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Computed and Estimated Pollutant Loads, West Fork Trinity River, Fort Worth, Texas, 1997

Water-Resources Investigations Report 01–4253

U.S. Department of the Interior
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Abbreviations

BCF, bias-correction factor
DA, total contributing drainage area
DFW, Dallas-Fort Worth
EMC, event-mean concentration
ft^3/s, cubic foot per second
GIS, Geographic Information System
IA, impervious area
LUC, commercial land use
LUI, industrial land use
LUN, nonurban land use
LUR, residential land use
mi, mile
NEXRAD, **NEX**t Generation Weather **RAD**ar
NPDES, National Pollutant Discharge Elimination System
R^2 adj., adjusted coefficient of determination
SE, standard estimate of error
TRN, total storm rainfall
USGS, U.S. Geological Survey
WMM, Watershed Management Model

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Abstract

In 1998 the U.S. Geological Survey, in cooperation with the Trinity River Authority, did a study to estimate storm-runoff pollutant loads using two models—a deterministic model and a statistical model; the estimated loads were compared to loads computed from measured data for a large (118,000 acres) basin in the Dallas-Fort Worth, Texas, metropolitan area. Loads were computed and estimated for 12 properties and constituents in runoff from two 1997 storms at streamflow-gaging station 08048543 West Fork Trinity River at Beach Street in Fort Worth. Each model uses rainfall as a primary variable to estimate pollutant load. In addition to using point rainfall at the Beach Street station to estimate pollutant loads, areal-averaged rainfall for the basin was computed to obtain a more representative estimate of rainfall over the basin. Loads estimated by the models for the two storms, using both point and areal-averaged rainfall, generally did not compare closely to computed loads for the 12 water-quality properties and constituents. Both models overestimated loads more frequently than they underestimated loads. The models tended to yield similar estimates for the same property or constituent. In general, areal-averaged rainfall data yielded better estimates of loads than point rainfall data for both models. Neither the deterministic model nor the statistical model (both using areal-averaged rainfall) was consistently better at estimating loads. Several factors could account for the inability of the models to estimate loads closer to computed loads. Chief among them is the fact that neither model was designed for the specific application of this study.

INTRODUCTION

In 1987, the U.S. Congress amended the Clean Water Act (Federal Water Pollution Control Act Amendments of 1972 and 1977) to require the U.S. Environmental Protection Agency to establish phased National Pollutant Discharge Elimination System (NPDES) regulations for various nonpoint-source discharges including discharges from municipal urban areas. The Clean Water Act amendments stipulate that all municipalities with populations greater than 100,000 and with municipal storm-sewer systems separate from sewage systems should acquire discharge permits according to regulations outlined for NPDES (U.S. Environmental Protection Agency, 1992). Part of these regulations require municipalities not only to characterize the quantity and quality of storm runoff with monitoring and sampling programs but also to estimate pollutant concentrations and annual pollutant loads from unmonitored watersheds (U.S. Environmental Protection Agency, 1990).

Two models (described later in this report) have been developed to estimate pollutant loads in storm runoff from urban basins in the Dallas-Fort Worth (DFW) metropolitan area, Texas. A deterministic model, the Watershed Management Model (WMM), estimates a total basin pollutant load by multiplying an event-mean concentration (EMC) by estimated runoff for each type of land use and then summing the loads for each land use (Rouge River National Wet Weather Demonstration Project, 1998). A statistical model, developed by the U.S. Geological Survey (USGS), uses multi-variable regression equations to estimate pollutant loads in storm runoff. The deterministic and the statistical models had not been tested to determine whether either could produce accurate estimates of pollutant loads in storm runoff for large basins (greater than 160 acres) within the DFW metropolitan area.

In 1998, the USGS did an investigation, in cooperation with the Trinity River Authority, to estimate storm-runoff pollutant loads with each of the two models and to compare the estimated loads to computed loads. The ability to reliably estimate pollutant loads in storm runoff from selected watersheds in the Trinity River Basin could aid the Trinity River Authority in evaluating suitable best management practices for reducing loads.

Purpose and Scope

This report documents the derivation of estimated storm-runoff pollutant loads from the two models and compares the estimated loads with loads computed from measured data at USGS streamflow-gaging station 08048543 West Fork Trinity River at Beach Street, Fort Worth. The properties and constituents for which loads were computed are biochemical oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, total nitrogen, total ammonia plus organic nitrogen (also known as total Kjeldahl nitrogen), total phosphorus, dissolved phosphorus, total recoverable copper, total recoverable lead, total recoverable zinc, and total diazinon.

Rainfall, streamflow, and water-quality data for this study were available from three storms—October 23–24, December 7–8, and December 20–21, 1997—for which samples were collected as a part of a previous study. However, data from the December 20–21 storm were not used because the computed volume of runoff associated with the sampled storm-hydrograph peak was small (less than 20 percent of the volumes of the two other storms). The sampled peak was believed to represent local runoff originating near the gaging station rather than runoff from the entire basin. Because the models estimate loads assumed to be from the entire basin, computed loads from a fraction of the basin (near the gaging station) would not be comparable.

Description of Study Area

The study area (about 118,000 acres) is located in north-central Texas in southwestern Tarrant County and eastern Parker County (fig. 1). Fort Worth is the largest city in the study area. The study area is coincident with the intervening drainage area of the West Fork Trinity River between the Beach Street station and Lake Worth and Benbrook Lake. The West Fork Trinity River is one of three major tributaries to the main stem Trinity River. The mean annual discharge (1977–98) at the Beach Street station is 630 ft^3/s (U.S. Geological Survey, 1999).

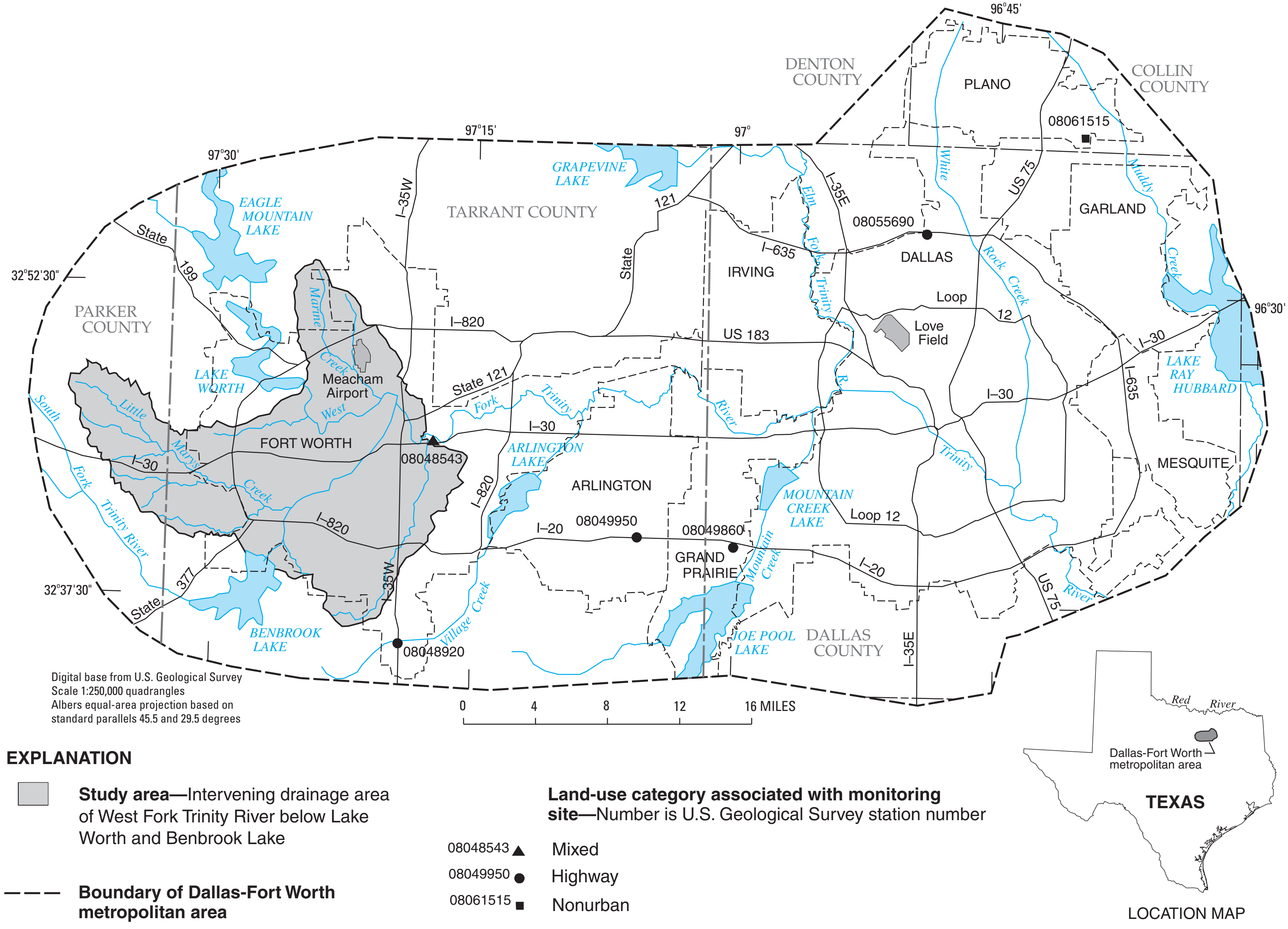
Tarrant and Parker Counties are in the Cross Timbers and Grand Prairies physiographic regions within the southern extension of the Interior Lowlands (Ramos, 1997). Six classifications of land use—residential, commercial, industrial, highway, nonurban, and water—were defined and delineated in the study area (fig. 2) using a geographic information system (GIS). Nonurban land use represents the largest part (47.3 percent) of the basin, and highway land use represents the smallest part (4.2 percent) (table 1). The impervious fraction of area estimated for each land-use category ranges from 0.1 for nonurban to 0.9 for highway.

Previous Studies

Driver and Tasker (1990) describe techniques for estimating storm-runoff loads, volumes, and selected water-quality property and constituent concentrations on the basis of regional data collected in urban watersheds throughout the United States. The regression model approach (Driver and Tasker, 1990) used a national database developed in the late 1970s as part of the Nationwide Urban Runoff Program for three major types of land use: residential, commercial, and industrial. Baldys and others (1998) used similar techniques on a local scale to estimate stormwater pollutant loads in the DFW metropolitan area for four land-use categories: residential, commercial, industrial, and nonurban. The data used by Baldys and others (1998) were collected by the USGS at 26 sites during 1992–93 as part of the DFW municipal NPDES storm-runoff characterization study (Baldys and others, 1997).

Table 1. Land-use characteristics

Land-use category	Drainage area (acres)	Percent of total drainage area	Estimated impervious fraction
Residential	39,000	33.1	0.5
Commercial	12,800	10.8	.7
Industrial	5,400	4.6	.8
Highway	5,000	4.2	.9
Nonurban	55,800	47.3	.1
All	118,000		



Digital base from U.S. Geological Survey
Scale 1:250,000 quadrangles
Albers equal-area projection based on standard parallels 45.5 and 29.5 degrees

EXPLANATION

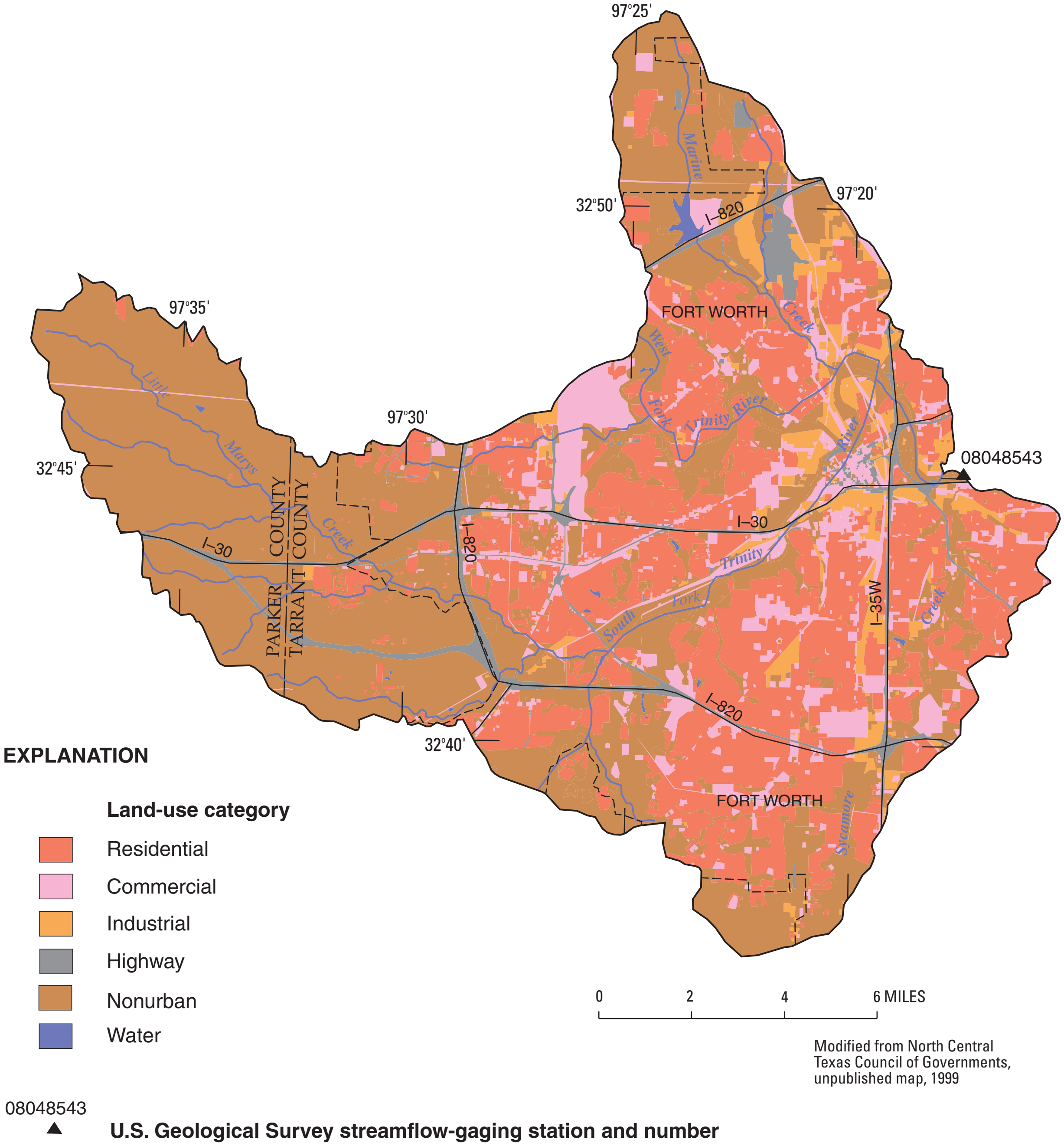
▨ **Study area**—Intervening drainage area of West Fork Trinity River below Lake Worth and Benbrook Lake

— — — **Boundary of Dallas-Fort Worth metropolitan area**

Land-use category associated with monitoring site—Number is U.S. Geological Survey station number

08048543 ▲	Mixed
08049950 ●	Highway
08061515 ■	Nonurban

Figure 1. Location of study area and monitoring sites in the Dallas-Fort Worth metropolitan area.



Modified from North Central Texas Council of Governments, unpublished map, 1999

Figure 2. Land-use categories in the study area.

These data were used to characterize stormwater quality and to compute loads of 12 selected water-quality properties and constituents in storm runoff. The data were collected from storm-sewer outfalls that had drainage areas of less than 160 acres and predominantly single land-use categories of residential, commercial, or industrial, with minimal nonurban land use.

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The authors thank the North Central Texas Council of Governments for their cooperation and assistance in the completion of this report. Their assistance with pollutant load estimation using the WMM, GIS land-use mapping and statistics, and average rainfall computations for the study area using National Weather

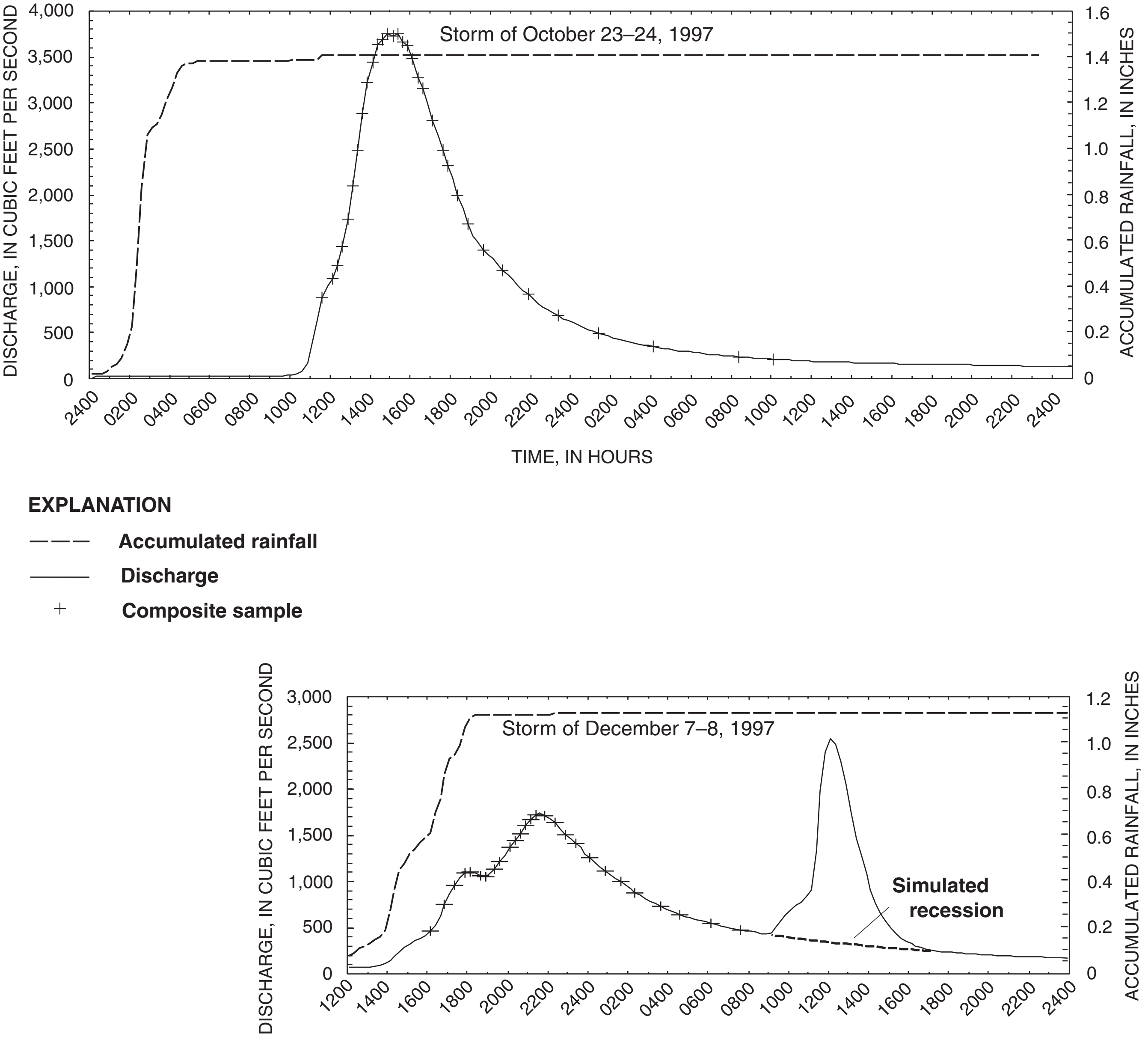

Figure 3. Hydrographs showing accumulated rainfall and discharge at streamflow-gaging station 08048543 for storms of October 23–24 and December 7–8, 1997.

Service doppler radar data (**NEX**t Generation Weather **RAD**ar [NEXRAD]) were invaluable.

METHODS OF COMPUTING AND ESTIMATING POLLUTANT LOADS

Computing Loads

Pollutant loads for two storms were computed from measured flow-weighted concentrations and storm-runoff volume at the Beach Street streamflow-gaging station (fig. 3). Concentrations of the 12 properties and constituents were determined analytically from a composited sample representing equal volumes of storm runoff. An EMC was determined for each property or constituent from the flow-weighted composite sample collected during a storm. The storm-runoff volume was computed using an established rating curve that relates recorded stage to measured discharge.

A load for an individual storm is computed by the equation:

$$\mathrm{LOAD_i} = \mathrm{EMC_i} \times \mathrm{RV_i} \times \mathrm{CF}, \qquad (1)$$

where

$\mathrm{LOAD_i}$ = pollutant load (in pounds) for storm i;
$\mathrm{EMC_i}$ = event-mean concentration of property or constituent (in milligrams per liter or micrograms per liter) for storm i;
$\mathrm{RV_i}$ = runoff volume (in cubic feet) for storm i; and
CF = conversion factor (6.2382^{-5} if constituent is in milligrams per liter or 6.2382^{-8} if constituent is in micrograms per liter).

Base-flow loads at the West Fork Trinity River at Beach Street station were considered negligible on the basis of the magnitude of difference between base-flow and storm-runoff volumes and associated pollutant concentrations. In addition, base flow was not enough to dilute storm-runoff concentrations. Therefore, no adjustment was made to the total storm load for loads produced during base-flow conditions.

Estimating Loads With Deterministic Model

The WMM, originally developed by Camp Dresser & McKee, Inc. (Rouge River National Wet Weather Demonstration Project, 1998), is a simple deterministic model that simulates the generation and fate of pollutant loads from a variety of pollutant sources in a basin. The model estimates annual or seasonal pollutant loads carried in storm runoff on the basis of associated EMCs, land use, impervious fraction, and rainfall.

The model estimates runoff volumes from storm rainfall and runoff coefficients for the pervious and impervious areas in each land-use category. For this report, a runoff coefficient of 0.90 was used for impervious areas and 0.20 for pervious areas. These coefficients designate 90 percent of the rainfall as runoff from the impervious fraction of each land-use area and 20 percent of the rainfall as runoff from the pervious fraction of each land-use area. The equation for runoff volume for any land use (L) is

$$\mathrm{RV_L} = [\mathrm{Cp} + (\mathrm{Ci} - \mathrm{Cp}) \times \mathrm{IMP_L}] \times \mathrm{I} \times \mathrm{A_L} \times \mathrm{CF}, \qquad (2)$$

where

$\mathrm{RV_L}$ = runoff volume for land use (in cubic feet);
Cp = pervious area runoff coefficient;
Ci = impervious area runoff coefficient;
$\mathrm{IMP_L}$ = impervious fraction of land-use area (table 1);
I = storm rainfall (in inches);
$\mathrm{A_L}$ = area of land use (in acres); and
CF = conversion factor (3,630).

The total storm runoff from the basin is the sum of the runoff volumes for all land uses.

For the deterministic model, an equation similar to equation 1 is used to estimate the pollutant load for each land use by multiplying the runoff volume for each land use ($\mathrm{RV_L}$) by the corresponding EMC for each land use:

$$\mathrm{LOAD_L} = \mathrm{EMC_L} \times \mathrm{RV_L} \times \mathrm{CF}, \qquad (3)$$

where

$\mathrm{LOAD_L}$ = pollutant load for each land use,
$\mathrm{EMC_L}$ = EMC for each land use, and

$\mathrm{RV_L}$ and CF are the same as defined for equation 2.

For this study, the median EMCs reported by Baldys and others (1998), which characterized storm runoff throughout the DFW metropolitan area during 1992–93, were used for residential, commercial, and industrial land uses (table 2). Median EMCs were used rather than means because medians are less influenced by outliers in the data. EMCs for highway land use (table 2) were computed using data collected during 28 storms sampled during 1993–94 at four highway storm-runoff monitoring sites (USGS stations 08048920, 08049860, 08049950, and 08055690) located throughout the DFW metropolitan area (fig. 1). EMCs for nonurban land use (table 2) were computed from one nonurban storm-runoff monitoring site (USGS station 08061515) in Plano (fig. 1), northeast of Dallas. These EMCs reflect concentrations in runoff from six storms sampled during 1998–99.

Estimating Loads With Statistical Model

The statistical model was developed by the USGS from a 1992–93 study (Baldys and others, 1998) using multiple regression analysis and local storm-runoff quality data representing three major (in terms of area) urban land-use categories (residential, commercial, and industrial) and one minor category (nonurban). The local regression equations developed were used to estimate pollutant loads produced by individual storms for each of the 12 selected properties and constituents. The storm-runoff quality data used to develop the regression

Table 2. Median event-mean concentrations by land-use category

[EMC, event-mean concentration; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no measured data above analytical detection limit]

Property or constituent	Residential (11 sites)[1]		Commercial (6 sites)[1]		Industrial (9 sites)[1]		Highway (4 sites)		Nonurban (1 site)	
	No. of samples	Median EMC	No. of samples	Median EMC	No. of samples	Median EMC	No. of samples	Median EMC	No. of samples	Median EMC
Biochemical oxygen demand, mg/L	72	7.3	38	6.6	61	7.5	28	6.5	6	3.7
Chemical oxygen demand, mg/L	76	70	42	56	59	67	28	59	3	26
Suspended solids, mg/L	69	78	35	52	60	104	27	90	6	236
Dissolved solids, mg/L	70	58	37	50	60	69	27	184	6	146
Total nitrogen, mg/L	77	1.7	42	1.2	63	1.4	28	2.0	6	2.5
Total ammonia plus organic nitrogen, mg/L	77	1.1	42	.80	63	.80	28	1.2	6	1.3
Total phosphorus, mg/L	77	.33	42	.14	63	.21	28	.21	6	.52
Dissolved phosphorus, mg/L	77	.21	42	.06	63	.09	28	.11	4	.28
Total recoverable copper, µg/L	74	8.0	38	8.0	61	12	28	11	6	7.0
Total recoverable lead, µg/L	74	13	40	30	61	29	28	11	6	6.0
Total recoverable zinc, µg/L	75	60	40	80	59	130	28	60	6	20
Total diazinon, µg/L	76	.55	40	.10	62	.05	28	--	5	.0050

[1] Baldys and others, 1998, table 14.

model were collected at 26 small (less than 160 acres) gaged basins throughout the DFW metropolitan area. These gaged basins have a median size of 51.4 acres.

Seven explanatory variables were used in the multiple regression analysis. The regression equation for the load produced by an individual storm was developed using a logarithmic transformation (log base-10) of the response and explanatory variables and then detransformed to become

$$\mathrm{LOAD} = b'_0 \times (\mathrm{TRN})^{b_1} \times (\mathrm{DA})^{b_2} \times (\mathrm{IA}+1)^{b_3} \times (\mathrm{LUI}+1)^{b_4} \times (\mathrm{LUC}+1)^{b_5} \times (\mathrm{LUR}+1)^{b_6} \times (\mathrm{LUN}+1)^{b_7} \times \mathrm{BCF}, \quad (4)$$

where

$b'_0 = 10^{b_0}$;

b_0–b_7 = regression coefficients;

TRN = total storm rainfall (in inches);

DA = total contributing drainage area (in square miles);

IA = impervious area, as a percentage of DA;

LUI = industrial land use, as a percentage of DA;

LUC = commercial land use, as a percentage of DA;

LUR = residential land use, as a percentage of DA;

LUN = nonurban land use, as a percentage of DA; and

BCF = bias correction factor.

Unity (+1) is added to the impervious-area and land-use percentages to avoid the (undefined) logarithm of zero. The BCF is included to obtain an unbiased estimate of the mean response (load), which is systematically underestimated during detransformation of the regression equation (Miller, 1984) and is defined by

$$\mathrm{BCF} = 10^{(1.151(\mathrm{SE}^2))}, \quad (5)$$

where

SE = standard error of estimate (in log units) of the regression equation.

The regression equation coefficients developed by Baldys and others (1998) for estimating loads of the 12 selected properties and constituents for residential, commercial, industrial, and nonurban land uses are listed in table 3. For a more detailed explanation of the multiple regression analysis method, see Baldys and others (1998) and Driver and Tasker (1990).

Table 3. Regression equation coefficients for estimating pollutant loads for residential, commercial, industrial, and nonurban land uses[1]

[LOAD, storm-runoff load of property or constituent, in pounds; b'_0, intercept in regression model; b_1, coefficient for variable TRN (total storm rainfall); b_2, coefficient for variable DA (drainage area); b_3, coefficient for variable IA (impervious area); b_4, coefficient for variable LUI (industrial land use); b_5, coefficient for variable LUC (commercial land use); b_6, coefficient for variable LUR (residential land use); b_7, coefficient for variable LUN (nonurban land use); BCF, bias correction factor; --, variable not included; SE, standard error of regression equation; R^2 adj., adjusted coefficient of determination, in percent. Equation form is:

$$\mathrm{LOAD} = b'_0 \times (\mathrm{TRN})^{b_1} \times (\mathrm{DA})^{b_2} \times (\mathrm{IA}+1)^{b_3} \times (\mathrm{LUI}+1)^{b_4} \times (\mathrm{LUC}+1)^{b_5} \times (\mathrm{LUR}+1)^{b_6} \times (\mathrm{LUN}+1)^{b_7} \times \mathrm{BCF}.]$$

Property or constituent	b'_0	b_1	b_2	b_3	b_4	b_5
Biochemical oxygen demand	9.01	0.879	0.725	0.656	0.104	0.085
Chemical oxygen demand	10.2	.711	.593	.961	.176	.123
Suspended solids	5.85	.889	.544	.913	.463	.170
Dissolved solids	104	.764	.745	.568	.131	.124
Total nitrogen	1.14	.838	.597	.725	.072	.056
Total ammonia plus organic nitrogen	.666	.878	.544	.716	.045	.037
Total phosphorus	.955	.932	.475	--	.286	.176
Dissolved phosphorus	.546	1.05	.477	--	.281	.121
Total recoverable copper	.0023	.894	.623	.996	.138	.057
Total recoverable lead	.00000086	1.21	.500	2.55	.371	.210
Total recoverable zinc	.00020	.905	.520	1.85	.363	.198
Total diazinon	.0013	1.47	.305	--	--	--

Property or constituent	b_6	b_7	**BCF**	**SE**	**R^2 adj.**
Biochemical oxygen demand	--	--	1.11	48.7	64.0
Chemical oxygen demand	0.130	--	1.16	58.5	53.6
Suspended solids	.328	--	1.52	115	42.0
Dissolved solids	--	--	1.13	52.3	59.2
Total nitrogen	.052	--	1.15	57.1	49.9
Total ammonia plus organic nitrogen	.077	--	1.18	63.0	45.0
Total phosphorus	.272	--	1.20	66.2	51.5
Dissolved phosphorus	.333	--	1.25	75.7	52.7
Total recoverable copper	.012	--	1.24	72.8	49.2
Total recoverable lead	.274	0.265	1.41	99.5	58.8
Total recoverable zinc	.201	.266	1.20	65.8	65.3
Total diazinon	.374	--	2.32	210	40.6

[1] Baldys and others, 1998, table 17.

Table 4. Regression equation coefficients for estimating pollutant loads for highway land use

[LOAD, storm-runoff load of property or constituent, in pounds; b'_0, intercept in regression model; b_1, coefficient for variable TRN (total storm rainfall); b_2, coefficient for variable DA (drainage area); BCF, bias correction factor; SE, standard error of regression equation; R^2 adj., adjusted coefficient of determination, in percent; --, variable not included. Equation form is:

$$\mathrm{LOAD} = b'_0 \times (\mathrm{TRN})^{b_1} \times (\mathrm{DA})^{b_2} \times \mathrm{BCF}].$$

Property or constituent	b'_0	b_1	b_2	BCF	SE	R^2 adj.	No. of storms
Biochemical oxygen demand	22.7	0.861	0.205	1.08	40	60	28
Chemical oxygen demand	286	.781	.381	1.31	85	34	28
Suspended solids	871	1.157	.507	1.28	80	31	27
Dissolved solids	2,004	.254	.760	1.11	48	74	27
Total nitrogen	8.24	.896	.245	1.09	42	61	28
Total ammonia plus organic nitrogen	6.54	.891	.323	1.14	54	54	28
Total phosphorus	.642	1.395	--	1.22	70	52	28
Dissolved phosphorus	.376	1.383	--	1.26	76	45	21
Total recoverable copper	.0175	.771	--	1.18	63	27	28
Total recoverable lead	.167	1.197	.508	1.51	113	42	28
Total recoverable zinc	.368	.613	.423	1.35	91	29	28
Total diazinon[1]	--	--	--	--	--	--	--

[1] No measured data higher than analytical detection limit.

The highway land-use category was not addressed by Baldys and others (1998) during development of the regression model. For this study, loads from areas categorized as highway land use were computed from flow-weighted EMCs (table 2) and runoff volumes from seven sampled storms in each of four gaged basins. These data were used to develop a regression equation for highway land use, which was needed to complete the statistical model for estimation of pollutant loads for the entire study area.

Stepwise regression with the explanatory variables TRN and DA was used to develop equations for highway land use for each property and constituent. An explanatory variable was retained if it was significant at the 5-percent level ($p = 0.05$); two constituents for which exceptions were made were dissolved solids and total recoverable zinc, with p-values of 0.19 and 0.065, respectively, for DA. The SE and the adjusted coefficient of determination (R^2 adj.) also were used to evaluate the use of a specific explanatory variable by indicating how well the regression equations fit the measured data; maximizing R^2 adj. and minimizing SE resulted in a better fit. The form of the regression equation relating the response and explanatory variables is

$$\mathrm{LOAD} = b'_0 \times (\mathrm{TRN})^{b_1} \times (\mathrm{DA})^{b_2} \times \mathrm{BCF}. \qquad (6)$$

The regression equation coefficients for estimating loads of the 12 selected properties and constituents for highway land use are listed in table 4. SE ranges from 40 to 113 percent, and R^2 adj. ranges from 27 to 74 percent. Estimated loads for each property and constituent from the statistical model were thus obtained by adding the loads obtained from equations 4 and 6.

COMPUTED AND ESTIMATED POLLUTANT LOADS

Pollutant loads for each property and constituent (table 5) were computed for each of the two storms on the basis of measured EMCs and computed runoff volumes. Accumulated point rainfall and runoff at the Beach Street station for the two storms are shown by the hydrographs in figure 3. The October 23–24 storm

Table 5. Computed and estimated pollutant loads for 12 selected properties and constituents

Property or constituent	Storm date	Computed load (pounds)	Deterministic model				Statistical model			
			Point rainfall		Areal-averaged rainfall		Point rainfall		Areal-averaged rainfall	
			Estimated load (pounds)	Difference[1] between estimated and computed loads (percent)	Estimated load (pounds)	Difference[1] between estimated and computed loads (percent)	Estimated load (pounds)	Difference[1] between estimated and computed loads (percent)	Estimated load (pounds)	Difference[1] between estimated and computed loads (percent)
Biochemical oxygen demand	10/23–24/1997	61,700	110,000	78	77,200	25	79,100	28	57,400	-7
	12/07–08/1997	28,300	87,200	208	58,700	107	65,200	130	45,100	60
Chemical oxygen demand	10/23–24/1997	266,000	970,000	264	690,000	159	731,000	175	562,000	111
	12/07–08/1997	119,000	770,000	548	520,000	338	625,000	426	462,000	289
Suspended solids	10/23–24/1997	1,900,000	2,100,000	11	1,500,000	-21	2,050,000	8	1,480,000	-22
	12/07–08/1997	1,340,000	1,700,000	27	1,100,000	-18	1,690,000	26	1,160,000	-13
Dissolved solids	10/23–24/1997	1,010,000	1,600,000	58	1,100,000	9	713,000	-30	557,000	-45
	12/07–08/1997	1,000,000	1,300,000	30	870,000	-13	602,000	-40	456,000	-55
Total nitrogen	10/23–24/1997	8,140	627	-92	444	-95	7,210	-11	5,480	-33
	12/07–08/1997	3,550	502	-86	338	-90	5,870	65	4,250	20
Total ammonia plus organic nitrogen	10/23–24/1997	5,810	19,000	227	13,500	132	12,800	121	9,420	62
	12/07–08/1997	6,220	15,200	144	10,200	64	10,600	70	7,150	15
Total phosphorus	10/23–24/1997	1,820	5,810	219	4,120	127	7,210	296	5,090	180
	12/07–08/1997	1,440	4,650	224	3,130	118	5,870	308	3,930	174
Dissolved phosphorus	10/23–24/1997	318	3,290	934	2,330	633	4,770	1,400	3,190	901
	12/07–08/1997	272	2,640	871	1,770	553	3,780	1,300	2,390	779
Total recoverable copper	10/23–24/1997	97	112	15	79	-19	104	6	75	-23
	12/07–08/1997	57	90	59	60	6	85	50	59	4
Total recoverable lead	10/23–24/1997	292	271	-7	192	-34	285	-3	187	-36
	12/07–08/1997	113	217	92	146	29	218	93	134	18
Total recoverable zinc	10/23–24/1997	390	1,030	164	730	87	2,850	630	2,010	416
	12/07–08/1997	283	825	192	555	96	2,330	723	1,570	455
Total diazinon	10/23–24/1997	.65	.05	-92	.04	-94	19.9	3,000	11.5	1,670
	12/07–08/1997	.37	.04	-89	.03	-92	14.4	3,810	7.68	1,990

[1] $\text{Difference} = \left[\frac{\text{estimated} - \text{computed}}{\text{computed}}\right] \times 100$.

produced a single-peak hydrograph in which the entire increase and recession of runoff was sampled (fig. 3). The December 7–8 storm produced two runoff peaks separated by more than 12 hours, with the first peak receding by about 75 percent before the second peak (fig. 3). Only the runoff volume represented by the first peak was sampled; a simulated 95-percent recession was used to compute the sampled runoff volume. The second peak likely resulted from rainfall in an ungaged part of the basin.

Each of the models uses rainfall as a primary variable to estimate pollutant load. In addition to using measured point rainfall at the Beach Street station to estimate pollutant loads, areal-averaged rainfall for the basin was computed to obtain a more representative estimate of rainfall over the entire basin. Areal-averaged rainfall was computed using NEXRAD data that consist of estimated hourly rainfall in 2.5-by-2.5-mi cells throughout the basin. The NEXRAD data were calibrated using control points where point rainfall was measured accurately. Estimated hourly rainfall for all 2.5-by-2.5-mi cells in the basin was averaged to provide a basin-wide hourly rainfall; the hourly averages then were summed for the duration of the storm to estimate total rainfall (Scott Rae, North Central Texas Council of Governments, oral commun., 1999). Areal-averaged rainfall was 29 percent smaller for the October 23–24 storm and 33 percent smaller for the December 7–8 storm than each corresponding point rainfall:

Storm date	Duration (hours)	Point rainfall (inches)	Areal-averaged rainfall (inches)
October 23–24	26	1.41	1.0
December 7–8	36	1.13	.76

Pollutant loads were estimated with the deterministic model and the statistical model using both point and areal-averaged rainfall for both storms (table 5). The ability of each model to estimate loads was evaluated by graphically comparing percent differences between estimated loads and computed loads (estimated load minus computed load divided by computed load, times 100) for the October 23–24 and December 7–8 storms (figs. 4–5). Loads estimated by the models for the two storms (using either point or areal-averaged rainfall) generally did not compare closely to computed loads for the 12 water-quality properties and constituents (figs. 4–5). Both models overestimated loads more frequently than they underestimated loads. The models tended to yield similar estimates for the same property or constituent—the differences for properties and constituents from the deterministic model (fig. 4) are similar to those for corresponding properties and constituents from the statistical model (fig. 5), except for nitrogen, zinc, and diazinon.

For the deterministic model using point rainfall, estimated loads were closest to computed loads for suspended solids (mean difference for the two storms 19 percent) (fig. 4). For the deterministic model using areal-averaged rainfall, estimated loads were closest to computed loads for dissolved solids (mean [absolute] difference for the two storms 11 percent)—and nearly as close for total recoverable copper (mean [absolute] difference for the two storms 13 percent). The deterministic model using both types of rainfall was least accurate in estimating dissolved phosphorus loads.

For the statistical model using point rainfall, estimated loads were closest to computed loads for suspended solids (mean difference for the two storms 17 percent) (fig. 5); using areal-averaged rainfall, estimated loads were closest to computed loads for total recoverable copper (mean [absolute] difference for the two storms 14 percent) and nearly as close for suspended solids (mean [absolute] difference for the two storms 18 percent) (fig. 5). The statistical model was least accurate in estimating total diazinon loads and also, like the deterministic model, relatively inaccurate in estimating dissolved phosphorus loads.

With one exception, areal-averaged rainfall data yielded better estimates of loads than point rainfall data for both models. The exception is dissolved solids loads from the statistical model—point rainfall data yielded estimated loads closer to computed loads for both storms.

Neither the deterministic model nor the statistical model (both using areal-averaged rainfall) was consistently better at estimating loads (fig. 6). The deterministic model yielded loads closer to computed loads than the statistical model for 7 of the 12 properties and constituents, and the statistical model yielded loads closer to computed loads than the deterministic model for 5 properties and constituents. The median difference between estimated and computed loads for the deterministic model (92 percent) was about twice that for the statistical model (45 percent) (both using areal-averaged rainfall); but the largest differences (mean differences for both storms of 840 and 1,830 percent for dissolved phosphorus and total diazinon, respectively) were associated with the statistical model.

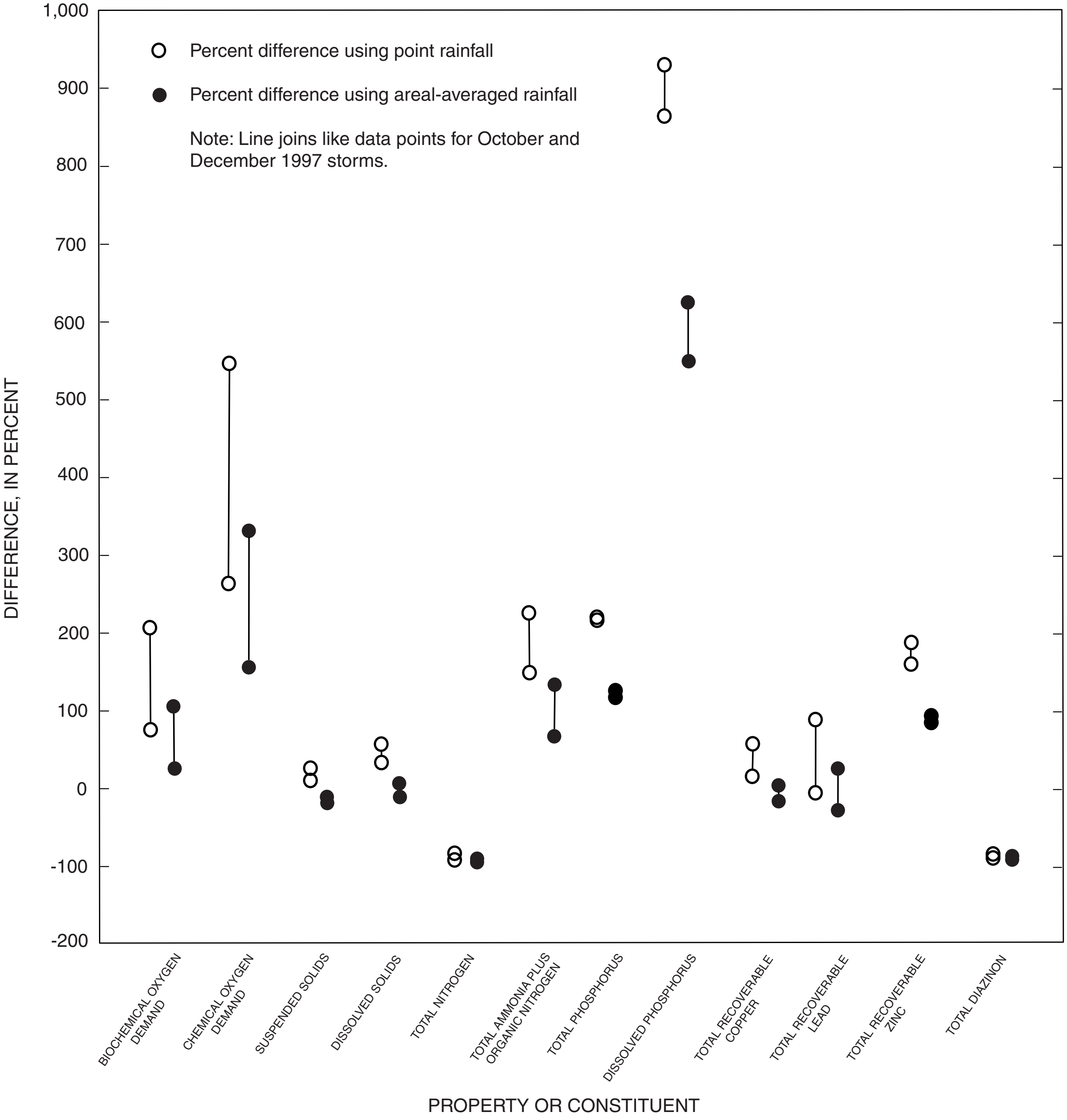

Figure 4. Comparison of use of point rainfall and areal-averaged rainfall, deterministic model—differences between estimated and computed pollutant loads for 12 properties and constituents for two storms (October 23–24 and December 7–8, 1997).

Several factors could account for the inability of the models to estimate loads closer to computed loads. The ability of the deterministic model to accurately estimate loads depends to a large extent on calibrated runoff coefficients and on EMCs. The lack of available storm data precluded optimum calibration of the runoff coefficients. Any inaccuracies in runoff coefficients and EMCs cause proportional inaccuracies in estimated loads. The deterministic model originally was developed to estimate annual or seasonal pollutant

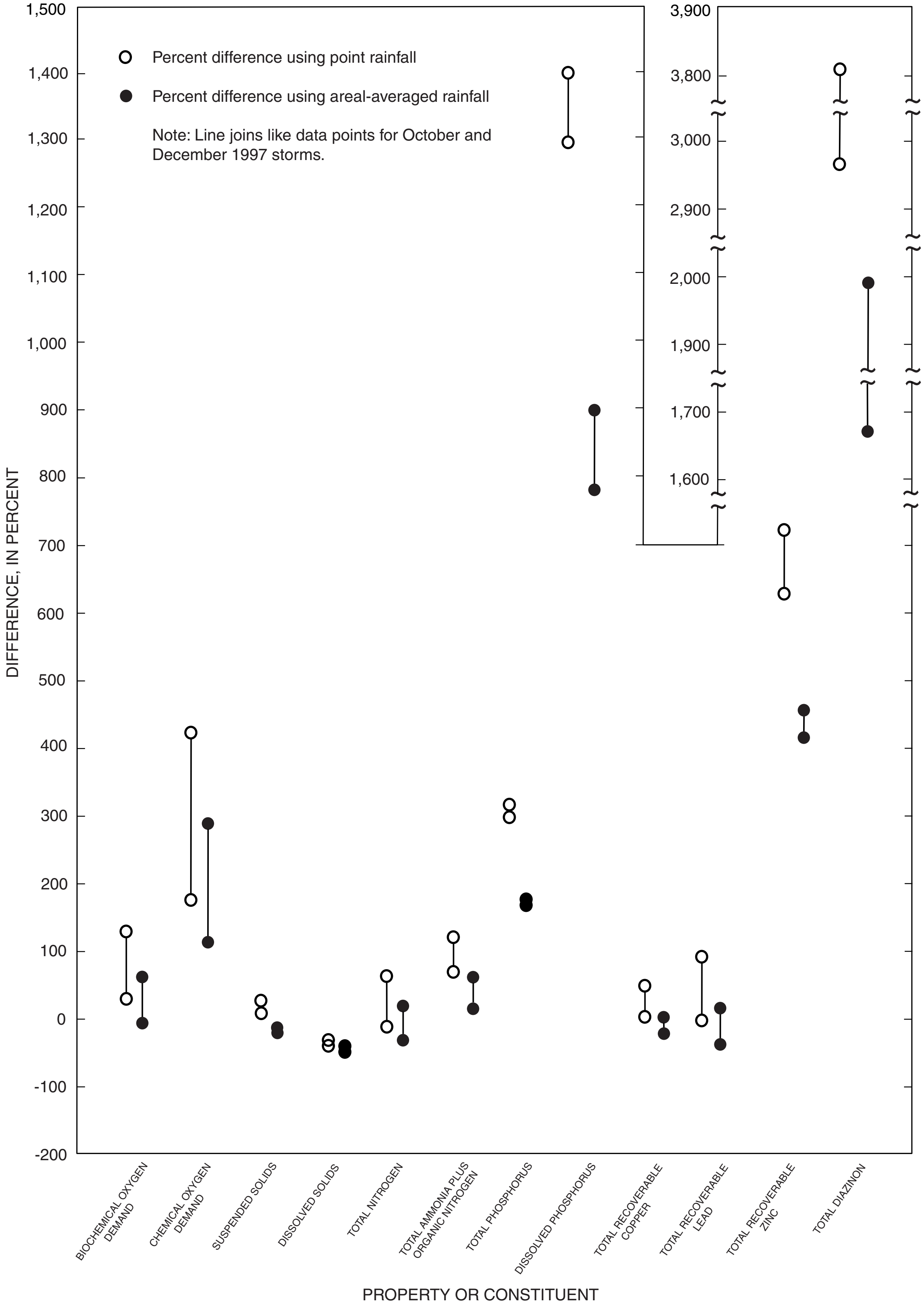

Figure 5. Comparison of use of point rainfall and areal-averaged rainfall, statistical model—differences between estimated and computed pollutant loads for 12 properties and constituents for two storms (October 23–24 and December 7–8, 1997).

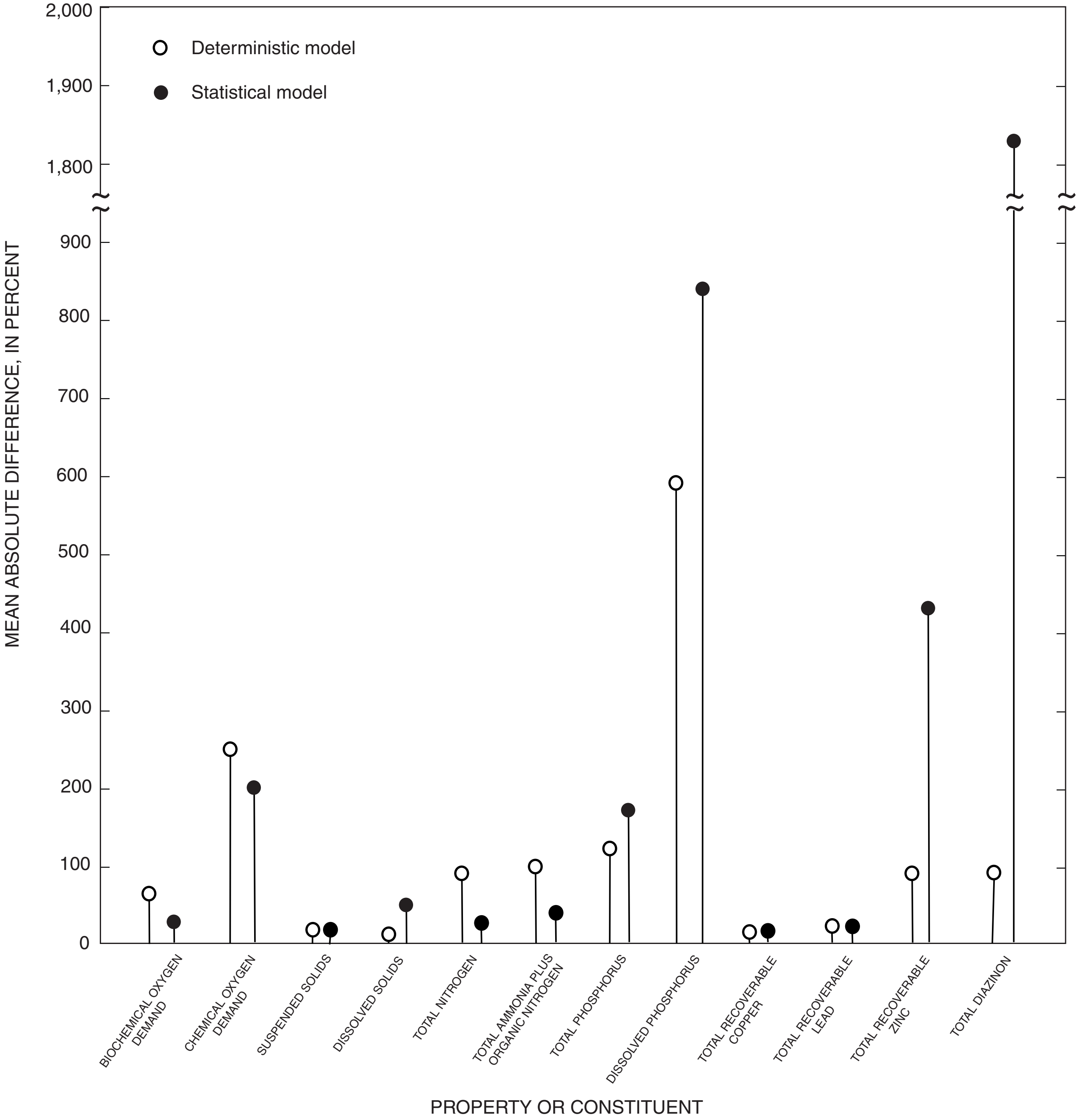

Figure 6. Comparison of results of deterministic model and statistical model, both using areal-averaged rainfall—mean absolute differences between estimated and computed pollutant loads for 12 properties and constituents for two storms (October 23–24 and December 7–8, 1997).

loads, not individual storm loads. The statistical model was developed from data for small (less than 160 acres) urban basins with little influence from nonurban land use. The study area (basin) in this application is 118,000 acres, of which nearly one-half is nonurban (table 1). Aside from these sources of inaccuracy, data from two storms are insufficient to thoroughly evaluate the ability of the two models to adequately estimate loads; but given these sources of inaccuracy, the potential for the two models to yield estimated loads close to computed loads probably is low.

SUMMARY

In 1998 the USGS, in cooperation with the Trinity River Authority, did a study to estimate storm-runoff pollutant loads using two models—a deterministic model and a statistical model; the estimated loads were compared to loads computed from measured data for a large (118,000 acres) basin in the DFW metropolitan area. Loads were computed and estimated for 12 selected properties and constituents: biochemical oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, dissolved phosphorus, total recoverable copper, total recoverable lead, total recoverable zinc, and total diazinon. The deterministic model, developed by Camp Dresser & McKee, Inc., estimates pollutant loads using storm-runoff estimates on the basis of rainfall, impervious fraction, and EMC data for each land-use category. The statistical model, developed by the USGS, uses multiple regression analysis of local storm-runoff data to estimate pollutant loads. The data from which computed and estimated loads were obtained were collected from two 1997 storms at USGS streamflow-gaging station 08048543 West Fork Trinity River at Beach Street in Fort Worth.

Each model uses rainfall as a primary variable to estimate pollutant load. In addition to using measured point rainfall at the Beach Street station to estimate pollutant loads, areal-averaged rainfall for the basin was computed to obtain a more representative estimate of rainfall over the entire basin. Pollutant loads were estimated using the deterministic model and the statistical model on the basis of both point and areal-averaged rainfall for both storms. The ability of each model to estimate loads was evaluated by graphically comparing percent differences between estimated loads and computed loads for the two storms.

Loads estimated by the models for the two storms, using both point and areal-averaged rainfall, generally did not compare closely to computed loads for the 12 water-quality properties and constituents. Both models overestimated loads more frequently than they underestimated loads. The models tended to yield similar estimates for the same property or constituent. In general, areal-averaged rainfall data yielded better estimates of loads than point rainfall data for both models.

Neither the deterministic model nor the statistical model (both using areal-averaged rainfall) was consistently better at estimating loads. The deterministic model resulted in estimated loads that were closer to computed loads than the statistical model for seven properties and constituents; and the statistical model resulted in estimated loads that were closer to computed loads than the deterministic model for five properties and constituents.

The ability of the deterministic model to accurately estimate loads depends to a large extent on calibrated runoff coefficients and on EMCs. The lack of available storm data precluded optimum calibration of the runoff coefficients. The deterministic model originally was developed to estimate annual or seasonal pollutant loads, not individual storm loads. The statistical model was developed from data for small (less than 160 acres) urban basins with little influence from nonurban land use. The study area (basin) in this application is 118,000 acres, of which nearly one-half is nonurban. Aside from these sources of inaccuracy, data from two storms are insufficient to thoroughly evaluate the ability of the two models to adequately estimate loads; but given these sources of inaccuracy, the potential for the two models to yield estimated loads close to computed loads probably is low.

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