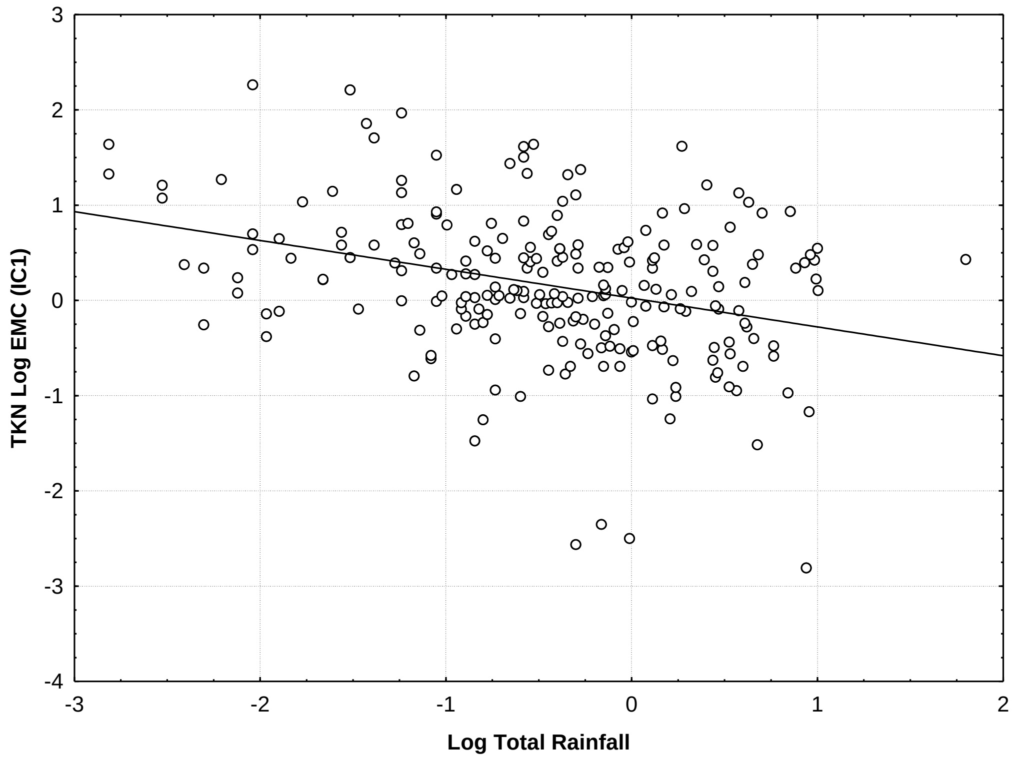
Graph E42. Scatterplot of Log of Total Rainfall vs. Log of EMC for TDS Group IC2



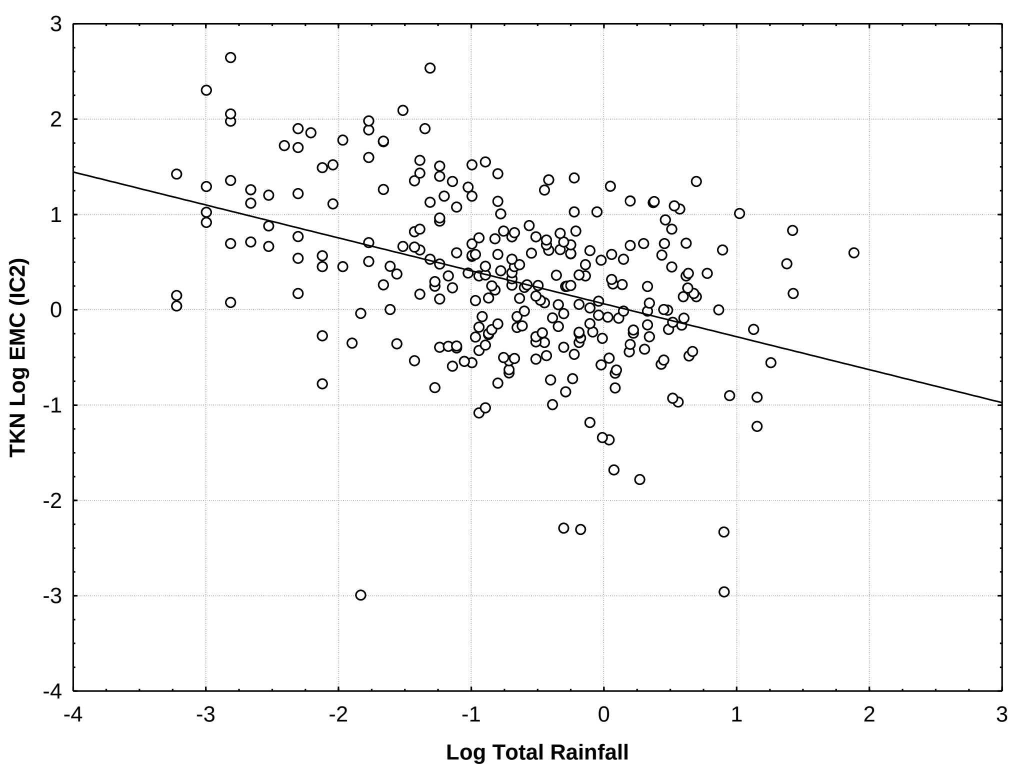
Graph E43. Scatterplot of Log of Total Rainfall vs. Log of EMC for TDS Group SFR



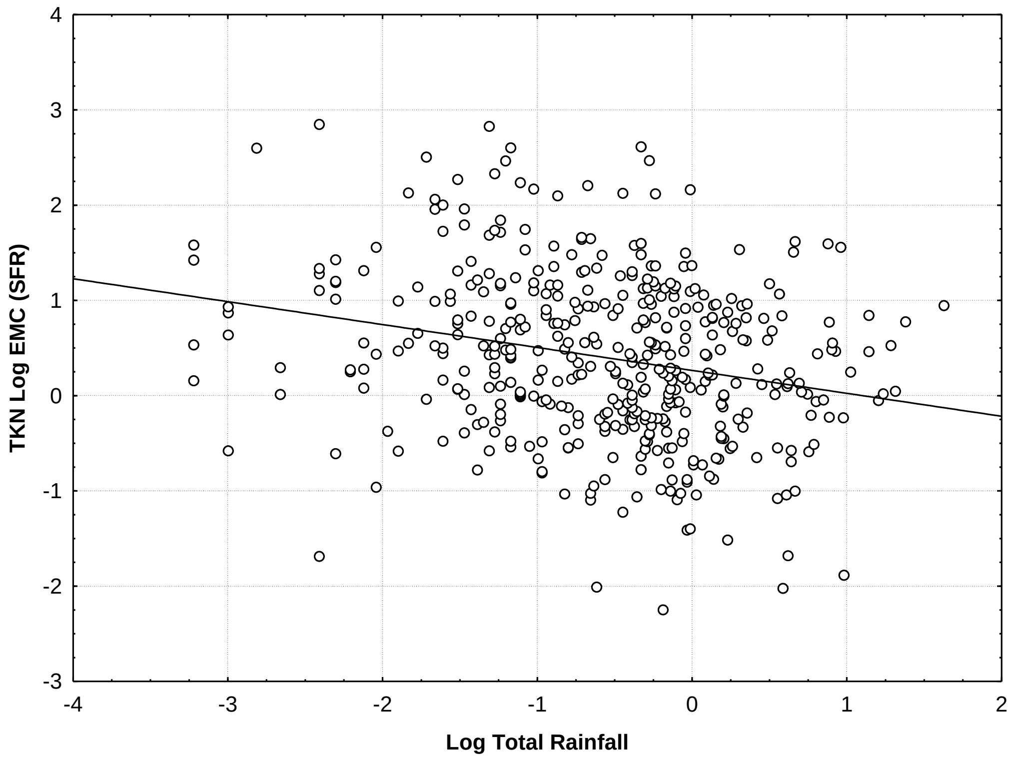
Graph E44. Scatterplot of Log of Total Rainfall vs. Log of EMC for TDS Group UND



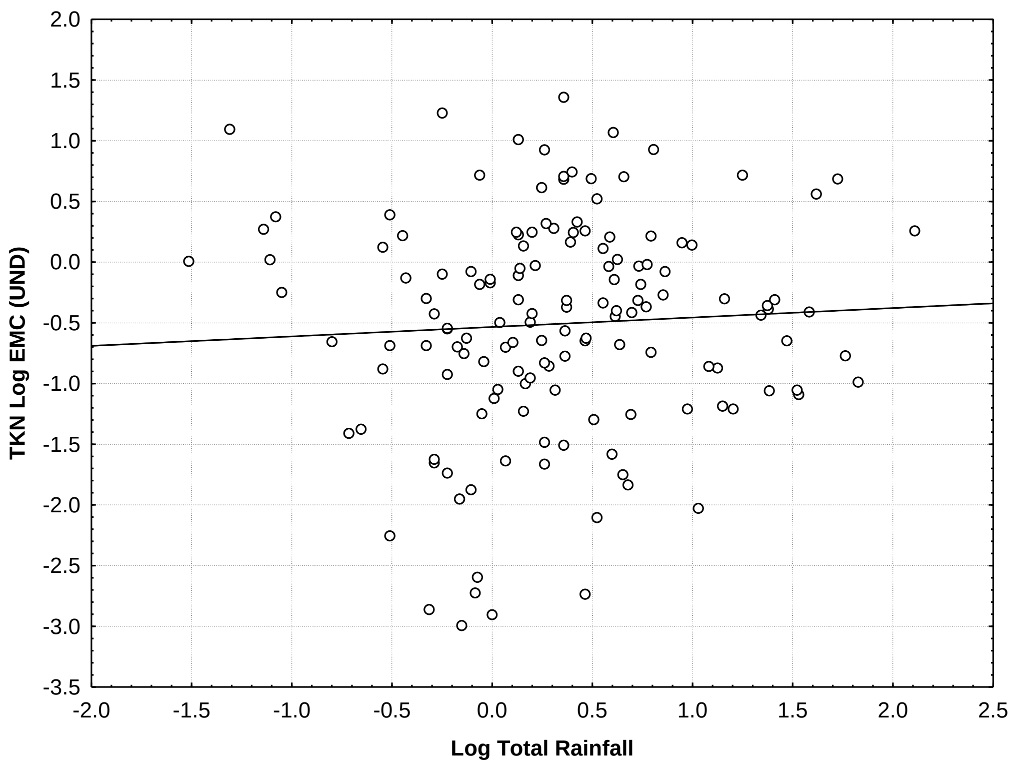
Graph E45. Scatterplot of Log of Total Rainfall vs. Log of EMC for TKN Group IC1



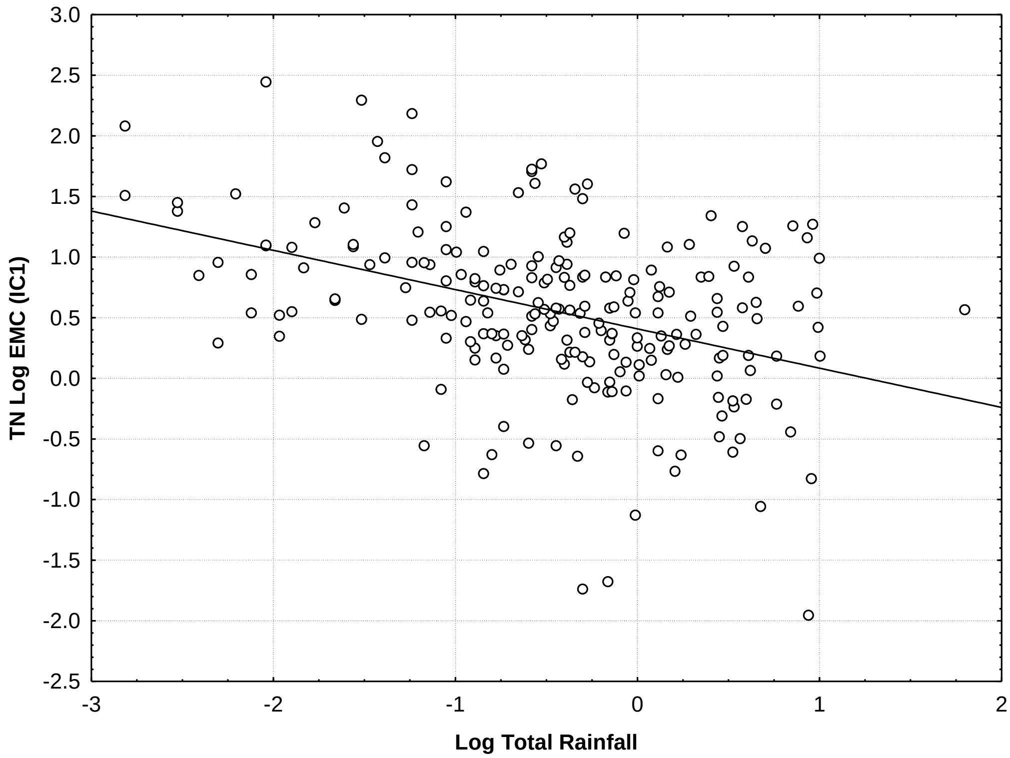
Graph E46. Scatterplot of Log of Total Rainfall vs. Log of EMC for TKN Group IC2



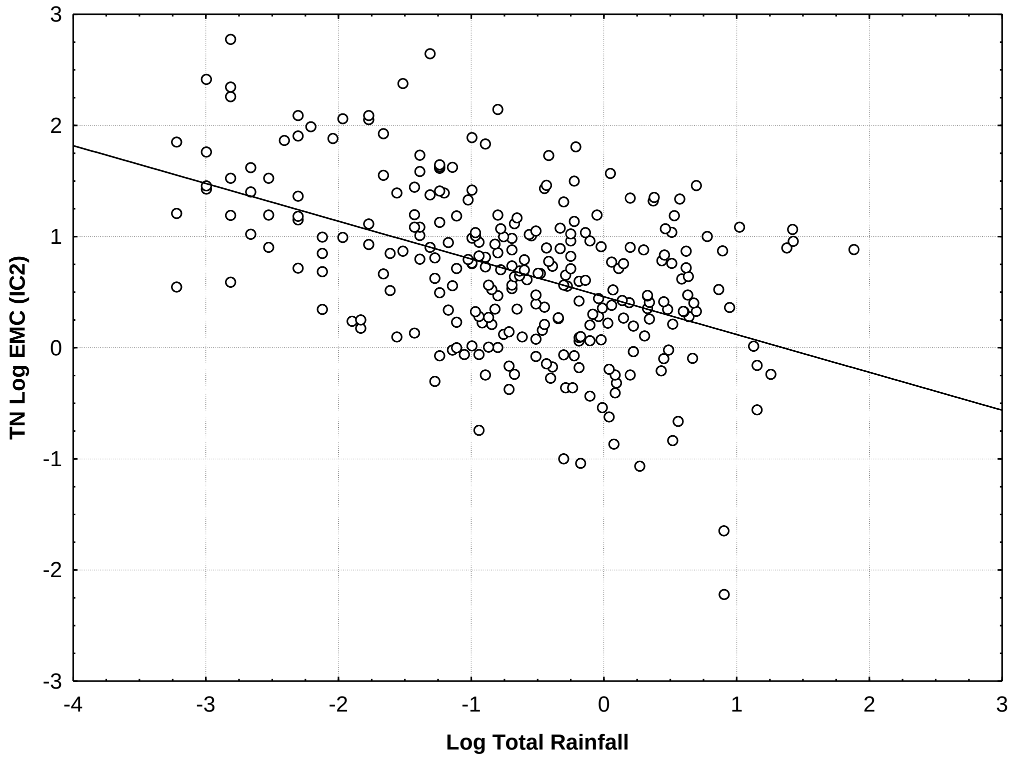
Graph E47. Scatterplot of Log of Total Rainfall vs. Log of EMC for TKN Group SFR



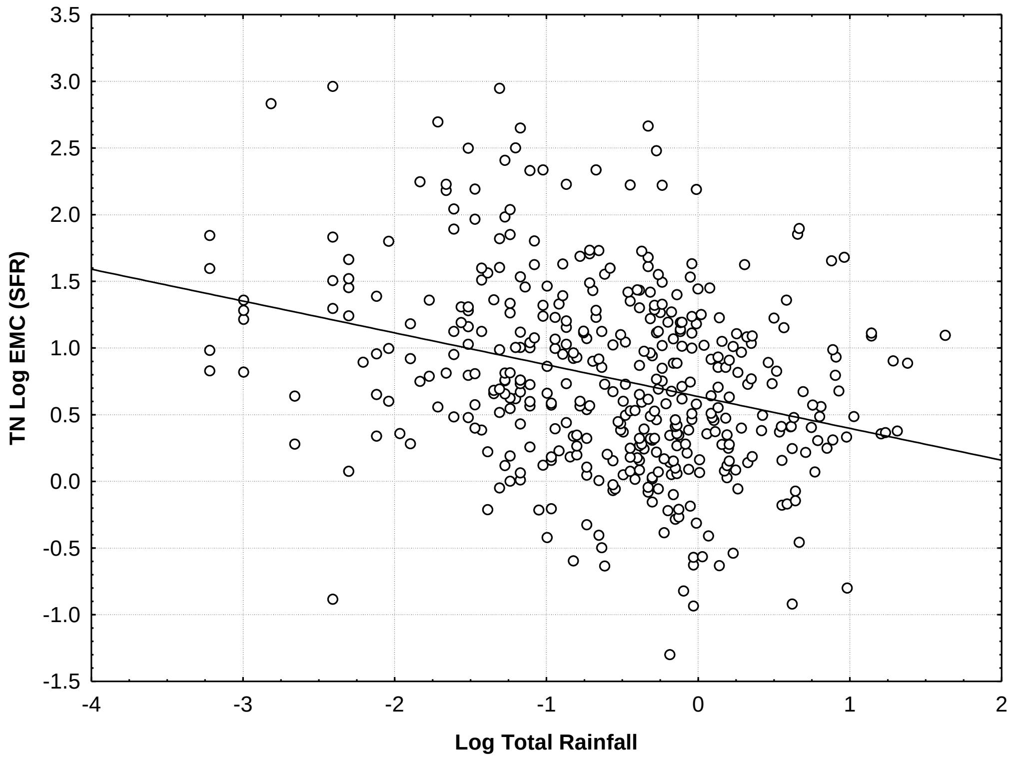
Graph E48. Scatterplot of Log of Total Rainfall vs. Log of EMC for TKN Group UND



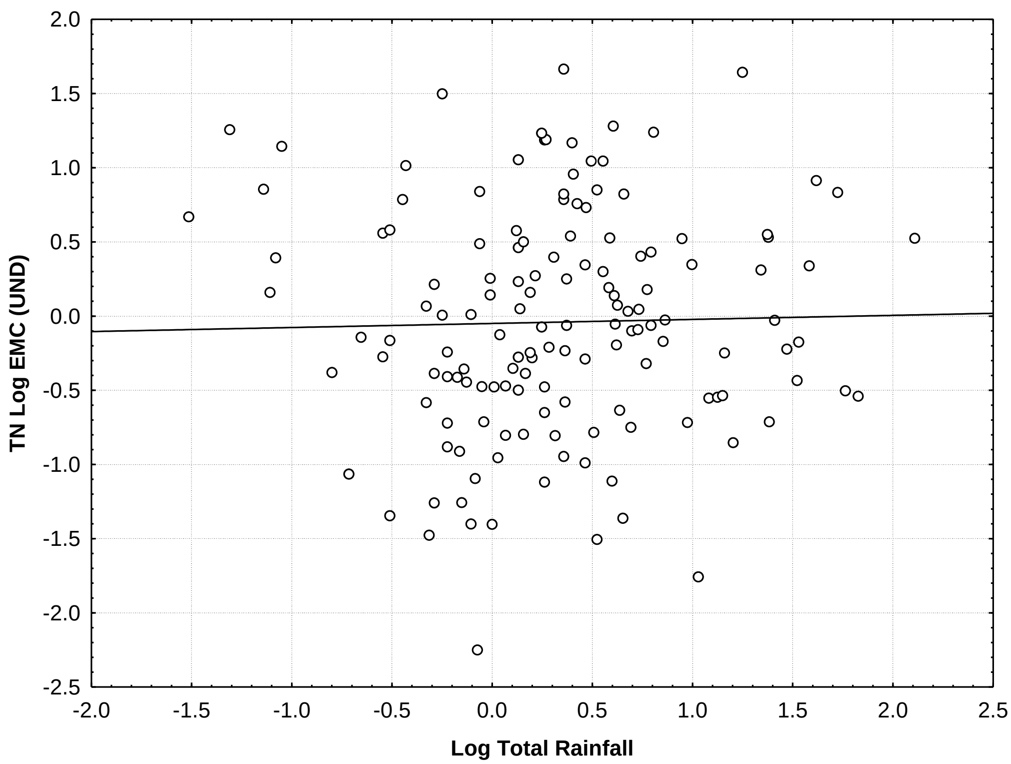
Graph E49. Scatterplot of Log of Total Rainfall vs. Log of EMC for TN Group IC1



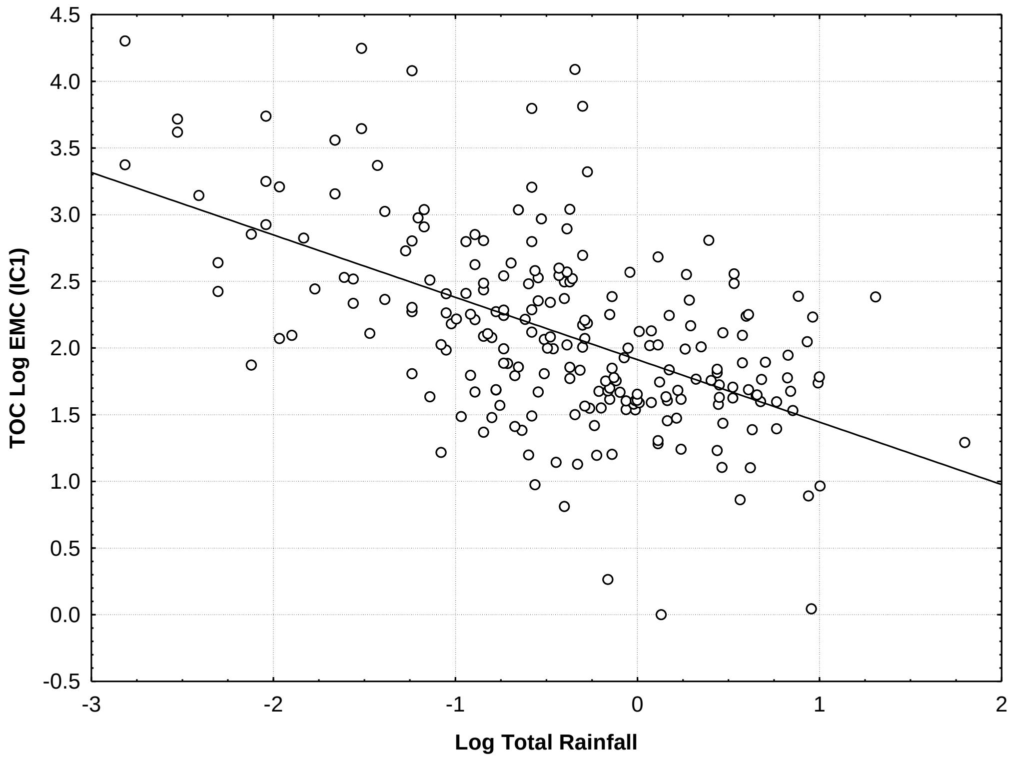
Graph E50. Scatterplot of Log of Total Rainfall vs. Log of EMC for TN Group IC2



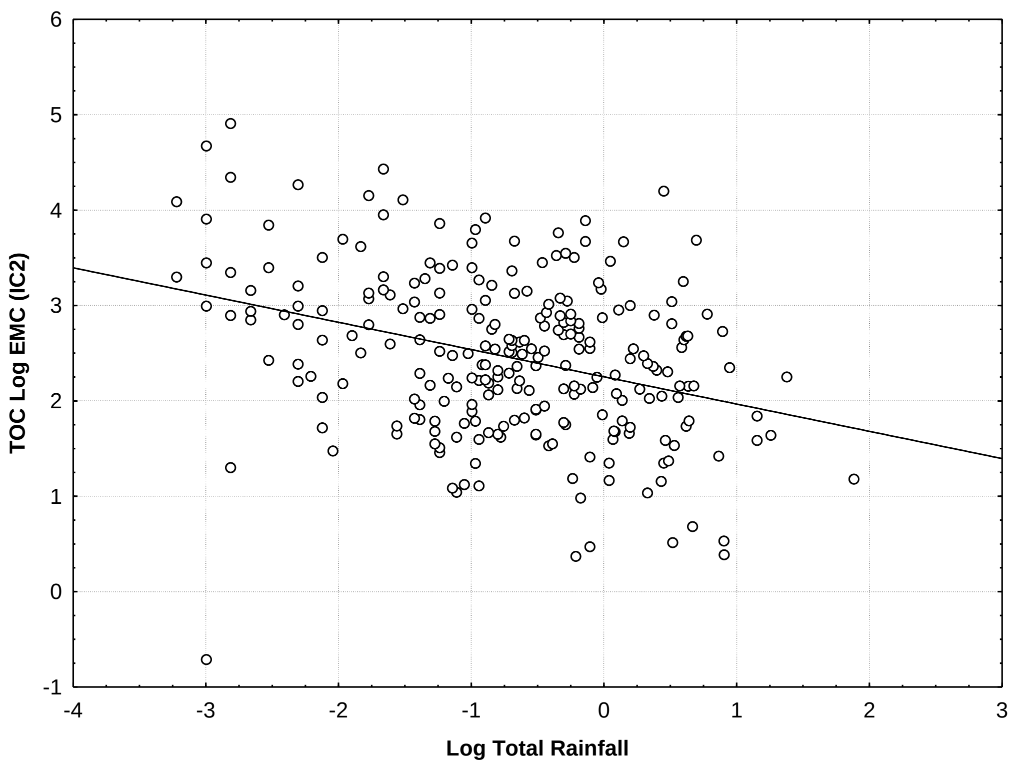
Graph E51. Scatterplot of Log of Total Rainfall vs. Log of EMC for TN Group SFR



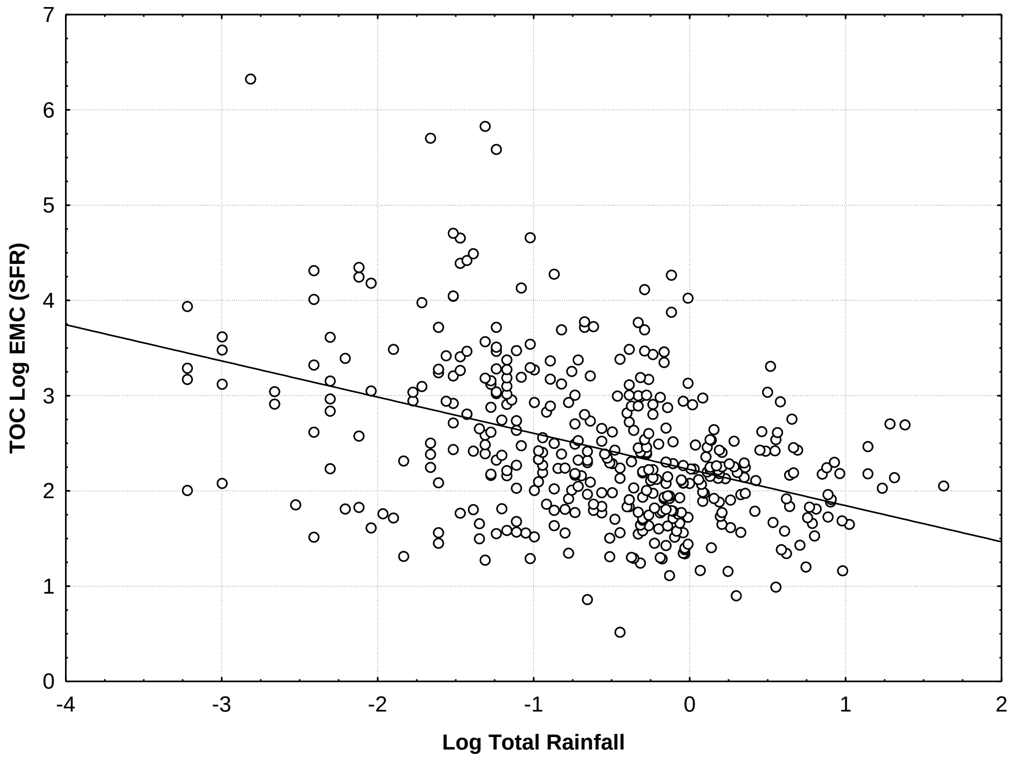
Graph E52. Scatterplot of Log of Total Rainfall vs. Log of EMC for TN Group UND



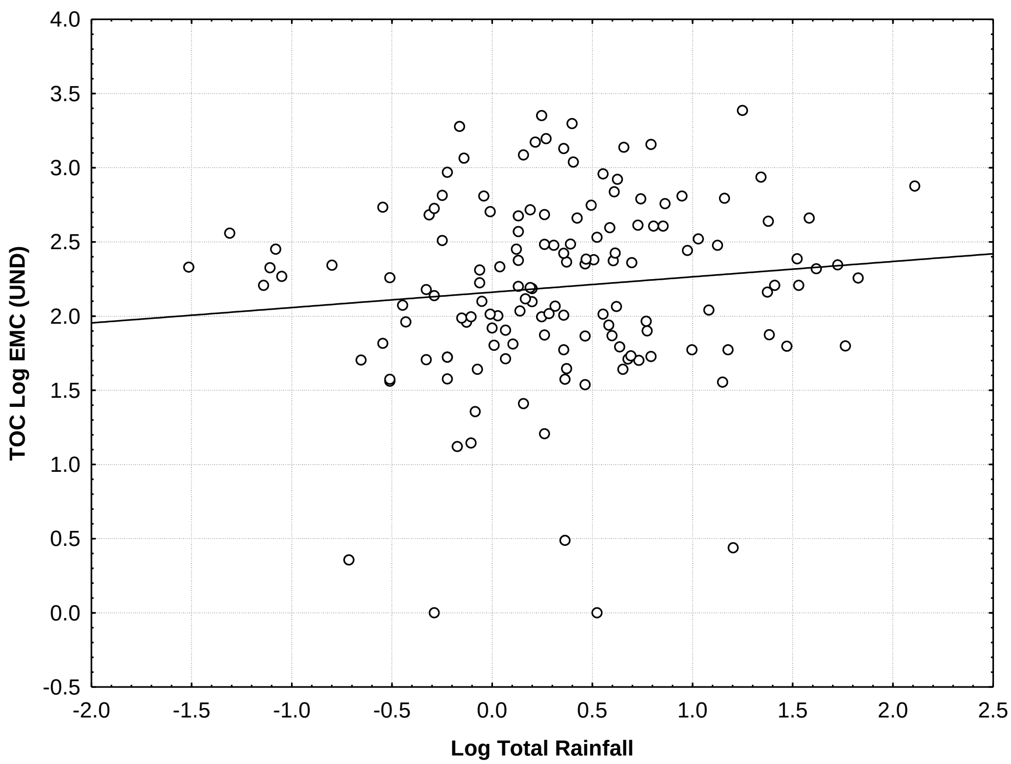
Graph E53. Scatterplot of Log of Total Rainfall vs. Log of EMC for TOC Group IC1



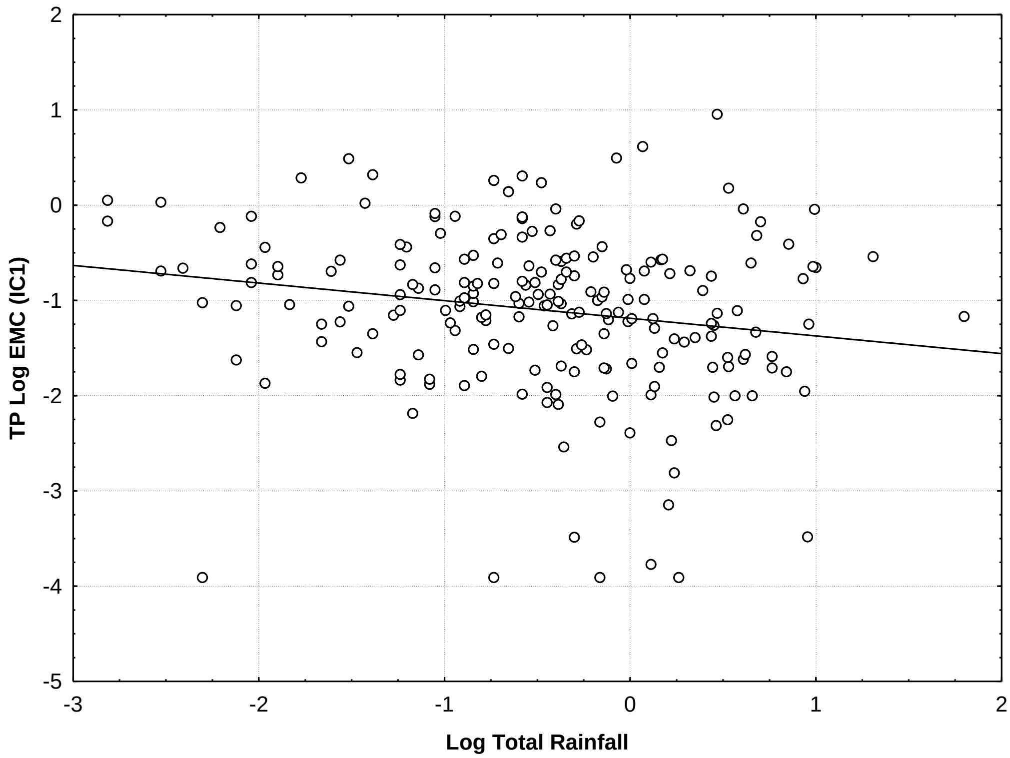
Graph E54. Scatterplot of Log of Total Rainfall vs. Log of EMC for TOC Group IC2



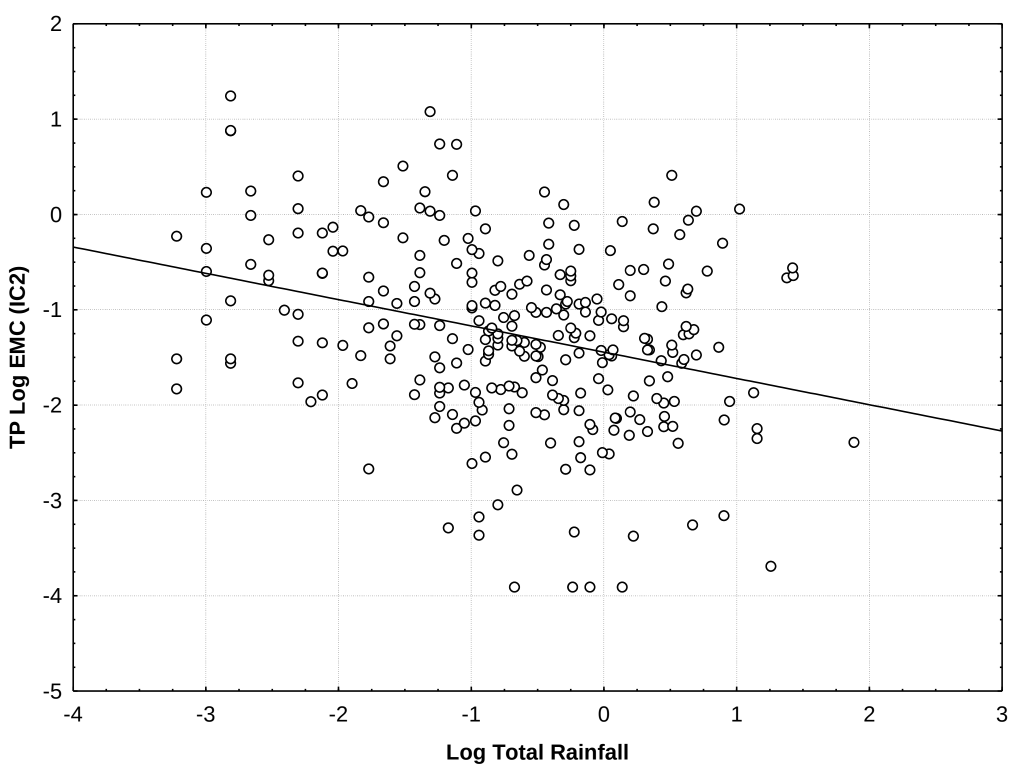
Graph E55. Scatterplot of Log of Total Rainfall vs. Log of EMC for TOC Group SFR



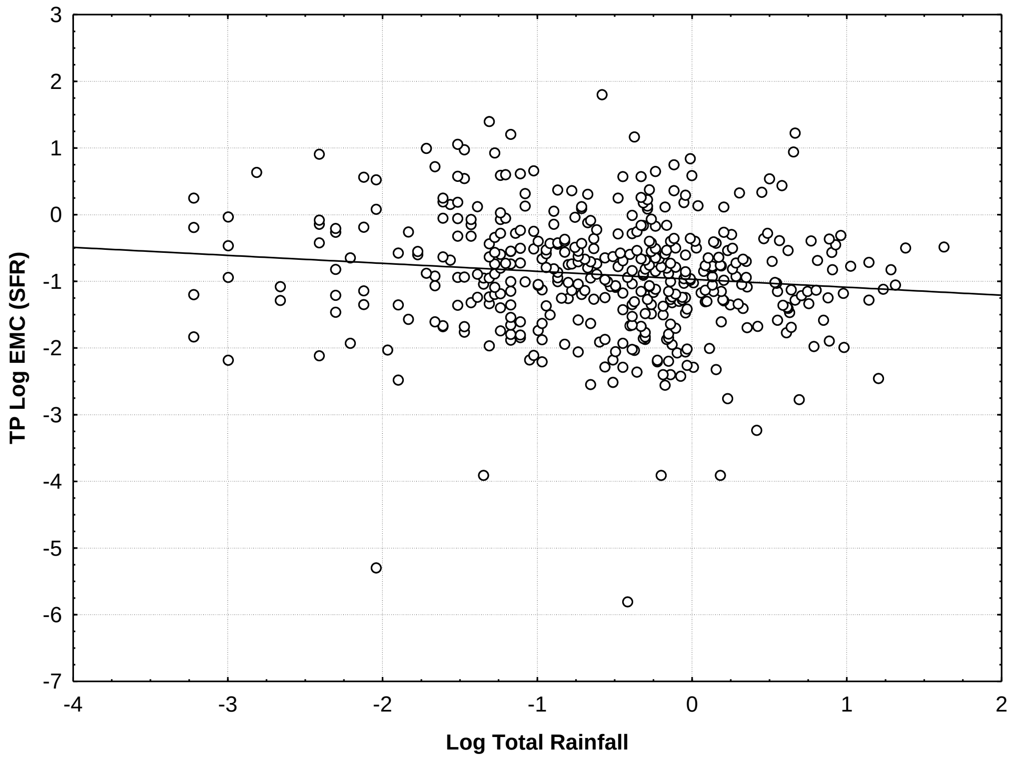
Graph E56. Scatterplot of Log of Total Rainfall vs. Log of EMC for TOC Group UND



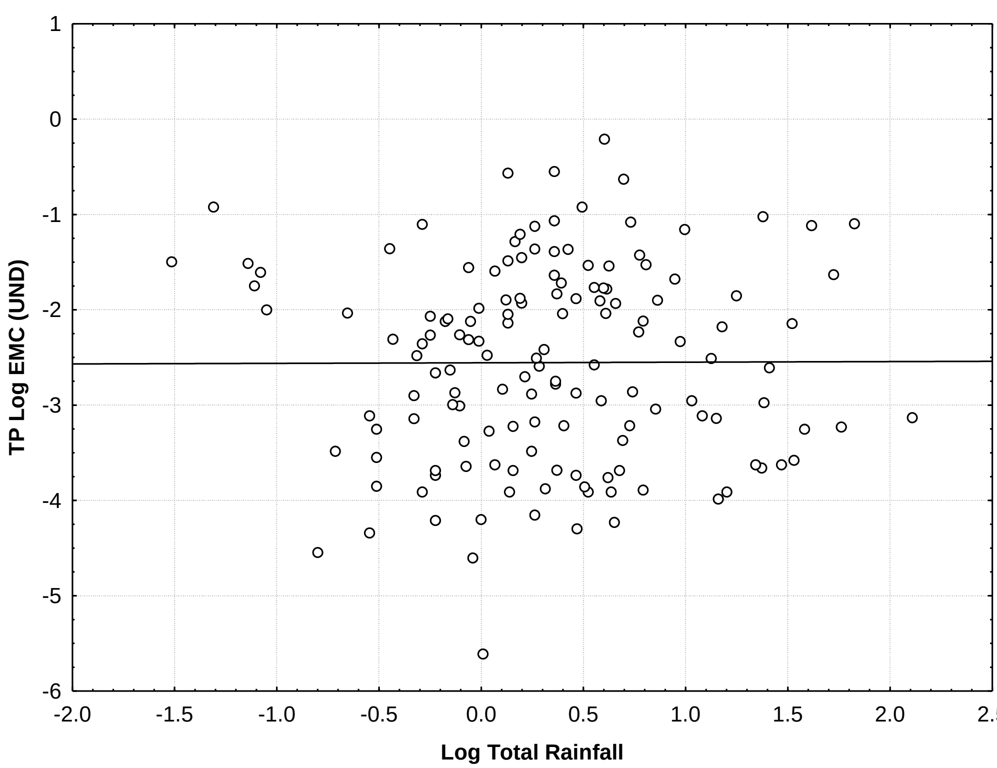
Graph E57. Scatterplot of Log of Total Rainfall vs. Log of EMC for TP Group IC1



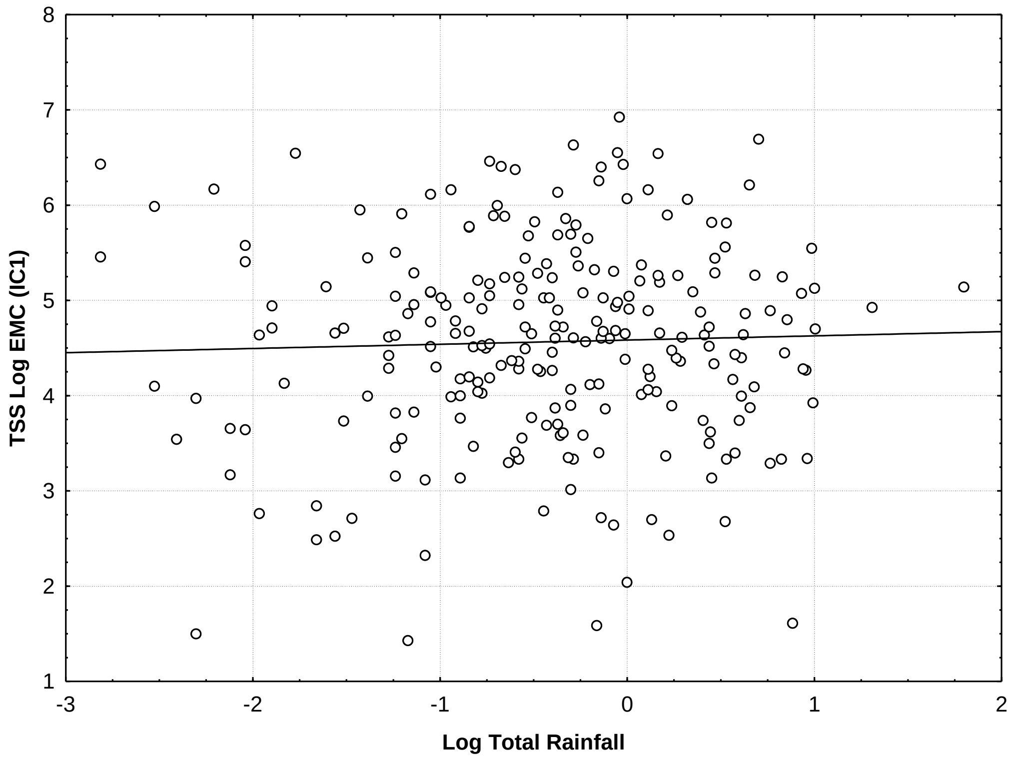
Graph E58. Scatterplot of Log of Total Rainfall vs. Log of EMC for TP Group IC2



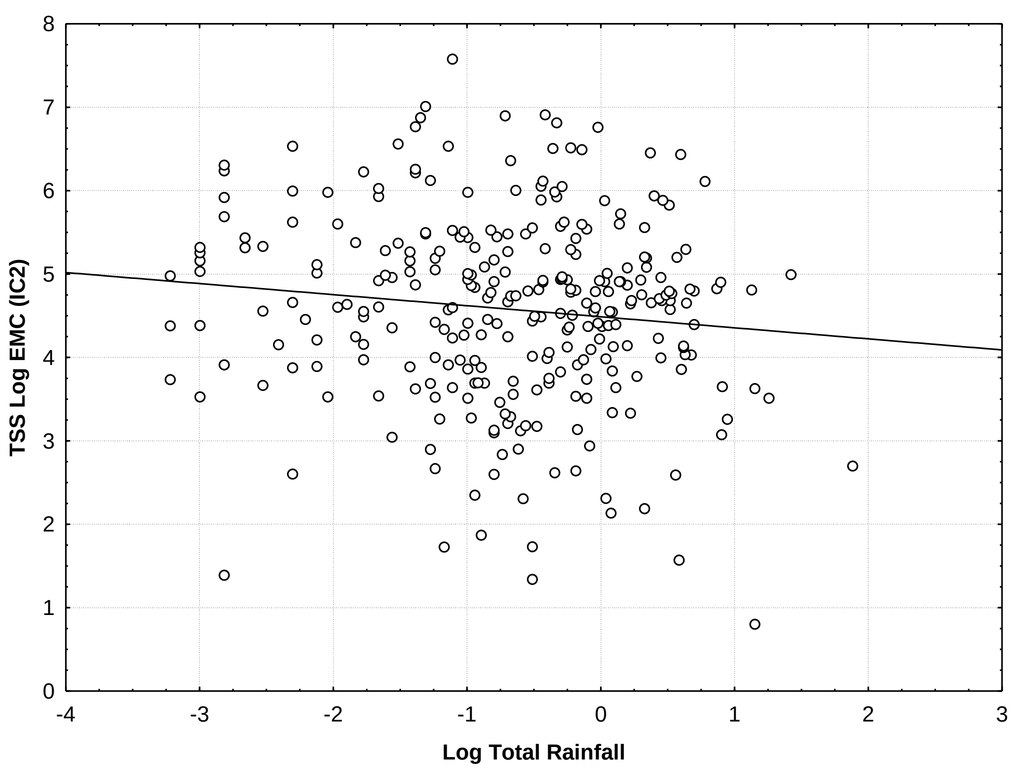
Graph E59. Scatterplot of Log of Total Rainfall vs. Log of EMC for TP Group SFR



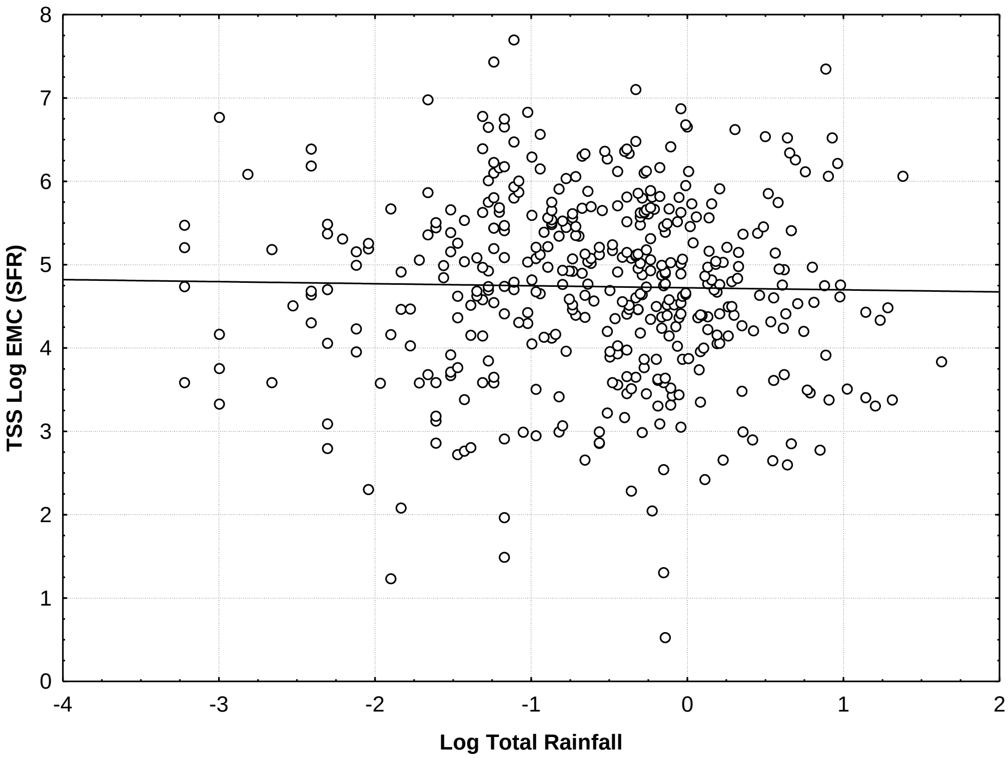
Graph E60. Scatterplot of Log of Total Rainfall vs. Log of EMC for TP Group UND



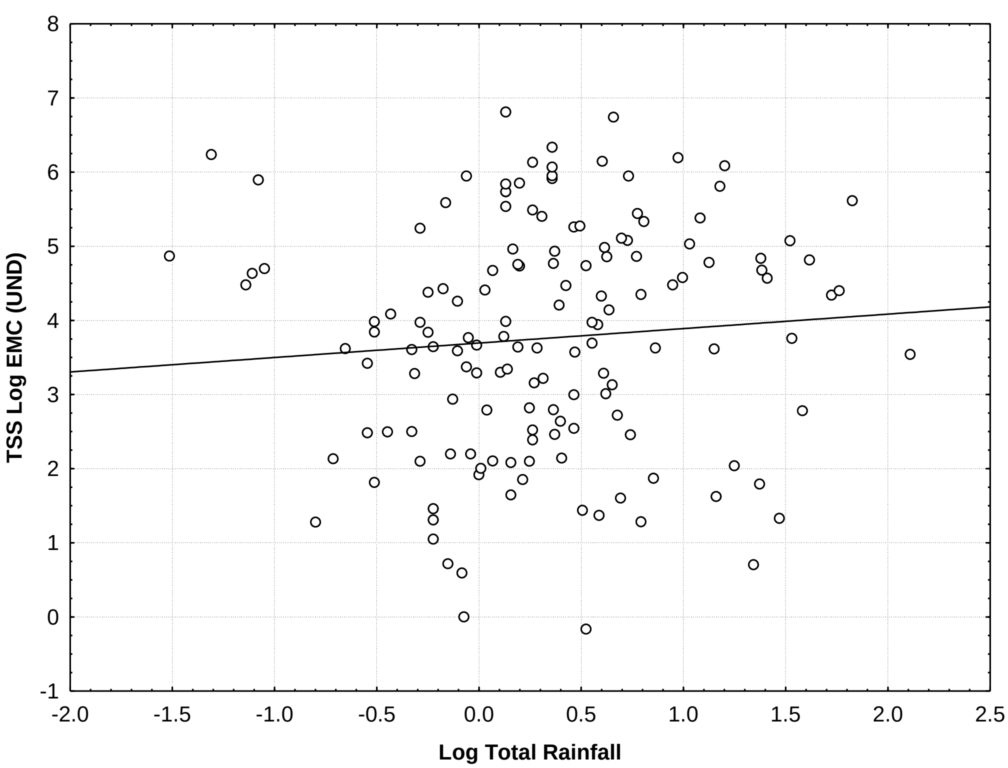
Graph E61. Scatterplot of Log of Total Rainfall vs. Log of EMC for TSS Group IC1



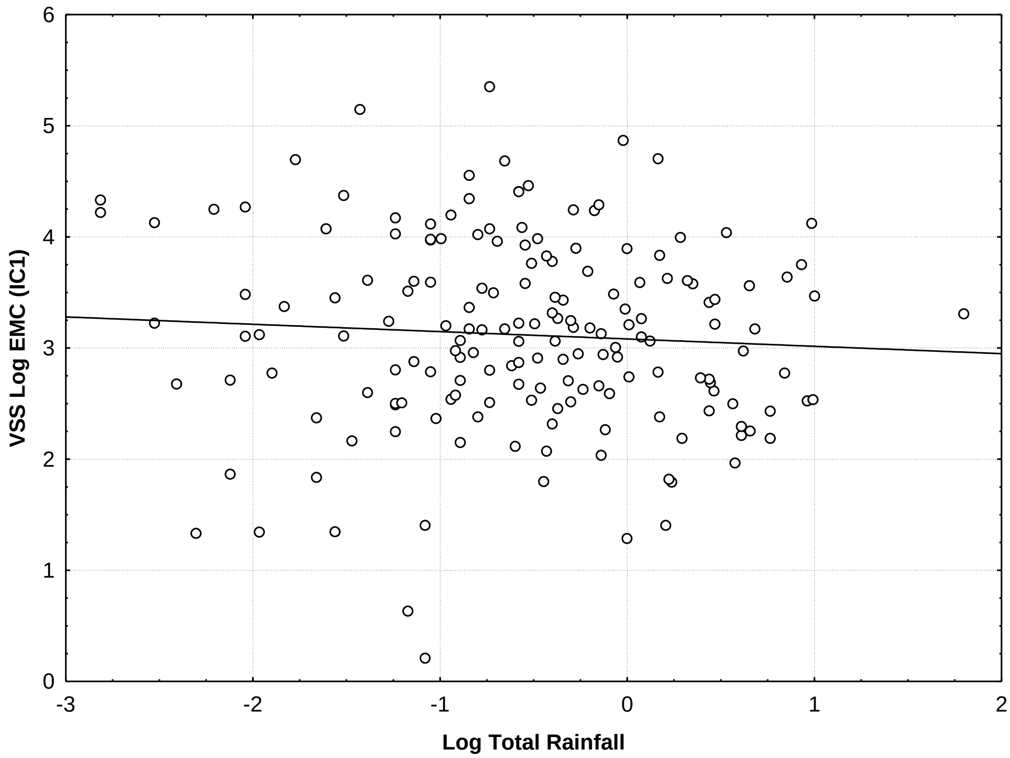
Graph E62. Scatterplot of Log of Total Rainfall vs. Log of EMC for TSS Group IC2



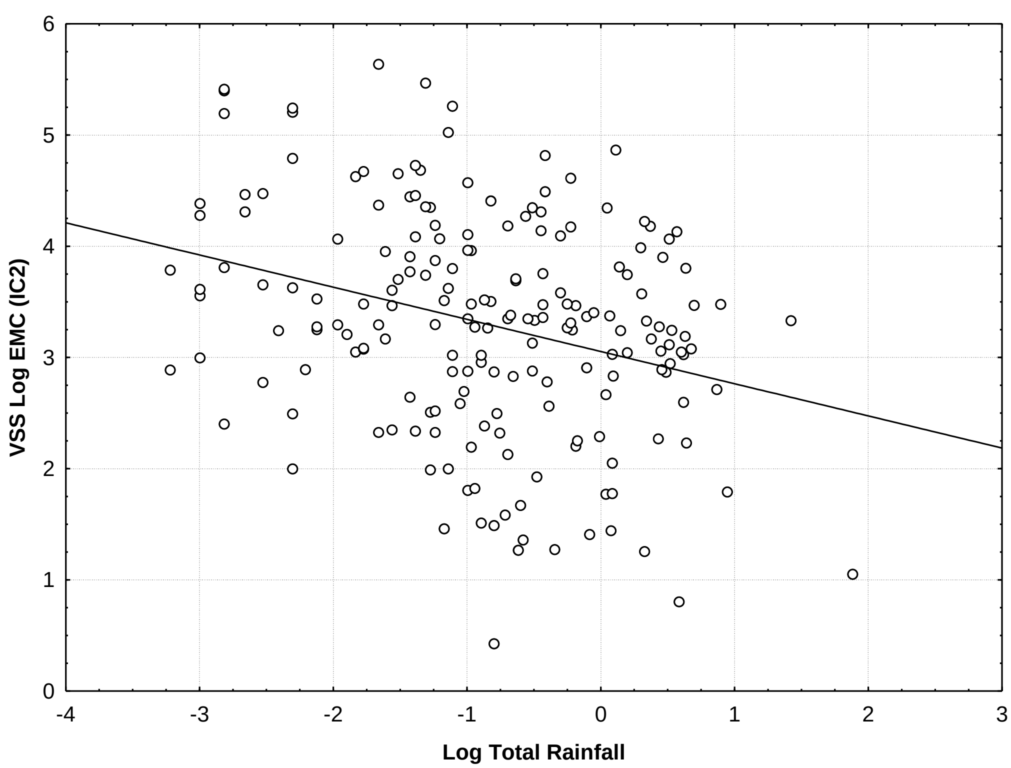
Graph E63. Scatterplot of Log of Total Rainfall vs. Log of EMC for TSS Group SFR



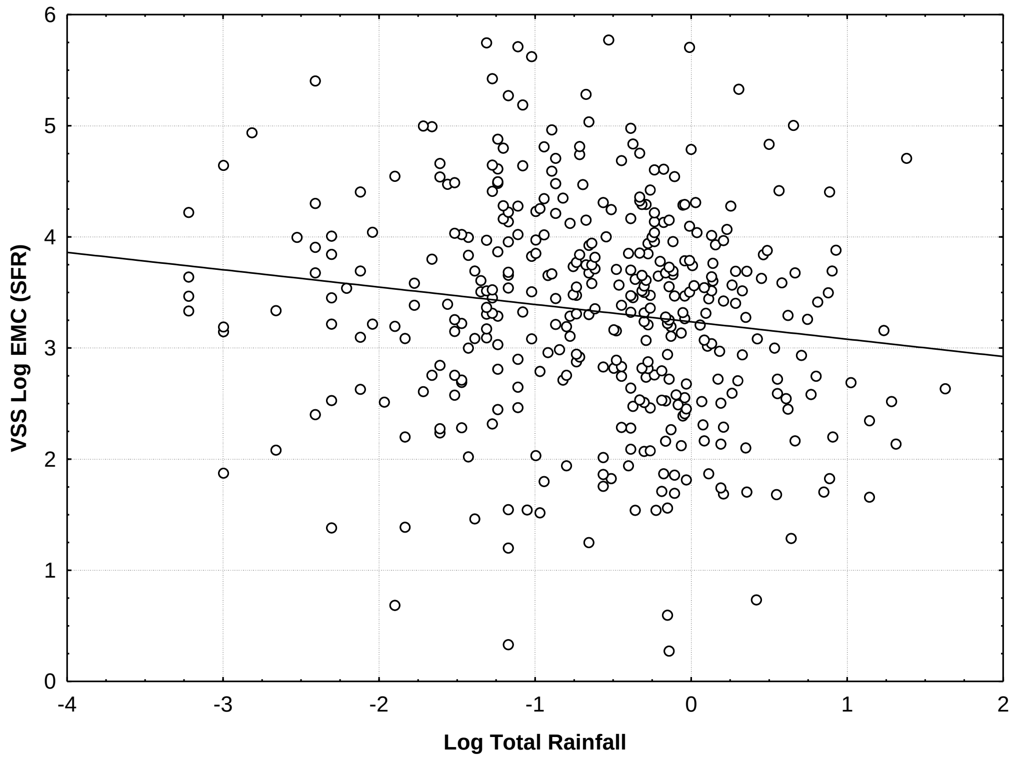
Graph E64. Scatterplot of Log of Total Rainfall vs. Log of EMC for TSS Group UND



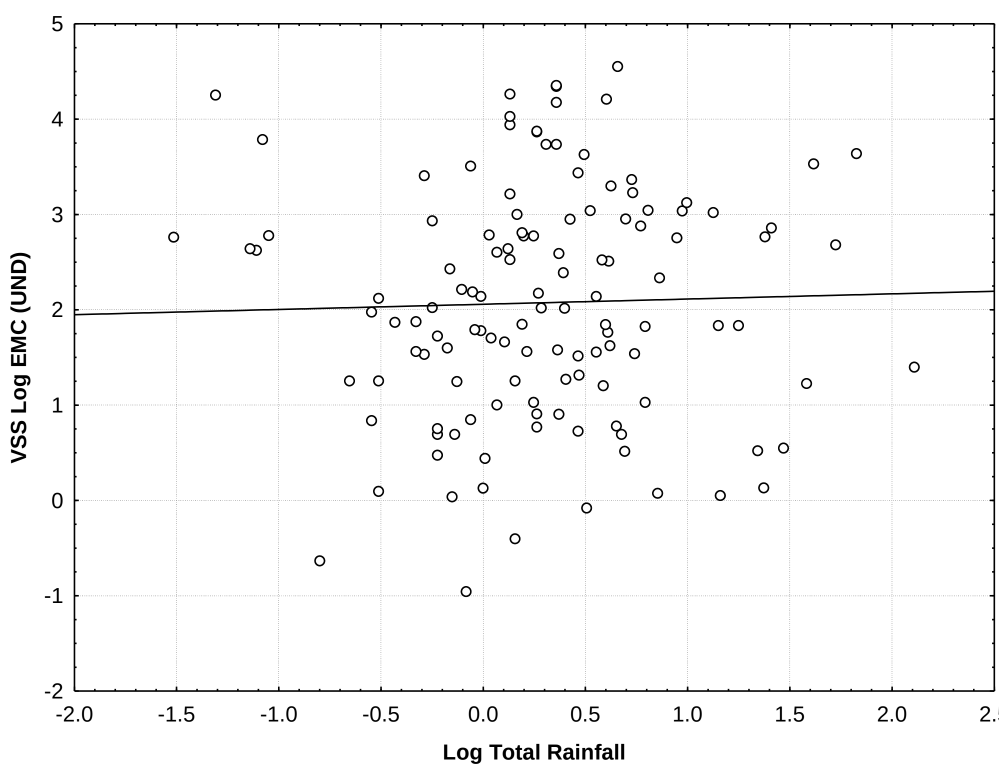
Graph E65. Scatterplot of Log of Total Rainfall vs. Log of EMC for VSS Group IC1



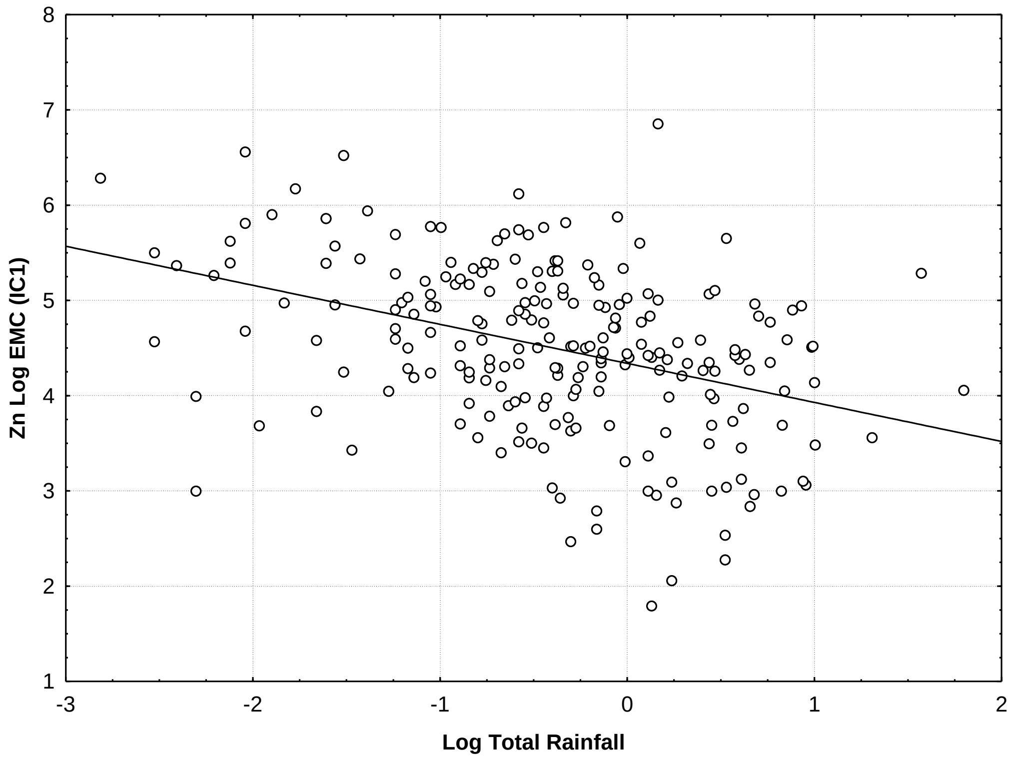
Graph E66. Scatterplot of Log of Total Rainfall vs. Log of EMC for VSS Group IC2



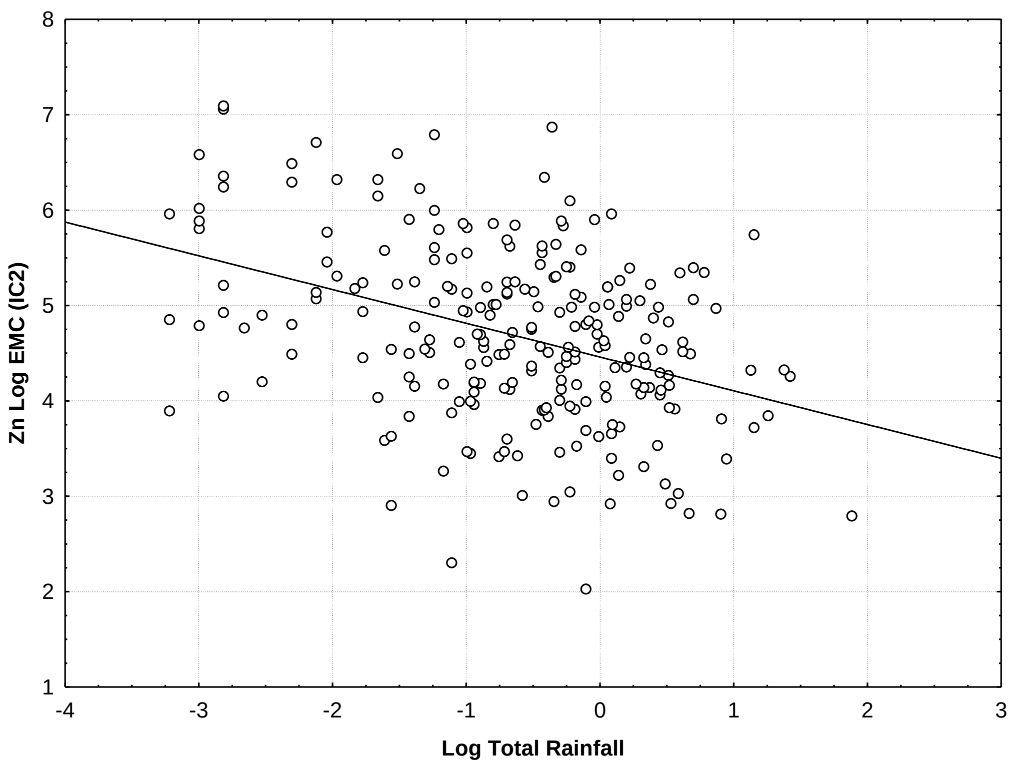
Graph E67. Scatterplot of Log of Total Rainfall vs. Log of EMC for VSS Group SFR



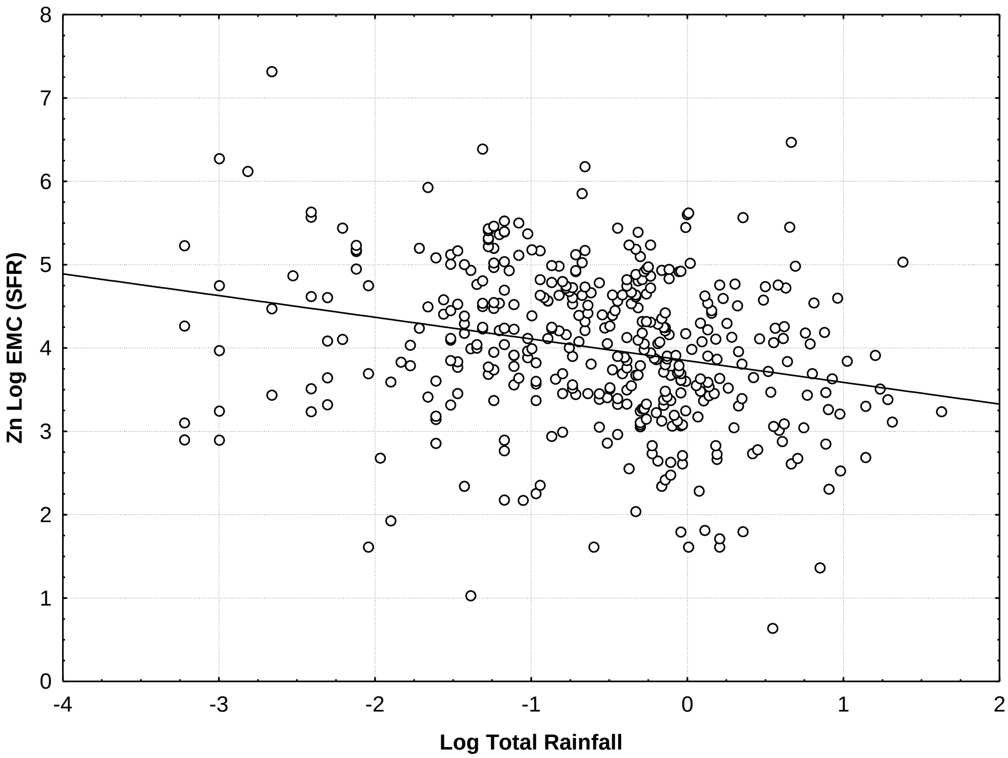
Graph E68. Scatterplot of Log of Total Rainfall vs. Log of EMC for VSS Group UND



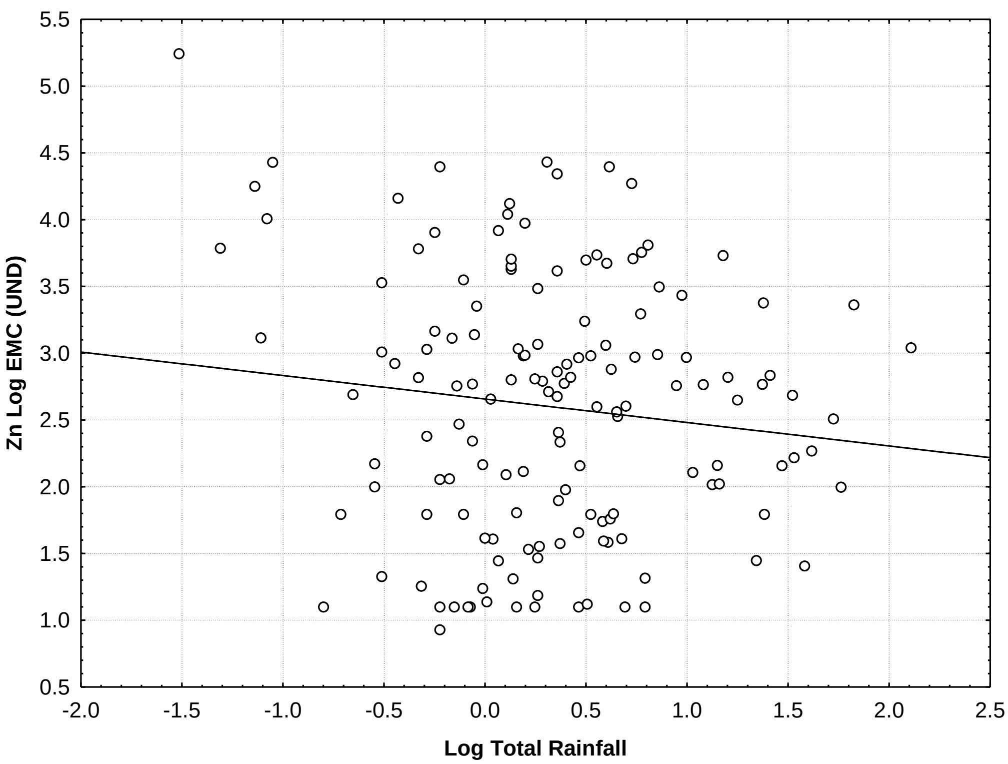
Graph E69. Scatterplot of Log of Total Rainfall vs. Log of EMC for Zn Group IC1



Graph E70. Scatterplot of Log of Total Rainfall vs. Log of EMC for Zn Group IC2

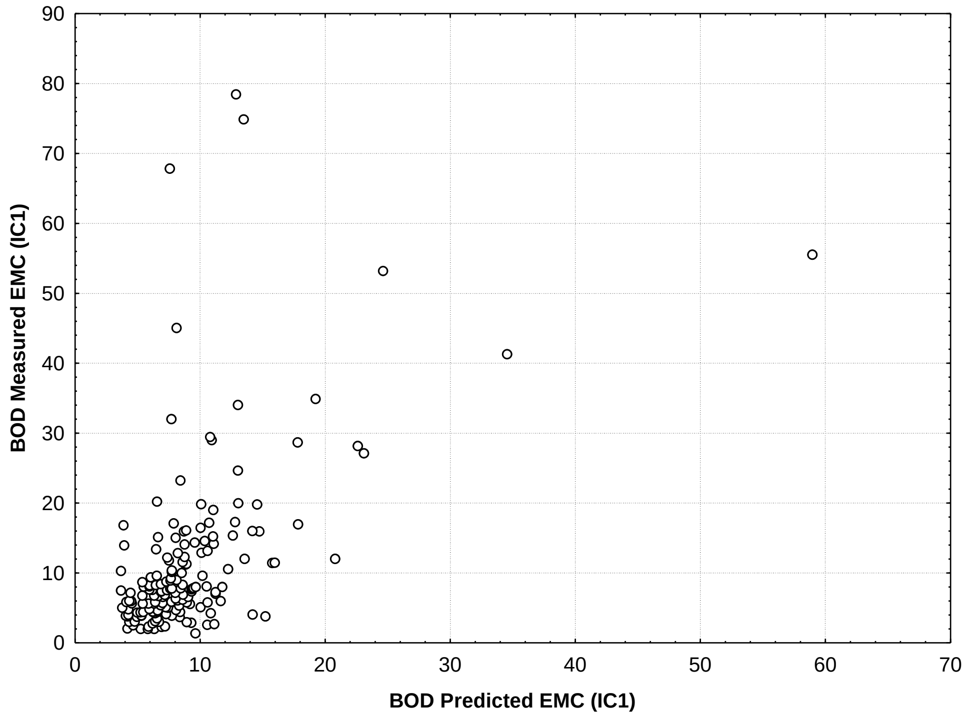


Graph E71. Scatterplot of Log of Total Rainfall vs. Log of EMC for Zn Group SFR

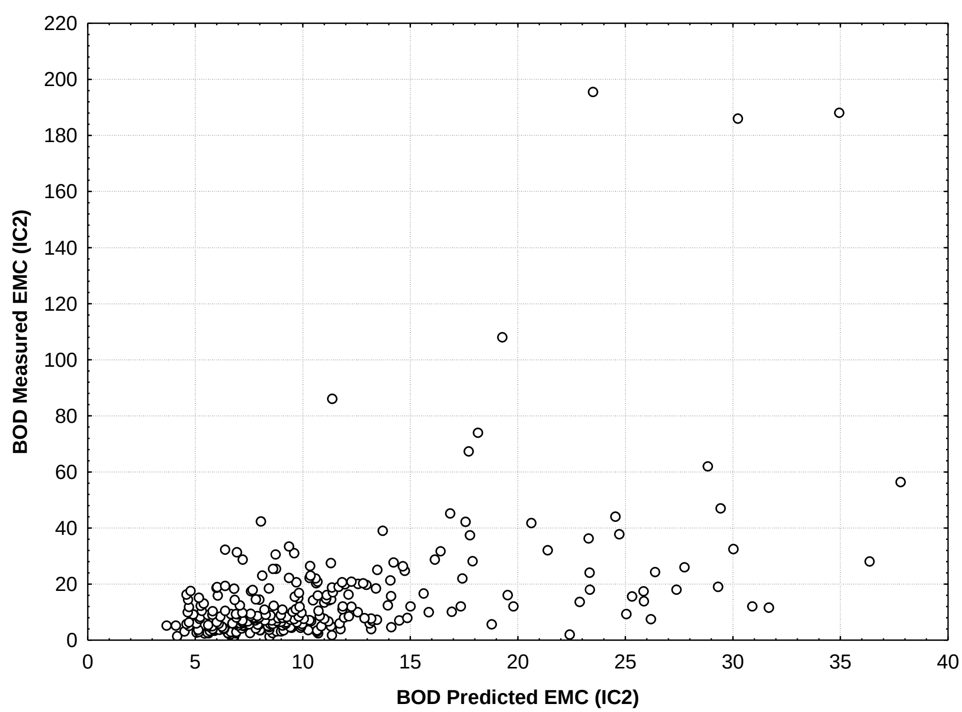


Graph E72. Scatterplot of Log of Total Rainfall vs. Log of EMC for Zn Group UND

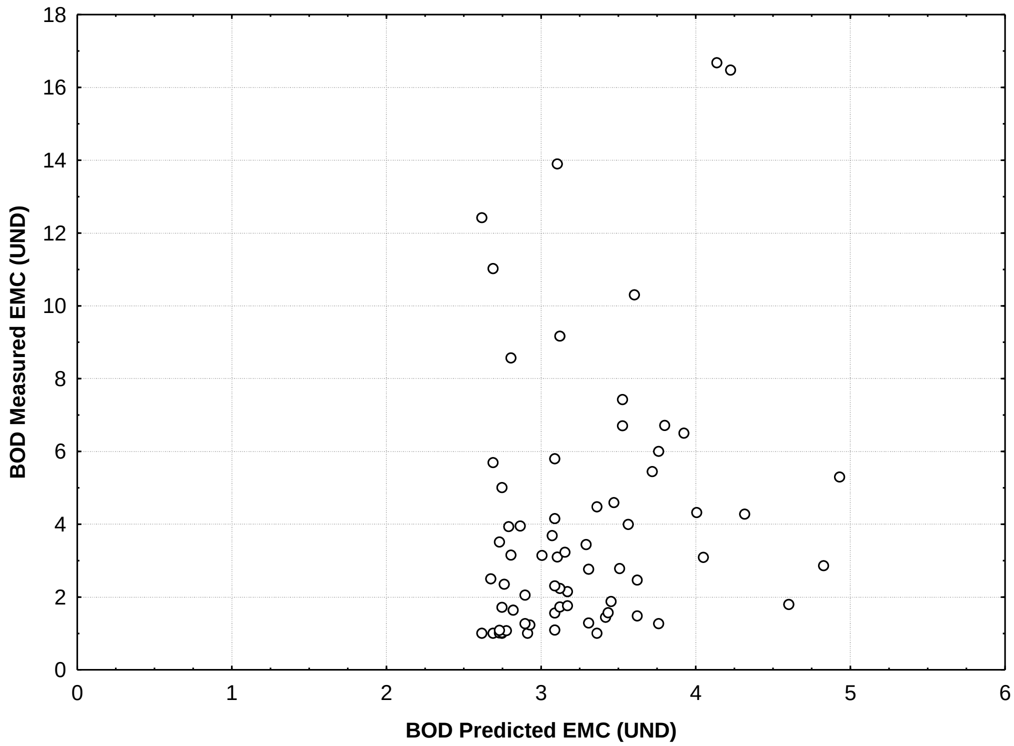
Appendix F Observed vs. Predicted EMCs



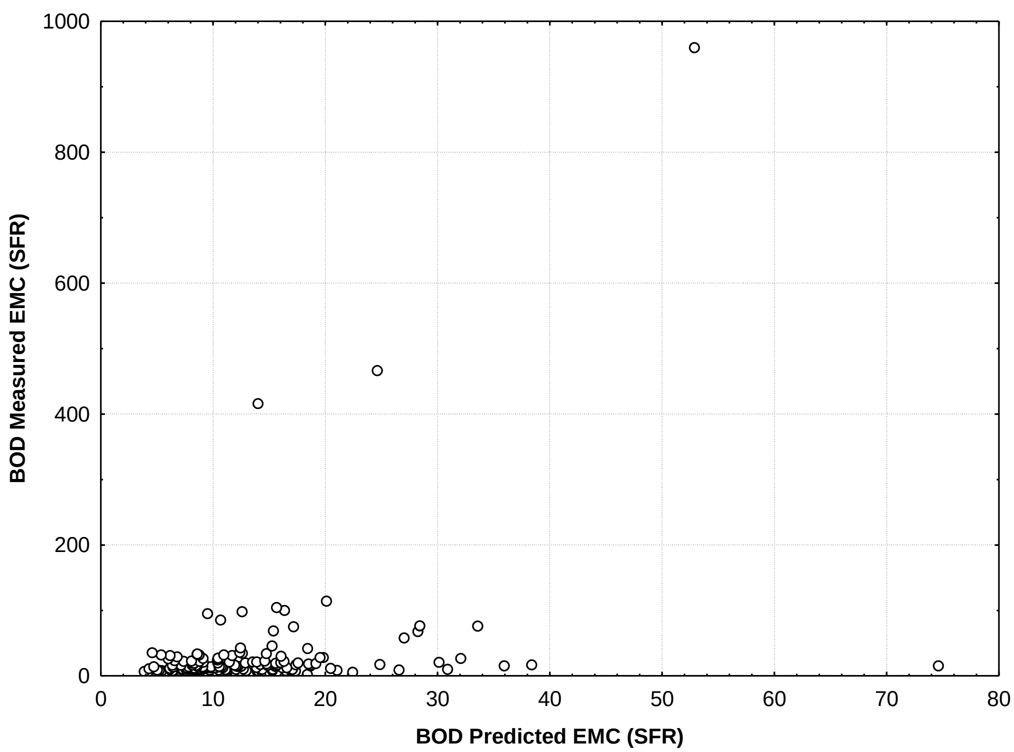
Graph F1. Scatterplot of Predicted EMC vs. Measured EMC for BOD Group IC1



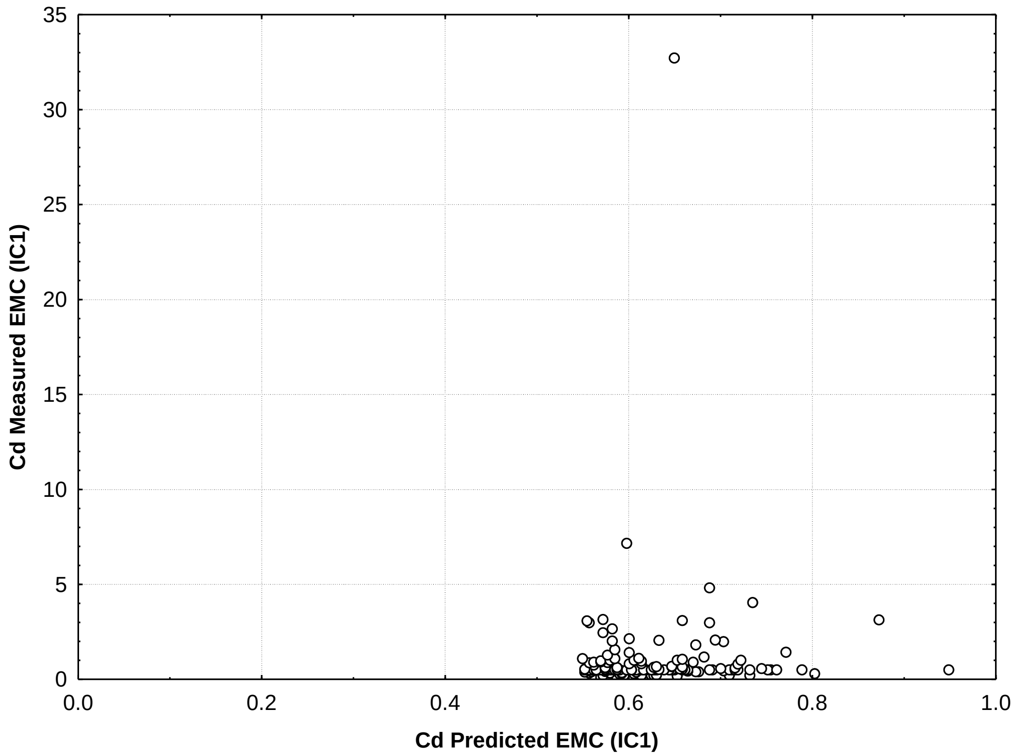
Graph F2. Scatterplot of Predicted EMC vs. Measured EMC for BOD Group IC2



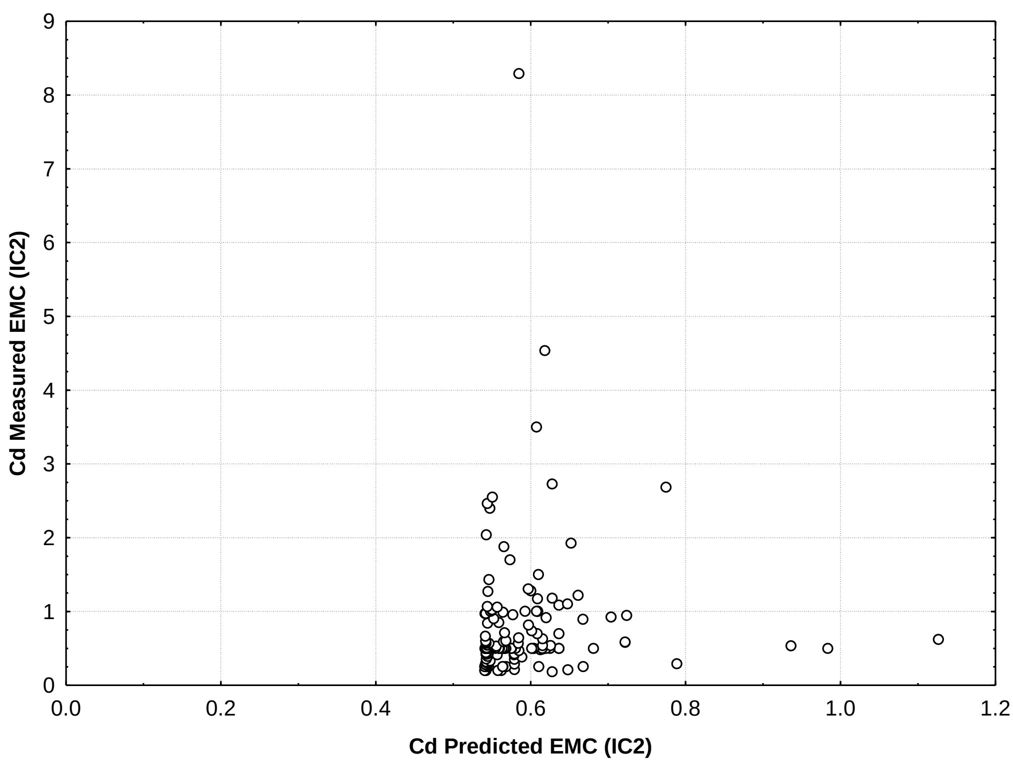
Graph F3. Scatterplot of Predicted EMC vs. Measured EMC for BOD Group SFR



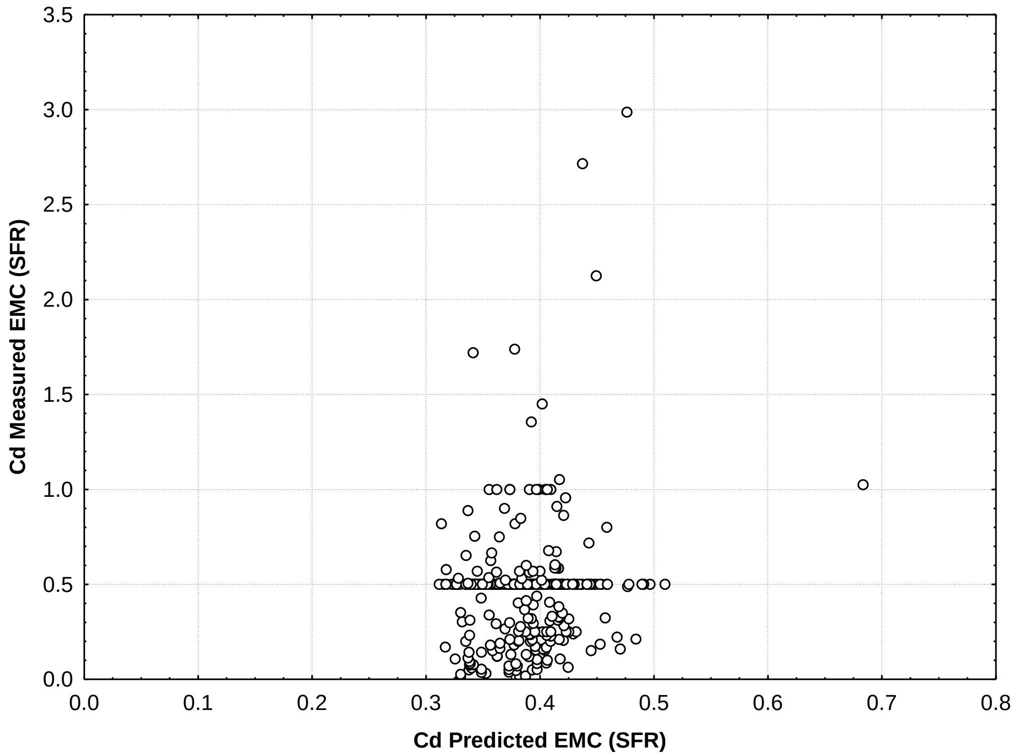
Graph F4. Scatterplot of Predicted EMC vs. Measured EMC for BOD Group UND



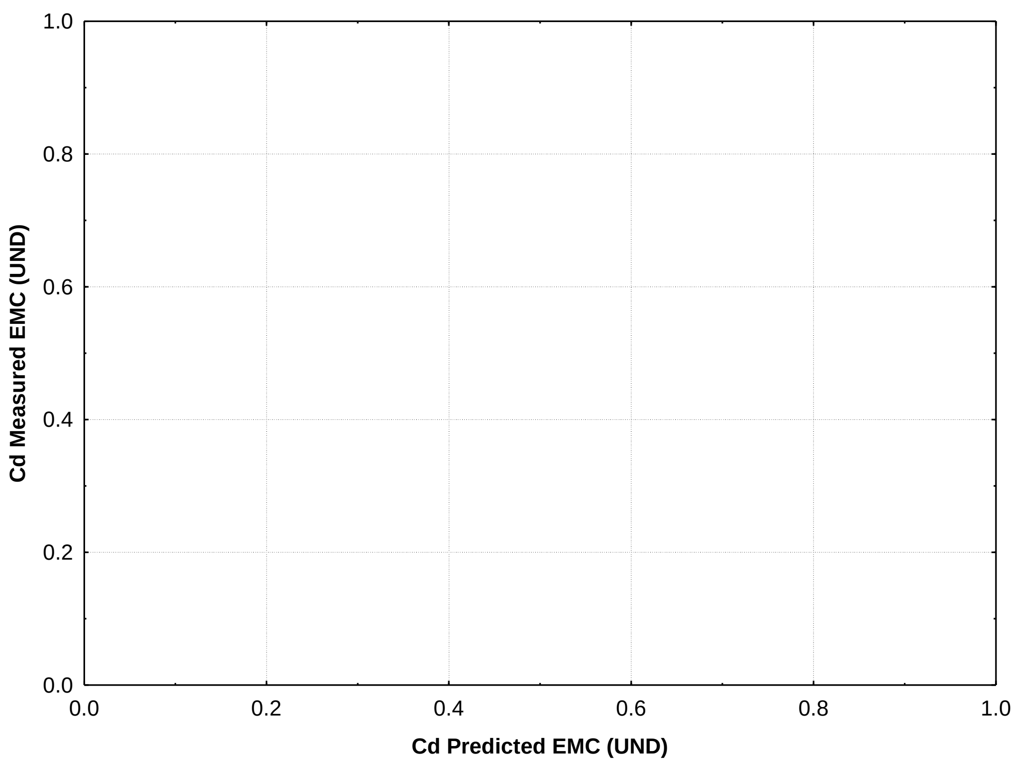
Graph F5. Scatterplot of Predicted EMC vs. Measured EMC for Cd Group IC1



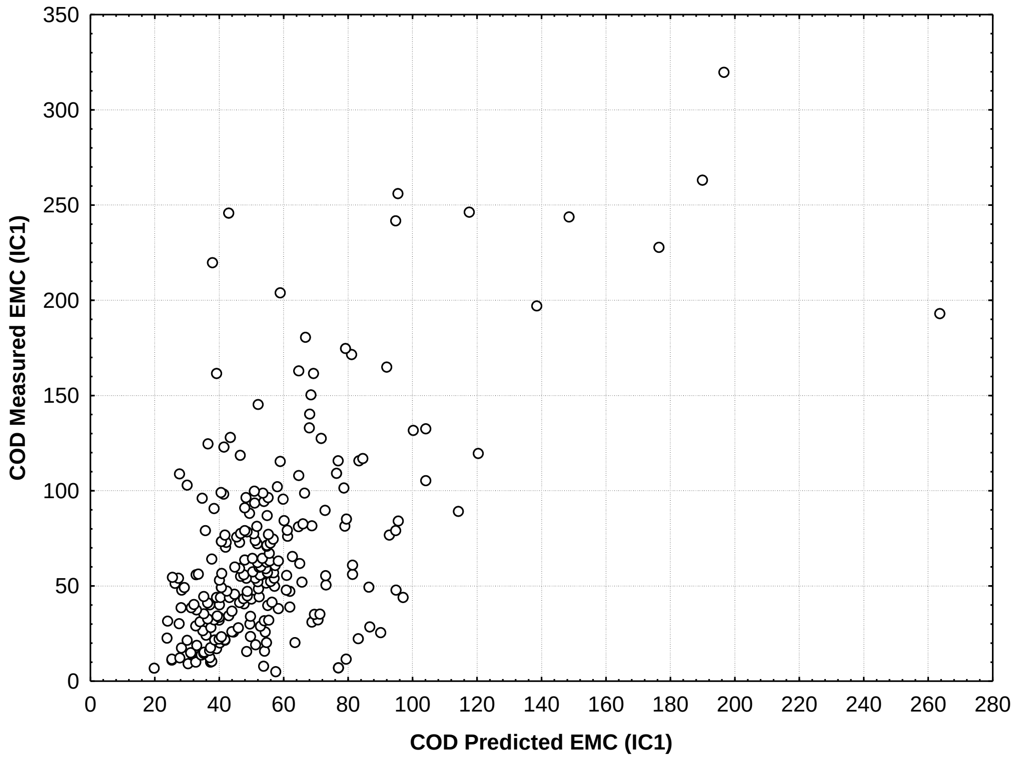
Graph F6. Scatterplot of Predicted EMC vs. Measured EMC for Cd Group IC2



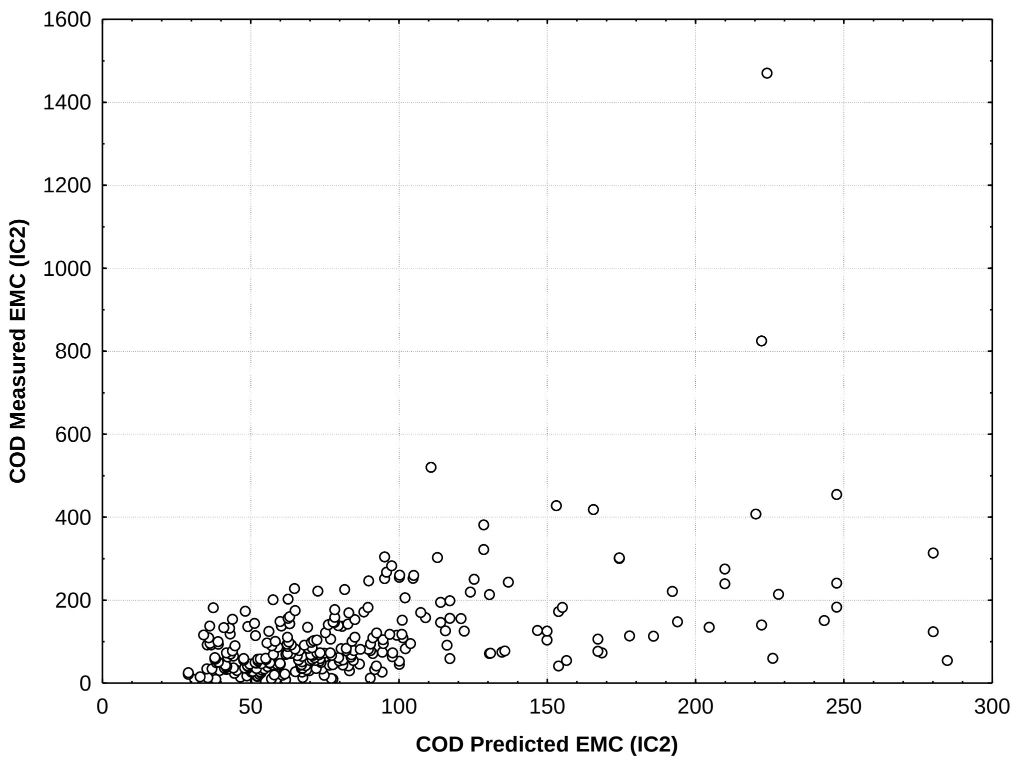
Graph F7. Scatterplot of Predicted EMC vs. Measured EMC for Cd Group SFR



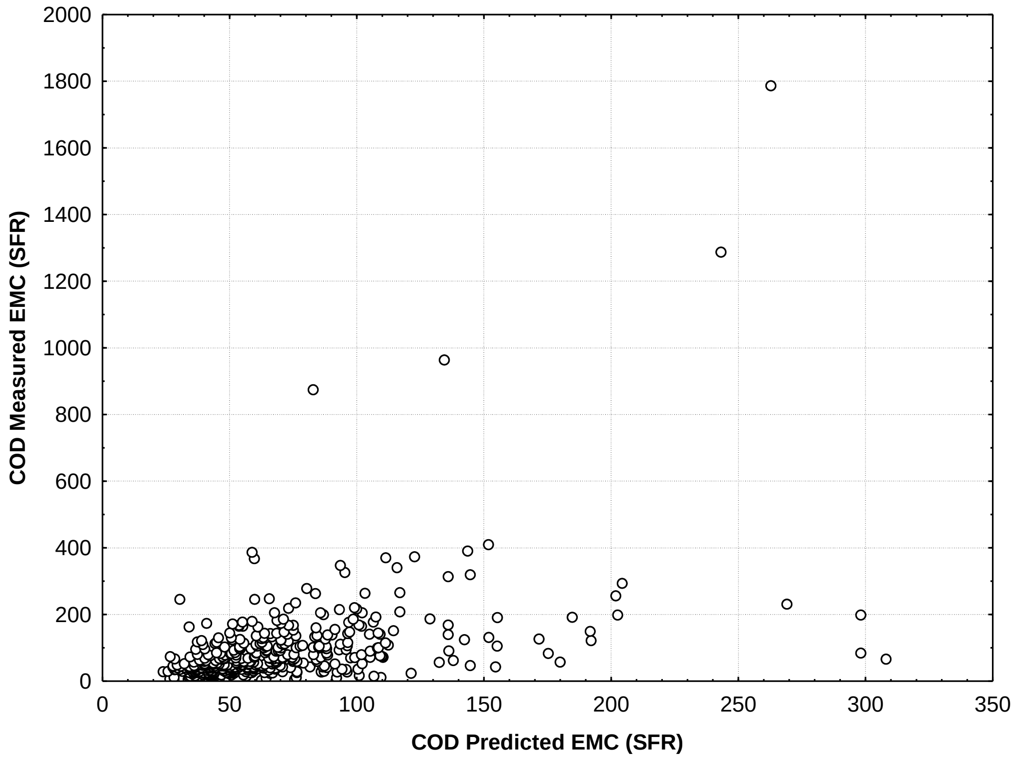
Graph F8. Scatterplot of Predicted EMC vs. Measured EMC for Cd Group UND



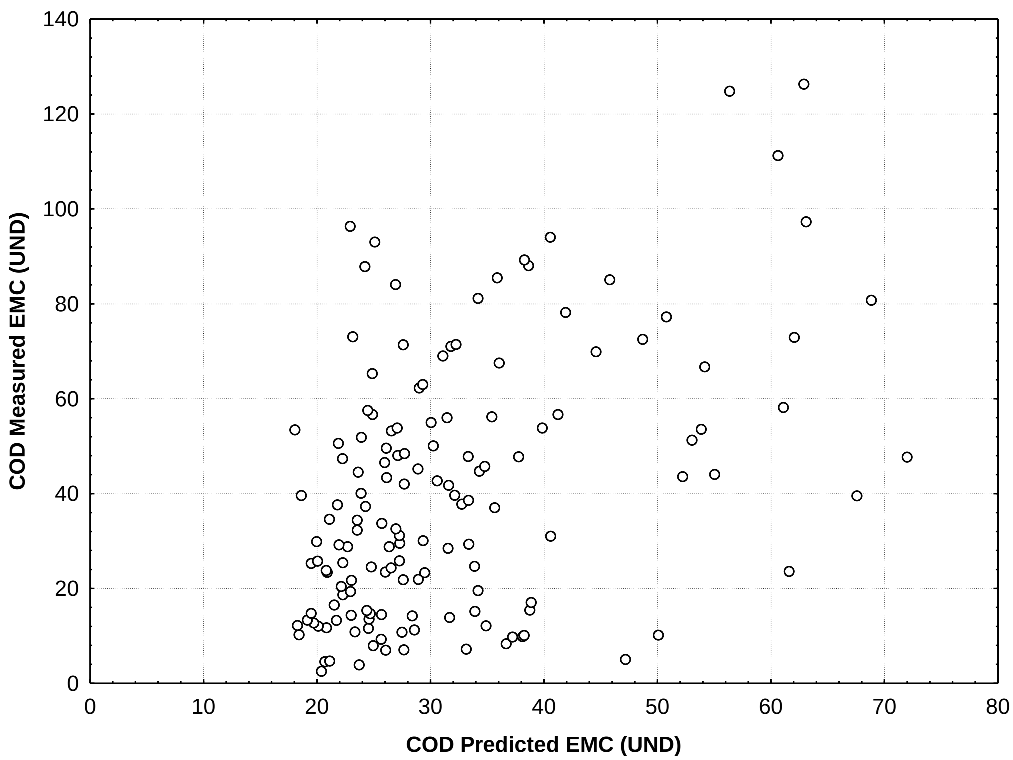
Graph F9. Scatterplot of Predicted EMC vs. Measured EMC for COD Group IC1



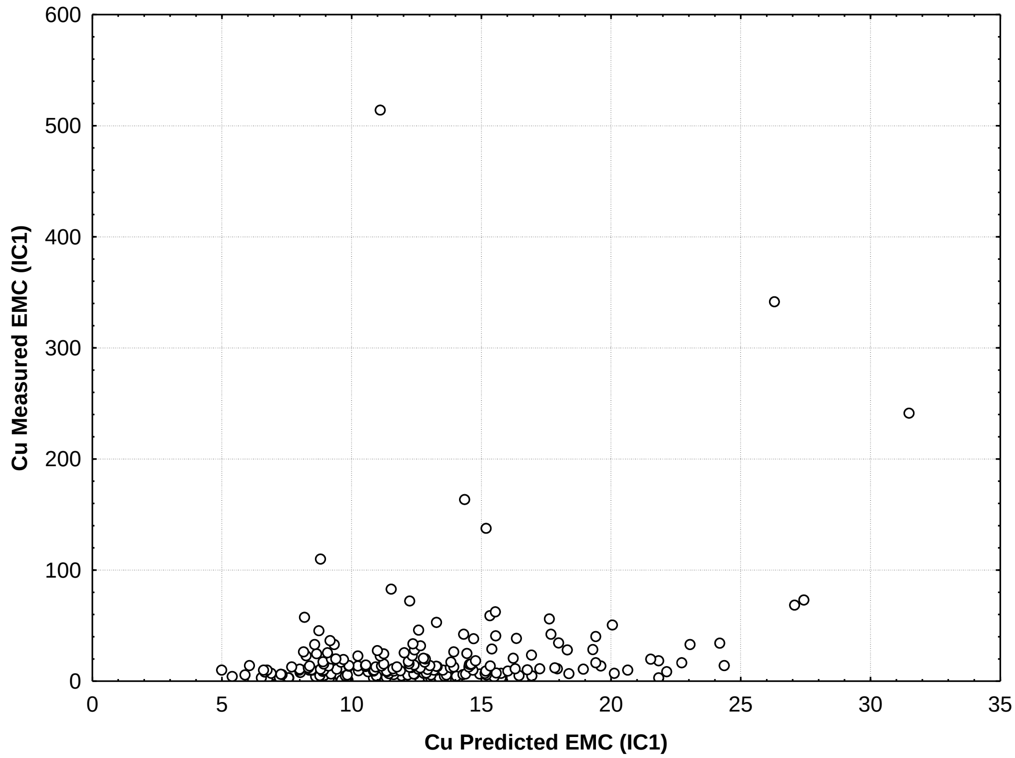
Graph F10. Scatterplot of Predicted EMC vs. Measured EMC for COD Group IC2



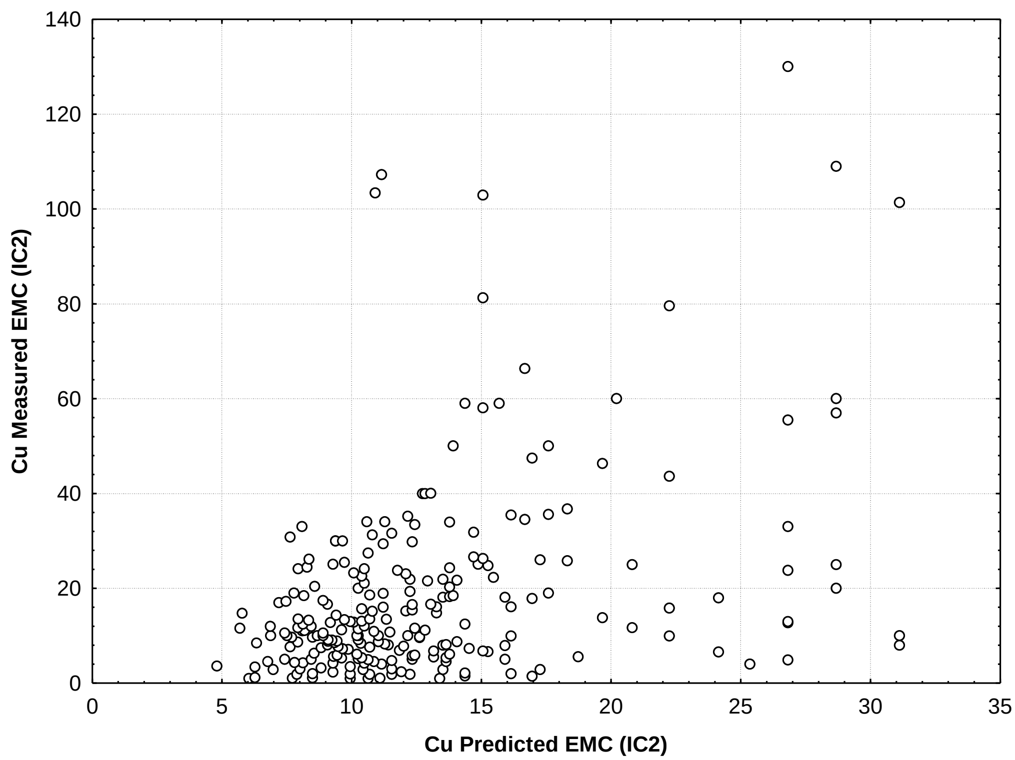
Graph F11. Scatterplot of Predicted EMC vs. Measured EMC for COD Group SFR



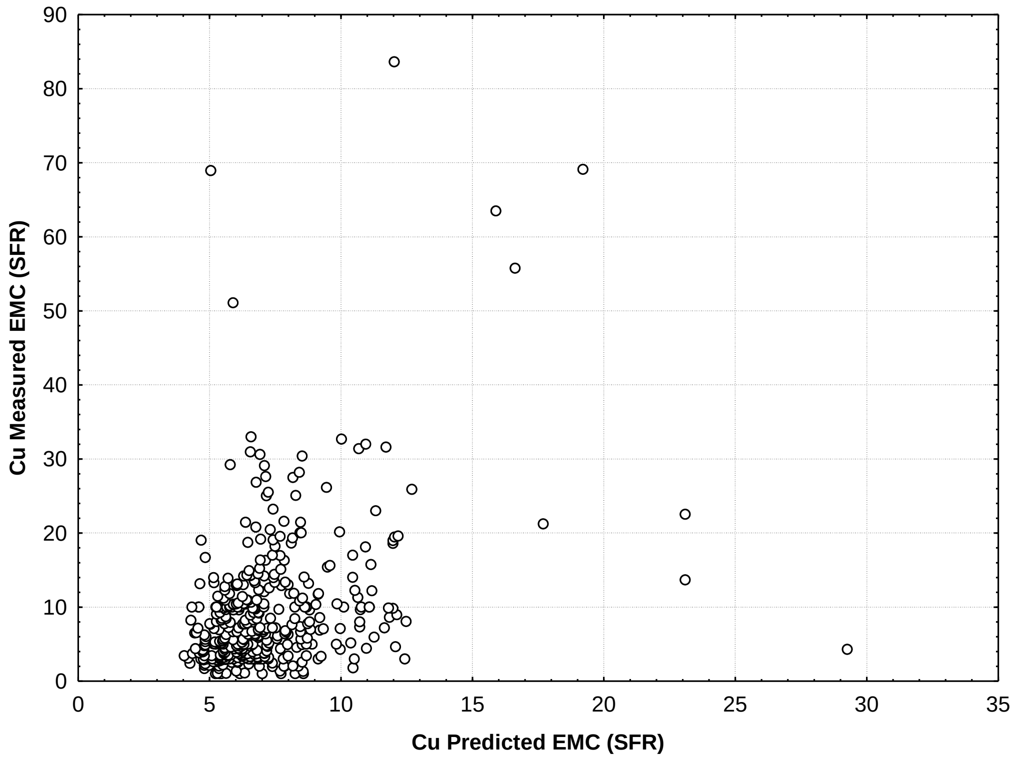
Graph F12. Scatterplot of Predicted EMC vs. Measured EMC for COD Group UND



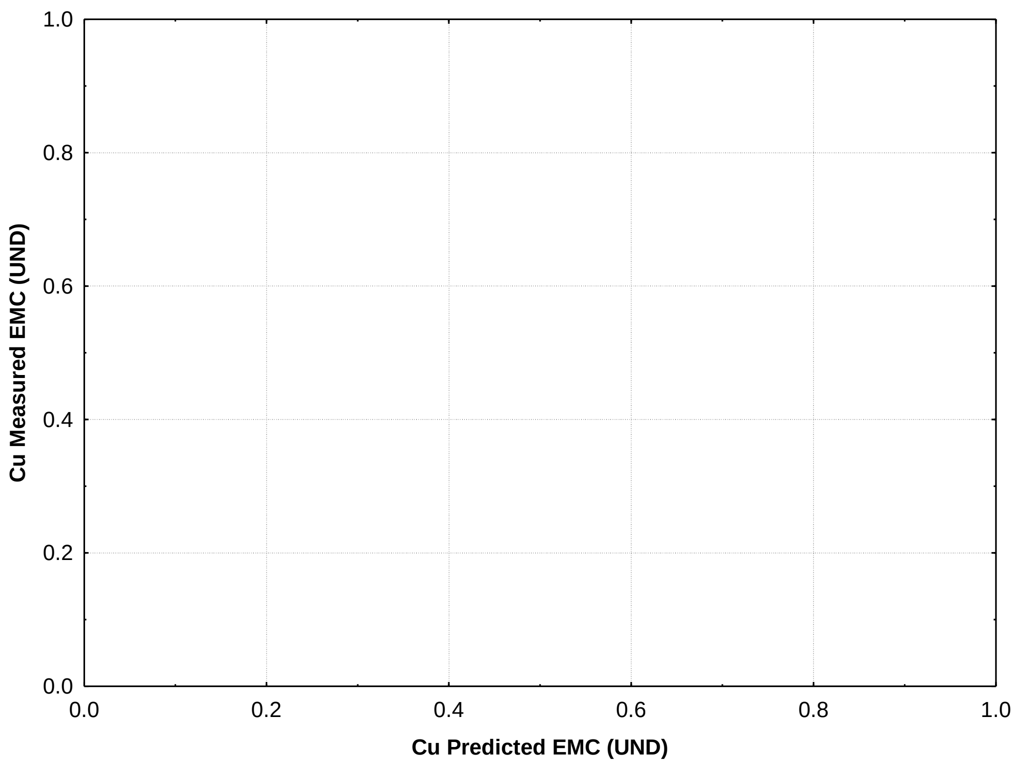
Graph F13. Scatterplot of Predicted EMC vs. Measured EMC for Cu Group IC1



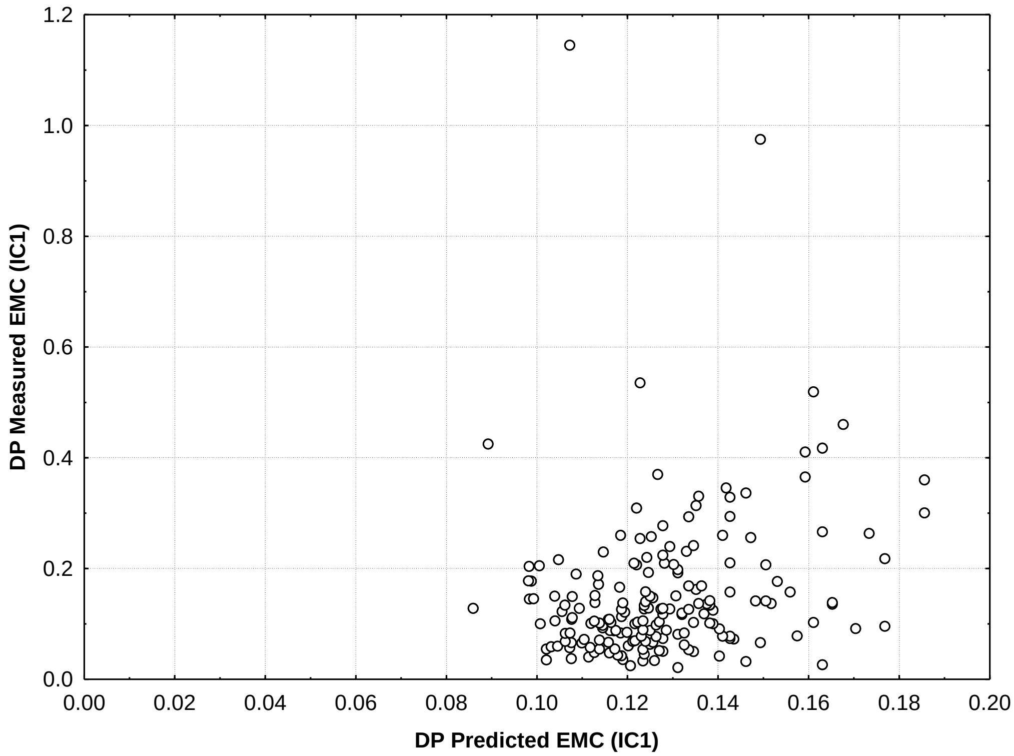
Graph F14. Scatterplot of Predicted EMC vs. Measured EMC for Cu Group IC2



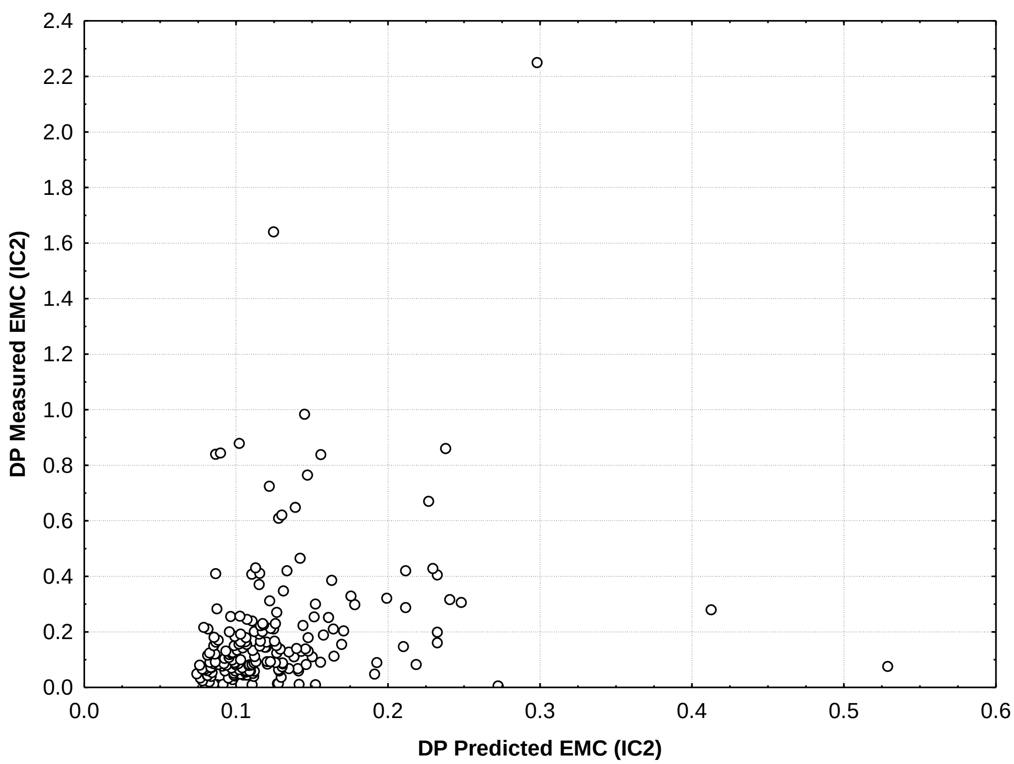
Graph F15. Scatterplot of Predicted EMC vs. Measured EMC for Cu Group SFR



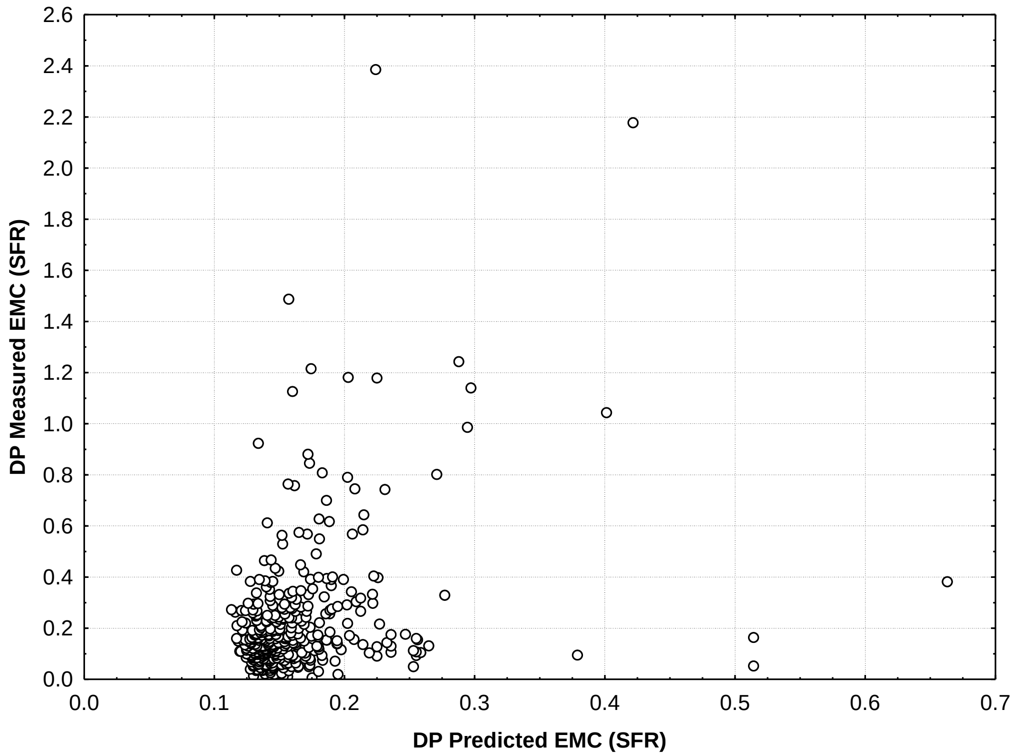
Graph F16. Scatterplot of Predicted EMC vs. Measured EMC for Cu Group UND



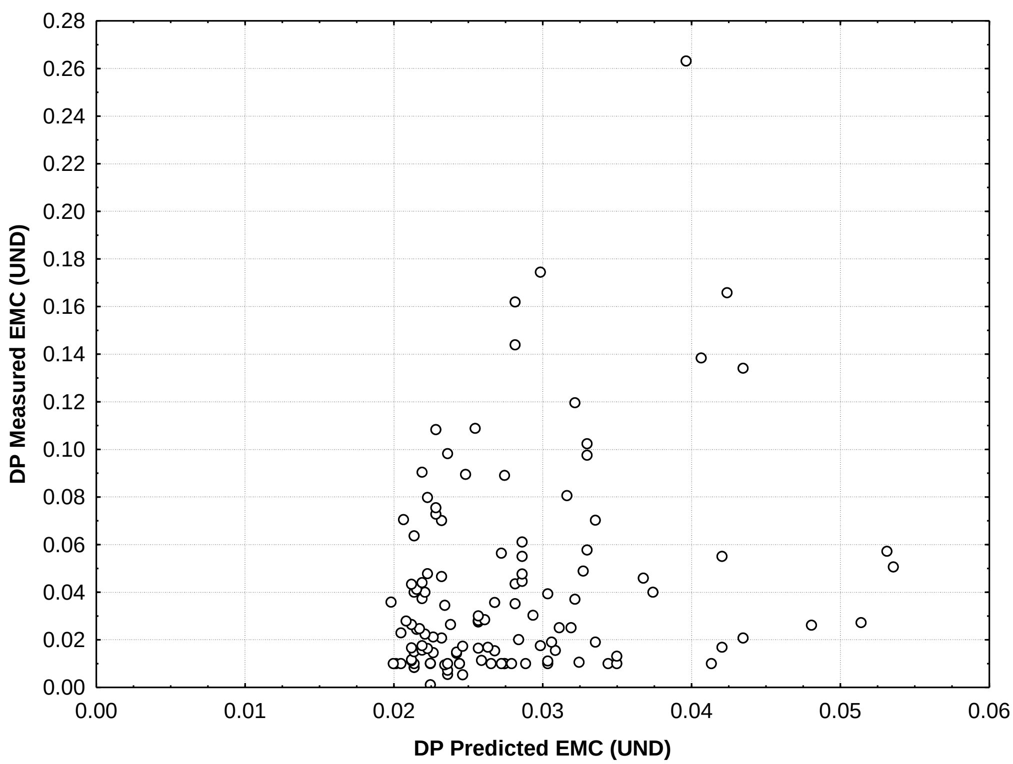
Graph F17. Scatterplot of Predicted EMC vs. Measured EMC for DP Group IC1



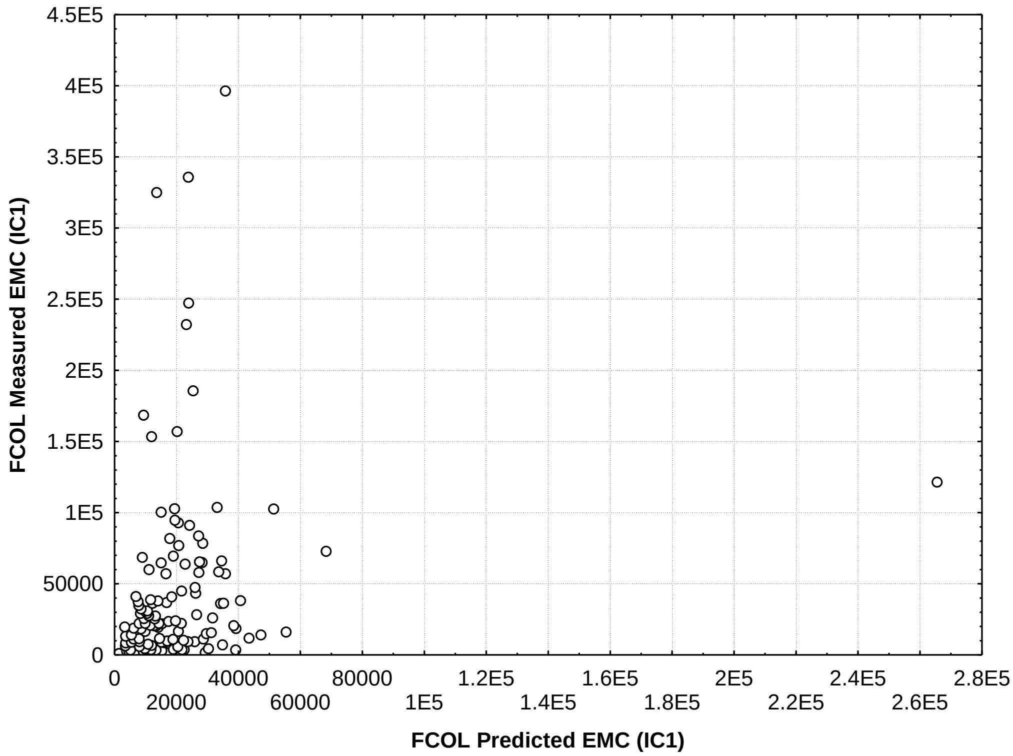
Graph F18. Scatterplot of Predicted EMC vs. Measured EMC for DP Group IC2



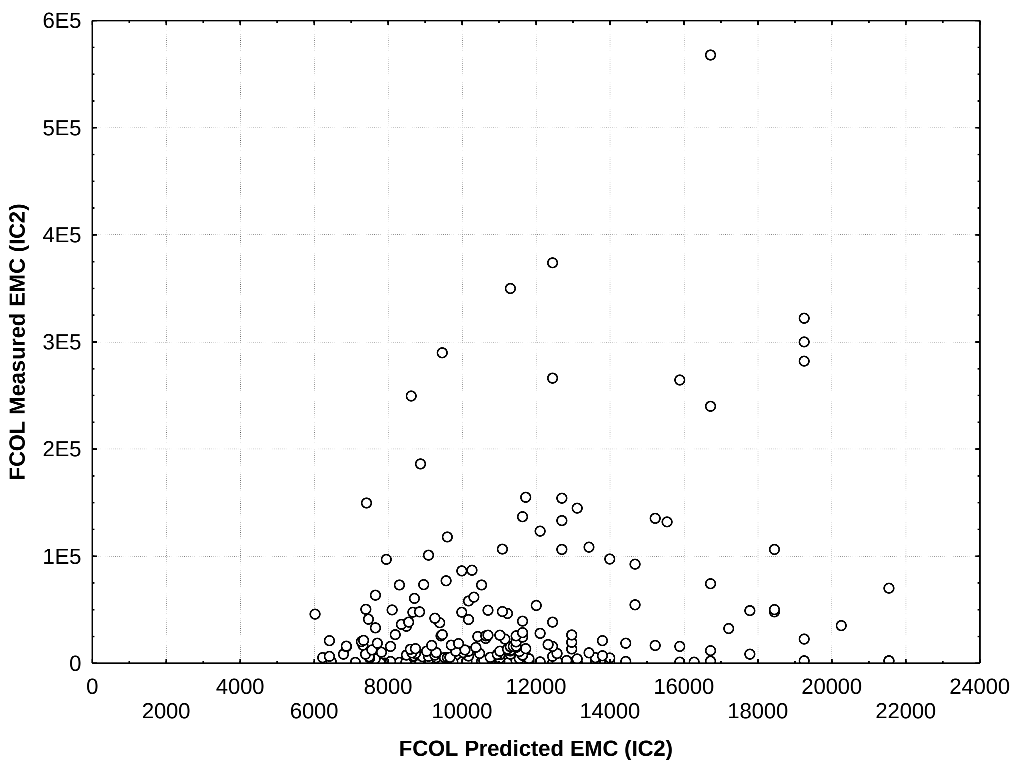
Graph F19. Scatterplot of Predicted EMC vs. Measured EMC for DP Group SFR



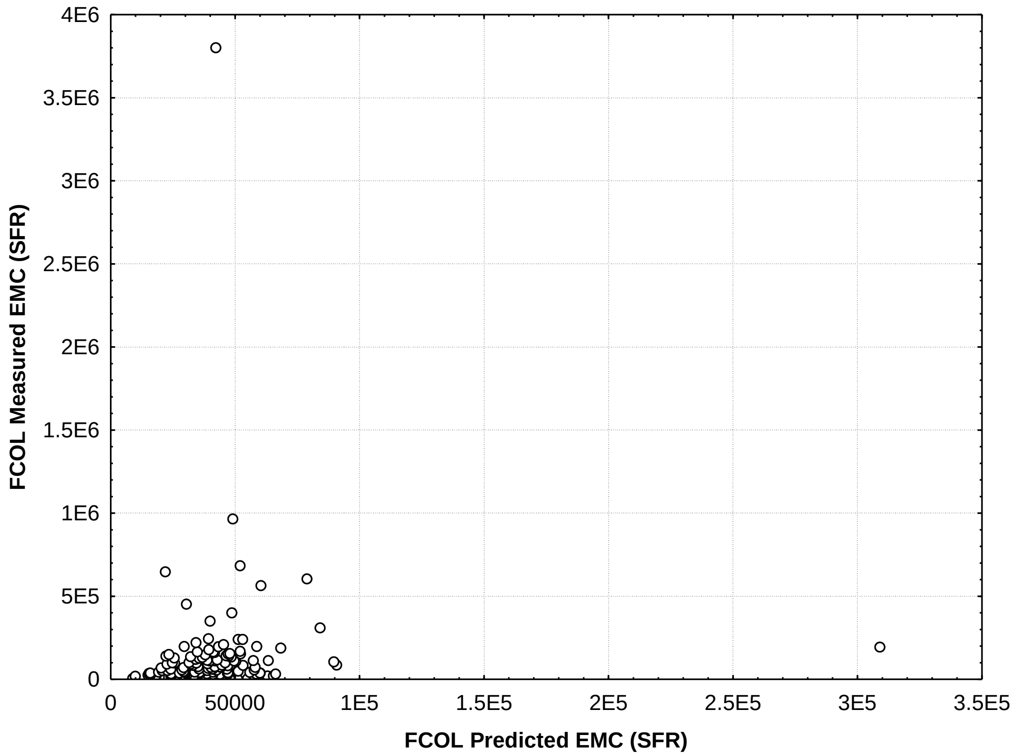
Graph F20. Scatterplot of Predicted EMC vs. Measured EMC for DP Group UND



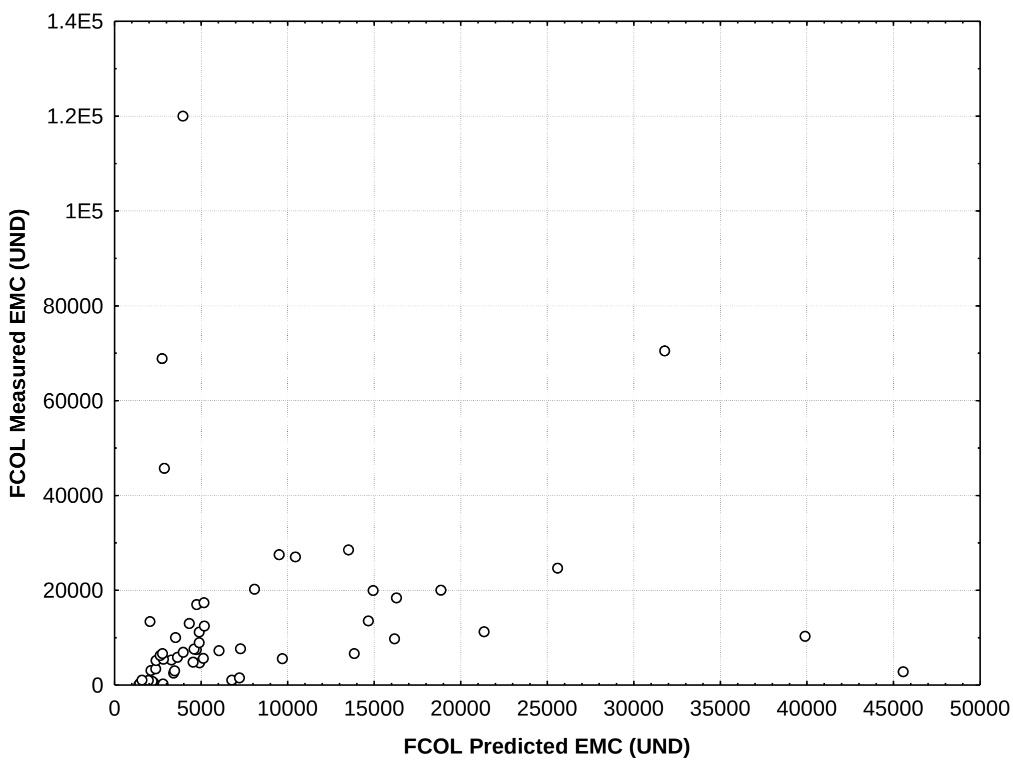
Graph F21. Scatterplot of Predicted EMC vs. Measured EMC for FCOL Group IC1



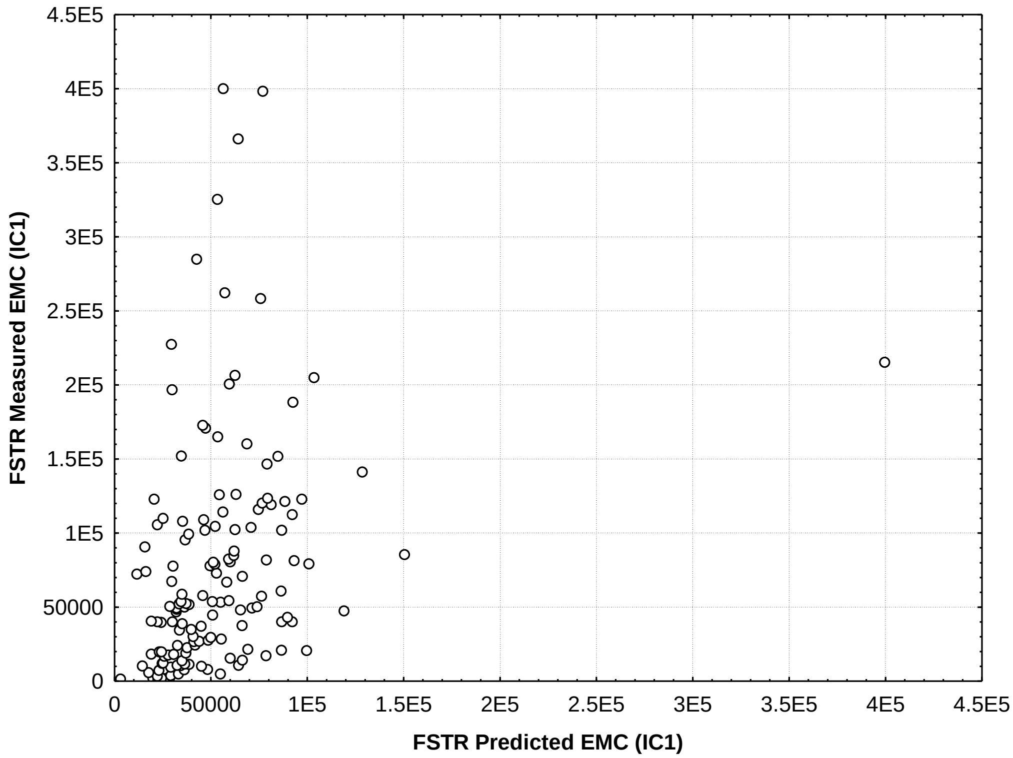
Graph F22. Scatterplot of Predicted EMC vs. Measured EMC for FCOL Group IC2



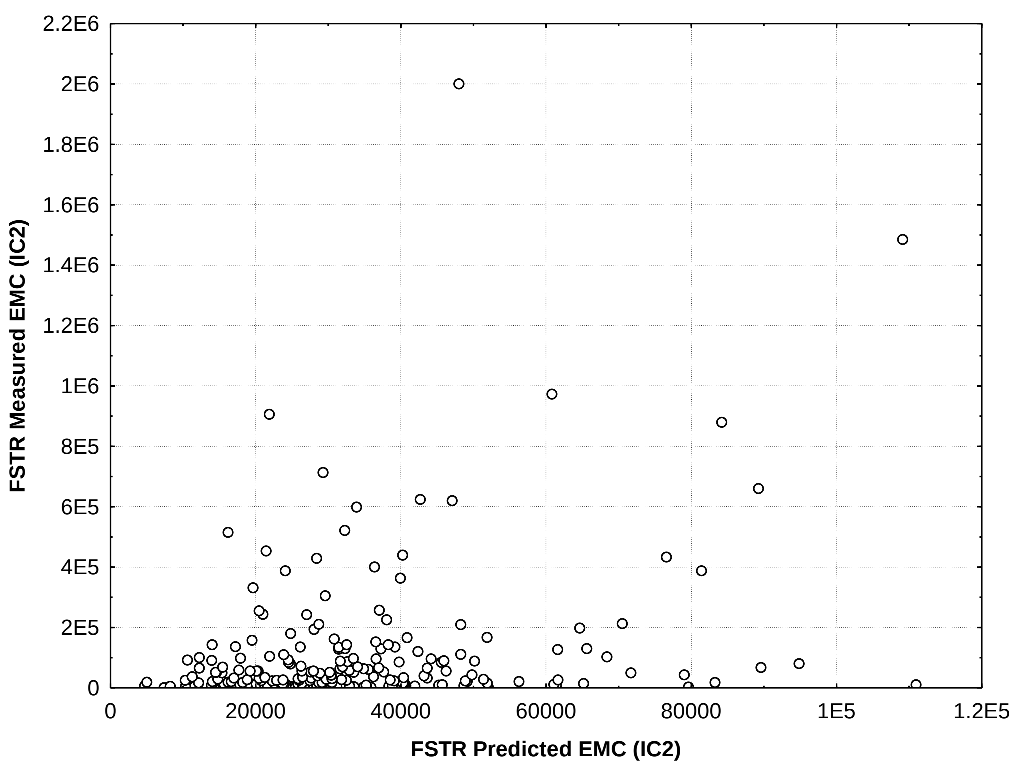
Graph F23. Scatterplot of Predicted EMC vs. Measured EMC for FCOL Group SFR



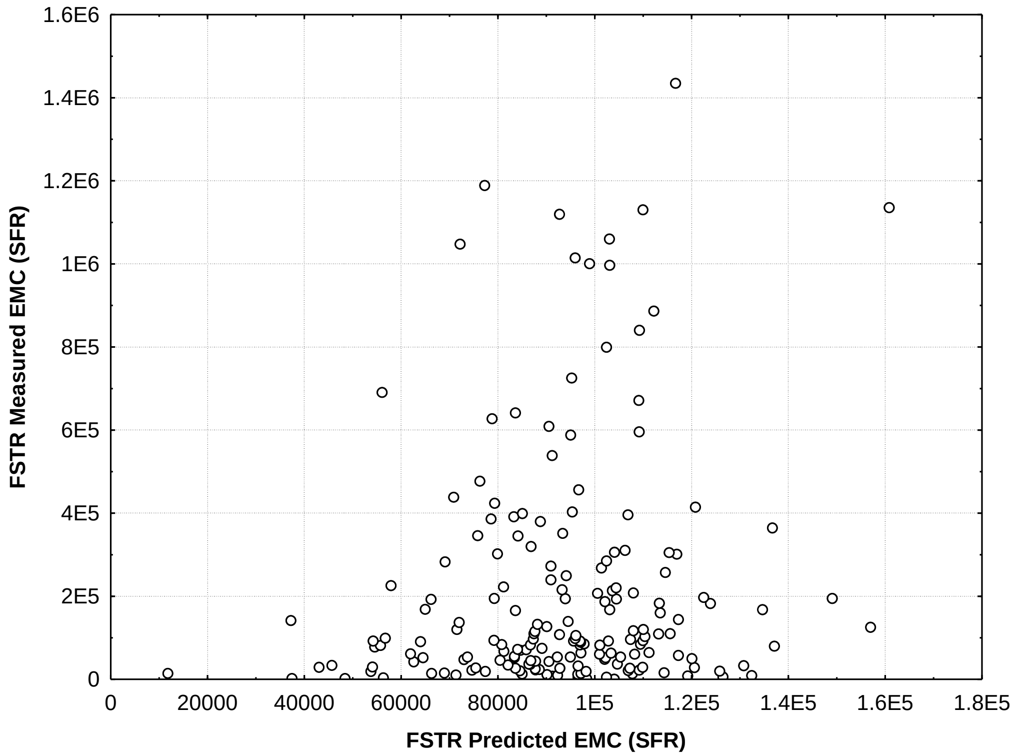
Graph F24. Scatterplot of Predicted EMC vs. Measured EMC for FCOL Group UND



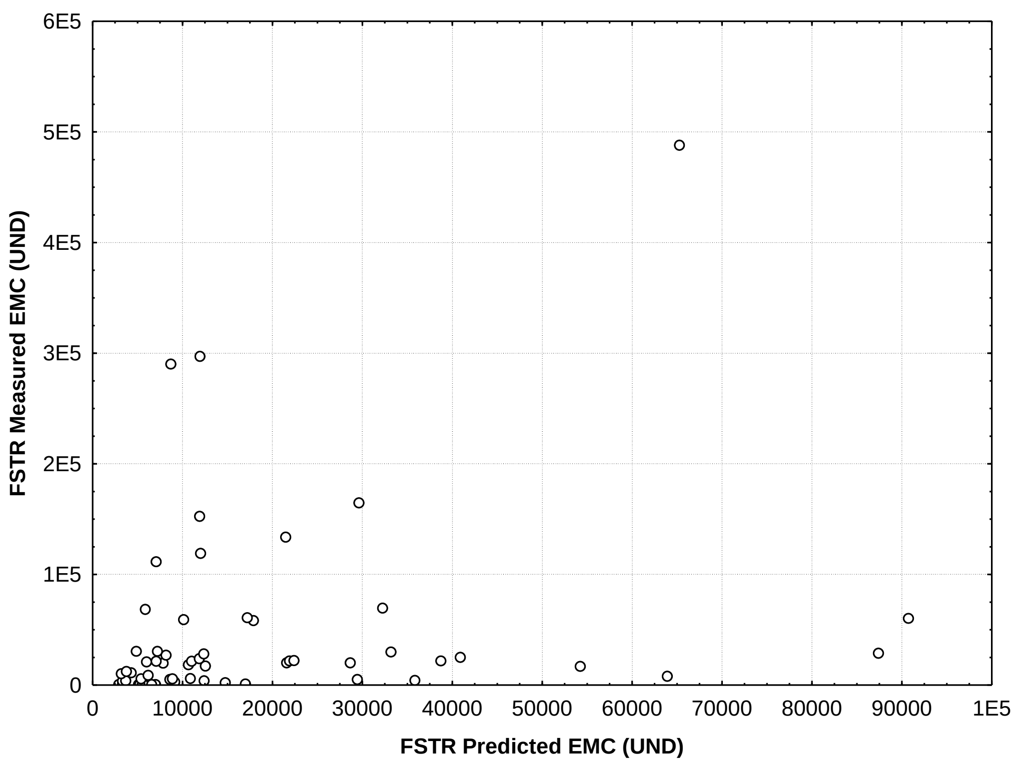
Graph F25. Scatterplot of Predicted EMC vs. Measured EMC for FSTR Group IC1



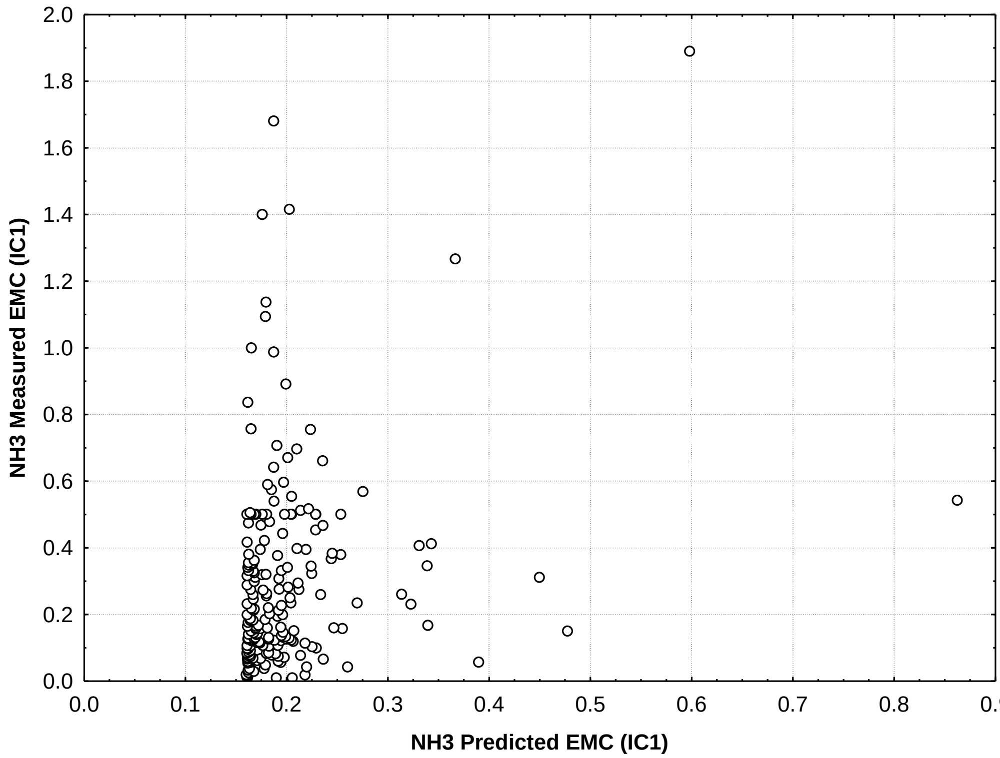
Graph F26. Scatterplot of Predicted EMC vs. Measured EMC for FSTR Group IC2



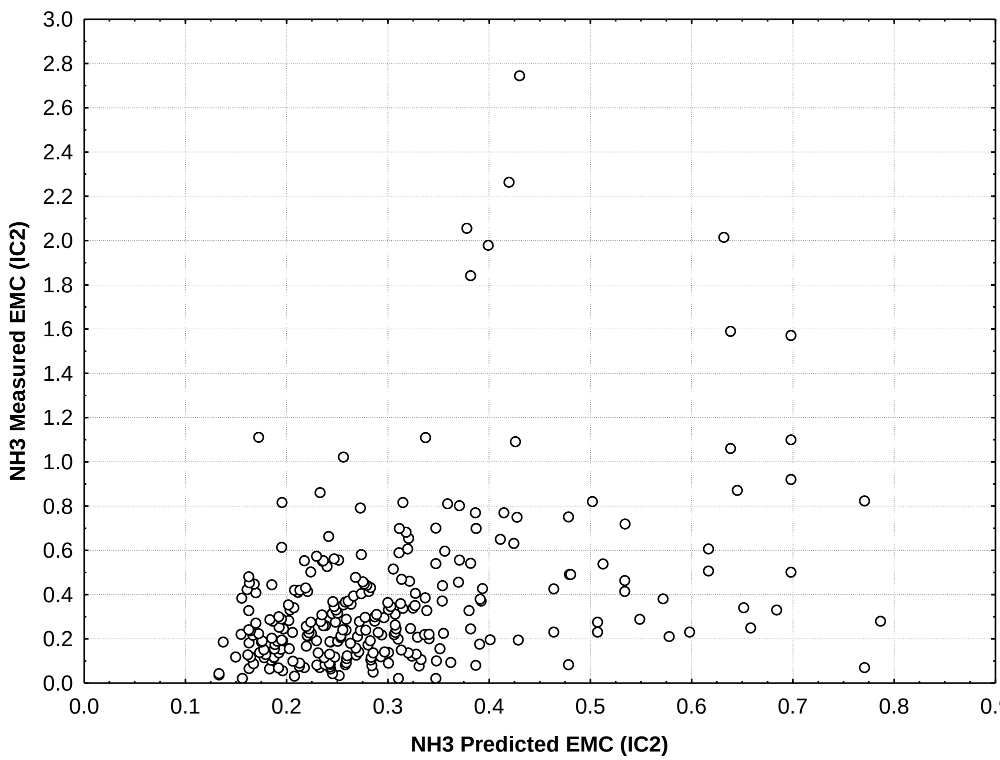
Graph F27. Scatterplot of Predicted EMC vs. Measured EMC for FSTR Group SFR



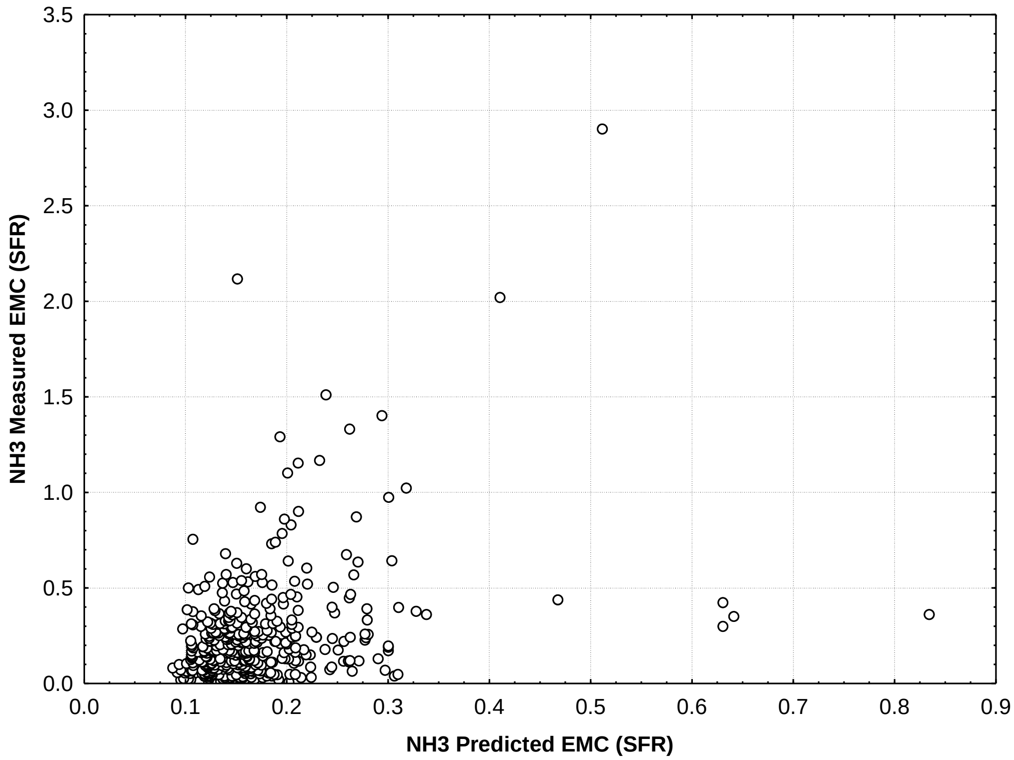
Graph F28. Scatterplot of Predicted EMC vs. Measured EMC for FSTR Group UND



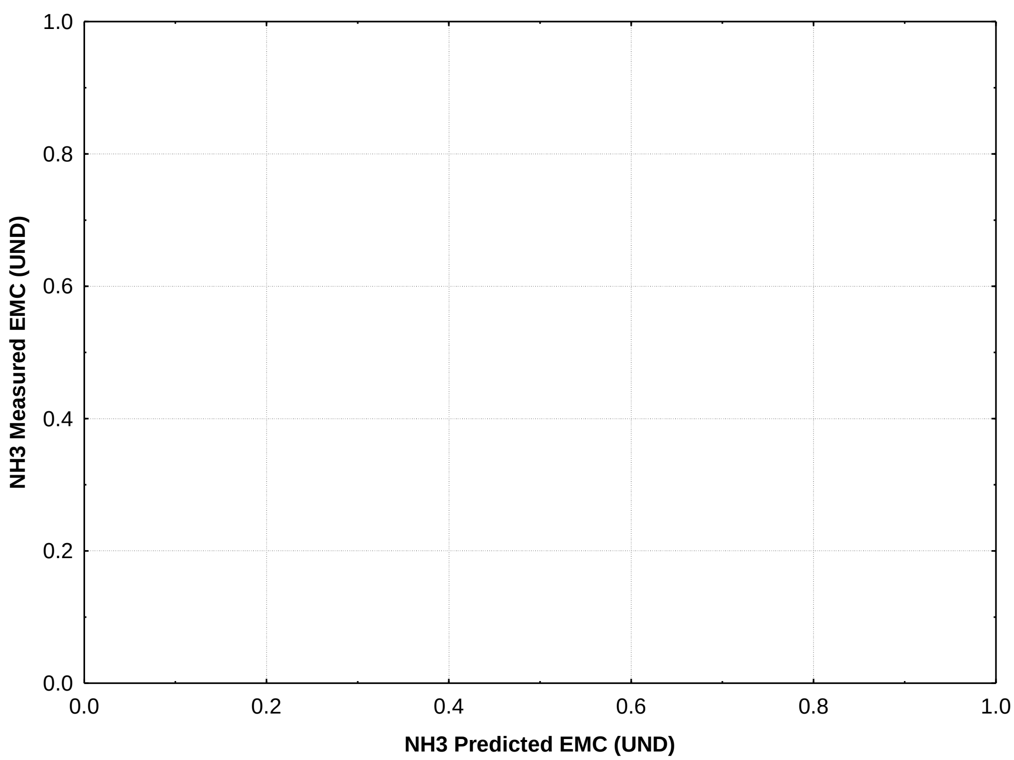
Graph F29. Scatterplot of Predicted EMC vs. Measured EMC for NH3 Group IC1



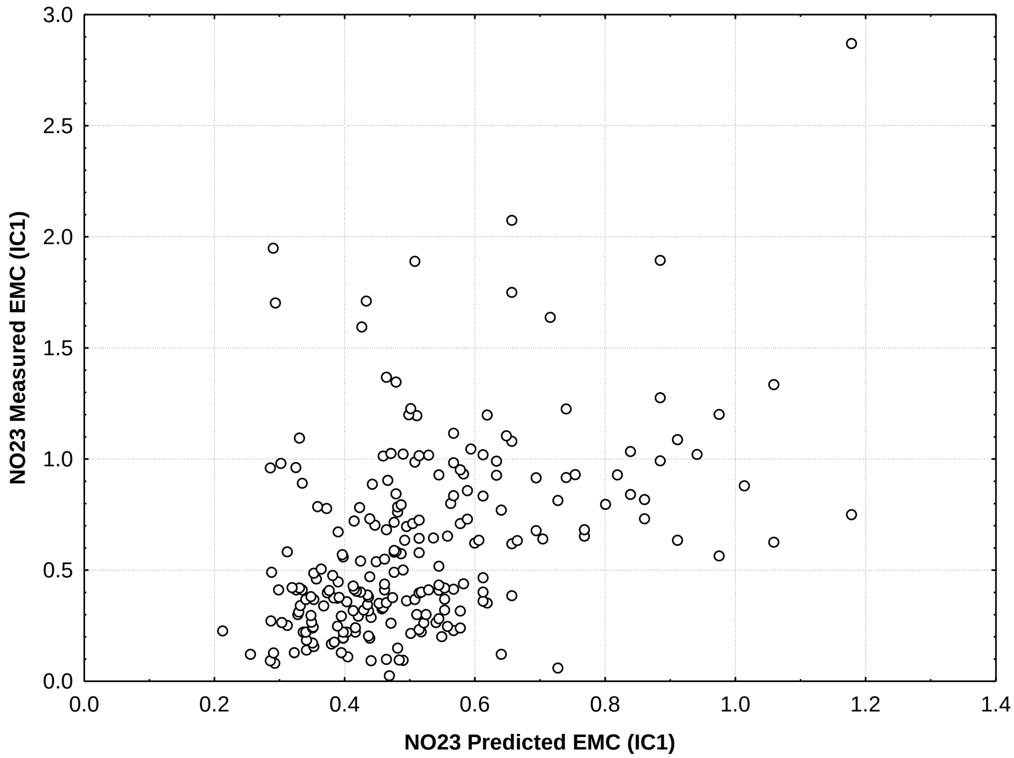
Graph F30. Scatterplot of Predicted EMC vs. Measured EMC for NH3 Group IC2



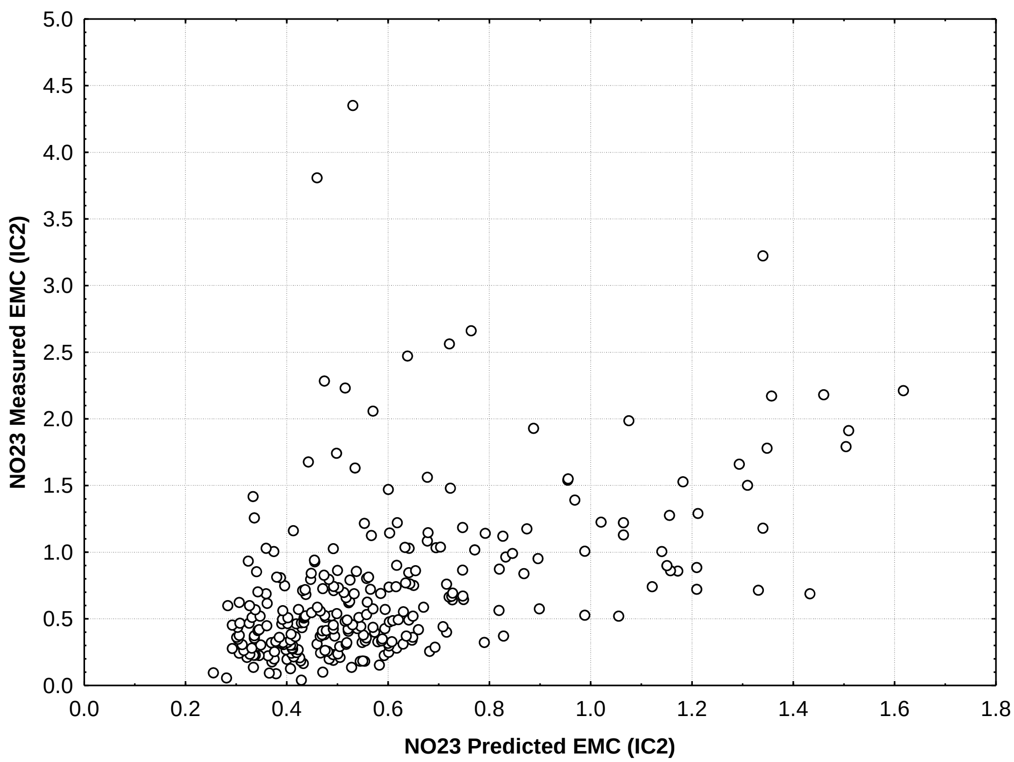
Graph F31. Scatterplot of Predicted EMC vs. Measured EMC for NH3 Group SFR



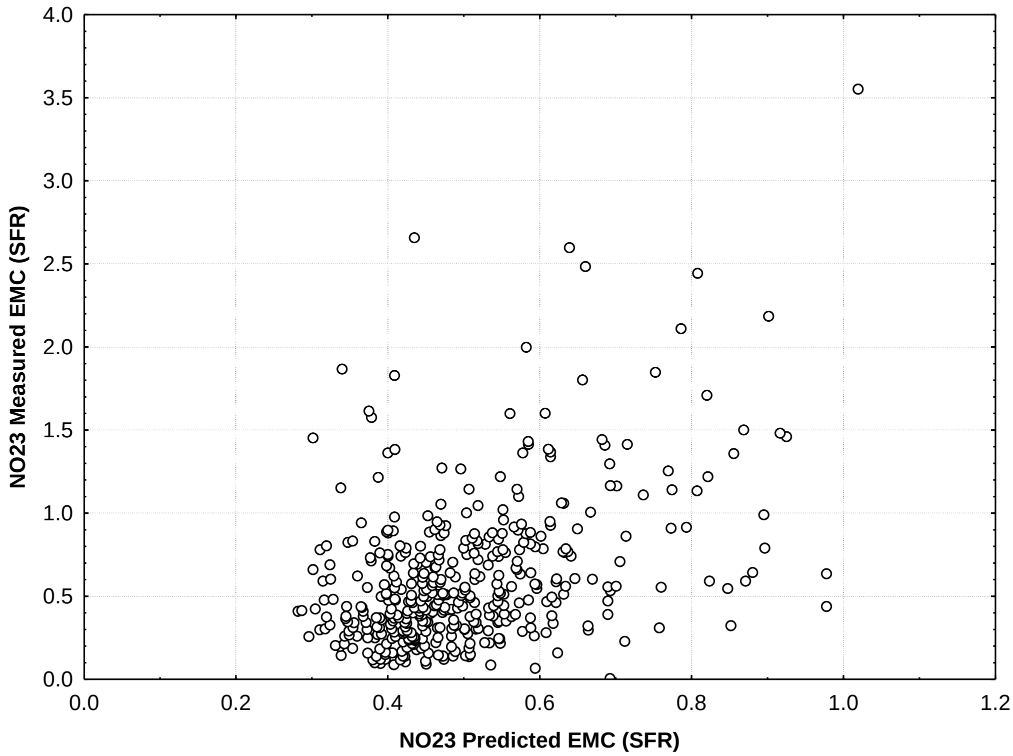
Graph F32. Scatterplot of Predicted EMC vs. Measured EMC for NH3 Group UND



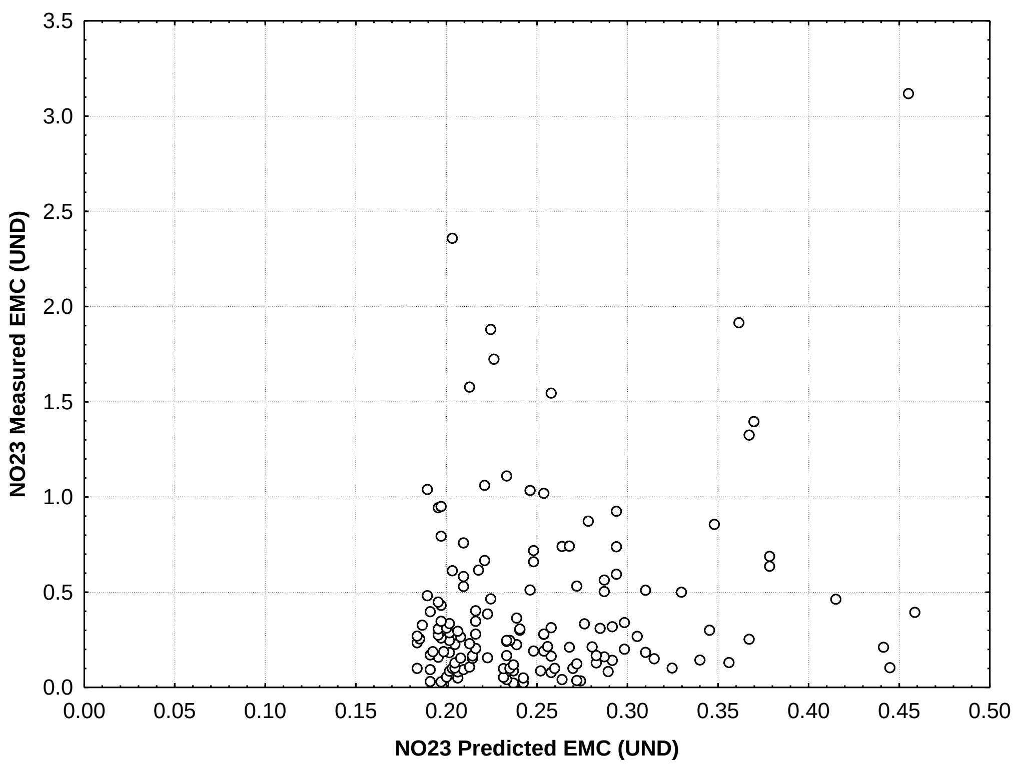
Graph F33. Scatterplot of Predicted EMC vs. Measured EMC for NO23 Group IC1



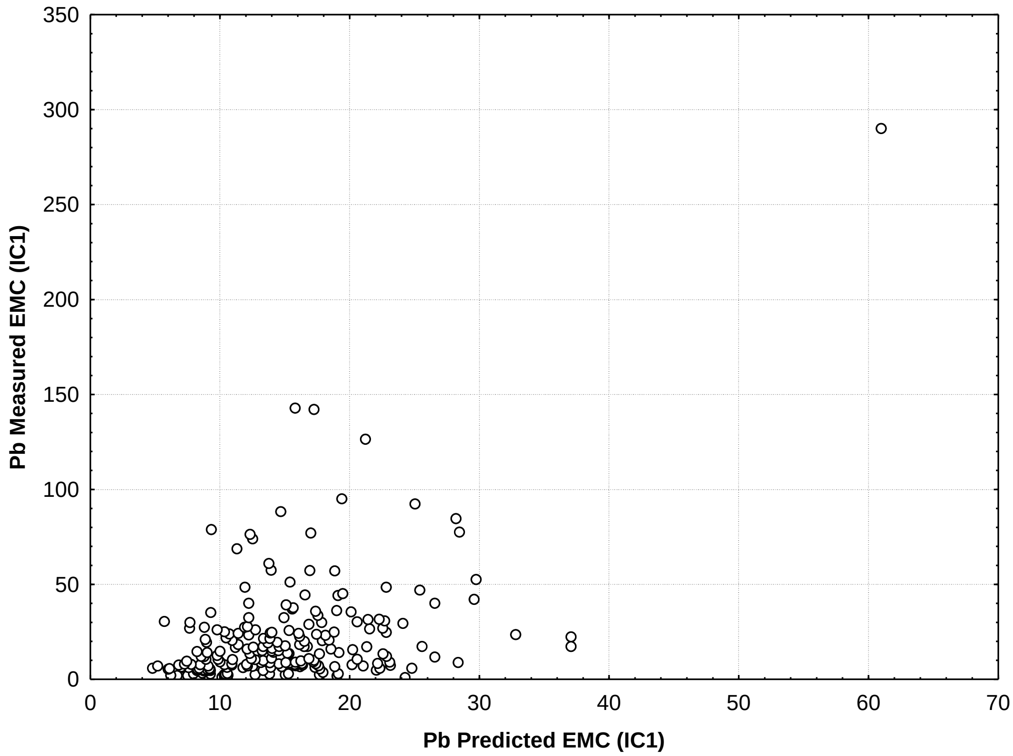
Graph F34. Scatterplot of Predicted EMC vs. Measured EMC for NO23 Group IC2



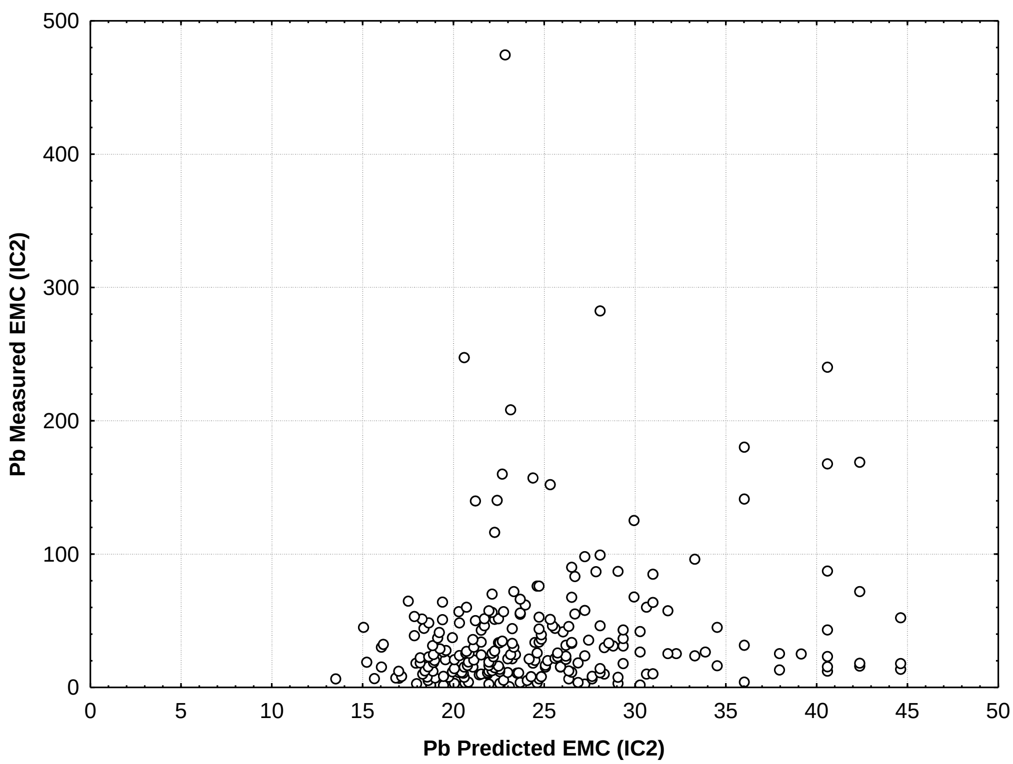
Graph F35. Scatterplot of Predicted EMC vs. Measured EMC for NO23 Group SFR



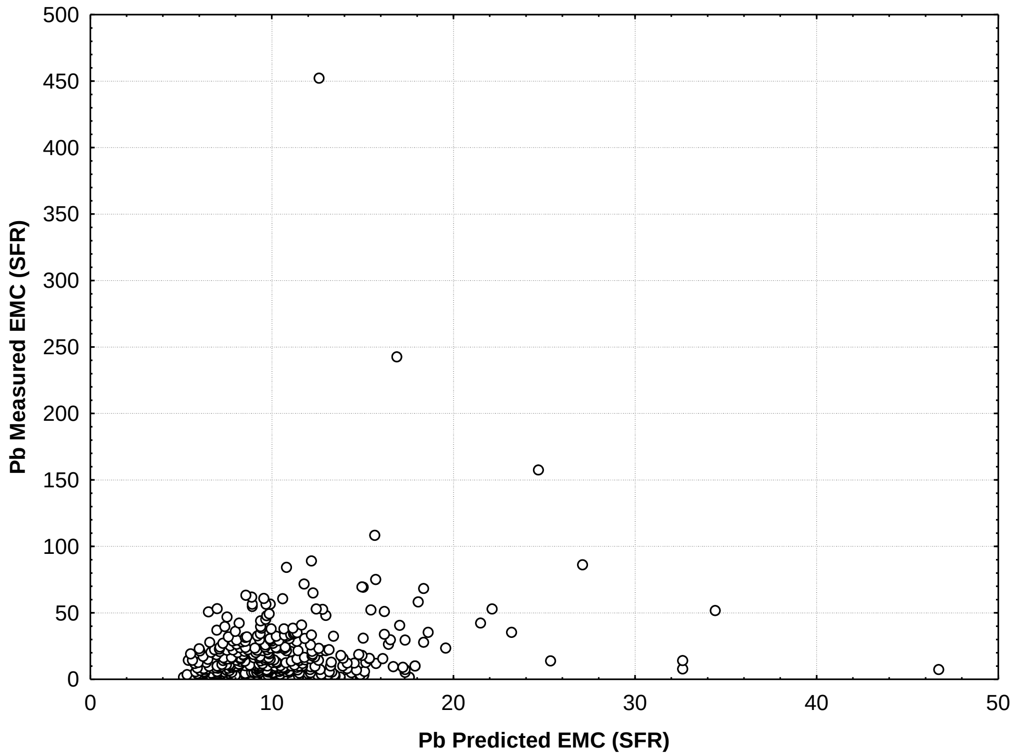
Graph F36. Scatterplot of Predicted EMC vs. Measured EMC for NO23 Group UND



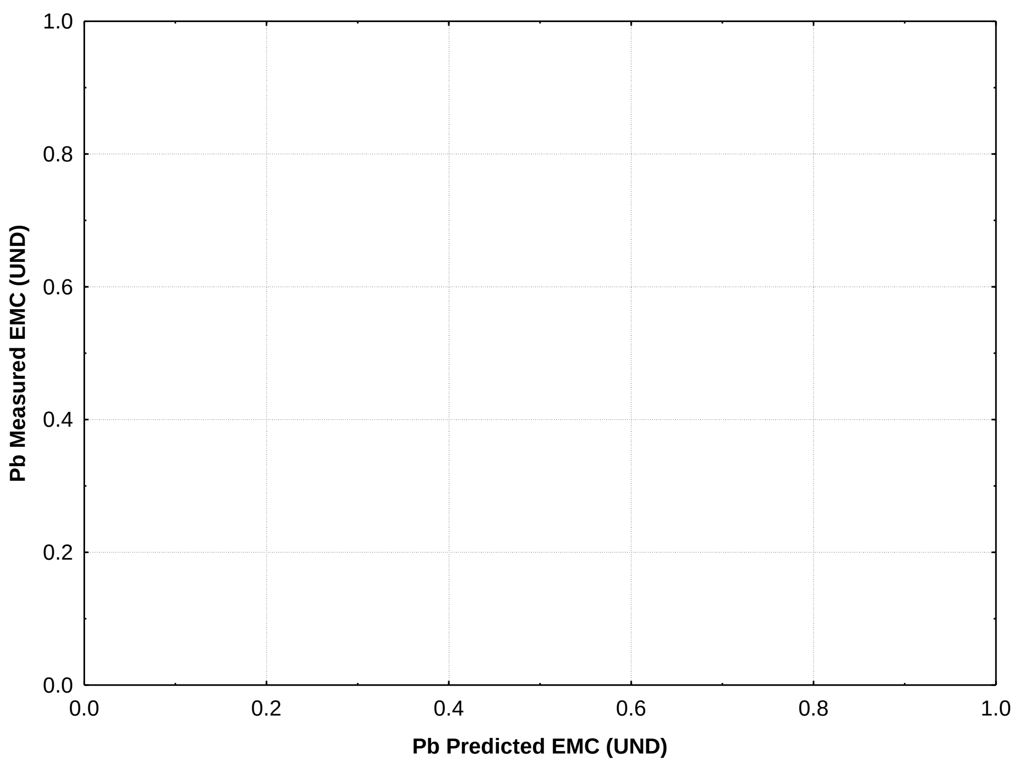
Graph F37. Scatterplot of Predicted EMC vs. Measured EMC for Pb Group IC1



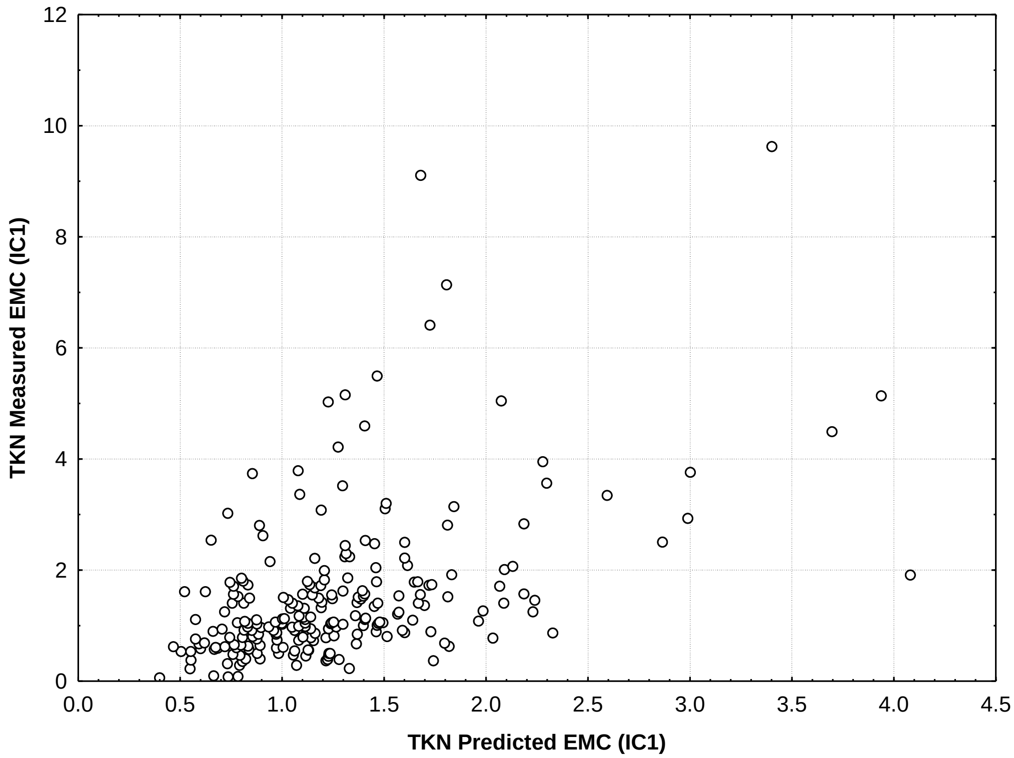
Graph F38. Scatterplot of Predicted EMC vs. Measured EMC for Pb Group IC2



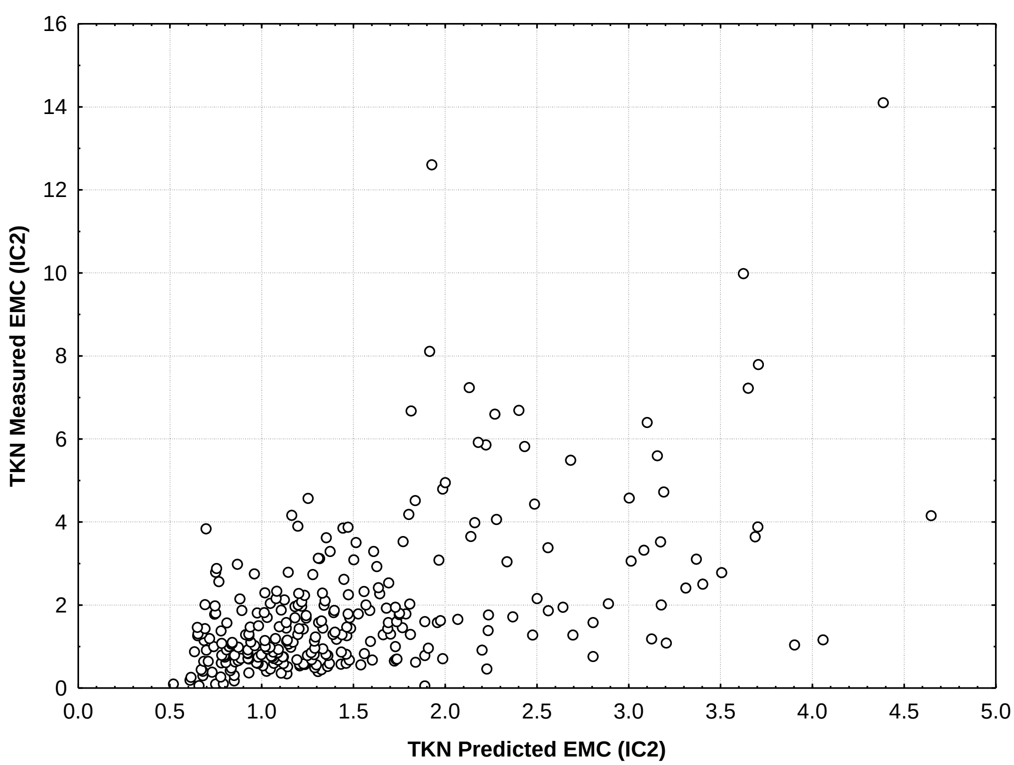
Graph F39. Scatterplot of Predicted EMC vs. Measured EMC for Pb Group SFR



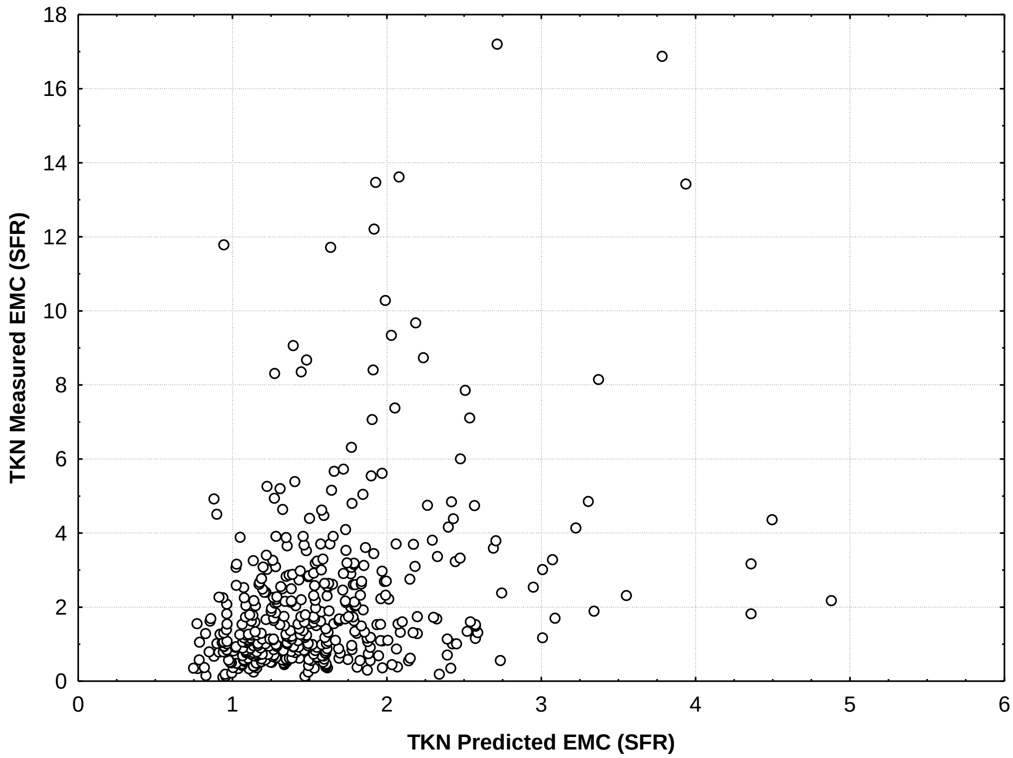
Graph F40. Scatterplot of Predicted EMC vs. Measured EMC for Pb Group UND



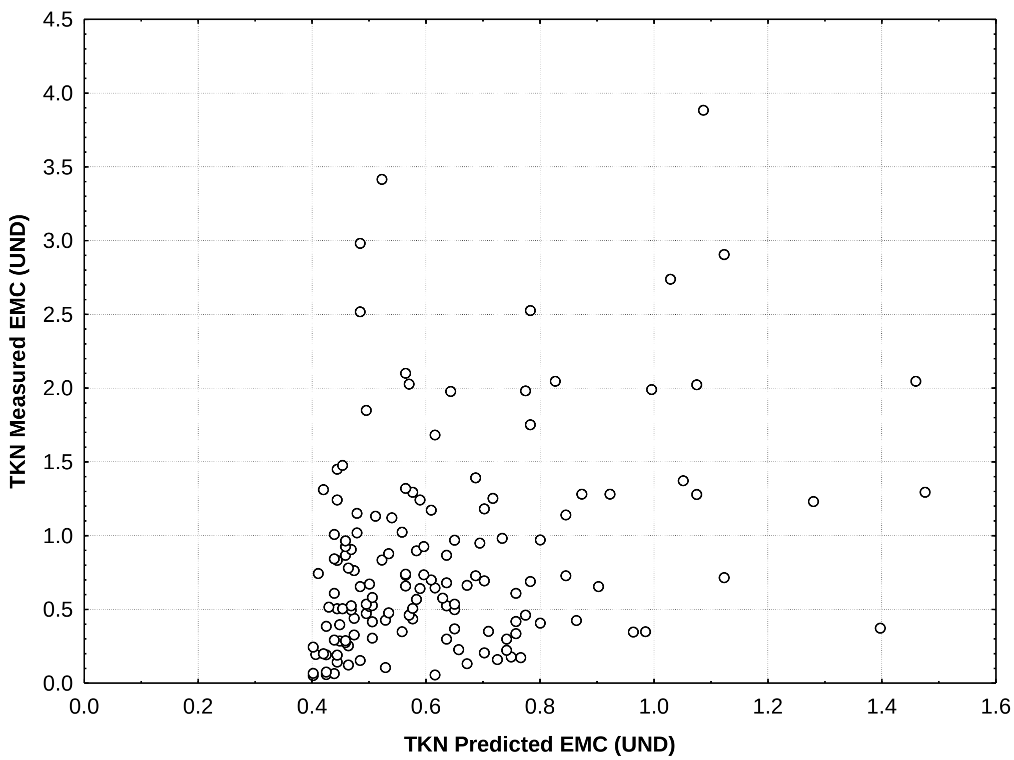
Graph F41. Scatterplot of Predicted EMC vs. Measured EMC for TKN Group IC1



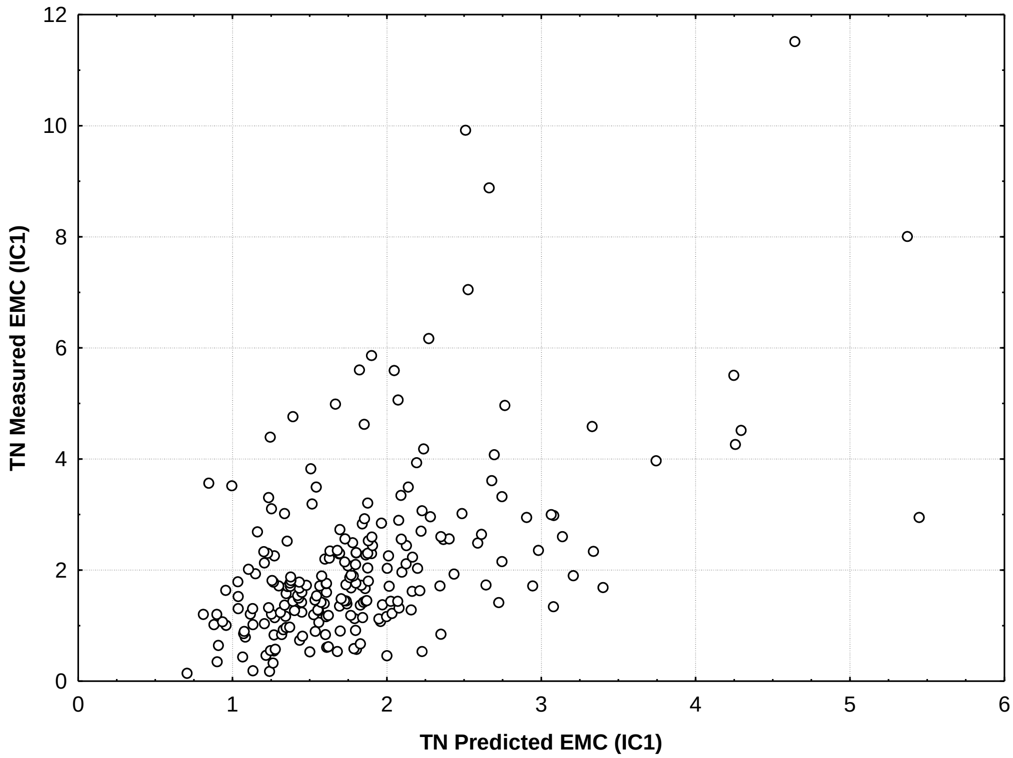
Graph F42. Scatterplot of Predicted EMC vs. Measured EMC for TKN Group IC2



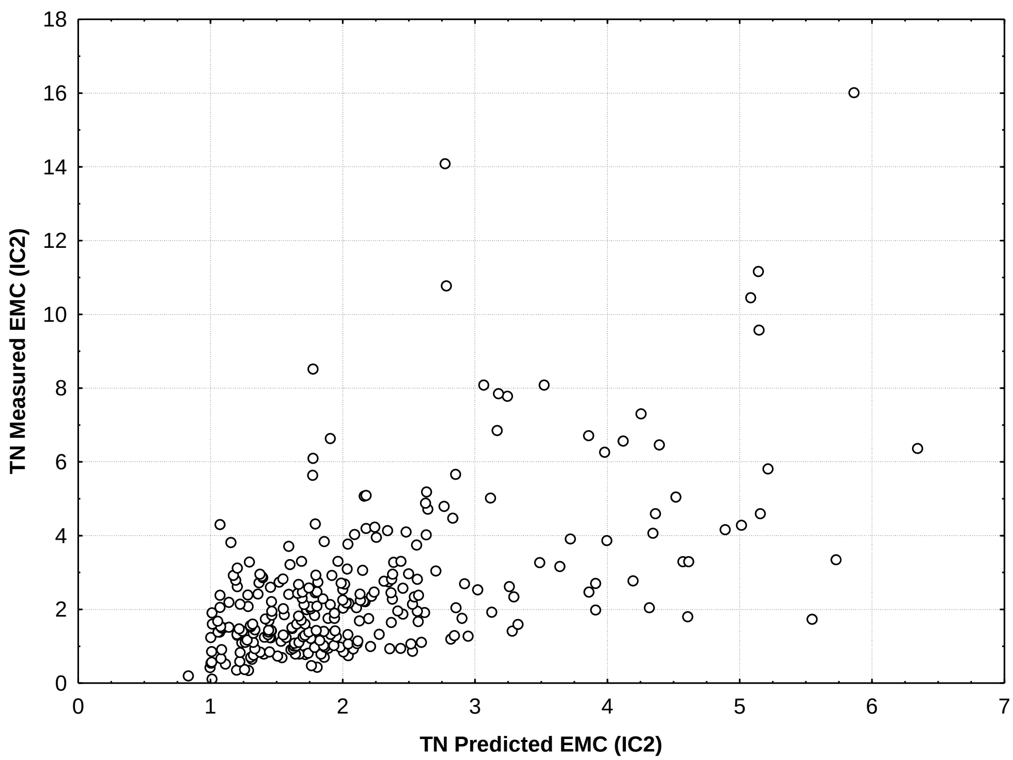
Graph F43. Scatterplot of Predicted EMC vs. Measured EMC for TKN Group SFR



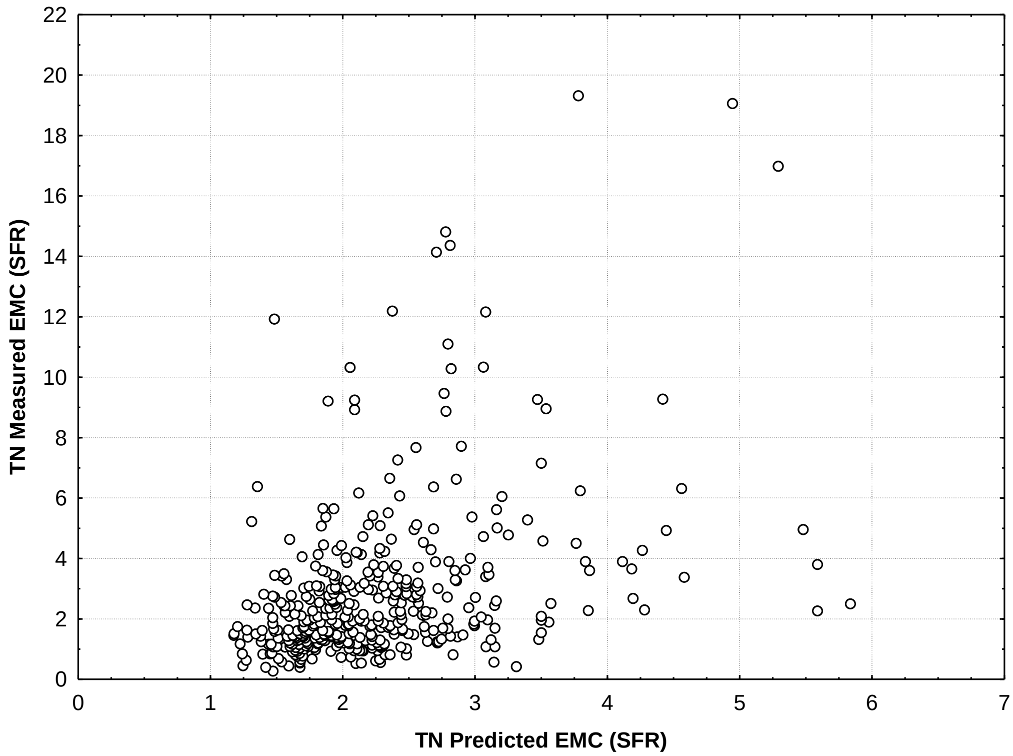
Graph F44. Scatterplot of Predicted EMC vs. Measured EMC for TKN Group UND



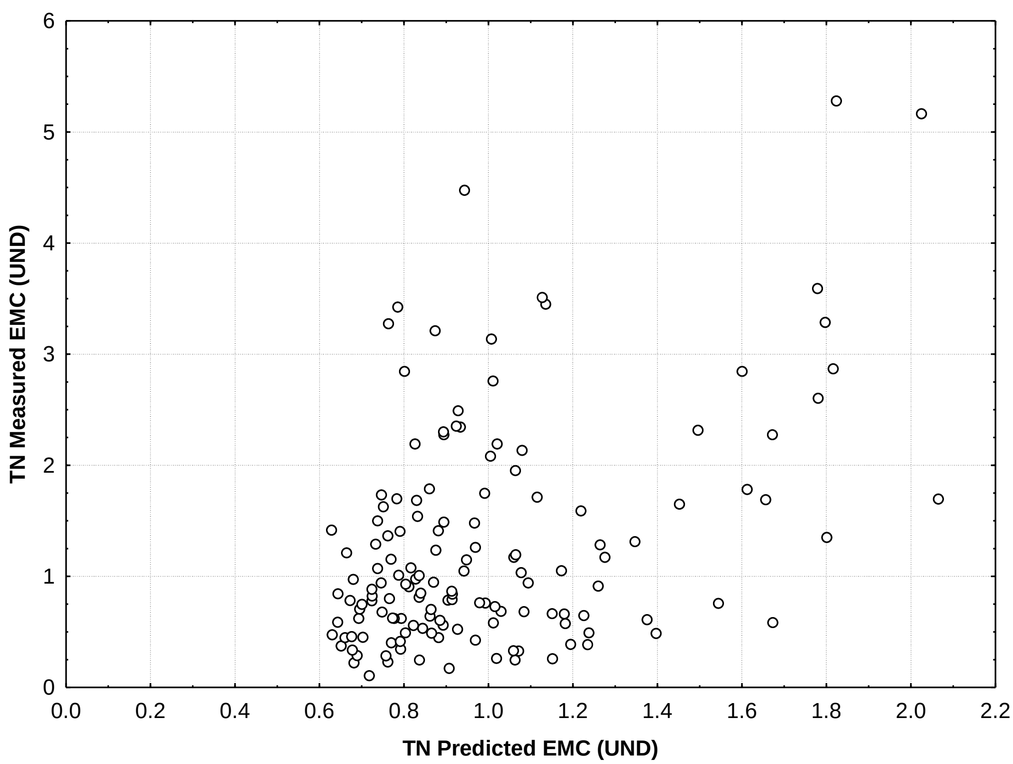
Graph F45. Scatterplot of Predicted EMC vs. Measured EMC for TN Group IC1



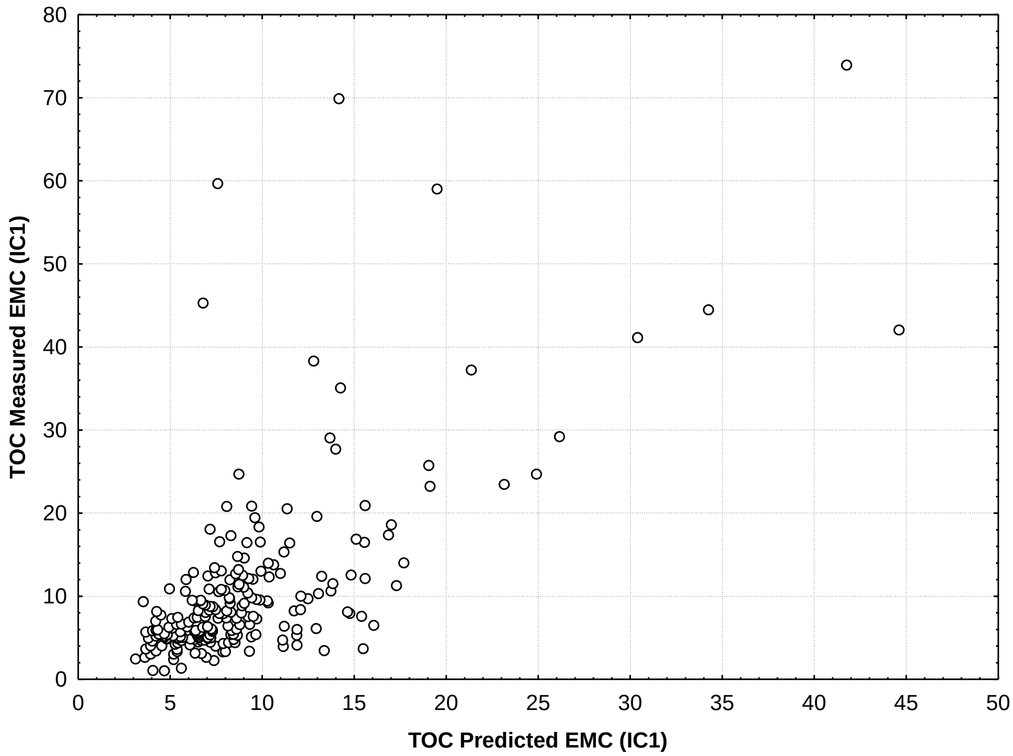
Graph F46. Scatterplot of Predicted EMC vs. Measured EMC for TN Group IC2



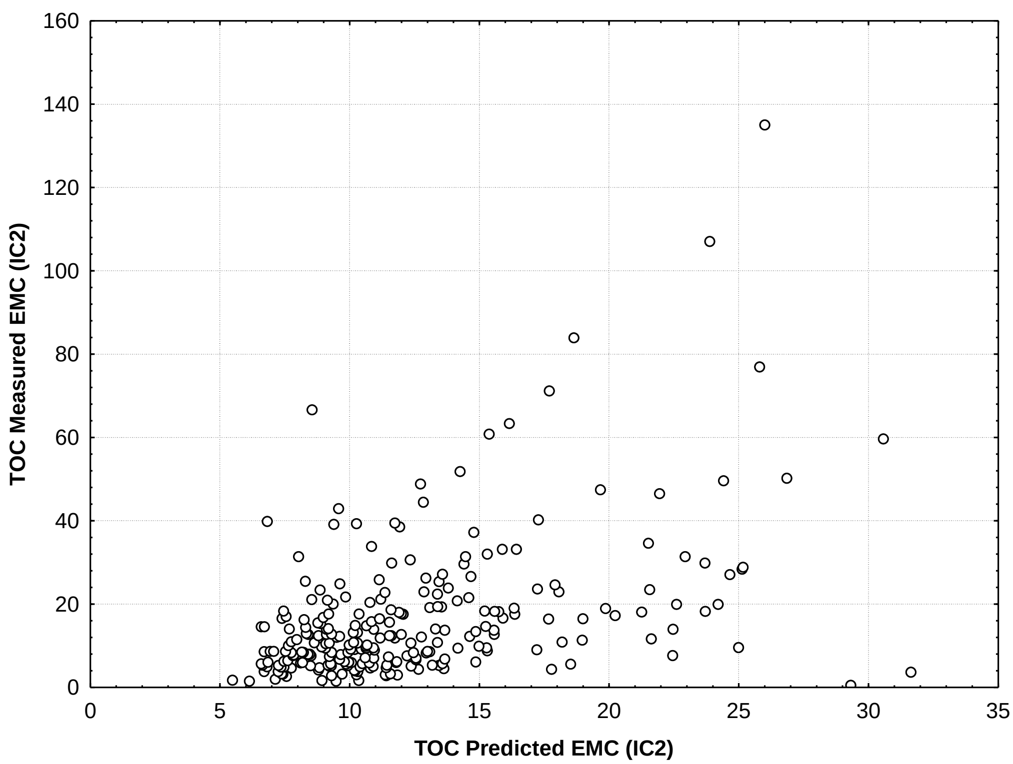
Graph F47. Scatterplot of Predicted EMC vs. Measured EMC for TN Group SFR



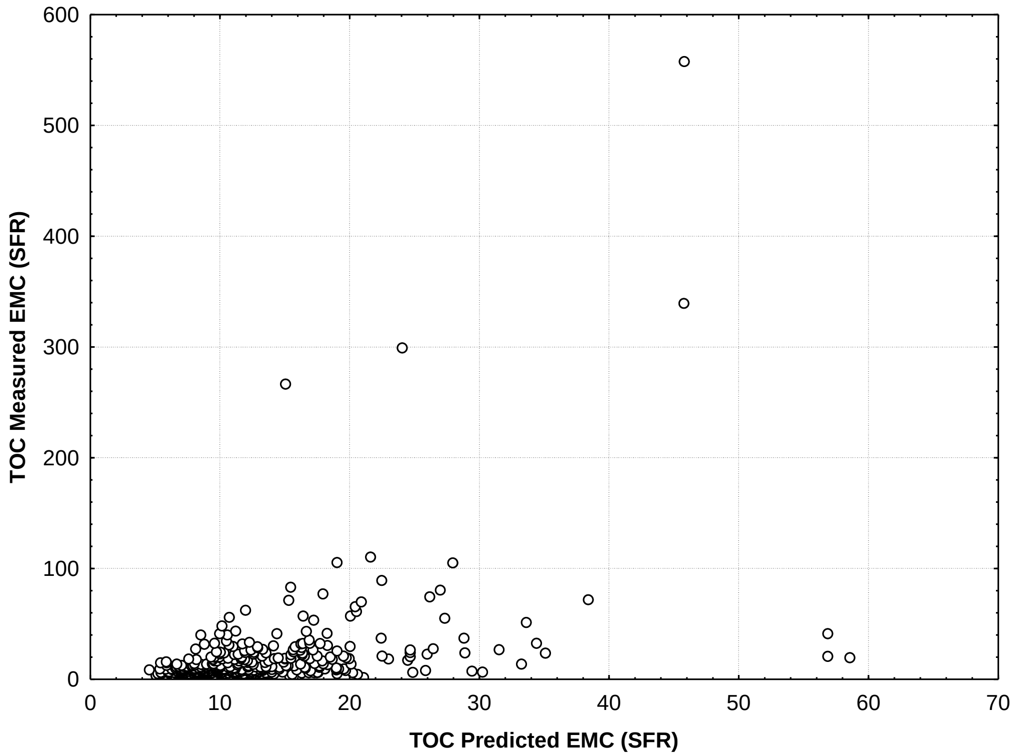
Graph F48. Scatterplot of Predicted EMC vs. Measured EMC for TN Group UND



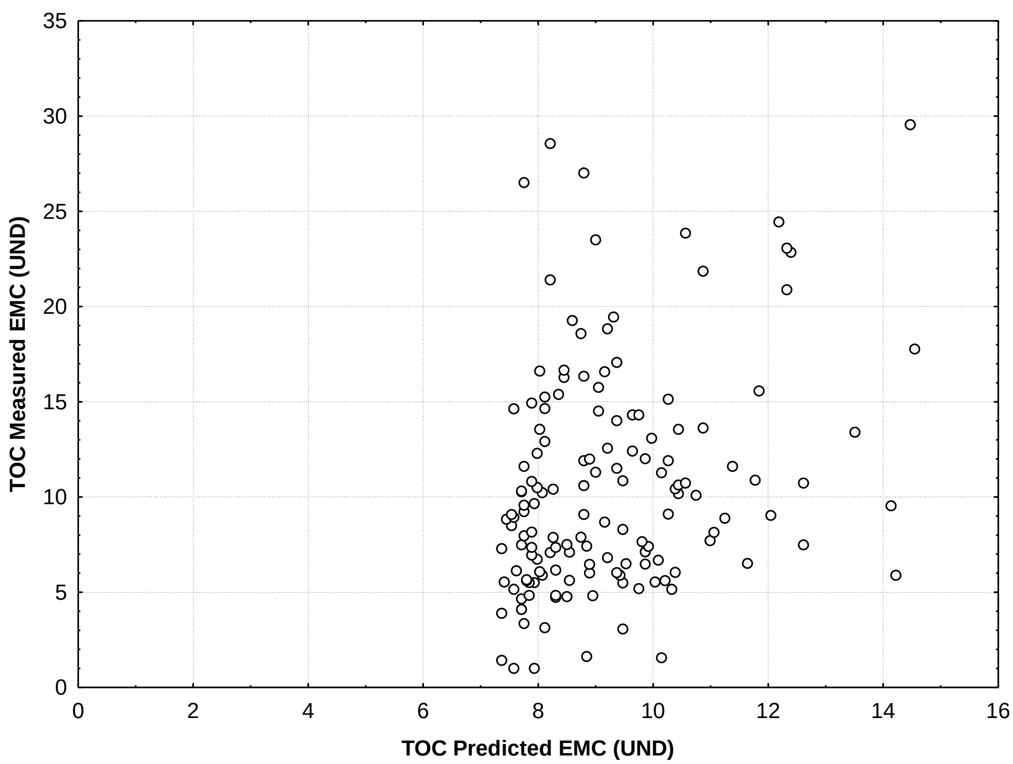
Graph F49. Scatterplot of Predicted EMC vs. Measured EMC for TOC Group IC1



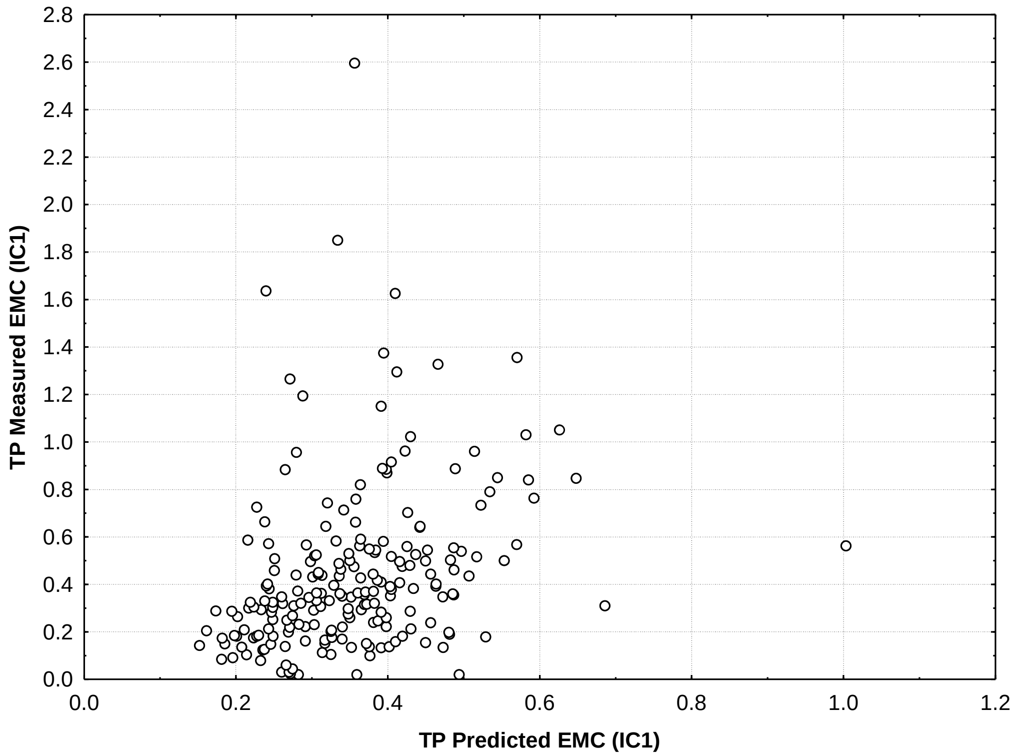
Graph F50. Scatterplot of Predicted EMC vs. Measured EMC for TOC Group IC2



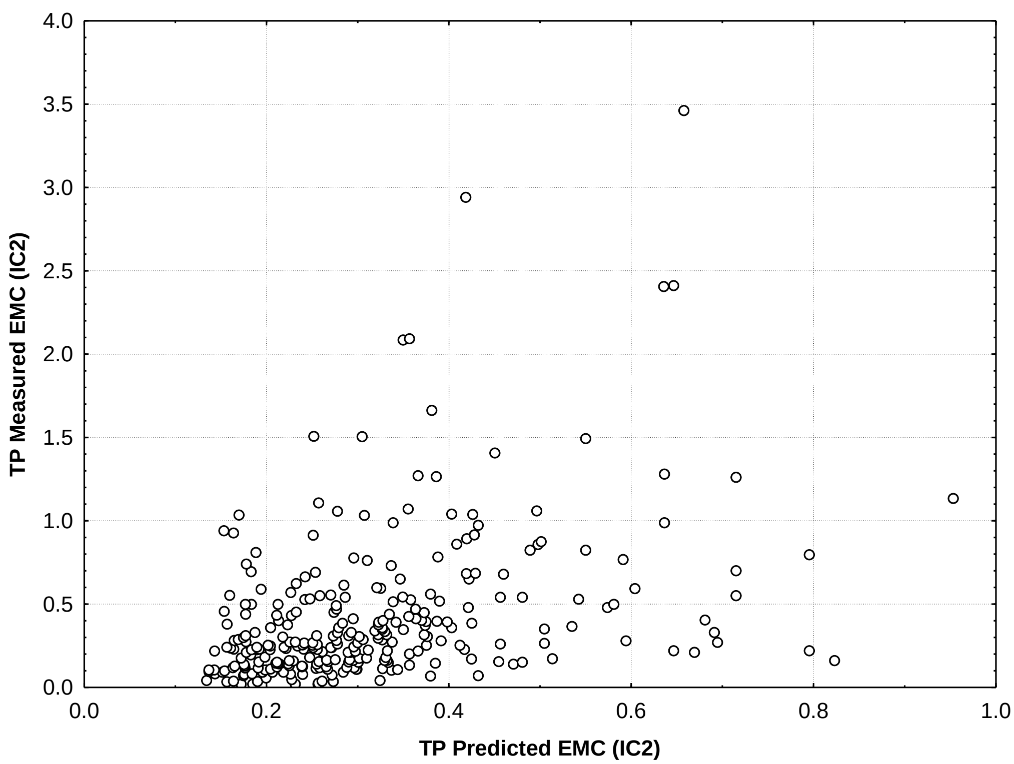
Graph F51. Scatterplot of Predicted EMC vs. Measured EMC for TOC Group SFR



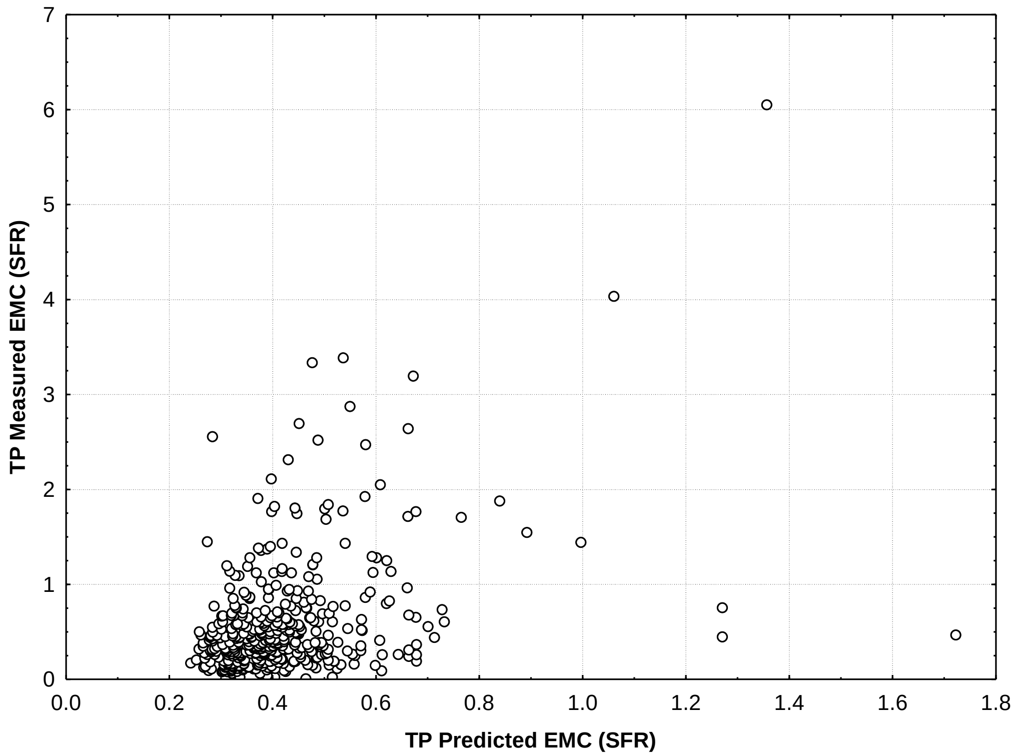
Graph F52. Scatterplot of Predicted EMC vs. Measured EMC for TOC Group UND



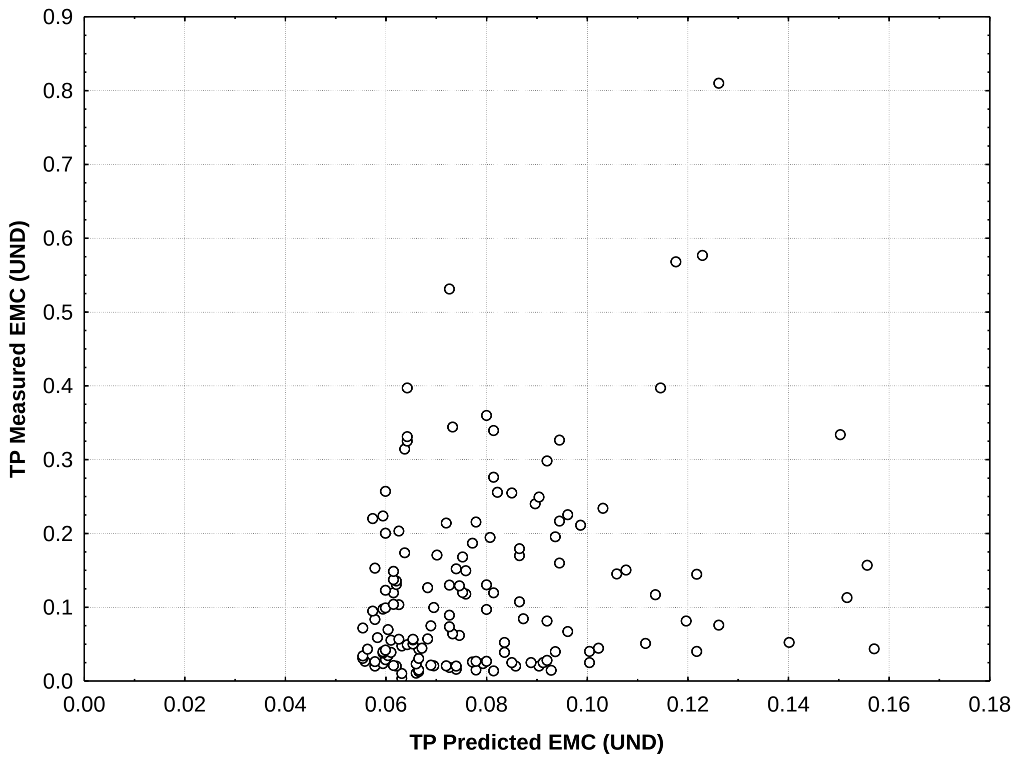
Graph F53. Scatterplot of Predicted EMC vs. Measured EMC for TP Group IC1



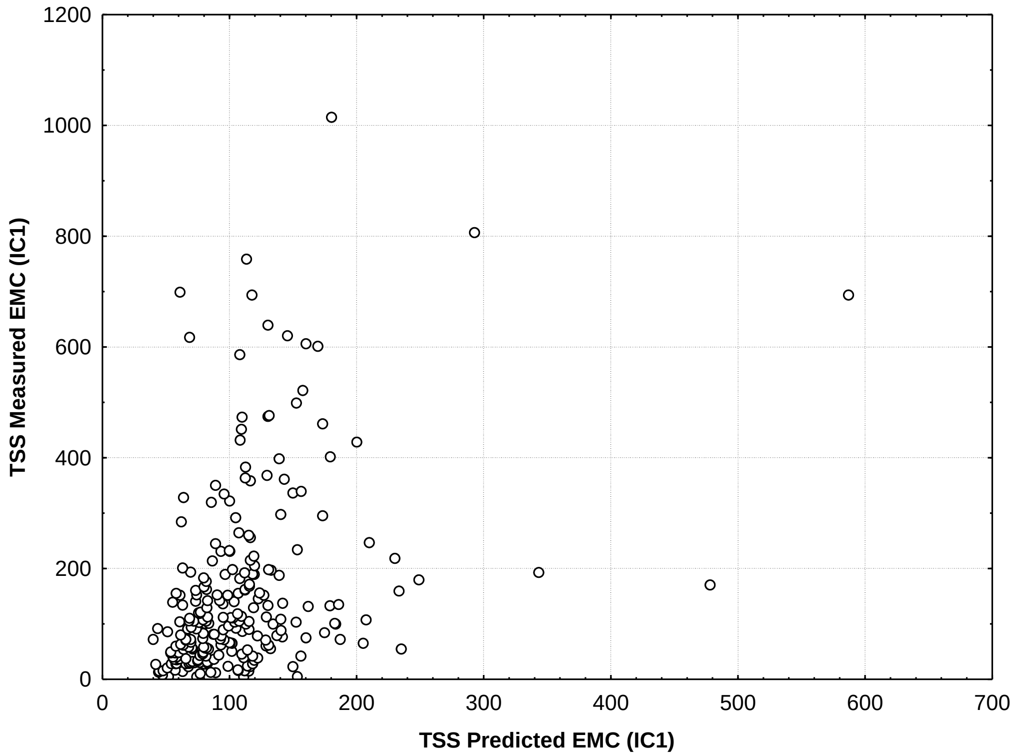
Graph F54. Scatterplot of Predicted EMC vs. Measured EMC for TP Group IC2



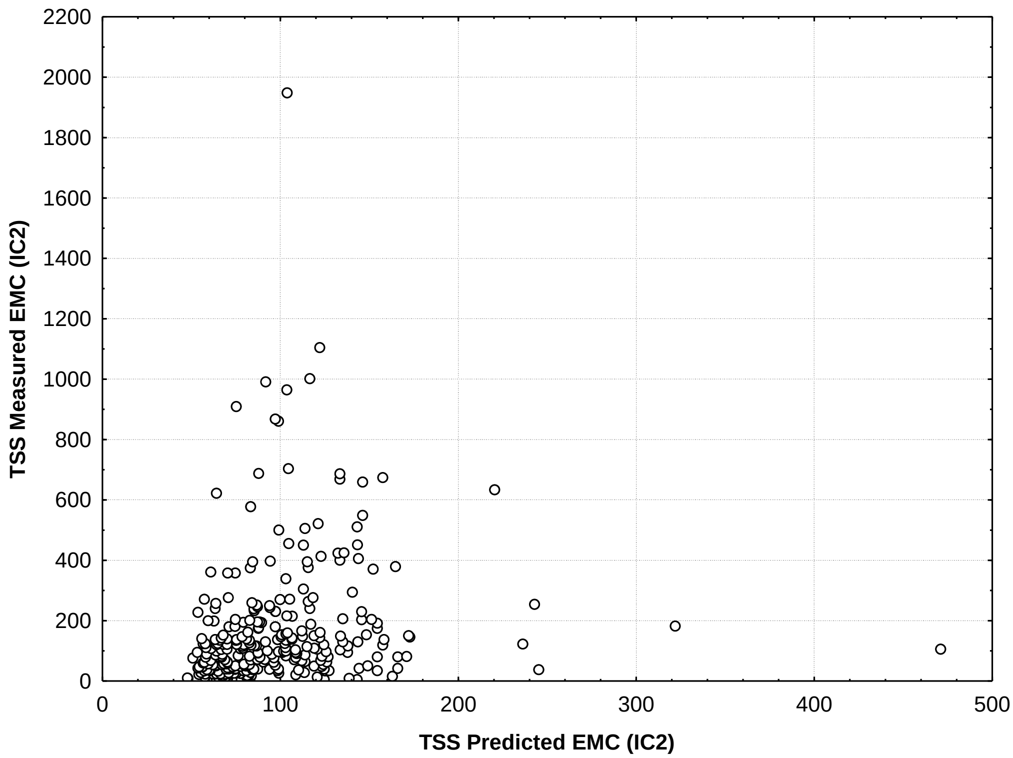
Graph F55. Scatterplot of Predicted EMC vs. Measured EMC for TP Group SFR



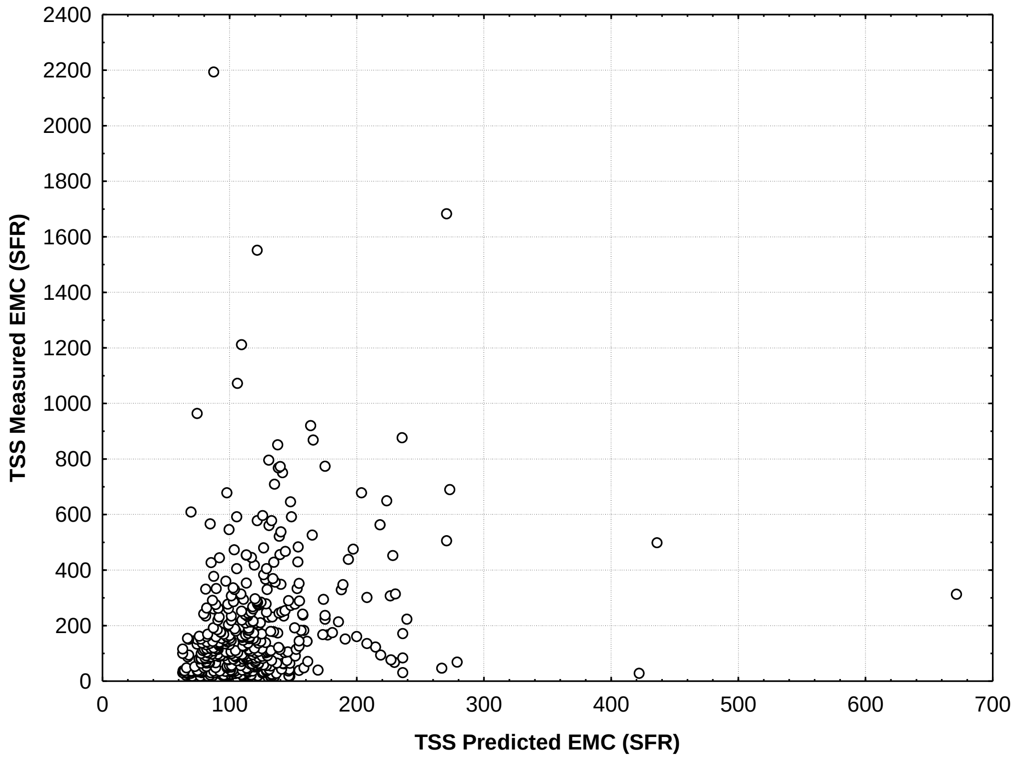
Graph F56. Scatterplot of Predicted EMC vs. Measured EMC for TP Group UND



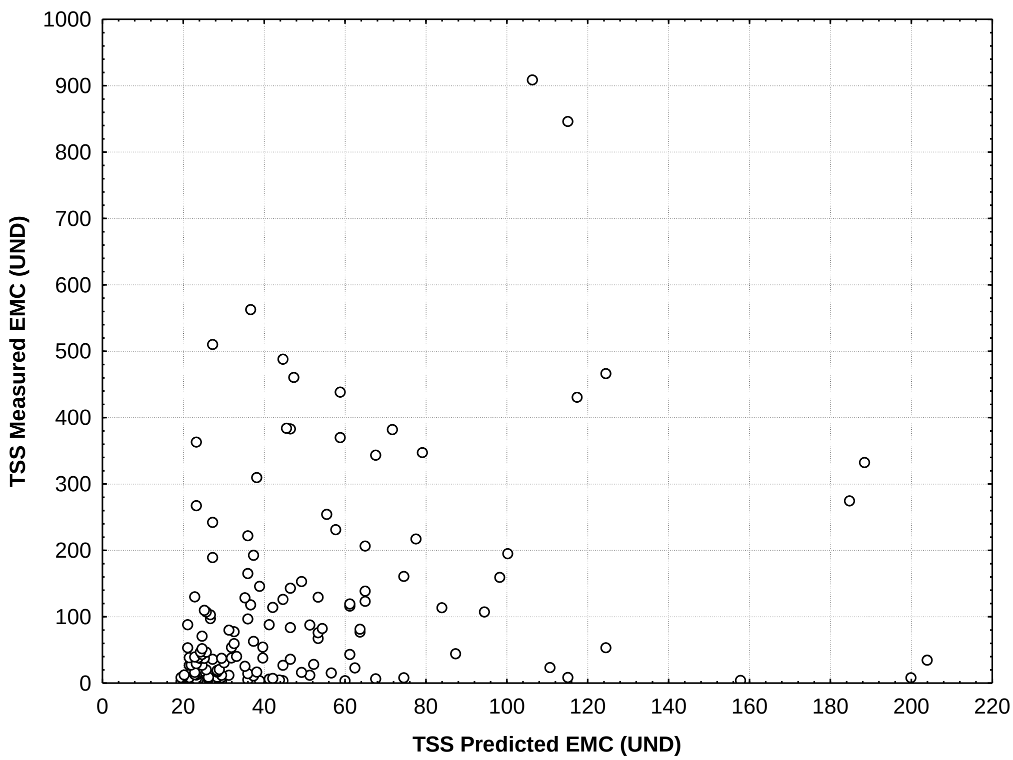
Graph F57. Scatterplot of Predicted EMC vs. Measured EMC for TSS Group IC1



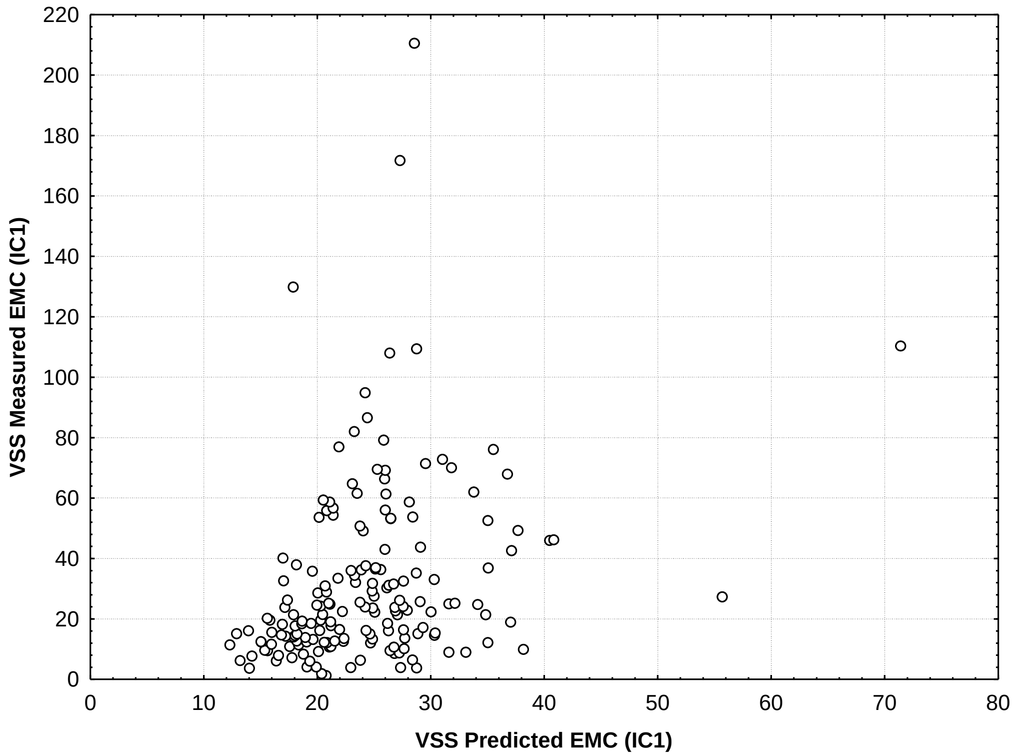
Graph F58. Scatterplot of Predicted EMC vs. Measured EMC for TSS Group IC2



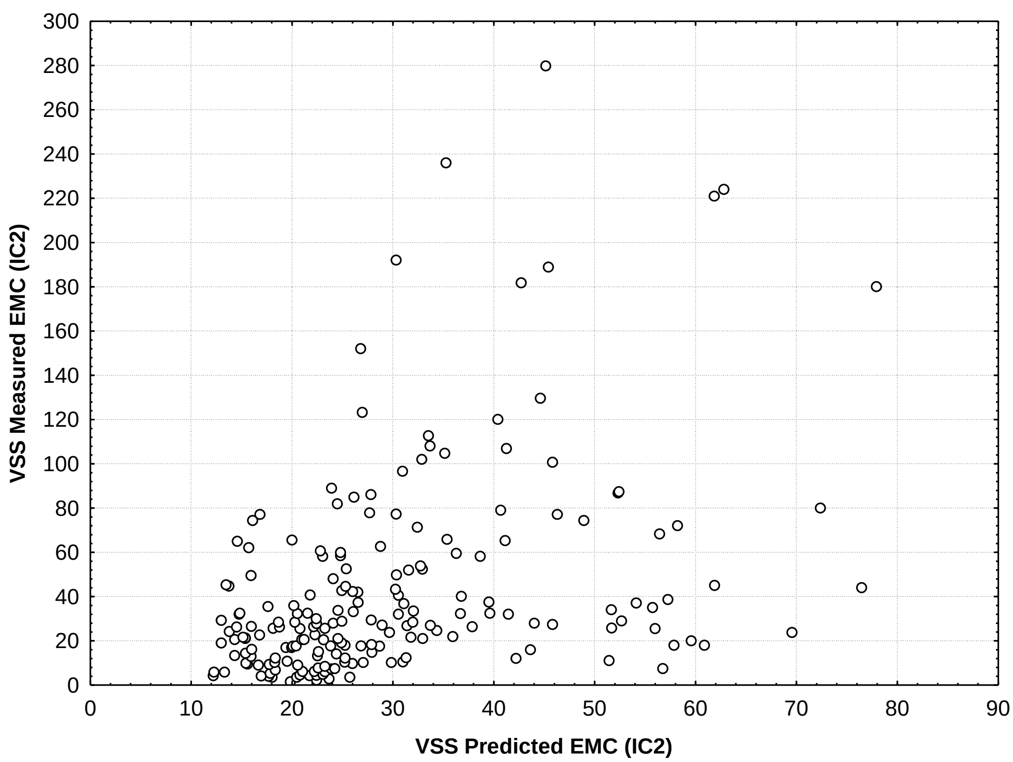
Graph F59. Scatterplot of Predicted EMC vs. Measured EMC for TSS Group SFR



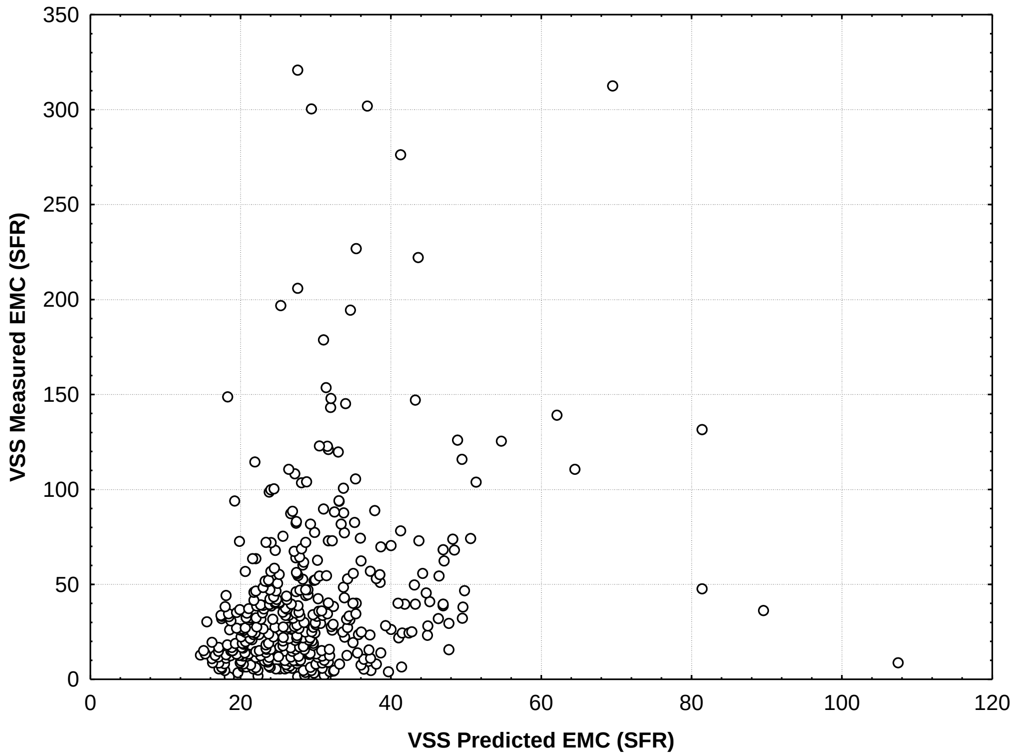
Graph F60. Scatterplot of Predicted EMC vs. Measured EMC for TSS Group UND



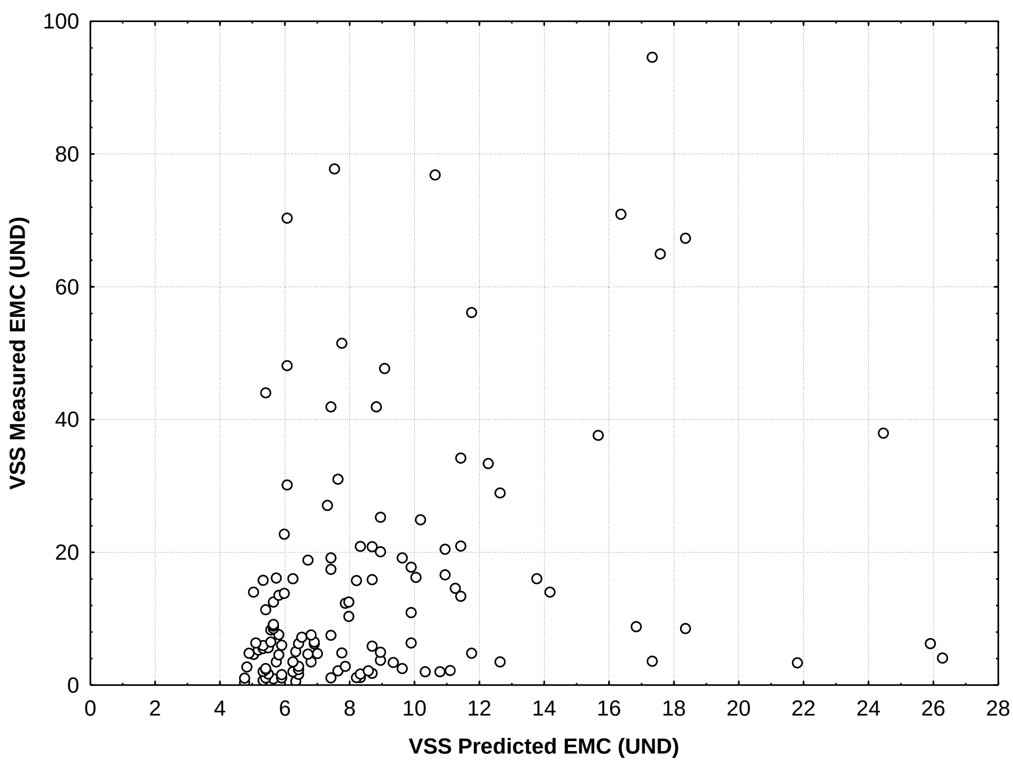
Graph F61. Scatterplot of Predicted EMC vs. Measured EMC for VSS Group IC1



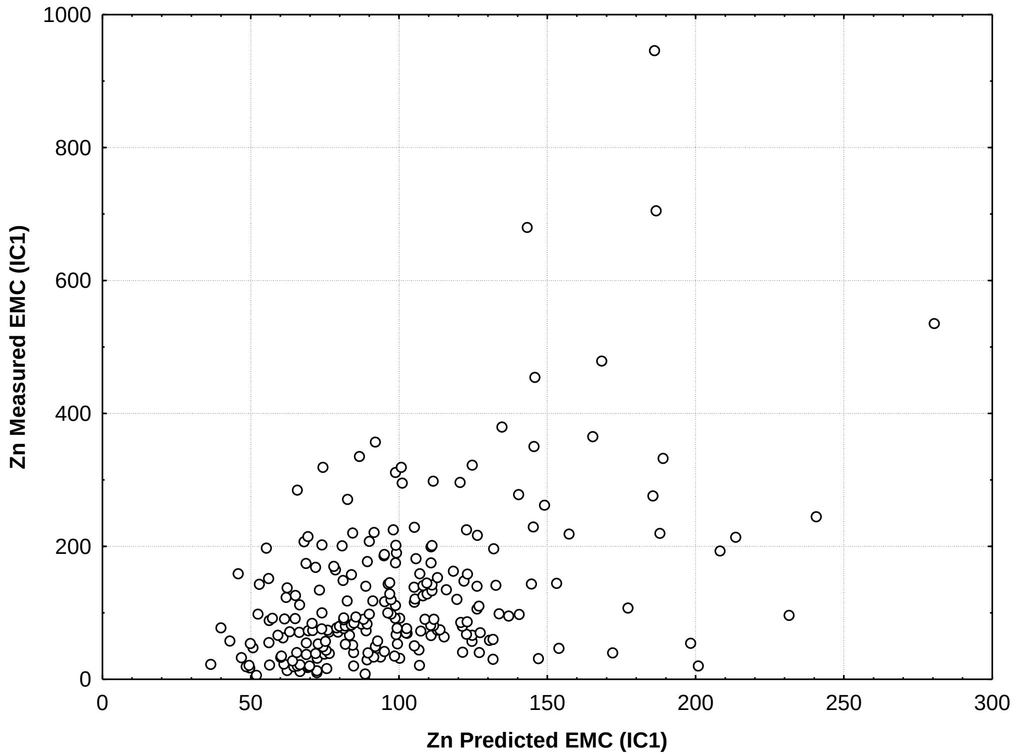
Graph F62. Scatterplot of Predicted EMC vs. Measured EMC for VSS Group IC2



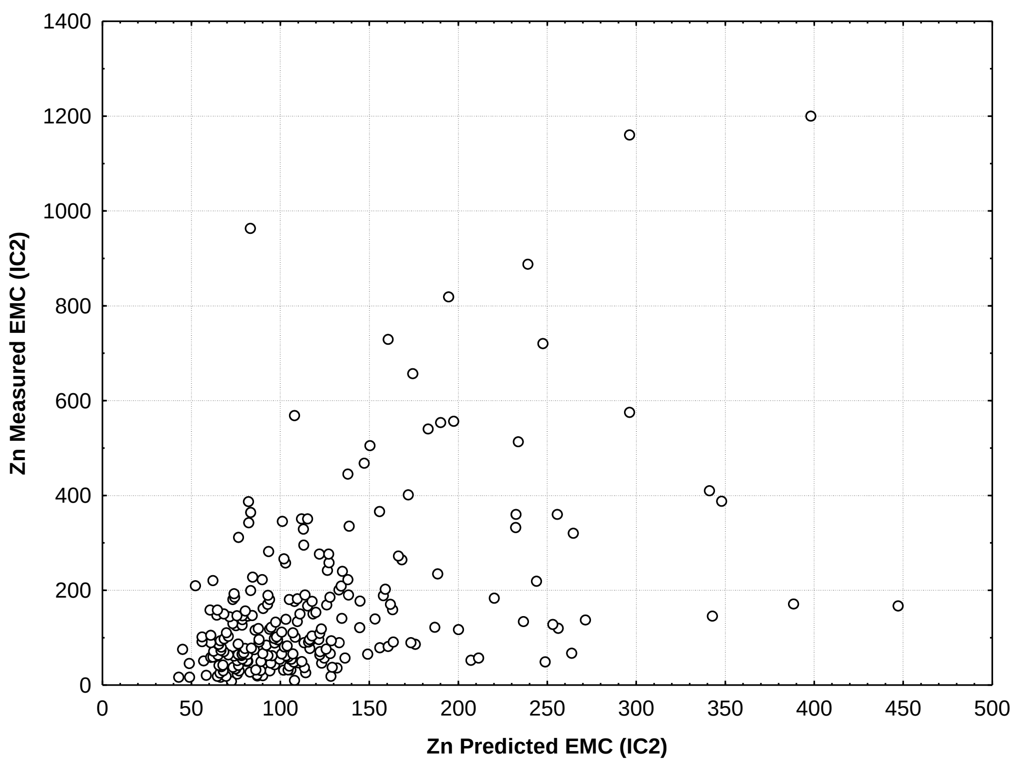
Graph F63. Scatterplot of Predicted EMC vs. Measured EMC for VSS Group SFR



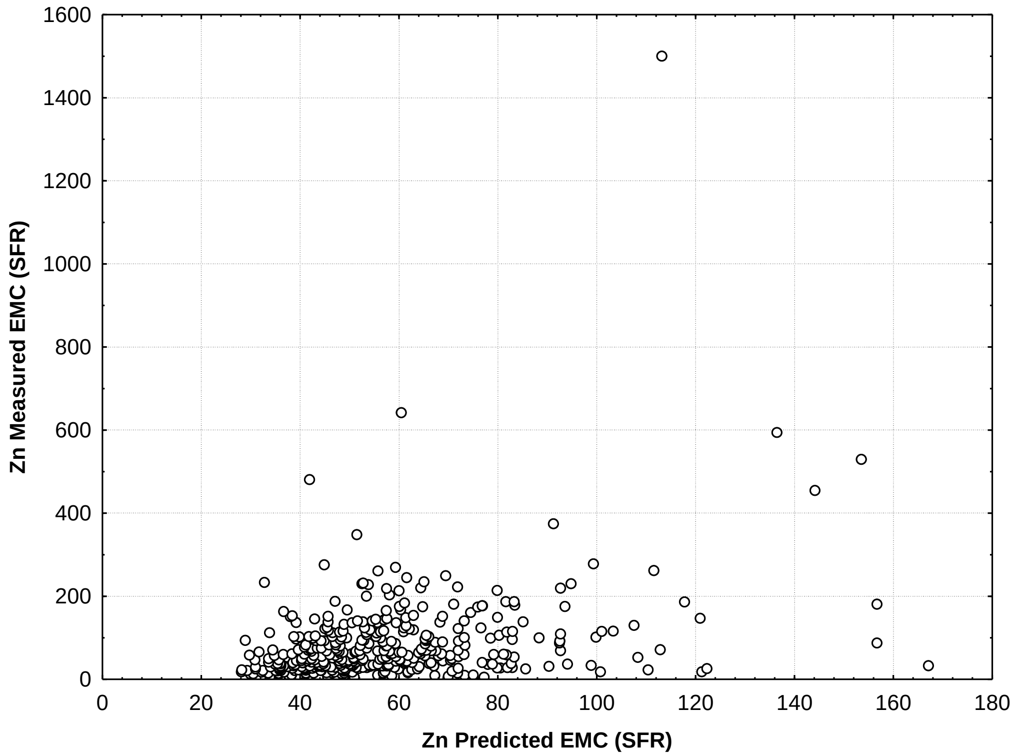
Graph F64. Scatterplot of Predicted EMC vs. Measured EMC for VSS Group UND



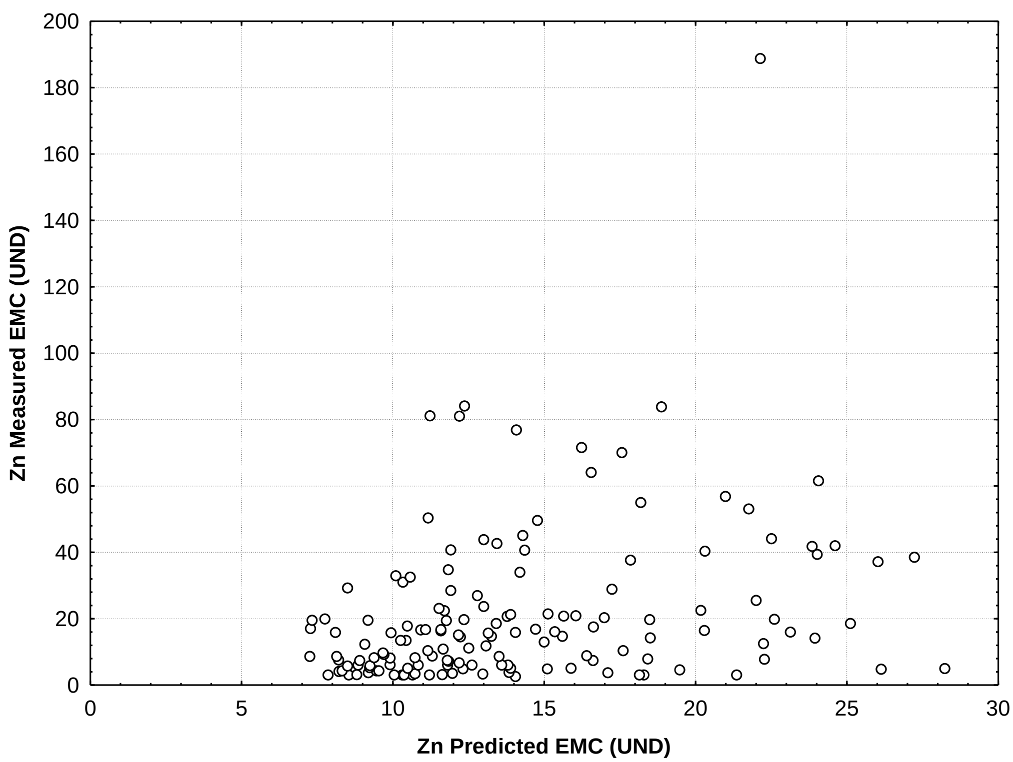
Graph F65. Scatterplot of Predicted EMC vs. Measured EMC for Zn Group IC1



Graph F66. Scatterplot of Predicted EMC vs. Measured EMC for Zn Group IC2



Graph F67. Scatterplot of Predicted EMC vs. Measured EMC for Zn Group SFR



Graph F68. Scatterplot of Predicted EMC vs. Measured EMC for Zn Group UND

Appendix G Intra-Event Plots by Sample Partition

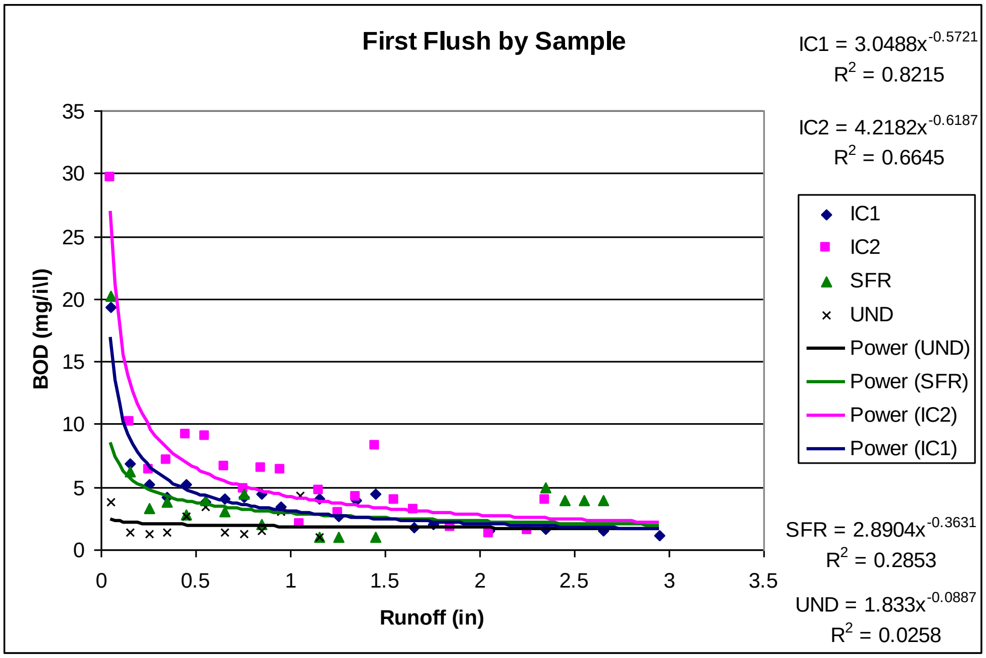


Figure G.1: First-flush analyses for BOD by sample.

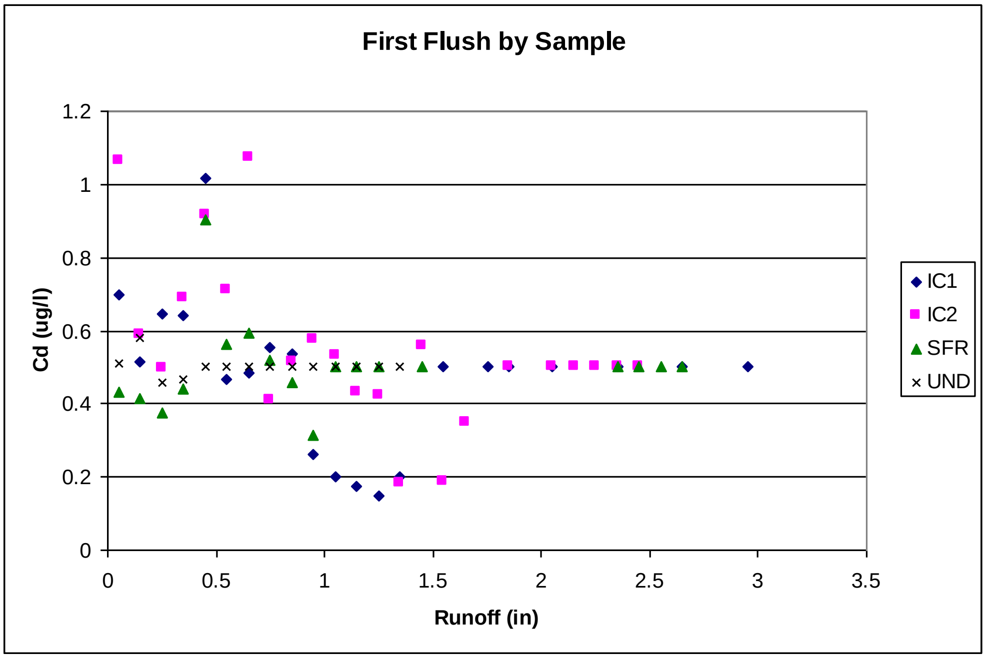


Figure G.2: First-flush analyses for Cd by sample.

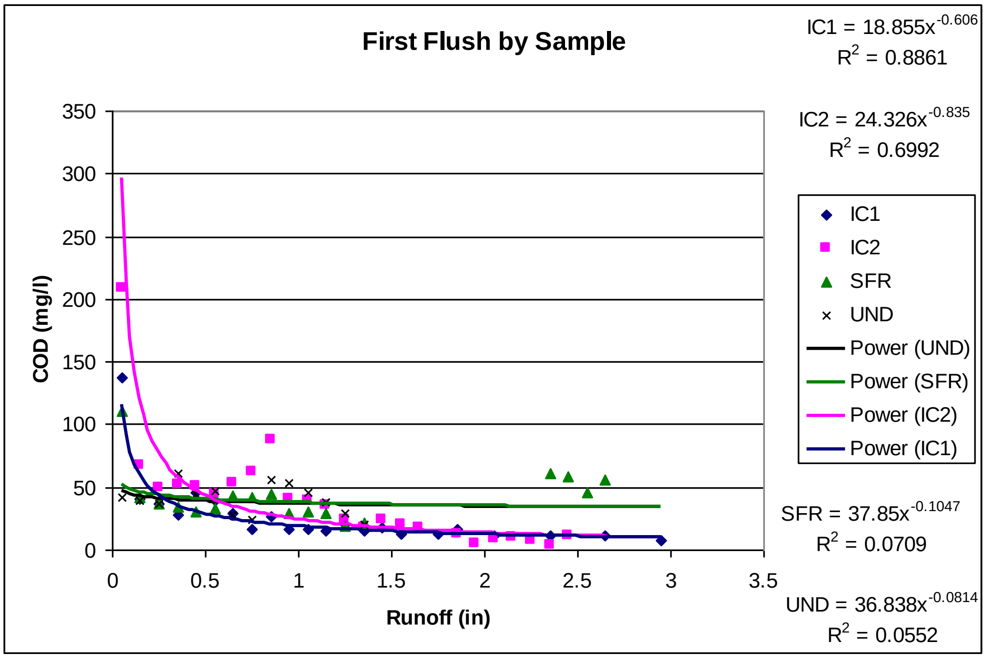


Figure G.3: First-flush analyses for COD by sample.

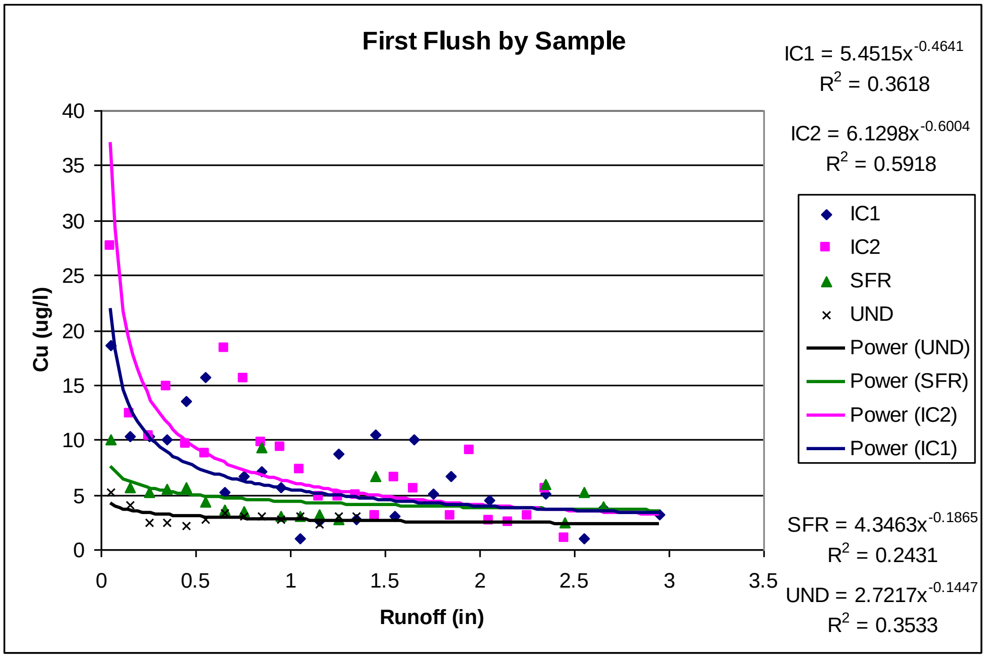


Figure G.4: First-flush analyses for Cu by sample.

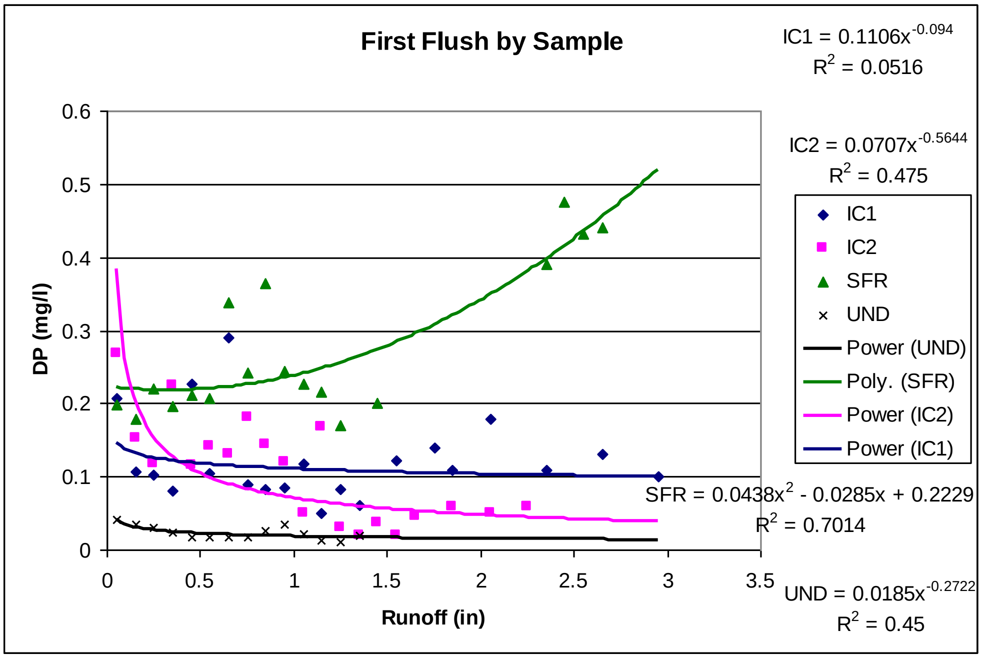


Figure G.5: First-flush analyses for DP by sample.

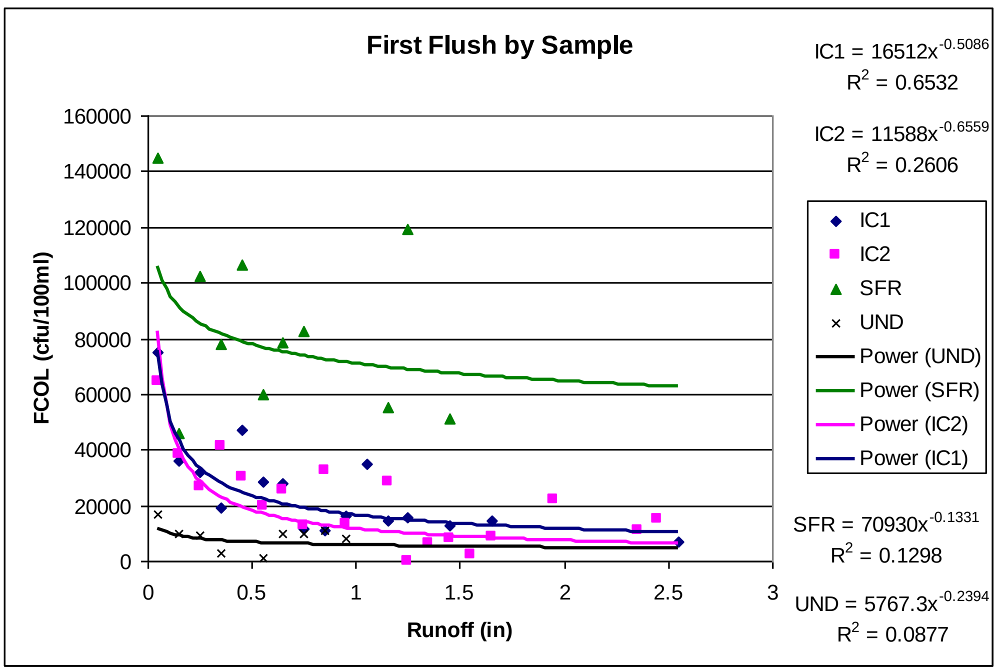


Figure G.6: First-flush analyses for FCOL by sample.

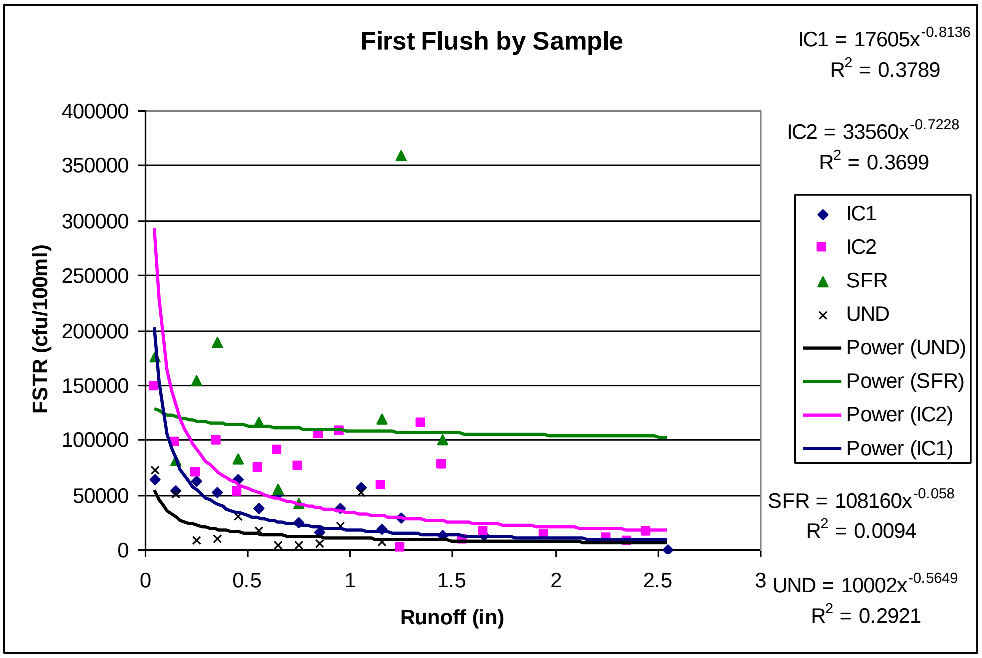


Figure G.7: First-flush analyses for FSTR by sample.

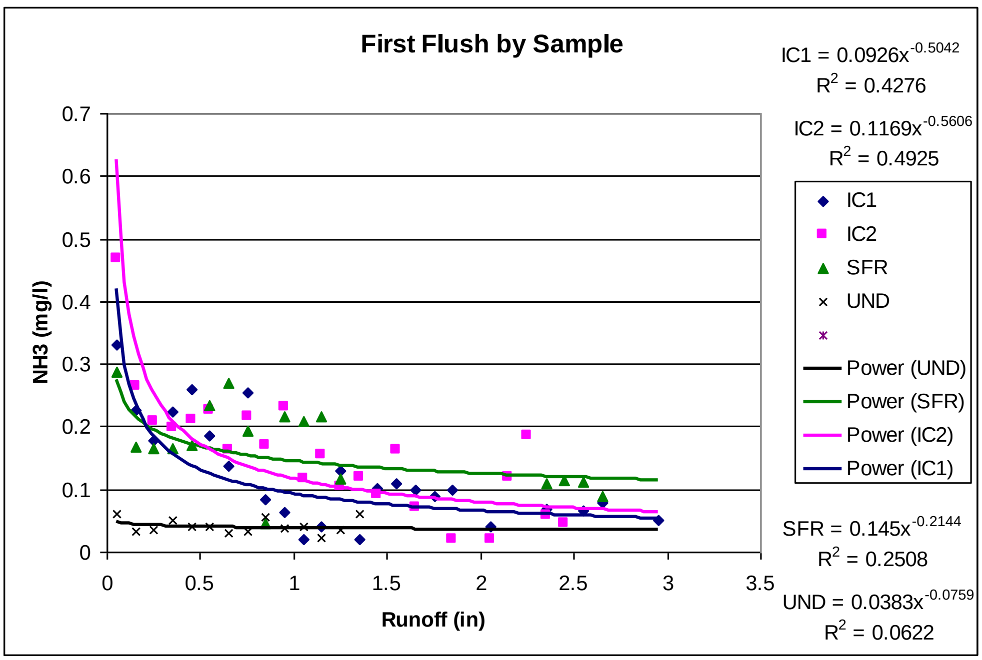


Figure G.8: First-flush analyses for NH_3 by sample.

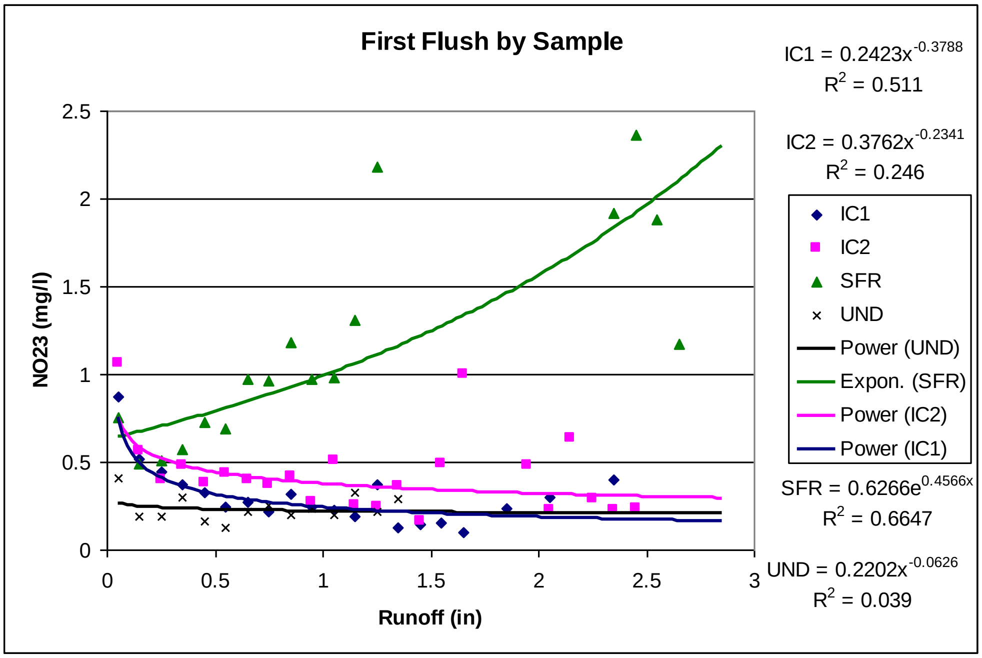


Figure G.9: First-flush analyses for NO_3+NO_2 by sample.

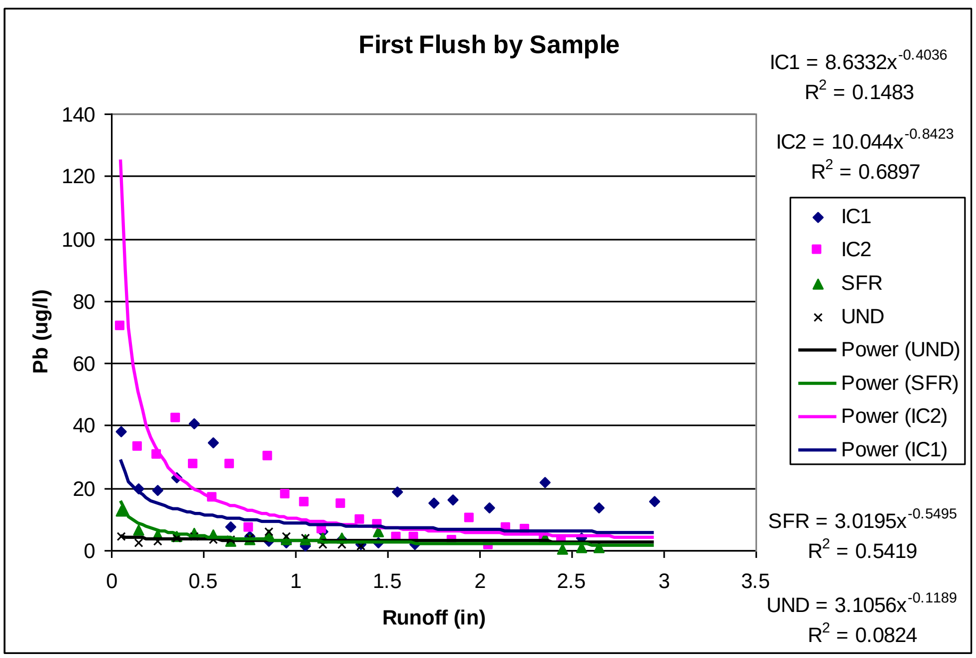


Figure G.10: First-flush analyses for Pb by sample.

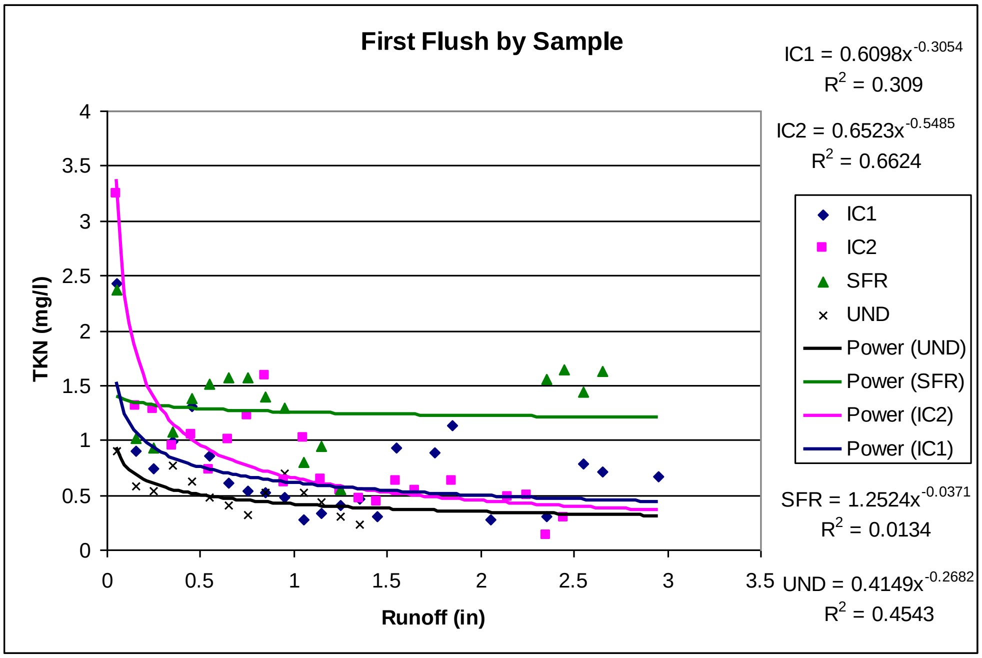


Figure G.11: First-flush analyses for TKN by sample.

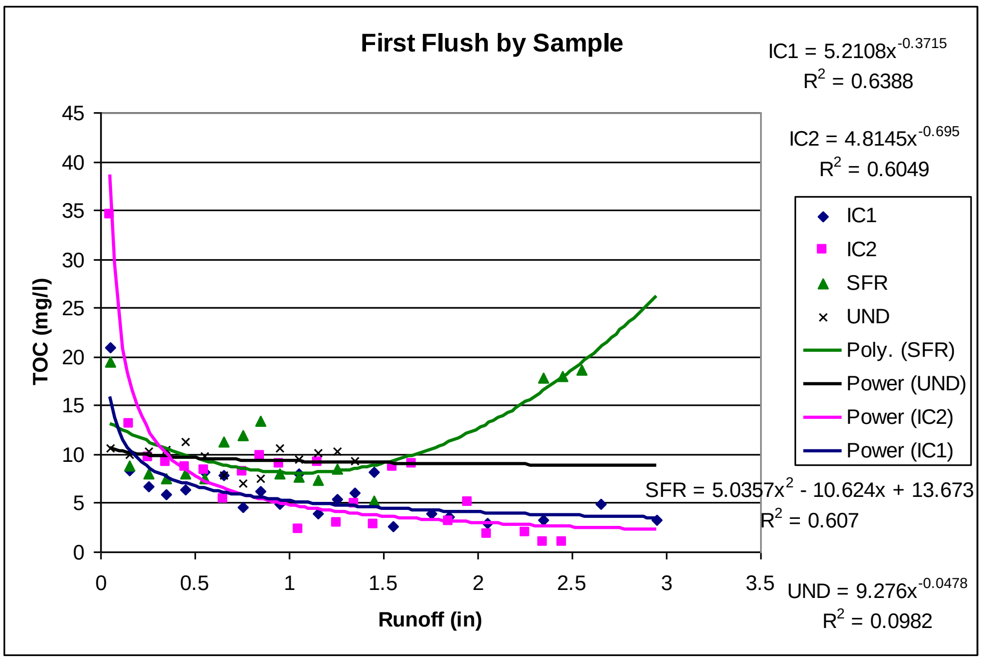


Figure G.12: First-flush analyses for TOC by sample.

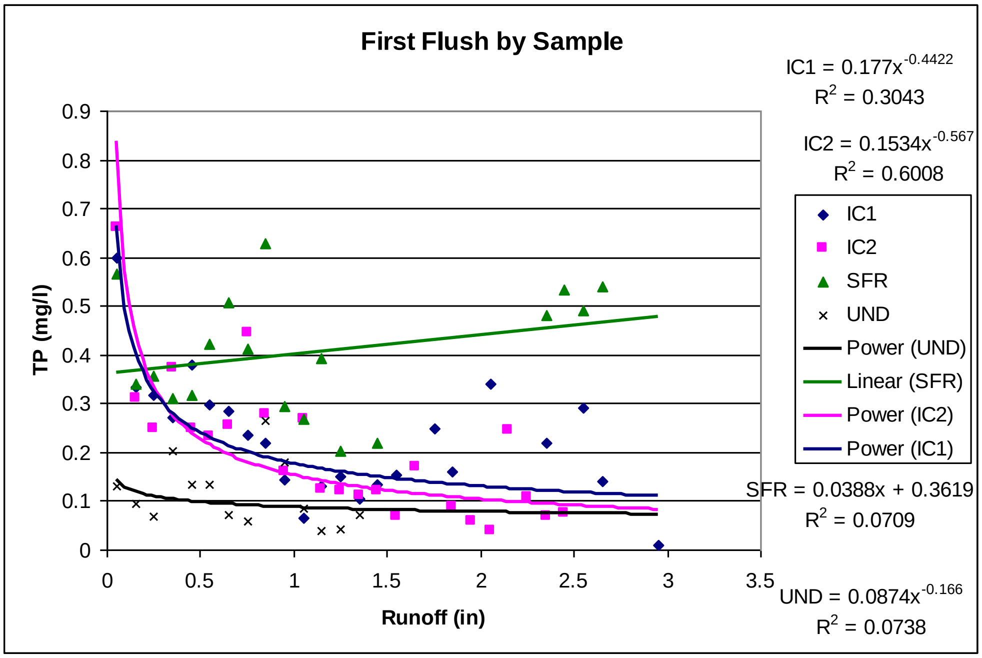


Figure G.13: First-flush analyses for TP by sample.

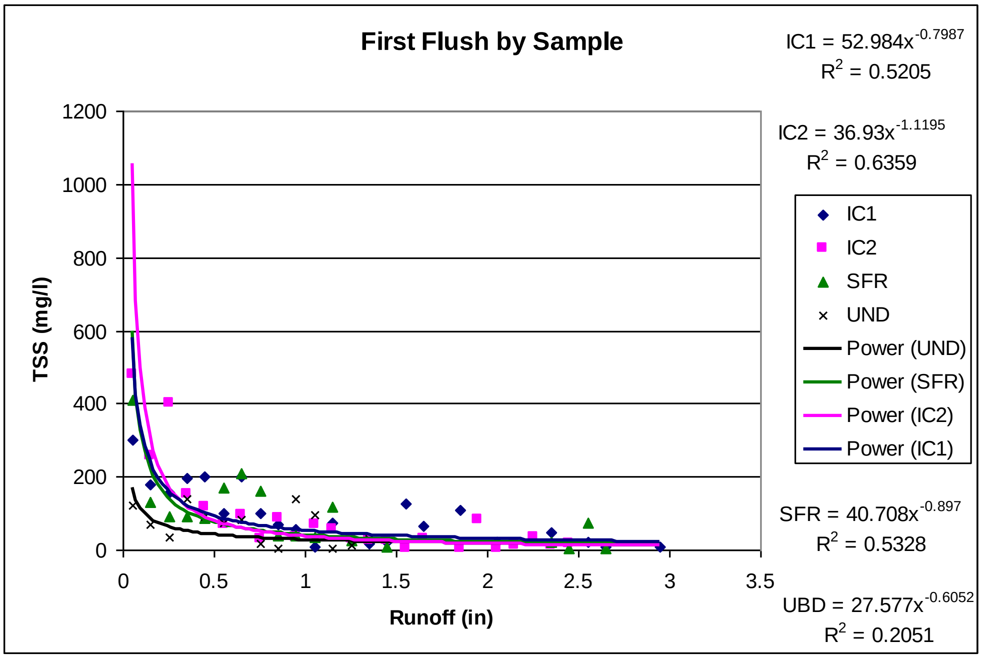


Figure G.14: First-flush analyses for TSS by sample.

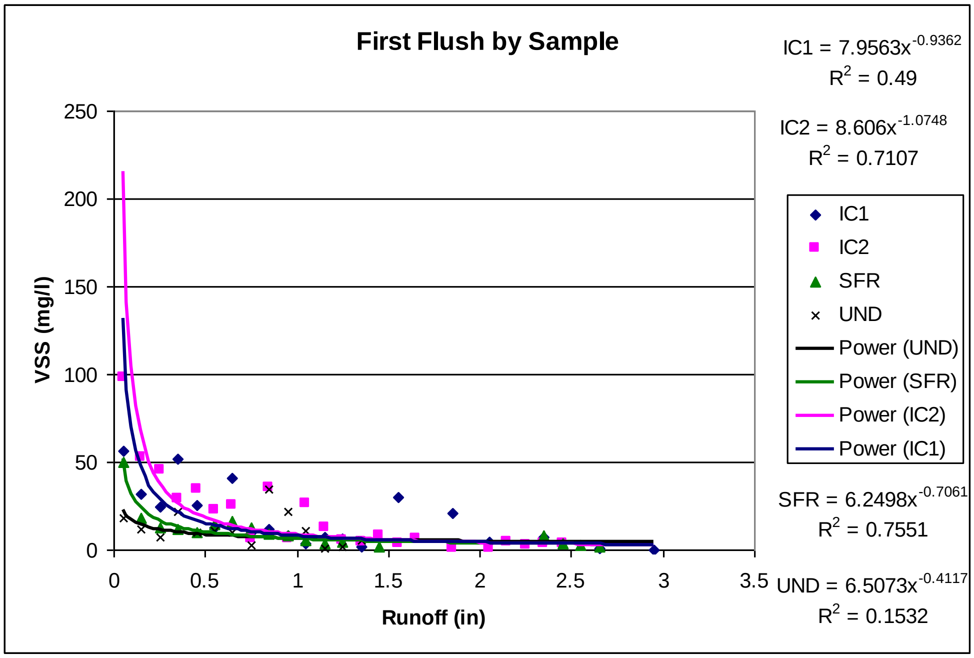


Figure G.15: First-flush analyses for VSS by sample.

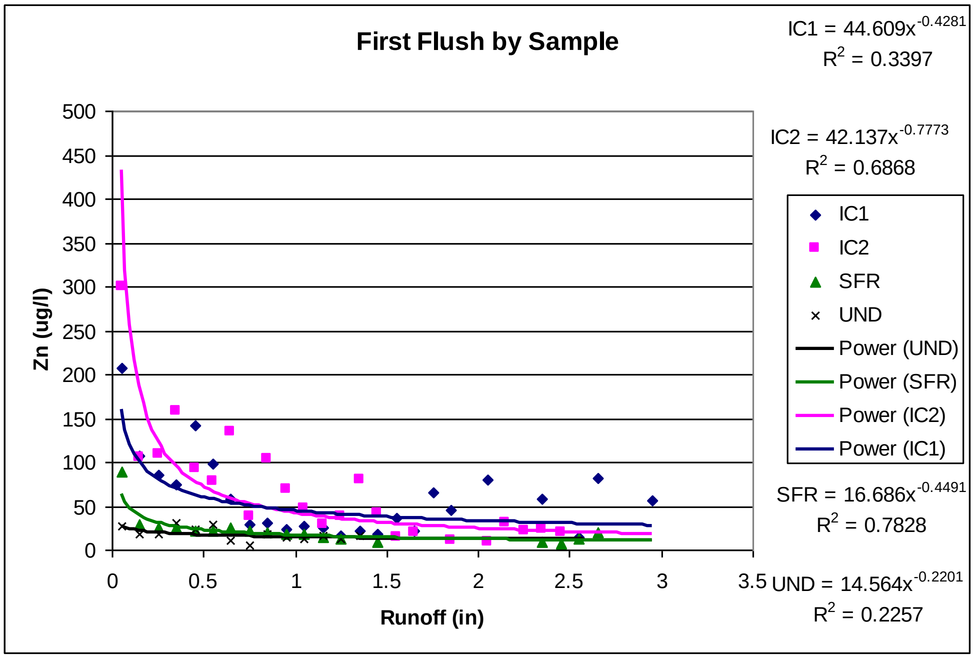


Figure G.16: First-flush analyses for Zn by sample.

Appendix H Intra-Event Plots by Load Partition, Percent

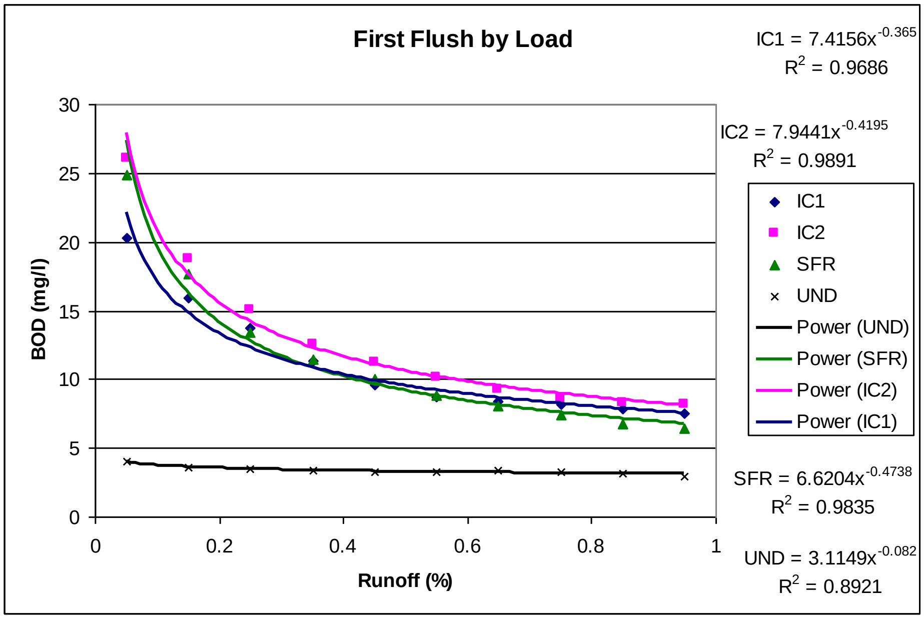


Figure H.1: First-flush analyses for BOD by load, percent runoff.

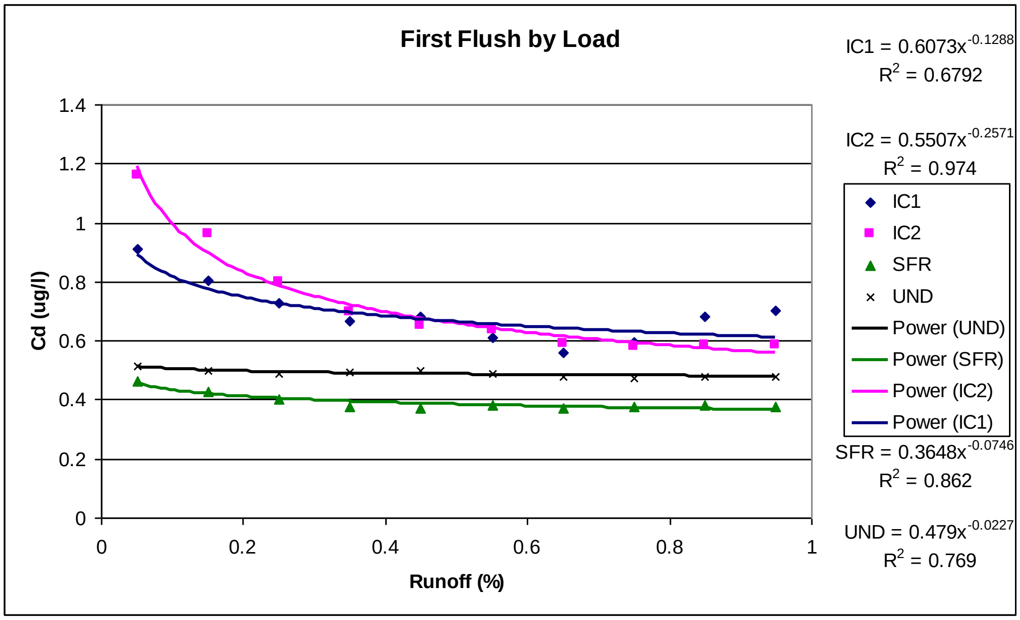


Figure H.2: First-flush analyses for Cd by load, percent runoff.

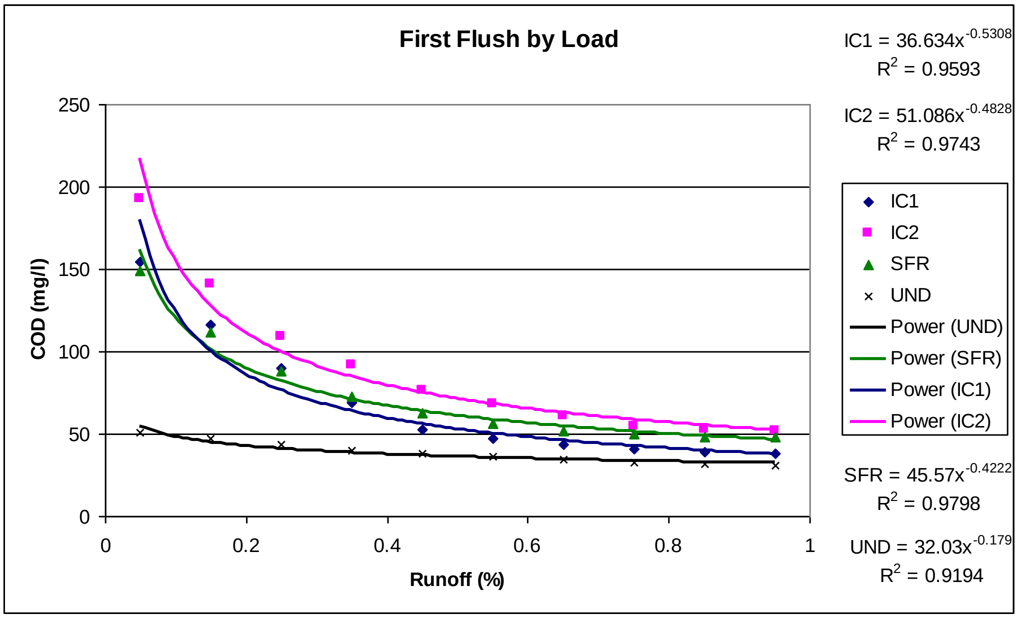


Figure H.3: First-flush analyses for COD by load, percent runoff.

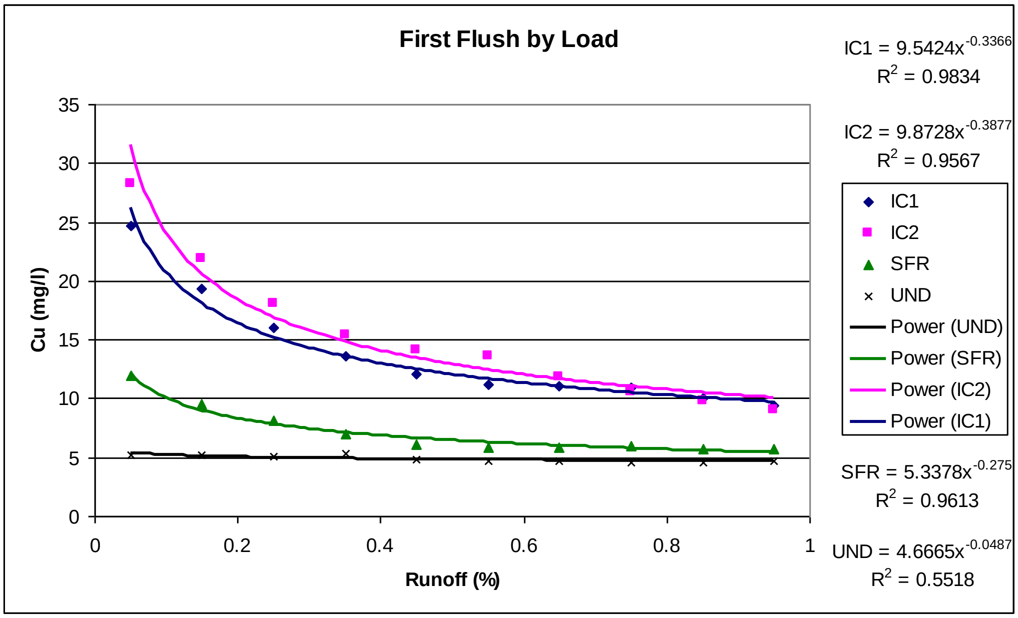


Figure H.4: First-flush analyses for Cu by load, percent runoff.

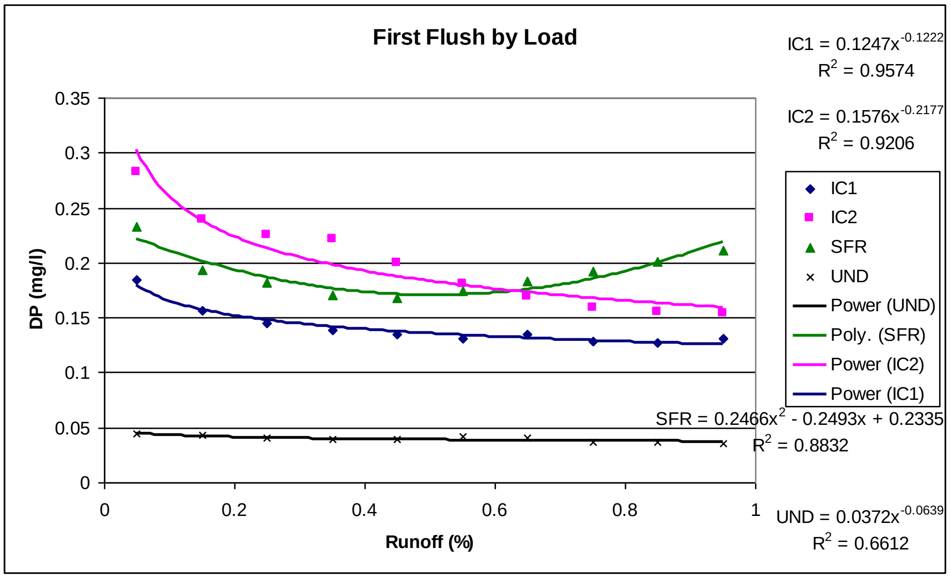


Figure H.5: First-flush analyses for DP by load, percent runoff.

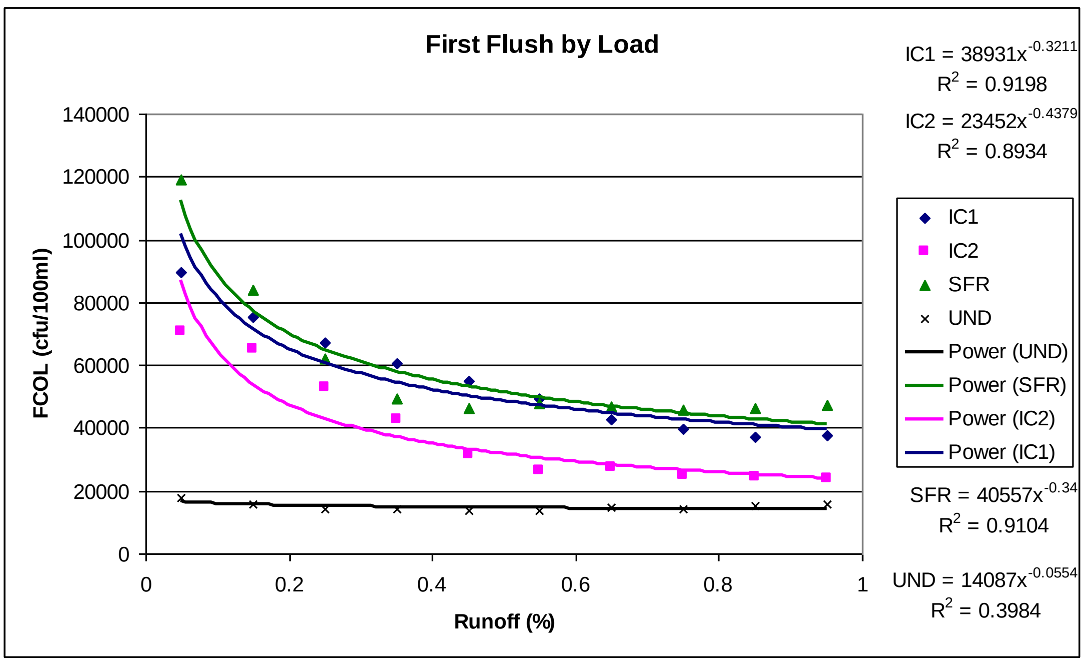


Figure H.6: First-flush analyses for FCOL by load, percent runoff.

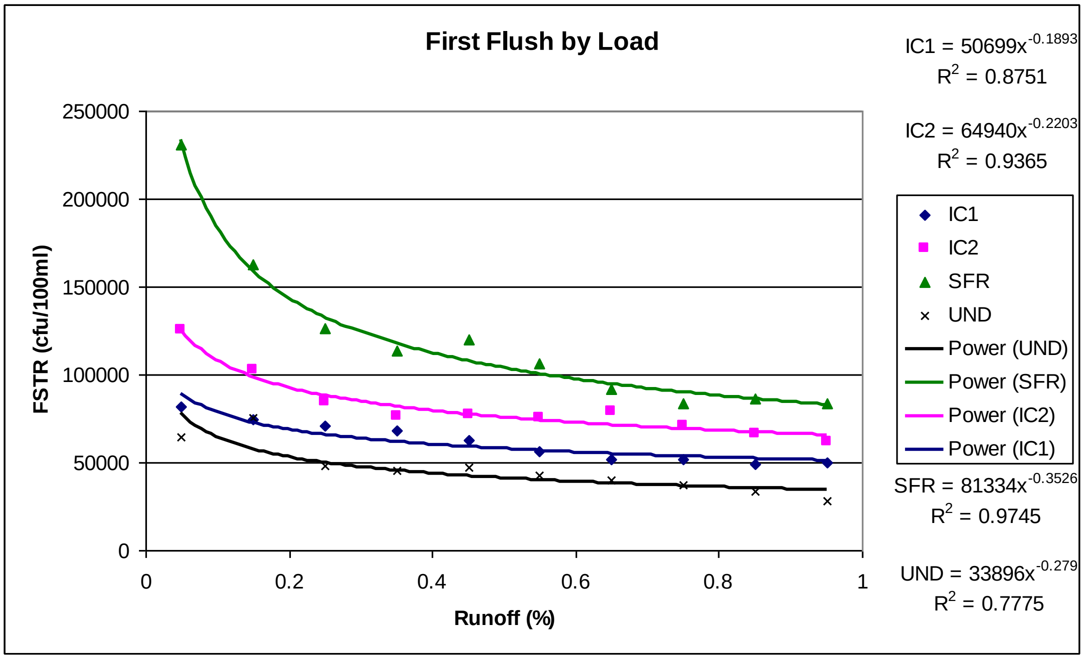


Figure H.7: First-flush analyses for FSTR by load, percent runoff.

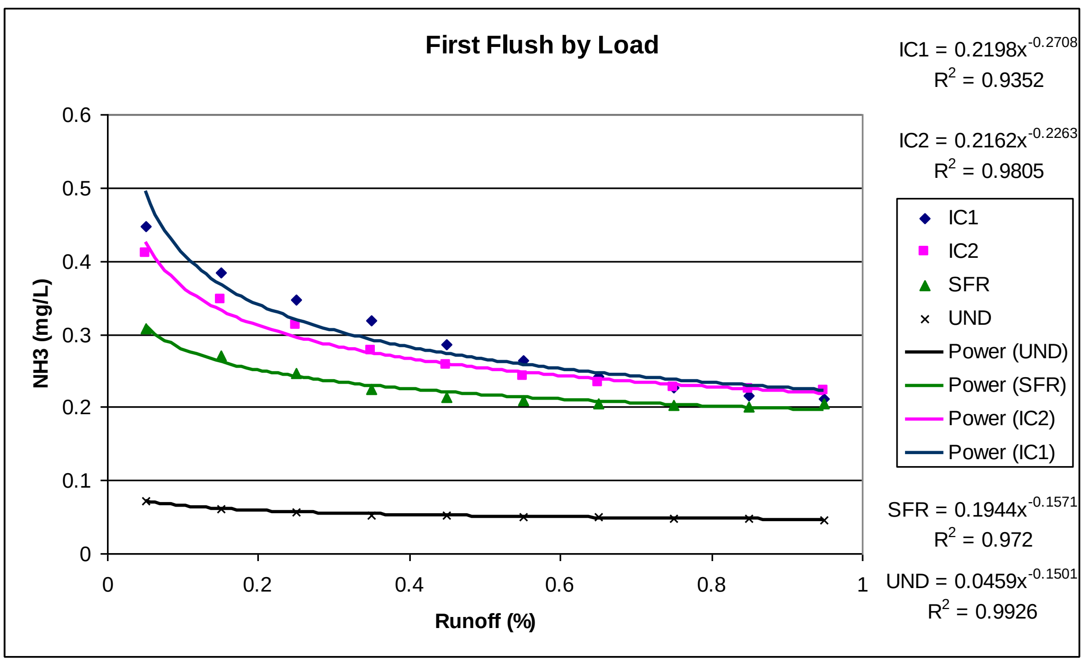


Figure H.8: First-flush analyses for NH_3 by load, percent runoff.

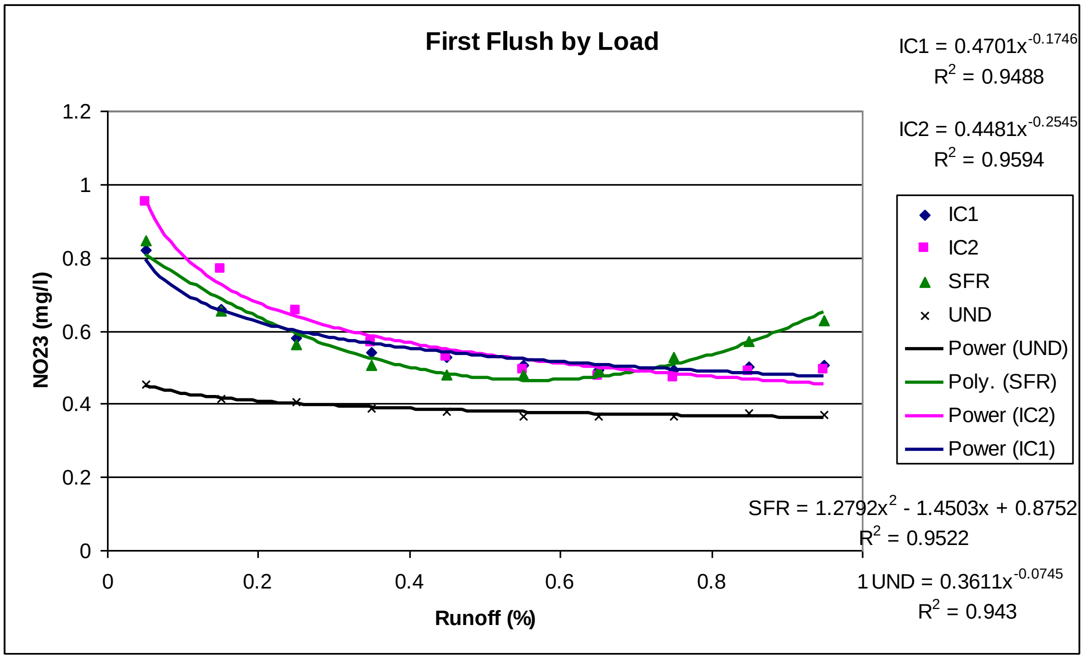


Figure H.9: First-flush analyses for NO_3+NO_2 by load, percent runoff.

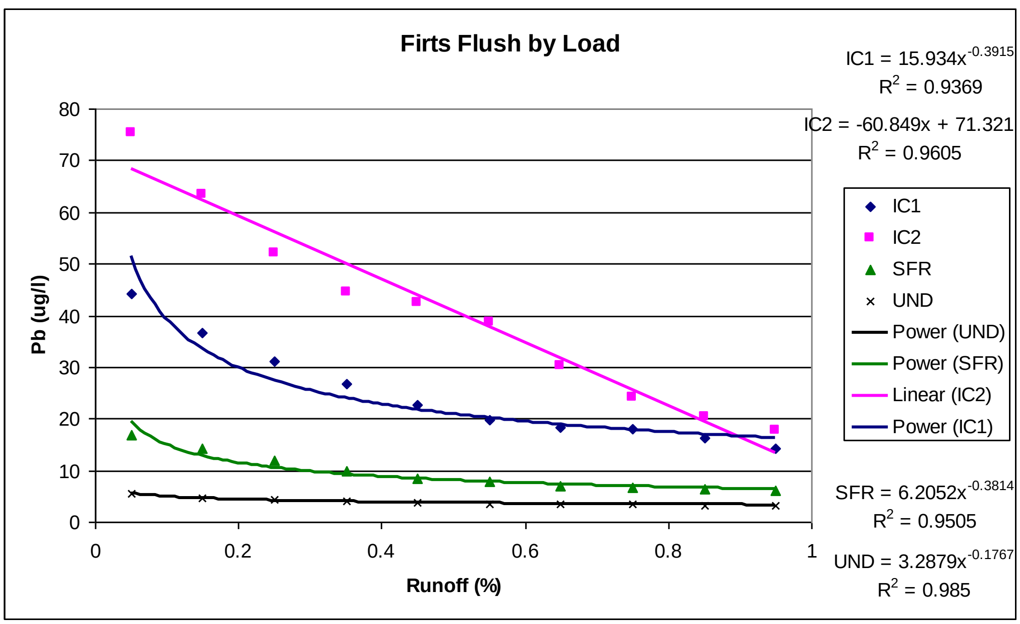


Figure H.10: First-flush analyses for Pb by load, percent runoff.

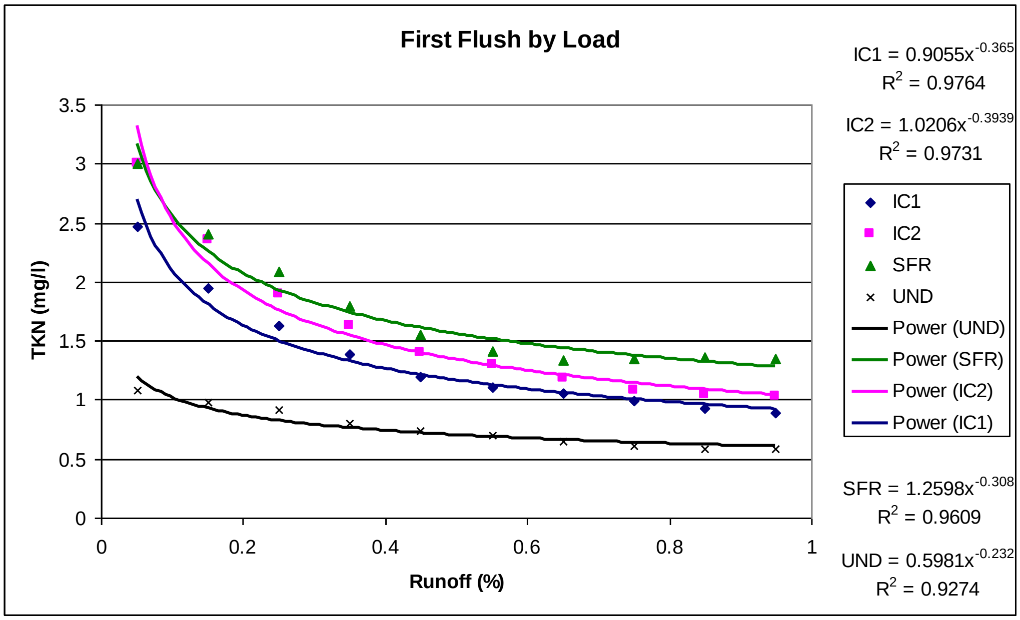


Figure H.11: First-flush analyses for TKN by load, percent runoff.

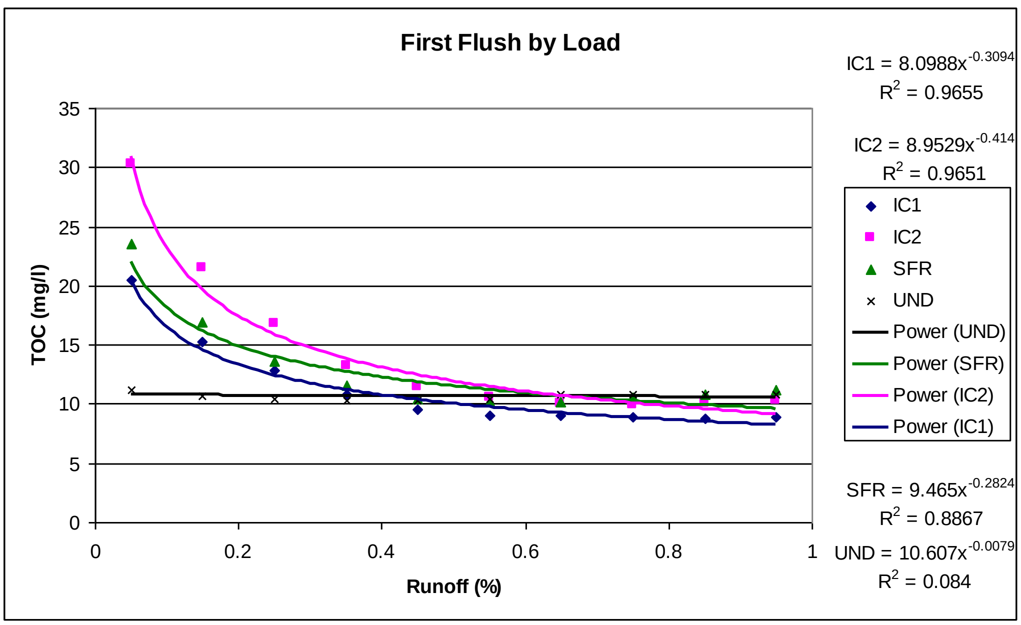


Figure H.12: First-flush analyses for TOC by load, percent runoff.

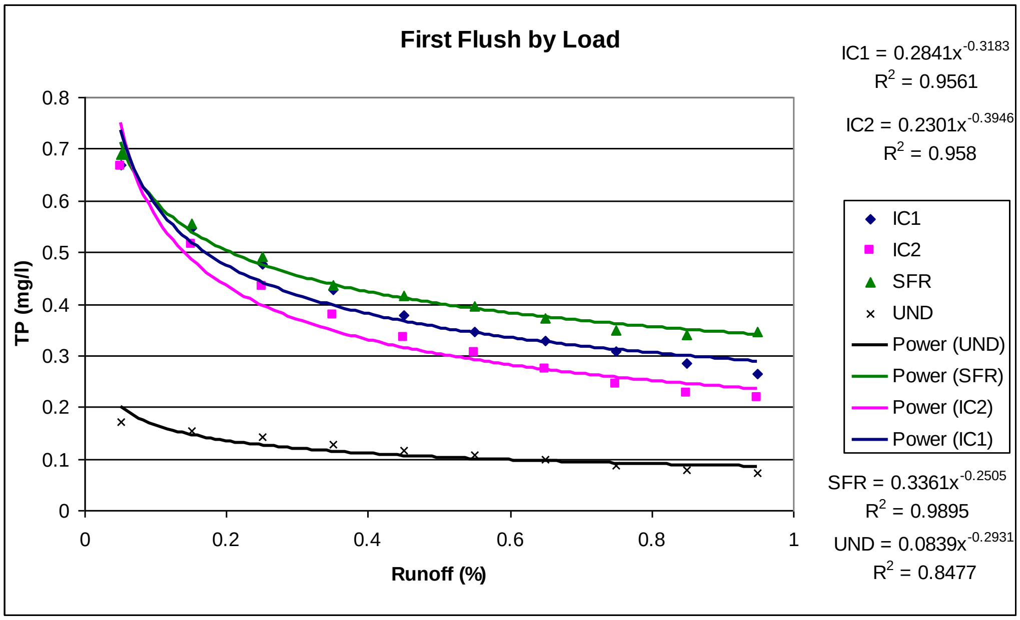


Figure H.13: First-flush analyses for TP by load, percent runoff.

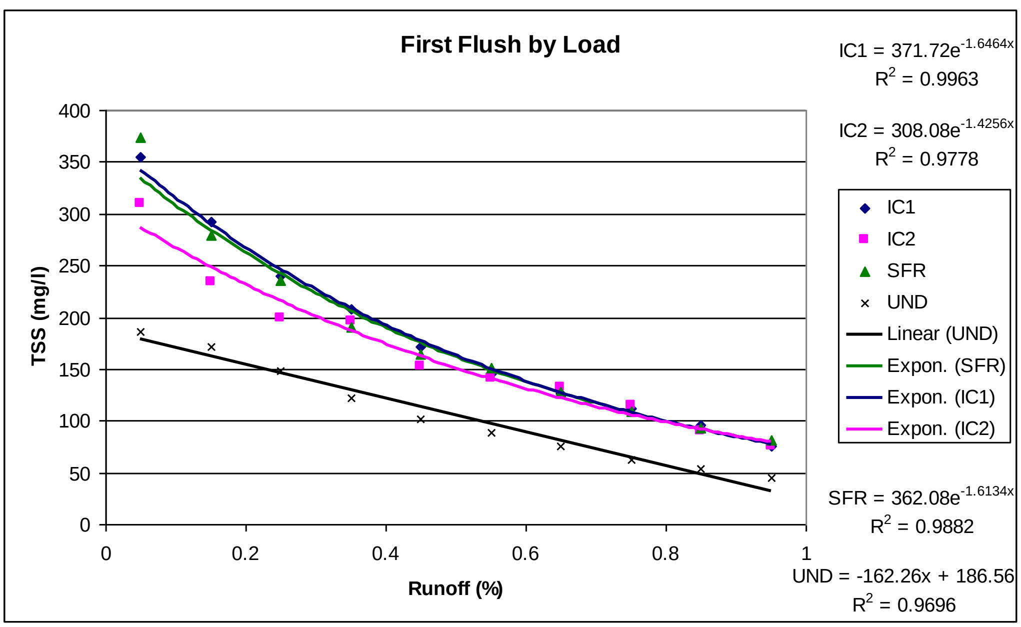


Figure H.14: First-flush analyses for TSS by load, percent runoff.

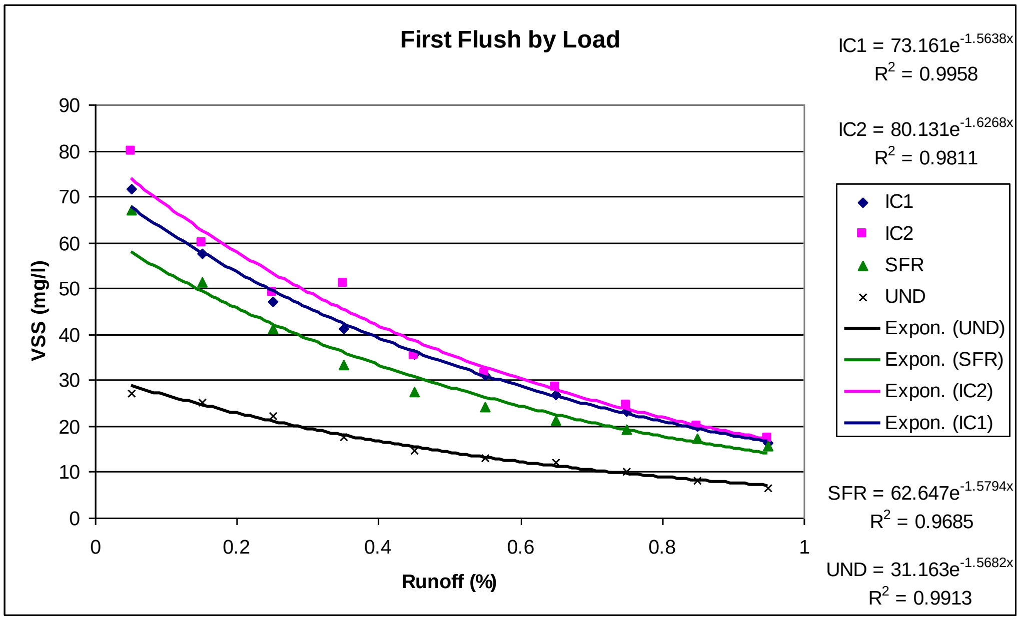


Figure H.15: First-flush analyses for VSS by load, percent runoff.

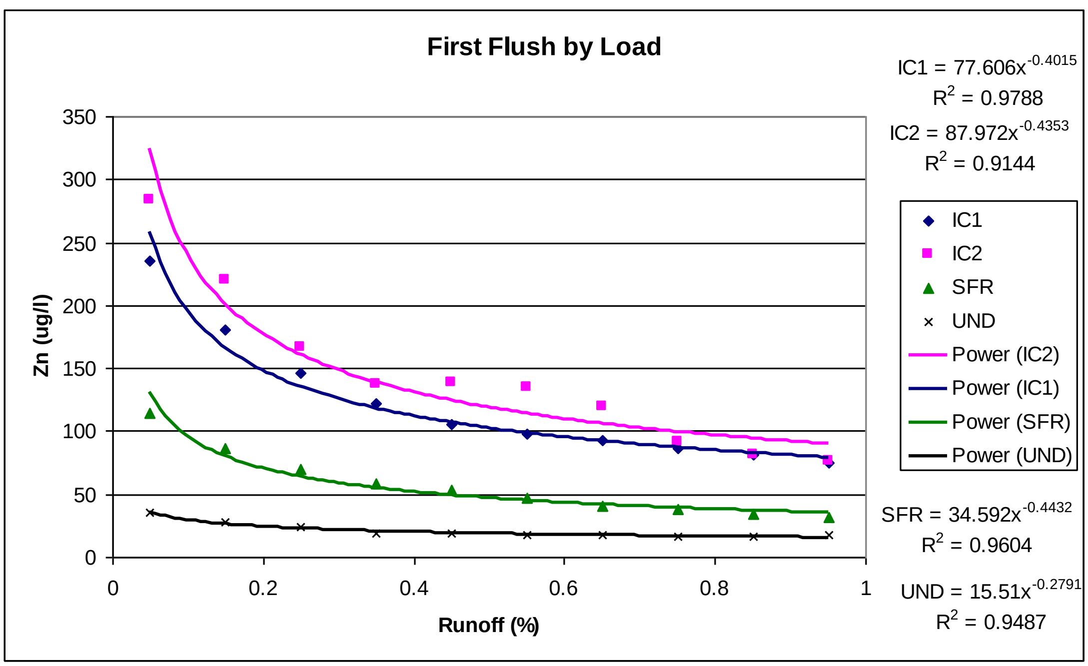


Figure H.16: First-flush analyses for Zn by load, percent runoff.

Appendix I Intra-Event Plots by Load Partition, Volume

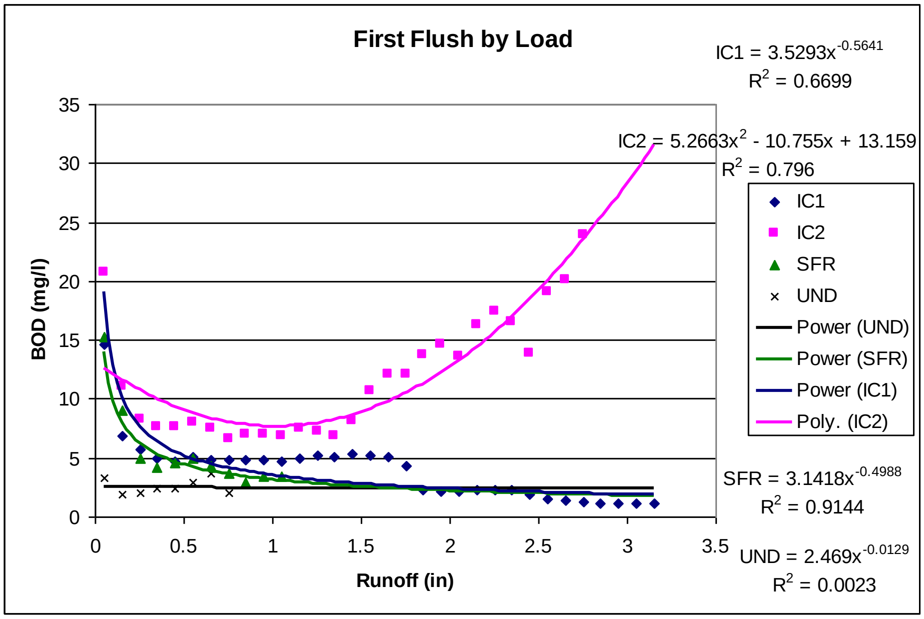


Figure I.1: First-flush analyses for BOD by load, volume of runoff.

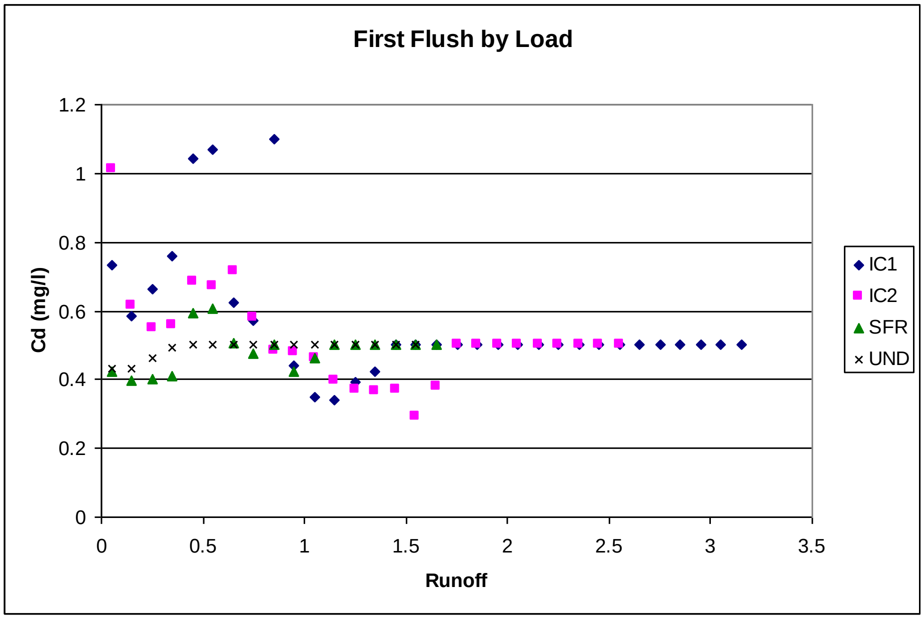


Figure I.2: First-flush analyses for Cd by load, volume of runoff.

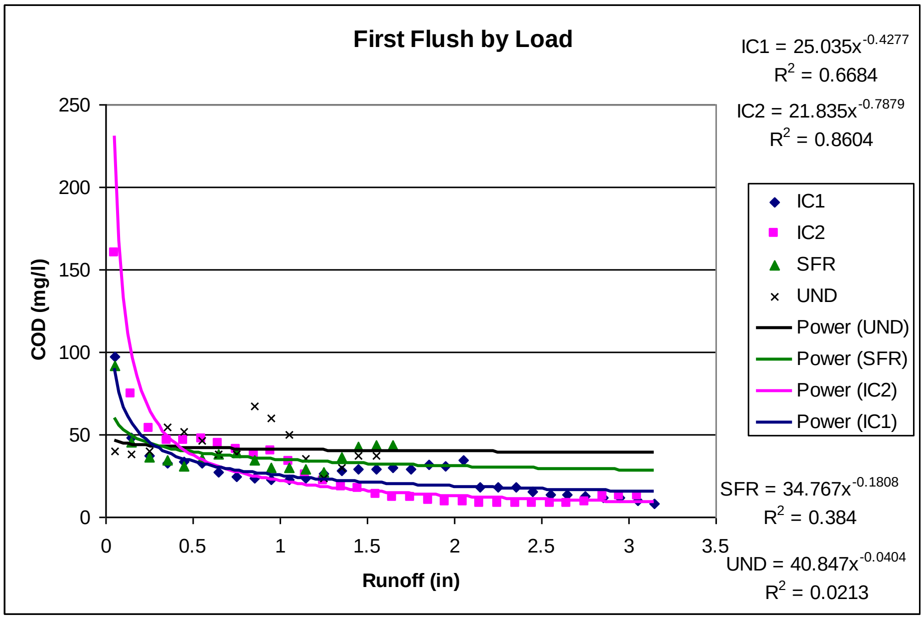


Figure I.3: First-flush analyses for COD by load, volume of runoff.

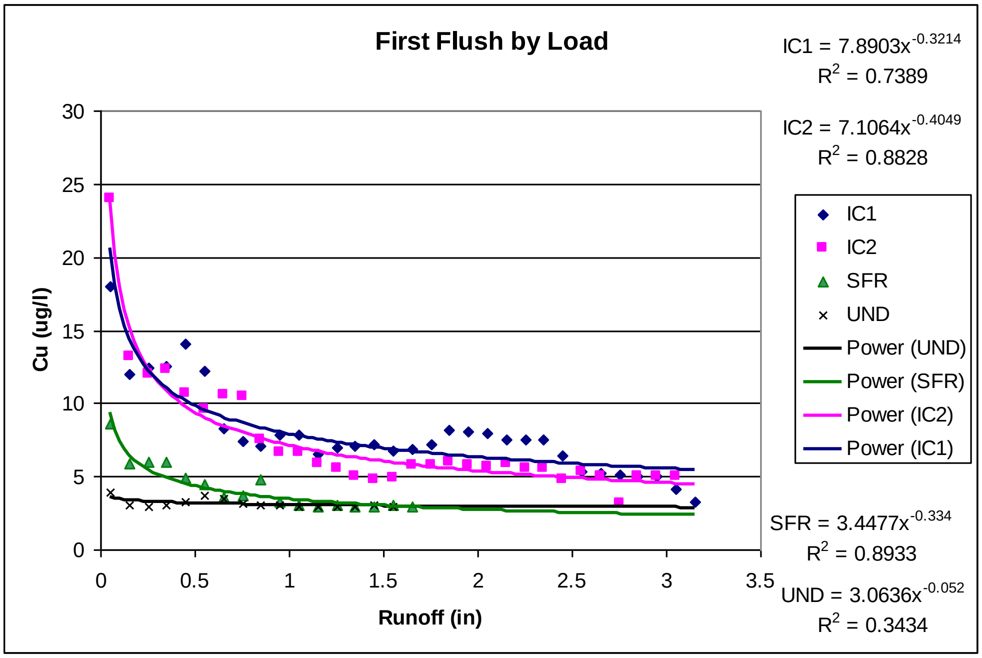


Figure I.4: First-flush analyses for Cu by load, volume of runoff.

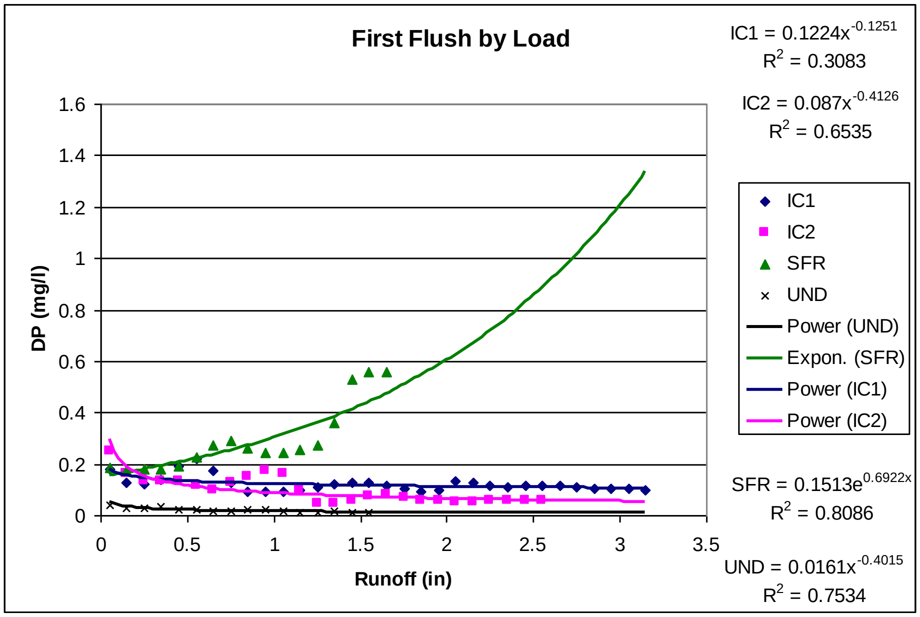


Figure I.5: First-flush analyses for DP by load, volume of runoff.

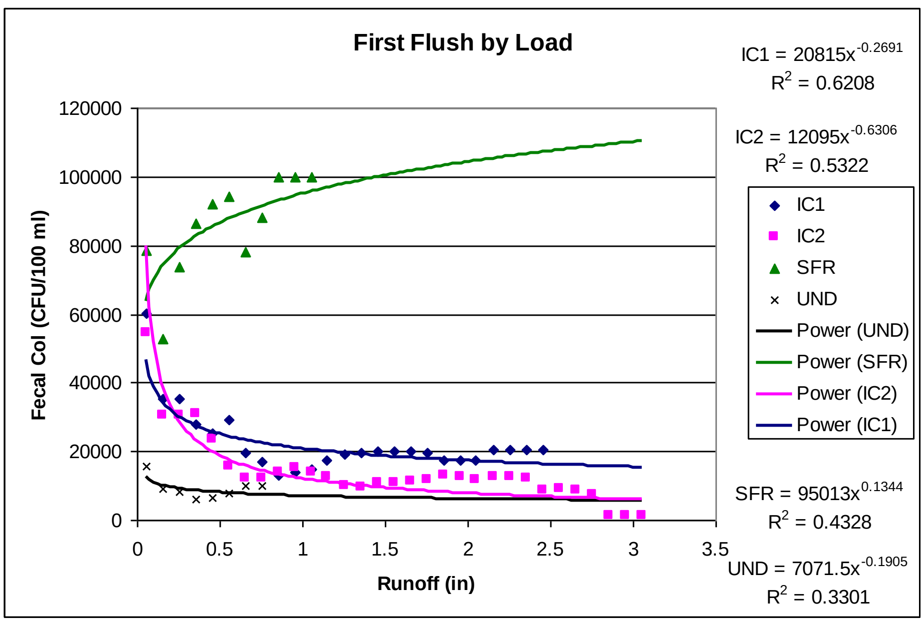


Figure I.6: First-flush analyses for FCOL by load, volume of runoff.

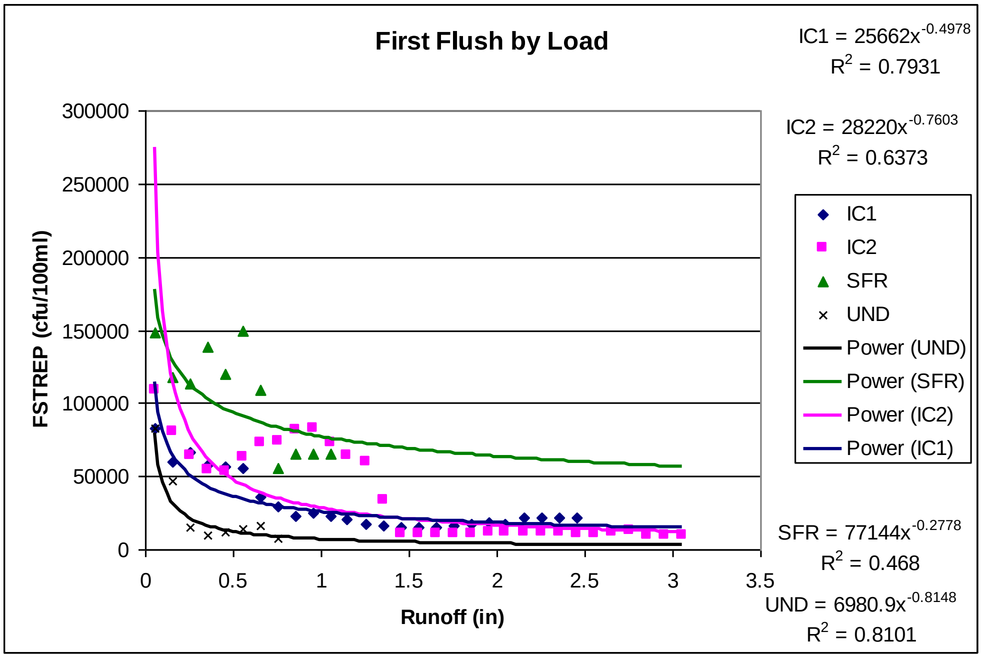


Figure I.7: First-flush analyses for FSTR by load, volume of runoff.

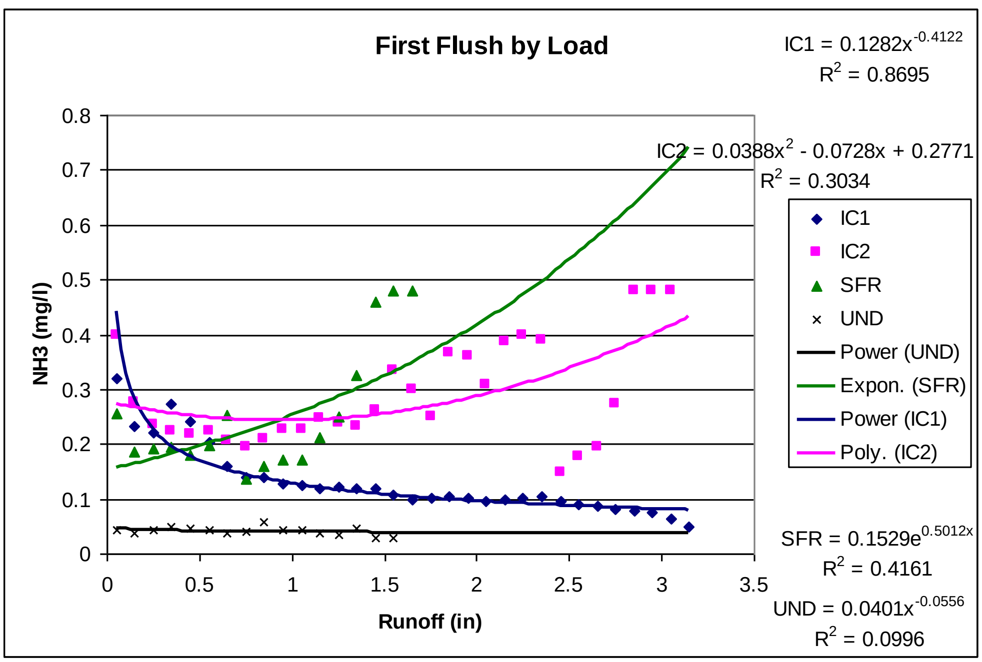


Figure I.8: First-flush analyses for NH_3 by load, volume of runoff.

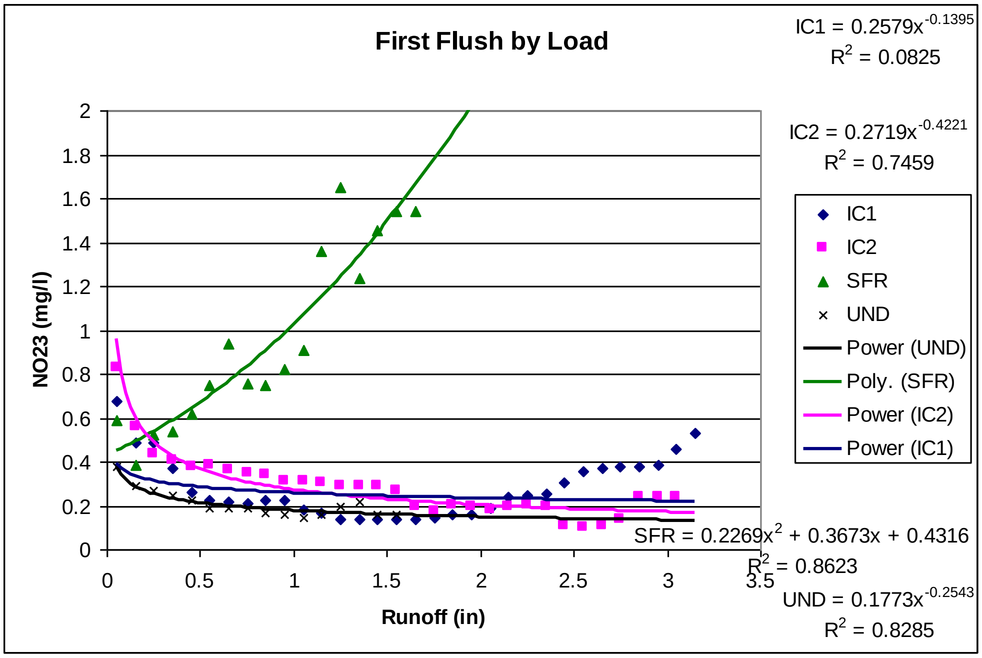


Figure I.9: First-flush analyses for NO_3+NO_2 by load, volume of runoff.

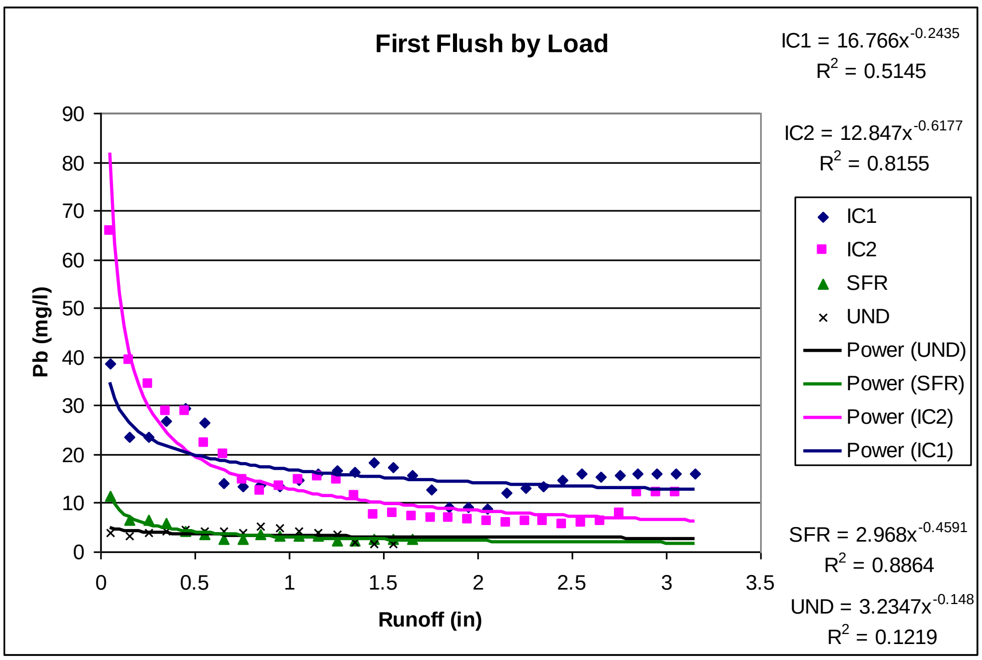


Figure I.10: First-flush analyses for Pb by load, volume of runoff.

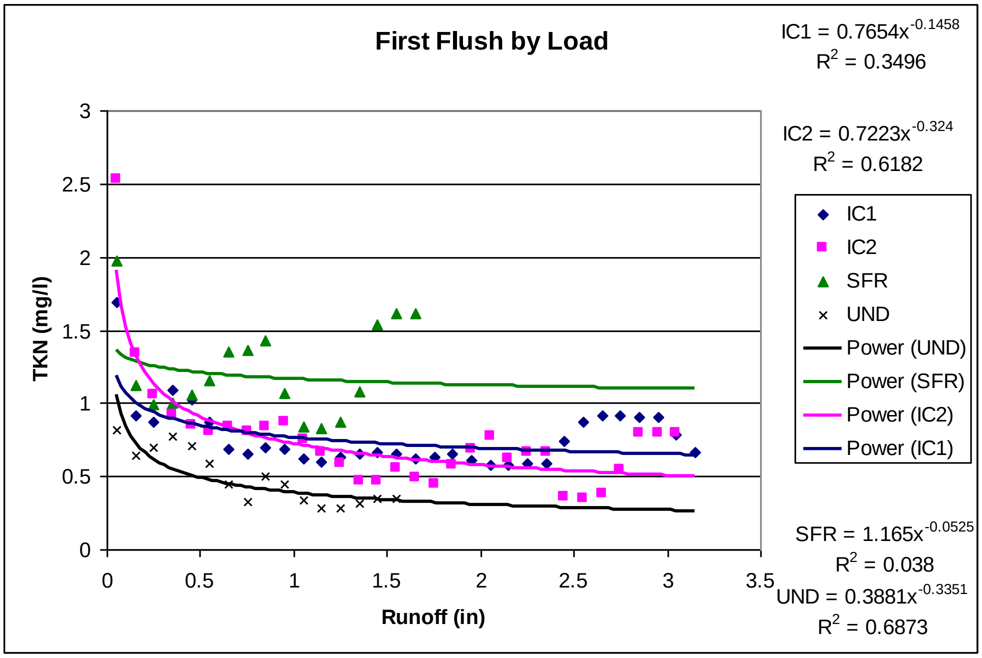


Figure I.11: First-flush analyses for TKN by load, volume of runoff.

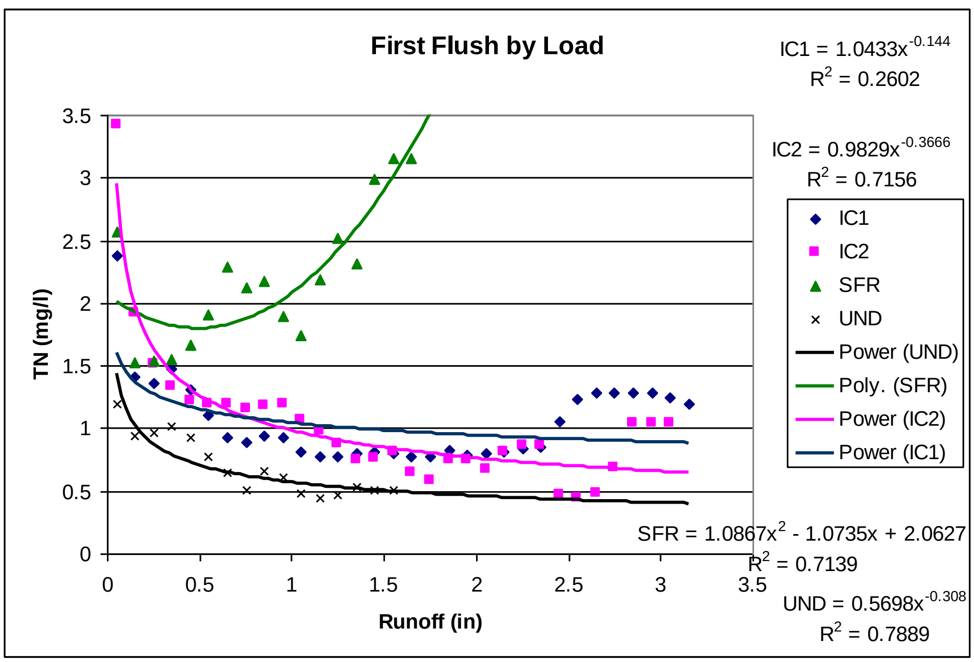


Figure I.12: First-flush analyses for TN by load, volume of runoff.

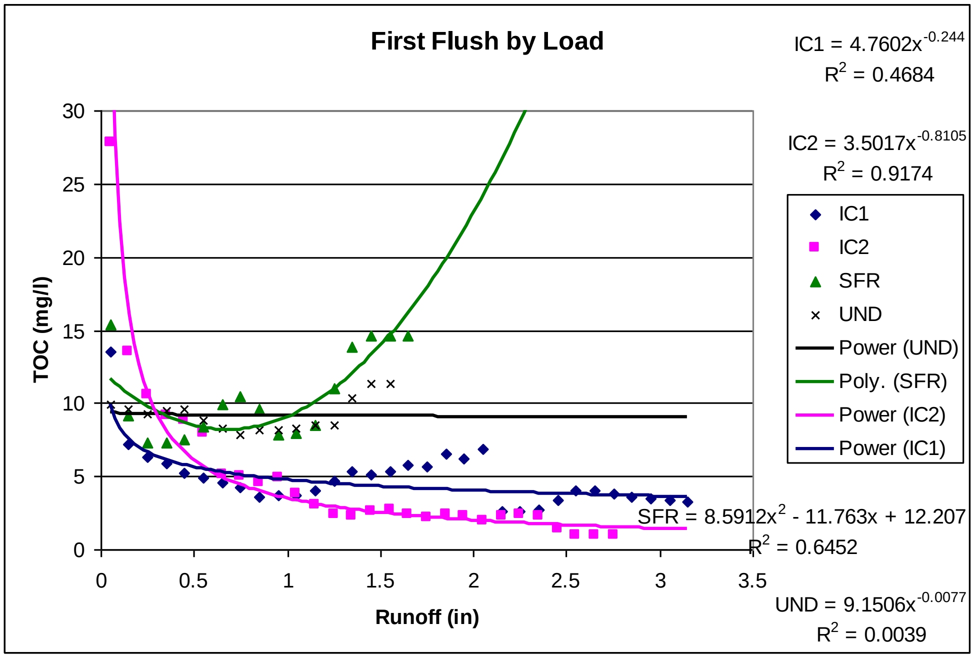


Figure I.13: First-flush analyses for TOC by load, volume of runoff.

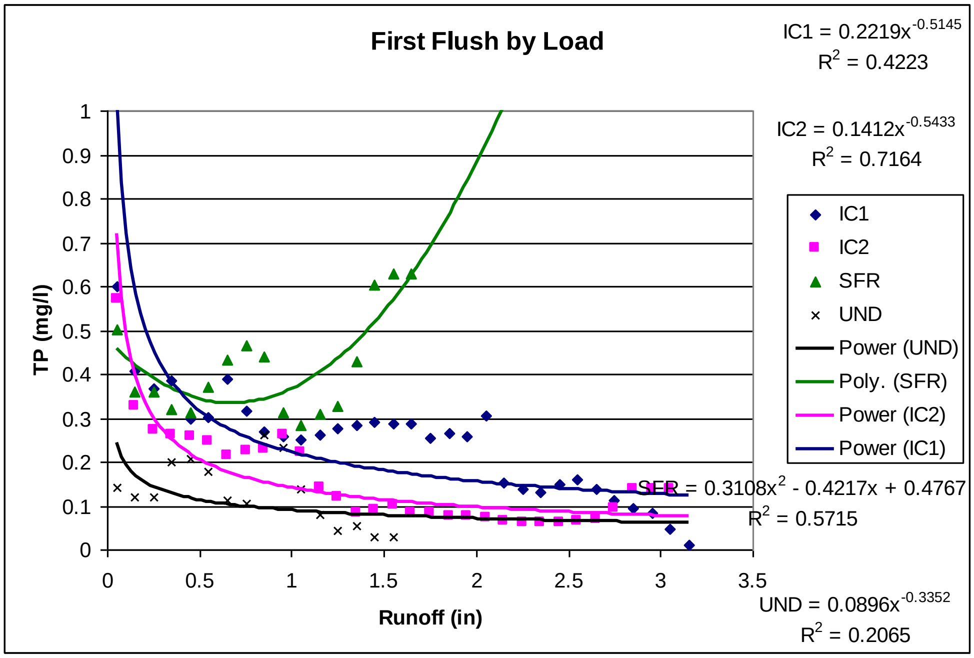


Figure I.14: First-flush analyses for TP by load, volume of runoff.

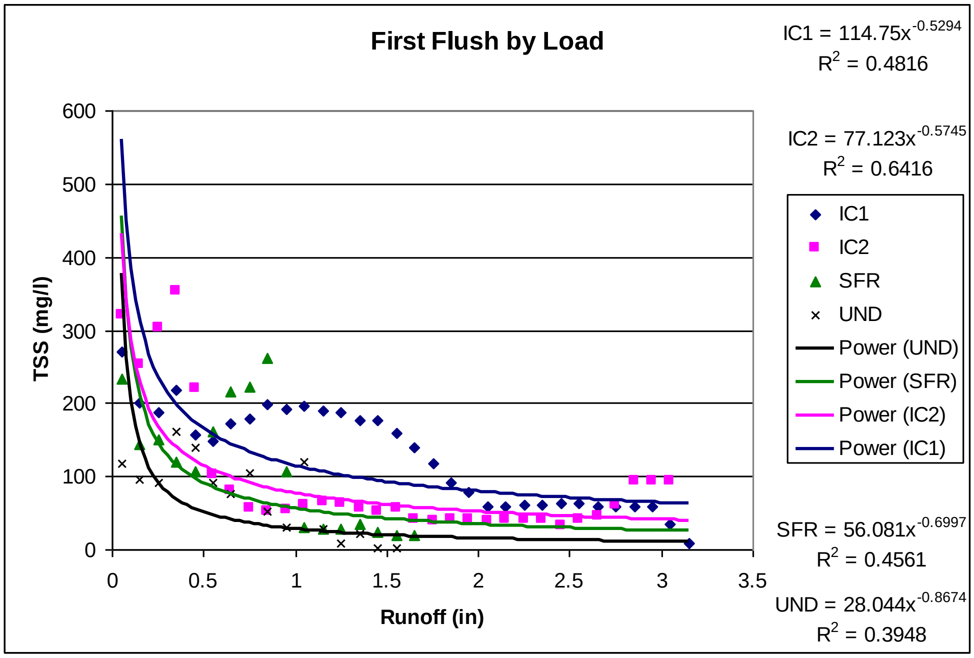


Figure I.15: First-flush analyses for TSS by load, volume of runoff.

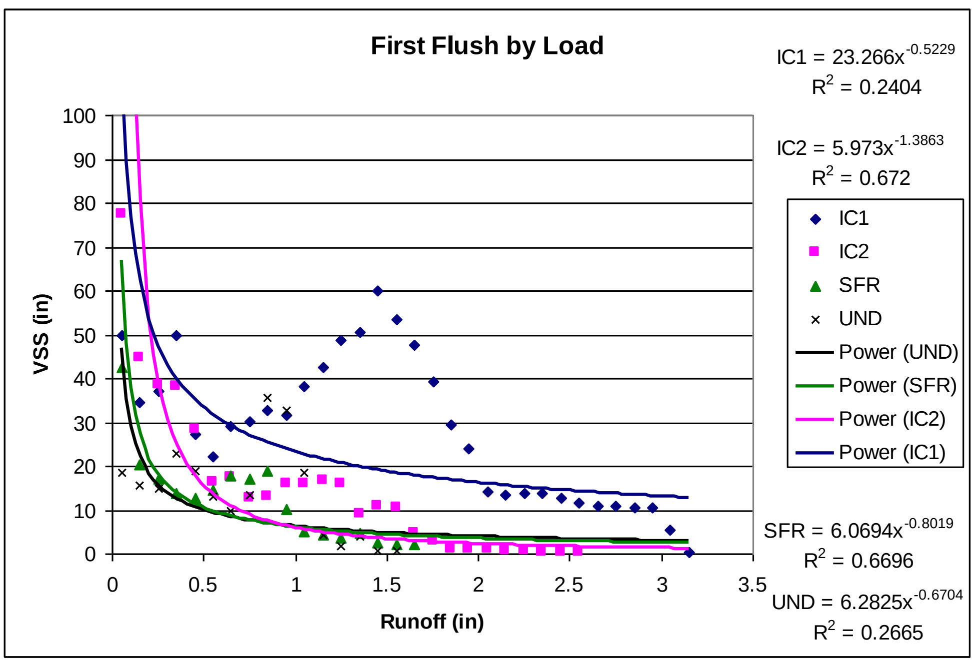


Figure I.16: First-flush analyses for VSS by load, volume of runoff.

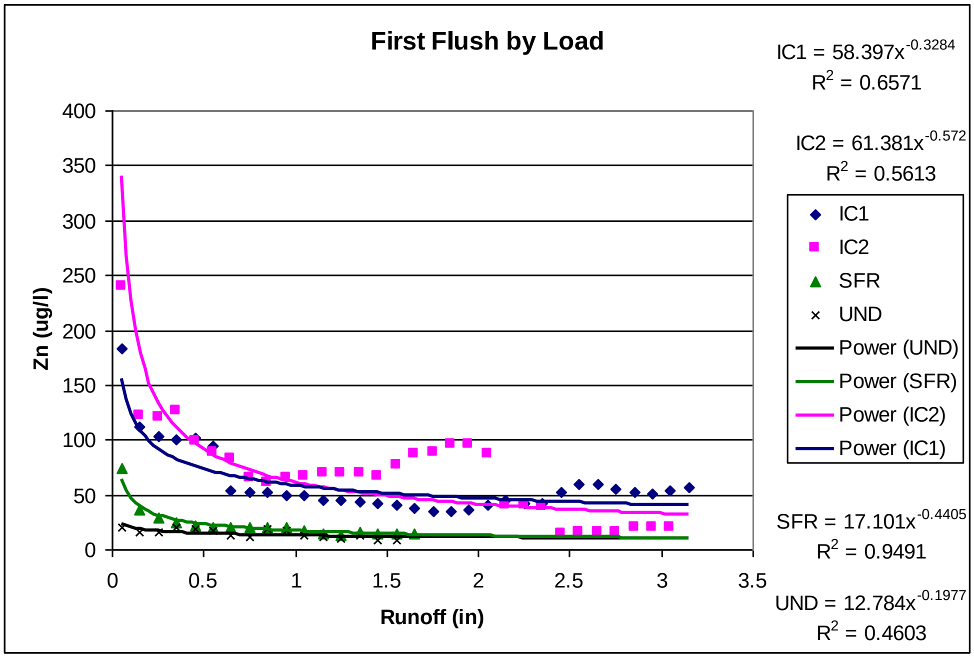


Figure I.17: First-flush analyses for Zn by load, volume of runoff.