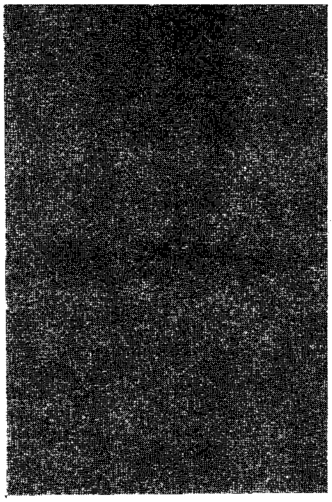
Techniques for Estimation of Storm-Runoff Loads, Volumes, and Selected Constituent Concentrations in Urban Watersheds in the United States



United States Geological Survey Water-Supply Paper 2363

USGS
science for a changing world

1986). Studies have indicated that the areas that contributed the largest loads of pollution were either highly erodible, such as plowed land or construction sites, or highly impervious, such as shopping malls (Randall, 1982). On the basis of these studies, perhaps more precisely defined land-use characteristics, such as area under construction, agricultural, or park, or other physical characteristics could explain more of the variation about the storm-runoff loads.

Regression models of urban storm-runoff quality need to include atmospheric contributions of ammonia and nitrate to more completely define the system (Halverson and others, 1984). Only extremely limited data were available on rainfall quality, but MNL was tested in all the nitrogen models as a means to define atmospheric contribution. Ellis, Harrop, and Revitt (1986) determined that storm duration was significant in explaining the observed variance in lead, cadmium, manganese, and sediment in storm-runoff loads. A variety of climatic characteristics would have been tested if the data base had had sufficient data for the intensity and duration of storms and for antecedent dry days. If the data for these limited explanatory variables become available nationally, many of these other physical, land-use, and climatic characteristics need to be tested to improve the models.

Validation, Testing, and Application of Regression Models

Several tests were made to determine the soundness of the most accurate models. These tests included split-sample analysis and standardized beta coefficients. The results of each of the tests are described briefly in the following sections; also, two examples of model application are described.

Split-Sample Analysis

The usefulness of the regression models may be assessed by comparing model results with observed storm-runoff loads or volumes for several independent watersheds not used in model calibration. However, all available data for the analysis were used in developing the models. Consequently, split-sample analyses were done on the 34 models of storm-runoff loads and volumes to assess their accuracy at ungaged watersheds and watersheds not included in the calibration data set. Model validation is important because, even though a model seems to perform well for a calibration data set, it may not perform well for a noncalibration data set and vice versa (Troutman, 1985).

The relative accuracy of the various models presented in this report is judged by the standard error of estimate, which is a measure of how well the regression models estimate the response variables at calibration stations. In contrast, the standard error of prediction is a measure of how well the regression models estimate the response variables at other than calibration stations. Standard error of prediction usually is larger than standard error of estimate because of parameter estimation error, which is a function of sample size. Because the estimation sample size is smaller in the split-sample procedure, the parameter esti-

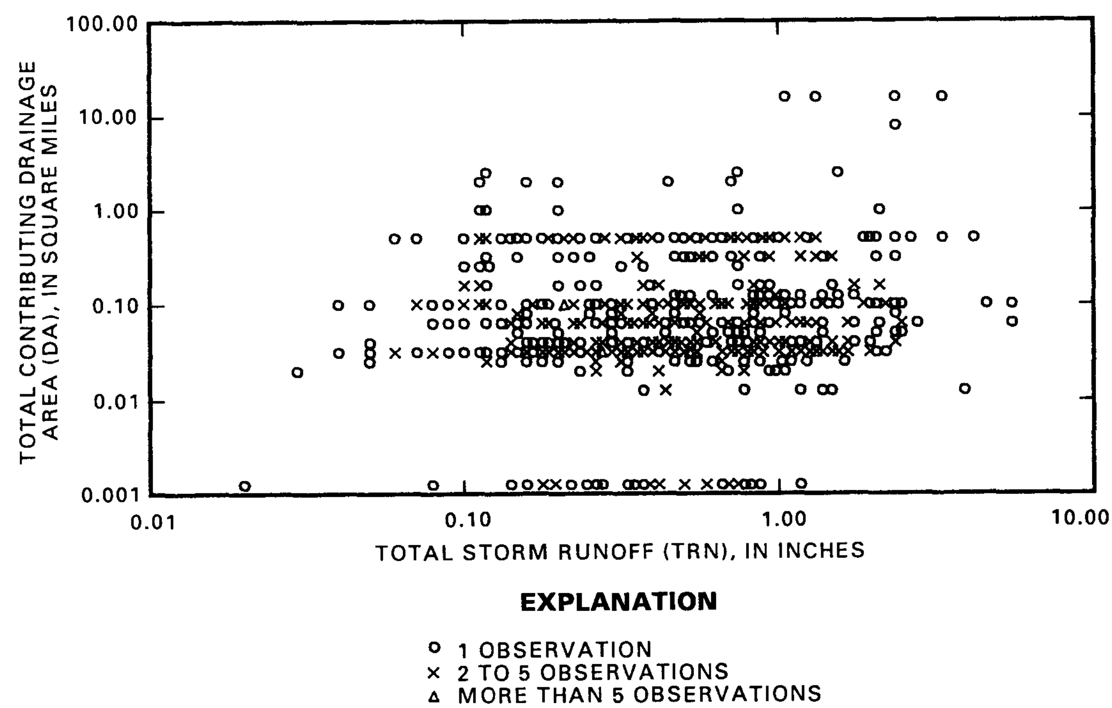


Figure 6. Relation between total storm rainfall and total contributing drainage area for storms in region III.

mation error, and hence the prediction error, would generally be larger than it would be by using the entire data set.

A split-sample analysis for each of the 34 regression models listed in table 1 was made to estimate the magnitude of the average prediction error and to determine whether the same explanatory variables were significant. The stations were divided into two groups of about equal size following a systematic procedure to avoid bias (the stations were listed numerically by station number and then assigned alternately to the first or second group). Multiple regression analysis done separately for each group yielded new regression (calibration) models very similar to the original models. Although in several of the calibration models some of the explanatory variables were not significant at the 5-percent level, the same explanatory variables used in the original models in table 1 are used in the calibration models. By using the calibration models from the first group to estimate storm-runoff loads or volumes in the second group, and vice versa, the average prediction error for storm-runoff loads ranged from 56 to 334 percent (table 2). Average prediction errors for storm-runoff volumes ranged from 69 to 119 percent.

Standardized Beta Coefficients

The explanatory variables for physical, land-use, and climatic characteristics in the regression models must be computed or estimated from maps, observations, and other data, which are subject to errors in measurement and judgment. Sensitivity tests indicate the effects of measurement and judgment errors on estimation of the response variables in regression models.

Standardized beta coefficients for all regression models of storm-runoff loads and volumes are listed in table 4 to facilitate comparisons between regression coefficients. The standardized beta coefficient is the standard deviation of the explanatory variable divided by the standard deviation of the response variable. This coefficient reflects the change in the mean response (in units of standard deviations of the log of the response variable, listed in table 2) per unit change in the explanatory variable (in units of standard deviations of the log of the explanatory variable, listed in table 4) when all other explanatory variables are held constant. The coefficient can be utilized for sensitivity testing. Certain explanatory variables have more natural variance than other explanatory variables. For instance, DA can change considerably in a metropolitan area, whereas MAR changes minimally. All these factors need to be considered in sensitivity testing.

The importance of the explanatory variable based on the standardized beta coefficient needs to be interpreted cautiously because correlations between the explanatory variables affect the magnitude of the standardized beta coefficient. Spacing of the observations on the explanatory variables also affects the standardized beta coefficients (Neter and others, 1985). Sometimes the spacings of the observations on the explanatory variables may be rather arbitrary.

Application of Regression Models

Two examples of how to apply the regression models are described in this section, one for region I and the other for region II. A city planner from Reno, Nev., is trying to estimate a storm-runoff load for TN for storms (TRN) that averaged 0.5 inch in a particular drainage area (DA) of 0.1 square mile, which has 5 percent industrial land use (LUI), 10 percent commercial land use (LUC), and 15 percent nonurban land use (LUN). The city planner would use the TN I model listed in table 1. Using equation 3, adding the appropriate constants to the land-use variables, and using a value of mean annual rainfall (MAR) of 7.20 inches for Reno, Nev., (National Oceanic and Atmospheric Administration, 1980), the storm-runoff load is calculated as follows:

$$\text{TN I} = 1{,}132 \times (0.5)^{(0.798)} \times (0.1)^{(0.960)} \times (6)^{(0.462)} \times (11)^{(0.260)} \times (17)^{(-0.194)} \times (7.20)^{(0.951)} \times 1.139$$

$$\text{TN I} = 31 \text{ pounds.}$$

If the median response of the response variable instead of the mean response is desired, the BCF of 1.139 would not be applied to the model.

A city engineer from Cleveland, Ohio, needs an estimate of storm-runoff load for DP for storms that averaged 1.2 inches in an urban watershed of 0.5 square mile, which has about 40 percent impervious area and a 2-year, 24-hour rainfall intensity of 2.5 inches. The city engineer would use the DP II model listed in table 1 because the mean annual rainfall in Cleveland is 34.99 inches. The calculations are as follows:

$$\text{DP II} = 0.025 \times (1.2)^{(0.914)} \times (0.5)^{(0.699)} \times (41)^{(0.649)} \times (2.5)^{(1.024)} \times 1.591$$

$$\text{DP II} = 0.82 \text{ pound.}$$

If the median response of the response variable is desired rather than the mean response, the BCF of 1.591 would not be applied to the model.

If the mean annual rainfall for a particular metropolitan area is almost equal to the quantity used to divide the Nation into regions (that is, about 20 inches or 40 inches), an averaging technique needs to be used. Calculate the storm-runoff load for each of the two appropriate regional models and then average the two storm-runoff loads.

ESTIMATING PROCEDURES FOR STORM-RUNOFF MEAN CONCENTRATIONS

Models of storm-runoff mean concentration were developed for additional estimations by city planners and engineers involved in determining urban water quality. Storm-runoff mean concentrations have been determined to be essentially uncorrelated with storm-runoff volume, and station comparisons can be made with high confidence levels using concentration data (U.S. Environmental Protection Agency, 1983). For each region, a regression model was developed that relates 11 storm-runoff mean concentrations to physical, land-use, and climatic characteristics. Methods for developing the regression models and corresponding statistics are described in the following sections.

Methods

Storm-runoff mean concentrations, expressed in either milligrams per liter or micrograms per liter, were calculated for U.S. Geological Survey data by dividing total storm-runoff load, in pounds, by average storm-runoff depth over the basin, in inches, and by total contributing drainage area, in square miles, multiplied by a conversion factor. U.S. Environmental Protection Agency data for storm-runoff mean concentration were cited directly from the results of the NURP (U.S. Environmental Protection Agency, 1983). The values of storm-runoff mean concentration from the U.S. Environmental Protection Agency were calculated by dividing storm-runoff load, in pounds per acre, by average storm-runoff depth over the basin, in inches, multiplied by a conversion factor.

After development of the storm-runoff-load models, development of storm-runoff mean concentration models was needed. Because development of storm-runoff mean concentration models was a secondary objective, the storm-runoff-load models were used as the basic structure from which to develop the storm-runoff mean concentration models. The explanatory variables selected for each storm-runoff-load model were used for corresponding storm-runoff mean concentration models. Explanatory variables that were not significant at the 5-percent or better level in a model have an asterisk beside the coefficient in table 5. Most of the explanatory variables were significant according to an *F*-test.

After applying the same transformations from the storm-runoff-load models to the storm-runoff mean concentration models, residual patterns were studied to verify if regression assumptions were met. Examination of the residuals indicated that the residuals were normalized, that the random errors had constant variance throughout the range of the response variables, and that the errors were uncorrelated. Therefore, all regression models for storm-runoff mean concentrations were based on logarithmic transformations of the response and explanatory variables. Regression models listed in table 5 have the same form as equation 3.

Models

Thirty-one models of storm-runoff mean concentrations were developed for metropolitan areas throughout the United States. There was one regression model for each of the storm-runoff mean concentrations in each of the three mean annual rainfall regions, except for dissolved solids and cadmium. These exceptions are explained in the "Models" for storm-runoff loads and volumes section.

These models and their BCF's are listed in table 5. The corresponding R^2, standard errors of estimate (expressed in percent and in logs), number of storms and stations, and mean of log of response variable are listed in table 6. The values of R^2 range from 0.10 to 0.68, and standard errors of estimate range from 45 to 179 percent. Although the explained variability as measured by R^2 is small, the standard errors of estimate are smaller in the models for storm-runoff mean concentrations than in the models for storm-runoff loads, because storm-runoff mean concentrations have reduced variability.

Signs of the coefficients for each of the models generally were logical. Correlations between explanatory variables in these models were small. The explanatory variables expected to indicate an increase in storm-runoff mean concentrations resulting from an increase in the variable were IA, LUI, LUC, LUR, PD, INT, and MNL. The explanatory variables TRN, DA, LUN, DRN, MAR, and MJT were expected to indicate a decrease in storm-runoff mean concentrations resulting from an increase in the variable. Storm-runoff mean concentrations generally had an inverse relation to rainfall and drainage area. The smaller the storm, the greater the storm-runoff mean concentrations, because the dilution effect was not as great during smaller storms. However, some concentrations such as suspended solids had a positive relation to rainfall, possibly because larger amounts of rainfall may indicate greater rainfall intensity, which would produce larger concentrations of suspended solids. Also, some concentrations had a positive relation to drainage area. A possible explanation for this phenomenon is that the larger the drainage area, the larger the percent of pervious area. Large concentrations of suspended solids and associated constituents generally are associated with pervious areas. Therefore, the drainage area may be a surrogate for pervious area in some models.

Although DA was significant in all of the models for storm-runoff loads, DA was not significant in many of the models for storm-runoff mean concentrations. TRN generally was significant, and IA, land-use, and mean annual climatic characteristics occasionally were significant in the models for storm-runoff mean concentrations.

ESTIMATING PROCEDURES FOR MEAN SEASONAL OR ANNUAL LOADS

Reconnaissance studies of urban storm-runoff loads often require preliminary estimates of mean seasonal or annual loads from stations that have minimal or no storm-runoff or concentration data. These preliminary estimates can be made by relating observed mean seasonal or annual loads from other stations in the region to physical, land-use, or climatic characteristics using a regional-regression analysis. The purpose of this part of the study is to decrease the large data base of urban-runoff water-quality data to a set of regression models that may be used to estimate mean loads for 10 chemical constituents—chemical oxygen demand (COD), suspended solids (SS), dissolved solids (DS), total nitrogen (TN), total ammonia plus organic nitrogen as nitrogen (TKN), total phosphorus (TP), dissolved phosphorus (DP), total recoverable copper (CU), total recoverable lead (PB), and total recoverable zinc (ZN).

The available data do not lend themselves to a direct application of ordinary least-squares regression analysis. First, the observed load data were collected over a relatively short period of time, and during the period of collection not all storm-runoff events were sampled. In addition, in some areas storm-runoff load data were not collected during winter months or during periods when the ground was covered with snow. To overcome the problem of short records, at-site regression models were developed based on observed records for each of the 10 constituents. These models were developed for each station by relating observed storm-runoff loads to observed total storm rainfall and sometimes to duration of storm rainfall for a number of individual storms. The reliability of each of these at-site regression models also varied greatly from station to station because of the number of storms recorded, and the fit of the observed storms varied greatly. Twenty-four of the thirty metropolitan areas met the selection criteria of having constituent and rainfall data for a minimum of six storms. In some metropolitan areas, much of the wintertime precipitation is snow rather than rain, which results in minimal direct runoff. At stations in these metropolitan areas (indicated by asterisks in tables 12*A* through 12*J* at the end of this report) the storm-runoff loads were calculated only for storms that occurred during April through September. At the remaining stations, the storm-runoff loads were calculated for storms that occurred throughout the year. The at-site load-rainfall models along with a nearby long-term rainfall record allow the load data to be extended, and a more reliable estimation of mean load then can be obtained.

Response Variable—Mean Load for a Storm

To overcome the problem of attempting a nationwide regression of mean loads when loads at some stations were based on seasonal calculations and loads at other stations were based on annual calculations, a new variable called mean load for a storm is defined. Before defining the mean load for a storm, a precise definition of a storm is given. For this report, a storm is a rainfall event in which the total rainfall is at least 0.05 inch. Storms are separated by at least six consecutive hours of zero rainfall. Rainfall records (Warren, 1983) from long-term rainfall-record stations near the storm-runoff load stations were examined; the number of storms were counted, and the total storm rainfall (TRN), in inches, and duration of storms (DRN), in hours, were averaged (table 7). The mean load for a storm, W, can be estimated in a two-step process. First, the coefficients for the following equation were derived using short-term storm data at each site:

$$\hat{W}_i = a_i + b_{1i}\,\bar{R}_i + b_{2i}\,\bar{D}_i \qquad (5)$$

where

$\hat{W}_i$ = estimated mean load for a storm (last column of table 12*A* through 12*J*),
a_i = intercept,
b_{1i} = coefficient for total storm rainfall,
$\bar{R}_i$ = mean rainfall for storms at station i,
b_{2i} = coefficient for duration of rainfall, and
$\bar{D}_i$ = mean duration of rainfall for storms at station i.

Then these coefficients were used to estimate the mean load for a storm by substituting the long-term mean rainfall and duration in equation 5. Values for each $\hat{W}$ for each station and each constituent are listed in tables 12*A* through 12*J* at the end of this report; a_i, b_{1i}, and b_{2i} are estimated from a linear regression model of observed storm-runoff loads from observed storms. Table 7 shows the mean number of storms per season or year, M. Mean seasonal load or mean annual load for each constituent may be calculated as $\hat{W} \times M$.

The models in tables 12*A* through 12*J* should not be used to determine loads for a single storm. They are used only to estimate the mean load for a storm, $\hat{W}_i$, by substituting $\bar{R}_i$ and $\bar{D}_i$ into equation 5. The variance of $\hat{W}$ can be approximated by

$$\mathrm{Var}\,(\hat{W}_i) \cong \frac{S_{ei}^2}{L_i} + b_{1i}^2\frac{S_{Rj}^2}{n_j} + b_{2i}^2\frac{S_{Dj}^2}{n_j} \qquad (6)$$

where

S_{ei}^2 = mean square residual for the regression at station i,
L_i = number of storms used to estimate coefficients for the at-site regression model,
S_{Rj}^2 = sample variance of total rainfall record for the jth rainfall record associated with station i,
S_{Dj}^2 = sample variance of duration of rainfall for the jth rainfall record associated with station i, and
n_j = number of storms in the record.

Table 5. Summary of regression models for storm-runoff mean concentrations

[$\hat{\beta}_0$ is the regression coefficient that is the intercept in the regression model; TRN is total storm rainfall; DA is total contributing drainage area; IA is impervious area; LUI is industrial land use; LUC is commercial land use; LUR is residential land use; LUN is nonurban land use; PD is population density; DRN is duration of each storm; INT is maximum 24-hour precipitation intensity that has a 2-year recurrence interval; MAR is mean annual rainfall; MNL is mean annual nitrogen load in precipitation; MJT is mean minimum January temperature; BCF is bias correction factor; COD is chemical oxygen demand in storm-runoff mean concentration, in milligrams per liter; I is region I representing areas that have mean annual rainfall less than 20 inches; II is region II representing areas that have mean annual rainfall of 20 to less than 40 inches; III is region III representing areas that have mean annual rainfall equal to or greater than 40 inches; SS is suspended solids in storm-runoff mean concentration, in milligrams per liter; DS is dissolved solids in storm-runoff mean concentration, in milligrams per liter; TN is total nitrogen in storm-runoff mean concentration, in milligrams per liter; TKN is total ammonia plus organic nitrogen as nitrogen in storm-runoff mean concentration, in milligrams per liter; TP is total phosphorus in storm-runoff mean concentration, in milligrams per liter; DP is dissolved phosphorus in storm-runoff mean concentration, in milligrams per liter; CD is total recoverable cadmium in storm-runoff mean concentration, in micrograms per liter; CU is total recoverable copper in storm-runoff mean concentration, in micrograms per liter; PB is total recoverable lead in storm-runoff mean concentration, in micrograms per liter; ZN is total recoverable zinc in storm-runoff mean concentration, in micrograms per liter; RUN is storm-runoff volume, in cubic feet; dashes (--) indicate that the variable is not included in the model; asterisk (*) indicates the explanatory variable is not significant at the 5-percent level; equation form is:

$$Y = \hat{\beta}_0' \times X_1^{\hat{\beta}_1} \times X_2^{\hat{\beta}_2} \ldots X_n^{\hat{\beta}_n} \times \text{BCF}]$$

Response variable and region	Regression coefficients														
	$\hat{\beta}_0'$	TRN (inches)	DA (square miles)	IA +1 (percent)	LUI +1 (percent)	LUC +1 (percent)	LUR +1 (percent)	LUN +2 (percent)	PD (people per square mile)	DRN (minutes)	INT (inches)	MAR (inches)	MNL (pounds of nitrogen per acre)	MJT (degrees Fahrenheit)	BCF
COD I	5.035	-0.473	-0.087	--	0.388	0.012*	--	0.048*	--	--	--	0.855	--	--	1.163
COD II	.254	-.259	-.054	--	.0003*	.025*	--	-.033*	--	--	--	1.556	--	--	1.299
COD III	46.9	-.179	-.047	--	.320	.031	--	-.169	--	--	--	--	--	--	1.270
SS I	2,041	.143*	.108	--	--	--	--	--	--	-0.370	--	--	--	--	1.543
SS II	734	.132	-.342	-0.329	--	--	--	--	0.041	--	--	--	--	-0.519	1.650
SS III	176	.054*	.286	--	.168	.072	--	-.295	--	--	--	--	--	--	1.928
DS I	.333	-.402	.469	.445	--	--	--	--	--	--	--	1.497	--	--	1.352
DS II	2,398	-.112	.519	.468	--	--	--	--	--	--	--	--	--	-1.373	1.179
TN I	3.52	-.285	.033*	--	.512	.017*	--	.012*	--	--	--	-.129	--	--	1.096
TN II	1.65	-.204	.065	.176	--	--	--	--	--	--	--	--	-0.296	--	1.256
TN III	26,915	-.253	-.169	.057*	--	--	--	--	--	--	--	-2.737	--	--	1.308
TKN I	1.282	-.449	.022*	--	.426	-.016*	--	-.012*	--	--	--	--	.347	--	1.167
TKN II	.830	-.224	-.066	.039*	--	--	--	--	--	--	--	--	.106	--	1.321
TKN III	9,549	-.157	-.159	--	--	--	--	-.086	--	--	--	-2.447	--	--	1.326
TP I	.085	-.232	-.012*	--	.552	-.080	--	.038*	--	--	--	.530	--	--	1.261
TP II	.022	-.177	-.133	.006	--	--	--	--	--	--	2.019	--	--	--	1.521
TP III	2.630	-.016	-.107	--	--	.053	0.184	-.168	--	--	--	--	--	-.710	1.365
DP I	.352	-.294	-.013*	--	.629	-.136	--	-.046*	--	--	--	-.297*	--	--	1.266
DP II	.003	-.209	-.174	.245	--	--	--	--	--	--	1.514	--	--	--	1.567
DP III	.060	.189	-.076	--	--	--	--	.358	--	--	--	--	--	--	1.341
CD I	.338	-.256	.025*	--	.090*	.033*	--	-.110	--	--	--	.481*	--	--	1.166
CD II	.851	.223*	.189*	--	--	--	--	--	--	--	--	--	--	.394*	1.284
CU I	11.3	-.327	.066*	--	.237	.048*	--	.155	--	--	.406*	--	--	--	1.297
CU II	9.683	-.298	-.151	.157*	--	--	--	--	--	--	--	--	--	--	1.473
CU III	1,774	-.104	-.077	--	.446	.078	--	-.204	--	--	-3.247	--	--	--	1.348
PB I	141	-.347	.145	--	-.109	.034*	--	-.086	--	--	--	.046*	--	--	1.304
PB II	.487	-.268	-.359	--	--	.099	.152	-.008*	--	--	--	1.088	--	--	1.433
PB III	39.8	-.196	.123	.404	--	--	--	--	--	--	--	--	--	--	1.510
ZN I	199	-.338	.070*	--	--	-.029	.114*	.068*	--	--	--	-.004*	--	--	1.242
ZN II	.149	-.238	-.201	.278	--	--	--	--	--	--	--	--	--	1.961	1.650
ZN III	1,879	-.149	-.061*	--	.285	.146	-.078	--	--	--	--	--	--	-.916	1.322

Note that equation 6 underestimates Var $(\hat{W}_i)$ because it does not include the additional variance in $\hat{W}_i$ due to uncertainty in the estimates of b_{1i} and b_{2i}. This additional variance is assumed to be negligible. Assuming rainfall quantities and duration are uncorrelated, the sample covariance between $\hat{W}_i$ at station i and $\hat{W}_k$ at station k, which was computed from a common long-term rainfall record, can be approximated by

$$\text{Cov}\ (\hat{W}_i, \hat{W}_k\ ) \cong b_{1i}\, b_{1k}\, \frac{S^2_{Rj}}{n_j} + b_{2i}\ b_{2k}\frac{S^2_{Dj}}{n_j}. \qquad (7)$$

At the stations for which $\hat{W}_i$ and $\hat{W}_k$ were computed using different long-term rainfall records, the Cov $(\hat{W}_i, \hat{W}_k\ )$ are assumed to be zero. Therefore, $\hat{W}$'s for stations located near different metropolitan areas are assumed to be uncorrelated, and $\hat{W}$'s for stations within or near a common long-term rainfall record have some degree of correlation.

Explanatory Variables

A number of physical, land-use, and climatic characteristics were screened for possible use in explaining variations from station to station in the mean seasonal or annual loads. Based on physical reasoning, preliminary regression runs, and plots, the following characteristics were chosen for further analysis:

Physical and land-use characteristics:

1. Total contributing drainage area (DA), in square miles.
2. Impervious area (IA), as a percent of total contributing drainage area.

Table 6. Summary of statistics for regression models of storm-runoff mean concentrations

[This table corresponds to models in table 5; COD is chemical oxygen demand in storm-runoff mean concentration, in milligrams per liter; I is region I representing areas that have mean annual rainfall less than 20 inches; II is region II representing areas that have mean annual rainfall of 20 to less than 40 inches; III is region III representing areas that have mean annual rainfall equal to or greater than 40 inches; SS is suspended solids in storm-runoff mean concentration, in milligrams per liter; DS is dissolved solids in storm-runoff mean concentration, in milligrams per liter; TN is total nitrogen in storm- runoff mean concentration, in milligrams per liter; TKN is total ammonia plus organic nitrogen as nitrogen in storm-runoff mean concentration, in milligrams per liter; TP is total phosphorus in storm-runoff mean concentration, in milligrams per liter; DP is dissolved phosphorus in storm-runoff mean concentration, in milligrams per liter; CD is total recoverable cadmium in storm-runoff mean concentration, in micrograms per liter; CU is total recoverable copper in storm-runoff mean concentration, in micrograms per liter; PB is total recoverable lead in storm-runoff mean concentration, in micrograms per liter; ZN is total recoverable zinc in storm-runoff mean concentration, in micrograms per liter]

Response variable and region	R^2	Standard error of estimate (percent)	Standard error of estimate (log)	Number of storms	Number of stations	Mean of log of response variable (pounds)
COD I	0.52	61	0.245	216	21	2.141
COD II	.20	79	.303	792	57	1.859
COD III	.18	78	.300	563	33	1.744
SS I	.13	131	.434	176	19	2.321
SS II	.19	128	.427	963	44	2.142
SS III	.14	178	.519	528	29	1.724
DS I	.68	86	.322	175	17	1.913
DS II	.66	63	.253	281	21	1.998
TN I	.54	45	.189	121	16	.584
TN II	.10	75	.291	573	45	.302
TN III	.37	78	.300	613	37	.279
TKN I	.59	60	.242	188	23	.503
TKN II	.12	85	.321	857	62	.177
TKN III	.31	85	.321	609	35	.106
TP I	.51	78	.303	186	19	- .237
TP II	.15	122	.415	1,090	60	-.615
TP III	.29	94	.345	635	35	-.608
DP I	.56	78	.300	248	23	-.688
DP II	.31	114	.396	467	31	-1.370
DP III	.24	90	.334	247	16	-.914
CD I	.20	61	.247	65	15	.196
CD II	.10	89	.333	47	5	.312
CU I	.34	83	.316	212	22	1.533
CU II	.14	109	.386	298	17	1.491
CU III	.67	81	.308	464	30	1.418
PB I	.19	88	.331	239	23	2.215
PB II	.41	103	.371	942	54	2.085
PB III	.37	179	.414	384	31	2.139
ZN I	.22	80	.308	224	21	2.319
ZN II	.15	138	.450	357	31	2.169
ZN III	.37	79	.345	591	30	2.084

3. An indicator variable ($X1$), that is 1 if residential land use (LUR) plus nonurban land use (LUN) exceeds 75 percent of the total contributing drainage area and that is zero otherwise.
4. An indicator variable ($X2$), that is 1 if industrial land use (LUI) plus commercial land use (LUC) exceeds 75 percent of the total contributing drainage area and that is zero otherwise.

Climatic characteristics:

1. Mean annual rainfall (MAR), in inches.
2. Mean minimum January temperature (MJT), in degrees Fahrenheit.

Values for the explanatory variables used in the regression analysis and the stations used for each regression are listed in table 8. Not all stations were used in the regression analysis because an estimate of the long-term mean seasonal or annual loads for each station was not always available. The regression analysis was limited to stations that had drainage areas that ranged from 0.01 to 0.85 square mile, although some data outside this range were available. This was done so that the analysis would not be greatly affected by a few points that plotted away from the bulk of the data.

Table 7. Location and long-term rainfall-record data for stations used in a nationwide study of urban mean seasonal and mean annual loads

[Rainfall record consists of alphabetical and numerical State code and rainfall-record identification according to the National Oceanic and Atmospheric Administration; mean number of storms marked with an asterisk (*) are seasonal (April-September) number of storms rather than annual number of storms; dashes (--) indicate that the variable is not included in the calculation]

		Statistics for long-term record					
				Sample variance for			
Metropolitan area	Rainfall record	Mean of rainfall per storm (inch)	Mean of duration of rainfall per storm (hours)	Storm rain-fall (inch)	Duration of rainfall (hours)	Number of storms in record	Mean number of storms per season or year
Ann Arbor, Mich.	MI 20 0230	0.3647	--	0.1456	--	691	38*
Austin, Tex.	TX 41 0428	.5846	--	.6209	--	2,194	54
Baltimore, Md.	MD 18 0470	.5627	--	.5672	--	1,374	39*
Bellevue, Wash.	WA 45 7473	.3740	12.3805	.2056	124.7356	1,866	98
Boston, Mass.	MA 19 0770	.3969	--	.3831	--	1,852	52*
Champaign-Urbana, Ill.	IL 11 8740	.5487	--	.4179	--	1,044	42*
Columbus, Ohio	OH 33 1786	.4459	--	.2267	--	1,690	48*
Durham, N.H.	NH 29 2174	.4356	--	.2661	--	1,214	38*
Fresno, Calif.	CA 04 3257	.2587	7.6070	.1262	61.1374	1,481	41
Glen Ellyn, Ill.	IL 11 1549	.4887	--	.3776	--	1,534	43*
Kansas City, Mo.	MO 23 4359	.5748	--	.4578	--	1,033	41*
Knoxville, Tenn.	TN 40 4950	.5078	--	.3328	--	3,260	92
Lake George, N.Y.	NY 30 9389	.3815	--	.1830	--	1,649	46*
Lakewood, Colo.	CO 05 2220	.3542	7.3483	.2335	72.2492	1,002	28*
Lansing, Mich.	MI 20 4641	.4063	--	.2730	--	1,276	41*
Miami, Fla.	FL 08 5663	.5547	--	.7633	--	3,418	100
Milwaukee, Wis.	WI 47 5479	.4396	6.7932	.2577	36.3012	1,504	42*
Portland, Oreg.	OR 35 6751	.3785	--	.2113	--	3,434	96
Rochester, N.Y.	NY 30 7167	.3605	--	.1560	--	1,582	45*
Saint Paul, Minn.	MN 21 5435	.4218	--	.2467	--	1,539	43*
Salt Lake City, Utah	UT 42 7598	.2961	7.8489	.1086	50.5012	834	23*
Tampa, Fla.	FL 08 8788	.6438	--	.7296	--	325	79
Washington D.C.	MD 18 9290	.5396	--	.4209	--	710	42*
Winston-Salem, N.C.	NC 31 7069	.5375	--	.3935	--	2,766	77

Therefore, the analysis was limited to stations that had drainage areas in the ranges listed in table 9. To extend the analysis outside these ranges requires additional data. In general, the models should not be used to estimate mean storm loads at stations whose characteristics are much beyond the range of values listed in table 9.

Methods

As indicated in equation 6, the variance of $\hat{W}_i$ is a function of a fit of the at-site storm-runoff-load and rainfall model, the value of S^2_{ei}, and the number of storms used to estimate its coefficient, L_i . Because S^2_{ei} and L_i (tables 12*A* through 12*J* at the end of this report) vary greatly from station to station, the variance of $\hat{W}_i$ also will vary from station to station.

A straightforward application of the ordinary least-squares method can be used to estimate the parameters of a nationwide regression model of load for a mean storm against basin characteristics, and the ordinary least-squares results are included for comparison. However, use of the ordinary least-squares method is not suggested for two important reasons. First, the station-to-station variance of the estimates of the load for a mean storm is large, as indicated in tables 12*A* through 12*J*. This violates the assumption of equal variances for the response variable that is necessary for ordinary least squares to be appropriate. Second, long-term mean seasonal or annual loads at many stations were calculated from common long-term rainfall records (eq 7). This calculation does not fulfill the assumption that the observed loads are independent from station to station, which also is necessary for ordinary least squares to be appropriate.

A method for estimating the parameters of a regression model when the variances of the response variables are not equal and when the response variables are not independent is generalized least squares. Let $\mathbf{y} = \log(\mathbf{W})$ denote a vector of log (base 10) transformed mean loads for a storm and $\mathbf{W}$ denote a vector of mean loads, $\hat{W}$, for a storm for the stations under consideration. Then the generalized least-squares model may be written

$$y = X\boldsymbol{\beta} + e \qquad (8)$$

where

X = $(n \times p)$ matrix of the physical, land-use, or climatic characteristics at the stations augmented by a column of 1's,

$\boldsymbol{\beta}$ = $(p \times 1)$ vector of regression coefficients to be estimated, and

Table 8. Explanatory variables used in regression models for mean seasonal or mean annual loads

[COD is chemical oxygen demand in mean seasonal or mean annual load, in pounds; SS is suspended solids in mean seasonal or mean annual load, in pounds; DS is dissolved solids in mean seasonal or mean annual load, in pounds; TN is total nitrogen in mean seasonal or mean annual load, in pounds; TKN is total ammonia plus organic nitrogen as nitrogen in mean seasonal or mean annual load, in pounds; TP is total phosphorus in mean seasonal or mean annual load, in pounds; DP is dissolved phosphorus in mean seasonal or mean annual load, in pounds; CU is total recoverable copper in mean seasonal or mean annual load, in pounds; PB is total recoverable lead in mean seasonal or mean annual load, in pounds; ZN is total recoverable zinc in mean seasonal or mean annual load, in pounds; DA is total contributing drainage area, in square miles; IA is impervious area, in percent; LUI is industrial land use, in percent; LUC is commercial land use, in percent; LUR is residential land use, in percent; LUN is nonurban land use, in percent; indicator variable X1 is 1 if residential land use plus nonurban land use exceed 75 percent of drainage area; indicator variable *X2* is 1 if commercial land use plus industrial land use exceed 75 percent drainage area; MAR is mean annual rainfall, in inches; MJT is mean minimum January temperature, in degrees Fahrenheit]

Metropolitan area	Station number	A '1' indicates that the site indicated was used in regression for the constituent below										Explanatory variables									
		COD	SS	DS	TN	TKN	TP	DP	CU	PB	ZN	DA	IA	LUI	LUC	LUR	LUN	X1	X2	MAR	MJT
Austin, Tex.	HART LANE	-	1	-	-	-	-	-	-	-	-	0.590	40	0	1	99	0	1	0	32.49	39.3
Austin, Tex.	ROLLING WOOD	1	-	-	-	-	1	-	-	-	-	.094	21	0	0	100	0	1	0	32.49	39.3
Baltimore, Md.	01589455	1	1	-	1	1	1	-	1	1	1	.026	29	0	0	100	0	1	0	40.46	24.9
Baltimore, Md.	01589460	-	-	1	1	1	-	-	-	1	1	.030	72	0	16	84	0	1	0	40.46	24.9
Baltimore, Md.	01589462	1	-	-	-	-	-	-	-	-	-	.036	29	0	0	100	0	1	0	40.46	24.9
Bellevue, Wash.	12119725	1	1	1	-	1	1	1	-	1	-	.150	36	0	7	90	3	1	0	37.21	33.9
Boston, Mass.	P1	1	-	-	1	1	-	1	1	1	1	.172	21	4	16	79	2	1	0	42.52	22.5
Boston, Mass.	P2	1	1	-	-	-	-	-	1	1	-	.528	23	11	24	47	18	0	0	42.52	22.5
Boston, Mass.	P3	1	1	-	-	1	1	1	1	1	1	.241	16	8	3	85	5	1	0	42.52	22.5
Boston, Mass.	P5	1	1	-	1	1	1	1	1	1	1	.156	33	0	63	8	29	0	0	42.52	22.5
Champaign-Urbana, Ill.	BASIN 1	1	1	-	-	1	1	-	1	1	-	.026	58	0	57	43	0	0	0	36.54	18.0
Champaign-Urbana, Ill.	BASIN 2	1	1	-	-	1	1	-	1	1	-	.043	37	0	10	90	0	1	0	36.54	18.0
Champaign-Urbana, Ill.	BASIN 4	1	1	-	-	1	1	-	1	1	-	.061	18	0	0	91	9	1	0	36.54	18.0
Champaign-Urbana, Ill.	BASIN 5	1	1	-	-	1	1	-	1	1	-	.085	19	0	0	100	0	1	0	36.54	18.0
Columbus, Ohio	03226900	1	1	1	1	1	1	-	1	1	1	.450	60	0	13	81	6	1	0	37.01	20.4
Columbus, Ohio	03227050	1	-	-	-	-	-	-	-	-	-	.600	85	0	23	74	4	1	0	37.01	20.4
Fresno, Calif.	364155119445000	1	-	1	-	-	-	-	1	1	1	.430	53	66	0	0	34	0	0	10.24	35.8
Fresno, Calif.	364746119445400	1	-	1	-	-	-	1	1	-	-	.150	43	0	0	96	4	1	0	10.24	35.8
Fresno, Calif.	364818119443800	1	-	1	-	-	-	1	1	1	1	.070	57	0	0	87	13	1	0	10.24	35.8
Fresno, Calif.	364818119464700	-	-	1	-	-	-	-	1	1	1	.090	99	0	100	0	0	0	1	10.24	35.8
Glen Ellyn, Ill.	415302088033804	-	-	-	1	-	1	-	1	1	1	.830	34	0	10	83	7	1	0	34.44	17.0
Kansas City, Mo.	IC	1	1	-	-	1	1	1	-	1	-	.091	97	0	96	0	4	0	1	37.00	19.3
Kansas City, Mo.	II	1	1	-	-	1	-	-	-	1	-	.112	44	56	0	0	44	0	0	37.00	19.3
Kansas City, Mo.	IR	1	-	-	-	1	1	1	-	-	-	.098	37	0	0	92	8	1	0	37.00	19.3
Kansas City, Mo.	RC	1	-	-	-	-	-	-	-	1	-	.056	68	0	50	50	0	0	0	37.00	19.3
Kansas City, Mo.	RR	1	1	-	-	-	-	-	1	1	-	.091	38	0	0	100	0	1	0	37.00	19.3
Knoxville, Tenn.	N47001	1	-	-	1	1	1	1	1	1	1	.040	99	0	100	0	0	0	1	46.18	32.2
Knoxville, Tenn.	N47004	-	-	-	-	-	-	1	-	-	-	.108	33	0	2	91	7	1	0	46.18	32.2
Knoxville, Tenn.	N47007	1	-	-	1	1	-	-	-	-	-	.140	13	0	4	96	0	1	0	46.18	32.2
Knoxville, Tenn.	N47010	1	1	-	1	-	-	-	1	1	1	.292	43	0	35	65	1	0	0	46.18	32.2
Lake George, N.Y.	3702	-	1	-	1	1	1	1	-	1	-	.119	5	0	36	6	58	0	0	33.62	10.8
Lakewood, Colo.	06711635	1	1	-	1	1	1	1	1	1	1	.110	59	0	30	33	37	0	0	15.51	16.2
Lansing, Mich.	001	1	1	-	1	1	1	1	1	1	1	.707	38	19	5	48	28	1	0	30.39	15.3
Lansing, Mich.	002	1	1	-	1	1	1	1	-	1	-	.098	64	100	0	0	0	0	1	30.39	15.3
Lansing, Mich.	006	1	-	-	1	1	1	1	-	1	1	.047	68	0	33	67	0	0	0	30.39	15.3
Lansing, Mich.	008	1	1	-	1	1	1	1	-	-	1	.256	28	10	0	55	34	1	0	30.39	15.3
Lansing, Mich.	010	1	1	-	1	1	1	1	1	1	1	.117	39	52	0	48	0	0	0	30.39	15.3
Miami, Fla.	261002080070100	1	-	-	1	1	1	-	1	1	1	.030	98	0	98	0	2	0	1	59.05	58.7
Miami, Fla.	261615080055900	1	-	-	1	1	1	-	-	-	-	.060	44	0	0	100	0	1	0	62.00	58.7
Miami, Fla.	261629080072400	1	-	-	1	1	1	-	1	1	1	.090	36	0	40	0	60	0	0	62.00	58.7
Milwaukee, Wis.	04086941	-	-	1	-	-	-	-	-	-	-	.060	44	0	0	100	0	1	0	29.07	11.4
Milwaukee, Wis.	04086943	-	-	1	1	-	-	1	-	-	1	.020	99	0	100	0	0	0	1	29.07	11.4
Milwaukee, Wis.	04086945	1	1	1	-	-	1	1	-	1	-	.020	98	0	100	0	0	0	1	29.07	11.4
Milwaukee, Wis.	04087056	-	-	-	-	-	-	1	-	-	-	.100	30	0	0	100	0	1	0	29.07	11.4
Milwaukee, Wis.	04087057	1	1	1	-	-	1	1	-	1	-	.050	30	0	0	100	0	1	0	29.07	11.4
Milwaukee, Wis.	04087115	-	1	1	-	-	-	-	-	1	-	.040	77	0	80	20	0	0	1	29.07	11.4
Milwaukee, Wis.	04087133	1	1	-	1	1	1	1	-	1	1	.070	81	0	70	30	0	0	0	29.07	11.4
Milwaukee, Wis	413630	1	1	-	1	-	-	-	-	1	-	.045	77	0	74	26	0	0	0	29.07	11.4
Milwaukee, Wis.	413631	1	1	-	1	1	1	-	-	1	1	.070	81	13	56	31	0	0	0	29.07	11.4
Milwaukee, Wis.	413632	1	1	-	1	1	1	-	-	1	1	.051	51	0	0	100	0	1	0	29.07	11.4
Milwaukee, Wis.	413633	1	1	-	1	1	1	-	-	1	1	.098	50	0	0	100	0	1	0	29.07	11.4
Milwaukee, Wis.	413634	1	1	-	1	1	1	-	-	1	1	.019	100	0	100	0	0	0	1	29.07	11.4
Milwaukee, Wis.	413635	1	1	-	1	1	1	-	-	1	1	.019	100	0	100	0	0	0	1	29.07	11.4
Milwaukee, Wis.	413636	1	1	-	-	-	1	-	-	1	-	.056	57	0	3	97	0	1	0	29.07	11.4
Portland, Oreg.	14206330	1	-	1	-	1	1	-	-	-	-	.210	19	0	0	58	43	1	0	37.61	32.5
Rochester, N.Y.	430403077311500	-	-	-	-	1	-	-	-	-	-	.260	22	0	0	100	0	1	0	31.33	16.7
Rochester, N.Y.	430428077261100	-	1	-	-	1	1	-	-	1	-	.360	16	0	37	28	35	0	0	31.33	16.7
Rochester, N.Y.	430649077285500	-	1	-	-	-	1	-	-	-	-	.570	38	0	12	88	0	1	0	31.33	16.7
Salt Lake City, Utah	10167220	1	1	-	-	1	1	1	-	1	-	.100	52	0	8	83	9	1	0	17.00	18.5
Salt Lake City, Utah	404653111545801	-	1	-	-	1	1	1	1	1	1	.230	64	0	35	56	9	0	0	17.00	18.5

Table 8. Explanatory variables used in regression models for mean seasonal or mean annual loads—Continued

Metropolitan area	Station number	A '1' indicates that the site indicated was used in regression for the constituent below										Explanatory variables									
		COD	SS	DS	TN	TKN	TP	DP	CU	PB	ZN	DA	IA	LUI	LUC	LUR	LUN	X1	X2	MAR	MJT
St. Paul, Minn.	445032092552801	1	1	-	1	1	1	-	-	1	-	.150	4	0	0	33	67	1	0	29.00	3.2
St. Paul, Minn.	445210093271701	-	1	-	1	1	1	-	-	1	-	.130	11	0	1	87	12	1	0	29.00	3.2
St. Paul, Minn.	445937093230701	1	1	-	1	1	1	-	-	1	-	.330	22	0	0	83	17	1	0	29.00	3.2
St. Paul, Minn.	450011093221901	1	1	-	1	1	1	-	-	1	-	.120	70	0	85	10	6	0	1	29.00	3.2
St. Paul, Minn.	450100093205501	1	1	-	1	1	1	-	-	1	-	.470	35	0	20	80	1	1	0	29.00	3.2
St. Paul, Minn.	450541093201201	1	1	-	1	1	1	-	-	1	-	.220	29	0	4	97	0	1	0	29.00	3.2
Tampa, Fla.	TNURPS013	-	-	-	-	-	-	-	1	-	-	.014	6	0	0	100	0	1	0	49.38	50.1
Tampa, Fla.	TNURPS023	1	-	-	1	1	1	-	1	1	1	.303	97	0	25	55	21	1	0	49.38	50.1
Tampa, Fla.	TNURPS033	1	-	-	1	1	1	-	1	1	1	.046	13	0	0	48	52	1	0	49.38	50.1
Tampa, Fla.	TNURPS173	1	1	-	1	1	-	-	1	1	1	.066	16	0	0	89	11	1	0	49.38	50.1
Tampa, Fla.	TNURPS183	-	1	-	-	-	-	-	-	-	-	.073	45	0	91	9	0	0	1	49.38	50.1
Washington, D.C.	DC151UR07	1	1	-	1	1	1	1	1	1	1	.107	27	0	0	100	0	1	0	40.00	25.0
Washington, D.C.	DC151UR09	1	-	-	1	1	1	1	-	-	1	.029	34	0	0	88	12	1	0	40.00	25.0
Washington, D.C.	DC151UR10	1	1	-	1	1	1	1	-	1	1	.043	34	0	0	78	23	1	0	40.00	25.0
Washington, D.C.	DC151UR15	1	-	-	1	1	1	1	-	-	-	.064	21	0	0	93	7	1	0	40.00	25.0
Winston-Salem, N.C.	Q2485000	1	1	-	1	1	1	-	1	1	1	.506	27	2	2	84	12	1	0	41.36	28.5

e = $(n \times 1)$ vector of error terms with $E(e) = \mathbf{0}$ and $E(ee') = \Lambda$, where $'$ = transpose.

The generalized least-squares parameter estimates (Stedinger and Tasker, 1985) are

$$\hat{\beta}_{GLS} = (X'\Lambda^{-1}X)^{-1}\, X'\Lambda^{-1}y. \tag{9}$$

The difficulty in using the generalized least-squares estimator of β is that Λ needs to be known. However, Λ is unknown and needs to be estimated from the data.

One approach is to assume that Λ is diagonal and has equal diagonal elements, $\Lambda = \sigma^2\mathbf{I}$, where $\mathbf{I}$ is an n-dimensional identity matrix. In this technique, the estimator is the same as the ordinary least-squares estimator, and the coefficients are estimated easily using standard statistical-computing packages. However, the ordinary least-squares estimator is not appropriate for this particular analysis. The ordinary least-squares results are included in table 10 for purposes of comparison.

Stedinger and Tasker (1985) reported on an operational generalized least-squares estimator that accounts for unequal variances in the response variables and for nonzero covariances between the variables at different sites. Although this generalized least-squares estimator was developed for streamflow, it can be adapted for use with the mean load for a storm, as described below.

Following the approach of Stedinger and Tasker (1985), the error term, e, is partitioned into an error inherent in the model and a parameter estimation error due to sampling. The estimator, $\hat{\Lambda}$, of the covariance matrix is

$$\hat{\Lambda} = \hat{\gamma}^2 I + \hat{\Sigma} \tag{10}$$

where

$\hat{\gamma}^2$ = an estimate of the variance of the error inherent in the model, and

$\hat{\Sigma}$ = an estimate of the sampling-error covariance matrix.

Assuming $\hat{y} = \log(\hat{W})$ is normally distributed, the diagonal elements of the sampling covariance matrix can be approximated by

$$(\hat{\Sigma})_{ii} = 0.1886 \ln\left[1 + \frac{\mathrm{Var}(\hat{W}_i)}{W_i^{\,2}}\right] \tag{10a}$$

where the Var $(\hat{W}_i)$ is given by equation 6 (Aitchison and Brown, 1957). The off-diagonal elements are given by

$$(\hat{\Sigma})_{ij} = 0.1886 \ln\left[1 + \frac{\mathrm{Var}(\hat{W}_i)^{1/2}\,\mathrm{Var}(\hat{W}_j)^{1/2}}{\hat{W}_i\,\hat{W}_j} \times \frac{\mathrm{Cov}(\hat{W}_i, \hat{W}_j)}{\mathrm{Var}(\hat{W}_i)^{1/2}\,\mathrm{Var}(\hat{W}_j)^{1/2}}\right] \tag{10b}$$

where Cov $(\hat{W}_i, \hat{W}_j)$ is given by equation 7 (Mejia and others, 1974).

The model error variance, γ^2, is estimated by solving

$$(y - X\hat{\beta}_{GLS})'\hat{\Lambda}^{-1}(y - X\,\beta_{GLS}) = n - p \tag{11}$$

where $\hat{\beta}_{GLS}$ is estimated by equation 9 with $\hat{\Lambda}$ substituted for Λ, and the variance-covariance matrix, U, for $\hat{\beta}_{GLS}$ is estimated by

$$U = \mathrm{Var}(\hat{\beta}_{GLS}) = (X\hat{\Lambda}^{-1}X)^{-1}. \tag{12}$$

Table 9. Range of explanatory variables used in regression models of mean seasonal or mean annual loads for indicated response variables

[DA is total contributing drainage area; IA is impervious area; MAR is mean annual rainfall; MJT is mean minimum January temperature; COD is chemical oxygen demand; SS is suspended solids in mean seasonal or mean annual load, in pounds; DS is dissolved solids in mean seasonal or mean annual load, in pounds; TN is total nitrogen in mean seasonal or mean annual load, in pounds; TKN is total ammonia plus organic nitrogen as nitrogen in mean seasonal or mean annual load, in pounds; TP is total phosphorus in mean seasonal or mean annual load, in pounds; DP is dissolved phosphorus in mean seasonal or mean annual load, in pounds; CU is total recoverable copper in mean seasonal or mean annual load, in pounds; PB is total recoverable lead in mean seasonal or mean annual load, in pounds; ZN is total recoverable zinc in mean seasonal or mean annual load, in pounds]

		Explanatory variables							
Response variable	Number of stations	DA (square miles) Minimum	DA (square miles) Maximum	IA (percent) Minimum	IA (percent) Maximum	MAR (inches) Minimum	MAR (inches) Maximum	MJT (degrees Fahrenheit) Minimum	MJT (degrees Fahrenheit) Maximum
COD	60	0.019	0.707	4	100	8.38	62.00	3.2	58.7
SS	48	.019	.707	4	100	8.38	49.38	3.2	50.1
DS	14	.020	.450	19	99	10.24	37.61	11.4	35.8
TN	41	.019	.830	4	100	11.83	62.00	3.2	58.7
TKN	52	.019	.707	4	100	8.38	62.00	3.2	58.7
TP	52	.019	.830	4	100	8.38	62.00	3.2	58.7
DP	28	.020	.707	5	99	8.38	46.18	10.8	35.8
CU	30	.014	.830	6	99	8.38	62.00	15.3	58.7
PB	57	.019	.830	4	100	8.38	62.00	3.2	58.7
ZN	34	.019	.830	13	100	8.38	62.00	11.4	58.7

An iterative search procedure is necessary to solve equation 11 because γ^2 is related to $\hat{\Lambda}$ using equation 10$\hat{\beta}_{GLS}$ and is related to $\hat{\Lambda}$ using equation 9.

Models

Models to estimate mean seasonal or annual loads as functions of physical, land-use, and climatic characteristics were developed for 10 chemical constituents: COD, SS, DS, TN, TKN, TP, DP, CU, PB, and ZN. Separate models were developed for each constituent using ordinary least squares and generalized least squares (table 10). A bias correction factor (BCF) was calculated for each model using a smearing estimate, which is a nonparametric method applying average retransformed residuals according to suggestions in Duan (1983). The BCF can be applied to each model to make the prediction models approximately unbiased because the linear regression model was fitted to the logarithms of the mean seasonal or annual loads (Ferguson, 1986).

The explanatory variables for each regression model were selected based on their contribution to explaining the variance in the log of the mean loads for a storm. All the variables listed in table 10 were significant at the 5-percent level. The square root of DA was a significant explanatory variable in every model. The transformation of DA to $DA^{1/2}$ was determined to be the best according to the maximum likelihood method (Draper and Smith, 1981) after looking at results from other candidate transformations, specifically DA, DA^2, $DA^{3/4}$, $DA^{1/4}$, log(DA), $DA^{-1/4}$, $DA^{-1/2}$, $DA^{-3/4}$, DA^{-1}, and DA^{-2}. The coefficient for IA was positive and statistically significant at the 5-percent level in the regression models for COD, TN, TKN, PB, and ZN mean loads for a storm. The coefficient for *X*2, a land-use indicator variable, was significantly negative for TN and TKN. This indicates that there are two relations for TN and TKN, one that applies when LUI + LUC is greater than 75 percent and one that applies when LUI + LUC is less than 75 percent. One or both of the climatic variables MAR and MJT were significant at the 5-percent level in the models for SS, DS, TKN, TP, and CU mean loads for a storm.

The fit of the regression models may be measured by the R^2 value (table 10), which is the fraction of variance in *Y* explained by the model. These values ranged from 0.20 for the model of DP to 0.65 for the model of TP. A measure of how accurate the models are for prediction at unmonitored stations is the average variance of prediction. This statistic is computed by averaging the estimated variance of prediction at a station over the stations used in the regression. In ordinary least squares, the variance of prediction at a station *i*, V_{pi}, is estimated by

$$\hat{V}_{pi} = \hat{\sigma}_e^2 (1 + x_i (X'X)^{-1} x_i') \qquad (13)$$

where

$\hat{\sigma}_e$ = standard error of estimate for the regression, and

x_i = a row vector of explanatory variables augmented by a 1 as the first element for station *i* (Draper and Smith, 1981).

Table 10. Results of regression models of mean loads of a storm for indicated constituents on physical, land-use, or climatic characteristics of the watershed

[The response variable, Y, is the runoff load associated with the long-term mean runoff event; regression coefficients are significant at the 0.05 level.

$$\text{Model is: } \hat{W} = 10^{[\hat{\beta}_0 + \hat{\beta}_1 SQRT(DA) + \hat{\beta}_2 IA + \hat{\beta}_3 MAR + \hat{\beta}_4 MJT + \hat{\beta}_5 X2]} \times BCF.$$

DA is total contributing drainage area, in square miles; IA is impervious area, in percent; MAR is mean annual rainfall, in inches; MJT is mean minimum January temperature, in degrees Fahrenheit; X2 is an indicator variable of commercial plus industrial land uses exceeding or not exceeding 75 percent of drainage area; COD is chemical oxygen demand in mean seasonal or mean annual load, in pounds; SS is suspended solids in mean seasonal or mean annual load, in pounds; DS is dissolved solids in mean seasonal or mean annual load, in pounds; TN is total nitrogen in mean seasonal or mean annual load, in pounds; TKN is total ammonia plus organic nitrogen as nitrogen in mean seasonal or mean annual load, in pounds; TP is total phosphorus in mean seasonal or mean annual load, in pounds; DP is dissolved phosphorus in mean seasonal or mean annual load, in pounds; CU is total recoverable copper in mean seasonal or mean annual load, in pounds; PB is total recoverable lead in mean seasonal or mean annual load, in pounds; ZN is total recoverable zinc in mean seasonal or mean annual load, in pounds; OLS is ordinary least squares; GLS is generalized least squares; dashes (--) indicate that the variable is not included in the calculation]

Response variable $\hat{W}$	Method	Regression constant β_0	Regression coefficients for indicated explanatory variables: $\sqrt{DA}$ β_1	IA β_2	MAR β_3	MJT β_4	X2 β_5	Bias correction factor (BCF)	Number of stations	R^2 [1]	SE [2] (logs)	SE [2] (percent)	Average prediction error [3] (ASEP) (logs)	ASEP (percent) -	ASEP (percent) +	ASEP Average percent
COD	OLS	1.1262	2.0004	0.0049	--	--	--	1.301	59	0.53	0.333	89	0.342	-55	120	93
	GLS	1.1174	2.0069	.0051	--	--	--	1.298			.302	79	.311	-51	105	82
SS	OLS	1.4627	1.6021	--	0.0299	-0.0342	--	1.670	47	.43	.462	145	.482	-67	203	156
	GLS	1.5430	1.5906	--	.0264	-.0297	--	1.521			.412	121	.433	-63	171	130
DS	OLS	1.8656	2.5501	--	--	-.0244	--	1.278	13	.61	.341	92	.378	-58	139	106
	GLS	1.8449	2.5468	--	--	-.0232	--	1.251			.310	81	.349	-55	123	95
TN	OLS	- .2398	1.6039	.0065	--	--	-0.4832	1.332	41	.49	.367	102	.385	-59	143	109
	GLS	- .2433	1.6383	.0061	--	--	-.4442	1.345			.345	94	.363	-57	131	100
TKN	OLS	- .7326	1.5991	.0067	.0219	-.0199	-.4553	1.264	51	.49	.339	92	.359	-56	129	99
	GLS	- .7282	1.6123	.0064	.0226	-.0210	-.4345	1.277			.316	83	.337	-54	119	91
TP	OLS	-1.4443	2.0918	--	.0246	-.0211	--	1.330	51	.65	.328	88	.341	-54	119	92
	GLS	-1.3884	2.0825	--	.0234	-.0213	--	1.314			.303	79	.316	-52	107	83
DP	OLS	-1.3898	1.4316	--	--	--	--	1.508	28	.20	.412	121	.427	-63	167	128
	GLS	-1.3661	1.3955	--	--	--	--	1.469			.372	104	.388	-59	144	110
CU	OLS	-1.4861	1.7646	--	--	-.0136	--	1.457	30	.41	.391	112	.410	-61	157	120
	GLS	-1.4824	1.8281	--	--	-.0141	--	1.403			.361	100	.381	-58	140	108
PB	OLS	-2.0676	1.9880	.0081	.0121	--	--	1.477	56	.46	.403	117	.417	-62	161	123
	GLS	-1.9679	1.9037	.0070	.0128	--	--	1.365			.353	97	.368	-57	133	102
ZN	OLS	-1.6504	2.0267	.0073	--	--	--	1.356	34	.59	.343	93	.358	-56	128	99
	GLS	-1.6302	2.0392	.0072	--	--	--	1.322			.310	81	.326	-53	128	87

[1] R^2 is the proportion of variance in Y explained by the sample regression model.

[2] SE in logs for OLS regression is the standard error of estimate (square root of first term on right side of equation 15). SE in logs for GLS regression is the standard error of the model (square root of first term on right side of equation 16).

[3] ASEP is the square root of the average variance of prediction. It is computed from equation 15 for OLS and equation 16 for GLS. ASEP is given in log units and percent. The conversion from logs to percent is

$$\text{ASEP (+percent)} = 100[10^{\text{ASEP(logs)}} - 1]$$

$$\text{ASEP (-percent)} = 100[10^{-\text{ASEP(logs)}} - 1]$$

$$\text{ASEP (average percent)} = 100[e^{SE^2 \times 5.302} - 1]^{1/2}$$

The equivalent statistic for the generalized least squares is

$$\hat{V}_{pi} = \hat{\gamma}^2 + x_i \, U \, x_i' \qquad (14)$$

(Stedinger and Tasker, 1985). The average prediction error at unmonitored stations can be appraised by assuming that the values of the explanatory variables at the monitored stations used in the regional regressions are a representative sample of stations. The variance of prediction is computed at each of these stations using either equation 13 or 14 and an average over all stations determined. The square root of this average, denoted ASEP, is shown in table 10.

A $100(1-\alpha)$ confidence interval for the true mean load for a storm, W_i, at a particular unmonitored station i can be computed by

$$\frac{1}{T}\frac{\hat{W}_i}{BCF} < W_i < \frac{\hat{W}_i}{BCF} T \qquad (15)$$

where $\hat{W}_i$ is the regression estimate for one of the models in table 10 and

$$T = 10^{[t_{(\alpha/2,\, n-p)} (\hat{V}_{pi})^{1/2}]} \qquad (16)$$

Table 11. Variance-covariance matrix for regression parameter estimates for each of the 10 regression models

[This table corresponds to models in table 10; DA is total contributing drainage area, in square miles; IA is impervious area, in percent; MAR is mean annual rainfall, in inches; MJT is mean minimum January temperature, in degrees Fahrenheit; X2 is an indicator variable of commercial plus industrial land uses exceeding or not exceeding 75 percent of drainage area; COD is chemical oxygen demand in mean seasonal or mean annual load, in pounds; SS is suspended solids in mean seasonal or mean annual load, in pounds; DS is dissolved solids in mean seasonal or mean annual load, in pounds; TKN is total ammonia plus organic nitrogen as nitrogen in mean seasonal or mean annual load, in pounds; TP is total phosphorus in mean seasonal or mean annual load, in pounds; DP is dissolved phosphorus in mean seasonal or mean annual load, in pounds; CU is total recoverable copper in mean seasonal or mean annual load, in pounds; PB is total recoverable lead in mean seasonal or mean annual load, in pounds; ZN is total recoverable zinc in mean seasonal or mean annual load, in pounds; values are in scientific notation (example: 1.9363E-02 is 0.019363)]

COD	Constant	$\sqrt{DA}$	IA
Constant	1.9363E-02	-2.716E-02	-1.682E-04
$\sqrt{DA}$	-2.716E-02	6.4332E-02	9.8363E-05
IA	-1.682E-04	9.8363E-05	2.7996E-06

SS	Constant	$\sqrt{DA}$	MAR	MJT
Constant	1.2799E-01	-4.440E-02	-3.779E-03	1.0304E-03
$\sqrt{DA}$	-4.440E-02	1.2989E-01	2.8962E-05	-2.991E-04
MAR	-3.779E-03	2.8962E-05	1.4849E-04	-6.608E-05
MJT	1.0304E-03	-2.991E-04	-6.608E-05	7.3585E-05

DS	Constant	$\sqrt{DA}$	MJT
Constant	5.6262E-02	-5.360E-02	-1.248E-03
$\sqrt{DA}$	-5.360E-02	3.9703E-01	-3.337E-03
MJT	-1.248E-03	-3.337E-03	9.9534E-05

TN	Constant	$\sqrt{DA}$	IA	X2
Constant	3.4590E-02	-4.493E-02	-3.324E-04	4.7196E-03
$\sqrt{DA}$	-4.493E-02	1.0309E-01	1.1757E-04	1.3013E-02
IA	-3.324E-04	1.1757E-04	7.2720E-06	-3.484E-04
X2	4.7196E-03	1.3013E-02	-3.484E-04	4.2067E-02

TKN	Constant	$\sqrt{DA}$	IA	X2	MAR	MJT
Constant	1.0696E-01	-5.283E-02	-4.887E-04	1.8916E-02	-2.605E-03	1.2411E-03
$\sqrt{DA}$	-5.283E-02	1.0073E-01	1.2527E-04	7.7172E-03	2.7698E-04	3.6202E-05
X2	1.8916E-02	7.7172E-03	-3.384E-04	3.8246E-02	-5.631E-04	3.8766E-04
IA	-4.887E-04	1.2527E-04	6.5176E-06	-3.384E-04	9.2175E-06	-6.013E-06
MAR	-2.605E-03	2.7698E-04	9.2175E-06	-5.631E-04	9.3696E-05	-5.564E-05
MJT	1.2411E-03	3.6202E-05	-6.013E-06	3.8766E-04	-5.564E-05	4.4696E-05

TP	Constant	$\sqrt{DA}$	MAR	MJT
Constant	5.5400E-02	-2.589E-02	-1.660E-03	6.7787E-04
$\sqrt{DA}$	-2.589E-02	6.1221E-02	5.5267E-05	8.9042E-05
MAR	-1.660E-03	5.5267E-05	7.0813E-05	-4.022E-05
MJT	6.7787E-04	8.9042E-05	-4.022E-05	3.3482E-05

DP	Constant	$\sqrt{DA}$
Constant	3.7200E-02	-9.503E-02
$\sqrt{DA}$	-9.503E-02	2.8924E-01

CU	Constant	$\sqrt{DA}$	MJT
Constant	6.5351E-02	-6.876E-02	-1.122E-03
$\sqrt{DA}$	-6.876E-02	1.3005E-01	5.8628E-04
MJT	-1.122E-03	5.8628E-04	3.0108E-05

Table 11. Variance-covariance matrix for regression parameter estimates for each of the 10 regression models—Continued

PB	Constant	√DA	IA	MAR
Constant	7.1623E-02	-4.938E-02	-3.567E-04	-9.865E-04
√DA	-4.938E-02	9.1551E-02	2.3984E-04	1.3275E-04
IA	-3.567E-04	2.3984E-04	4.2164E-06	1.7693E-06
MAR	-9.865E-04	1.3275E-04	1.7693E-06	2.5135E-05

ZN	Constant	√DA	IA
Constant	0.4020E-01	-0.4700E-01	-0.3564E-03
√DA	-0.4700E-01	0.9232E-01	0.2412E-03
IA	-0.3564E-03	0.2412E-03	0.4873E-05

where $t_{(\alpha/2,\, n-p)}$ is the critical value of the t-distribution for $n-p$ degrees of freedom and is tabulated in many statistical texts. The variance-covariance matrices, U, needed to calculate $\hat{V}_{pi}$ in T for each of the 10 regression models are listed in table 11.

The computed values of the regression coefficients for the ordinary least-squares and the generalized least-squares models are similar. However, because the generalized least-squares models allow for heterogeneous errors and account for cross correlations between stations, they are more accurate predictors of mean seasonal or annual loads at unmonitored stations than are the ordinary least-squares models.

Example

To compute the mean annual load of total nitrogen, in pounds, at a 0.5-square-mile basin which is 90 percent residential (the sum of industrial and commercial land use is therefore less than 75 percent) with impervious area of 30 percent and in a region where the mean number of storms per year is 79, first compute the mean load for a storm, $\hat{W}$, using the appropriate equation from table 10:

$$\hat{W} = 10^{[-0.2433 + 1.6383(0.5)^{1/2} + 0.0061(30) - 0.4442(0)]} \times 1.345 = 16.9 \text{ pounds}$$

The mean annual load can be calculated by multiplying $\hat{W}$ by 79, the average number of storms per year, to yield a mean annual load of TN = 79 (16.9) = 1,335 pounds. The calculation to obtain the 90-percent confidence interval for this example follows:

Given:

$n - p$ = 41–4= 37 (degrees of freedom)

α = 0.1 (90-percent confidence)

$t_{\alpha/2\,.\,n-p}$ = 1.69 (from statistical tables)

x_i = [1 0.707 30 0] (vector of basin characteristics)

U = (from table 11):

$$\begin{bmatrix} 0.0346 & -0.0449 & -0.00033 & 0.00472 \\ -.0449 & .1031 & .00012 & .0130 \\ -.00033 & .00012 & .0000073 & -.000348 \\ .00472 & .0130 & -.000348 & .0421 \end{bmatrix}$$

$\hat{\gamma}$ = $(0.345)^2 = 0.119$ (from table 10)

BCF = 1.345 (from table 10)

Calculate:

$$\hat{V}_{pi} = 0.119 + x_i U x_i' = 0.119 + 0.014 = 0.133$$

$$T = 10^{[1.69\,(0.133)^{1/2}]} = 4.13$$

$$\frac{1}{4.13}\,\frac{16.9}{1.345} < \hat{W} < \frac{16.9}{1.345}\,4.13$$

$$3.0 < \hat{W} < 51.9$$

Therefore, a 90-percent confidence interval for $\hat{W}$ = 16.9 is (3.0, 51.9).

SUMMARY

Two sets of regression models for estimating storm-runoff loads and volumes were developed and included 34 models of the most accurate set of explanatory variables and 34 models of the simplified three-variable models. The three-variable models are based on explanatory variables of total storm rainfall, total contributing drainage area, and impervious area. Thirty-one models for estimating storm-runoff mean concentrations were developed for urban areas throughout the United States. Ten models for estimating mean seasonal or annual loads were developed from long-term mean seasonal and annual loads, which were computed by analyzing long-term storm rainfall records using at-site regression models. These models are useful for water-quality management and planning and design of pollution-control facilities.

Where sufficient data were available, the United States was divided into three regions on the basis of mean annual rainfall to decrease the variability in storm-runoff loads and volumes and storm-runoff mean concentrations caused by differences in physical, land-use, and climatic characteristics. Data compiled by the U.S. Geological Survey and the U.S. Environmental Protection Agency were used to develop the regression models.

Total storm rainfall and total contributing drainage area were the most significant explanatory variables in all the regression models. Other significant variables in the models included impervious area, land-use, and mean annual climatic characteristics. Models for estimating storm-runoff loads of dissolved solids, total nitrogen, and total ammonia plus organic nitrogen as nitrogen provided the most accurate estimates, whereas models for storm-runoff loads of suspended solids provided the least accurate estimates. The most accurate models were those for the more arid Western States, and the least accurate models were those for the East Coast and Southern States that had large mean annual rainfall. If additional national data become available, explanatory variables that presently are not available need to be considered to improve the accuracy of the models, especially in region III.

Models for estimating storm-runoff loads as compared with the three-variable models and with the models for estimating storm-runoff mean concentrations were the most accurate models that were developed by using ordinary least squares. Generally, the storm-runoff-volume models were more accurate than the storm-runoff-load models. Models for estimating storm-runoff loads have R^2 values that range from 0.35 to 0.95, standard errors of estimate that range from 57 to 265 percent, and average prediction errors that range from 56 to 334 percent. Models for estimating storm-runoff volumes have R^2 values that range from 0.70 to 0.88, standard errors of estimate that range from 69 to 118 percent, and average prediction errors that range from 69 to 119 percent. Generally, the three-variable models and models for estimating storm-runoff mean concentrations had smaller values of R^2 and were less accurate than the models for estimating storm-runoff loads.

Urban water-quality storm data were summarized in 10 regression models that can be used to predict mean loads at unmonitored stations that have drainage areas in the range of 0.015 to 0.85 square mile. Statistically significant ($\alpha = 0.05$) explanatory variables include drainage area in all 10 models; impervious area (an indicator variable for urban land use), mean annual rainfall, and mean minimum January temperature were statistically significant in some models. An operational generalized least-squares estimator of regression coefficients was introduced and compared with the ordinary least-squares estimator usually used for such models. The computed values of the regression coefficients for the ordinary least-squares models and the generalized least-squares models are similar. However, because the generalized least-squares models allow for heterogeneous errors and account for cross correlations between stations, prediction errors of loads at unmonitored stations are smaller than those produced by ordinary least-squares models. Models for estimating mean seasonal or annual loads have R^2 values that range from 0.20 to 0.65; the average variance of prediction for the generalized least-squares models ranged from –63 to +171 percent.

Ideally, storm-runoff loads and volumes, mean concentrations, and mean seasonal or annual loads need to be determined by direct measurements. Because weather and monetary constraints commonly make direct measurements impossible, models in this report may be used for planning and making preliminary estimates. Critical issues and design analysis probably would involve direct measurement of constituents. The regression models could be useful in identifying data-collection needs. However, all the limitations of the models need to be considered when applying them to estimate loads or concentrations at a watershed.

REFERENCES CITED

Aitchison, J., and Brown, J.A.C., 1957, The lognormal distribution: London, Cambridge University Press, 176 p.

Alley, W.M., and Veenhuis, J.E., 1979, Determination of basin characteristics for an urban distributed routing rainfall-runoff model, *in* Huber, W.C., ed., Stormwater Management Model (SWMM) Users Group Meeting, Montreal, Canada, 1979, Proceedings: Washington, D.C., U.S. Environmental Protection Agency Miscellaneous Reports Series EPA 600/79–026, 27 p.

Athayde, D.N., Healy, R.P., and Field, Richard, 1982, Preliminary results of nationwide urban runoff program: Washington, D.C., U.S. Environmental Protection Agency, Water Planning Division, 2 volumes.

Bissonnette, Pam, 1986, Nonpoint pollution—It's urban, too: EPA Journal, v. 12, no. 4, p. 6–7.

Blevins, D.W., 1984, Quality of stormwater of the Blue River basin in Kansas City, Missouri: U.S. Geological Survey Water-Resources Investigations Report 84–4226, 140 p.

Colyer, P.J., and Yen, B.C., 1983, Current issues and future needs in urban storm drainage: Water Resources, v. 17, no. 9, p. 1067–1071.

Davies, P.H., 1986, Toxicology and chemistry of metals in urban runoff, *in* Urbonas, Ben, and Roesner, L.A., eds., Urban runoff quality—Impact and quality enhancement technology, Henniker, N.H., 1986, Proceedings: New York, American Society of Civil Engineers, p. 60–78.

Draper, N.R., and Smith, Harry, 1981, Applied regression analysis, 2d ed.: New York, John Wiley, 709 p.

Driver, N.E., and Lystrom, D.J., 1986, Estimation of urban storm-runoff loads, *in* Urbonas, Ben, and Roesner, L.A., eds., Urban runoff quality—Impact and quality enhancement technology, Henniker, N.H., 1986, Proceedings:

New York, American Society of Civil Engineers, p. 122–132.

———1987, Estimation of urban storm-runoff loads and volumes in the United States, *in* Gujer, W., and Krejci, V., eds., Topics in urban storm water quality, planning and management, Lausanne, Switzerland, 1987, Proceedings: International Association for Hydraulic Research, p. 214–219.

Driver, N.E., Mustard, M.H., Rhinesmith, R.B., and Middelburg, R.F., 1985, U.S. Geological Survey urban-stormwater data base for 22 metropolitan areas throughout the United States: U.S. Geological Survey Open-File Report 85–337, 219 p.

Duan, Naihua, 1983, Smearing estimate: A nonparametric retransformation method: Journal of the American Statistical Association, v. 78, no. 383, p. 605–610.

Ellis, J.B., Harrop, P.O., and Revitt, D.M., 1986, Hydrological controls of pollutant removal from highway surfaces: Water Research, v. 20, no. 5, p. 589–595.

Ellis, S.R., Doerfer, J.T., Mustard, M.H., Blakely, S.R., and Gibbs, J.W., 1984, Analysis of urban storm-runoff data and the effects on the South Platte River, Denver metropolitan area, Colorado: U.S. Geological Survey Water-Resources Investigations Report 84–4159, 66 p.

Ferguson, R.I., 1986, River loads underestimated by rating curves: Water Resources Research, v. 22, no. 1, p. 74–76.

Halverson, H.G., DeWalle, D.R., and Sharpe, W.E., 1984, Contribution of precipitation to quality of urban storm runoff: Water Resources Bulletin, v. 20, no. 6, p. 859–864.

Huber, W.C., 1986, Deterministic modeling of urban runoff quality, *in* Torno, H.C., Marsalek, Jiri, and Desbordes, Michael, eds., Urban runoff pollution, a NATO advanced workshop, Montpellier, France, 1985, Proceedings: Berlin, Springer-Verlag, NATO ASI Series G, Ecological Sciences, v. 10, p. 167–242.

Huber, W.C., and Heaney, J.P., 1982, Analyzing residuals discharge and generation from urban and non-urban land surfaces, *in* Basta, D.J., and Bower, B.T., eds., Analyzing natural systems, analysis for region residuals—Environmental Quality Management: Washington, D.C., U.S. Environmental Protection Agency, EPA–600/3–83–046 [Available from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 as PB83–223321], chap. 3, p. 121–243.

Kibler, D.F., ed., 1982, Urban stormwater hydrology: Washington, D.C., Water Resources Monograph 7, 271 p.

Kircher, J.E., Choquette, A.F., and Richter, B.D., 1985, Estimation of natural streamflow characteristics in western Colorado: U.S. Geological Survey Water-Resources Investigations Report 85–4086, 28 p.

Koch, R.W., and Smillie, G.M., 1986, Bias in hydrologic prediction using log-transformed regression models: Water Resources Bulletin, v. 22, no. 5, p. 717–723.

Lichty, R.W., and Liscum, F., 1978, A rainfall-runoff modeling procedure for improving estimates of T-year (annual) floods for small drainage basins: U.S. Geological Survey Water-Resources Investigations 78–7, 44 p.

Lindner-Lunsford, J.B., and Ellis, S.R., 1987, Comparison of conceptually based and regression rainfall-runoff models, Denver metropolitan area, Colorado, and potential application in urban areas: U.S. Geological Survey Water-Resources Investigations Report 87–4104, 39 p.

Loganathan, G.V., and Delleur, J.W., 1984, Effects of urbanization on frequencies of overflows and pollutant loadings from storm sewer overflows—A derived distribution approach: Water Resources Research, v. 20, no. 7, p. 857–865.

Lystrom, D.J., Rinella, F.A., Rickert, D.A., and Zimmermann, Lisa, 1978, Regional analysis of the effects of land use on stream-water quality— Methodology and application in the Susquehanna River basin, Pennsylvania and New York: U.S. Geological Survey Water-Resources Investigations 78–12 [Available from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 as PB-284185], 60 p.

Mejia, J.M., Rodriguez-Iturbe, I., and Cordova, J.R., 1974, Multivariate generation of mixtures of normal and lognormal variables: Water Resources Research, v. 21, no. 9, p. 1421–1432.

Miller, D.M., 1984, Reducing transformation bias in curve fitting: The American Statistician, v. 38, no. 2, p. 124–126.

Miller, R.A., and Mattraw, H.C., 1982, Storm water runoff quality from three land-use areas in South Florida: Water Resources Bulletin, v. 18, no. 3, p. 513–519.

Miller, T.L., and McKenzie, S.W., 1978, Analysis of urban storm-water quality from seven basins near Portland, Oregon: U.S. Geological Survey Open-File Report 78–662 [Available from U.S. Geological Survey, Water Resources Division, 830 N.E. Holladay St., Portland, OR 97232], 47 p.

Mustard, M.H., Driver, N.E., Chyr, John, and Hansen, B.G., 1987, U.S. Geological Survey urban-stormwater data base of constituent storm loads; characteristics of rainfall, runoff, and antecedent conditions; and basin characteristics: U.S. Geological Survey Water-Resources Investigations Report 87–4036, 328 p.

National Oceanic and Atmospheric Administration, 1980, Climates of the States, 2d ed.: Detroit, Gale Research Company, 2 volumes.

Neter, John, Wasserman, William, and Kutner, M.H., 1985, Applied linear statistical models, 2d ed.: Homewood, Ill., Irwin, 1127 p.

Newton, D.W., and Herrin, J.C., 1982, Assessment of commonly used flood frequency methods: Transportation Research Record 896, 64 p.

Novotny, Vladmir, Sung, Hung-Ming, Bannerman, Roger, and Baum, Ken, 1985, Estimating nonpoint pollution from small urban watersheds: Journal of Water Pollution Control Federation, v. 57, no. 4, p. 339–348.

Randall, C.W., 1982, Stormwater detention ponds for water quality control, *in* DeGrout, William, ed., Stormwater detention facilities—Planning, design, operation, and maintenance, Henniker, N.H., 1982, Proceedings: New York, American Society of Civil Engineers, p. 200–204.

SAS Institute, Inc., 1985, SAS user's guide—Statistics: Raleigh, N.C., 956 p.

Sauer, V.B., Thomas, W.O., Jr., Stricker, V.A., and Wilson, K.V., 1983, Flood characteristics of urban watersheds in the United States: U.S. Geological Survey Water-Supply Paper 2207, 63 p.

Schuster, E., and Yakowitz, S.J., 1985, Parametric/nonparametric mixture density estimation with application to flood-frequency analysis: Water Resources Bulletin, v. 21, no. 5,

p. 797–804.
Stedinger, J.R., and Tasker, G.D., 1985, Regional hydrologic analysis. 1. Ordinary, weighted, and generalized least squares compared: Water Resources Research, v. 21, no. 9, p. 1421–1432.
Troutman, B.M., 1985, Errors and parameter estimation in precipitation-runoff modeling—1. Theory: Water Resources Research, v. 21, no. 8, p. 1195–1213.
U.S. Environmental Protection Agency, 1983, Results of the nationwide urban runoff program: U.S. Environmental Protection Agency Final Report, 4 volumes.
Warren, L.H., 1983, Selective guide to climatic data sources—Key to meteorological record documentation no. 4.11: Asheville, N.C., National Climatic Data Center, 338 p.
Waylen, P.R., and Woo, Ming-Ko, 1984, Regionalization and prediction of floods in the Fraser River catchment, B.C.: Water Resources Bulletin, v. 20, no. 6, p. 941–949.
Whipple, William, Grigg, N.S., Grizzard, T.J., Randall, C.W., Shubinski, R.P., and Tucker, L.S., 1984, Stormwater management in urbanizing areas: Englewood Cliffs, N.J., Prentice-Hall, 234 p.
Young, G.K., Bondelid, T.R., and Athayde, D.N., 1979, Urban runoff pollution method: Journal of the Water Resources Planning and Management Division, v. 105, no. WR2, Paper 14854, p. 353–369.

Table 12A. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for chemical oxygen demand for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients			Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
		Intercept	Coefficients for Total rainfall (TRN)	Coefficients for Rainfall duration (DRN)				
Austin, Tex.	ROLLING WOOD	6.95	16.62	--	8	15.94	16.7	902
Baltimore, Md.	01589455	-3.48	100.28	--	13	18.04	52.9	2,060*
Baltimore, Md.	01589462	39.94	323.63	--	7	199.51	222.0	8,660*
Bellevue, Wash.	12119725	22.84	301.09	-5.41	31	34.37	68.5	6,710
Boston, Mass.	P1	20.93	324.95	--	8	83.09	150.0	7,800*
Boston, Mass.	P2	-387.14	3,164.45	--	6	461.71	869.0	45,200*
Boston, Mass.	P3	-399.08	3,077.79	--	6	212.30	823.0	42,800*
Boston, Mass.	P5	-55.61	832.42	--	8	223.63	275.0	14,300*
Champaign-Urbana, Ill.	BASIN 1	65.99	97.05	--	28	50.25	119.0	5,000*
Champaign-Urbana, Ill.	BASIN 2	38.67	163.72	--	25	39.84	128.0	5,380*
Champaign-Urbana, Ill.	BASIN 4	23.46	81.02	--	22	25.26	67.9	2,850*
Champaign-Urbana, Ill.	BASIN 5	14.10	171.06	--	26	49.80	108.0	4,540*
Columbus, Ohio	03226900	240.21	1,764.04	--	19	530.95	1,030.0	49,400*
Columbus, Ohio	03227050	-1,327.16	5,796.11	--	10	606.68	1,260.0	60,500*
Fresno, Calif.	364155119445000	-501.16	6,693.56	--	11	1,037.63	1,230.0	50,400
Fresno, Calif.	364746119445400	48.80	199.74	--	9	82.96	100.0	4,100
Fresno, Calif.	364818119443800	-.23	328.27	--	16	63.96	84.7	3,470
Kansas City, Mo.	IC	-127.64	577.65	--	17	184.68	204.0	8,360*
Kansas City, Mo.	II	152.36	170.30	--	14	127.08	250.0	10,300*
Kansas City, Mo.	IR	55.70	--	--	9	42.53	55.7	2,280*
Kansas City, Mo.	RC	25.50	23.99	--	12	26.86	39.3	1,610*
Kansas City, Mo.	RR	80.01	119.31	--	9	145.36	149.0	6,110*
Knoxville, Tenn.	N47001	13.39	61.99	--	14	27.13	44.9	4,130
Knoxville, Tenn.	N47007	3.50	35.51	--	11	20.44	21.5	1,980
Knoxville, Tenn.	N47010	-76.69	519.75	--	11	78.25	187.0	17,200
Lakewood, Colo.	06711635	64.45	509.91	--	26	57.74	245.0	6,860*
Lansing, Mich.	001	-154.12	1,095.78	--	16	256.46	291.0	11,900*
Lansing, Mich.	002	1.69	109.77	--	11	55.77	46.3	1,900*
Lansing, Mich.	006	38.68	52.97	--	25	35.53	60.2	2,470*
Lansing, Mich.	008	20.52	254.18	--	16	84.66	124.0	5,080*
Lansing, Mich.	010	12.72	73.46	--	9	24.90	42.6	1,750*
Miami, Fla.	261002080070100	125.12	126.06	--	30	143.96	195.0	19,500
Miami, Fla.	261615080055900	2.74	11.24	--	31	6.76	9.0	900
Miami, Fla.	261629080072400	21.10	44.93	--	40	26.75	46.0	4,600
Milwaukee, Wis.	04086945	13.50	141.93	--	10	40.97	75.9	3,190*
Milwaukee, Wis.	04087057	-1.68	63.50	--	8	23.14	26.2	1,100*
Milwaukee, Wis.	04087133	67.14	322.98	--	10	78.80	209.0	8,780*
Milwaukee, Wis.	413630	47.19	202.36	--	16	81.13	136.0	5,710*
Milwaukee, Wis.	413631	-14.43	733.92	--	35	179.34	308.0	12,900*
Milwaukee, Wis.	413632	6.40	61.86	--	17	17.83	33.6	1,410*
Milwaukee, Wis.	413633	-.09	186.57	--	21	61.27	81.9	3,440*
Milwaukee, Wis.	413634	13.56	92.90	--	20	40.36	54.4	2,290*
Milwaukee, Wis.	413635	7.21	102.52	--	32	42.29	52.3	2,200*
Milwaukee, Wis.	413636	-81.17	358.72	--	13	83.16	76.5	3,210*
Portland, Oreg.	14206330	-32.32	301.08	--	6	10.39	81.6	7,830
Salt Lake City, Utah	10167220	31.76	148.10	-5.65	20	23.77	31.2	718*
St. Paul, Minn.	445032092552801	-220.49	836.54	--	13	259.45	132.0	5,680*
St. Paul, Minn.	445937093230701	153.46	288.65	--	7	125.42	275.0	11,800*
St. Paul, Minn.	450011093221901	14.73	611.56	--	15	192.89	273.0	11,700*
St. Paul, Minn.	450100093205501	-71.18	1,537.18	--	12	318.83	577.0	24,800*
St. Paul, Minn.	450541093201201	80.29	168.09	--	15	112.23	151.0	6,490*
Tampa, Fla.	TNURPS023	34.15	1,018.22	--	13	715.42	690.0	54,500
Tampa, Fla.	TNURPS033	-46.21	236.86	--	14	114.16	106.0	8,370
Tampa, Fla.	TNURPS173	25.82	95.78	--	11	88.92	87.5	6,910
Washington, D.C.	DC151UR07	1.09	189.18	--	36	41.49	103.0	4,330*
Washington, D.C.	DC151UR09	37.57	20.49	--	29	50.76	48.6	2,040*
Washington, D.C.	DC151UR10	13.18	33.06	--	29	27.55	31.0	1,300*
Washington, D.C.	DC151UR15	11.58	33.84	--	27	22.73	29.8	1,250*
Winston-Salem, N.C.	Q2485000	137.39	318.75	--	32	336.65	309.0	23,800

Table 12*B*. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for suspended solids for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients: Intercept	Regression coefficients: Coefficients for Total rainfall (TRN)	Regression coefficients: Coefficients for Rainfall duration (DRN)	Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
Austin, Tex.	HART LANE	-28.11	947.60	--	9	316.12	526.0	28,400
Baltimore, Md.	01589455	-13.78	100.59	--	13	21.77	42.8	1,670*
Bellevue, Wash.	12119725	-2.64	486.57	-6.40	31	39.38	100.0	9,800
Boston, Mass.	P2	-2,417.03	16,618.59	--	7	1,985.38	4,180.0	217,000*
Boston, Mass.	P3	-673.82	7,699.95	--	6	1,525.44	2,380.0	124,000*
Boston, Mass.	P5	103.92	188.88	--	8	183.41	179.0	9,310*
Champaign-Urbana, Ill.	BASIN 1	112.01	211.00	--	45	246.19	228.0	9,580*
Champaign-Urbana, Ill.	BASIN 2	47.43	389.15	--	51	210.04	261.0	11,000*
Champaign-Urbana, Ill.	BASIN 4	-117.42	816.76	--	35	172.42	331.0	13,900*
Champaign-Urbana, Ill.	BASIN 5	4.41	383.62	--	40	120.85	215.0	9,030*
Columbus, Ohio	03226900	-303.47	5,979.47	--	20	1,756.68	2,360.0	113,000*
Kansas City, Mo.	IC	110.08	293.17	--	19	455.23	279.0	11,400*
Kansas City, Mo.	II	-865.38	2,474.63	--	16	378.54	557.0	22,800*
Kansas City, Mo.	RR	1,628.79	1,036.18	--	10	2,229.47	2,220.0	91,000*
Knoxville, Tenn.	N47010	-28.12	457.10	--	12	276.12	204.0	18,800
Lake George, N.Y.	3702	133.51	83.80	--	22	245.50	165.0	7,590*
Lakewood, Colo.	06711635	155.34	2,550.76	-48.49	26	321.56	703.0	19,700*
Lansing, Mich.	001	-161.85	1,833.45	--	21	763.55	583.0	23,900*
Lansing, Mich.	002	-.63	121.68	--	16	50.05	48.8	2,000*
Lansing, Mich.	008	2.41	768.92	--	22	359.96	315.0	12,900*
Lansing, Mich.	010	-26.61	439.89	--	18	202.14	152.0	6,230*
Milwaukee, Wis.	04086945	-7.05	988.55	-59.37	13	38.64	24.2	1,020*
Milwaukee, Wis.	04087057	-14.29	175.49	--	12	97.98	62.9	2,640*
Milwaukee, Wis.	04087115	-5.49	471.52	--	12	100.07	202.0	8,480*
Milwaukee, Wis.	04087133	250.58	656.07	--	12	312.22	539.0	22,600*
Milwaukee, Wis.	413630	69.36	833.90	--	24	275.45	436.0	18,300*
Milwaukee, Wis.	413631	-190.74	3,379.66	--	43	1,301.18	1,300.0	54,600*
Milwaukee, Wis.	413632	-74.02	461.59	--	27	105.90	129.0	5,420*
Milwaukee, Wis.	413633	-57.39	1,235.02	--	38	339.13	485.0	20,400*
Milwaukee, Wis.	413634	-50.95	468.41	--	36	121.17	155.0	6,510*
Milwaukee, Wis.	413635	30.02	362.39	--	46	210.37	189.0	7,940*
Milwaukee, Wis.	413636	-248.04	1,225.68	--	18	514.87	291.0	12,200*
Rochester, N.Y.	430428077261100	-61.79	929.63	--	11	372.10	273.0	12,300*
Rochester, N.Y.	430649077285500	-1,799.51	5,824.62	--	6	1,895.37	300.0	13,500*
Salt Lake City, Utah	10167220	58.92	93.09	-8.32	16	31.08	21.2	488*
Salt Lake City, Utah	404653111545801	48.79	142.34	--	9	76.37	90.9	2,090*
St. Paul, Minn.	445032092552801	-4,732.47	17,555.51	--	20	3,853.03	2,670.0	115,000*
St. Paul, Minn.	445210093271701	-1,336.69	6,820.10	--	17	1,054.54	1,540.0	66,200*
St. Paul, Minn.	445937093230701	192.53	1,751.04	--	13	499.55	931.0	40,000*
St. Paul, Minn.	450011093221901	-452.38	2,793.35	--	22	540.77	726.0	31,200*
St. Paul, Minn.	450100093205501	-500.48	3,375.85	--	21	653.33	924.0	39,700*
St. Paul, Minn.	450541093201201	48.10	199.65	--	24	98.56	132.0	5,680*
Tampa, Fla.	TNURPS173	-39.79	78.70	--	11	94.41	10.9	861
Tampa, Fla.	TNURPS183	30.37	36.17	--	12	38.78	53.7	4,240
Washington, D.C.	DC151UR07	-259.25	1,529.88	--	40	429.28	566.0	23,800*
Washington, D.C.	DC151UR10	23.51	23.76	--	30	44.13	36.3	1,530*
Winston-Salem, N.C.	Q2485000	-.61	3,197.41	--	63	4,031.43	1,720.0	132,000

Table 12C. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for dissolved solids for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients: Intercept	Coefficients for Total rainfall (TRN)	Coefficients for Rainfall duration (DRN)	Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
Baltimore, Md.	01589460	-21.24	204.60	--	7	116.55	93.90	3,660*
Bellevue, Wash.	12119725	-8.41	184.29	--	35	14.19	54.30	5,320
Columbus, Ohio	03226900	1,094.72	1,463.88	--	19	806.86	1,750.00	84,000*
Fresno, Calif.	364155119445000	-281.60	2,060.07	24.87	16	216.50	441.00	18,100
Fresno, Calif.	364746119445400	-192.24	2,339.64	--	16	226.68	413.00	16,900
Fresno, Calif.	364818119443800	5.68	208.23	-5.92	32	24.84	14.60	599
Fresno, Calif.	364818119464700	41.93	235.55	--	28	49.26	103.00	4,220
Milwaukee, Wis.	04086941	-7.69	380.45	-10.96	12	28.76	85.10	3,570*
Milwaukee, Wis.	04086943	10.03	211.91	--	13	61.59	103.00	4,330*
Milwaukee, Wis.	04086945	23.32	200.38	--	11	43.25	111.00	4,660*
Milwaukee, Wis.	04087057	-66.47	401.77	--	11	81.37	110.00	4,620*
Milwaukee, Wis.	04087115	45.21	237.36	--	12	57.46	149.00	6,260*
Portland, Oreg.	14206330	-44.52	314.53	--	6	34.60	74.50	7,150

Table 12*D*. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for total nitrogen for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients			Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
		Intercept	Coefficients for Total rainfall (TRN)	Coefficients for Rainfall duration (DRN)				
Baltimore, Md.	01589455	0.51	6.29	--	14	1.47	4.04	158
Baltimore, Md.	01589460	1.18	26.22	--	7	14.58	15.90	620
Boston, Mass.	P1	.69	11.59	--	9	6.77	5.29	275
Boston, Mass.	P5	4.10	13.07	--	6	3.63	9.29	483
Columbus, Ohio	03226900	12.77	75.24	--	19	22.10	46.30	2,220
Glen Ellyn, Ill.	415302088033804	16.37	46.56	--	15	33.29	39.10	1,680
Knoxville, Tenn.	N47001	.16	1.16	--	14	.28	.75	69
Knoxville, Tenn.	N47007	-.00	.65	--	11	.25	.33	30
Knoxville, Tenn.	N47010	.96	3.47	--	11	.96	2.72	250
Lake George, N.Y.	3702	.27	1.02	--	16	.86	.66	30
Lakewood, Colo.	06711635	.84	13.43	--	23	1.50	5.60	15[illegible]
Lansing, Mich.	001	2.02	24.82	--	21	10.00	12.10	496
Lansing, Mich.	002	-.24	3.49	--	17	1.15	1.18	48
Lansing, Mich.	006	.91	3.34	--	33	1.14	2.27	93
Lansing, Mich.	008	.76	10.00	--	21	3.35	4.82	198
Lansing, Mich.	010	.96	3.20	--	16	1.26	2.26	93
Miami, Fla.	261002080070100	1.86	1.66	--	31	1.59	2.78	278
Miami, Fla.	261615080055900	.08	.79	--	31	.37	.52	52
Miami, Fla.	261629080072400	.26	.98	--	41	.43	.81	81
Milwaukee, Wis.	04086943	.02	1.15	--	6	.15	.52	22*
Milwaukee, Wis.	04087133	1.62	3.86	--	7	2.00	3.31	139*
Milwaukee, Wis.	413630	1.66	4.05	--	6	1.55	3.45	145*
Milwaukee, Wis.	413631	.81	17.03	--	14	3.52	8.30	349*
Milwaukee, Wis.	413632	-.37	4.52	--	15	.72	1.62	68*
Milwaukee, Wis.	413633	-1.18	13.50	--	10	2.54	4.75	199*
Milwaukee, Wis.	413634	.08	3.53	--	19	.79	1.63	68*
Milwaukee, Wis.	413635	-.55	4.89	--	18	.87	1.60	67*
St. Paul, Minn.	445032092552801	-6.37	27.75	--	21	5.95	5.33	229*
St. Paul, Minn.	445210093271701	-6.77	39.45	--	17	4.97	9.87	424*
St. Paul, Minn.	445937093230701	6.51	8.60	--	11	3.98	10.10	434*
St. Paul, Minn.	450011093221901	-.43	18.18	--	21	2.27	7.24	311*
St. Paul, Minn.	450100093205501	-6.52	50.79	--	19	4.39	14.90	641*
St. Paul, Minn.	450541093201201	-.15	9.76	--	24	2.19	3.97	171*
Tampa, Fla.	TNURPS023	3.36	27.85	--	13	18.38	21.30	1,680
Tampa, Fla.	TNURPS033	-.37	4.81	--	13	2.05	2.73	216
Tampa, Fla.	TNURPS173	.90	3.90	--	11	4.22	3.41	269
Washington, D.C.	DC151UR07	-.55	9.22	--	39	1.53	4.42	186*
Washington, D.C.	DC151UR09	1.23	2.58	--	28	2.38	2.62	110*
Washington, D.C.	DC151UR10	2.01	1.46	--	31	2.97	2.80	118*
Washington, D.C.	DC151UR15	-.03	3.15	--	27	1.01	1.67	70*
Winston-Salem, N.C.	Q2485000	1.89	15.19	--	64	13.47	10.10	778

Table 12E. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for total ammonia plus organic nitrogen as nitrogen for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients: Intercept	Coefficients for: Total rainfall (TRN)	Coefficients for: Rainfall duration (DRN)	Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
Baltimore, Md.	01589455	-0.25	5.98	--	14	1.19	3.12	122*
Baltimore, Md.	01589460	2.32	7.91	--	7	4.67	6.77	264*
Bellevue, Wash.	12119725	.04	9.20	-.15	30	.44	1.58	155
Boston, Mass.	P1	.54	6.38	--	9	4.50	3.07	160*
Boston, Mass.	P3	-5.88	57.49	--	6	2.26	16.90	879*
Boston, Mass.	P5	.11	9.41	--	8	1.64	3.85	200*
Champaign-Urbana, Ill.	BASIN 1	.86	2.18	--	28	.99	2.06	87*
Champaign-Urbana, Ill.	BASIN 2	.65	3.53	--	27	.87	2.59	109*
Champaign-Urbana, Ill.	BASIN 4	.53	2.75	--	24	.99	2.05	86*
Champaign-Urbana, Ill.	BASIN 5	.34	5.76	--	28	1.84	3.50	147*
Columbus, Ohio	03226900	5.28	52.90	--	19	17.63	28.90	1,390*
Kansas City, Mo.	IC	-4.38	16.04	--	15	5.65	4.84	198*
Kansas City, Mo.	II	-2.21	12.62	--	10	4.51	5.04	207*
Kansas City, Mo.	IR	2.62	--	--	7	.66	2.62	107*
Knoxville, Tenn.	N47001	.08	.60	--	14	.17	.38	35
Knoxville, Tenn.	N47007	.03	.36	--	11	.15	.21	19
Lake George, N.Y.	3702	.21	.81	--	16	.59	.52	24*
Lakewood, Colo.	06711635	.78	1.78	--	27	1.00	1.41	40*
Lansing, Mich.	001	.95	16.85	--	21	5.98	7.80	320*
Lansing, Mich.	002	-.13	2.23	--	17	.84	.77	32*
Lansing, Mich.	006	.62	2.17	--	33	.91	1.50	61*
Lansing, Mich.	008	.07	7.83	--	21	2.50	3.25	133*
Lansing, Mich.	010	.55	2.40	--	16	1.04	1.53	63*
Miami, Fla.	261002080070100	1.73	1.02	--	31	1.40	2.30	230
Miami, Fla.	261615080055900	.08	.53	--	31	.30	.38	38
Miami, Fla.	261629080072400	.20	.55	--	41	.25	.51	51
Milwaukee, Wis.	04087133	2.08	5.20	--	7	2.52	4.37	183*
Milwaukee, Wis.	413631	.60	11.46	--	14	2.40	5.63	236*
Milwaukee, Wis.	413632	-.24	2.79	--	15	.42	.99	42*
Milwaukee, Wis.	413633	-1.05	9.19	--	10	1.58	2.99	126*
Milwaukee, Wis.	413634	-.13	2.37	--	19	.42	.91	38*
Milwaukee, Wis.	413635	.18	1.54	--	19	.37	.85	36*
Portland, Oreg.	14206330	-1.67	9.82	--	6	.52	2.05	197
Rochester, N.Y.	430403077311500	3.47	5.42	--	13	4.56	5.43	244*
Rochester, N.Y.	430428077261100	7.50	3.62	--	13	5.82	8.81	396*
Salt Lake City, Utah	10167220	.37	2.77	--	16	.40	1.19	27*
Salt Lake City, Utah	404653111545801	1.21	4.49	--	8	.99	2.55	59*
St. Paul, Minn.	445032092552801	-6.00	26.18	--	21	5.68	5.04	217*
St. Paul, Minn.	445210093271701	-6.49	36.32	--	18	5.03	8.83	380*
St. Paul, Minn.	445937093230701	6.09	7.61	--	13	4.44	9.30	400*
St. Paul, Minn.	450011093221901	-.43	14.74	--	23	2.82	5.79	249*
St. Paul, Minn.	450100093205501	-5.22	44.47	--	22	4.97	13.50	580*
St. Paul, Minn.	450541093201201	.90	5.84	--	24	1.82	3.36	144*
Tampa, Fla.	TNURPS023	2.49	20.29	--	13	14.11	15.60	1,230
Tampa, Fla.	TNURPS033	-.17	3.64	--	14	1.60	2.17	171
Tampa, Fla.	TNURPS173	-.70	3.35	--	11	3.22	1.46	115
Washington, D.C.	DC151UR07	-.27	6.36	--	39	1.34	3.16	133*
Washington, D.C.	DC151UR09	1.39	.54	--	28	1.75	1.68	71*
Washington, D.C.	DC151UR10	1.43	.83	--	30	1.93	1.88	79*
Washington, D.C.	DC151UR15	-.04	2.27	--	27	.73	1.19	50*
Winston-Salem, N.C.	Q2485000	1.47	10.41	--	64	10.62	7.07	544

Table 12F. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for total phosphorus for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients: Intercept	Regression coefficients: Coefficients for Total rainfall (TRN)	Regression coefficients: Coefficients for Rainfall duration (DRN)	Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
Austin, Tex.	ROLLING WOOD	0.03	0.05	--	8	0.04	0.06	3.2
Baltimore, Md.	01589455	.09	.15	--	6	.17	.17	6.6*
Bellevue, Wash.	12119725	-.01	1.66	-.03	30	.11	.29	28.4
Boston, Mass.	P3	-4.32	36.14	--	6	1.97	10.00	520.0*
Boston, Mass.	P5	-.12	4.63	--	8	5.19	1.72	89.4*
Champaign-Urbana, Ill.	BASIN 1	.16	.31	--	28	.13	.33	13.9*
Champaign-Urbana, Ill.	BASIN 2	.07	.75	--	26	.14	.48	20.2*
Champaign-Urbana, Ill.	BASIN 4	.06	.79	--	24	.18	.49	20.6*
Champaign-Urbana, Ill.	BASIN 5	.11	.97	--	28	.25	.64	26.9*
Columbus, Ohio	03226900	1.02	6.93	--	19	2.16	4.11	197.0*
Glen Ellyn, Ill.	415302088033804	1.60	6.76	--	15	3.47	4.91	211.0*
Kansas City, Mo.	IC	.15	.98	--	17	.79	.71	29.1*
Kansas City, Mo.	IR	.50	--	--	9	.37	.50	20.5*
Knoxville, Tenn.	N47001	.05	.15	--	14	.05	.12	11.0
Lake George, N.Y.	3702	.02	.61	--	26	1.05	.25	11.5*
Lakewood, Colo.	06711635	.16	2.52	-.03	27	.27	.85	23.8*
Lansing, Mich.	001	.05	4.82	--	20	1.90	2.01	82.4*
Lansing, Mich.	002	-.09	.95	--	16	.31	.30	12.3*
Lansing, Mich.	006	.11	.21	--	33	.14	.19	7.8*
Lansing, Mich.	008	.11	1.33	--	21	.44	.64	26.2*
Lansing, Mich.	010	.17	.50	--	15	.36	.37	15.2*
Miami, Fla.	261002080070100	.18	.15	--	30	.18	.26	26.0
Miami, Fla.	261615080055900	.01	.16	--	31	.07	.10	10.0
Miami, Fla.	261629080072400	.01	.12	--	40	.03	.07	7.0
Milwaukee, Wis.	04086945	.05	.76	-.04	13	.06	.09	3.8*
Milwaukee, Wis.	04087057	-.16	.82	--	13	.17	.20	8.4*
Milwaukee, Wis.	04087133	.29	.87	--	12	.34	.67	28.1*
Milwaukee, Wis.	413631	-.19	2.84	--	42	.72	1.06	44.5*
Milwaukee, Wis.	413632	-.12	.80	--	28	.14	.23	9.7*
Milwaukee, Wis.	413633	-.07	1.24	--	37	.27	.48	20.2*
Milwaukee, Wis.	413634	-.01	.21	--	36	.05	.08	3.4*
Milwaukee, Wis.	413635	.01	.23	--	47	.06	.10	4.2*
Milwaukee, Wis.	413636	-.36	1.97	--	18	.48	.51	21.4*
Portland, Oreg.	14206330	-.73	4.12	--	6	.18	.83	79.7
Rochester, N.Y.	430428077261100	.01	1.72	--	11	.72	.63	28.3*
Rochester, N.Y.	430649077285500	3.98	2.53	--	7	2.20	4.89	220.0*
Salt Lake City, Utah	10167220	.07	.22	--	14	.05	.14	3.2*
Salt Lake City, Utah	404653111545801	.03	1.08	--	8	.15	.35	8.0*
St. Paul, Minn.	445032092552801	-2.72	12.57	--	21	3.04	2.59	111.0*
St. Paul, Minn.	445210093271701	-1.94	10.03	--	18	1.41	2.29	98.5*
St. Paul, Minn.	445937093230701	2.06	3.23	--	13	1.67	3.43	147.0*
St. Paul, Minn.	450011093221901	-.09	3.20	--	22	.73	1.26	54.2*
St. Paul, Minn.	450100093205501	-1.34	9.96	--	22	1.18	2.86	123.0*
St. Paul, Minn.	450541093201201	-.17	1.75	--	24	.41	.57	24.5*
Tampa, Fla.	TNURPS023	1.40	3.00	--	13	3.27	3.33	263.0
Tampa, Fla.	TNURPS033	-.13	.72	--	14	.26	.33	26.1
Washington, D.C.	DC151UR07	-.34	2.42	--	39	.47	.96	40.3*
Washington, D.C.	DC151UR09	.22	.10	--	28	.29	.27	11.3*
Washington, D.C.	DC151UR10	.06	.48	--	31	.35	.32	13.4*
Washington, D.C.	DC151UR15	.07	.28	--	27	.19	.22	9.2*
Winston-Salem, N.C.	Q2485000	.38	4.32	--	64	4.63	2.70	208.0

Table 12G. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for dissolved phosphorus for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients: Intercept	Coefficients for: Total rainfall (TRN)	Coefficients for: Rainfall duration (DRN)	Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
Bellevue, Wash.	12119725	0.040	0.827	-0.023	29	0.122	0.066	6.47
Boston, Mass.	P1	-.392	2.337	--	7	.680	.536	27.90*
Boston, Mass.	P3	-.290	3.418	--	6	.042	1.070	55.60*
Boston, Mass.	P5	-1.345	5.397	--	6	.898	.798	41.50*
Fresno, Calif.	364746119445400	.218	.449	--	19	.157	.335	13.70
Fresno, Calif.	364818119443800	.048	.696	--	31	.152	.228	9.35
Kansas City, Mo.	IC	.015	.473	--	18	.249	.287	11.80*
Kansas City, Mo.	IR	.146	--	--	9	.135	.146	5.99*
Knoxville, Tenn.	N47001	.009	.032	--	14	.014	.025	2.30
Knoxville, Tenn.	N47004	.008	.068	--	9	.032	.042	3.86
Lake George, N.Y.	3702	.015	.087	--	20	.181	.048	2.21*
Lakewood, Colo.	06711635	.007	.578	--	26	.073	.211	5.91*
Lansing, Mich.	001	-.154	1.018	--	19	.179	.259	10.60*
Lansing, Mich.	002	-.074	.303	--	13	.084	.049	2.01*
Lansing, Mich.	006	.001	.091	--	30	.034	.038	1.56*
Lansing, Mich.	008	-.008	.199	--	20	.057	.073	2.99*
Lansing, Mich.	010	-.014	.113	--	15	.030	.031	1.27*
Milwaukee, Wis.	04086943	.010	.047	--	12	.029	.031	1.30*
Milwaukee, Wis.	04086945	.004	.052	--	11	.015	.027	1.13*
Milwaukee, Wis.	04087056	-.354	.995	--	6	.246	.083	3.49*
Milwaukee, Wis.	04087057	-.042	.282	--	13	.047	.082	3.44*
Milwaukee, Wis.	04087133	.021	.174	--	11	.041	.097	4.07*
Salt Lake City, Utah	10167220	.013	.239	--	16	.039	.084	1.93*
Salt Lake City, Utah	404653111545801	.023	.726	--	8	.067	.238	5.47*
Washington, D.C.	DC151UR07	-.146	.866	--	38	.128	.322	13.50*
Washington, D.C.	DC151UR09	.174	.096	--	28	.245	.226	9.49*
Washington, D.C.	DC151UR10	-.021	.334	--	29	.145	.159	6.68*
Washington, D.C.	DC151UR15	-.001	.252	--	27	.144	.135	5.67*

Table 12*H*. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for total recoverable copper for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients			Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
		Intercept	Coefficients for Total rainfall (TRN)	Coefficients for Rainfall duration (DRN)				
Baltimore, Md.	01589455	0.017	0.003	--	6	0.034	0.019	0.74*
Boston, Mass.	P1	.050	.302	--	8	.096	.170	8.84*
Boston, Mass.	P2	-.263	3.894	--	7	.830	1.280	66.60*
Boston, Mass.	P3	-.282	2.502	--	6	.137	.711	37.00*
Boston, Mass.	P5	.032	1.000	--	7	.216	.429	22.30*
Champaign-Urbana, Ill.	BASIN 1	.008	.053	--	31	.019	.037	1.55*
Champaign-Urbana, Ill.	BASIN 2	.016	.036	--	29	.021	.036	1.51*
Champaign-Urbana, Ill.	BASIN 4	.003	.058	--	28	.019	.035	1.47*
Champaign-Urbana, Ill.	BASIN 5	.014	.109	--	32	.047	.074	3.11*
Columbus, Ohio	03226900	-.232	2.139	--	19	.325	.722	34.70*
Fresno, Calif.	364155119445000	-.078	1.007	--	16	.176	.182	7.46
Fresno, Calif.	364746119445400	.006	.050	--	8	.014	.019	.78
Fresno, Calif.	364818119443800	-.001	.086	--	15	.016	.021	.86
Fresno, Calif.	364818119464700	.042	.104	--	14	.052	.069	2.83
Glen Ellyn, Ill.	415302088033804	-.152	1.040	--	15	.269	.356	15.30*
Kansas City, Mo.	RR	.054	.091	--	8	.053	.107	4.39*
Knoxville, Tenn.	N47001	.007	.024	--	13	.010	.020	1.84
Knoxville, Tenn.	N47010	-.103	.394	--	11	.059	.097	8.92
Lakewood, Colo.	06711635	.018	.335	-.007	27	.031	.083	2.32*
Lansing, Mich.	001	-.151	.664	--	13	.236	.118	4.84*
Lansing, Mich.	010	.013	.012	--	6	.007	.017	.70*
Miami, Fla.	261002080070100	.012	.038	--	28	.020	.033	3.30
Miami, Fla.	261629080072400	.001	.009	--	39	.004	.006	.60
Salt Lake City, Utah	404653111545801	.004	.132	--	9	.027	.043	.99*
Tampa, Fla.	TNURPS013	.005	.003	--	11	.004	.007	.55
Tampa, Fla.	TNURPS023	.034	.082	--	13	.080	.086	6.79
Tampa, Fla.	TNURPS033	-.006	.025	--	14	.008	.010	.79
Tampa, Fla.	TNURPS173	.010	.013	--	11	.023	.018	1.42
Washington, D.C.	DC151UR07	-.014	.163	--	11	.044	.074	3.11*
Winston-Salem, N.C.	Q2485000	.043	.289	--	63	.231	.199	15.30

Table 12*l*. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for total recoverable lead for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (--) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients: Intercept	Coefficients for: Total rainfall (TRN)	Coefficients for: Rainfall duration (DRN)	Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
Baltimore, Md.	01589455	0.01	0.03	--	6	0.02	0.03	1.2*
Baltimore, Md.	01589460	-.03	.50	--	7	.30	.25	9.8*
Bellevue, Wash.	12119725	.03	1.11	-0.0003	30	.07	.44	43.1
Boston, Mass.	P1	.24	.52	--	9	.35	.45	23.4*
Boston, Mass.	P2	-1.85	17.21	--	7	2.86	4.98	259.0*
Boston, Mass.	P3	-1.32	9.83	--	6	.74	2.58	134.0*
Boston, Mass.	P5	-.03	1.73	--	7	.30	.66	34.3*
Champaign-Urbana, Ill.	BASIN 1	.11	.37	--	31	.13	.31	13.0*
Champaign-Urbana, Ill.	BASIN 2	.05	.46	--	28	.11	.30	12.6*
Champaign-Urbana, Ill.	BASIN 4	.01	.29	--	25	.07	.17	7.1*
Champaign-Urbana, Ill.	BASIN 5	.01	.39	--	28	.11	.23	9.7*
Columbus, Ohio	03226900	1.16	3.30	--	19	1.72	2.63	126.0*
Fresno, Calif.	364155119445000	-.20	1.49	--	17	.22	.18	7.4
Fresno, Calif.	364818119443800	-.04	.89	--	17	.14	.19	7.8
Fresno, Calif.	364818119464700	.35	.83	--	18	.48	.57	23.4
Glen Ellyn, Ill.	415302088033804	.37	6.61	--	10	3.18	3.60	155.0*
Kansas City, Mo.	IC	-.08	1.08	--	7	.51	.54	22.1*
Kansas City, Mo.	II	-.18	1.26	--	6	.13	.54	22.1*
Kansas City, Mo.	RC	.06	.08	--	8	.13	.11	4.5*
Kansas City, Mo.	RR	.03	.16	--	9	.11	.12	4.9*
Knoxville, Tenn.	N47001	.04	.11	--	14	.06	.10	9.2
Knoxville, Tenn.	N47010	-.29	1.99	--	11	.34	.72	66.2
Lake George, N.Y.	3702	-.05	.18	--	22	.12	.02	.9*
Lakewood, Colo.	06711635	.06	.73	--	27	.13	.32	9.0*
Lansing, Mich.	001	.10	1.04	--	16	.44	.52	21.3*
Lansing, Mich.	002	-.01	.18	--	12	.07	.07	2.9*
Lansing, Mich.	006	.07	.12	--	23	.12	.12	4.9*
Lansing, Mich.	010	.02	.16	--	11	.06	.09	3.7*
Miami, Fla.	261002080070100	.74	.83	--	29	.71	1.20	120.0
Miami, Fla.	261629080072400	.02	.55	--	40	.23	.32	32.0
Milwaukee, Wis.	04086945	.01	1.92	-0.11	13	.09	.11	4.6*
Milwaukee, Wis.	04087057	-.05	.28	--	13	.05	.07	2.9*
Milwaukee, Wis.	04087115	.09	.88	--	12	.29	.48	20.2*
Milwaukee, Wis.	04087133	.74	1.26	--	12	.84	1.29	54.2*
Milwaukee, Wis.	413630	.20	.81	--	22	.37	.56	23.5*
Milwaukee, Wis.	413631	-.62	6.73	--	40	2.85	2.34	98.3*
Milwaukee, Wis.	413632	-.05	.31	--	30	.06	.09	3.8*
Milwaukee, Wis.	413633	.06	.31	--	37	.21	.20	8.4*
Milwaukee, Wis.	413634	-.00	.24	--	37	.07	.11	4.6*
Milwaukee, Wis.	413635	.05	.28	--	46	.16	.17	7.1*
Milwaukee, Wis.	413636	-.36	1.78	--	19	.84	.42	17.6*
Rochester, N.Y.	430428077261100	-.02	.35	--	12	.13	.11	4.9*
Salt Lake City, Utah	10167220	.04	.02	--	18	.03	.05	1.2*
Salt Lake City, Utah	404653111545801	.11	.32	--	8	.46	.20	4.6*
St. Paul, Minn.	445032092552801	-.15	.71	--	11	.13	.15	6.5*
St. Paul, Minn.	445210093271701	-.08	.79	--	15	.13	.25	10.8*
St. Paul, Minn.	445937093230701	.29	.25	--	12	.20	.39	16.8*
St. Paul, Minn.	450011093221901	-.05	1.10	--	22	.27	.42	18.1*
St. Paul, Minn.	450100093205501	-.84	5.88	--	22	.65	1.64	70.5*
St. Paul, Minn.	450541093201201	.09	.46	--	22	.17	.29	12.5*
Tampa, Fla.	TNURPS023	.87	.32	--	12	1.10	1.07	84.5
Tampa, Fla.	TNURPS033	-.06	.24	--	14	.08	.10	7.9
Tampa, Fla.	TNURPS173	-.03	.09	--	11	.12	.02	1.6
Washington, D.C.	DC151UR07	.06	.22	--	16	.11	.18	7.6*
Washington, D.C.	DC151UR10	.04	.14	--	8	.08	.12	5.0*
Winston-Salem, N.C.	Q2485000	.26	1.81	--	63	2.17	1.24	95.5

Table 12J. Mean seasonal or mean annual loads, mean load for a storm, and at-site regression results for total recoverable zinc for the stations used in a nationwide study of urban mean seasonal and mean annual loads

[Mean loads marked with an asterisk (*) are seasonal (April-September) loads rather than annual loads; dashes (—) indicate that the variable is not included in the model]

Metropolitan area	Station number	Regression coefficients			Number of storms in at-site regression	Standard error of at-site regression (pounds)	Mean load for a storm (pounds)	Mean seasonal or mean annual load (pounds)
		Intercept	Coefficients for Total rainfall (TRN)	Coefficients for Rainfall duration (DRN)				
Baltimore, Md.	01589455	0.00	0.05	--	13	0.01	0.03	1.2*
Baltimore, Md.	01589460	-.04	.68	--	7	.39	.35	13.7*
Boston, Mass.	P1	.17	.78	--	9	.31	.48	25.0*
Boston, Mass.	P3	-.35	4.10	--	6	.23	1.28	66.6*
Boston, Mass.	P5	-.04	2.23	--	7	.52	.84	43.7*
Columbus, Ohio	03226900	.88	6.36	--	19	1.63	3.72	179.0*
Fresno, Calif.	364155119445000	-.25	6.09	--	15	.85	1.32	54.1
Fresno, Calif.	364818119443800	-.03	.76	--	15	.13	.17	7.0
Fresno, Calif.	364818119464700	.47	.84	--	15	.24	.69	28.3
Glen Ellyn, Ill.	415302088033804	.23	3.89	--	15	1.65	2.13	91.6*
Knoxville, Tenn.	N47001	.07	.22	--	14	.09	.18	16.6
Knoxville, Tenn.	N47010	.13	.69	--	12	.38	.48	44.2
Lakewood, Colo.	06711635	.11	1.52	-0.02	27	.16	.50	14.0*
Lansing, Mich.	001	-.03	2.59	--	13	.78	1.02	41.8*
Lansing, Mich.	006	.09	.14	--	16	.07	.15	6.1*
Lansing, Mich.	008	.06	.54	--	9	.15	.28	11.5*
Lansing, Mich.	010	.09	.18	--	6	.10	.17	7.0*
Miami, Fla.	261002080070100	.19	.32	--	29	.19	.36	36.0
Miami, Fla.	261629080072400	.02	.12	--	41	.07	.09	9.0
Milwaukee, Wis.	04086943	-.22	1.38	--	8	.18	.39	16.4*
Milwaukee, Wis.	04087133	.44	1.64	--	10	.72	1.16	48.7*
Milwaukee, Wis.	413631	-.58	4.78	--	24	1.72	1.53	64.3*
Milwaukee, Wis.	413632	-.10	.32	--	15	.08	.04	1.7*
Milwaukee, Wis.	413633	.24	--	--	14	.22	.24	10.1*
Milwaukee, Wis.	413634	-.04	.42	--	16	.13	.14	5.9*
Milwaukee, Wis.	413635	-.04	.31	--	26	.10	.10	4.2*
Salt Lake City, Utah	404653111545801	.07	.41	--	9	.12	.19	4.4*
Tampa, Fla.	TNURPS023	-.05	1.14	--	13	.83	.69	54.5
Tampa, Fla.	TNURPS033	-.06	.32	--	14	.12	.15	11.8
Tampa, Fla.	TNURPS173	-.03	.13	--	11	.15	.05	3.9
Washington, D.C.	DC151UR07	.02	.25	--	39	.08	.16	6.7*
Washington, D.C.	DC151UR09	.05	.04	--	26	.07	.07	2.9*
Washington, D.C.	DC151UR10	.03	.07	--	30	.07	.06	2.5*
Winston-Salem, N.C.	Q2485000	.07	1.41	--	64	1.34	.83	63.9