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QUANTITY AND QUALITY OF URBAN STORMWATER RUNOFF FROM SELECTED DRAINAGE BASINS, OMAHA, NEBRASKA, 1992-93

Water-Resources Investigations Report 98–4168

U.S. Department of the Interior
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Omaha, Nebraska
1999

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.004047	square kilometer
square foot (ft^2)	929.0	square centimeter
gallon (gal)	0.003785	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

QUANTITY AND QUALITY OF URBAN STORMWATER RUNOFF FROM SELECTED DRAINAGE BASINS, OMAHA, NEBRASKA, 1992-93

By Abraham H. Chen *and* Francis J. Jelinek

ABSTRACT

The U.S. Geological Survey, in cooperation with the City of Omaha and the Papio-Missouri River Natural Resources District, Nebraska, conducted a study to describe stormwater-runoff quantity and quality from selected basins in Omaha. The study was done to meet technical data requirements for the City of Omaha to obtain a National Pollutant Discharge Elimination System Permit from the U.S. Environmental Protection Agency.

Stormwater-runoff quantity and quality from five sites located in residential, commercial, and industrial land-use basins were monitored from May to November 1992 and April through August 1993. Sites 1 and 4 were representative of residential land use; sites 2 and 5 were representative of commercial land use; and site 3 was representative of industrial land use.

Total rainfall, runoff volume, runoff-rainfall ratio, peak discharge, rainfall and runoff duration, and number of dry hours between storms were calculated and compiled. Mean rainfall during the study was slightly greater in the residential basins (0.60 inch) than in the commercial (0.45 inch) and industrial (0.46 inch) basins. However, mean runoff-rainfall ratio for the industrial (0.32) and commercial (0.38) basins was more than twice the runoff-rainfall ratio of the residential basins (0.15).

Grab samples and flow-weighted composite samples were collected at each of the five sites during six storms and were analyzed for 147 chemical, physical, and biological characteristics. Grab samples, collected within the first 30 minutes of each storm, represented the storm's first-flush effects, and were analyzed for pH, water temperature, residual chlorine, volatile organic compounds, cyanide, total phenols, biological oxygen demand, fecal coliform and fecal streptococcus bacteria, and oil and grease. Flow-weighted samples were composited during the first 3 hours of a storm and were analyzed for acid and base/neutral organic compounds, pesticides and polychlorinated biphenyls, trace elements, chemical oxygen demand, suspended solids, dissolved solids, nutrients, major ions, alkalinity, pH, specific conductance, and total organic carbon.

The volatile organic compounds—chloroform, dichlorobromomethane, methyl chloride, and toluene—were detected in concentrations ranging from 0.4 to 7.0 micrograms per liter. Toluene was detected only in the residential basins. Eleven base/neutral compounds with concentrations ranging from 9 to 150 micrograms per liter were detected in a commercial basin (site 5) during a storm-runoff event May 22, 1993. Eleven of 12 base/neutral compounds sampled for were detected at five sites. Concentrations of six of the compounds exceeded U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCLs) for drinking water.

No pesticide or polychlorinated biphenyl concentrations exceeded MCLs. The trace elements—total beryllium and total lead—exceeded MCLs for drinking water. Total lead also exceeded treatment action levels established by the USEPA for drinking water. Median concentrations of lead from the industrial basin were about 6 times greater than in the residential and commercial basins. Median concentrations of total copper, total nickel, and total zinc were about 3 times greater in samples collected from the industrial basin than from the residential and commercial basins.

Stormwater-runoff constituent loads for 12 constituents were estimated using three methods. The 12 constituents were biochemical oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, total nitrogen as nitrogen (N), total ammonia plus organic nitrogen as N, total phosphorus, dissolved phosphorus, total cadmium, total copper, total lead, and total zinc. The first method used was direct computation of observed data. The second method used was the USEPA simple method for calculating annual pollutant loads. The third method used was a statistical regression method, adjusting the regional models by using local monitoring data. The regression models estimated stormwater-runoff constituent loads.

INTRODUCTION

Section 402 of the Water Quality Act of 1987 requires municipalities with populations of 100,000 or greater to obtain permits to discharge urban stormwater to receiving streams. Final regulations for a National Pollutant Discharge Elimination System (NPDES) were published by the U.S. Environmental Protection Agency (USEPA) in November 1990 (U.S. Environmental Protection Agency, 1990) that required cities to provide, as part of the permit application, the following technical data:

1. Characterization of the quantity and quality of water from storm-sewer outfalls during dry periods when flows are not a result of storm runoff, but are primarily seepage from shallow ground water and return flows from urban water uses that are not part of the sanitary sewer system,
2. Characterization of the quality of water in bodies receiving stormwater-runoff discharges and the impact of pollutants from these discharges on the receiving body, based on existing data,
3. Characterization of meteorological conditions (rainfall), based on existing data,
4. Characterization of the quantity and quality of discharge from 5 to 10 representative outfalls during six representative storm events, and
5. Determination of annual and seasonal pollutant loads from each storm-sewer outfall in the reporting area.

The U.S. Geological Survey (USGS), in cooperation with the City of Omaha and the Papio-Missouri River Natural Resources District, conducted a study describing the quantity and quality of stormwater discharges from selected storm sewers draining areas representative of the various urban land uses in Omaha, Nebraska. The NPDES permit applications require the city to characterize the stormwater discharges from separate municipal storm-sewer systems. This effort primarily was intended to address item 4 of the technical data requirements previously described for a stormwater discharge permit.

Purpose and Scope

This report describes the results of the USGS stormwater data collection and analysis work in Omaha, Nebraska, to meet technical data needs for item 4 of the NPDES permitting requirements. Site selection and the sampling strategy for documenting the stormwater discharges from five urban basins in Omaha are included in the report. Storm characteristics and water-quality data collected at the five sites from May to November 1992 and from April through August 1993 also are provided. A statistical summary of the concentrations of an extensive list of water-quality constituents detected in the storm water discharged from the five basins shows the type and relative significance of contaminants that might be expected from urban storm sewers in the Omaha metropolitan area. Finally, the mass transport of loads for selected constituents in the five basins is presented based on three methods: the direct method, the USEPA simple method, and a statistical method. Two methods were used to estimate the transport by individual storms, and one method was used to estimate the annual load from each urban basin.

Description of Study Area

The City of Omaha, the largest city and principal industrial center in Nebraska, is located in the eastern part of the State (fig. 1) and has a population in excess of 350,000. Within Omaha, approximately 1,725 miles of sewer lines are used for the collection of stormwater and sanitary waste. About one third of this total is combined stormwater and sanitary waste sewers in the Missouri River and Little Papillion Creek watersheds east of 72nd Street. A study area

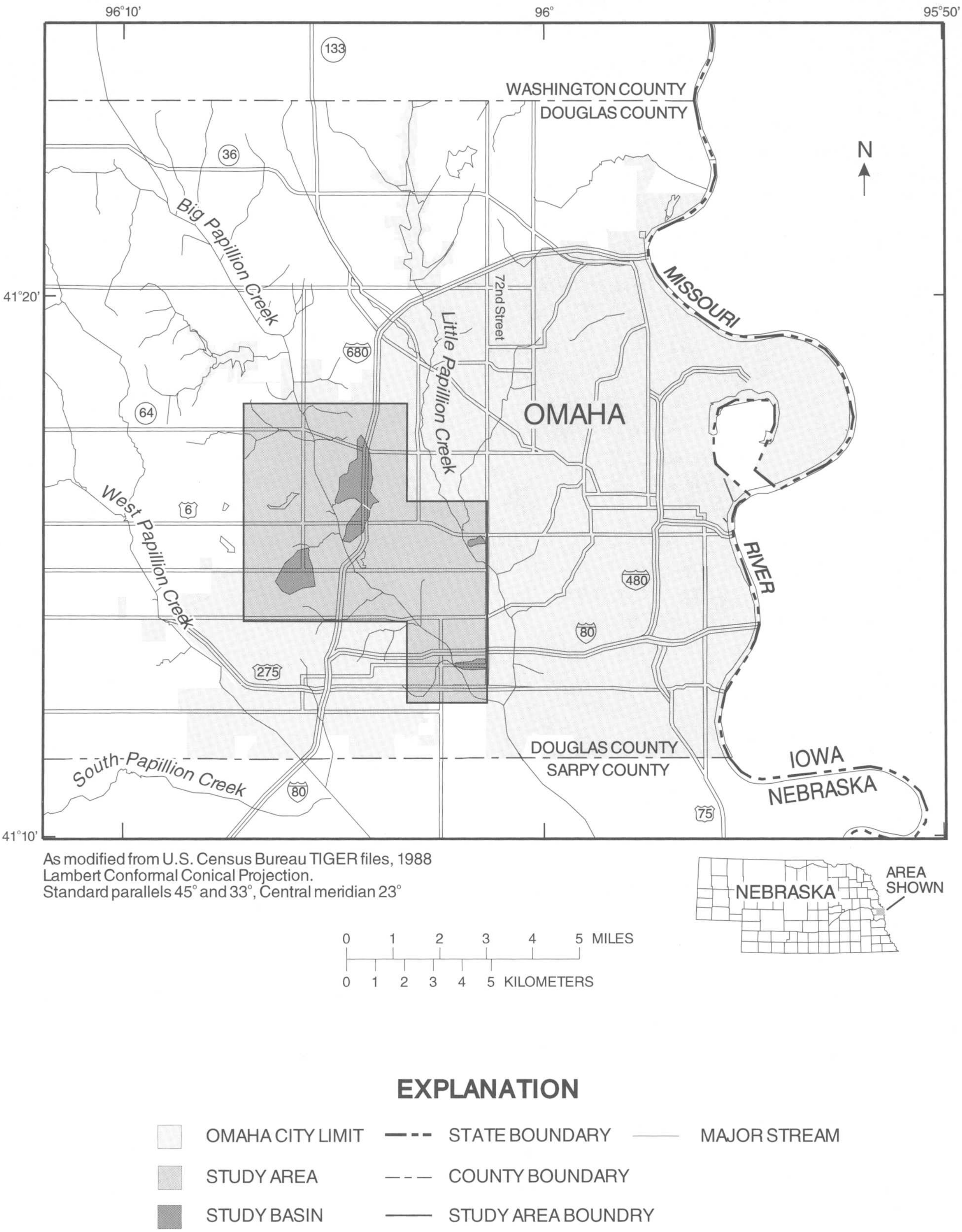

Figure 1. Location of study area, Omaha, Nebraska.

was delineated to include selected basins representing major types of land-use activities (residential, commercial, and industrial).

The natural landscape of the study area consists of a loess-mottled, upland glacial-till surface of Quaternary age. Locally, the land surface is eroded, accentuating topographically high areas. The loess-covered hills have average basin slopes ranging from 1 to 3 percent. Bedrock of Pennsylvanian age underlies the glacial till in the study area. About 2,000 feet of unexposed sedimentary rock of Pennsylvanian age overlies igneous and metamorphic rocks of Precambrian age (Miller, 1964).

Weather in the study area is highly variable. Extreme changes in temperature are typical, especially during the winter months. The maximum temperature is greater than or equal to 90 °F about 40 days per year, and the minimum temperature is less than or equal to 32 °F about 136 days per year. Normal precipitation (rainfall) ranges from 28 to 30 inches annually. About 75 percent of the precipitation occurs from April to September. Intense storms are common, particularly during the spring and early summer. The annual mean relative humidity is approximately 70 percent. Snowfall averages about 30 inches per year. Prevailing winds typically are from the northwest during the winter months and from the south and southeast during summer months (City of Omaha, 1992).

Methods

Collection of hydrologic data during storms for the purpose of meeting Federal regulations requires specialized procedures (U.S. Environmental Protection Agency, 1990; 1992a; and 1992b). The following sections provide a description of the site selection and sampling strategy, instrumentation and data collection, and quality assurance and quality-control procedures used for this study.

Site Selection

Five basins were selected in the study area for monitoring stormwater runoff (fig. 2). Each basin drained at least one of the major types of urban land use typical of the Omaha urban landscape—single-dwelling (site 1) and multiple-dwelling (site 4) residential, commercial (sites 2 and 5), and industrial (site 3). Major basin characteristics of stormwater runoff monitoring sites are described in table 1. Basin and site selection were based on specific criteria:

1. Relatively homogeneous land use; if possible, only one major land use dominant.
2. A minimum of 70 percent of the land developed to minimize effects of substantial construction activity during the period of data collection.
3. A maximum of 500 acres in size.
4. Suitable site for equipment shelter and storm-drain access.

Monitoring sites were located in an area of the city containing storm sewer systems separate from sanitary systems, generally west of 72nd Street, to avoid sampling mixed sanitary and storm sewer discharges. All sampling sites were within a 5-mile radius for effective field-sampling operations during and after storm events (fig. 2). Intense storms during the spring and early summer result in large runoff of short duration. Stormwater runoff in the study area drains into Little Papillion Creek or Big Papillion Creek and its tributaries, both of which drain into the Missouri River (fig. 1). Sampling sites in each basin were selected for the collection of rainfall, stormwater discharges, and stormwater-quality data. A suitable site selected for reliable and credible data required a straight, uniform pipe slope at least six pipe diameters upstream from the flow-measuring device, a location an adequate distance from upstream inflows to allow complete mixing of effluents, and a location unaffected by backwater.

Instrumentation and Data Collection

To meet stormwater data-collection requirements, instrumentation was installed at each site to monitor rainfall and runoff discharge, and to collect a first-flush sample (grab sample) as well as flow-weighted composite samples. Monitoring equipment at each site consisted of a rain gage, stage recorder, automatic water sampler, solar panel and ancillary plumbing, electrical equipment, and shelter to make the site functional and weatherproof. The rain gage recorded on-site measurements of rainfall in 0.01-inch increments. Water levels or pipe pressures in the storm sewers were recorded in 5-minute increments, and discharges and flow volumes were computed on-site using Manning's equation (Grant, 1991) by a data processor. The automatic water sampler was activated each time a specified volume of water was measured flowing through the storm

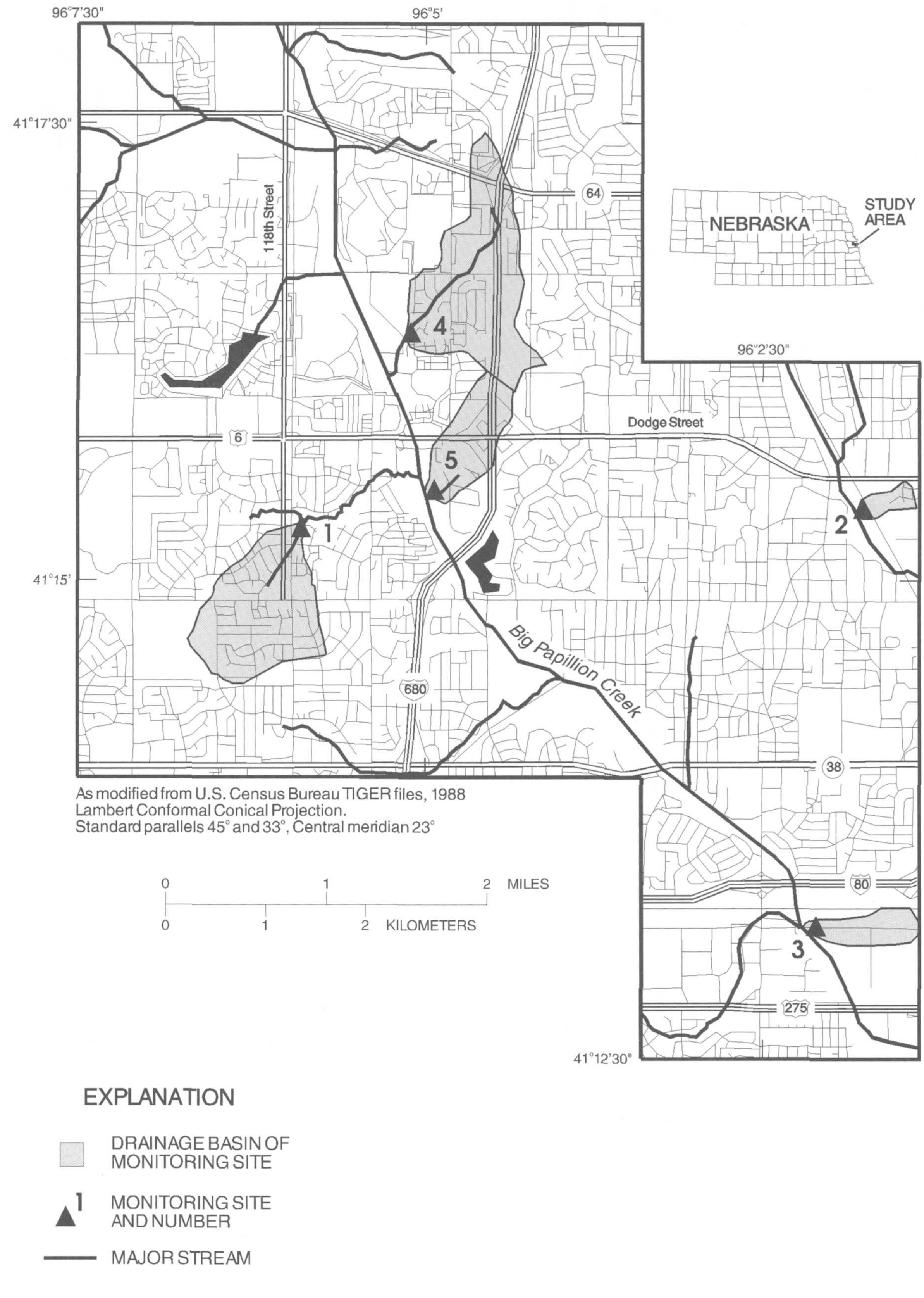

Figure 2. Location of monitoring sites and their discharge basins, Omaha, Nebraska.

Table 1. Characteristics of stormwater-runoff monitoring sites and basins, Omaha, Nebraska

[See figure 2 for site locations]

Basin or site characteristic	Site 1	Site 2	Site 3	Site 4	Site 5
Contributing drainage area					
Square miles	0.53	0.05	0.16	0.70	0.20
Acres	339	32	101	446	129
Land use (percentage of drainage area)					
Residential	82	0	0	60	0
Commercial	18	100	0	10	100
Industrial	0	0	100	0	0
Idle or vacant	0	0	0	30	0
Dominant land use	Single-dwelling residential	Commercial	Industrial	Multiple-dwelling residential	Commercial
Impervious area (percentage of drainage area)	32	65	75	36	65
Average basin slope (percent)	2.7	2.0	1.3	2.4	2.6
Stormwater outfall					
Pipe diameter (inches)	96	48	78	Open channel[1]	60
Slope (percent)	.75	.52	.40	.21	1.0
Roughness coefficient[2]	.016	.016	.017	.035	.016

[1]Open channel is any conduit in which water flows with a free surface. All rivers, canals, flumes, and other uncovered conduits are classed as open channels. Certain closed channels, such as pipes and sewers when flowing partially full and not under pressure, also are classified as open channels.

[2]Roughness coefficient is an index of the fractional resistance to flow offered by the conduit (Grant, 1991).

sewer. The sampler pumped water from the storm sewer through Teflon tubing into glass sample bottles inside the sampler. Sample bottles filled during the storm were retrieved after the storm. Instruments at the site recorded the incremental rainfall, continuous stage, discharge computations, and the number of times samples were collected.

Six storm events were documented at each site from May to November 1992 and April through August 1993. The following three general guidelines, provided by the USEPA (1992a) for selection of storms to be documented, were used to decide which storms to sample. Departures from these guidelines occurred when field conditions and operational limitations prevented the guidelines from being met or might have prevented the sampling of six storm events.

1. The storm should be preceded by at least 72 hours of dry weather,
2. Precipitation over the entire basin must be greater than 0.1 inch, and
3. Where feasible, the storm rainfall should not vary by more than 50 percent from the average storm rainfall volume and duration.

Storm characteristics were determined for each storm event recorded. Information included in appendix A, table 2 provides characteristics of storm-runoff events that have been found to be related to the transport of contaminants and have been used in conjunction with water-quality data to estimate transport of selected contaminants from urban landscapes. These characteristics include total rainfall, runoff volume, runoff-rainfall ratio, peak discharge, rainfall and runoff duration, and number of dry hours between storms. Missing rainfall values at some sites were replaced by data from the nearest site (for example, site 5 data was used for missing data at site 1). Runoff volumes for each storm were computed by accumulating the instantaneous discharges recorded at each site. The runoff-rainfall ratio is determined by dividing the runoff volume by the rainfall total. Rainfall duration is the time from the first 0.01 inch to the last 0.01 inch of rainfall. The time since previous storm (dry hours) is the approximate time between the last 0.01 inch of rainfall of the previous storm to the first 0.01 inch of rainfall of the next storm.

Stormwater samples were collected and analyzed for 147 constituents and properties for each storm recorded at the five sampling sites and were tabulated according to NPDES guidance (U.S. Environmental Protection Agency, 1992a). Of the 147 constituents and properties, 135 were pollutants or naturally occurring constituents that could be considered pollutants if concentrations were sufficiently large. The 147 constituents and properties required for analysis and their analytical detection limits are listed in appendix B, table 3. Concentrations of constituents detected for each site also are listed in appendix B and include: volatile organic compounds (VOCs) (table 4), base/neutral organic compounds (table 5), pesticides and polychlorinated biphenyls (PCBs) (table 6), trace elements and total phenols (table 7), constituents or properties (table 8), and major ions, properties, and total organic carbon (table 9). Each sample set consisted of a grab sample and flow-weighted composite samples.

A single grab sample was collected during the first 30 minutes of a runoff event from each storm and represented the storm's first-flush effects. This sample was used to make on-site measurements of pH, water temperature, and residual chlorine. Because the presence of residual chlorine in grab samples might cause degradation of organic contaminants after sample collection, field test kits were used to detect the residual chlorine in these samples. If residual chlorine was detected, then samples collected for VOC and biochemical oxygen demand (BOD) analysis were treated with sodium thiosulfate to preserve sample integrity in accordance with the NPDES sampling protocol. The sample also was used for laboratory analysis for VOCs, cyanide, total phenols, BOD, fecal coliform and fecal streptococcus bacteria, and oil and grease. Samples were retrieved, using grab-sampling techniques, and processed within 3 hours after collection because the constituents have a tendency to volatilize or degrade with time.

Flow-weighted samples collected by the automatic sampler during the first 3 hours of a runoff event were composited into one sample. Composite samples consisted of a minimum of three discrete aliquots per hour from the stormwater discharge using the automatic samplers. These flow-weighted composite samples were analyzed in the laboratory for acid and base/neutral organic compounds, pesticides and PCBs, trace elements, chemical oxygen demand (COD), suspended solids, dissolved solids, nutrients, major ions, alkalinity, pH, specific conductance, and total organic carbon.

Water-quality samples were collected, preserved, and shipped (Ward and Harr, 1990), in accordance with applicable USGS protocols and the USEPA sampling Protocols (U.S. Environmental Protection Agency, 1990 and 1992a) to the USGS National Water Quality Laboratory (NWQL) in Arvada, Colorado, for analysis. Some constituents, such as selected trace elements and nutrients, were analyzed as total concentrations that included both dissolved and particulate concentrations. Total concentrations of antimony, cyanide, silver, and thallium were determined at the Rocky Mountain Analytical Laboratory in Denver, Colorado; BOD samples were analyzed by HWS Technologies, Inc., in Lincoln, Nebraska; fecal coliform and fecal streptococcus bacteria counts were determined at the USGS Nebraska District Laboratory, in Lincoln, Nebraska; and the remainder of the analyses were determined at the USGS NWQL in Arvada, Colorado.

Quality Assurance and Quality Control

Quality-assurance and quality-control protocols were used during this study to ensure the accuracy of the data collected and to assist in the interpretation of collected data. Quality-control samples were collected to assess the adequacy of the general water-quality sampling and analysis procedures and to identify factors that might have produced discrepancies in the data.

Quality assurance refers to proper office, field, and laboratory procedures. Field quality-assurance practices involved calibration of all field meters and probes, and cleaning of sampling equipment prior to all site visits. Immediately prior to each sampling, meters and probes were recalibrated. Because water is electrically neutral (the sum of cations equals the sum of the anions), the percent difference between the sum of the cations and the sum of the anions helps determine if the analytical results are accurate. The balance of cations and anions, in milliequivalents per liter (meq/L), was used to ensure internal consistency of analytical results. Analytical results were compared within each sample set or with previous results for each site and with other study sites to detect possible inconsistencies. If inconsistencies were detected, checks for transcribing errors were conducted at the NWQL, and analytical reruns were requested on the remaining sample.

Quality-control samples for 107 of 147 chemical constituents were submitted to the NWQL on one or more occasions for duplicate, field-blank, and field-spike analyses. Analysis of duplicate samples was intended to identify precision associated with sample collection, shipping and storage, as well as laboratory analytical methods. Analysis of field-blank and field-spike samples was used as a means of estimating the accuracy of the analytical methods. The results of duplicate, field-blank, and field-spike analyses are presented in appendix C, tables 10, 11, and 12. Quality control of all analyses conducted for any constituent at the NWQL consists of reference materials from the USEPA and the National Bureau of Standards, spiked samples, and samples split between different laboratories (Fishman and Friedman, 1989).

A summary of differences in concentrations between primary- and duplicate-sample pairs for 38 constituents analyzed is included in appendix C, table 10. In general, the duplicate analyses for pesticides, trace elements, major ions, and nutrients implies that sample preparation and analytical methods were within acceptable limits, with the exception of arsenic. Concentrations of arsenic showed a 67 percent difference between the original and duplicate samples. The percent difference for replicate samples of arsenic is misleading because concentrations are so small. Small differences of even 1 µg/L (micrograms per liter) between concentrations can result in large percent differences.

Field blanks, in which organic-free water was used as a water sample, were exposed to all aspects of sample collection and processing equipment, preservation and transportation procedures, and laboratory handling. Chemical analysis of this water was designed to determine the adequacy of the process of equipment cleaning between sampled sites, or to quantify carryover of any chemical contamination between sites. The blanks were tested for VOCs, carbaryl pesticides, trace elements, nutrients, and major ions to determine if contamination was introduced. Results of the analyses of the field-blank samples (appendix C, table 11) show that small concentrations of methylene chloride, arsenic, lead, six major ions, and dissolved and total phosphorus were detected in the field blanks. No residues were detected in the field blanks for any other constituent.

Field-spike samples are collected from a stream and have commercially prepared mixtures of known concentration added to the samples. Field samples were collected and spiked with mixtures of known concentrations of acid and base/neutral compounds and selected organochlorine pesticides. They were submitted to the NWQL for laboratory analysis on two occasions. The results of the analyses were expressed as the recoveries of each constituent in percent (appendix C, table 12). Acceptable ranges of recoveries are 60-140 percent for acid organic compounds, 70-130 percent for base/neutral organic compounds, and 50-140 percent for organochlorine pesticides (Franson, 1989, p. 1-8). Most of the recoveries for acid and base/neutral compounds were within these ranges. The recoveries for common pesticides, such as 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, were within the acceptable range. Ranges of recovery for eight pesticides were greater than 170 percent; however, these compounds were not present in stream samples collected without commercially prepared mixtures added.

Acknowledgments

The authors appreciate the assistance and cooperation from personnel of the City of Omaha and the Papio-Missouri River Natural Resources District during this study. Special thanks are given to Michael J. Merriex, Kirk R. Pfeffer, and Royal Lewis and his crews, of the Omaha Public Works Department, for their assistance in collecting stormwater samples.

CHARACTERIZATION OF STORMWATER

Storm intensity and duration are measurable parts of the precipitation and runoff process that might affect the amount of potential contaminant in a receiving stream. The time between runoff events also might affect the amount of potential contaminant in a receiving stream because contaminants can accumulate with time in a watershed prior to a runoff event. Concentrations of constituents might vary in receiving streams as a result of differences in storm characteristics, as well as differences in land use. Concentrations of constituents determined from single grab samples collected from a stream represent the water-quality conditions at a specific point in time during the storm event. In contrast, samples that result from combining single samples collected during a storm into one composite sample represent the average water quality of a single storm.

Storm Characteristics

Statistical summary information, provided in table 13, is computed from the information for each storm monitored (appendix A, table 2). Measures of the central tendency of the values and their distribution are included for both parametric and nonparametric methods. Minimum and maximum values define the overall range of the variables, and 25th and 75th percentiles define a range of values for a more general examination of the variation (table 13).

Storm characteristics from sites with similar dominating land use in the basin were grouped together into residential, commercial, and industrial land-use (table 13). Mean rainfall was larger in the residential basins (0.60 inch) than in the commercial (0.45 inch) or industrial basins (0.46 inch). Runoff-rainfall ratios are always less than one, which is to be expected, unless some stream discharge reaches the site that is not from rainfall. Ratios are dependent on the physical characteristics of a basin—percent impervious surface, shape, size, and slope, and rainfall amount, intensity, and duration. For example, infiltration and retention of stormwater will decrease the ratio, whereas greater percentage of impervious surface increases the ratio. Commercial and industrial areas that typically have more impervious area and less retention have a runoff-rainfall ratio 2 or more times larger than the residential areas (table 13). Also, the storm drainage systems in the commercial and industrial basins appear to be more direct and probably have more developed channelization than the residential areas. Commercial and industrial basins had a shorter duration of runoff even though the rainfall duration tended to be longer than in the residential basins.

Stormwater Quality

Statistical summaries of the quality of stormwater by constituent group are presented in tables 14-16. The summaries use descriptive statistics to describe the central tendency and the variability in concentrations of each constituent. Detection limits and their exceedances also are included in the summaries. Separate summaries were made for each major land-use category for comparisons of constituent concentrations among the three types of land use. Thirty-eight of the 147 constituents were detected in water samples from the basins, and 8 constituents exceeded the USEPA's maximum contaminant levels (MCLs) for drinking water at least once.

Volatile Organic Compounds

Small concentrations of chloroform, dichlorobromomethane, methyl chloride, and toluene were detected in samples collected at one or more sites, except in one of the commercial basins (site 2) (appendix B, table 4). Analytical detection limits are listed in appendix B, table 3. The largest concentrations of these four compounds were 7.0, 0.4, 0.5, and 2.9 μg/L, respectively. Methyl chloride was detected at four of the five sites. Methyl chloride is a commonly used solvent and degreasing compound. One residential basin (site 4) had the most detections of VOCs. Toluene was detected only in the residential basins (sites 1 and 4). Toluene is used for many purposes, including industrial solvents, thinner in nitrocellulose lacquers, and detergents, and is a component of gasoline. Even though VOCs were detected, no concentrations exceeded the MCLs. Also, the 75th percentile did not exceed the detection limit for any VOC in any basin, except for methyl chloride in the residential basins (tables 14-16).

Acid and Base/Neutral Organic Compounds

Of the 10 acid organic compounds analyzed, none were detected in stormwater-runoff samples (appendix B, table 3). Twelve of 45 base/neutral organic compounds were detected in 45 percent of samples collected in the five basins (appendix B,

Table 13. Summary of storm characteristics for the three land-use types, Omaha, Nebraska, 1992-93

[See figure 2 for site location; in., inches; min, minute; hrs, hours]

Characteristic	Number of storms	Minimum	Mean	Median	Maximum	25th percentile	75th percentile	Standard deviation
Residential basins (sites 1 and 4)								
Rainfall total (in.)	133	0.03	0.60	0.41	3.06	0.16	0.84	0.59
Runoff volume, total (in.)	127	.00	.10	.05	1.11	.01	.14	.16
Runoff-rainfall ratio	127	.00	.15	.13	.53	.07	.21	.11
Rainfall duration (min)	127	10	335	175	2,085	86	447	386
Runoff duration (min)	127	40	597	480	3,600	279	825	520
Time since previous storm (hrs)	133	8	88	62	592	25	119	98
Commercial basins (sites 2 and 5)								
Rainfall total (in.)	128	.01	.45	.31	2.55	.12	.63	.46
Runoff volume, total (in.)	128	.00	.20	.08	2.04	.03	.24	.32
Runoff-rainfall ratio	123	.01	.38	.26	1.01	.11	.67	.29
Rainfall duration (min)	128	1	164	90	1,470	42	192	233
Runoff duration (min)	128	30	526	472	2,280	241	660	407
Time since previous storm (hrs)	128	8	91	60	624	28	111	99
Industrial basin (site 3)								
Rainfall total (in.)	86	.02	.46	.29	2.18	.12	.58	.49
Runoff volume, total (in.)	84	.01	.17	.09	1.19	.03	.24	.21
Runoff-rainfall ratio	84	.05	.32	.31	.95	.20	.41	.17
Rainfall duration (min)	84	5	244	151	1,350	74	323	262
Runoff duration (min)	84	30	421	345	1,980	240	517	302
Time since previous storm (hrs)	86	6	76	55	525	24	97	79

Table 14. Statistical summary of constituents and properties in stormwater-runoff samples for the residential land-use basins, sites 1 and 4, Omaha, Nebraska, 1992-93

[µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; cols/100 mL, colonies per 100 milliliters; NA, not applicable; °C, degrees Celsius; <, less than, based on analytical detection limit (app. B, table 3)]

Constituent or property	Number of samples	Number of detections	Percent detection	Concentration or value: Minimum	Median	Maximum	25th percentile	75th percentile
				Volatile organic compounds, µg/L				
Chloroform	12	3	25	<0.2	<0.2	7.0	0.2	<0.2
Dichlorobromomethane	12	1	8	<.2	<.2	.4	<.2	<.2
Methyl chloride	12	3	25	<.2	<.2	.5	<.2	.3
Toluene	12	4	36	<.2	<.2	2.9	<.2	.2
				Base/neutral organic compounds, µg/L				
Anthracene	12	0	0	<5	<5	<5	<5	<5
Benzo-A-anthracene	12	0	0	<10	<10	<10	<10	<10
Benzo-A-pyrene	12	0	0	<10	<10	<10	<10	<10
3,4-Benzofluoranthene	12	0	0	<10	<10	<10	<10	<10
2,4-Benzo(ghi)perylene	12	0	0	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	12	0	0	<10	<10	<10	<10	<10
Bis(2-ethylhexyl)phthalate	12	4	33	<5	<5	17	<5	6
Chrysene	12	0	0	<10	<10	<10	<10	<10
Fluoranthene	12	2	17	<5	<5	7	<5	<5
Indeno(1,2,3-CD)pyrene	12	0	0	<10	<10	<10	<10	<10
Phenanthrene	12	0	0	<5	<5	<5	<5	<5
Pyrene	12	1	8	<5	<5	6	<5	<5
				Pesticides and polychlorinated biphenyls, µg/L				
Chlordane	10	2	20	<.1	<.1	.1	<.1	<.1
4,4'-DDT	10	0	0	<.1	<.1	<.1	<.1	<.1
4,4'-DDE	10	0	0	<.04	<.04	<.04	<.04	<.04
Diazinon	2	2	100	.5	1.0	1.5	NA	NA
Carbaryl	4	1	25	<.01	<.01	.70	<.01	<.01
2,4-D	4	4	100	.89	7.2	13	6.4	8.0
PCB-1242	10	1	10	<.1	<.1	.1	<.1	<.1
PCB-1254	10	1	10	<.1	<.1	.1	<.1	<.1
				Trace elements and total phenols, µg/L				
Arsenic, total	12	11	92	<1	3	12	2	5
Beryllium, total	12	1	8	<10	<10	10	<10	<10
Cadmium, total	12	0	0	<1	<1	<1	<1	<1
Chromium, total	12	11	92	<1	5	18	3	7
Copper, total	12	12	100	6	8.5	20	7	10.5
Lead, total	12	12	100	9	13.5	28	10	22
Mercury, total	12	1	8	<.1	<.1	.5	<.1	<.1
Nickel, total	12	12	100	3	5	22	3.5	9
Zinc, total	12	12	100	40	60	120	50	90
Phenols, total	12	9	75	<1	2	4	<1	3

Table 14. Statistical summary of constituents and properties in stormwater-runoff samples for the residential land-use basins, sites 1 and 4, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Number of samples	Number of detections	Percent detection	Concentration or value				
				Minimum	Median	Maximum	25th percentile	75th percentile
				Oxygen demand, mg/L				
Biochemical oxygen demand	12	12	100	6.8	14	21	12	16
Chemical oxygen demand	12	12	100	33	64.5	110	52	70.5
				Physical properties, mg/L				
Suspended solids, total	12	12	100	37	112	728	52	294
Dissolved solids, total	12	12	100	33	91	109	59	102
				Bacterial, cols/100mL				
Fecal coliform	10	10	100	1,500	20,000	110,000	6,000	63,000
Fecal streptococcus	10	10	100	3,200	71,500	110,000	20,000	95,500
				Nutrients, mg/L				
Nitrogen, total, as N	12	12	100	1.2	2.3	3.7	1.6	2.8
Nitrogen, ammonia plus organic, total	12	12	100	.70	1.5	2.7	1.1	1.9
Phosphorus, total, as P	12	12	100	.10	.30	.70	.20	.50
Phosphorus, dissolved	12	12	100	.08	.19	.38	.10	.30
				Oil and grease, mg/L				
Oil and grease	12	6	50	<1	<1	3	<1	2
				Major ions, mg/L				
Alkalinity, total as $CaCO_3$	12	NA	NA	33	37	71	35	50
Calcium, dissolved	12	NA	NA	8.8	13	21	10	17
Chloride, dissolved	12	NA	NA	1.2	4.7	8.7	2.9	6.4
Magnesium, dissolved	12	NA	NA	.8	2.5	3.4	1.0	3.1
Potassium, dissolved	12	NA	NA	1.9	3.8	5.7	2.7	5.3
Sodium, dissolved	12	NA	NA	2.4	6.9	9.1	3.5	8.5
Sulfate, dissolved	12	NA	NA	2.5	11	22	6.5	19
				Field measurements				
pH, standard units	12	NA	NA	6.7	7.0	7.5	6.9	7.3
Specific conductance, μS/cm	12	NA	NA	91	146	208	100	167
Water temperature, °C	12	NA	NA	10	19	24	16	21
				Total organic carbon, mg/L				
Total organic carbon	12	12	100	.6	15	23	13.3	17.5

Table 15. Statistical summary of constituents and properties in stormwater-runoff samples for the two commercial land-use basins, sites 2 and 5, Omaha, Nebraska, 1992-93

[µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; cols/100 mL, colonies per 100 milliliters; --, no data; NA, not applicable; °C, degrees Celsius; <, less than, based on analytical detection limit (app. B, table 3)]

Constituent or property	Number of samples	Number of detections	Percent detection	Concentration or value				
				Minimum	Median	Maximum	25th percentile	75th percentile
Volatile organic compounds, µg/L								
Chloroform	12	1	8	<0.2	<0.2	0.4	<0.2	<0.2
Dichlorobromomethane	12	1	8	<.2	<.2	.2	<.2	<.2
Methyl chloride	12	1	8	<.2	<.2	.2	<.2	<.2
Toluene	12	0	0	<.2	<.2	<.2	<.2	<.2
Base/neutral organic compounds, µg/L								
Anthracene	12	1	8	<5	<5	9	<5	<5
Benzo-A-anthracene	12	1	8	<10	<10	36	<10	<10
Benzo-A-pyrene	12	1	8	<10	<10	43	<10	<10
3,4-Benzofluoranthene	12	1	8	<10	<10	53	<10	<10
2,4-Benzo(ghi)perylene	12	1	8	<10	<10	32	<10	<10
Benzo(k)fluoranthene	12	1	8	<10	<10	38	<10	<10
Bis(2-ethylhexyl)phthalate	12	1	8	<5	<5	6	< 5	< 5
Chrysene	12	2	17	<10	<10	57	<10	<10
Fluoranthene	12	2	17	<5	<5	150	<5	<5
Indeno(1,2,3-CD)pyrene	12	1	8	<10	<10	30	<10	<10
Phenanthrene	12	1	8	<5	<5	73	<5	<5
Pyrene	12	2	17	<5	<5	110	<5	<5
Pesticides and polychlorinated biphenyls, µg/L								
Chlordane	11	1	9	<.1	<.1	.1	<.1	<.1
4,4'-DDT	11	0	0	<.1	<.1	<.1	<.1	<.1
4,4'-DDE	11	0	0	<.04	<.04	<.04	<.04	<.04
Diazinon	0	--	--	--	--	--	--	--
Carbaryl	1	0	0	NA	<.01	<.01	NA	NA
2,4-D	1	1	100	NA	.14	.14	NA	NA
PCB-1242	11	0	0	<.1	<.1	<.1	<.1	<.1
PCB-1254	11	0	0	<.1	<.1	<.1	<.1	<.1
Trace elements and total phenols, µg/L								
Arsenic, total	12	11	92	<1	2	8	2	3
Beryllium, total	12	0	0	<10	<10	<10	<10	<10
Cadmium, total	12	0	0	<1	<1	<1	<1	<1
Chromium, total	12	9	75	<1	3	6	1	5
Copper, total	12	12	100	4	6.5	12	5	8.5
Lead, total	12	12	100	2	11.5	31	5	21
Mercury, total	11	0	0	<.1	<.1	<.1	<.1	<.1
Nickel, total	12	12	100	2	5	9	3	5.5
Zinc, total	12	12	100	40	80	170	50	95
Phenols, total	11	10	91	<1	2	NA	1	6

Table 15. Statistical summary of constituents and properties in stormwater-runoff samples for the two commercial land-use basins, sites 2 and 5, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Number of samples	Number of detections	Percent detection	Concentration or value: Minimum	Median	Maximum	25th percentile	75th percentile
Oxygen demand, mg/L								
Biochemical oxygen demand	12	12	100	6.8	13	32	11	18
Chemical oxygen demand	12	12	100	31	47	110	42	75
Properties, mg/L								
Suspended solids, total	12	12	100	31	84	370	52	170
Dissolved solids, 16otal	12	12	100	28	76	188	59	93
Bacteria, cols/100 mL								
Fecal coliform	11	11	100	200	5,600	28,000	1,500	20,000
Fecal streptococcus	11	11	100	200	7,800	100,000	3,700	16,000
Nutrients, mg/L								
Nitrogen, total, as N	12	12	100	.7	1.7	3.1	1.2	2.3
Nitrogen, ammonia plus organic, total	12	12	100	.4	1.0	1.9	.7	1.5
Phosphorus, total, as P	12	12	100	.09	.16	.44	.10	.30
Phosphorus, dissolved, as P	12	12	100	.06	.11	.41	.10	.20
Oil and grease, mg/L								
Oil and grease	12	7	58	<1	2	4	<1	2
Major ions, mg/L								
Alkalinity, total as $CaCO_3$	12	NA	NA	26	43	69	32	53
Calcium, dissolved	12	NA	NA	5.6	14	25	10	16.5
Chloride, dissolved	12	NA	NA	1.1	4.4	11	2.8	6.7
Magnesium, dissolved	12	NA	NA	.3	1.2	5.3	.8	2.5
Potassium, dissolved	12	NA	NA	1.1	2.5	6.3	1.7	2.7
Sodium, dissolved	12	NA	NA	1.1	4.7	19	3.2	8.2
Sulfate, dissolved	12	NA	NA	2.9	11	51	4.4	17
Field measurements								
pH, standard units	12	NA	NA	6.7	7.6	8.0	7.1	7.7
Specific conductance, µS/cm	12	NA	NA	70	138	283	100	157
Water temperature, °C	11	NA	NA	15	20	24	24	17
Total organic carbon, mg/L								
Total organic carbon	12	12	100	5.7	12.5	37	7	21.8

Table 16. Statistical summary of constituents and properties in stormwater-runoff samples for the industrial land-use basin, site 3, Omaha, Nebraska, 1992-93

[µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; cols/100 mL, colonies per 100 milliliters; --, no data, NA, not applicable; °C, degrees Celsius; <, less than, based on analytical detection limit (app. B, table 3)]

Constituent or property	Number of samples	Number of detections	Percent detection	Concentration or value				
				Minimum	Median	Maximum	25th percentile	75th percentile
Volatile organic compounds, µg/L								
Chloroform	6	1	17	<0.2	<0.2	1.0	<0.2	<0.2
Dichlorobromomethane	6	0	0	<.2	<.2	<.2	<.2	<.2
Methyl chloride	6	1	17	<.2	<.2	.5	<.2	<.2
Toluene	6	0	0	<.2	<.2	<.2	<.2	<.2
Base/neutral organic compounds, µg/L								
Anthracene	5	0	0	<5	<5	<5	<5	<5
Benzo-A-anthracene	5	0	0	<10	<10	<10	<10	<10
Benzo-A-pyrene	5	0	0	<10	<10	<10	<10	<10
3,4-Benzofluoranthene	5	0	0	<10	<10	<10	<10	<10
2,4-Benzo(ghi)perylene	5	0	0	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	5	0	0	<10	<10	<10	<10	<10
Bis(2-ethylhexyl)phthalate	5	3	60	<5	6	7	<5	6
Chrysene	5	0	0	<10	<10	<10	<10	<10
Fluoranthene	5	3	60	<5	5	13	<5	7
Indeno(1,2,3-CD)pyrene	5	0	0	<10	<10	<10	<10	<10
Phenanthrene	5	1	20	<5	<5	6	<5	<5
Pyrene	5	2	40	<5	<5	9	<5	6
Pesticides and polychlorinated biphenyls, µg/L								
Chlordane	5	1	20	<.1	<.1	.1	<.1	<.1
4,4'-DDT	5	1	20	<.1	<.1	.1	<.1	<.1
4,4'-DDE	5	1	20	<.04	<.04	.11	<.04	<.04
Diazinon	0	--	--	--	--	--	--	--
Carbaryl	0	--	--	--	--	--	--	--
2,4-D	0	--	--	--	--	--	--	--
PCB-1242	5	0	0	<.1	<.1	<.1	<.1	<.1
PCB-1254	5	1	20	<.1	<.1	.2	<.1	<.1
Trace elements and total phenols, µg/L								
Arsenic, total	6	6	100	2	5	11	3	9
Beryllium, total	6	0	0	<10	<10	<10	<10	<10
Cadmium, total	6	5	83	<1	2	4	2	3
Chromium, total	6	6	100	6	13	30	7	17
Copper, total	6	6	100	15	27	70	19	37
Lead, total	6	6	100	22	72	180	30	96
Mercury, total	6	1	17	<.1	<.1	.2	<.1	<.1
Nickel, total	6	6	100	8	17	39	10	27
Zinc, total	6	6	100	150	285	640	210	300
Phenols, total	5	4	80	<1	4	5	2	4

Table 16. Statistical summary of constituents and properties in stormwater-runoff samples for the industrial land-use basin, site 3, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Number of samples	Number of detections	Percent detection	Concentration or value				
				Minimum	Median	Maximum	25th percentile	75th percentile
				Oxygen demand, mg/L				
Biochemical oxygen demand	6	6	100	11	19	32	11	22
Chemical oxygen demand	6	6	100	<10	115	180	42	120
				Properties, mg/L				
Suspended solids, total	6	12	100	358	606	1,860	406	1,225
Dissolved solids, total	6	12	100	64	90	166	76	103
				Bacteria, cols/100 mL				
Fecal coliform	6	6	100	2,000	10,850	36,000	2,650	24,000
Fecal streptococcus	6	6	100	7,200	22,000	100,000	9,100	46,500
				Nutrients, mg/L				
Nitrogen, total, as N	6	6	100	.9	2.7	3.8	1.2	3.0
Nitrogen, ammonia plus organic, total	6	6	100	.4	1.7	2.9	.7	2.1
Phosphorus, total, as P	6	6	100	.13	.26	.55	.15	.50
Phosphorus, dissolved, as P	6	6	100	.09	.13	.25	.11	.18
				Oil and grease, mg/L				
Oil and grease	5	5	100	1	2	4	1	3
				Major ions, mg/L				
Alkalinity, total as $CaCO_3$	6	NA	NA	65	80	130	69	95
Calcium, dissolved	6	NA	NA	11	14.5	29	11.8	20
Chloride, dissolved	6	NA	NA	6.2	10.4	20	7.1	16.3
Magnesium, dissolved	6	NA	NA	1.3	1.9	4.7	1.4	2.9
Potassium, dissolved	6	NA	NA	2.3	3.2	5.3	2.5	4.0
Sodium, dissolved	6	NA	NA	4.9	8.8	14	5.5	11.8
Sulfate, dissolved	6	NA	NA	8.1	13	37	10	21
				Field measurements				
pH, standard units	6	NA	NA	7.1	7.5	8.3	7.5	8.0
Specific conductance, µS/cm	6	NA	NA	130	210	395	142	267
Water temperature, °C	5	NA	NA	12	17	24	15	18
				Total organic carbon, mg/L				
Total organic carbon	6	6	100	16	22.5	45	19	26

table 5). The four most commonly detected compounds were bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene. Bis(2-ethylhexyl)phthalate is used as a plasticizer, an organic compound added to a high-density polymer both to facilitate processing and to increase the flexibility and toughness of the final product by solution of the polymer molecule (Sax and Lewis, 1987). Fluoranthene, phenanthrene, and pyrene are derived from coal tar (Sax and Lewis, 1987). The presence of these compounds might be an indicator of leaching from road surfaces or roofing materials.

Although more base/neutral organic compounds were detected in samples collected from the residential basins, concentrations were less than the USEPA MCLs for drinking water. Statistical summaries of the 12 compounds detected are listed in tables 14-16. Median concentrations of the four compounds were less than the analytical detection limit (less than 5 μg/L) in all basins except the industrial basin, where median concentrations of bis(2-ethylhexyl)phthalate (6 μg/L) and fluoranthene (5 μg/L) exceeded the detection limit. Phen-anthrene was detected in the commercial and industrial basins but median concentrations were less than the detection limit. Chrysene was detected in one of two commercial basins (site 5) but in less than 17 percent of the samples collected at two commercial sites. Eleven base/neutral compounds having concentrations ranging from 9 to 150 μg/L were detected in a commercial basin (site 5) during a storm-runoff event May 22, 1993. This was not a typical sampling event during this study because 11 of the 12 base/neutral organic compounds were detected (appendix B, table 5). Concentrations of six compounds —benzo-A-anthracene (36 μg/L), benzo-A-pyrene (43 μg/L), 3,4-benzo-fluoranthene (53 μg/L), benzo(k)fluoranthene (38 μg/L), chrysene (57 μg/L) and indeno(1,2,3-CD)pyrene (30 μg/L)—exceeded USEPA MCLs for drinking water. Four of the base/neutral compounds were detected only during the storm event of May 22, 1993.

Pesticides and Polychlorinated Biphenyls

Twenty-one pesticides and seven PCBs were analyzed in samples collected from the study area (appendix B, table 3). Not all pesticides listed were analyzed in samples from each site. Diazinon, carbaryl, and 2,4-D, pesticides commonly used on lawns and gardens, were analyzed selectively in samples collected from the residential (sites 1 and 4) and commercial (sites 2 and 5) basins. Fewer samples were collected for the pesticides diazinon, carbaryl, and 2,4-D because these compounds were not mandated by USEPA for the NPDES sampling design. Six pesticides and two PCBs were detected in the five basins (appendix B, table 6). Concentrations of pesticides ranged from 0.1 μg/L (chlordane and DDT) to 13 μg/L (2,4-D), none of which exceeded USEPA MCLs for drinking water. Analytical detection limits are listed in appendix B, table 3 and MCLs for the eight constituents detected are listed in appendix B, table 6. Diazinon was detected in both of two samples collected and 2,4-D was detected in all five samples collected (appendix B, table 6). The largest concentration of 2,4-D detected in samples collected from the residential basins was about 3 orders of magnitude greater than the analytical detection limit of 0.01 μg/L. PCB-1254 was detected in samples collected from a residential basin (site 4) (0.1 μg/L) and the industrial basin (site 3) (0.2 μg/L); PCB-1242 was detected in the same residential basin (site 4)(0.1 μg/L). PCB concentrations were less than the MCLs of 0.5 μg/L established by the USEPA (1996) for drinking water. Statistical summaries of the six pesticides and two PCBs are listed in tables 14-16.

Trace Elements and Total Phenols

Fourteen trace elements and total phenols were analyzed from samples collected in the study area (appendix B, table 3). Nine trace elements and total phenols were detected in the five basins (appendix B, table 7). Analytical detection limits are listed in appendix B, table 3 and MCLs are listed in appendix B, table 7. Concentrations of trace elements did not exceed MCLs for drinking water established by the USEPA (1996) with the exception of beryllium and lead. Trace-element concentrations in samples collected from the industrial basin were, in general, greater than concentrations in samples collected from the residential and commercial basins; total beryllium and total mercury were the only exceptions. Statistical summaries of the nine trace elements and total phenols are listed in tables 14-16.

Copper, lead, nickel, and zinc were detected in all samples collected. Median concentrations of copper (27 μg/L), nickel (17 μg/L), and zinc (285 μg/L) were about 3 times greater in samples collected from the industrial basin than from the residential and commercial basins. Median concentrations of copper were 8.5 μg/L in the residential basins (table 14) and 6.5 µg/L in the commercial basins (table 15). The median concentration of nickel was 5 µg/L in both the residential and commercial basins. Median concentrations of zinc were 60 µg/L in the residential basins and 80 µg/L in the commercial basins. Median concentrations of lead in the industrial basin (72 µg/L) (table 16) were about 6 times greater than in the residential (13.5 µg/L) (table 14) and commercial (11.5 µg/L) (table 15) basins. Fifty-seven percent of the samples collected had lead concentrations equal to or greater than 15 µg/L (table 7), which is the treatment action level for public-water supplies established by the USEPA (1988). The treatment action level is the target concentration of the contaminant that, if exceeded more than 5 percent of the time, requires treatment of the water to reduce the concentration of the contaminant prior to public consumption. A concentration of beryllium (10 µg/L) was detected in one sample collected in a residential basin (site 1).

Arsenic was detected in 93 percent of the samples collected and chromium in 87 percent (tables 14-16). Both trace elements were detected in all six samples collected in the industrial basin (appendix B, table 7). Median concentrations of arsenic and chromium in the residential and commercial basins ranged from 2 to 5 µg/L, and median concentrations were about 2 to 3 times greater in the industrial basin.

Cadmium was detected in five of the six samples collected in the industrial basin, but was not detected in the residential or commercial basins. Antimony, cyanide, selenium, silver, and thallium were not detected in any samples collected in the study area.

Total phenols were detected in 82 percent of the samples collected (tables 14-16). Median concen-trations were 2 µg/L in the residential and commercial basins, but were about twice as large (4 µg/L) in the industrial basin. Phenols are organic compounds used as solvents, herbicides, and as components in resins. Health advisory levels for total phenols (6 mg/L) (U.S. Environmental Protection Agency, 1996) are about 3 orders of magnitude larger than concentrations detected in the study area.

Oxygen Demand, Properties, and Bacteria

Analytical limits for constituents and properties are listed in appendix B, table 3, and concentrations of the constituents and properties (BOD, COD, suspended solids, dissolved solids, fecal coliform, fecal streptococcus, nutrients, and oil and grease) are listed in appendix B, table 8. Statistical summaries of these constituents and properties are listed in tables 14-16.

The BOD test is the best method available for evaluating the oxygen demand associated with organic-polluted water. BOD is the quantity of oxygen used in aerobic stabilization of wastes and polluted water. The COD test is an indication of the concentration of organic matter in water. Median concentrations of BOD (19 mg/L) and COD (115 mg/L) in the industrial basin were about 1.5 to 2 times greater than in the residential and commercial basins.

High concentrations of suspended solids and dissolved solids can cause water to be unsuitable for domestic, agricultural, and industrial supply, and also can harm aquatic organisms. Suspended solids and dissolved solids in stormwater often are a result of natural weathering of rock, soil erosion, and human activity. The median concentration of suspended solids in samples collected from the industrial basin was 606 mg/L, in comparison to a median concentration of 111.5 mg/L in samples collected in the residential basins and a median concentration of 84 mg/L in samples collected in the commercial basins. Median concentrations of dissolved solids in samples collected from the residential and industrial basins were about 90 mg/L, in comparison to a median concentration of 76 mg/L in the commercial basins (tables 14-16). Dissolved-solids concentrations in all samples collected did not exceed the secondary maximum contaminant level (SMCL) of 500 mg/L for drinking water established by the U.S. Environmental Protection Agency (1996).

Fecal coliform and fecal streptococcus bacteria are used as indicators of fecal contamination from humans and other warm-blooded animals. Bacteria concentrations ranged from 200 to 110,000 colonies/100 mL (appendix B, table 8). Median concentrations of fecal coliform (20,000 colonies/100 mL) in samples collected in the residential basins were about twice as large as in samples collected from the industrial basin (10,850 colonies/100 mL) and about 3.5 times greater from the commercial basins (5,600 colonies/100 mL) (tables 14-16). Median concentrations of fecal streptococcus in samples collected in the residential basins (71,500 colonies/100 mL) were about 3 times greater than in the industrial basin

(22,000 colonies/100 mL) and about 9 times greater than in samples collected from the commercial basins (7,800 colonies/100 mL).

Nutrients

Nitrogen and phosphorus are common constituents in fertilizers. Concentrations of total nitrogen as N, total ammonia plus organic nitrogen, total phosphorus, and dissolved phosphorus were detected in all stormwater samples. Concentrations of total nitrogen ranged from 0.7 to 3.8 mg/L and total phosphorus ranged from 0.09 to 0.66 mg/L (appendix B, table 8). Median concentrations of total nitrogen were 2.3 mg/L in the residential basins and 2.7 mg/L in the industrial basin, in comparison to 1.7 mg/L in the commercial basins (tables 14-16). Median concentrations of total nitrogen and total ammonia plus organic nitrogen were greater in the industrial basin (2.7 mg/L and 1.7 mg/L) than in the residential (2.3 mg/L and 1.5 mg/L) and commercial (1.7 mg/L and 1.0 mg/L) basins. The median concentrations of total phosphorus were greater in samples collected from the residential basins (0.30 mg/L) than in samples collected from the commercial (0.16 mg/L) and industrial (0.26 mg/L) basins. Median concentrations of dissolved phosphorus ranged from 0.11 to 0.19 mg/L, and median concentrations of total phosphorus in all samples collected in the five basins ranged from 0.16 to 0.30 mg/L. MCLs have not been established for total nitrogen, ammonia plus organic nitrogen, and total and dissolved phosphorus.

Oil and Grease

Oil and grease were detected in all samples collected from the industrial basin (appendix B, table 8) and were detected in 50 percent of samples from the residential and 58 percent of samples from the commercial basins (tables 14-16). Median concentrations were less than 1 mg/L in the residential basins, in comparison to 2 mg/L in the commercial and industrial basins. No MCL has been established for oil and grease.

Major Ions, Field Measurements, and Total Organic Carbon

Data for the seven major ions analyzed, two field measurements, and total organic carbon (TOC) are listed in appendix B, table 3. Quantitative results are listed in appendix B, table 9. Statistical summaries are listed in tables 14-16.

The median concentration of alkalinity in the industrial basin was 80 mg/L, and the median concentration of chloride was 10.4 mg/L, which is about twice as large as median concentrations in the residential (37 mg/L and 4.7 mg/L) and commercial (43 mg/L and 4.4 mg/L) basins (tables 14-16). Median concentrations of calcium and sulfate ranged from 11.0 to 14.5 mg/L in all five basins. The largest median concentration of sodium (8.8 mg/L) was detected in the industrial basin. No MCLs have been established for chloride and sodium concentrations in drinking water. SMCLs for chloride in drinking water (250 mg/L) have been established by the USEPA (1996).

Median pH was 7.0 in the residential basins, 7.6 in the commercial basins, and 7.5 in the industrial basin. The median value of specific conductance (210 μS/cm) in the industrial basin was about 1.5 times greater than median values in the residential (146 μS/cm) and commercial (138 μS/cm) basins (tables 14-16).

Median concentration of total organic carbon (22.5 mg/L) in samples collected from the industrial basin was about 1.5 times greater than in samples collected in the residential (15 mg/L) and commercial (12.5 mg/L) basins (tables 14-16). Even though median concentrations in samples collected from the commercial basins were smaller than median in samples from residential basins, the concentrations of the largest 25 percent of the samples collected from the commercial basins were greater than the largest 25 percent of concentrations in samples collected from the residential basins.

ESTIMATED CONSTITUENT TRANSPORT

The USEPA regulations for NPDES require an annual constituent load calculation for the entire urban storm drainage system. Separate annual load computations must be calculated for 12 constituents: BOD, COD, suspended solids, dissolved solids, total nitrogen as N, total ammonia plus organic nitrogen as N, total phosphorus, dissolved phosphorus, total cadmium, total copper, total lead, and total zinc. Storm-runoff and water-quality data collected at the five sites were used to compute loads for these constituents. Stormwater-runoff loads were estimated using direct, simple, and statistical regression methods, the latter of which used regional and local equations. The three methods are described in the following sections.

Direct Method for Estimating Single-Storm Constituent Loads

Discharge and chemical data collected during the study were used to calculate stormwater-runoff volumes, constituent loads, and mean concentrations for each storm sampled for each site. Stormwater-constituent loads for a specific storm were computed from measured data using the following equation (Oltmann and Shulters, 1989):

$$L = 6.243 \times 10^{-5}(\mathrm{RUN} \times \mathrm{CONC}) , \qquad (1)$$

where L is the observed stormwater-constituent load, in pounds,

6.243×10^{-5} is a unit conversion factor,

RUN is the storm runoff volume, in cubic feet, and

CONC represents the average constituent concentration, in milligrams per liter.

The resultant load is the quantity of a constituent, in pounds, that is transported into a stream for a specific storm at a specific site. Representative average constituent concentration (CONC) is the laboratory-determined concentration for the flow-weighted composite sample collected for that particular storm (appendix B, tables 7-9). Runoff volume for each storm (*RUN*) was computed by accumulating the instantaneous discharge calculated using Manning's equation and recorded by a portable flow-meter device (table 17). Estimated stormwater-constituent loads for 12 constituents and corresponding *RUN* (storm runoff volume, in cubic feet) values are listed in table 17. The loads varied greatly depending on sites and rainfall events. In general, the greater the runoff volume for a specific basin, the greater the loads that were produced.

Simple Method for Estimating Annual Constituent Loads

The USEPA simple method, described in detail by U.S. Environmental Protection Agency (1992a), provides a quick and reasonable estimate of the load with a minimum amount of data. Annual constituent loads for individual outfalls are calculated using the following equation:

$$L_i = \left[\frac{(P)(CF)(Rv_i)}{12}\right](C_i)(A_i)(2.72), \qquad (2)$$

where L_i is the annual constituent load for site i, in pounds per year,

P is the annual precipitation, in inches per year,

CF is the correction factor that adjusts for storms in which no runoff occurs (a value of 0.9 typically is used),

Rv_i is the weighted-average runoff-rainfall ratio for the area drained by site i,

C_i is the mean concentration of the constituent, in mg/L, at site i, and

A_i is the stormwater contributing drainage area for site i, in acres.

The 30-year (1961-90) mean annual precipitation *(P)* 29.56 inches, was obtained from climatological data from the National Weather Service, North Omaha Airport Station, Omaha. A correction factor *(CF)* of 0.9 was used for this study, and mean runoff-rainfall ratios (Rv_i) were computed from data based on flow measurements (table 13) for residential (0.15), commercial (0.38), and industrial (0.32) land-use basins. Stormwater contributing drainage basin areas A_i are listed in table 1.

Mean concentration of constituent (C_i) is the mean concentration for a specific constituent determined from chemical analyses of the flow-weighted composite samples. To determine the mean concentration of 12 constituents by land-use basins, mean concentrations were recalculated using data (appendix B, tables 7 and 8) from sites 1 and 4 to represent residential; sites 2 and 5, commercial; and site 3, industrial land-use basins (table 18).

Table 17. Stormwater loads per event for 12 constituents at five monitoring sites as calculated by the direct method

[All load data are in pounds. BOD, biochemical oxygen demand; *COD*, chemical oxygen demand; *SS*, suspended solids; *DS*, dissolved solids; *TN*, total nitrogen as N; *TKN*, total ammonia plus organic nitrogen as N; *TP*, total phosphorus; *DP*, dissolved phosphorus; *CD*, total cadmium; *CU*, total copper; *PB*, total lead; *ZN*, total zinc; *RUN*, recorded storm runoff volume, in cubic feet; N, not detected; <, less than]

Site number (fig. 2)	Sampling date	Load												RUN
		BOD	COD	SS	DS	TN	TKN	TP	DP	CD	CU	PB	ZN	
1	06-05-92	11.4	28.1	39	32	1	1	0.1	0.1	N	<0.01	0.01	0.04	10,700
	07-02-92	4.7	16.7	12	23	1	1	.1	.1	N	<.01	<.01	.02	5,000
	08-25-92	5.0	38.6	27	72	1	1	.1	.2	N	<.01	<.01	.05	11,900
	10-07-92	444	2,252	12,591	3,076	76	51	10	5.1	N	.28	.57	3.2	508,000
	05-22-93	93.2	311	444	306	9	5	1	.8	N	.03	.12	.35	71,100
	06-17-93	36.4	80	112	80	5	3	.3	.2	N	.01	.02	.12	38,900
2	06-05-92	19.6	63	127	123	2	1	.1	.1	N	.01	.03	.11	22,440
	07-02-92	49.9	144	293	100	5	3	.7	.3	N	.02	.05	.17	25,000
	08-25-92	1.7	11	15	10	<1	<1	<.1	<.1	N	<.01	<.01	.01	1,570
	06-17-93	16.9	102	516	99	3	2	.4	.2	N	.01	.02	.11	22,600
	06-24-93	32.3	157	561	133	3	2	.6	.4	N	<.01	.06	.24	76,200
	08-19-93	17.3	36	49	39	1	<1	.1	.1	N	<.01	.01	.08	15,400
3	05-22-92	115.6	867	5,417	549	9	5	1.4	.8	.01	.22	.67	2.02	115,700
	07-02-92	57.3	312	1,169	432	10	8	1.4	.3	.01	.06	.13	.75	41,700
	10-07-92	597.3	N	6,683	1,512	47	36	9.3	3.4	.02	.35	.56	3.92	299,000
	05-22-93	111.9	916	8,650	544	15	8	.8	1.3	.02	.36	.91	3.25	81,500
	06-17-93	36.3	313	1,523	330	10	7	1.0	.5	N	.05	.07	.49	52,800
	06-24-93	94.8	948	16,024	551	8	3	1.1	.8	.02	.32	.83	2.58	138,000
4	06-17-92	72.5	307	810	375	16	11	2.3	1.4	N	.04	.05	.26	68,300
	07-02-92	55.8	340	623	553	16	11	2.6	1.9	N	.05	.05	.25	81,200
	08-25-92	84.8	345	1,029	648	10	7	2.2	.8	N	.07	.06	.24	97,000
	10-07-92	680	3,351	4,566	2,234	136	92	32	10.2	N	.39	1.26	4.85	778,000
	05-22-93	46.4	426	2,818	360	10	7	1.1	1.4	N	.08	.11	.46	62,000
	06-17-93	42	217	1,479	374	5	4	.7	.5	N	.04	.03	.14	56,000

Table 17. Stormwater loads per event for 12 constituents at five monitoring sites as calculated by the direct method--Continued

Site number (fig. 2)	Sampling date	Load												
		BOD	*COD*	*SS*	*DS*	*TN*	*TKN*	*TP*	*DP*	*CD*	*CU*	*PB*	*ZN*	*RUN*
5	06-05-92	11.8	13	14	42	1	<1	0.1	0.1	N	<0.01	<0.01	0.02	7,000
	06-17-92	12.6	54	60	215	3	2	.4	.5	N	<.01	<.01	.06	18,300
	07-02-92	7.1	29	50	58	1	1	.2	.1	N	<.01	<.01	.05	10,400
	05-22-93	15.7	111	296	92	2	1	.1	.1	N	.01	.04	.24	22,800
	06-17-93	17.2	37	25	66	1	1	.1	.1	N	<.01	<.01	.04	13,000
	06-24-93	42	222	274	255	5	3	.8	.5	N	.02	.04	.12	75,600

Table 18. Mean and median concentrations of 12 constituents from samples collected during storms for residential, commercial, and industrial land-use basins, Omaha, Nebraska, 1992-93

[*BOD*, biochemical oxygen demand; *COD*, chemical oxygen demand; *SS*, suspended solids; *DS*, dissolved solids; *TN*, total nitrogen as N; *TKN*, total ammonia plus organic nitrogen as N; *TP*, total phosphorus; *DP*, dissolved phosphorus; *CD*, total cadmium; *CU*, total copper; *PB*, total lead; *ZN*, total zinc; NURP, the National Urban Runoff Program (U.S. Environmental Protection Agency, 1983); mg/L, milligrams per liter; µg/L, micrograms per liter; --, values were not available; <, less than]

Constituent	Residential basin			Commercial basin			Industrial basin		
	Mean	Median	NURP median	Mean	Median	NURP median	Mean	Median	NURP median
BOD (mg/L)	14.1	14	10	15.3	13	9.3	19	19	--
COD (mg/L)	63.3	64.5	73	57	47	57	105	115	--
SS (mg/L)	200	112	101	119	84	69	930	606	--
DS (mg/L)	81	91	--	80	76	--	99	90	--
TN (mg/L)	2.2	2.3	--	1.7	1.7	--	2.4	2.7	--
TKN (mg/L)	1.5	1.5	1.9	1.1	1.0	1.2	1.6	1.7	--
TP (mg/L)	.33	.30	.38	.21	.16	.20	.31	.26	--
DP (mg/L)	.21	.19	.14	.14	.11	.08	.15	.13	--
[1]*CD* (µg/L)	<1	<1	--	<1	<1	--	2	2	--
CU (µg/L)	10	8.5	33	7	6.5	29	33	27	--
PB (µg/L)	16	13.5	144	14	11.5	104	79	72	--
ZN (µg/L)	69	60	135	82	80	226	312	285	--

[1]One-half of analytical detection limit was used for less-than values.

In addition to determining the median concentrations of the 12 constituents for residential, commercial, and industrial basins, concentrations were compared to median concentrations obtained from the National Urban Runoff Program's (NURP) databases (U.S. Environmental Protection Agency, 1983). The median concentrations of *BOD*, *COD*, suspended solids, total ammonia plus organic nitrogen as N, dissolved phosphorus, and total phosphorus from this study were similar to concentrations from NURP, whereas median concentrations of copper, lead, and zinc for residential land-use basins differed appreciably between this study and NURP. Median concentrations of lead (144 µg/L) from NURP in the residential land-use basins, for instance, was about 11 times greater than in the residential (14 mg/L) land-use basin from the City of Omaha. The NURP did not compile data on the industrial land-use basin.

Annual constituent loads for the 12 constituents for each basin, based on six sampled storms at each of the five monitoring sites, were estimated using equation 2 and are listed in table 19. By using a per-site basis of the estimated annual pollutant loads, the per-watershed and city-wide annual constituent loads could be estimated.

Statistical Regression Methods for Estimating Single-Storm Loads

Stormwater-runoff loads at an unmonitored site can be estimated using either a deterministic model of runoff and transport processes in a basin, or by using a statistical model developed and calibrated from observed data.The deterministic model requires a substantial amount of historical data for the drainage areas serviced by storm-sewer outfalls. Although neither type of model can be calibrated with on-site data when estimating loads at an unmonitored site, the statistical model has the advantage of providing a measure of certainty of the estimates not provided in the deterministic model predictions.

Regional Regression Analysis

Linear-regression models were developed by the USGS (Driver and Tasker, 1990) to estimate stormwater-runoff volumes, constituent loads, and mean concentrations from basin characteristics. Regression equations were derived using the NURP database compiled by the USEPA (1983). Models of stormwater-runoff load and mean concentration for a single storm were developed for 11 constituents (*COD*, suspended solids, dissolved solids, total nitrogen as N, total ammonia plus organic nitrogen as N, total phosphorus, dissolved phosphorus, total cadmium, total copper, total lead, and total zinc) by relating concentrations and stormwater runoff (*RUN*) to easily measured physical, land use, and climatic characteristics (the explanatory variables) of urban basins in three regions of the United States. The three regions were defined by the ranges of annual rainfall. Annual rainfall in Region II ranges from 20 to 40 inches, thus the City of Omaha, with an average annual rainfall of 30 inches, is in Region II. The one runoff equation and 11 load equations for Region II, with the three most significant explanatory variables—total storm rainfall, total contributing drainage area, and impervious area—are listed in table 20.

The general form of the regression equation that applies to estimate stormwater-runoff loads and volumes is:

$$Y = \beta_0 \times X_1^{\beta_1} \times X_2^{\beta_2} \ldots X_n^{\beta_n} \times BCF \quad (3)$$

where Y is the estimated stormwater-runoff load (response variable),

$\beta_o \ldots \beta_n$ are the regression coefficients,

$X_1 \ldots. X_n$ are the physical, land-use, or climatic characteristics (explanatory variables),

n is the number of physical, land-use, and climatic characteristics in the regression equations, and

BCF is a bias-correction factor.

A bias-correction factor (*BCF*) needs to be included in the regression equation if an unbiased estimate of the mean is to be obtained. For a more detailed discussion, the reader is referred to Driver and Tasker (1990). The effectiveness of the equation in predicting stormwater-runoff load, *Y*, is expressed by the equation's coefficient of determination, R^2, which is the ratio of the variation described by the explanatory variables to the total variation of the response variable.

Table 19. Estimated annual constituent loads as determined by the U.S. Environmental Protection Agency simple method using data from the five sites, Omaha, Nebraska, 1992-93

(All load data are in pounds. *BOD*, biochemical oxygen demand; *COD*, chemical oxygen demand; *SS*, suspended solids; *DS*, dissolved solids; *TN*, total nitrogen as N; *TKN*, total ammonia plus organic nitrogen as N; *TP*, total phosphorus; *DP*, dissolved phosphorus; *CD*, total cadmium; *CU*, total copper; *PB*, total lead; *ZN*, total zinc]

Site (fig. 2)	Area (acres)	Load											
		BOD	*COD*	*SS*	*DS*	*TN*	*TKN*	*TP*	*DP*	*CD*	*CU*	*PB*	*ZN*
1	339	4,538	16,457	34,598	21,311	583	377	67	49	0	2.25	5.01	21.46
2	32	1,219	4,766	11,806	4,754	123	73	15	9	0	.61	1.39	6.6
3	101	3,703	20,464	181,221	19,295	464	308	60	29	.37	6.33	15.33	60.74
4	446	5,378	29,381	116,186	36,982	1,041	718	173	105	0	4.77	6.32	27.57
5	129	4,133	14,485	22,664	28,378	526	340	56	47	0	1.72	2.66	21.68

Table 20. Coefficients for three variable linear regression models for stormwater-runoff loads for Region II

[Driver and Tasker, 1990. β_0, the regression coefficient that is the intercept in the regression model; *TRN*, total storm rainfall; *DA*, total contributing drainage area; *IA* + 1, impervious area plus 1 percent; *BCF*, bias-correction factor; *COD*, chemical oxygen demand, in pounds; *SS*, suspended solids, in pounds; *DS*, dissolved solids, in pounds; *TN*, total nitrogen, in pounds; *TKN*, total ammonia plus organic nitrogen as nitrogen, in pounds; *TP*, total phosphorus, in pounds; *DP*, dissolved phosphorus, in pounds; *CD*, total cadmium, in pounds; *CU*, total copper, in pounds; *PB*, total lead, in pounds;
ZN, total zinc, in pounds; *RUN*, stormwater-runoff volume, in cubic feet; *, explanatory variable is not significant at the 5-percent level; R^2, coefficient of determination]

Equation form is: $Y = \beta_0 \times (TRN)^{\beta_1} \times (DA)^{\beta_2} \times (IA+1)^{\beta_3} \times BCF$

Response variable (*Y*)	Regression coefficients				*BCF*	R^2	Standard error of estimate		Number of storms
	β_0	β_1	β_2	β_3			%	Log	
COD	151	0.823	0.726	0.564	1.451	0.67	106	0.376	793
SS	812	1.236	.436	.202	1.938	.60	173	.512	964
DS	3.26	1.251	1.218	1.964	1.434	.86	101	.367	281
TN	4.04	.936	.937	.692	1.373	.77	97	.353	574
TKN	3.89	.944	.765	.556	1.524	.75	107	.381	858
TP	.697	1.008	.628	.469	1.790	.62	120	.411	1,091
DP	.060	.991	.718	.701	1.757	.63	121	.412	467
CD	.021	1.367	1.062	.328*	1.469	.62	109	.386	47
CU	.013	.504	.585	.816	1.548	.55	123	.417	298
PB	.150	.791	.426	.522	1.665	.43	135	.442	943
ZN	.046	.880	.808	1.108	1.813	.51	166	.500	357
RUN	62,951	1.127	.809	.522	1.212	.88	69	.270	1,353

The utility of regional-regression equations in estimating loads for basins in the study area was assessed by comparing regression-derived estimates using the models in table 20 with estimates computed from the site data (table 1 and table 24). Insufficient data for cadmium were collected during the study; thus, comparison of cadmium was excluded. The discrepancy between observed and corresponding predicted values for dissolved solids and total ammonia plus organic nitrogen as N for six storms (designated as A, B, C, D, E, and F) in the five basins (1, 2, 3, 4, and 5), for example, is illustrated in figure 3. The regression-derived estimates were generally greater than observed stormwater-runoff loads. The accuracy of these estimates for load and runoff values produced by the regional-regression equations might be improved substantially by using only data collected on-site in the calibration of the regional-regression models.

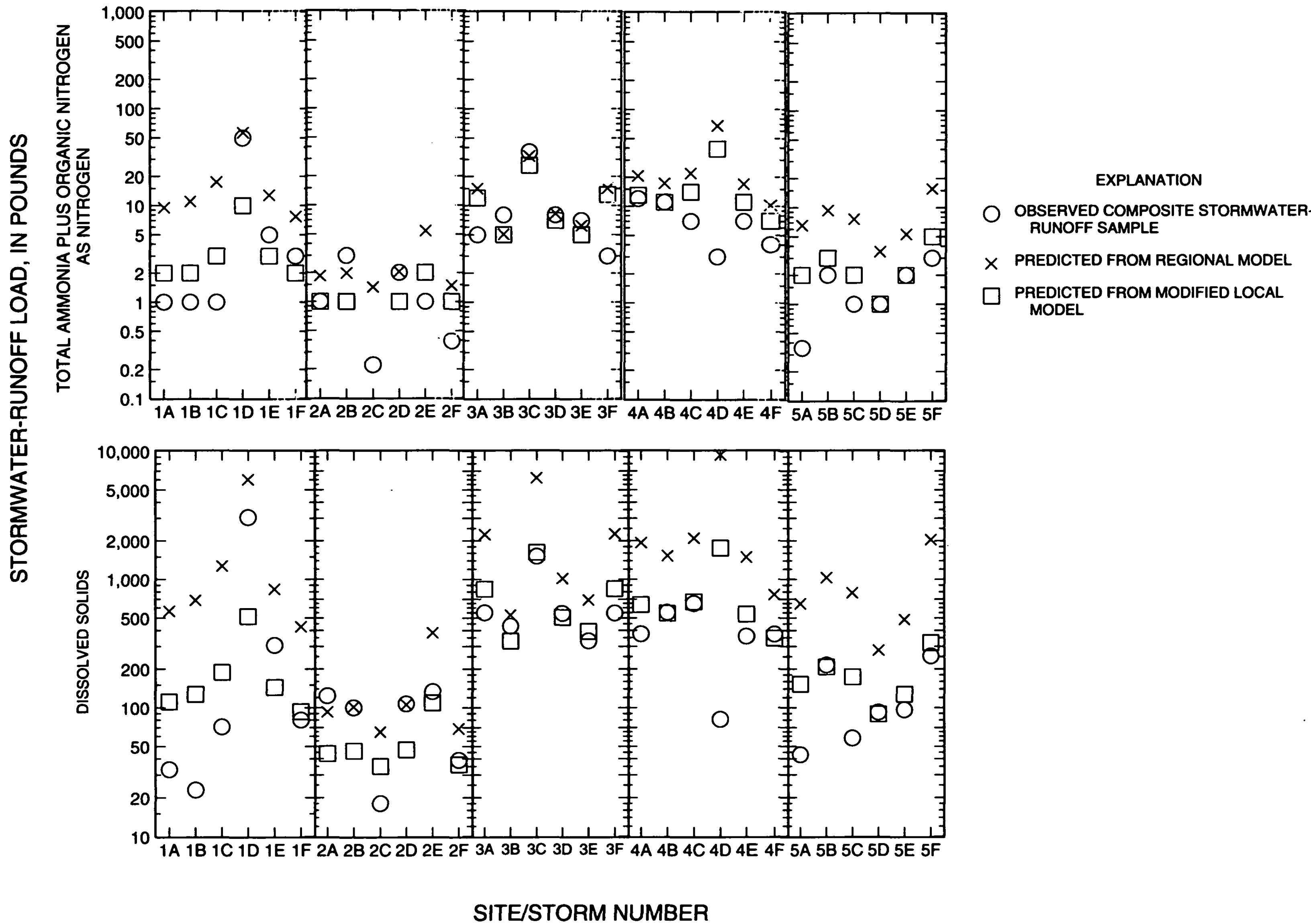

Figure 3. Observed and predicted loads of dissolved solids and total ammonia plus organic nitrogen as nitrogen in stormwater runoff, Omaha, Nebraska, 1992-93.

Local Regression Analysis

Local regression equations were developed for each of the 11 constituents identified for load computations (BOD, COD, suspended solids, dissolved solids, total nitrogen as N, total ammonia plus organic nitrogen as N, total phosphorus, dissolved phosphorus, total copper, total lead, and total zinc). An equation was not derived for total cadmium because cadmium was detected only in samples collected from site 3.

All equations were derived as functions of total storm rainfall (*TRN*), total contributing drainage area (*DA*), impervious areas (*IA*), and land-use characteristics, and can be transformed to an analysis of covariance by using an indicator variable to identify if the basin is residential, commercial, or industrial. The form of the regression equation, using a logarithmic transformation (base 10) of the response variable of *Y* and explanatory variables of *TRN*, *DA*, and *IA*, is given by:

$$\log Y = \beta_0 + \beta_1 \log(TRN) + \beta_2 \log(DA) + \beta_3 \log(IA + 1) + \beta_4 X_1 + \beta_5 X_2, \quad (4)$$

where Y is the estimated stormwater-runoff load or volume (response variable),
$\beta_0 \ldots \beta_5$ are the regression coefficients, and
X_1, X_2 are indicator variables. Defined as:

X_1	X_2	
0	0	Residential land use,
1	0	Commercial land use, and
0	1	Industrial land use.

The response variables, regression coefficients, coefficient of determination (R^2), standard error of estimate (expressed in percent and in log forms), and number of storms are listed in table 21. R^2 indicates the proportion of the total variation of the response variable described by the explanatory variables. Therefore, the value of R^2 is used as a summary measure to judge the fit of the regression model to the data. The standard error of estimate is an estimate of the standard deviation about the regression. The smaller the standard error of estimate, the more precise will be the estimate of the response variable.

However, the accuracy of the equations cannot be compared based on the standard error of estimate if the units of the response variable in each case are different. Thus, the standard error of estimate, in percent, was calculated for all the regression models using the following formula.

$$SE = 100[e^{(\sigma^2 \times 5.302)} - 1]^{\frac{1}{2}} \quad (5)$$

where SE is the standard error of estimate, in percent, and
σ^2 is the mean square error in log (base 10) units.

The values of R^2 in the local-regression equations ranged from 0.60 to 0.83 (table 21). Standard errors of estimate ranged from 72 to 160 percent. Because the indicator variables in the equations were significant at the 5-percent level, a significant difference in storm loads is evident for the three types of land use after adjusting for the effect of the explanatory variables *TRN, DA,* and *IA*.

The R^2 statistics were sufficiently large and the *SE* statistics were sufficiently small to imply that the relations between these estimates and three explanatory variables are mathematically definable (table 21). The local regression equations could be used to make reasonable estimates of stormwater-runoff constituent loads and volumes at gaged and ungaged urban outfalls and basins in the City of Omaha. The number of storms used to develop the local regression equations for 11 constituent loads was small (30) (table 21) in comparison to regional equations, where the number of storms ranged from 47 to 1,091 (table 20). Because of the small number of samples used, the associated confidence level for the local regression equations was not high.

Adjusted Regional Regression Equations

Hoos and Sisolak (1993) proposed four model-adjustment procedures (MAPs) to estimate stormwater-runoff quality at gaged and ungaged urban basins from existing regression equations (Driver-Tasker equations) by combining or weighting them with information from local data.

Table 21. Summary of coefficients for local regression models for stormwater-runoff loads for drainage basins, Omaha, Nebraska, 1992-93

[*Y*, stormwater-runoff load; β_0 - β_5, regression coefficients; *TRN*, total storm rainfall, in inches; *DA*, total contributing drainage area, in square miles; *IA* + 1, impervious area plus 1 percent, in percent; *BOD*, biochemical oxygen demand, in pounds; *COD*, chemical oxygen demand, in pounds; *SS*, suspended solids, in pounds; *DS*, dissolved solids, in pounds; *TN*, total nitrogen as nitrogen, in pounds; *TKN*, total ammonia plus organic nitrogen as nitrogen, in pounds; *TP*, total phosphorus, in pounds; *DP*, dissolved phosphorus, in pounds; *CU*, total copper, in pounds; *PB*, total lead, in pounds; *ZN*, total zinc, in pounds; *RUN*, stormwater-runoff volume, in cubic feet (ft^3); X_1 and X_2, indicator variables; R^2, coefficient of determination; *, explanatory variable is not significant at the 5-percent level; %, percent]

Equation form is: $\log Y = \beta_o + \beta_1 \log(TRN) + \beta_2 \log(DA) + \beta_3 \log(IA+1) + \beta_4 X_1 + \beta_5 X_2$

Response variable	Regression coefficients							Standard error of estimate		Number of
(*Y*)	β_0	β_1	β_2	β_3	β_4	β_5	R^2	%	(log)	storms
BOD	-13.73	1.17	-0.17*	10.17	-3.16	-3.24*	0.71	92	0.34	30
COD	-19.79	.89	.19*	14.48	-4.48	-4.71	.60	124	.42	30
SS	-33.80	1.31	-.66*	23.77	-7.36	-7.41	.75	160	.49	30
DS	-17.18	1.11	.23*	12.94	-3.65	-3.95	.78	75	.29	30
TN	-19.25	1.15	.05*	13.26	-3.96	-4.25	.73	95	.35	30
TKN	-20.36	1.14	.13*	13.87	-4.12	-4.44	.72	99	.36	30
TP	6.55	1.52	-.14*	13.30	-4.23	-4.52	.81	88	.33	30
DP	5.49	1.35	-.01*	11.44	-3.62	-3.90	.83	72	.28	30
CU	4.31	1.13	.31*	11.99	-3.99	-3.62	.81	88	.33	30
PB	3.01	1.24	.91*	8.96*	-3.64	-2.82*	.72	149	.47	30
ZN	3.18	1.22	.29*	7.66*	-2.57	-2.00*	.76	103	.37	30
RUN	8.76	1.06	.04*	7.54	-2.45	-2.71	.77	76	.29	325

The four MAPs are:

1. Single-factor regression against the predicted values (load or concentration or both) from a regional regression model *Pu* (termed MAP-1F-P),
2. regression against *Pu* (termed MAP-R-P),
3. regression against *Pu* and local data (termed MAP-R-P + nV), and
4. weighted combination of *Pu* and a local-regression prediction (termed MAP-W).

One of the procedures for adjusting the regional regression models, regression against *Pu* and local data (MAP-R-P + *nV*), was selected for adjusting the regional models to estimate constituent loads after examining the Omaha (local) database. Statistical tests and figure 3 indicate that the pattern of correspondence between the observed and predicted values from the local database has the following two characteristics, both of which support the model adjustment as a valid approach:

1. The direction of bias of predicted values relative to observed values of all 11 constituent loads is consistent (that is, overestimated) with the exception of suspended solids. A Wilcoxon signed rank test (SAS Institute, Inc., 1982) on the predicted and observed paired data at a 5-percent significance level indicated that consistent direction of bias existed.
2. The predicted and observed values are strongly and positively correlated, so that the variation in predicted values explains much of the variation in the observed values. A Spearman correlation coefficient test (SAS Institute, Inc., 1982) indicated that the correlations between the regional model predicted and observed values for all 11 constituent loads were significant at a 5-percent level. This implies that the regional model does explain the relation between the response variable and the explanatory variables.

MAP-R-P + nV log-transformed observed values (*O*) (Hoos and Sisolak, 1993) are regressed against several independent variables (including the log-transformed predicted values *Pu*, from the unadjusted regional model in table 20) in a traditional multiple linear regression:

$$\log O = \beta_o + \beta_1 \log Pu + \beta_2 \log V_1 + \ldots + \beta_{n+1} \log V_n, \quad (6)$$

where $\beta_0, \beta_1, \ldots, \beta_{n+1}$ are the regression coefficients fitted from multiple linear regression analysis of the calibration of the local data set, and $V_1, V_2, \ldots, V_n$ are the values of additional explanatory variables from the calibration set.

The prediction at an unmonitored site i (Pa_i) is then calculated from equation 6 by detransformed form as:

$$Pa_i = \beta'_0 \times Pu_1^{\beta_1} \times V_1^{\beta_2} \times \ldots V_n^{\beta_{n+1}} \times BCF, \quad (7)$$

where $\beta'_0 = 10^{\beta_0}$, and

BCF is the bias-correction factor.

The detransformation of a regression model provides a consistent estimate of median response, but systematically underestimates the mean response. A *BCF* is included to obtain an unbiased estimate of the mean responses; a good approximation equation was defined by Ferguson (1986) as:

$$BCF = 10^{0.5SE^2}, \quad (8)$$

where *SE* is the standard error of estimate, in log units.

Local regression models indicated that land-use type is significant; thus, three additional explanatory variables in the Omaha database—residential (*LUR*), commercial (*LUC*), and industrial (*LUI*) land use—were selected for the multiple-regression analysis. Results of the analysis are listed in table 22. The significance of regression is determined by hypothesis testing on the slopes and intercepts at a 5-percent level. All 11 regression models were significant at the 5-percent level, except the land-use variables in some of the models, such as *COD*, total nitrogen as N, trace elements, and *RUN* models, which were insignificant at the 5-percent level. Values of R^2 ranged from 0.54 to 0.75 and standard errors of estimate ranged from 82 to 200 percent (table 22). The greater the values of R^2, the more the variability in the stormwater-runoff loads is explained by the regression model. By comparing R^2 of the adjusted regional models with unadjusted regional models (table 20), the adjusted models for suspended solids, total phosphorus, dissolved phosphorus, copper, lead, and zinc loads have larger R^2 values than the unadjusted models.

For example, 75-percent of the variability of total phosphorus in stormwater-runoff loads is explained by the total phosphorus regression model of four explanatory variables. The standard errors of estimate generally were less than 135 percent except for the models of stormwater-runoff loads of suspended solids (187 percent) and lead (200 percent) (table 22), indicating a relatively small departure from mean stormwater-runoff load estimations.

The stormwater-runoff load and volume equations developed by the regression analysis in tables 21 and 22 can be applied to estimate constituent loads and volumes for every storm event, month, and year by outfall and by basin. The stormwater-runoff loads and volumes were estimated using adjusted regional regression models for each individual storm event at five sites (table 23).

Long-term climatic data were compiled to calculate the monthly and annual loads (table 24). The volumes of precipitation for all storms that occurred during 1983-92 with less than 0.1 inch were excluded from the statistics. Snowfall duration was not taken into account because of the time lag between a snow storm and resulting runoff. Mean monthly and annual stormwater-runoff loads and volumes were estimated for a residential basin (site 1)(table 25). Annual loads were estimated for each of the 11 constituents for the five monitoring sites (table 26).

For example, the average number of storms in June in the study area was five (table 24); therefore, the total *COD* load for a residential basin (site 1) for the month of June was calculated to be:

COD load (pounds per month) = COD load (pounds per event) x number of storms for that month (9)

For June, it would be:

184.72 (pounds per event)(eq. 12) × 5 events (table 24)
= 923.60 pounds (table 25)

Table 22. Coefficients for the MAP-R-P + nV adjusted regression models for stormwater-runoff loads and volumes at monitored/unmonitored basins, Omaha, Nebraska, 1992-93

[Hoos and Sisolak, 1993; β_0^1, regression coefficient, intercept in the regression model; Pa_i, prediction at unmonitored site i; Pu_i, log-transformed predicted loads and volumes from the unadjusted regional model in table 20; *BCF*, bias-correction factor; *LUI*, percent industrial land use; *LUC*, percent commercial land use; *LUR*, percent residential land use; *COD*, chemical oxygen demand, in pounds; *SS*, suspended solids, in pounds; *DS*, dissolved solids, in pounds; *TN*, total nitrogen as nitrogen, in pounds; *TKN*, total ammonia plus organic nitrate as nitrogen, in pounds; *TP*, total phosphorus, in pounds; *DP*, dissolved phosphorus, in pounds; *CU*, total copper, in pounds; *PB*, total lead, in pounds; *ZN*, total zinc, in pounds; *RUN*, storm-runoff volume in cubic feet; %, percent; *, the explanatory variable is not significant at the 5-percent level]

Equation form is: $Pa_i = \beta_0^1(Pu_i)^{\beta_1} \times (LUR)^{\beta_2} \times (LUC)^{\beta_3} \times (LUI)^{\beta_4} \times BCF$

Response variable	Regression coefficients					BCF	R^2	Standard error of estimate	
(Pa_i)	β_0^1	β_1	β_2	β_3	β_4			%	Log
COD	5,840	0.667	-0.689*	-1.752*	-1.451*	1.254	0.54	135	0.443
SS	483,393	.845	-1.214	-2.921	-2.279	1.385	.70	187	.532
DS	1,317	.646	-.580	-1.398	-1.202*	1.119	.73	82	.313
TN	575	.804	-.658*	-1.510*	-1.278*	1.182	.66	108	.381
TKN	783	.932	-.731	-1.707	-1.479*	1.178	.69	106	.377
TP	3,317	1.174	-.891	-2.036	-1.830	1.177	.75	106	.376
DP	2,675	1.255	-.762	-1.555	-1.488	1.158	.74	98	.357
CU	392	1.064	-.664*	-1.811*	-1.293*	1.206	.72	117	.403
PB	6.2	.982	-.340*	-1.151*	-.553*	1.418	.61	200	.551
ZN	9.8	.813	-.392*	-.928*	-.462*	1.238	.66	129	.431
RUN	524	.824	-.536*	-1.092*	-.931*	1.149	.66	95	.347

Similarly, the mean monthly *COD* loads for the remaining 11 months were calculated and the mean annual *COD* load, 6,247.66 pounds (table 25), was obtained by summing 12 months of *COD* loads.

$$COD\ \#/\text{event} = 5{,}840 \times (Pu_i)^{0.667}(LUR)^{-0.689} \times (LUC)^{-1.752} \times (LUI)^{-1.451} \times 1.254\ \text{(table 22)} \quad (10)$$

where:

$$Pu_i(COD) = 151 \times (TRN)^{0.823} \times (DA)^{0.726} \times (IA+1)^{0.564} \times 1.451\ \text{(table 20)} \quad (11)$$

Using a mean rainfall value of 0.72 inches (table 24), the values for the explanatory variables, *DA* and *IA* from table 1, the regression equation becomes:

$$COD = 5,840 \times (757.7)^{0.667} \times (82)^{-0.689} \times (18)^{-1.752} \times 1^{-1.451} \times 1.254 = 184.72\ \text{pounds per event} \quad (12)$$

and

$$Pu_i(COD) = 151 \times (0.72)^{0.823} \times (0.53)^{0.726} \times (33)^{0.564} \times 1.451 = 757.7\ \text{pounds per event} \quad (13)$$

The modified 10 constituent load equations, stormwater-runoff regression models, and a local *BOD* regression equation can be applied to gaged and ungaged outfalls and basins in the City of Omaha.

Table 23. Estimated stormwater-runoff event loads and volumes for five monitoring sites using adjusted regional regression models, Omaha, Nebraska, 1992-93

[Values are in pounds, unless otherwise noted. *BOD*, biochemical oxygen demand; *COD*, chemical oxygen demand; *SS*, suspended solids; *DS*, dissolved solids; *TN*, total nitrogen as nitrogen; *TKN*, total ammonia plus organic nitrogen as nitrogen; *TP*, total phosphorus; *DP*, dissolved phosphorus; *CU*, total copper; *PB*, total lead; *ZN*, total zinc; *RUN*, storm-runoff volume, in cubic feet]

Site	Sampling date	*BOD*[1]	*COD*	*SS*	*DS*	*TN*	*TKN*	*TP*	*DP*	*CU*	*PB*	*ZN*	*RUN*
1	6-5-92	21	112	139	111	3	2	0.3	0.2	0.02	0.03	0.14	26,668
	7-2-92	25	123	164	127	4	2	.4	.3	.02	.04	.15	30,889
	8-25-92	44	161	274	188	6	3	.7	.5	.02	.06	.22	48,742
	10-7-92	189	317	1,003	514	14	10	2.9	2.3	.04	.15	.52	154,486
	5-22-93	30	134	193	144	4	3	.4	.3	.02	.04	.17	35,759
	6-17-93	16	99	110	93	3	2	.2	.2	.01	.03	.12	21,676
2	6-5-92	18	46	84	44	1	1	.1	.1	.01	.01	.05	10,373
	7-2-92	19	48	91	46	1	1	.1	.1	.01	.01	.06	11,060
	8-25-92	13	39	63	35	1	0	.1	.1	0	.01	.04	7,941
	6-17-93	20	49	94	47	1	1	.1	.1	.01	.01	.06	11,402
	6-24-93	67	86	276	109	2	2	.4	.3	.01	.02	.12	29,730
	8-19-93	13	40	66	36	1	1	.1	.1	0	.01	.05	8,292
3	5-22-92	205	659	8,889	839	19	12	2.8	1.5	.25	.70	2.68	152,044
	7-2-92	53	350	2,662	330	8	5	.7	.4	.13	.29	1.17	52,035
	10-7-92	531	1,031	20,835	1,623	36	26	7.3	4.1	.39	1.33	4.79	324,344
	5-22-93	98	466	4,604	504	12	7	1.3	.7	.18	.43	1.70	84,697
	6-17-93	68	394	3,337	393	10	5	.9	.5	.15	.34	1.37	63,608
	6-24-93	207	663	8,989	846	20	13	2.8	1.5	.25	.71	2.70	153,578
4	6-17-92	126	578	1,947	634	19	13	3.0	1.8	.09	.13	.49	117,709
	7-2-92	101	522	1,604	545	16	11	.4	1.4	.08	.11	.43	99,061
	8-25-92	136	599	2,086	668	20	14	3.2	1.9	.09	.14	.52	125,104
	10-7-92	548	1,153	7,260	1,755	487	39	13.2	8.4	.17	.34	.22	379,349
	5-22-95	99	516	1,570	536	16	11	2.3	1.4	.08	.11	.43	97,182
	6-17-93	53	384	894	347	11	7	1.2	.7	.06	.07	.29	58,908
5	6-5-92	18	101	177	152	3	2	.4	.4	.01	.02	.16	32,159
	6-17-92	28	125	263	207	5	3	.6	.6	.02	.03	.21	45,621
	7-2-92	22	111	209	173	4	2	.4	.4	.02	.02	.18	37,250
	5-22-93	8	70	89	89	2	1	.2	.2	.01	.01	.10	17,341
	6-17-93	14	90	140	127	3	2	.3	.3	.01	.02	.14	26,140
	6-24-93	53	168	464	321	7	5	1.1	1.1	.02	.04	.31	75,717
Mean		95	308	2,286	386	10	7	2	1	.07	.18	.69	77,962

[1]Local regression *BOD* models (table 19) were used to estimate *BOD* event loads.

Table 24. Storm statistics for Omaha, Nebraska

[Based on National Weather Service's North Omaha Airport Weather Station, 1983-92 climatological data]

Month	Mean duration[1] (hours)	Mean depth of rainfall[2] (inches)	Number of storms
January	14.4	0.27	1.63
February	10.1	.26	1.88
March	15.3	.72	2.6
April	11.5	.78	3.4
May	6.8	.64	5.4
June	5.8	.72	5.0
July	5.3	.70	3.4
August	6.8	.68	3.1
September	7.5	.78	3.0
October	8.2	.52	3.6
November	16.1	.83	1.3
December	8.3	.38	2.38
Year average	9.7	.61	36.69

[1]Periods of snowfall were not included because of the time lag between the precipitation and resulting runoff.

[2]Only storms with greater than 0.1 inch of rainfall were used.

Table 25. Mean monthly and annual estimated stormwater-runoff loads and volumes for a residential basin (site 1) using adjusted regional regression models, Omaha, Nebraska, 1992-93

[Values are in pounds, unless otherwise noted. *BOD*, biochemical oxygen demand; *COD*, chemical oxygen demand; *SS*, suspended solids; *DS*, dissolved solids; *TN*, total nitrogen as nitrogen; *TKN*, total ammonia plus organic nitrogen as nitrogen; *TP*, total phosphorus; *DP*, dissolved phosphorus; *CU*, total copper; *PB*, total lead; *ZN*, total zinc; *RUN*, storm-runoff volume, in cubic feet]

Constit-uent	Month												Total
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
BOD	23.49	25.92	117.82	169.17	213.24	226.57	149.08	131.40	149.27	111.54	69.55	51.12	1,438.18
COD	175.81	198.62	480.28	656.25	935.10	923.60	618.43	554.97	579.04	556.29	259.62	309.64	6,247.66
SS	205.32	227.66	912.12	1,296.76	1,675.15	1,754.07	1,158.19	1,024.51	1,144.20	899.06	529.06	428.36	11,254.46
DS	158.70	177.54	559.52	780.61	1,056.51	1,076.00	456.06	637.00	688.77	595.47	313.85	305.48	6,805.50
TN	4.97	5.57	16.58	23.04	31.52	31.90	21.23	18.94	20.33	17.98	9.23	9.38	210.68
TKN	4.20	4.69	15.88	22.28	29.74	30.54	20.26	18.01	19.66	16.52	9.00	8.29	199.08
TP	.41	.45	2.10	3.02	3.79	4.03	2.65	2.34	2.66	1.98	1.24	.90	25.58
DP	.28	.31	1.51	2.19	2.72	2.91	1.91	1.68	1.93	1.40	.90	.62	18.37
CU	.02	.03	.06	.09	.13	.12	.08	.07	.08	.07	.03	.04	.84
PB	.05	.05	.17	.23	.32	.32	.21	.19	.20	.18	.09	.09	2.11
ZN	.19	.22	.62	.86	1.19	1.19	.80	.71	.76	.68	.34	.36	7.92
RUN	36,375	40,509	144,283	203,238	268,612	277,467	183,805	163,135	179,328	147,667	82,325	72,953	1,799,696

Table 26. Estimated annual loads for five monitoring sites using adjusted regional regression models, Omaha, Nebraska, 1992-93

[Values are in pounds. *BOD*, biochemical oxygen demand, *COD*, chemical oxygen demand; *SS*, suspended solids; *DS*, dissolved solids; *TN*, total nitrogen as nitrogen; *TKN*, total ammonia plus organic nitrogen as nitrogen; *TP*, total phosphorus; *DP*, dissolved phosphorus; *CU*, total copper, *PB*, total lead; *ZN*, total zinc]

Site	*BOD*[1]	*COD*	*SS*	*DS*	*TN*	*TKN*	*TP*	*DP*	*CU*	*PB*	*ZN*
1	1,438	6,248	11,254	6,805	211	199	26	18	0.8	2.1	7.9
2	1,693	2,667	7,482	3,253	71	71	10	8	.3	.7	3.6
3	4,883	19,762	225,816	21,007	542	501	67	35	7.5	19.2	75.0
4	4,393	25,915	103,427	25,365	826	882	146	83	3.9	5.5	20.6
5	1,339	5,215	12,468	8,788	203	191	28	28	.7	1.2	8.9

[1]Local regression *BOD* models were used to estimate annual *BOD* loads.

SUMMARY

The U.S. Geological Survey, in cooperation with the City of Omaha and the Papio-Missouri River Natural Resources District, Nebraska, conducted a study to describe stormwater-runoff quantity and quality from selected basins in Omaha. The study was done to meet technical data requirements for the City of Omaha to obtain a National Pollutant Discharge Elimination System (NPDES) Permit from the U.S. Environmental Protection Agency.

Stormwater-runoff quantity and quality from five sites located in residential, commercial, and industrial land-use basins in Omaha, Nebraska, were monitored from May to November 1992 and April through August 1993. The study describes the quantity and quality of stormwater discharges from selected storm sewers draining areas representative of the various urban land uses in Omaha, Nebraska. Sites 1 and 4 were representative of residential land use; sites 2 and 5 were representative of commercial land use; and site 3 was representative of industrial land use.

Grab samples and flow-weighted composite samples were collected at each of the five sites during six storms and were analyzed for 147 chemical, physical, and biological characteristics. Total rainfall, runoff volume, runoff-rainfall ratio, peak discharge, rainfall and runoff duration, and number of dry hours between storms were calculated and compiled. Mean rainfall during the study was slightly greater in the residential basins (0.60 inch) than in the commercial (0.45 inch) and industrial (0.46 inch) basins. However, mean runoff-rainfall ratio for the commercial (0.38) and industrial (0.32) basins was more than twice the runoff-rainfall ratio of the residential basins (0.15).

Grab samples were collected within the first 30 minutes of each storm. The samples represented the storm's first-flush effects. These samples were used to determine pH, water temperature, residual chlorine, volatile organic compounds (VOCs), cyanide, total phenols, biological oxygen demand, fecal coliform and fecal streptococcus bacteria, and oil and grease.

To estimate mean water quality in the study area, flow-weighted samples were composited from discrete samples collected by automatic samplers during the first 3 hours of a storm and were analyzed for a variety of constituents and physical properties. The constituents and properties included acid and base/neutral organic compounds, pesticides and polychlorinated biphenyls (PCBs), trace elements, chemical oxygen demand, suspended solids, dissolved solids, nutrients, major ions, alkalinity, pH, specific conductance, and total organic carbon.

Thirty-eight of the 147 constituents were detected in the basins, and eight constituents exceeded the U.S. Environmental Agency's Maximum Contaminant Levels (USEPA MCLs) for drinking water in at least one sample. Analytical results indicated that four VOCs—chloroform, dichlorobromomethane, methyl chloride, and toluene—were detected. Toluene was detected only at the residential sites (1 and 4).

Of the 10 acid organic compounds analyzed, none were detected in stormwater-runoff samples, whereas 12 of 45 base/neutral organic compounds were detected in 45 percent of the samples. The four most commonly detected compounds were bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene. Although more base/neutral organic compounds were detected in samples collected from the residential basins, concentrations were less than the USEPA MCLs for drinking water. Eleven base/neutral organic compounds with concentrations ranging from 9 to 150 µg/L were detected in a commercial basin (site 5) during a storm-runoff event May 22, 1993. This was not a typical sampling event because 11 of the 12 base/neutral compounds were detected. Concentrations of six of the compounds exceeded USEPA MCLs for drinking water.

Only 6 of 21 pesticides were detected in samples collected in the study area. Concentrations of pesticides ranged from 0.1 µg/L (chlordane and 4,4-DDT) to 13 µg/L (2,4-D) in the study area, none of which exceeded the USEPA MCLs for drinking water. PCB 1242 and PCB 1254 were detected in two samples collected from a residential basin (site 4), and PCB 1254 was detected in one sample collected from the industrial basin (site 3). PCB concentrations were less than the MCLs established by the USEPA for drinking water.

Nine of the 14 trace elements were detected in samples collected in the study area. Concentrations of trace elements did not exceed USEPA MCLs for drinking water with the exception of total beryllium and total lead. Total lead also exceeded treatment action levels established by USEPA in drinking

water. Trace-element concentrations in samples collected from the industrial basin were, in general, greater than concentrations in samples collected from the residential and commercial basins; total beryllium and total mercury were the only exceptions. Median concentrations of lead in samples collected from the industrial basin (72 µg/L) were about 6 times greater than those collected in the residential and commercial basins. Median concentrations of total copper (27 µg/L), total nickel (17 µg/L), and total zinc (285 µg/L) were about 3 times greater in samples collected in the industrial basin than those collected in the residential and commercial basins.

Median concentrations of BOD (19 mg/L) and COD (115 mg/L) in the industrial basin were about 1.5 to 2 times greater than in the residential and commercial basins. Bacterial concentrations ranged from 200 to 110,000 colonies/100 mL. Bacteria concentrations in samples collected in the residential land-use basins were much greater than in samples collected from the commercial and industrial basins.

Concentrations of total nitrogen as N, total ammonia plus organic nitrogen as N, total phosphorus, and dissolved phosphorus were detected in all stormwater samples. Concentrations of total nitrogen ranged from 0.7 mg/L to 3.8 mg/L and total phosphorus ranged from 0.09 mg/L to 0.66 mg/L. Median concentrations of total nitrogen and total ammonia plus organic nitrogen (2.7 mg/L and 1.7 mg/L) were greater in samples collected from the industrial basin than in samples collected from the residential (2.3 mg/L and 1.5 mg/L) and commercial (1.7 mg/L and 1.0 mg/L) basins. Median concentrations of total phosphorus were greater in samples collected from the residential basins (0.3 mg/L) than in samples collected from the commercial (0.16 mg/L) and industrial (0.26 mg/L) basins. Median concentrations of dissolved phosphorus ranged from 0.11 to 0.19 mg/L.

The USEPA regulations for NPDES require a city-wide (cumulative) annual load calculation for 12 constituents: biological oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, total nitrogen as N, total ammonia plus organic nitrogen as N, total phosphorus, dissolved phosphorus, total cadmium, total copper, total lead, and total zinc. Constituent loads were computed for the 12 constituents by direct computation of observed data for six storms at each of the five sites. The loads varied greatly depending on the site and rainfall event. In general, the greater the runoff volume for a specific basin, the greater the loads that were produced.

Annual stormwater-runoff constituent loads were estimated for 11 constituents—biochemical oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, total nitrogen as N, total ammonia plus organic nitrogen as N, total phosphorus, dissolved phosphorus, total copper, total lead, and total zinc—for each site using the USEPA simple method, and by multiple-regression models. An equation was not derived for total cadmium because cadmium was detected only in samples collected from the industrial basin (site 3).

Although local regression models were more appropriate in terms of the amount of explained variation (R^2 ranged from 0.60 to 0.83 percent), the number of storms used to derive these regression equations was limited to 30. Because of the small number of samples used, the associated confidence level was not high. Thus, modified regression models with a larger sample size were developed by adjusting regional models with local monitoring data.

The modified 10 constituent load equations, stormwater-runoff regression models, and a local biological oxygen demand regression equation can be applied to gaged and ungaged outfalls and basins in the City of Omaha.

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APPENDIX A—STORM RAINFALL AND RUNOFF CHARACTERISTICS FOR FIVE SITES, OMAHA, NEBRASKA, 1992-93

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site locations. Total runoff volume means observed runoff volume, in inches, on the contributing drainage area. in., inches; ft^3/s, cubic feet per second; min, minutes; hrs, hours; --, no data available]

Storm duration				Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
First rainfall		End of runoff								
Date	Time	Date	Time							
				Residential, single-dwelling (site 1)						
[1]05-22-92	1618	05-22-92	1734	0.14	0.002	0.014	1.3	--	60	--
[1]05-25-92	0405	05-25-92	1010	.21	.010	.046	1.3	329	360	59.8
[2]05-31-92	2041	06-01-92	1530	.16	.015	.092	1.5	1,092	1,020	160.6
[1]06-05-92	2006	06-05-92	2318	.35	.009	.026	2.2	162	180	119.4
[1]06-17-92	0000	06-17-92	0145	.51	.015	.029	24.3	29	105	267.9
[1]06-24-92	1006	06-24-92	1148	.15	.003	.020	1.5	81	60	178.1
[1]07-02-92	0716	07-02-92	1000	.41	.004	.010	2.0	115	160	189.2
[1]07-04-92	2218	07-05-92	0200	.33	.003	.010	2.5	98	225	63.0
[3]07-05-92	0621	07-05-92	1400	.44	.013	.029	1.5	294	480	8.1
[1]07-12-92	0323	07-12-92	0830	1.89	.101	.053	101.1	325	300	165.0
[1]07-12-92	2143	07-13-92	1100	1.09	.027	.025	9.6	611	720	18.3
[1]07-30-92	0040	07-30-92	0430	.80	.016	.020	2.8	270	220	411.0
[1]08-02-92	0410	08-02-92	0900	.71	.010	.014	11.8	140	220	75.5
[1]08-07-92	0320	08-07-92	0800	1.73	.175	.101	248.4	90	279	119.2
[1]08-12-92	0520	08-12-92	0605	.09	.001	.010	1.6	90	40	122.0
[1]08-25-92	0855	08-25-92	1025	.67	.011	.015	5.1	350	150	315.6
[1]09-01-92	1320	09-01-92	2210	.17	.010	.059	3.9	500	515	172.4
[1]09-02-92	0120	09-02-92	0735	.54	.031	.057	4.9	185	370	12.0
[1]09-05-92	0710	09-05-92	1000	.11	.012	.110	5.2	75	120	77.8
[1]09-09-92	0555	09-09-92	1150	.05	.004	.080	3.5	35	85	94.8
[1]09-14-92	0525	09-14-92	1400	1.57	.205	.132	112.2	430	480	119.5
[4]09-15-92	0840	09-15-92	1000	.06	.009	.150	14.8	10	90	27.2
[1]09-17-92	2210	09-18-92	0130	.41	.052	.127	99.2	110	190	61.5
[1]09-26-92	0015	09-26-92	0415	.32	.033	.103	9.9	300	230	194.1
[1]10-07-92	1705	10-08-92	1445	2.32	.413	.178	31.7	1,119	1,300	280.8
[1]10-31-92	1711	10-31-92	1830	.14	.021	.150	--	--	--	576.6
[1]05-06-93	1513	05-06-93	2300	.18	.100	.556	53.9	420	300	--
[1]05-07-93	2246	05-09-93	0000	.51	.043	.084	8.6	1,440	1,515	31.6
[1]05-09-93	2018	05-10-93	1500	.87	.217	.250	17.6	1,110	1,122	45.5
[1]05-11-93	0010	05-11-93	0300	.10	.013	.130	9.4	150	90	27.9

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration				Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
First rainfall		End of runoff								
Date	Time	Date	Time							
				Residential, single-dwelling (site 1)--Continued						
[1]05-11-93	1524	05-11-93	1800	0.12	0.021	0.173	5.8	81	150	15.2
[1]05-19-93	1005	05-19-93	1200	.04	.007	.187	5.7	90	105	186.7
[1]05-22-93	0525	05-22-93	1100	.18	.058	.321	30.7	175	300	67.3
[1]05-23-93	0220	05-23-93	0600	.20	.046	.229	12.1	105	210	20.9
[1]05-30-93	0546	05-30-93	0730	.03	.002	.060	1.8	99	90	171.4
[1]06-01-93	1325	06-02-93	0200	.15	.027	.182	9.9	531	240	55.7
[1]06-03-93	1645	06-04-93	1200	.50	.108	.216	13.8	960	960	51.3
[1]06-06-93	0335	06-06-93	1300	.35	.093	.280	120.9	420	600	58.8
[1]06-11-93	1930	06-12-93	0300	.42	.099	.237	110.0	306	900	134.0
[1]06-13-93	0340	06-13-93	1900	.43	.150	.349	92.8	405	960	34.1
[1]06-17-93	1755	06-17-93	2400	.28	.032	.114	9.2	147	360	110.3
[2]06-18-93	0240	06-18-93	2000	1.71	.320	.187	271.6	810	660	8.8
[1]06-19-93	0610	06-19-93	1200	.12	.009	.073	33.1	186	360	27.5
[1]06-23-93	0325	06-23-93	0900	.01	.006	.551	1.9	300	360	93.3
[1]06-24-93	0150	06-24-93	1000	.88	.124	.141	88.3	330	480	22.4
[1]06-28-93	0100	06-28-93	1200	.73	.109	.149	50.5	510	600	95.2
[1]06-30-93	1750	07-01-93	2000	.35	.038	.107	60.5	115	130	60.6
[1]07-04-93	0130	07-04-93	0700	.09	.010	.111	9.0	150	360	83.9
[1]07-05-93	0445	07-05-93	1600	.77	.095	.124	12.7	585	675	24.3
[1]07-07-93	0530	07-07-93	1100	.35	.049	.140	7.6	221	300	51.7
[1]07-08-93	0425	07-08-93	0900	.47	.081	.171	90.4	117	300	22.9
[1]07-08-93	1930	07-09-93	0600	.41	.072	.175	19.6	480	660	15.1
[1]07-10-93	0405	07-10-93	1430	.17	.003	.020	2.3	150	150	31.7
[1]07-11-93	0125	07-11-93	0600	.33	.105	.317	159.2	15	300	22.3
[2]07-13-93	0430	07-13-93	1800	1.60	.150	.094	169.3	105	360	51.1
[1]07-13-93	2105	07-14-93	0600	.43	.014	.032	4.5	40	180	16.6
[1]07-17-93	1340	07-17-93	0700	.25	.024	.094	5.0	528	660	88.6
[1]07-20-93	0915	07-20-93	1300	.30	.034	.114	18.9	192	240	67.6
[2]07-21-93	1125	07-22-93	1900	3.06	.780	.255	579.5	1,350	1,860	26.2
[2]07-24-93	0550	07-25-93	1800	1.82	.880	.484	587	156	420	18.3

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration: First rainfall Date	Storm duration: First rainfall Time	Storm duration: End of runoff Date	Storm duration: End of runoff Time	Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak dis-charge (ft^3/s)	Rainfall dura-tion (min)	Runoff dura-tion (min)	Time since previous storm (hrs)
					Commercial (site 2)					
05-22-92	1407	05-23-92	0900	0.59	0.371	0.629	21.8	126	1,080	--
05-25-92	0422	05-25-92	1400	.21	.148	.703	2.5	121	570	62.3
05-31-92	2101	06-02-92	0100	.19	.141	.744	.6	70	1,680	160.7
[1]06-05-92	2010	06-06-92	0130	.35	.193	.552	7.4	136	1,200	119.2
06-14-92	1138	06-14-92	1600	.12	.086	.714	12.8	102	300	207.5
06-16-92	2357	06-17-92	0600	.38	.244	.642	26.4	44	360	60.3
06-24-92	1020	06-24-92	1500	.11	.057	.520	2.4	59	300	78.4
07-02-92	0722	07-02-92	1900	.30	.215	.717	27.7	38	780	189.0
07-04-92	2150	07-05-92	1600	.70	.556	.794	25.3	183	1,680	62.5
07-07-92	0334	07-07-92	1100	.07	.038	.542	2.1	37	480	53.7
07-11-92	0912	07-11-92	2300	.82	.619	.755	22.4	136	840	101.6
07-12-92	0330	07-13-92	1700	2.55	2.036	.799	51.7	410	2,280	18.3
07-18-92	2304	07-19-92	1100	1.49	1.044	.700	55.8	39	720	163.6
07-21-92	2355	07-22-92	1600	.62	.476	.767	28.2	123	960	72.8
07-24-92	1345	07-25-92	0900	.50	.435	.869	48.3	41	1,200	61.8
07-25-92	1800	07-26-92	0300	.29	.263	.907	31.3	5	540	28.3
07-28-92	0545	07-28-92	2100	.52	.318	.611	23.4	52	960	59.7
07-30-92	0040	07-30-92	1600	1.10	1.015	.923	42.0	157	960	42.9
08-02-92	0410	08-02-92	1600	.72	.639	.888	39.8	65	720	75.5
08-04-92	2050	08-04-92	2300	.01	.001	.105	.1	1	120	64.7
08-07-92	0320	08-07-92	1400	1.76	1.073	.609	57.9	90	660	54.5
08-12-92	0520	08-12-92	0625	.05	.002	.036	.1	36	30	122.0
08-25-92	0855	08-25-92	1245	.21	.013	.064	3.9	127	220	315.6
[1]09-01-92	1325	09-01-92	1930	.17	.022	.129	1.7	285	150	172.5
[1]09-02-92	0000	09-02-92	0530	.54	.211	.391	16.6	265	300	10.6
[1]09-02-92	2130	09-02-92	2200	.04	.016	.400	3.1	1	30	21.5
09-05-92	0710	09-05-92	0945	.52	.096	.185	9.0	75	155	57.7
09-05-92	1630	09-05-92	1705	.04	.004	.112	.7	1	35	9.3
05-06-93	1513	05-06-93	2400	.84	.730	.870	37.1	420	525	--
05-07-93	2246	05-08-93	2400	.73	--	--	8.1	1,440	1,500	31.6

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration				Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak dis-charge (ft^3/s)	Rainfall dura-tion (min)	Runoff dura-tion (min)	Time since previous storm (hrs)
First rainfall		End of runoff								
Date	Time	Date	Time							
				Commercial (site 2)--Continued						
05-09-93	2018	05-10-93	1630	.92	--	--	9.2	1,110	1,230	45.5
05-11-93	0010	05-11-93	0400	.10	--	--	5.1	150	210	27.9
05-11-93	1522	05-11-93	2000	.14	--	--	3.7	113	270	15.2
05-19-93	1005	05-19-93	1400	.03	.010	.333	.3	70	240	186.7
05-22-93	0520	05-22-93	1100	.32	--	--	19.2	115	360	67.3
05-23-93	0220	05-23-93	0600	0.27	--	--	19.8	95	240	21.0
05-30-93	0150	05-30-93	1000	.03	.008	--	.283	10	480	167.5
06-01-93	1350	06-02-93	0300	.28	.251	.895	6.8	120	1,620	60.0
06-03-93	2100	06-04-93	1300	.70	--	--	11.0	260	960	55.2
06-06-93	0335	06-06-93	1400	.43	.415	.965	21.1	55	660	54.6
06-11-93	1745	06-12-93	0300	.41	.273	.665	13.3	315	600	134.2
06-13-93	0340	06-13-93	1800	.81	.789	.974	24.6	255	900	33.9
06-17-93	1815	06-17-93	2200	.31	.195	.629	10.7	100	360	110.6
06-18-93	0315	06-18-93	0900	.21	.196	.934	2.8	90	420	9.0
06-18-93	1500	06-18-93	2300	1.24	.841	.679	73.0	85	480	11.8
06-19-93	0635	06-19-93	1200	.08	.058	.725	1.2	75	420	15.6
06-23-93	0330	06-23-93	1100	.08	.016	.194	.5	45	360	92.9
06-24-93	0155	06-24-93	1200	.87	.656	.754	27.5	230	600	22.4
06-28-93	0105	06-28-93	1300	.96	.609	.635	24.1	210	720	95.2
06-30-93	1350	06-30-93	2400	.30	.193	.643	15.0	55	420	60.8
07-04-93	0135	07-04-93	0700	.12	.042	.347	3.9	40	360	83.8
07-05-93	0405	07-05-93	1500	.63	.438	.695	5.0	275	660	26.5
07-07-93	0545	07-07-93	1400	.37	.244	.658	3.4	205	480	49.7
07-08-93	0430	07-08-93	1300	.45	.304	.675	28.6	60	480	22.8
07-08-93	1935	07-09-93	0900	.47	.343	.730	8.6	115	840	15.1
07-10-93	0405	07-10-93	1400	.41	.170	.415	19.5	10	600	32.5
07-11-93	0125	07-11-93	1300	.33	.290	.695	24.4	20	660	21.3
07-13-93	0435	07-13-93	1500	.89	.601	.675	48.6	70	660	51.2
07-13-93	2105	07-14-93	0700	.29	.194	.668	5.6	30	660	16.5
07-16-93	0945	07-16-93	1700	.05	.008	.169	.3	30	480	60.7

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration: First rainfall: Date	First rainfall: Time	End of runoff: Date	End of runoff: Time	Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
					Commercial (site 2)--Continued					
07-17-93	1525	07-18-93	0300	.20	.089	.443	1.1	160	660	29.7
07-20-93	0925	07-20-93	1800	.15	.072	.481	2.6	80	540	66.0
07-21-93	1125	07-22-93	1900	1.93	1.58	.807	56.4	345	1,920	26.0
07-23-93	0150	07-23-93	1800	.58	.421	.726	16.4	145	1,020	38.4
[3]07-24-93	0550	07-24-93	1300	.22	.131	.597	2.6	150	420	28.0
07-24-93	2015	07-25-93	1300	1.14	1.122	.984	86.7	50	1,020	14.4
07-26-93	1240	07-26-93	1800	.09	.032	.352	1.1	55	360	40.4
07-27-93	0840	07-27-93	1700	.08	.025	.313	1.0	45	540	20.0
07-31-93	1555	07-31-93	1900	.09	.018	.199	2.6	20	180	103.3
08-05-93	0635	08-05-93	0900	.03	.004	.134	.3	20	180	110.7
08-11-93	1400	08-11-93	2200	1.13	.771	.682	39.2	100	480	151.4
08-12-93	1925	08-13-93	0200	.31	.206	.663	30.5	20	420	29.4
08-17-93	0150	08-17-93	1100	.79	.624	.789	39.7	80	540	102.4
08-19-93	0130	08-19-93	1600	.22	.133	.603	3.1	130	900	48.0
08-21-93	1240	08-21-93	2200	.12	.064	.531	3.1	50	540	59.2
08-23-93	0215	08-23-93	0800	.08	.032	.403	1.2	65	360	37.6
					Industrial (site 3)					
05-22-92	1455	05-22-92	2000	.92	.316	.343	23.8	136	300	75.0
05-25-92	0431	05-25-92	1200	.20	.033	.165	1.2	322	420	61.6
05-31-92	2202	06-01-92	0226	.16	.009	.053	.2	995	179	161.5
[2]06-05-92	2010	06-06-92	0117	.28	.189	.673	10.9	136	239	118.1
06-14-92	1138	06-14-92	1322	.08	.025	.316	3.7	102	97	207.5
06-17-92	0000	06-17-92	0849	.40	.380	.950	23.8	29	524	60.4
06-24-92	1019	06-24-92	1334	.12	.045	.372	4.9	72	171	178.3
07-02-92	0719	07-02-92	1100	.29	.114	.392	17.0	61	210	189.0
07-04-92	2215	07-05-92	0100	.18	.140	.780	16.0	23	165	62.9
07-05-92	0621	07-05-92	1400	.41	.254	.620	11.8	294	440	8.1
07-07-92	0332	07-07-92	0600	.06	.018	.305	2.3	91	150	45.2
07-09-92	1301	07-09-92	1900	.29	.084	.291	4.8	159	330	57.5
[4]07-18-92	2304	07-19-92	0615	1.49	.721	.484	60.1	39	413	145.5
07-21-92	2355	07-22-92	0530	.53	.059	.112	12.2	250	300	72.9
07-24-92	1345	07-24-92	1520	.07	.003	.044	1.2	55	70	61.8

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration				Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
First rainfall		End of runoff								
Date	Time	Date	Time							
Industrial (site 3)--Continued										
07-24-92	1945	07-24-92	2155	.18	.022	.121	7.8	5	125	6.0
07-25-92	1800	07-25-92	2020	.29	.041	.141	17.4	5	140	22.3
07-28-92	0545	07-28-92	0830	.29	.037	.128	12.1	175	155	59.7
07-28-92	1510	07-28-92	1600	.05	.002	.037	1.4	15	30	9.4
07-30-92	0040	07-30-92	0610	1.16	.204	.176	44.4	270	310	33.5
08-02-92	0410	08-02-92	0830	0.52	0.094	0.180	21.0	140	240	75.5
08-07-92	0320	08-07-92	1600	1.76	.345	.196	103.7	90	740	119.2
08-12-92	0520	08-12-92	0835	.14	.018	.130	4.9	90	185	122.0
08-25-92	0855	08-25-92	1440	.20	.038	.192	4.1	350	315	315.6
09-01-92	1320	09-01-92	2210	.26	.035	.135	5.1	500	515	172.4
09-02-92	0120	09-02-92	0735	1.24	.214	.172	38.8	185	370	12.0
09-05-92	0710	09-05-92	1130	.83	.175	.211	59.4	75	250	77.8
09-05-92	1630	09-05-92	1825	.05	.013	.255	2.7	1	105	9.3
09-09-92	0555	09-09-92	0810	.04	.010	.242	2.6	35	115	85.4
09-14-92	0525	09-14-92	2255	1.42	.423	.298	35.7	430	1,045	119.5
09-17-92	2210	09-18-92	0100	.46	.363	.789	32.2	110	--	88.7
09-26-92	0015	09-26-92	0520	.35	.027	.077	5.2	300	235	194.1
10-07-92	1705	10-08-92	0935	2.08	.815	.392	14.5	1,119	950	280.8
04-12-93	0846	04-12-93	1700	.29	.080	.276	6.1	310	480	--
04-13-93	0857	04-13-93	1400	.07	.015	.219	3.6	105	300	24.2
04-15-93	1447	04-16-93	0100	.19	.079	.415	3.8	420	600	53.8
04-17-93	0844	04-17-93	1400	.22	.097	.443	12.2	75	305	42.0
04-18-93	0235	04-19-93	1100	.24	.096	.398	9.1	273	495	17.9
04-19-93	1840	04-20-93	0400	.24	.130	.541	6.6	350	540	40.1
05-11-93	1524	05-11-93	2100	.07	.027	.380	1.5	81	315	524.7
05-19-93	1005	05-19-93	1800	.08	.010	.129	1.7	90	480	186.7
05-22-93	0525	05-22-93	1200	.49	.222	.454	20.2	175	360	254.0
05-23-93	0220	05-23-93	0900	.31	.144	.465	10.9	105	420	20.9
05-30-93	0546	05-30-93	1100	.18	.037	.203	9.8	99	300	167.5
06-01-93	1355	06-02-93	0400	.22	.076	.344	6.3	531	840	60.1

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration										
First rainfall		End of runoff		Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak dis-charge (ft^3/s)	Rainfall dura-tion (min)	Runoff dura-tion (min)	Time since previous storm (hrs)
Date	Time	Date	Time							
				Industrial (site 3)--Continued						
06-03-93	1645	06-04-93	1400	.65	.332	.511	9.7	960	900	50.8
06-06-93	0335	06-06-93	1400	.42	.176	.418	14.1	420	660	58.8
06-11-93	1735	06-12-93	0300	.44	.119	.271	15.7	306	480	134.0
06-13-93	0340	06-13-93	1200	.57	.213	.374	15.1	405	540	34.1
06-17-93	1755	06-17-93	2130	.36	.144	.400	13.0	147	215	110.3
06-18-93	0240	06-18-93	2100	1.19	.582	.489	65.9	810	1,020	8.8
06-19-93	0610	06-19-93	1200	.12	.033	.274	1.5	186	300	27.5
06-23-93	0325	06-23-93	1100	0.09	0.008	0.093	0.6	300	240	93.3
06-24-93	0150	06-24-93	1200	.93	.376	.405	26.1	330	600	116.0
06-28-93	0100	06-28-93	1300	1.70	.661	.389	55.3	510	720	95.2
06-30-93	1632	06-30-93	2400	.32	.084	.262	13.0	290	420	60.6
07-04-93	0130	07-04-93	0600	.09	.010	.111	1.3	150	300	83.9
07-05-93	0150	07-05-93	1800	.62	.252	.407	7.1	810	780	24.3
07-07-93	0530	07-07-93	1300	.36	.142	.394	5.9	221	420	51.7
07-08-93	0425	07-08-93	1000	.31	.134	.434	17.1	117	360	22.9
07-08-93	1930	07-09-93	0900	.45	.188	.418	13.0	480	600	15.1
07-10-93	0310	07-10-93	0900	.41	.202	.493	30.6	150	300	31.7
07-11-93	0125	07-11-93	0900	.65	.267	.411	45.2	15	480	22.3
07-13-93	0430	07-13-93	1300	.88	.363	.413	50.2	105	540	51.1
07-13-93	2105	07-14-93	0100	.05	.012	.242	.1	40	240	22.1
07-17-93	1340	07-18-93	0200	.24	.058	.243	1.6	528	600	88.6
07-20-93	0915	07-20-93	1600	.27	.045	.168	2.0	192	420	67.6
07-21-93	1125	07-22-93	2000	2.18	1.186	.544	64.7	1,350	1,980	26.2
07-23-93	0135	07-23-93	1700	.87	.439	.504	27.5	546	960	38.2
07-24-93	0550	07-24-93	1300	.22	.090	.411	3.9	150	420	28.3
07-24-93	2000	07-25-93	1900	1.29	.798	.618	109.7	156	1,440	14.2
07-26-93	1245	07-26-93	1900	.07	.031	.439	1.4	48	360	40.8
07-27-93	0840	07-27-93	1400	.04	.014	.362	.6	70	300	19.9
07-31-93	1615	07-31-93	2000	.09	.021	.235	2.1	174	240	103.6
08-05-93	0630	08-05-93	1200	.07	.012	.171	.8	204	360	110.3

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration: First rainfall Date	First rainfall Time	End of runoff Date	End of runoff Time	Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak dis-charge (ft^3/s)	Rainfall dura-tion (min)	Runoff dura-tion (min)	Time since previous storm (hrs)
				Industrial (site 3)--Continued						
08-11-93	1555	08-11-93	2000	.22	.063	.287	7.4	96	300	153.4
08-12-93	1910	08-13-93	0100	.39	.150	.384	30.4	35	360	27.3
08-13-93	0420	08-13-93	0800	.03	.006	.201	.1	15	60	9.2
08-15-93	0720	08-15-93	1100	.02	.008	.418	.5	5	240	51.0
08-17-93	0245	08-17-93	0700	.17	.046	.270	5.8	25	300	43.4
08-19-93	0125	08-19-93	1000	.29	.083	.287	4.6	190	480	46.7
08-21-93	1235	08-21-93	1900	.11	.029	.266	3.4	45	240	59.2
08-23-93	0220	08-23-93	0700	.08	.017	.211	1.2	50	300	37.8
				Residential, multiple-dwelling (site 4)						
05-22-92	1317	05-23-92	0000	0.11	0.010	0.091	2.2	210	435	--
05-25-92	0410	05-25-92	1900	.20	.026	.130	2.8	408	855	62.9
[3]05-31-92	2202	06-01-92	0518	.16	.025	.156	1.3	600	377	161.9
06-01-92	0858	06-01-92	1157	.04	.021	.515	1.4	76	280	10.9
06-05-92	2010	06-06-92	0106	.29	.025	.087	6.9	136	480	107.2
[4]06-16-92	2249	06-17-92	1000	.59	.042	.071	23.3	510	600	266.4
06-24-92	1005	06-24-92	1600	.14	.007	.052	2.2	105	315	179.2
07-02-92	0720	07-02-92	1228	.49	.050	.102	14.4	180	300	189.2
07-04-92	2145	07-05-92	1630	.91	.130	.143	34.4	802	1,110	62.4
07-07-92	0328	07-07-92	0830	.08	.008	.094	2.0	29	300	53.7
07-11-92	0925	07-11-92	1635	.77	.116	.151	25.2	350	405	102.0
07-12-92	0340	07-12-92	1615	1.76	.381	.216	129.6	160	750	18.2
07-12-92	2155	07-13-92	1310	.93	.219	.235	29.9	620	900	18.3
07-21-92	2355	07-22-92	1350	.92	.137	.148	37.5	415	615	218.0
07-24-92	1340	07-24-92	2020	.48	.081	.168	32.6	55	390	61.8
07-25-92	1755	07-25-92	2335	.27	.049	.181	22.2	5	335	28.3
07-28-92	0530	07-28-92	2040	.58	.101	.174	30.2	55	860	59.6
07-30-92	0020	07-30-92	1120	.89	.211	.238	96.5	220	610	42.8
08-02-92	0405	08-02-92	1645	.69	.158	.228	45.0	140	740	75.8
08-07-92	0330	08-07-92	1010	1.13	.244	.216	134.4	110	385	119.4

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration: First rainfall Date	Storm duration: First rainfall Time	Storm duration: End of runoff Date	Storm duration: End of runoff Time	Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
Residential, multiple-dwelling (site 4)--Continued										
08-12-92	0525	08-12-92	0720	.08	.010	.128	1.4	140	60	121.9
08-25-92	0745	08-25-92	1500	.63	.060	.095	10.5	330	415	314.3
09-01-92	1325	09-02-92	0830	.81	.107	.131	9.5	162	895	173.7
09-02-92	2130	09-03-92	0025	.08	.003	.040	3.5	1	150	32.1
09-05-92	0705	09-05-92	1840	.41	.061	.148	17.2	42	680	57.6
09-07-92	0100	09-07-92	0725	.17	.017	.102	2.8	18	170	41.9
09-14-92	0525	09-14-92	1540	1.23	.065	.053	46.3	142	590	172.4
09-15-92	0840	09-15-92	1110	.06	.002	.030	2.0	10	110	27.3
09-17-92	2215	09-18-92	0250	.24	.007	.027	5.0	31	245	61.6
09-26-92	0010	09-26-92	0725	.25	.009	.034	4.0	63	370	193.9
10-07-92	0115	10-08-92	2245	2.08	0.480	0.231	32.2	1,435	1,745	265.1
10-31-92	1717	11-01-92	0030	1.48	.235	.159	10.0	1,806	1,890	592.0
05-06-93	1245	05-07-93	0500	1.46	.060	.040	19.6	555	540	--
05-07-93	2235	05-09-93	0300	.51	.043	.085	4.0	1,465	1,620	33.8
05-09-93	2010	05-10-93	2300	.87	.138	.159	10.5	990	1,560	45.6
05-11-93	0015	05-11-93	1100	.10	.012	.117	1.8	150	600	28.1
05-11-93	1520	05-12-93	0100	.40	.017	.042	3.5	135	540	15.1
05-19-93	0949	05-19-93	1300	.06	.002	.041	.4	83	150	186.5
05-22-93	0550	05-22-93	1200	.48	.038	.080	10.7	135	360	68.0
05-23-93	0220	05-23-92	0900	.30	.033	.110	6.7	120	420	20.5
05-30-93	0140	05-30-92	0900	.21	.005	.023	2.1	285	300	167.3
06-01-93	2240	06-02-93	0600	.21	.013	.062	2.7	195	420	69.0
06-03-93	2015	06-04-93	1800	.76	.160	.211	19.0	305	1,260	25.4
06-06-93	0145	06-06-93	1900	.66	.159	.241	38.2	78	960	53.5
06-11-93	1915	06-12-93	0600	.96	.182	.190	58.9	225	660	137.5
06-13-93	0330	06-13-93	1700	1.04	.243	.233	37.3	420	840	32.3
06-17-93	1800	06-18-93	0100	.28	.035	.123	7.5	115	360	110.5
06-18-93	0355	06-19-93	0100	1.71	.445	.260	155.8	735	1,320	9.9
06-19-93	0150	06-19-93	1400	.12	.020	.167	2.1	480	480	21.9
06-23-93	0145	06-23-93	1800	.19	.016	.082	1.4	320	840	95.9

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration				Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
First rainfall		End of runoff								
Date	Time	Date	Time							
				Residential, multiple-dwelling (site 4)--Continued						
06-24-93	0155	06-24-93	1700	.88	.185	.210	27.0	360	900	24.2
06-28-93	0050	06-28-93	2000	.73	.143	.195	23.5	555	1,140	94.9
06-30-93	1755	07-01-93	0100	.35	.072	.205	22.9	130	480	65.1
07-04-93	0120	07-04-93	1000	.09	.019	.212	3.9	175	480	79.4
07-05-93	0415	07-05-93	2100	.77	.179	.233	17.1	660	960	26.9
07-07-93	0525	07-07-93	2300	.35	.096	.274	11.1	210	1,020	49.2
07-08-93	0425	07-08-93	1600	.47	.156	.332	50.7	150	720	23.0
07-08-93	1930	07-09-93	0900	.41	.122	.298	21.4	465	780	15.1
[4]07-10-93	0405	07-10-93	1400	.17	.065	.379	12.9	10	600	32.6
[4]07-11-93	0125	07-11-93	1700	.33	.176	.534	71.2	20	960	21.3
07-13-93	0400	07-13-93	1800	1.60	0.249	0.155	87.4	70	840	50.6
07-13-93	2055	07-14-93	0600	.43	.190	.442	44.2	45	540	16.9
07-14-93	0905	07-14-93	1300	.07	.018	.255	5.8	10	240	12.2
07-16-93	0925	07-16-93	1900	.09	.031	.344	4.5	255	540	48.3
07-17-93	1320	07-18-93	0700	.20	.066	.330	4.8	525	1,080	27.9
07-20-93	0855	07-20-93	1700	.29	.052	.178	6.6	285	480	67.6
07-21-93	0920	07-23-93	2100	3.06	1.110	.363	277.0	2,085	3,600	24.4
07-24-93	0525	07-25-93	1800	1.82	.655	.360	245.8	975	2,280	68.1
07-26-93	1230	07-26-93	1800	.09	.021	.231	3.0	65	360	55.1
07-27-93	0830	07-27-93	1300	.04	.012	.295	1.6	40	300	20.0
					Commercial (site 5)					
05-22-92	1554	05-22-92	2000	.14	.010	.071	.9	84	240	--
05-25-92	0422	05-25-92	1200	.21	.010	.048	.7	121	450	60.5
06-05-92	2009	06-05-92	2250	.35	.015	.043	2.0	143	165	279.8
06-17-92	0000	06-17-92	0430	.51	.039	.077	26.7	29	270	267.9
06-24-92	1015	06-24-92	1300	.15	.005	.033	1.0	84	180	178.3
07-02-92	0720	07-02-92	1300	.41	.022	.054	6.4	75	345	189.1
07-04-92	2149	07-05-92	0300	.33	.026	.078	8.9	29	300	62.5
07-05-92	0602	07-05-92	1500	.44	.027	.061	1.8	310	525	8.2
07-07-92	0327	07-07-92	0600	.13	.005	.040	1.9	37	150	45.4
07-11-92	0935	07-11-92	1500	.75	.064	.086	9.8	106	330	102.1

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration										
First rainfall		End of runoff		Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak discharge (ft^3/s)	Rainfall duration (min)	Runoff duration (min)	Time since previous storm (hrs)
Date	Time	Date	Time							
Commercial (site 5)--Continued										
07-12-92	0325	07-12-92	0800	1.89	--	--	--	166	285	.3
07-12-92	2155	07-13-92	0730	1.09	.101	.092	13.5	480	570	18.5
07-22-92	0015	07-22-92	0500	.95	.090	.094	25.9	210	300	218.3
07-24-92	1340	07-24-92	1600	.68	.074	.109	29.2	55	130	61.4
07-25-92	1755	07-25-92	2000	.37	.033	.088	29.3	10	120	28.3
07-28-92	0535	07-28-92	0800	.64	.063	.099	35.6	60	150	59.7
07-30-92	0040	07-30-92	0420	.80	.125	.156	19.0	200	210	43.1
08-02-92	0405	08-02-92	0800	.71	.072	.102	40.7	140	225	75.4
08-07-92	0325	08-07-92	0655	1.73	--	--	--	105	200	119.5
08-12-92	0525	08-12-92	0700	.09	.004	.048	.7	30	90	146.6
08-25-92	0745	08-25-92	1200	.67	.037	.056	7.6	255	245	289.7
09-01-92	1325	09-01-92	1930	.17	.001	.008	1.1	285	150	173.7
09-02-92	0000	09-02-92	0530	.54	.046	.085	4.9	265	300	10.6
09-02-92	2130	09-02-92	2200	0.04	0.004	0.097	1.7	1	30	21.5
09-05-92	0720	09-05-92	0930	.11	.019	.174	4.1	65	125	57.8
09-09-92	0555	09-09-92	0800	.05	.007	.142	.3	35	115	94.6
09-14-92	0525	09-14-92	1300	1.57	.272	.173	38.1	150	450	119.5
09-17-92	2210	09-18-92	0100	.41	.052	.126	16.9	120	160	88.7
09-26-92	0010	09-26-92	0500	.32	.039	.121	3.4	195	270	194.0
10-07-92	0425	10-07-92	0520	.06	.003	.057	1.9	20	35	268.2
10-07-92	1635	10-08-92	1600	2.32	.529	.228	11.8	1,470	1,370	12.2
10-31-92	1711	10-31-92	1830	.14	.005	.037	2.8	34	75	576.6
11-01-92	1250	11-02-92	0600	1.42	.325	.229	8.2	969	1,020	19.7
[3]04-12-93	0846	04-12-93	1400	.29	.070	.241	4.1	310	300	--
[3]04-13-93	0857	04-13-93	1400	.07	.009	.132	1.1	105	195	24.2
[3]04-15-93	1447	04-15-93	2330	.19	.028	.147	8.6	420	465	53.8
04-17-93	0844	04-17-93	1400	.22	.060	.271	24.2	75	315	42.0
05-06-93	1300	05-07-93	0200	.18	.131	.727	26.7	15	540	460.3
[2]05-07-93	2235	05-09-93	0100	.51	.120	.235	3.3	1,465	1,380	33.6
[2]05-09-93	2010	05-10-93	2200	.87	.299	.344	7.4	990	1560	45.6

Table 2. Storm rainfall and runoff characteristics for five sites, Omaha, Nebraska, 1992-93--Continued

Storm duration										
First rainfall		End of runoff								
Date	Time	Date	Time	Rainfall, total (in.)	Runoff volume, total (in.)	Runoff-rainfall ratio	Peak dis-charge (ft^3/s)	Rainfall dura-tion (min)	Runoff dura-tion (min)	Time since previous storm (hrs)
				Commercial (site 5)--Continued						
[2]05-11-93	0015	05-11-93	0900	.10	.025	.245	3.1	150	540	28.1
05-11-93	1450	05-11-93	2300	.12	.040	.333	1.8	143	480	14.6
05-19-93	0949	05-19-93	1300	.04	.005	.113	1.9	83	150	187.0
05-22-93	0140	05-22-93	1100	.18	.049	.270	7.1	115	300	250
05-23-93	0225	05-23-93	0800	.20	.046	.228	3.5	105	360	24.8
05-30-93	0540	05-30-93	0800	.03	.005	.168	2.0	20	180	171.3
06-01-93	2245	06-02-93	0300	.15	.036	.238	4.0	80	300	65.1
06-03-93	2055	06-04-93	1300	.50	.132	.265	5.4	270	840	46.2
06-06-93	0330	06-06-93	1300	.35	.103	.295	26.6	85	660	54.6
06-11-93	1930	06-12-93	0300	.42	.159	.379	30.4	135	480	136.0
06-13-93	0355	06-13-93	2000	.43	--	--	--	340	1,020	--
[2]06-17-93	1800	06-17-93	2100	.28	.029	.099	3.1	115	540	110.1
[2]06-19-93	0150	06-19-93	1100	.12	--	--	--	480	1,200	31.8
06-23-93	0320	06-23-93	0800	.01	.005	.473	.8	5	180	97.5
[2]06-24-93	0155	06-24-93	1100	.88	.161	.183	25.9	360	540	120
[2]06-28-93	0050	06-28-93	1200	73	0.108	0.148	9.8	555	660	94.9
[2]06-30-93	1755	07-01-93	0100	.35	.050	.144	23.3	130	480	65.1
[2]07-04-93	0120	07-04-93	0500	.09	.007	.080	2.5	175	180	79.4
[2]07-05-93	0415	07-05-93	1700	.77	.145	.188	5.0	660	720	26.9
[2]07-07-93	0525	07-07-93	1300	.35	.072	.207	3.8	210	480	49.2
[2]07-08-93	0425	07-09-93	0500	.41	.090	.220	94.7	610	1,200	23.0
[4]07-10-93	0405	07-10-93	1400	.17	.019	.109	5.9	10	300	47.7
[4]07-11-93	0125	07-11-93	0600	.33	.134	.405	43.3	20	300	21.3
07-16-93	0922	07-16-93	1600	.18	.017	.094	5.5	267	390	128.0
07-17-93	1316	07-17-93	2400	.25	.026	.106	1.3	441	630	27.9
07-20-93	0900	07-20-93	1200	.30	.028	.094	4.0	82	180	67.7

[1] Rain data collected from site 5.
[2] Rain data collected from site 3.
[3] Rain data collected from site 4.
[4] Rain data collected from site 2.

APPENDIX B—WATER-QUALITY DATA COLLECTED FROM FIVE SITES, OMAHA, NEBRASKA, 1992-93

Table 3. Constituents and properties and detection limits in water samples collected at the five monitoring sites from six stormwater-runoff events, Omaha, Nebraska, 1992-93

[See figure 2 for site locations. µg/L, microgram per liter; --, not analyzed; mg/L, milligram per liter; D, detected in one or more samples; N, not detected; tons/acre-ft, tons per acre-foot; cols/100mL, colonies per 100 milliliters; NA, not applicable; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Constituent or property	Analytical detection limit	Unit	Site number (fig. 2)				
			1	2	3	4	5
Volatile organic compounds							
Acrolein, total	20	µg/L	N	N	N	N	N
Acrylonitrile, total	20	µg/L	N	N	N	N	N
Benzene, total	.2	µg/L	N	N	N	N	N
Bromoform, total	.2	µg/L	N	N	N	N	N
Carbon tetrachloride, total	.2	µg/L	N	N	N	N	N
Chlorobenzene	.2	µg/L	N	N	N	N	N
Chlorodibromomethane	.2	µg/L	N	N	N	N	N
Chloroethane	.2	µg/L	N	N	N	N	N
2-Chloroethylvinyl ether	1	µg/L	N	N	N	N	N
Chloroform	.2	µg/L	N	N	D	D	D
Dichlorobromomethane	.2	µg/L	N	N	N	D	D
1,1-Dichloroethane	.2	µg/L	N	N	N	N	N
1,2-Dichloroethane	.2	µg/L	N	N	N	N	N
1,1-Dichloroethylene	.2	µg/L	N	N	N	N	N
1,2-Dichloropropane	.2	µg/L	N	N	N	N	N
1,3-Dichloropropylene	.2	µg/L	N	N	N	N	N
Ethylbenzene	.2	µg/L	N	N	N	N	N
Methyl bromide	.2	µg/L	N	N	N	N	N
Methyl chloride	.2	µg/L	D	N	D	D	D
Methylene chloride	.2	µg/L	N	N	N	N	N
1,1,2,2-Tetrachloroethane	.2	µg/L	N	N	N	N	N
Tetrachloroethylene	.2	µg/L	N	N	N	N	N
Toluene	.2	µg/L	D	N	N	D	N
1,2-Transdichloroethylene	.2	µg/L	N	N	N	N	N
1,1,1-Trichloroethane	.2	µg/L	N	N	N	N	N
1, 1, 2-Trichloroethane	.2	µg/L	N	N	N	N	N
Trichloroethylene	.2	µg/L	N	N	N	N	N
Vinyl chloride	.2	µg/L	N	N	N	N	N

Table 3. Constituents and properties and detection limits in water samples collected at the five monitoring sites from six stormwater-runoff events, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Analytical detection limit	Unit	Site number (fig. 2)				
			1	2	3	4	5
		Acid organic compounds					
2-Chlorophenol	5	µg/L	N	N	N	N	N
2,4-Dichlorophenol	5	µg/L	N	N	N	N	N
2,4-Dimethylphenol	5	µg/L	N	N	N	N	N
4,6-Dinitro-O-cresol	30	µg/L	N	N	N	N	N
2-Nitrophenol	5	µg/L	N	N	N	N	N
4-Nitrophenol	30	µg/L	N	N	N	N	N
P-Choloro-M-cresol	30	µg/L	N	N	N	N	N
Pentachlorophenol	30	µg/L	N	N	N	N	N
Phenol	5	µg/L	N	N	N	N	N
2,4,6-Trichlorophenol	20	µg/L	N	N	N	N	N
		Base/neutral organic compounds					
Acenaphthalene	5	µg/L	N	N	N	N	N
Acenaphthene	5	µg/L	N	N	N	N	N
Anthracene	5	µg/L	N	N	N	N	D
Benzidine	40	µg/L	N	N	N	N	N
Benzo-A-anthracene	10	µg/L	N	N	N	N	D
Benzo-A-pyrene	10	µg/L	N	N	N	N	D
3,4-Benzofluoranthene	10	µg/L	N	N	N	N	D
2,4-Benzo(ghi)perylene	10	µg/L	N	N	N	N	D
Benzo(k)fluoranthene	10	µg/L	N	N	N	N	D
Bis (2-Chloroethoxy) methane	5	µg/L	N	N	N	N	N
Bis (2-Chloroethyl) ether	5	µg/L	N	N	N	N	N
Bis (2-Chloroisopropyl) ether	5	µg/L	N	N	N	N	N
Bis (2-ethylhexyl) phthalate	5	µg/L	D	D	D	D	N
4-Bromophenyl phenyl ether	5	µg/L	N	N	N	N	N
Butylbenzyl phthalate	5	µg/L	N	N	N	N	N
2-Chloronaphthalene	5	µg/L	N	N	N	N	N
4-Chlorophenyl phenyl ether	5	µg/L	N	N	N	N	N
Chrysene	10	µg/L	N	N	N	N	D
Dibenzo (A,H) anthracene	10	µg/L	N	N	N	N	N
1,2-Dichlorobenzene	5	µg/L	N	N	N	N	N
1,3-Dichlorobenzene	5	µg/L	N	N	N	N	N
1,4-Dichlorobenzene	5	µg/L	N	N	N	N	N
3,3-Dichlorobenzidine	20	µg/L	N	N	N	N	N
Diethyl phthalate	5	µg/L	N	N	N	N	N
Dimethyl phthalate	5	µg/L	N	N	N	N	N

Table 3. Constituents and properties and detection limits in water samples collected at the five monitoring sites from six stormwater-runoff events, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Analytical detection limit	Unit	Site number (fig. 2) 1	2	3	4	5
Base/neutral organic compounds--Continued							
Di-N-butyl phthalate	5	µg/L	N	N	N	N	N
2,4-Dinitrotoluene	5	µg/L	N	N	N	N	N
2,6-Dinitrotoluene	5	µg/L	N	N	N	N	N
Di-N-octyl phthlate	10	µg/L	N	N	N	N	N
1,2-Diphenylhydrazine (azobenzene)	5	µg/L	N	N	N	N	N
Fluoranthene	5	µg/L	D	D	D	N	D
Fluorene	5	µg/L	N	N	N	N	N
Hexachlorobenzene	5	µg/L	N	N	N	N	N
Hexachlorobutadiene	5	µg/L	N	N	N	N	N
Hexachlorocyclopentadiene	5	µg/L	N	N	N	N	N
Hexachloroethane	5	µg/L	N	N	N	N	N
Indeno (1,2,3-CD) pyrene	10	µg/L	N	N	N	N	D
Isophorone	5	µg/L	N	N	N	N	N
Napthalene	5	µg/L	N	N	N	N	N
Nitrobenzene	5	µg/L	N	N	N	N	N
N-Nitrosodimethylamine	5	µg/L	N	N	N	N	N
N-Nitrosodi-N-propylamine	5	µg/L	N	N	N	N	N
N-Nitrosodiphenylamine	5	µg/L	N	N	N	N	N
Phenanthrene	5	µg/L	N	N	D	N	D
Pyrene	5	µg/L	D	N	D	N	D
Pesticides and polychlorinated biphenyls							
Aldrin	0.04	µg/L	N	N	N	N	N
Alpha-BHC	.03	µg/L	N	N	N	N	N
Beta-BHC	.03	µg/L	N	N	N	N	N
Gamma-BHC	.03	µg/L	N	N	N	N	N
Delta-BHC	.09	µg/L	N	N	N	N	N
Chlordane	.1	µg/L	N	D	D	D	N
4,4'-DDT	.1	µg/L	N	N	D	N	N
4,4'-DDE	.04	µg/L	N	N	D	N	N
4,4'-DDD	.1	µg/L	N	N	N	N	N
Dieldrin	.02	µg/L	N	N	N	N	N

Table 3. Constituents and properties and detection limits in water samples collected at the five monitoring sites from six stormwater-runoff events, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Analytical detection limit	Unit	Site number (fig. 2) 1	2	3	4	5
		Pesticides and polychlorinated biphenyls--Continued					
Alpha-endosulfan	.1	μg/L	N	N	N	N	N
Beta-endosulfan	.04	μg/L	N	N	N	N	N
Endosulfan sulfate	.6	μg/L	N	N	N	N	N
Endrin	0.06	μg/L	N	N	N	N	N
Endrin aldehyde	.2	μg/L	N	N	N	N	N
Heptachlor	.03	μg/L	N	N	N	N	N
Heptachlor epoxide	.8	μg/L	N	N	N	N	N
PCB-1242	.1	μg/L	N	N	N	D	N
PCB-1254	.1	μg/L	N	N	D	D	N
PCB-1221	.1	μg/L	N	N	N	N	N
PCB-1232	.1	μg/L	N	N	N	N	N
PCB-1248	.1	μg/L	N	N	N	N	N
PCB-1260	.1	μg/L	N	N	N	N	N
PCB-1016	.1	μg/L	N	N	N	N	N
Toxaphene	2	μg/L	N	N	N	N	N
Diazinon	.01	μg/L	D	--	--	D	--
Carbaryl	.01	μg/L	N	--	--	D	N
2,4-D	.01	μg/L	D	--	--	D	D
		Trace elements, cyanide, and total phenols					
Antimony, total	10	μg/L	N	N	N	N	N
Arsenic, total	1	μg/L	D	D	D	D	D
Beryllium, total	10	μg/L	D	N	N	N	N
Cadmium, total	1	μg/L	N	N	D	N	N
Chromium, total	1	μg/L	D	D	D	D	D
Copper, total	1	μg/L	D	D	D	D	D
Cyanide, total	10	μg/L	N	N	N	N	N
Lead, total	1	μg/L	D	D	D	D	D
Mercury, total	.1	μg/L	N	N	D	D	N
Nickel, total	1	μg/L	D	D	D	D	D
Phenols, total	1	μg/L	D	D	D	D	D
Selenium, total	2	μg/L	N	N	N	N	N
Silver, total	1	μg/L	N	N	N	N	N
Thallium, total	10	μg/L	N	N	N	N	N
Zinc, total	10	μg/L	D	D	D	D	D

Table 3. Constituents and properties and detection limits in water samples collected at the five monitoring sites from six stormwater-runoff events, Omaha, Nebraska, 1992-93--Continued

Constituent or property	Analytical detection limit	Unit	Site number (fig. 2) 1	2	3	4	5
Other conventional constituents or properties							
Biochemical oxygen demand	18	mg/L	D	D	D	D	D
Chemical oxygen demand	10	mg/L	D	D	D	D	D
Suspended solids, total	1	mg/L	D	D	D	D	D
Dissolved solids, total	NA	tons/acre-ft	D	D	D	D	D
Fecal coliform	NA	cols/100mL	D	D	D	D	D
Fecal streptococcus	NA	cols/100 mL	D	D	D	D	D
Nitrogen, total, as nitrogen	0.1	mg/L as N	D	D	D	D	D
Nitrogen, ammonia plus organic, total	.2	mg/L as N	D	D	D	D	D
Phosphorous, total, as phosphorous	.01	mg/L as P	D	D	D	D	D
Phosphorous, dissolved, as phosphorous	.01	mg/L as P	D	D	D	D	D
Oil and grease	1	mg/L	D	D	D	D	D
Major ions, properties, and total organic carbon							
Alkalinity, total	1	mg/L as $CaCO_3$	D	D	D	D	D
Calcium, dissolved	.1	mg/L as Ca	D	D	D	D	D
Chloride, dissolved	.01	mg/L as Cl	D	D	D	D	D
Magnesium, dissolved	.1	mg/L as Mg	D	D	D	D	D
Potassium, dissolved	.1	mg/L as K	D	D	D	D	D
Sodium, dissolved	.1	mg/L as Na	D	D	D	D	D
Sulfate, dissolved	.01	mg/L as SO_4	D	D	D	D	D
pH	.1	Standard units	NA	NA	NA	NA	NA
Specific conductance	1	µS/cm	D	D	D	D	D
Total organic carbon	.1	mg/L as C	D	D	D	D	D

Table 4. Concentrations of volatile organic compounds in stormwater-runoff in grab samples from five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site location. All units are in micrograms per liter; --, no data; N, not detected; MCL, Maximum Contaminant Level. Analytical detection limits for constituents are in appendix B, table 3]

Site	Date sampled	Chloroform	Dichloro-bromomethane	Methyl chloride	Toluene
		MCL[1]: 100	100	--	1,000
1	06-05-92	N	N	N	N
	07-02-92	N	N	N	N
	08-25-92	N	N	N	N
	10-07-92	N	N	0.4	0.2
	05-22-93	N	N	N	N
	06-17-93	N	N	N	N
2	06-05-92	N	N	N	N
	07-02-92	N	N	N	N
	08-25-92	N	N	N	N
	06-17-93	N	N	N	N
	06-24-93	N	N	N	N
	08-19-93	N	N	N	N
3	05-22-92	N	N	N	N
	07-02-92	N	N	N	N
	10-07-92	1.0	N	.5	N
	05-22-93	N	N	N	N
	06-17-93	N	N	N	N
	06-24-93	N	N	N	N
4	06-17-92	N	N	N	.9
	07-02-92	1.0	0.2	N	2.9
	08-25-92	.2	N	N	.4
	10-07-92	.2	N	.3	N
	05-22-93	N	N	N	.2
	06-17-93	7.0	.4	N	N
5	06-05-92	N	N	N	N
	06-17-92	.4	.2	.2	N
	07-02-92	N	N	N	N
	05-22-93	N	N	N	N
	06-17-93	N	N	N	N
	06-24-93	N	N	N	N

[1] Maximum Contaminant Level. The highest concentration of a solute permissible in a public-water supply, as specified in the national Primary Drinking-Water Standards established under the Safe Drinking Water Act by the U.S. Environmental Protection Agency (1996).

Table 5. Concentrations of base/neutral organic compounds in stormwater-runoff flow-weighted composite samples collected from five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site location. All units are in micrograms per liter; --, no data; N, not detected; MCL, Maximum Contaminant Level. Analytical limits for the compounds are listed in appendix B, table 3]

Site	Date sampled	Anthracene	Benzo-A-anthracene	Benzo-A-pyrene	3,4-Benzo-fluor-anthene	2,4-Benzo-(ghi) perylene	Benzo-(k)fluor-anthene	Bis (2-ethyl-hexyl) phthalate	Chrysene	Fluor-anthene	Indeno-(1,2,3-CD) pyrene	Phen-anthrene	Pyrene
		MCL[1]: --	0.1	0.2	0.2	--	0.2	--	0.2	--	0.4	--	--
1	06-05-92	N	N	N	N	N	N	N	N	7	N	N	6
	07-02-92	N	N	N	N	N	N	N	N	N	N	N	N
	08-25-92	N	N	N	N	N	N	7	N	N	N	N	N
	10-07-92	N	N	N	N	N	N	7	N	N	N	N	N
	05-22-93	N	N	N	N	N	N	N	N	6	N	N	N
	06-17-93	N	N	N	N	N	N	6	N	N	N	N	N
2	06-05-92	N	N	N	N	N	N	N	N	N	N	N	N
	07-02-92	N	N	N	N	N	N	N	N	N	N	N	N
	08-25-92	N	N	N	N	N	N	6	N	5	N	N	N
	06-17-93	N	N	N	N	N	N	N	N	N	N	N	N
	06-24-93	N	N	N	N	N	N	N	N	N	N	N	N
	08-19-93	N	N	N	N	N	N	N	N	N	N	N	N
3	05-22-92	N	N	N	N	N	N	6	N	7	N	N	6
	07-02-92	N	N	N	N	N	N	N	N	N	N	N	N
	10-07-92	N	N	N	N	N	N	7	N	N	N	N	N
	05-22-93	N	N	N	N	N	N	6	N	13	N	6	9
	06-17-93	--	--	--	--	--	--	--	--	--	--	--	--
	06-24-93	N	N	N	N	N	N	N	N	5	N	N	N

Table 5. Concentrations of base/neutral organic compounds in stormwater-runoff flow-weighted composite samples collected from five sites, Omaha, Nebraska, 1992-93--Continued

Site	Date sampled	Anthracene	Benzo-A-anthracene	Benzo-A-pyrene	3,4-Benzo-fluor-anthene	2,4-Benzo-(ghi) perylene	Benzo-(k)fluor-anthene	Bis (2-ethyl-hexyl) phthalate	Chrysene	Fluor-anthene	Indeno-(1,2,3-CD) pyrene	Phen-anthrene	Pyrene
		MCL[1]: --	0.1	0.2	0.2	--	0.2	--	0.2	--	0.4	--	--
4	06-17-92	N	N	N	N	N	N	N	N	N	N	N	N
	07-02-92	N	N	N	N	N	N	N	N	N	N	N	N
	08-25-92	N	N	N	N	N	N	N	N	N	N	N	N
	10-07-92	N	N	N	N	N	N	17	N	N	N	N	N
	05-22-93	N	N	N	N	N	N	N	N	N	N	N	N
	06-17-93	N	N	N	N	N	N	N	N	N	N	N	N
5	06-05-92	N	N	N	N	N	N	N	N	N	N	N	N
	06-17-92	N	N	N	N	N	N	N	N	N	N	N	N
	07-02-92	N	N	N	N	N	N	N	N	N	N	N	N
	05-22-93	9	36	43	53	32	38	N	57	150	30	73	110
	06-17-93	N	N	N	N	N	N	N	N	N	N	N	N
	06-24-93	N	N	N	N	N	N	N	10	N	N	11	20

[1]Maximum Contaminant Level. The highest concentration of a solute permissible in a public-water supply, as specified in the national Primary Drinking-Water Standards established under the Safe Drinking Water Act by the U.S. Environmental Protection Agency (1996).

Table 6. Concentrations of pesticides and polychlorinated biphenyls in stormwater-runoff flow-weighted composite samples collected from five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site location. All units are in micrograms per liter; --, no data; N, not detected; MCL, Maximum Contaminant Level]

Site	Date sampled	Chlordane	4,4'-DDT	4,4'-DDE	Diazinon	Carbaryl	2,4-D	PCB-1242	PCB-1254
		MCL[1]: 2.0	--	--	--	--	70	0.5	0.5
1	06-05-92	--	--	--	--	--	--	--	--
	07-02-92	N	N	N	--	--	--	N	N
	08-25-92	N	N	N	--	--	--	N	N
	10-07-92	N	N	N	--	--	--	N	N
	05-22-93	N	N	N	0.5	N	8.0	N	N
	06-17-93	--	--	--	--	N	6.4	--	--
2	06-05-92	N	N	N	--	--	--	N	N
	07-02-92	0.1	N	N	--	--	--	N	N
	08-25-92	N	N	N	--	--	--	N	N
	06-17-93	N	N	N	--	--	--	N	N
	06-24-93	--	--	--	--	--	--	--	--
	08-19-93	N	N	N	--	--	--	N	N
3	05-22-92	N	N	N	--	--	--	N	N
	07-02-92	N	N	N	--	--	--	N	0.2
	10-07-92	--	--	--	--	--	--	--	--
	05-22-93	N	N	N	--	--	--	N	N
	06-17-93	N	N	N	--	--	--	N	N
	06-24-93	.1	0.1	0.11	--	--	--	N	N
4	06-17-92	N	N	N	--	--	--	N	N
	07-02-92	N	N	N	--	--	--	N	N
	08-25-92	N	N	N	--	--	--	N	N
	10-07-92	0.1	N	N	--	--	--	N	N
	05-22-93	.1	N	N	1.5	0.7	13	0.1	N
	06-17-93	N	N	N	--	N	.89	N	.1
5	06-05-92	N	N	N	--	--	--	N	N
	06-17-92	N	N	N	--	--	--	N	N
	07-02-92	N	N	N	--	--	--	N	N
	05-22-93	N	N	N	--	--	--	N	N
	06-17-93	N	N	N	--	--	--	N	N
	06-24-93	N	N	N	--	N	.14	N	N

[1]Maximum Contaminant Level. The highest concentration of a solute permissible in a public-water supply, as specified in the national Primary Drinking-Water Standards established under the Safe Drinking Water Act by the U.S. Environmental Protection Agency (1996).

Table 7. Concentrations of trace elements in stormwater-runoff in flow-weighted composite samples and total phenols in stormwater-runoff grab samples collected from five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site location. All units are in micrograms per liter; --, no data; N, not detected; MCL, Maximum Contaminant Level]

Site	Date sampled	Arsenic, total	Beryllium, total	Cadmium, total	Chromium, total	Copper, total	Lead, total	Mercury, total	Nickel, total	Zinc, total	Phenols, total
		MCL[1]: 50	4	5	100	–	[2]15	2	100	–	–
1	06-05-92	N	N	N	5	7	18	N	4	60	4
	07-02-92	3	N	N	3	7	15	N	3	60	3
	08-25-92	4	10	N	N	7	10	N	3	70	4
	10-07-92	11	N	N	8	9	18	N	14	100	2
	05-22-93	1	N	N	12	8	27	N	4	80	3
	06-17-93	1	N	N	5	6	10	N	3	50	N
2	06-05-92	2	N	N	5	8	20	N	5	80	6
	07-02-92	8	N	N	5	10	31	N	9	110	9
	08-25-92	3	N	N	6	12	22	N	7	140	4
	06-17-93	2	N	N	3	9	18	N	5	80	1
	06-24-93	2	N	N	4	5	12	N	5	50	N
	08-19-93	2	N	N	N	6	11	N	3	80	1
3	05-22-92	7	N	2	17	30	93	N	21	280	5
	07-02-92	2	N	2	9	24	51	N	14	290	4
	10-07-92	3	N	1	7	19	30	N	10	210	4
	05-22-93	11	N	4	30	70	180	0.2	39	640	--
	06-17-93	3	N	N	6	15	22	N	8	150	N
	06-24-93	9	N	2	17	37	96	N	27	300	2

Table 7. Concentrations of trace elements in stormwater-runoff in flow-weighted composite samples and total phenols in stormwater-runoff grab samples collected from five sites, Omaha, Nebraska, 1992-93--Continued

Site	Date sampled	Arsenic, total	Beryllium, total	Cadmium, total	Chromium, total	Copper, total	Lead, total	Mercury, total	Nickel, total	Zinc, total	Phenols, total
		MCL[1]: 50	4	5	100	--	[2]15	2	100	--	--
4	06-17-92	5	N	N	6	9	12	N	10	60	N
	07-02-92	3	N	N	3	9	9	N	6	50	2
	08-25-92	3	N	N	3	12	10	N	7	40	3
	10-07-92	2	N	N	5	8	26	N	4	100	3
	05-22-93	12	N	N	18	20	28	N	22	120	2
	06-17-93	4	N	N	4	13	9	.5	8	40	N
5	06-05-92	N	N	N	N	5	3	N	2	50	6
	06-17-92	3	N	N	1	6	2	N	4	50	--
	07-02-92	2	N	N	3	7	7	N	5	80	2
	05-22-93	3	N	N	N	8	31	N	6	170	3
	06-17-93	1	N	N	2	5	3	--	3	50	2
	06-24-93	2	N	N	3	4	8	N	3	40	1

[1]Maximum Contaminant Level. The highest concentration of a solute permissible in a public-water supply, as specified in the national Primary Drinking-Water Standards established under the Safe Drinking Water Act by the U.S. Environmental Protection Agency (1996).

[2]U.S. Environmental Protection Agency (1988). The treatment level for lead is 15 micrograms per liter.

Table 8. Concentrations of constituents and properties in stormwater-runoff in flow-weighted composite and grab samples collected from five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site location. mg/L, milligrams per liter; cols/100 mL, colonies per 100 milliliters; org, organic; N, not detected; K, countable results outside of ideal range; *, grab sample; --, not analyzed]

Site	Date	*Bio-chemical oxygen demand (mg/L)	Chemical oxygen demand (mg/L)	Suspended solids, total (mg/L)	Dissolved solids, total (mg/L)	*Fecal colliform (cols/ 100 mL)	*Fecal strepto-coccus (cols/ 100 mL)	Nitrogen, total, as N (mg/L)	Nitrogen NH3+org, total (mg/L as nitrogen)	Phos-phorus, total (mg/L as phos-phorus)	Phos-phorus, dissolved (mg/L as phos-phorus)	*Oil and grease (mg/L)
1	06-05-92	17	42	58	48	K 90,000	97,000	1.2	0.8	0.12	0.11	3
	07-02-92	15	54	39	73	37,000	42,000	2.5	1.8	.35	.24	2
	08-25-92	6.8	52	37	97	--	--	1.3	.7	.19	.2	N
	10-07-92	14	71	397	97	12,000	20,000	2.4	1.6	.32	.16	N
	05-22-93	21	70	100	69	10,000	53,000	2.1	1.2	.22	.17	3
	06-17-93	15	33	46	33	K 6,000	95,000	1.9	1.3	.12	.08	2
2	06-05-92	14	45	91	88	28,000	13,000	1.3	.6	.09	.08	1
	07-02-92	32	92	188	64	11,000	16,000	3.1	1.9	.44	.20	2
	08-25-92	17	110	152	99	--	--	2.0	1.2	.21	.19	2
	06-17-93	12	72	366	70	K 200	3,700	2.2	1.5	.28	.14	2
	06-24-93	6.8	33	118	28	20,000	7,800	.7	.4	.13	.08	N
	08-19-93	18	38	51	40	K 200	K 200	.8	.4	.09	.07	4
3	05-22-92	16	120	750	76	35,000	K100,000	1.2	.7	.20	.11	4
	07-02-92	22	120	449	166	K 8,700	11,000	3.8	2.9	.55	.12	1
	10-07-92	32	N	358	81	K 3,300	12,000	2.5	1.9	.5	.18	3
	05-22-93	22	180	1,700	107	K 13,000	61,000	3.0	1.5	.15	.25	--
	06-17-93	11	95	462	100	K 2,000	7,200	2.9	2.1	.31	.15	1
	06-24-93	11	110	1,860	64	36,000	32,000	.9	.4	.13	.09	2

Table 8. Concentrations of constituents and properties in stormwater-runoff in flow-weighted composite and grab samples collected from five sites, Omaha, Nebraska, 1992-93--Continued

Site	Date	*Bio-chemical oxygen demand (mg/L)	Chemical oxygen demand (mg/L)	Suspended solids, total (mg/L)	Dissolved solids, total (mg/L)	*Fecal colliform (cols/ 100 mL)	*Fecal strepto-coccus (cols/ 100 mL)	Nitrogen, total, as N (mg/L)	Nitrogen NH3+org, total (mg/L as nitrogen)	Phos-phorus, total (mg/L as phos-phorus)	Phos-phorus, dissolved (mg/L as phos-phorus)	*Oil and grease (mg/L)
4	06-17-92	17	72	190	88	K 63,000	K110,000	3.7	2.7	0.54	0.33	N
	07-02-92	11	67	123	109	110,000	90,000	3.2	2.2	.52	.38	N
	08-25-92	14	57	170	107	--	--	1.7	1.1	.37	.13	N
	10-07-92	14	69	94	46	K 1,500	K 3,200	2.8	1.9	.66	.21	3
	05-22-93	12	110	728	93	28,000	95,000	2.7	1.7	.28	.37	N
	06-17-93	12	62	423	107	K 2,200	5,600	1.4	1.1	.21	.15	1
5	06-05-92	27	31	33	97	K 1,500	4,200	1.5	.8	.14	.13	N
	06-17-92	11	47	53	188	24,000	K 100,000	2.3	1.7	.32	.41	N
	07-02-92	11	45	77	90	5,600	12,000	2.3	1.5	.26	.18	N
	05-22-93	11	78	208	65	3,800	16,000	1.6	.9	.09	.06	3
	06-17-93	15	46	31	82	K 1,900	K 900	1.9	1.3	.12	.08	2
	06-24-93	8.9	47	58	54	K 14,000	7,800	1.1	.7	.18	.10	N

Table 9. Major ions, properties, and total organic carbon in flow-weighted stormwater-runoff samples from five sites, Omaha, Nebraska, 1992-93

[See figure 2 for site location. mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Site	Date	Alkalinity, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sulfate, dissolved (mg/L as SO_4)	pH, (standard units)	Specific conductance (µS/cm)	Total organic carbon (mg/L)
1	06-05-92	37	9.9	2.3	0.91	1.9	2.4	3.6	7.2	91	0.6
	07-02-92	35	11	3.5	1.5	3.4	4.9	10	7.0	120	13
	08-25-92	65	21	4.6	3.3	3.3	6.6	9.6	7.4	173	15
	10-07-92	36	13	5.1	2.6	4.2	7.2	22	7.0	149	16
	05-22-93	50	13	4.7	1.3	3.4	4.6	6.1	7.5	128	14
	06-17-93	37	10	2.7	.9	2.5	3.1	2.5	7.1	92	9.2
2	06-05-92	53	17	3.5	1.2	1.6	3.1	10	8.0	136	11
	07-02-92	69	15	3.1	1.1	2.6	4.8	12	7.7	175	24
	08-25-92	53	17	4.4	1.2	2.4	6.3	12	7.2	156	37
	06-17-93	47	13	2.7	.7	2.2	3.5	7.1	7.6	127	15
	06-24-93	30	5.6	1.1	.3	1.1	1.1	2.9	7.9	70	6.9
	08-19-93	33	9.3	1.3	.4	1.3	1.9	3.4	7.6	82	7.2
3	05-22-92	65	12	7.7	1.4	2.3	7.5	11	8.3	146	26
	07-02-92	130	29	20	4.7	5.3	14	37	7.5	395	26
	10-07-92	70	12	6.2	1.3	3.2	4.9	11	7.1	130	19
	05-22-93	83	17	15	2.3	3.3	10	15	7.6	224	45
	06-17-93	80	17	13	2.3	3.6	11	15	7.5	210	16
	06-24-93	80	11	7.4	1.4	2.5	5.7	8.1	8.0	209	19

Table 9. Major ions, properties, and total organic carbon in flow-weighted stormwater-runoff samples from five sites, Omaha, Nebraska, 1992-93--Continued

Site	Date	Alkalinity, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sulfate, dissolved (mg/L as SO_4)	pH, (standard units)	Specific conductance (μS/cm)	Total organic carbon (mg/L)
4	06-17-92	37	12	6.7	2.3	5.7	7.6	16	6.7	144	19
	07-02-92	35	15	5.3	2.8	5.3	9.1	22	6.9	164	16
	08-25-92	48	17	4.5	3.2	5.5	8.3	20	7.0	168	18
	10-07-92	33	8.8	1.2	.8	2.4	2.6	7.5	6.9	94	15
	05-22-93	71	17	8.7	3.4	5.3	9.0	13	7.4	208	23
	06-17-93	44	16	8.5	2.8	4.9	8.5	12	7.0	163	15
5	06-05-92	40	15	6.5	2.6	2.5	8.7	19	7.5	157	5.7
	06-17-92	55	25	11	5.3	6.3	19.0	51	7.0	283	14
	07-02-92	31	14	4.3	2.6	2.7	8.9	24	7.1	155	25
	05-22-93	46	12	6.8	1.2	1.9	4.6	6.8	7.7	127	14
	06-17-93	33	14	7.7	2	2.9	6.7	12	6.7	139	9.1
	06-24-93	26	7.8	6.1	1	2.6	4.4	3.6	6.9	91	6.8

APPENDIX C—QUALITY ASSURANCE INFORMATION SUMMARY

Table 10. Summary of results of duplicate analyses for stormwater-runoff samples, Omaha, Nebraska, 1992-93

[µg/L, micrograms per liter; mg/L, milligrams per liter; N, not detected]

Constituent	Primary sample	Duplicate sample	Difference	Relative Percent difference	Constituent	Primary sample	Duplicate sample	Difference	Relative Percent difference
Pesticides (µg/L)									
Aldrin	N	N	0	0	Dieldrin	N	N	0	0
Alpha-BHC	N	N	0	0	Alpha-endosulfan	N	N	0	0
Beta-BHC	N	N	0	0	Beta-endosulfan	N	N	0	0
Gamma-BHC	N	N	0	0	Endosulfan sulfate	N	N	0	0
Delta-BHC	N	N	0	0	Endrin	N	N	0	0
4,4'-DDT	N	N	0	0	Endrin aldehyde	N	N	0	0
4,4'-DDE	N	N	0	0	Heptachlor	N	N	0	0
4,4'-DDD	N	N	0	0	Heptachlor epoxide	N	N	0	0
					Carbaryl	N	N	0	0
Trace elements (µg/L)									
Arsenic, total	3	4	1	29	Nickel, total	10	13	3	26
	1	2	1	67		3	3	0	0
Beryllium, total	N	N	0	0	Selenium	N	N	0	0
	N	N	0	0		N	N	0	0
Cadmium, total	1	1	0	0	Silver, total	N	N	0	0
	N	N	0	0		N	N	0	0
Chromium, total	7	9	2	25	Thallium, total	N	N	0	0
	2	2	0	0		N	N	0	0
Copper, total	19	21	2	10	Zinc, total	210	240	30	3
	5	6	1	18		50	50	0	0
Lead, total	30	34	4	12					
	3	4	1	29					

Table 10. Summary of results of duplicate analyses for stormwater-runoff samples, Omaha, Nebraska, 1992-93--Continued

Constituent	Primary sample	Duplicate sample	Difference	Relative Percent difference	Constituent	Primary sample	Duplicate sample	Difference	Relative Percent difference
			Major ions (mg/L)						
Calcium, dissolved	17	17	0	0	Potassium, dissolved	3.6	3.6	0	0
	5.6	5.7	.1	2		1.1	1.2	.1	9
Chloride, dissolved	13	14	1	7	Sodium, dissolved	11	9.3	1.7	17
	1.1	0.8	.3	32		1.1	1	.1	9
Magnesium, dissolved	2.3	2.3	0	0	Sulfate, dissolved	15	16	1	6
	0.28	0.29	.01	4		2.9	3.1	.2	7
			Nutrient (mg/L)						
Nitrogen, nitrite plus nitrate, as nitrogen	0.9	0.91	.01	1	Phosphorus, total	.66	.70	.04	6
Nitrogen, ammonium plus organic nitrogen, as nitrogen	1.9	20	.1	5	Phosphorus, dissolved	.21	.20	.01	5

Table 11. Summary of results of field-blank analyses for stormwater-runoff samples, Omaha, Nebraska, 1992-93

[µg/L, micrograms per liter; mg/L, milligrams per liter; N, not detected]

Constituent	Primary sample	Field blank sample	Constituent	Primary sample	Field blank sample
Volatile organic compounds (µg/L)					
Benzene, total	N	N	1,2-Dichloropropane	N	N
	N	N		N	N
	N	N		N	N
Bromoform, total	N	N	Ethylbenzene	N	N
	N	N		N	N
	N	N		N	N
Carbon tetrachloride, total	N	N	Methylene chloride	N	1.2
	N	N		N	.9
	N	N		N	.8
Chlorobenzene	N	N	1,1,2,2-Tetrachloroethane	N	N
	N	N		N	N
	N	N		N	N
Chloroethane	N	N	Tetrachloroethylene	N	N
	N	N		N	N
	N	N		N	N
2-Chloroethylvinyl ether	N	N	Toluene	0.2	N
	N	N		N	N
	N	N		N	N
Chloroform	N	N	1,1,1-Trichloroethane	N	N
	N	N		N	N
	N	N		N	N
Dichlorobromomethane	N	N	1, 1, 2-Trichloroethane	N	N
	N	N		N	N
	N	N		N	N
1,1-Dichloroethane	N	N	Trichloroethylene	N	N
	N	N		N	N
	N	N		N	N
1,2-Dichloroethane	N	N	Vinyl chloride	N	N
	N	N		N	N
	N	N		N	N
1,1-Dichloroethylene	N	N		N	N
	N	N		N	N
	N	N		N	N
Pesticide (µg/L)					
Carbaryl	N	N			

Table 11. Summary of results of field-blank analyses for stormwater-runoff samples, Omaha, Nebraska, 1992-93--Continued

Constituent	Primary sample	Field blank sample	Constituent	Primary sample	Field blank sample
Trace elements (μg/L)					
Arsenic, total	11	2	Nickel, total	14	N
Beryllium, total	N	N	Selenium	N	N
Cadmium, total	N	N	Silver, total	N	N
Chromium, total	8	N	Thallium, total	N	N
Copper, total	9	N	Zinc, total	100	N
Lead, total	18	2			
Major ions (mg/L)					
Calcium, dissolved	13	1.1	Potassium, dissolved	4.2	0.2
Chloride, dissolved	5.1	.2	Sodium, dissolved	7.2	1.5
Magnesium, dissolved	2.6	.14	Sulfate, dissolved	22	.3
Nutrient (mg/L)					
Nitrogen, nitrite plus nitrate, as nitrogen	.79	N	Phosphorus, total	.32	.01
Nitrogen, ammonium plus oranic nitrogen, as nitrogen	1.6	N	Phosphorus, dissolved	.16	.02

Table 12. Summary of results of field-spike analyses for stormwater-runoff samples, Omaha, Nebraska, 1992-93

[µg/L, micrograms per liter]

Constituent	Sample fortification concentrations	First Field spike sample (08-28-92)	Recovery percent	Second Field spike sample (06-17-93)	Recovery percent
Acid organic compounds (µg/L)					
2-Chlorophenol	50	32	64	34	68
2,4-Dichlorophenol	50	17	34	42	84
2,4-Dimethylphenol	50	11	22	45	90
2-Nitrophenol	50	39	78	50	100
4-Nitrophenol	250	150	60	130	52
Pentachlorophenol	250	230	92	200	80
Phenol	50	<5	0	<5	0
2,4,6-Trichlorophenol	150	130	87	160	107
Base/neutral organic compounds (µg/L)					
Acenaphthalene	20	12	60	12	60
Acenaphthene	20	13	65	15	75
Anthracene	20	13	65	14	70
Benzo-A-anthracene	20	15	75	17	85
Benzo-A-pyrene	20	13	65	14	70
3,4-Benzofluoranthene	20	16	80	18	90
2,4-Benzo(ghi)perylene	20	11	55	14	70
Benzo(k)fluoranthene	20	16	80	16	80
Bis (2-Chloroethoxy) methane	20	15	75	16	80
Bis (2-Chloroethyl) ether	20	15	75	15	75
Bis (2-Chloroisopropyl) ether	20	12	60	14	70
Bis (2-ethylhexyl) phthalate	20	21	105	24	120
Butylbenzyl phthalate	20	10	50	12	60
2-Chloronaphthalene	20	14	70	13	65
4-Chlorophenyl phenyl ether	20	15	75	15	75
Chrysene	20	16	80	16	80
Dibenzo (A,H) anthracene	20	11	55	13	65
1,2-Dichlorobenzene	20	11	55	13	65
1,3-Dichlorobenzene	20	10	50	13	65
1,4-Dichlorobenzene	20	10	50	13	65
3,3-Dichlorobenzidine	20	<20	0	<20	0
Diethyl phthalate	20	14	70	17	85
Dimethyl phthalate	20	13	65	15	75
Di-N-butyl phthalate	20	11	55	10	50
2,4-Dinitrotoluene	20	7	35	23	115
2,6-Dinitrotoluene	20	16	80	23	115
Di-N-octyl phthlate	20	29	145	23	115

Table 12. Summary of results of field spike analyses for stormwater-runoff samples, Omaha, Nebraska, 1992-93--Continued

Constituent	Sample fortification concentrations	First Field spike sample (08-28-92)	Recovery percent	Second Field spike sample (06-17-93)	Recovery percent
Base/neutral organic compounds (μg/L)--Continued					
Fluoranthene	20	18	90	13	65
Fluorene	20	12	60	<5	0
Hexachlorocyclopentadiene	20	<5	0	<5	0
Hexachloroethane	20	8	40	<5	0
Indeno (1,2,3-CD) pyrene	20	12	60	<5	0
Isophorone	20	6	30	<5	0
Napthalene	20	13	65	8	40
Nitrobenzene	20	16	80	17	85
N-Nitrosodimethylamine	20	11	55	<5	0
N-Nitrosodi-N-propylamine	20	14	70	<5	0
N-Nitrosodiphenylamine	20	8	40	<5	0
Phenanthrene	20	9	45	<5	0
Pyrene	20	16	80	18	90
Pesticides (μg/L)					
Aldrin	1	.70	70	.89	89
Alpha-BHC	1	.92	92	.73	73
Beta-BHC	1	2.0	200	1.9	190
Gamma-BHC	1	.93	93	.83	83
Delta-BHC	1	2.3	230	2.2	220
4,4'-DDT	6	5.2	87	5.2	87
4,4'-DDE	2	1.9	95	1.8	90
4,4'-DDD	6	5.1	85	5.0	83
Dieldrin	2	4.8	240	4.5	225
Alpha-endosulfan	2	3.4	170	3.6	180
Beta-endosulfan	2	4.0	200	3.1	155
Endosulfan sulfate	6	13	217	12	200
Endrin	2	4.7	235	4.2	210
Endrin aldehyde	6	.80	13	.9	15
Heptachlor	1	1.0	100	.94	94
Heptachlor epoxide	1	1.7	170	1.7	170

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