# Statistical Summary of Selected Physical, Chemical, and Microbial Characteristics, and Estimates of Constituent Loads in Urban Stormwater, Maricopa County, Arizona

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U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 94—4240

Prepared in cooperation with the
FLOOD CONTROL DISTRICT OF
MARICOPA COUNTY

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

Tucson, Arizona
1995

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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## CONVERSION FACTORS

| **Multiply** | **By** | **To obtain** |
|---|---|---|
| inch (in.) | 25.40 | millimeter |
| inch (in.) | 2.540 | centimeter |
| foot (ft) | 0.305 | meter |
| square mile ($mi^2$) | 2.590 | square kilometer |
| cubic foot per second ($ft^3/s$) | 0.0283 | cubic meter per second |
| pound (lb) | 0.907 | megagram |

In this report, temperature is reported in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$°C = (°F - 32)/1.8$$

## ABBREVIATED WATER-QUALITY UNITS

Chemical concentrations are given only in metric units. Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute mass per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million (ppm). Specific conductance is given in microsiemens per centimeter (µS/cm) at 25°C.

## VERTICAL DATUM

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

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **BOD** | 5-day biological oxygen demand, in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **CD** | Total recoverable cadmium in storm-runoff load, in pounds, or in storm-runoff mean concentration, in micrograms per liter. |
| **COD** | Chemical oxygen demand in storm-runoff load, in pounds, or in storm-runoff mean concentration, in micrograms per liter. |
| **CU** | Total recoverable copper in storm-runoff load, in pounds, or in storm-runoff mean concentration, in micrograms per liter. |
| **DA** | Total contributing drainage area. |
| **DDE** | Dichlorodiphenyldichloroethylene. |
| **DDT** | Dichlorodiphenyltrichloroethane. |
| **DP** | Dissolved phosphorus in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **DRN** | Duration of each storm, in minutes, for storm-runoff load and mean concentration models. |
| **DS** | Dissolved solids in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **FCDMC** | Flood Control District of Maricopa County. |
| **GIS** | Geographic-information system. |
| **IA** | Impervious area, as a percentage of total contributing drainage area. |
| **LUC** | Commercial land use, as a percentage of total contributing drainage area. |
| **LUI** | Industrial land use, as a percentage of total contributing drainage area. |
| **LUN** | Undeveloped land use, as a percentage of total contributing drainage area. |
| **LUR** | Residential land use, as a percentage of total contributing drainage area. |
| **MAP** | Model-adjustment procedure. |
| **NPDES** | National Pollution Discharge Elimination System. |
| **PB** | Total recoverable lead in storm-runoff load, in pounds, or in storm-runoff mean concentration, in micrograms per liter. |
| **RUN** | Storm-runoff volume, in cubic feet. |
| **SS** | Suspended solids in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **TKN** | Total ammonia plus organic nitrogen as nitrogen in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **TN** | Total nitrogen in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **TP** | Total phosphorus in storm-runoff load, in pounds, or in storm-runoff mean concentration, in milligrams per liter. |
| **TRN** | Total storm rainfall, in inches. |
| **ZN** | Total recoverable zinc in storm-runoff load, in pounds, or in storm-runoff mean concentration, in micrograms per liter. |

# Statistical Summary of Selected Physical, Chemical, and Microbial Characteristics, and Estimates of Constituent Loads in Urban Stormwater, Maricopa County, Arizona

*By* Thomas J. Lopes, Kenneth D. Fossum, Jeffrey V. Phillips, *and* Jim E. Monical

## Abstract

Stormwater and streamflow were monitored to describe the physical, chemical, and microbial characteristics of stormwater from areas having different land uses, to describe the characteristics of streamflow in a river that receives urban stormwater, and to estimate constituent loads in stormwater from unmonitored areas in Maricopa County. Spearman rank correlations indicate that certain constituents are associated with suspended solids and that the concentration of suspended solids decreases with increasing percentages of impervious area. Land use affects urban stormwater chemistry mostly because the percentage of impervious area varies with the type of land use. The percentage of impervious area is typically largest for commercial and industrial areas and smallest for residential areas. Urban activities also seem to concentrate cadmium, lead, and zinc in sediments. Urban stormwater, streamflow, and stormwater from a drainage basin with undeveloped land use had similar ranges in most other constituent concentrations. The concentration of dissolved solids in urban stormwater was less than in streamflow from the Salt River and the stormwater would dilute most constituent concentrations. Urban stormwater, however, had larger concentrations of chemical oxygen demand and biological oxygen demand, oil and grease, and higher counts of fecal bacteria. These constituents could degrade the quality of streamflow when the Salt River flows.

Organochlorine pesticides, semivolatile compounds, and volatile organic compounds were seldom detected in urban stormwater and were not detected in streamflow or stormwater from the drainage basin with undeveloped land use. Dichlorodiphenyldichloroethylene (commonly referred to as DDE) was the most commonly detected pesticide and was measured in concentrations of 0.04 to 1.1 micrograms per liter at most urban drainage basins. DDE is a degradation product of dichlorodiphenyltrichloroethane (commonly referred to as DDT) and may be a residue from the 1950's and 1960's when most of the land in the metropolitan Phoenix area was used for agriculture.

Loads for a mean storm, mean seasonal loads, and mean annual loads of 12 constituents and volumes of runoff were estimated for municipalities in the Phoenix area by adjusting regional-regression equations of loads for an individual storm. Most of the adjusted equations require three explanatory variables (total rainfall, drainage area, and percentage of impervious area) to estimate constituent loads and had standard errors that ranged from 65 to 266 percent. Localized areas in the cities of Chandler, Mesa, Paradise Valley, and Peoria seem to contribute a large proportion of the constituent loads. These localized areas typically have 40 percent or more impervious area and are associated with industrial, commercial, and high-density residential land use. Constituent loads seem to be evenly distributed in other municipalities. Regional-regression equations for estimating event-mean constituent concentrations for an individual storm also were adjusted. However, the equations did not estimate constituent concentrations accurately; therefore, the use of the mean value of the event-mean constituent concentrations measured in stormwater may be the best way of estimating constituent concentrations.

# INTRODUCTION

The U.S. Environmental Protection Agency, under section 402(p) of the Water Quality Act of 1987, has required municipalities with populations of more than 100,000 to obtain National Pollution Discharge Elimination System (NPDES) permits for urban stormwater discharge. This regulation is intended to minimize pollutant loadings from urbanized areas and preserve the quality of streams that receive stormwater. To apply for a NPDES permit, a municipality must monitor the chemistry of stormwater from areas having residential, commercial, and industrial land uses and estimate storm- and annual-pollutant loads and event-mean concentrations of 12 selected constituents discharged in stormwater. These estimates will be used by the municipalities to evaluate the magnitude of pollutant loadings and the efficiency of management strategies that are intended to reduce pollutant loads.

Phoenix, Mesa, Tempe, Scottsdale, Glendale, and unincorporated Maricopa County (fig. 1) each have populations of more than 100,000. These municipalities and other contiguous municipalities with populations less than 100,000 constitute the metropolitan Phoenix area. Most stormwater in the Phoenix area is routed into drainage channels, which are tributary to ephemeral streams including the Gila, Salt, New, and Agua Fria Rivers. Data on the types and amounts of constituents discharged in stormwater were needed by water-management agencies to design stormwater-management strategies and to assess the effects of stormwater on the water resources of Maricopa County. The U.S. Geological Survey (USGS), in cooperation with the Flood Control District of Maricopa County (FCDMC), monitored stormwater in three of the municipalities affected by NPDES regulations from October 1991 to October 1993. Stormwater was monitored to (1) characterize the chemistry of stormwater from drainage basins with urban land uses, (2) characterize the chemistry of streamflow from an ephemeral stream that receives urban stormwater, and (3) estimate the loads and concentrations of constituents in stormwater that discharges from urbanized Maricopa County.

## Purpose and Scope

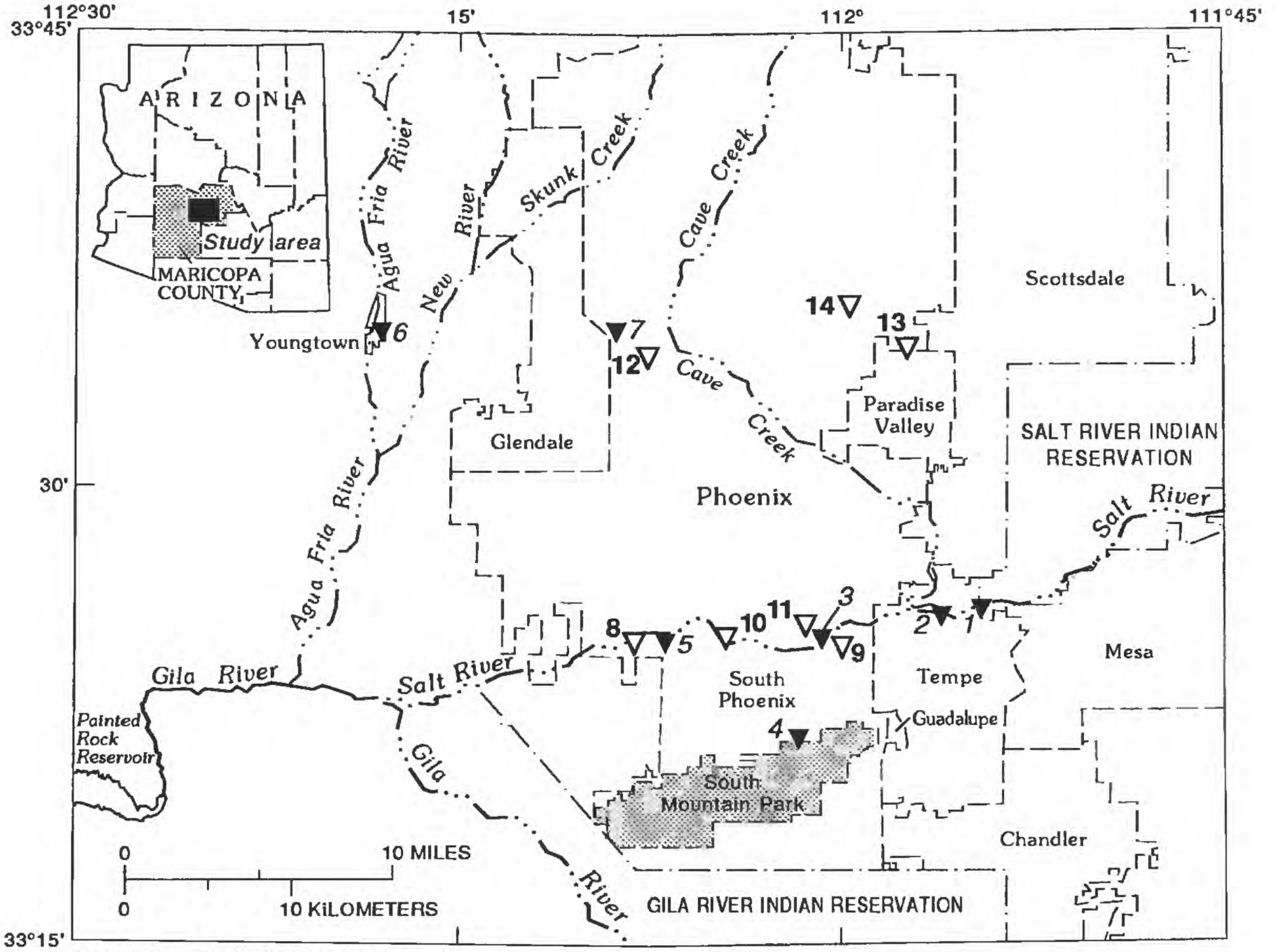
This report presents physical, chemical, and microbial characteristics of stormwater from drainage basins with residential, commercial, light industrial, heavy industrial, and undeveloped land uses, and characteristics of streamflow from the Salt River. Constituent loads, volumes of runoff, and event-mean constituent concentrations for a mean storm, mean seasonal rainfall, and mean annual rainfall were estimated for municipalities and major drainage basins in the Phoenix area.

Estimates of constituent loads and concentrations are reported for chemical oxygen demand, 5-day biological oxygen demand, suspended solids, dissolved solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, dissolved phosphorus, total recoverable cadmium, total recoverable copper, total recoverable lead, and total recoverable zinc. The report includes data collected from August 1992 through February 1993 for the Salt River, and from October 1991 to October 1993 from five drainage basins with areas of residential, commercial, light industrial, heavy industrial, or undeveloped land use.

## Approach

Drainage basins with a predominant land use were monitored so that stormwater from areas with different land uses could be characterized. The duration of storm flow typically is short and makes sampling difficult. Streamflow-gaging stations were instrumented with equipment that allowed remote monitoring of rainfall and stream discharge so that field crews could collect manual grab samples before storm flow stopped. Streamflow-gaging stations were instrumented with automatic samplers to collect samples during the entire storm and to reduce the personnel requirements for the study. Only five drainage basins could be monitored because of the costs of instrumenting sites and limited personnel. A consultant for the City of Phoenix monitored seven drainage basins using a similar approach. Two of these drainage basins, however, were of mixed land use.

Estimates were made by adjusting regional regression equations (Driver and Tasker, 1990) for



Base from U.S. Geological Survey
1:500,000 State base map and
Arizona State Land Department

EXPLANATION

STORMWATER-MONITORING STATIONS—Number is site identifier

2 ▼ U.S. Geological Survey

8 ▽ City of Phoenix

| Site | Station number | Station name |
|---|---|---|
| U.S. GEOLOGICAL SURVEY STATION | | |
| 1 | 09512165 | Salt River at Priest Drive, at Phoenix |
| 2 | 09512184 | Box culvert at 48th Street drain |
| 3 | 09512190 | Salt River at 24th Street, at Phoenix |
| 4 | 09512200 | Salt River tributary in South Mountain Park, at Phoenix |
| 5 | 09512403 | 27th Avenue at Salt River |
| 6 | 09513700 | Agua Fria River tributary at Youngtown |
| 7 | 09513885 | 43rd and Peoria |
| CITY OF PHOENIX STATION | | |
| 8 | 332333112080301 | 35th Avenue at Salt River |
| 9 | 332409111594101 | 40th Street at Salt River |
| 10 | 332501112042201 | Central Avenue at Salt River |
| 11 | 332525112011001 | Old Tower Road at Salt River |
| 12 | 333416112072701 | Metro Center at Arizona Canal Diversion Channel |
| 13 | 333431111573501 | 56th Street at Indian Bend Wash |
| 14 | 333557111594201 | 40th Street at Indian Bend Wash |

**Figure 1.** Study area and stormwater-monitoring stations, Maricopa County, Arizona.

local application. Land-use data and a geographic-information system (GIS) were used with the adjusted equations to estimate constituent loads and volume of runoff from each municipality, to evaluate the areal distribution of constituent loads, and to identify areas that are contributing a large proportion of the total loads.

Monitoring stations were installed in drainage basins with residential, commercial, light industrial, heavy industrial, and undeveloped land use. Drainage basins with a predominant land use were selected so that stormwater from different land uses could be characterized. Additional criteria for the selection of drainage basins included (1) an outfall at which a stage-discharge rating could be developed so that stream discharge could be computed, (2) definite drainage-basin boundaries so that drainage-basin characteristics could be quantified, and (3) a contributing area of less than 1,920 acres so that data would be consistent with data used to develop regional-regression equations (Driver and Tasker, 1990, table 4).

## Acknowledgments

Roland Wass and Catesby Moore, Flood Control District of Maricopa County (FCDMC), and David Phillips, formerly with FCDMC, provided support and cooperation throughout the study. Carol Davis, formerly with FCDMC, obtained permits to install the monitoring stations. Jess and Sons allowed access through their property at 27th Avenue. Gary Tasker, research hydrologist, USGS, assisted in statistical analyses of constituent loads.

## DESCRIPTION OF THE STUDY AREA

The Phoenix area is in a broad, flat basin in south-central Arizona (fig. 1). The basin is about 1,000 to 1,300 ft above sea level and slopes downward from east to west. The highest peak in the surrounding mountains is about 2,700 ft above sea level in South Mountain Park. The study area is about 957 $mi^2$ and includes the cities of Chandler, Gilbert, Glendale, Guadalupe, Mesa, Paradise Valley, Peoria, Phoenix, Scottsdale, Tempe, Tolleson, and Youngtown.

The combined population of municipalities included in this study is 2,036,845 (Maricopa Association of Governments, 1993), which is about 89 percent of the total population of Maricopa County. Residential and open spaces are the most abundant land-use types and constitute about 62 and 18 percent of the Phoenix area, respectively (Maricopa Association of Governments, 1989). The remaining 20 percent includes other land uses such as commercial and industrial land use, parks, and schools.

Maricopa County is in the northern Sonoran Desert climatic zone. Mean monthly maximum temperatures are 105°F during summer and mean monthly minimum temperatures are 40°F during winter (National Oceanic and Atmospheric Administration, 1990; table 1, this report).

**Table 1.** Mean monthly precipitation and mean monthly maximum and minimum temperatures, Sky Harbor Airport, Phoenix, Arizona

[Precipitation values are given in inches; temperature values are given in degrees Fahrenheit. Data from National Oceanic and Atmospheric Administration, 1990]

| Month | Climatic variable | | |
|---|---|---|---|
| | Mean monthly precipitation, in inches | Mean monthly temperature, in degrees Fahrenheit | |
| | | Maximum | Minimum |
| January | 0.73 | 65.2 | 39.4 |
| February | .59 | 69.7 | 42.5 |
| March | .81 | 74.5 | 46.7 |
| April | .27 | 83.1 | 53.0 |
| May | .14 | 92.4 | 61.5 |
| June | .17 | 102 | 70.6 |
| July | .74 | 105 | 79.5 |
| August | 1.02 | 102 | 77.5 |
| September | .64 | 98 | 70.9 |
| October | .63 | 87 | 59.1 |
| November | .54 | 74.3 | 46.9 |
| December | .83 | 66.4 | 40.2 |
| Annual | 7.11 | 85.1 | 57.3 |

Mean annual rainfall at Sky Harbor International Airport is 7.11 in. Most of the annual rainfall occurs from two weather patterns that have distinct characteristics (table 2). About 40 percent of the annual rainfall occurs between July and October from subtropical monsoons that originate from the Gulf of Mexico and Gulf of California and typically are short duration, high-intensity thunderstorms. About 50 percent of the annual rainfall occurs between November and March from cold fronts that originate in the Gulf of Alaska and typically are long duration, low-intensity storms. The remaining 10 percent of the annual rainfall occurs between April and June and could be the result of either type of weather pattern.

Stormwater from a drainage basin with residential land use was monitored near the intersection of Oregon and Peoria Avenues in Youngtown (USGS streamflow-gaging station 09513700; table 3). This site is an open channel that is tributary to the Agua Fria River and was monitored for streamflow by the USGS from 1961 to 1968. About 50 percent of the homes in the basin have desert landscaping and about 50 percent have irrigated lawns. Commercial areas in the northern part of the drainage basin consist of two small shopping malls with parking lots, a gas station, and an automobile-repair shop.

Stormwater from a drainage basin with commercial land use was monitored at the northwest corner of Peoria and 43rd Avenues in Phoenix (09513885). Runoff at this site flows through a weir and into the Arizona Canal Diversion Channel, which is a stormwater conveyance that discharges into the New River. About 50 percent of the pervious area is undeveloped, and about 50 percent has desert landscaping with some irrigation. Commercial businesses include a restaurant and retail stores. Resurfacing of the parking lot in March 1993 may have influenced the chemistry of the stormwater samples collected on March 26 and August 24, 1993.

Stormwater from a drainage basin with light industrial land use was monitored at a 120-inch-wide box culvert in Tempe near the intersection of 48th Street and the 48th Street drain (09512184). The box culvert discharges into the 48th Street drain, which is a stormwater conveyance that discharges to the Salt River. Most of the pervious area has irrigated landscaping. Light industrial businesses include offices, warehouses, small manufacturing shops, and heavy equipment rental. Commercial land use includes a hotel and a restaurant.

Stormwater from a drainage basin with heavy industrial land use was monitored at a 96-inch-diameter culvert at the intersection of 27th Avenue and the left bank of the Salt River in Phoenix, streamflow-gaging station 09512403. Most businesses are automobile recycling and repair shops that operate on unpaved lots. A precast concrete-product plant, a chemical storage facility, and a mobile-home park also are in the drainage basin.

Stormwater from a drainage basin with undeveloped land was monitored in an open channel at South Mountain Park (09512200), where continuous stream-discharge records have been collected since 1961. The drainage basin is tributary to the Salt River; however, a retention pond was constructed downstream from the streamflow-gaging station in 1979 and reduces the amount of streamflow that reaches the river. The drainage basin was designated as a mountain preserve in 1973 and is used as an outdoor recreation area.

Urban stormwater also was monitored at seven drainage basins by the City of Phoenix from January to August 1992. These data were combined with data from the five drainage basins monitored by the USGS. The combined data, which represent a wide range in basin and storm characteristics, were used in statistical analyses of stormwater characteristics and estimates of constituent loads and concentrations. Drainage basins were 77 to 1,582 acres and consisted of homogenous and mixed land uses (table 3). The percentage of impervious area was not measured, but was estimated using percentages that represent each land use (Flood Control District of Maricopa County, 1993)—very low-density residential, 15 percent; low-density residential, 25 percent; medium-density residential, 45 percent; multiple-family residential, 65 percent; industrial, 75 percent; and commercial, 90 percent. Comparison of these percentages with the percentage of impervious areas measured at drainage basins monitored by the USGS indicates that these estimated values are accurate.

**Table 2.** Characteristics of seasonal storms with greater than 0.1 inches of precipitation in the Phoenix area

[Values were calculated using data from Sky Harbor Airport, 1954–90. Storm separation is the criterion used to differentiate separate storms. Storms were considered separate when the number of hours without rainfall was equal to or greater than the storm separation]

| Type of storm | Months of season | Storm separation, in hours | Storm rainfall, in inches[1] |  | Mean storm rainfall, in inches | Standard deviation, in inches | Storm duration, in hours[1] |  | Mean storm duration, in hours | Number of storms[1] |  | Mean number of storms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | From | To |  |  | From | To |  | From | To |  |
| Summer monsoon | July–October | 6 | 0.44 | 0.46 | 0.46 | 0.43 | 4.36 | 5.82 | 5.06 | 7 | 6 | 7 |
| Winter cold front | November–March | 12 | .41 | .47 | .46 | .39 | 10.6 | 17.06 | 14.1 | 8 | 7 | 7 |
| Either cold front or monsoon | April–June | 9 | .32 | .38 | .36 | .32 | 5.44 | 10.10 | 8.56 | 2 | 2 | 2 |

[1] Values are ranges when storm separation is varied by 50 percent.

**Table 3.** Drainage area, land use, and impervious area for urban drainage-basin sites and Salt River monitoring sites, Maricopa County, Arizona

[South Mountain drainage area has about 1 percent roads, which were not categorized into a particular land use. Station numbers with a 0951-prefix were monitored by the U.S. Geological Survey; station numbers with a 33-prefix were monitored by the City of Phoenix. NA, not available]

| Station number | Local identifier | Area of drainage basin, in acres | Land use, in percent |  |  |  |  | Impervious area, in percent |
|---|---|---|---|---|---|---|---|---|
|  |  |  | Residential | Light industry | Heavy industry | Commercial | Undeveloped |  |
| **Urban drainage-basin sites** |  |  |  |  |  |  |  |  |
| 09512184 | 48th Street | 39 | 0 | 85 | 0 | 8 | 7 | 80 |
| 09512200 | South Mountain | 1,120 | 0 | 0 | 0 | 0 | 99 | 1 |
| 09512403 | 27th Avenue | 45 | 6 | 0 | 94 | 0 | 0 | 15 |
| 09513885 | Peoria | 3.4 | 0 | 0 | 0 | 97 | 3 | 94 |
| 09513700 | Youngtown | 81 | 90 | 0 | 0 | 10 | 0 | 33 |
| 333416112072701 | AC-05 | 77 | 7 | 0 | 0 | 62 | 31 | 58 |
| 333557111594201 | IB-08 | 609 | 78 | 0 | 0 | 11 | 11 | 37 |
| 333431111573501 | IB-11 | 1,582 | 84 | 0 | 0 | 2 | 14 | 32 |
| 332333112080301 | SR-03 | 1,363 | 21 | 24 | 18 | 18 | 19 | 54 |
| 332525112011001 | SR-21 | 631 | 0 | 0 | 0 | 77 | 23 | 57 |
| 332501112042201 | SR-33 | 989 | 47 | 6 | 14 | 16 | 17 | 49 |
| 332409111594101 | SR-45 | 120 | 0 | 0 | 100 | 0 | 0 | 74 |
| **Salt River monitoring sites** |  |  |  |  |  |  |  |  |
| 09512165 | Salt River at Priest Drive | 8,565,000 | NA | NA | NA | NA | NA | NA |
| 09512190 | Salt River at 24th Street | 8,570,000 | NA | NA | NA | NA | NA | NA |

The Salt River was sampled at the streamflow-gaging stations, Salt River at 24th Street, at Phoenix, Arizona (09512190), and Salt River at Priest Drive, at Phoenix, Arizona (09512165). These gaging stations are in the central part of the Phoenix area, and less than about 5 percent of the drainage areas are urbanized. The Salt River is ephemeral and typically flows only during large storms in the Phoenix area or when dams upstream from Maricopa County release water. Most streamflow samples were collected during the flood of 1993 when water was released from dams on the Verde and Salt Rivers and streamflow reached a maximum of 129,000 $ft^3/s$ on January 8, 1993. Streamflow was sampled near the 24th Street streamflow-gaging station when water was released from a dam on the Verde River. Runoff from urban areas was not significant at the time that the samples were collected.

## DATA-COLLECTION METHODS

Runoff and precipitation data were collected by the USGS from October 1991 to October 1993 using the following equipment:

Campbell Scientific Instruments, Inc., CR10 datalogger and SM192 storage module
Sierra-Misco Environment Ltd., model 2500 tipping-bucket rain gage
Druck PDCR 940 pressure transducer
Conoflow and pressure-regulator system
Isco, Inc., Model 3700 automatic-pumping sampler
Motorola MC310 cellular telephone

Measurement of stage and precipitation and activation of the automatic-pumping sampler were controlled by the datalogger. The datalogger was programmed to record instrument readings, calculate stream discharge, and activate the automatic-pumping sampler when a specified volume of water had been discharged from the drainage basin. The datalogger also initiated a telephone call to a hydrologist when precipitation or discharge was measured so that the hydrologist could make manual discharge measurements and collect grab samples during runoff. Data were recorded at 1-minute intervals when either rainfall or stream discharge was measured. Data were recorded once a day (at midnight) if dry conditions persisted.

### Precipitation

Precipitation was measured at all monitoring sites with a tipping-bucket rain gage calibrated to tip when 0.01 in. was collected. A pulse was transmitted to the datalogger each time 0.01 in. of rainfall was collected. The number of pulses in each minute was recorded to measure rainfall intensity. Rainfall during each successive minute was recorded and summed to obtain accumulated rainfall.

### Stream Discharge

Gage height was measured at urban drainage basins and South Mountain using a Conoflow and pressure-regulator system. The Conoflow and pressure regulator maintain a constant rate of nitrogen flowing through a tube that extends from the gaging station to an orifice at the bottom of the channel or culvert. Greater pressure is required to maintain a constant-flow rate through the tube as stage increases. Pressure in the tube was measured by the pressure transducer, which was calibrated to within 0.02 ft and, except for the 27th Avenue streamflow-gaging station, placed 3 to 5 ft underground to reduce effects of temperature on measurements. At 27th Avenue, the transducer was placed in the culvert and insulated. Temperature of the pressure transducer varied by about 4°F/d; temperature corrections were not necessary. Gage height was measured by a float at Salt River at 24th Street, at Phoenix, Arizona (09512190), and by a wire-weight gage at Salt River at Priest Drive, at Phoenix, Arizona (09512165).

Stage-discharge ratings for all urban drainage basins were developed on the basis of channel geometry and slope using the slope-conveyance method (Kennedy, 1984). A stage-discharge rating based on manual-discharge measurements was used at the South Mountain site, and instantaneous discharge measurements were made when streamflow samples were collected from the Salt River. Stream-discharge measurements were made at all streamflow-gaging stations using either a pygmy meter or Price AA meter and the 0.6-depth or 0.2- and 0.8-depth wading method or a calibrated bucket (Rantz and others, 1982). Stream-discharge measurements compared well with stage-discharge ratings.

Instantaneous discharge rates at urban drainage basins and South Mountain were computed by programming the datalogger with a log-normal regression equation that was fit to the stage-discharge rating of each site (Kolb, 1983). The log-normal equations compared well with all stage-discharge ratings (correlation coefficients were 0.99 or greater). Stream-discharge volumes were computed by multiplying the mean of two consecutive discharge-rate measurements by 60 seconds to obtain the mean volume of stream discharge during that 1-minute interval. The mean volumes were summed to obtain the total volume of runoff.

## Stormwater and Streamflow Samples

Stormwater samples were collected from drainage basins by automatic-pumping samplers and by manually collecting grab samples. Streamflow samples were collected from the Salt River using the equal-width-increment method and by collecting grab samples. For the equal-width-increment method, samples are collected at equal distances perpendicular to the direction of river flow. Samples are then composited to obtain a single sample that is representative of the stream at a specific time. The automatic-pumping sampler is a portable, nonrefrigerated unit calibrated to pump a specified volume of stormwater. Twenty-four 1-liter, teflon-lined, polyethylene bottles were used to hold discrete samples that were pumped when a specified volume of water had discharged from the drainage basin. Samples were placed on ice and transported to the field office for processing. The samples were poured into a teflon-lined, stainless-steel churn splitter to split the flow-weighted composite sample into the bottles required for each chemical analysis. Samples for dissolved-chemical analysis were filtered using a 0.45-micron effective pore-size cellulose filter. Preservatives were then added to sample bottles as required. All components of the sampling equipment that came into contact with sample water were constructed of either glass, teflon, or stainless steel, except for the distribution hose in the automatic-pumping sampler, which was silicon rubber. Equipment that was in contact with sample water was cleaned by washing with Liquinox followed by rinsing with large quantities of tap water, a rinse of ultrapure methanol, and a final rinse of deionized water.

Manual grab samples for cyanide, oil and grease, volatile organic compounds, phenols, and fecal bacteria counts were collected by depth integration at the deepest and swiftest part of flow to represent the largest volume of discharge in the cross section. Samples were preserved and placed on ice during transport to the field office. Field measurements of dissolved-oxygen concentration, pH, specific conductance, and temperature were measured at the point where grab samples were collected. A Corning Checkmate 90 meter was used for all field measurements and was calibrated with standard solutions before each measurement.

Quality-assurance procedures were followed throughout the study to identify potential problems in data collection caused by sampling methods or equipment contamination. These procedures included the use of trip-blank, duplicate, field-spike, and equipment-blank samples. Trip-blank samples were prepared by the USGS National Water Quality Laboratory and were used to check for contamination of volatile-organic compound samples during transport from the field to the laboratory. Trip blanks were transported in the same containers as bottles containing sample water. Results of trip-blank analyses indicate that contamination did not occur. Duplicate samples were used to check the precision of laboratory analyses and the sample-splitting process. Analyses from duplicate samples indicated that laboratory analyses and the sample-splitting process were producing consistent results. A field-spike sample was used to evaluate sample degradation and constituent recovery by the laboratory. Results of the spike-sample analysis indicated that degradation of certain constituents may have occurred during sample shipment. Equipment-blank samples were collected by pumping and processing inorganic-free and organic-free water in the same manner as sample water. Analyses from equipment blanks indicated that the cleaning procedure was efficient and minimal cross contamination occurred between sampled storms.

The representativeness of samples collected with the automatic-pumping sampler was evaluated by collecting manual, depth-integrated samples simultaneously with automatically collected samples. Samples were analyzed for nutrients, selected metals, and suspended-solids concentrations. Results indicated that flow in shallow, swift channels is well mixed and can be accurately represented by samples collected at a single point.

All chemical analyses, except 5-day biological oxygen demand (BOD), were done by the USGS National Water Quality Laboratory. BOD was analyzed by a laboratory contracted by FCDMC. Alkalinity and fecal-bacteria counts were measured in the Tempe office of the USGS.

# SELECTED PHYSICAL, CHEMICAL, AND MICROBIAL CHARACTERISTICS

A total of 35 stormwater and streamflow samples were collected from October 1991 to August 1993 to characterize stormwater from the five drainage basins monitored by the USGS and streamflow from the Salt River. Concentrations measured in flow-weighted composite samples are the mean concentrations for a storm (event-mean concentration), whereas, concentrations measured in equal-width increments and manual-grab samples are concentrations at a specific time of the hydrograph (instantaneous concentrations). Unless stated otherwise, concentrations referred to in this report are event-mean concentrations. Of the 35 samples, 5 samples were analyzed for a reduced number of properties and constituents because the volumes of water collected were insufficient to analyze all constituents. Of the 210 properties and constituents analyzed, 127 were not detected in any of the 35 samples (table 4). Quality-assurance data are not presented in this report, but are available upon request from the Tucson office of the USGS. Twenty-six samples were collected from seven sites by the City of Phoenix and analyzed for selected constituents; data on specific conductance, temperature, alkalinity, and dissolved-oxygen and dissolved-constituent concentrations were not available for these samples. Data collected by the City of Phoenix were used in all statistical and regression analyses and can be requested from the City of Phoenix.

## Physical Characteristics

Stormwater and streamflow temperatures ranged from 46° to 86°F, and the initial runoff from Youngtown, Peoria, and 48th Street typically was black in color. The black color could have been from oil and grease, particulates from ground-up tires, or other sources. Event-mean specific-conductance values from urban and undeveloped drainage basins ranged from 52 to 894 μS/cm and instantaneous specific-conductance values of samples from the Salt River 309 to 880 μS/cm. In general, specific conductance decreased during storms, indicating that most soluble constituents were washed from exposed surfaces during the initial part of a storm or were diluted (fig. 2). Specific conductance increased during some storms at 48th Street and 27th Avenue. The increase could be due to runoff from areas in the drainage basin arriving at the streamflow-gaging station at different times.

Dissolved-solids concentrations from urban drainage basins and South Mountain seem log-normally distributed and ranged from 33 to 660 mg/L; about 90 percent of samples had less than 150 mg/L. These low concentrations indicate that the drainage basins have few soluble solids, that stormwater had little time to dissolve solids from exposed surfaces, or that soluble solids were diluted. Instantaneous dissolved-solids concentrations of streamflow from the Salt River at 24th Street and Priest Drive ranged from 180 to 491 mg/L. Instantaneous dissolved-solids concentrations ranged from 287 to 855 mg/L for all samples collected at the streamflow-gaging station, Salt River below Stewart Mountain Dam, Arizona (09502000) during 1960 to 1993, which is about 20 miles northeast of Mesa. The dissolved-solids concentrations indicate that streamflow would be diluted by urban runoff.

Suspended-solids concentrations in urban runoff seem log-normally distributed, ranged from less than 1 to 1,480 mg/L, and were inversely correlated with percentage of impervious area (rank correlation was -0.44; table 5, fig. 3). The rank correlation refers to the Spearman rank correlation,

**Table 4.** Constituents that were not detected in samples of stormwater, Maricopa County, Arizona

| Watstore code | Constituent | Watstore code | Constituent |
|---|---|---|---|
| 01012 | Beryllium, total | 34596 | Dinoctyl phthalate, total |
| 01030 | Chromium, dissolved | 34601 | 2,4-Dichlorophenol, total |
| 01035 | Cobalt, dissolved | 34606 | 2,4,Dimethylphenol, total |
| 01059 | Thallium, total | 34611 | 2,4-Dinitrotoluene, total |
| 30217 | Dibromomethane, recoverable | 34616 | 2,4-Dinitrophenol, total |
| 32101 | Dichlorobromomethane, total | 34621 | 2,4,6-Trichlorophenol, total |
| 32102 | Carbontetrachloride, total | 34626 | 2,6-Dinitrotoluene, total |
| 32103 | 1,2-Dichloroethane, total | 34631 | 3,3'-Dichlorobenzidine, total |
| 32104 | Bromoform, total | 34636 | 4-Bromophenylphenylether, total |
| 32105 | Chlorodibromomethane, total | 34641 | 4-Chlorophenylphenylether, total |
| 32106 | Chloroform, total | 34646 | 4-Nitrophenol, total |
| 34030 | Benzene, total | 34657 | 4,6-Dinitroorthocresol, total |
| 34200 | Acenapthylene, total | 34668 | Dichlorodifluoromethane, total |
| 34205 | Acenaphthene, total | 34671 | Aroclor 1016 pcb, total |
| 34210 | Acrolein, total | 34696 | Naphthalene, total |
| 34215 | Acrylonitrile, total | 34699 | Trans-1,3-dichloropropene, total |
| 34220 | Anthracene, total | 34704 | Cis-1,3-dichloropropene, total |
| 34242 | Benzo K fluoranthene, total | 39032 | Pentachlorophenol, total |
| 34247 | Benzo A pyrene, total | 39062 | Chlordane, cis isomer, total |
| 34259 | Delta benzene hexachloride, total | 39065 | Chlordane, trans isomer, total |
| 34273 | Bis 2-chloroethyl ether, total | 39110 | Dinbutylphthalate, total |
| 34278 | Bis (2-chloroethoxy) methane, total | 39120 | Benzidine, total |
| 34283 | Bis (2-chloroisopropyl) ether, total | 39175 | Vinylchloride, total |
| 34292 | n-Butylbenzyl phthalate, total | 39180 | Trichloroethylene, total |
| 34301 | Chlorobenzene, total | 39310 | P,P' DDD, total |
| 34311 | Chloroethane, total | 39330 | Aldrin, total |
| 34336 | Diethyl phthalate, total | 39337 | Alpha bhc, total |
| 34341 | Dimethyl phthalate, total | 39338 | Beta benzene hexachloride, total |
| 34351 | Endosulfan sulfate, total | 39340 | Lindane, total |
| 34356 | Endosulfan beta, total | 39350 | Chlordane, total |
| 34361 | Endosulfan i, recoverable | 39390 | Endrin, recoverable |
| 34366 | Endrin aldehyde total | 39400 | Toxaphene, total |

**Table 4.** Constituents that were not detected in samples of stormwater, Maricopa County, Arizona—Continued

| Watstore code | Constituent | Watstore code | Constituent |
|---|---|---|---|
| 34371 | Ethylbenzene, total | 39410 | Heptachlor, total |
| 34381 | Fluorene, total | 39420 | Heptachlor epoxide, total |
| 34386 | Hexachlorocyclopentadiene, total | 39488 | Aroclor 1221 pcb, total |
| 34396 | Hexachloroethane, total | 39492 | Aroclor 1232 pcb, total |
| 34408 | Isophorone, total | 39496 | Aroclor 1242 pcb, total |
| 34413 | Methylbromide, total | 39500 | Aroclor 1248 pcb, total |
| 34418 | Methylchloride, total | 39508 | Aroclor 1260 pcb, total |
| 34428 | n-Nitrosodi-n-propylamine, total | 39700 | Hexachlorobenzene, total |
| 34433 | n-Nitrosodiphenylamine, total | 39702 | Hexachlorobutadiene, total |
| 34438 | n-Nitrosodimethylamine, total | 77093 | Cis-1,2-dichloroethene, total |
| 34447 | Nitrobenzene, total | 77168 | 1,1-Dichloropropene, total |
| 34452 | Parachlorometa cresol, total | 77170 | 2,2-Dichloropropane, total, |
| 34461 | Phenanthrene, total | 77173 | Propane, 1,3-dichloro-, total |
| 34475 | Tetrachloroethylene, total | 77223 | Benzene, isopropyl-, recoverable |
| 34488 | Trichlorofluoromethane, total | 77224 | Benzene, n-propyl-, recoverable |
| 34496 | 1,1-Dichloroethane, total | 77226 | Mesitylene, total |
| 34501 | 1,1-Dichloroethylene, total | 77275 | O-Chlorotoluene, total |
| 34506 | 1,1,1-Trichloroethane, total | 77277 | Toluene, p-chloro-, recoverable |
| 34511 | 1,1,2-Trichloroethane, total | 77297 | Methane, bromochloro-, recoverable |
| 34516 | Ethane, 1,1,2,2-tetrachloro-, recoverable | 77342 | Benzene, n-butyl-, recoverable |
| 34526 | Benzo(a)anthracene1, 2-benzanthracene, total | 77350 | Benzene, sec-butyl-, recoverable |
| 34536 | Benzene, o-chloro-, recoverable | 77353 | Benzene, tert-butyl-, recoverable |
| 34541 | 1,2-Dichloropropane, total | 77443 | 1,2,3-Trichloropropane, total, |
| 34546 | 1,2-Transdichloroethene, total | 77562 | Ethane, 1,1,1,2-tetrachloro-, recoverable |
| 34551 | Benzene, 1,2,4-trichloro-, recoverable | 77613 | Benzene, 1,2,3-trichloro-, recoverable |
| 34556 | 1,2,5,6-Dibenzanthracene, total | 77651 | 1,2-Dibromoethane, total |
| 34566 | Benzene, 1,3-dichloro-, recoverable | 77652 | Freon 113, recoverable |
| 34571 | Benzene, 1,4-dichloro-,recoverable | 81555 | Bromobenzene, total |
| 34576 | 2-Chloroethylvinylether, total | 82625 | Dibromochloropropane, recoverable |
| 34581 | 2-Chloronaphthalene, total | 82626 | 1,2-Diphenylhydrazine, recoverable |
| 34586 | 2-Chlorophenol, total | 99897 | Antimony, total recoverable |
| 34591 | 2-Nitrophenol, total | | |

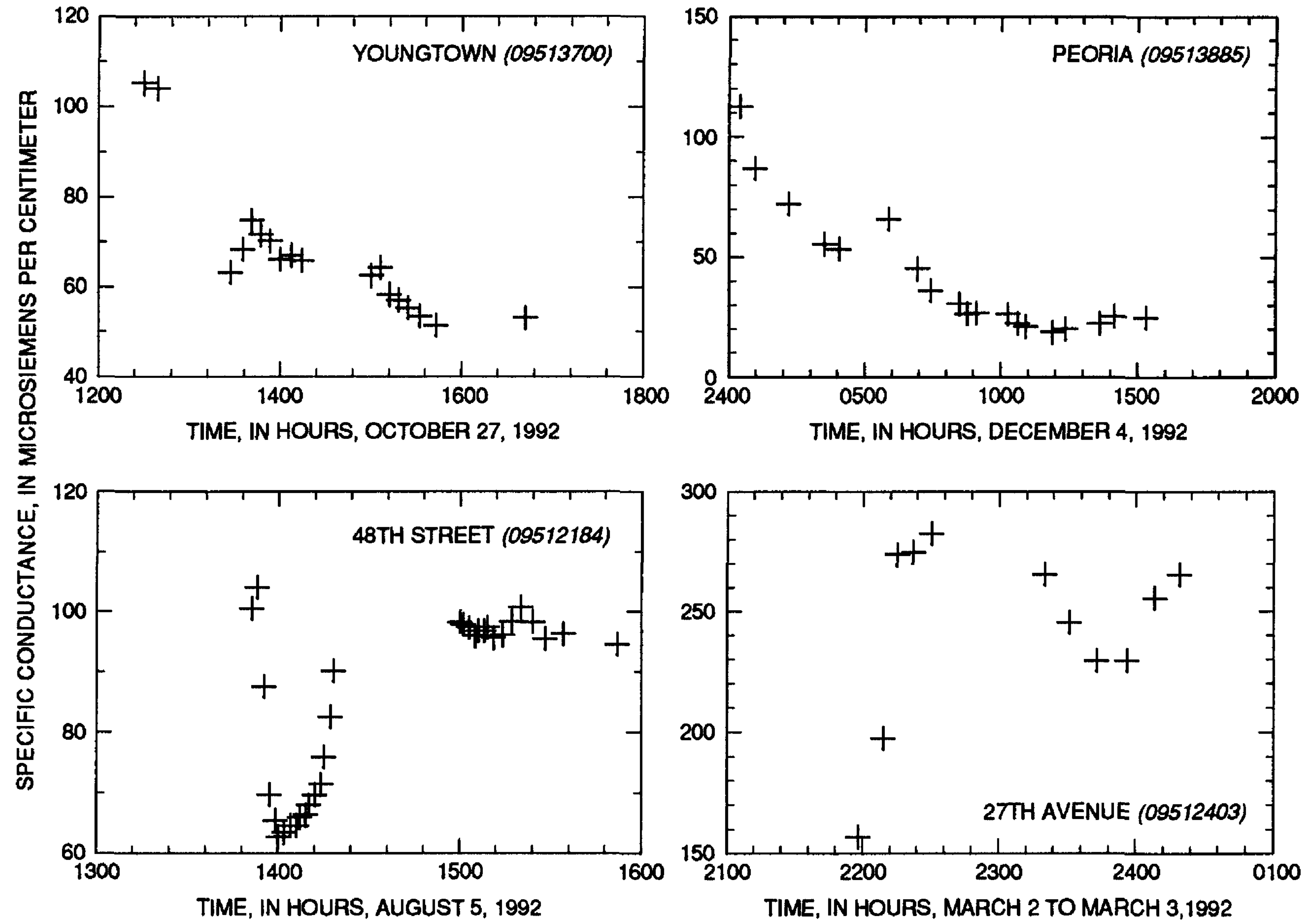


**Figure 2.** Specific conductance of stormwater as a function of time during a storm, Maricopa County, Arizona. Time refers to Mountain Standard Time and is given according to the 24-hour clock. U.S. Geological Survey stormwater-monitoring station number is in italics.

which correlates two variables using their relative ranking rather than using absolute values and gives outliers less weight in the correlation. The largest suspended-solids concentration (3,390 mg/L) was from South Mountain. Instantaneous suspended-solids concentrations from the Salt River were from 3 to 720 mg/L, and correlated strongly and directly with stream discharge (rank correlation was 0.77).

## Chemical Characteristics

Values of each physical property and constituent concentration commonly varied by an order of magnitude among the drainage basins and seem log-normally distributed, with the exception of nutrients. Summary statistics for the urban drainage basins (table 6) were computed using the log-probability regression method (Helsel and Cohn, 1988). This method does not assume a log-normal distribution in the data and uses censored data (less-than values) to more accurately estimate means and standard deviations.

Stormwater and streamflow had pH values from 6.3 to 9.0, which are typical values for most river waters (Hem, 1985, p. 64). Dissolved- and whole-water alkalinity values ranged from 10 to 150 and 10 to 228 mg/L as calcium carbonate, respectively. For all samples, alkalinity values were larger in whole water or about equal to filtered samples because the surface of sediments can neutralize acids. Dissolved-oxygen concentrations ranged from 3.8 to 10.2 mg/L, and about 75 percent of samples were saturated 80 percent or more with atmospheric oxygen (Hem, 1985, p. 155). Low dissolved-oxygen concentrations occurred in

**Table 5.** Correlations of percentage of impervious area, total recoverable trace metals, and total nutrients to event-mean concentrations of suspended solids, Maricopa County, Arizona

[Data from South Mountain and the Salt River are not included. Significance is the probability that the two variables are independent. Data from USGS and City of Phoenix were used in statistical analyses]

| Variable | Spearman rank correlation to suspended solids | Significance | Number of samples |
|---|---|---|---|
| Chemical oxygen demand, in milligrams per liter | 0.50 | 0.00 | 41 |
| 5-day biological oxygen demand, in milligrams per liter | .32 | .04 | 41 |
| Total nitrogen, in milligrams per liter | .42 | .00 | 35 |
| Total ammonia plus organic nitrogen, in milligrams per liter | .30 | .05 | 40 |
| Total phosphorus, in milligrams per liter | .57 | .00 | 40 |
| Cadmium, total recoverable, in micrograms per liter | .71 | .00 | 27 |
| Copper, total recoverable, in micrograms per liter | .57 | .00 | 38 |
| Lead, total recoverable, in micrograms per liter | .76 | .00 | 45 |
| Zinc, total recoverable, in micrograms per liter | .76 | .00 | 44 |
| Fecal coliform, in colonies per 100 milliliters | .18 | .28 | 38 |
| Fecal streptococci, in colonies per 100 milliliters | .29 | .08 | 38 |
| Impervious area, in percent | -.44 | .00 | 46 |

samples that were black in color. Calcium and bicarbonate were the predominant dissolved ions in samples from urban drainage basins and South Mountain; sodium and chloride were the predominant dissolved ions in samples from the Salt River.

Ranges in total recoverable trace-metal concentrations for all land uses were similar, except for heavy industrial land use (fig. 4, table 7). Large trace-metal concentrations for heavy industrial land use are mostly due to the large suspended-solids concentrations from 27th Avenue, which has only 15 percent impervious area. Heavy industrial land use typically has about 75 percent impervious area and likely contributes less suspended solids to stormwater runoff. Naturally occurring trace metals adsorb onto sediments and probably account for most concentrations in stormwater; however, industrial activities could increase the concentration of certain trace metals. Concentrations of selected constituents were compared by grouping data by land use as follows: Youngtown, 1B-08, and 1B-11 represent residential land use; Peoria and SR-21 represent commercial land use; 27th Avenue and SR-45 represent heavy industrial land use; and 48th Street represents light industrial land use. AC-05, SR-03, and SR-33 represent mixed land use in figure 4; however, statistics of constituent concentrations for mixed land use were not computed.

Data from South Mountain and the Salt River were combined to represent nonurban sources. Concentrations of most constituents from South Mountain and the Salt River were within the range of concentrations from urbanized drainage basins (table 6). Total recoverable trace-metal concentrations from South Mountain and the Salt River varied and directly correlated with discharge and suspended-solids concentrations. The sample of January 12, 1992, at South Mountain was collected during low discharge near the end of the storm and was a manual-grab sample. Concentrations for all total recoverable trace metals were consistently smaller in this sample than in the sample of February 7, 1992, which was a flow-weighted composite sample.

Comparison of total recoverable to dissolved trace-metal concentrations and correlations between suspended-solids and total recoverable trace-metal concentrations indicate that most trace metals are in the solid phase. Dissolved trace-metal concentrations were typically less than detection limits or, when detected, less than 20 percent of the

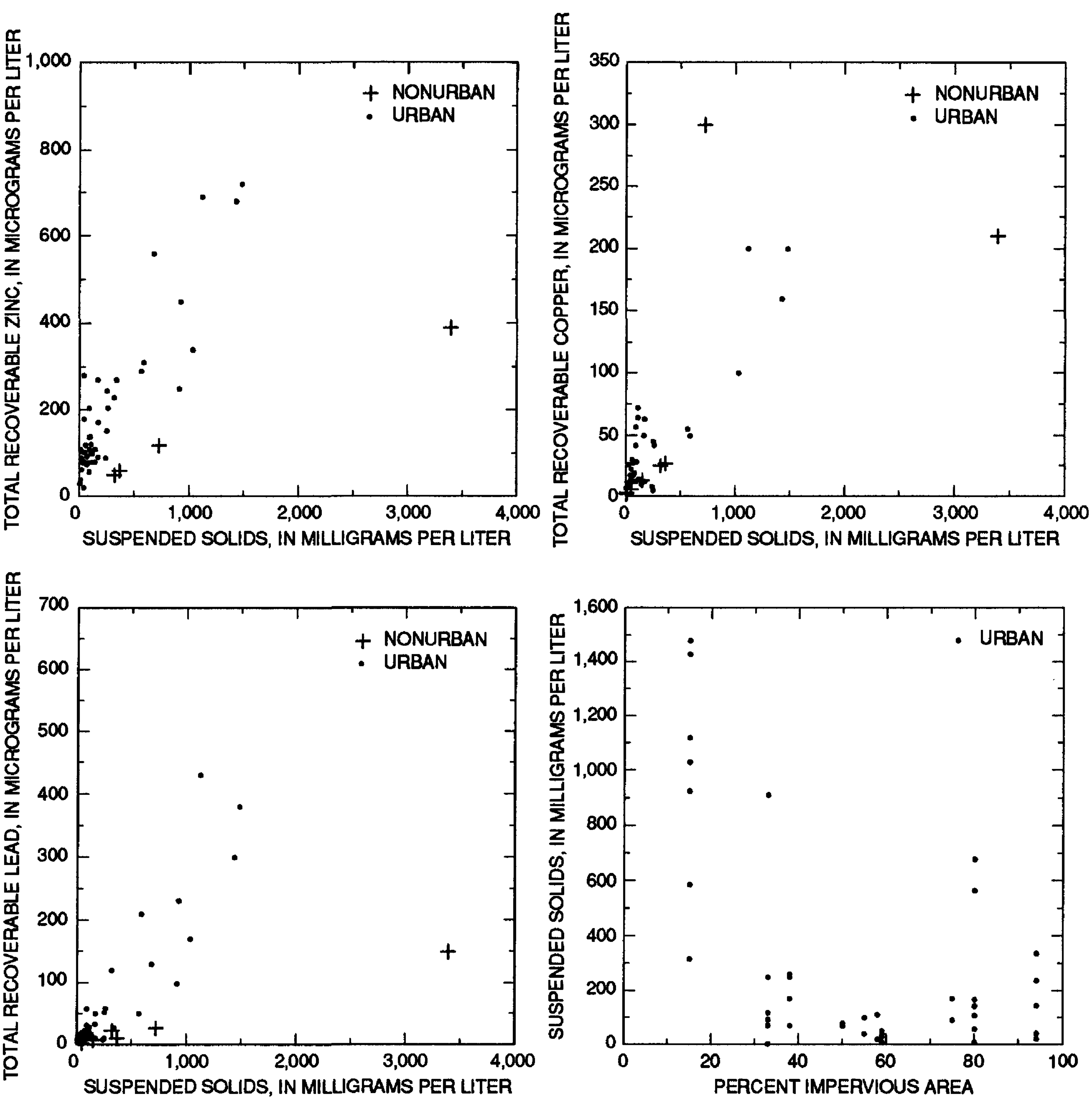


**Figure 3.** Event-mean concentrations of total recoverable trace metals in stormwater as a function of suspended-solids concentrations and suspended-solids concentrations as a function of percentage of impervious area, Maricopa County, Arizona.

total recoverable concentrations. About half the samples from Peoria, however, had dissolved-copper and dissolved-zinc concentrations that were greater than 50 percent of the total recoverable concentration. Rank correlations between concentrations of suspended solids and total recoverable trace metals ranged from 0.57 to 0.76 (table 5). Five discrete samples were collected at 48th Street on May 20, 1992, and rank correlations between instantaneous concentrations of suspended solids and total recoverable trace metals ranged from 0.89 to 0.97. These correlations indicate that trace metals are associated with the suspended solids.

Data form a linear trend when selected constituent concentrations measured in urban

**Table 6.** Summary statistics for selected properties and event-mean constituent concentrations measured in stormwater from urban drainage basins monitored by the USGS and City of Phoenix, Maricopa County, Arizona

[Data from South Mountain and the Salt River are not included. Samples were collected between October 1991 and October 1993. Mean values were calculated using the log probability method. <, less than; NA, not analyzed. Dashes indicate no data]

| Property or constituent | Maximum | Minimum | Mean | Standard deviation | Number of samples | Number less than detection limit | Detection limit | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | USGS | City of Phoenix |
| Chemical oxygen demand, in milligrams per liter | 4,300 | <10 | 239 | 645 | 43 | 1 | 10 | 1 |
| Biological oxygen demand, in milligrams per liter | 3,600 | 3 | 109 | 528 | 46 | 3 | 5 | 1 |
| Suspended solids, in milligrams per liter | 1,480 | <1 | 227 | 381 | 46 | 1 | 1 | 10 |
| Dissolved solids, in milligrams per liter | 660 | 33 | 102 | 93.6 | 45 | 0 | 1 | 10 |
| Nitrogen, total, in milligrams per liter | 7.3 | 1.3 | 3.26 | 1.39 | 40 | 0 | .1 | ------- |
| Nitrogen, ammonia plus organic, total, in milligrams per liter | 4.9 | .6 | 2.1 | 1.0 | 41 | 0 | .2 | ------- |
| Phosphorus, total, in milligrams per liter | 1.7 | .11 | .41 | .32 | 41 | 0 | .01 | .05 |
| Phosphorus, dissolved, in milligrams per liter | .63 | .03 | .17 | .14 | 25 | 0 | .01 | NA |
| Cadmium, total recoverable, in micrograms per liter | 6 | <0.2 | .99 | 1.17 | 50 | 19 | 1 | .2 |
| Copper, total recoverable, in micrograms per liter | 320 | 5 | 47.0 | 63.4 | 42 | 0 | 1 | 1 |
| Lead, total recoverable, in micrograms per liter | 620 | 3 | 71.6 | 125 | 49 | 0 | 1 | 1 |
| Zinc, total recoverable, in micrograms per liter | 980 | <5 | 204 | 204 | 49 | 1 | 10 | 1 |
| Fecal coliform, in colonies per 100 milliliters | 1,600,000 | 130 | 44,400 | 240,000 | 44 | 0 | 1 | 2 |
| Fecal streptococci, in colonies per 100 milliliters | 160,000 | 130 | 17,400 | 27,300 | 45 | 0 | 1 | 2 |

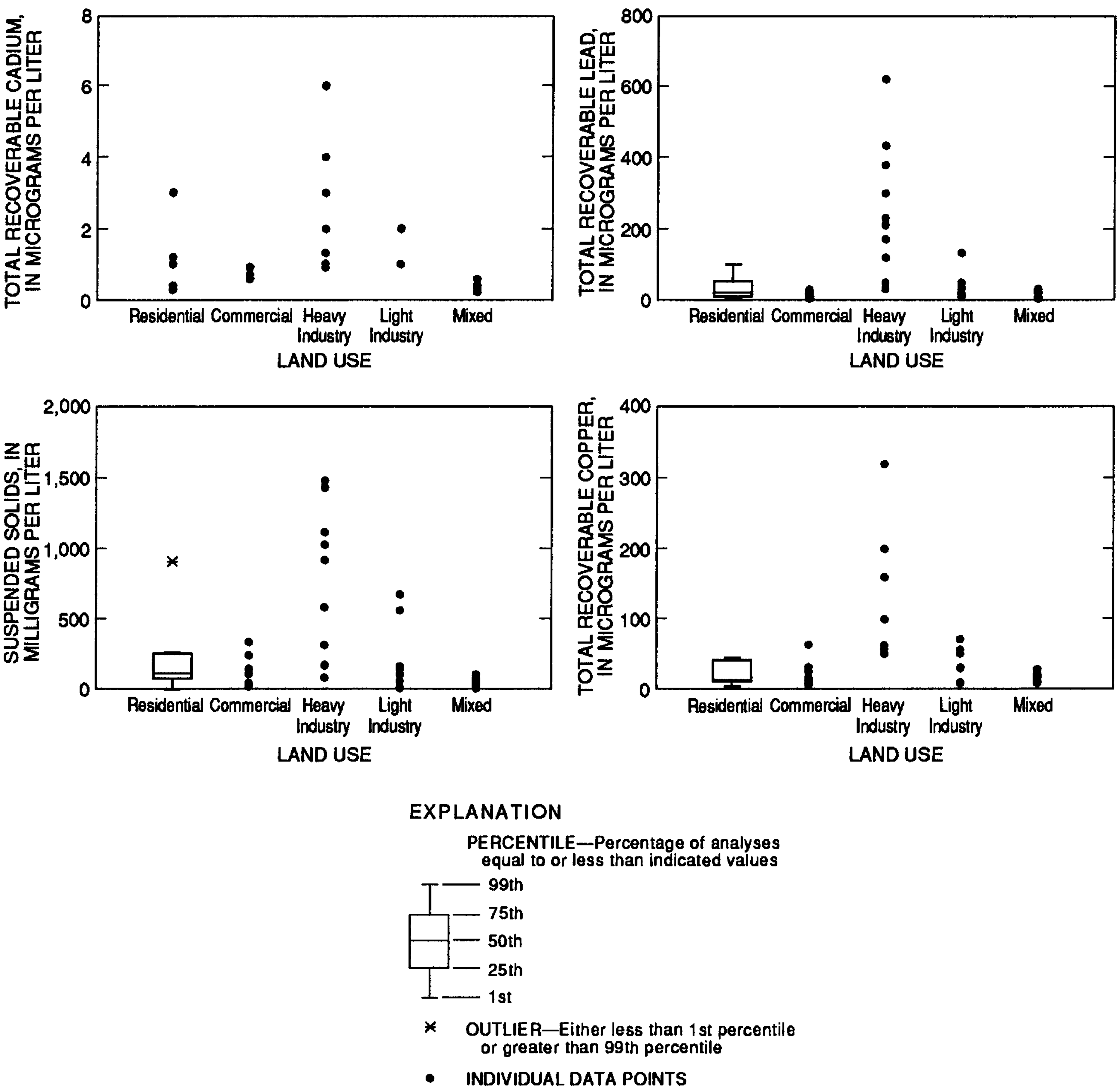


**Figure 4.** Ranges in selected event-mean constituent concentrations in stormwater as a function of land use, Maricopa County, Arizona.

stormwater are plotted as a function of suspended-solids concentrations (fig. 3). Data from South Mountain and the Salt River also form a linear trend, but the slopes and intercepts for total recoverable zinc and total recoverable lead seem to be lower. These trends indicate that urbanization may have elevated the concentration of certain constituents in urban sediments and that sediments from different land uses have roughly equal constituent concentrations. If sediments from different land uses had different constituent concentrations, then the combined urban data would not form a linear trend. Cadmium was detected in only one nonurban sample, but was detected in 31 urban samples. Urban activities also seem to have elevated the concentration of cadmium and may have elevated the concentration of other constituents.

**Table 7.** Summary statistics for selected event-mean constituent concentrations measured in stormwater and streamflow, Maricopa County, Arizona

[Data for South Mountain and Salt River were combined to represent nonurban sources and include event-mean and instantaneous concentrations. Data from drainage basins with mixed land use were not grouped into any land-use category. <, less than. Dashes indicate that statistics could not be computed]

| Constituent | Number of samples | Number of samples containing concentration less than the detection limit | Concentration | | | Standard deviation | Detection limit | |
|---|---|---|---|---|---|---|---|---|
| | | | Maximum | Minimum | Mean | | U.S. Geological Survey | City of Phoenix |
| **Residential** | | | | | | | | |
| Chemical oxygen demand, in milligrams per liter | 13 | 1 | 200 | <10 | 100 | 50 | 10 | 1 |
| Suspended solids, in milligrams per liter | 14 | 1 | 910 | <1 | 180 | 230 | 1 | 10 |
| Cadmium, total recoverable, in micrograms per liter | 14 | 5 | 3 | <.2 | .8 | .7 | 1 | .2 |
| Copper, total recoverable, in micrograms per liter | 11 | 0 | 45 | 5 | 23 | 5 | 1 | 1 |
| Lead, total recoverable, in micrograms per liter | 14 | 0 | 99 | 5 | 32 | 28 | 1 | 1 |
| **Commercial** | | | | | | | | |
| Chemical oxygen demand, in milligrams per liter | 8 | 0 | 330 | 60 | 150 | 90 | 10 | 1 |
| Suspended solids, in milligrams per liter | 8 | 0 | 337 | 20 | 120 | 120 | 1 | 10 |
| Cadmium, total recoverable, in micrograms per liter | 9 | 6 | .9 | .6 | .7 | .2 | 1 | .2 |
| Copper, total recoverable, in micrograms per liter | 9 | 0 | 64 | 8 | 20 | 17 | 1 | 1 |
| Lead, total recoverable, in micrograms per liter | 9 | 0 | 27 | 3 | 12 | 7.7 | 1 | 1 |
| **Heavy industry** | | | | | | | | |
| Chemical oxygen demand, in milligrams per liter | 9 | 0 | 4,300 | 110 | 720 | 90 | 10 | 1 |
| Suspended solids, in milligrams per liter | 9 | 0 | 1,480 | 84 | 790 | 530 | 1 | 10 |
| Cadmium, total recoverable, in micrograms per liter | 10 | 1 | 6 | .9 | 2.5 | 1.7 | 1 | .2 |
| Copper, total recoverable, in micrograms per liter | 8 | 0 | 320 | 50 | 140 | 90 | 1 | 1 |
| Lead, total recoverable, in micrograms per liter | 10 | 0 | 620 | 31 | 250 | 180 | 1 | 1 |

**Table 7.** Summary statistics for selected event-mean constituent concentrations measured in stormwater and streamflow, Maricopa County, Arizona—Continued

| Constituent | Number of samples | Number of samples containing concentration less than the detection limit | Concentration | | | Standard deviation | Detection limit | |
|---|---|---|---|---|---|---|---|---|
| | | | Maximum | Minimum | Mean | | U.S. Geological Survey | City of Phoenix |
| **Light industry** | | | | | | | | |
| Chemical oxygen demand, in milligrams per liter | 6 | 0 | 300 | 53 | 120 | 1,360 | 10 | 1 |
| Suspended solids, in milligrams per liter | 7 | 0 | 680 | 10 | 250 | 260 | 1 | 10 |
| Cadmium, total recoverable, in micrograms per liter | 7 | 4 | 2 | <1 | .8 | .8 | 1 | .2 |
| Copper, total recoverable, in micrograms per liter | 5 | 0 | 72 | 10 | 43 | 24 | 1 | 1 |
| Lead, total recoverable, in micrograms per liter | 7 | 0 | 130 | 11 | 38 | 43 | 1 | 1 |
| **South Mountain and Salt River** | | | | | | | | |
| Chemical oxygen demand, in milligrams per liter | 8 | 0 | 21,000 | 12 | 2,650 | 7,420 | 10 | 1 |
| Suspended solids, in milligrams per liter | 8 | 0 | 3,390 | 3 | 620 | 1,140 | 1 | 10 |
| Cadmium, total recoverable, in micrograms per liter | 8 | 7 | 2 | <1 | ------- | ------- | 1 | .2 |
| Copper, total recoverable, in micrograms per liter | 8 | 0 | 300 | 2 | 70 | 120 | 1 | 1 |
| Lead, total recoverable, in micrograms per liter | 8 | 2 | 150 | <1 | 28 | 50 | 1 | 1 |

The difference in the slopes and intercepts between urban and nonurban data could be due to differences in the grain size of suspended solids. Trace metals concentrate on fine-grained materials, which tend to have a greater capacity for adsorbing metals than coarse-grained material (Horowitz and Elrick, 1987). Suspended solids in runoff from urban drainage basins generally were about fine sand or less in size. Coarse sand was observed in samples from South Mountain and the Salt River, which could account for the lower trace-metal concentrations per mass of suspended solids. Total recoverable copper, however, formed a linear trend with suspended solids, and the slope and intercept for urban and nonurban data do not appear to be different. The similarity indicates that lead and zinc could be released by urban activities and become concentrated in sediments. Additional data on sediments of equal grain size are needed to assess the effects of urbanization on sediment chemistry.

Nutrient concentrations for all stormwater samples seem normally distributed and were significantly and positively correlated with suspended-solids concentrations (table 5). Total organic nitrogen plus ammonia concentrations comprised a mean 64 percent of the total-nitrogen concentrations with a standard deviation of 16 percent. Total organic nitrogen concentrations were larger than the ammonia concentrations in all but six samples from Youngtown, Peoria, SR-03, and 48th Street. The large proportion of ammonia in these six samples could be from fertilizers applied to landscaped areas in these drainage basins. Dissolved phosphorus constituted a mean 47 percent of the total phosphorus concentration with a standard deviation of 27 percent. The significant correlation of total phosphorus concentrations with suspended-solids concentrations indicates that phosphorus in stormwater is associated with the solid phase (table 5). Phosphorus has a low solubility and may be present as a precipitate with the suspended solids (Hem, 1985, p. 126).

BOD and chemical oxygen demand (COD) seem log-normally distributed and ranged from less than 5 to 3,600 mg/L and from less than 10 to 21,000 mg/L, respectively. About 25 percent of samples from urban drainage basins exceeded the maximum allowable BOD limit of 30 mg/L for secondary treated effluent from publicly owned treatment works (State of Arizona, 1989). The rank correlation between BOD and total organic carbon was not significantly correlated (rank correlation of 0.21). The rank correlation between COD and total organic carbon was 0.94 and was significant at a level of 1 percent. BOD and COD are different measures of the amount of oxidizable material in stormwater. The large difference in correlations could be due to the differences in analyzing for oxidizable material and preservation techniques. Samples for BOD are preserved by chilling and are analyzed within 48 hours of sample collection. BOD analysis measures only the amount of readily oxidizable material. Samples for COD are chemically preserved and analyzed for all oxidizable material. The high correlation between COD and total organic carbon indicates that most of the oxygen demand is due to organic carbon. The low correlation between BOD and total organic carbon indicates that either most of the organic carbon is not readily oxidizable or that significant oxidation occurs before BOD is analyzed. The maximum BOD concentration (3,600 mg/L) from 27th Avenue probably is due to the large total organic carbon concentration (1,100 mg/L). The cause of the large COD concentration (21,000 mg/L) from South Mountain, however, is unknown and cannot be due to the low total organic carbon concentration (210 mg/L).

Oil and grease were detected in about 80 percent of urban stormwater samples and concentrations ranged from less than 1 to 9 mg/L. The strainer for the automatic-pumping sampler at Youngtown and Peoria was coated with oil and grease after most storms. Oil and grease were not detected in samples from the Salt River or South Mountain. Total phenols were detected in about 55 percent of urban stormwater samples and concentrations ranged from less than 1 to 1,900 μg/L. Total phenols were detected in about 50 percent of samples from the Salt River and concentrations ranged from less than 1 to 2 μg/L.

Organochlorine pesticides, semivolatile compounds, and volatile organic compounds were seldom detected in stormwater and were not detected in streamflow. Dichlorodiphenyldichloroethylene (DDE) was the most commonly detected pesticide, and concentrations ranged from 0.04 to 1.1 μg/L in stormwater from Youngtown, Peoria, and 27th Avenue. Dichlorodiphenyltrichloroethane (DDT) and arochlor 1254 were detected at 27th Avenue at concentrations from 0.1 to 0.3 μg/L. Dieldrin was detected in one sample from Youngtown at a concentration of 0.04 μg/L. DDT and its degradation product, DDE, could be residual insecticides from the 1950's and 1960's when most of the land in the metropolitan Phoenix area was used for agriculture (Hanks, 1988) or are byproducts in the manufacturing of other organochlorine pesticides that are still in use. Organochlorine pesticides were not detected in samples from 48th Street, South Mountain, or the Salt River.

Semivolatile compounds and volatile organic compounds were detected in only three samples from 48th Street and four samples from Peoria and were near detection levels. Detected compounds included polyaromatic hydrocarbons, plasticizers, and gasoline additives. Chemical analyses indicate that these compounds were not significant in stormwater.

## Microbial Characteristics

Fecal coliform and fecal streptococci counts seem log-normally distributed (table 6), and in some samples, counts were estimated because the colonies were too numerous to count accurately. Total fecal-bacteria counts (fecal coliform plus fecal streptococci) were not significantly correlated with suspended-solids concentrations at a level of 5 percent. The largest counts of fecal coliform and fecal streptococci were measured in samples from SR-03 (1,600,000 and greater than 160,000 col/100 mL, respectively) and could be due to sewer overflows diluted with runoff. Total fecal-bacteria counts were lowest in samples from the Salt River.

## ESTIMATES OF CONSTITUENT LOADS AND EVENT-MEAN CONSTITUENT CONCENTRATIONS

Estimates of constituent loads and concentrations discharged in stormwater from each municipality were needed by the FCDMC in anticipation of NPDES permit requirements. Estimates of constituent loads discharged from major drainage basins were needed to quantify the effect of urban stormwater on the receiving ephemeral streams. A statistical approach was used to estimate constituent loads and concentrations from unmonitored drainage basins in the Phoenix area.

Drainage-basin and storm characteristics for basins and storms monitored by the USGS and City of Phoenix were used with regional-regression equations (Driver and Tasker, 1990) to predict constituent loads and concentrations. These predictions were compared with measured values to evaluate the accuracy of the regional-regression equations, and then the equations were adjusted for application to unmonitored basins in the Phoenix area. The adjustments are regressions that combine the regional-regression equations and local data. Therefore, the adjusted equations are based on a large data set that includes local and regional data. This reduces the amount of local data needed to estimate constituent loads and concentrations but maintains the statistical strength of the equations.

Procedures for adjusting the regional-regression equations (model adjustment procedures, MAP's) are described by Hoos and Sisolak (1993). In this report, the term, prediction ($P_u$), refers to a value computed from the regional-regression equations that has a corresponding measured (observed) value. The term, estimate, refers to a value computed from a regression equation at an unmonitored drainage basin. Drainage basin, land use, and precipitation data from Sky Harbor Airport were used with the adjusted regression equations to estimate constituent loads and mean concentrations for each municipality and major drainage in the Phoenix area.

The regional-regression equations consist of two sets of equations that apply to regions that were delineated on the basis of mean annual precipitation (Driver and Tasker, 1990). One set of equations uses subsets of 13 explanatory variables to estimate constituent loads, concentrations, and volume of runoff (RUN) from urban drainage basins. The subsets were determined using a stepwise multiple-regression analysis and are referred to in this report as the stepwise equations. The explanatory variables include storm, drainage basin, and climatic characteristics. The second set of equations uses only total rainfall (TRN), drainage area (DA), and percentage of impervious area (IA) as the independent variables for estimating constituent loads. Regressions were developed using log (base 10) transformations of the response and explanatory variables. The general form of the detransformed regional-regression equation is:

$$P_u = \beta_o \times \chi_1^{\beta_1} \times \chi_2^{\beta_2} \ldots \chi_n^{\beta_n} \times BCF \qquad (1)$$

where

$P_u$ = unadjusted storm-runoff load or volume (response variable) computed using regional-regression equation;

$\beta_o, \beta_1, \beta_2, \beta_n$ = regression coefficients;

$\chi_1, \chi_2, \chi_n$ = explanatory variables such as physical, land-use, and climatic characteristics; and

*BCF* = bias-correction factor that corrects for systematic biases that occur during the detransformation of the explanatory variables.

The stepwise and three-variable equations were used to predict the loads and concentrations of 11 constituents and RUN for storms that were sampled by the USGS and the City of Phoenix. The 11 constituents were chemical oxygen demand (COD), suspended solids (SS), dissolved solids (DS), total nitrogen (TN), total ammonia plus organic nitrogen (TKN), total phosphorus (TP), dissolved phosphorus (DP), total recoverable cadmium (CD), total recoverable copper (CU), total recoverable lead (PB), and total recoverable zinc (ZN). Regional-regression equations for BOD were not developed.

## Constituent Loads

Observed loads were computed by multiplying the volume of runoff from a storm, in cubic feet, by the concentration of constituents in the flow-weighted composite, in milligrams or micrograms per liter. The product was then multiplied by a conversion factor to obtain units in pounds. Dissolved phosphorus was not analyzed by the City of Phoenix, so there were no observed values from seven drainage basins to compare with predictions using either the stepwise or three-variable equations. Some spurious observed values were noted (COD from 27th Avenue on December 10, 1991; SS from Youngtown on December 10, 1991; TKN for all samples from AC-05; CD from IB-08 on January 3, 1992). These data were included in all statistical analyses to reflect the large variability and error in estimating stormwater chemistry. Observed loads from Peoria had to be estimated because of errors in measuring the volume of runoff from the basin. The measured volume of runoff for all storms, except for the storm of October 6, 1993, was about 1.2 to 3.9 times larger than the volume of rainfall that fell within the drainage basin indicating that either the rating was not properly defined or the bubbler system did not accurately measure stage. The volume of runoff and observed constituent loads were estimated by using a runoff coefficient of 0.80, which is reasonable for drainage basins with about 90 percent impervious area and flat slopes (Sabol and others, 1990).

### Adjustment of Regional-Regression Equations

Rank correlations, using log-transformed values of predicted and observed constituent loads, were significant at a level of 1 percent or less, except for dissolved phosphorus, and were about equal for the stepwise and three-variable equations (table 8). Both the stepwise and three-variable equations overestimated (positive bias) most constituent loads or had no bias. The stepwise equation, however, underestimated suspended-solids loads (negative bias), and the three-variable equation underestimated dissolved-solids loads. In general, the three-variable equations had less error in predicting the constituent loads than the thirteen-variable equations; however, errors were unacceptably high to apply the regional-regression equations directly to the Phoenix area. The positive correlation between predicted and observed values and bias of the predictions can be used to adjust the regional-regression equations for local application.

The MAP's use a log (base 10) transformation of the observed, predicted, and explanatory variables before correlations and regressions are computed. Explanatory variables are factors that correlate with observed loads; only those variables that were not used in the regional-regression equations can be used in the adjustment procedure. A strong linear relation exists between the untransformed values of observed and predicted loads for certain constituents (fig. 5). An alternative procedure of adjusting the regional-regression equations without the log transformation could improve the estimation of pollutant loads in the Phoenix area. A standard statistical method for comparing accuracy between regression equations using transformed and untransformed values was not available; therefore, regressions of untransformed values were not performed. Local regression equations, using only data from the Phoenix area, were developed for BOD because it was not included in the regional-regression equations. Local regression equations for other constituents also could be developed with the available data. Hoos and Sisolak (1993), however,

**Table 8.** Comparison of predicted constituent loads with observed constituent loads in stormwater and comparison of predicted volume of storm runoff with observed volume of storm runoff, Maricopa County, Arizona

[Constituent loads are in pounds, and storm runoff is in cubic feet. Plus sign (+), equations overestimate loads; minus sign (–), equations underestimate loads. NA, not applicable. Significance, probability that predicted and observed constituent loads are independent]

| Variable | Number of data pairs used in computations | Stepwise equation |  |  |  | Three-variable equation |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Root mean square error, in percent | Spearman rank correlation | Significance | Bias | Root mean square error, in percent | Spearman rank correlation | Significance | Bias |
| Chemical oxygen demand | 39 | 616 | 0.69 | 0.00 | + | 131 | 0.69 | 0.00 | + |
| Suspended solids | 42 | 16, 846 | .74 | .00 | – | 535 | .62 | .00 | + |
| Dissolved solids | 42 | 150 | .93 | .00 | None | 161 | .91 | .00 | – |
| Nitrogen, total | 31 | 1,896 | .74 | .00 | + | 135 | .69 | .00 | + |
| Nitrogen, ammonia plus organic, total | 39 | 174 | .76 | .00 | None | 201 | .76 | .00 | + |
| Phosphorus, total | 39 | 18,399 | .54 | .00 | + | 260 | .78 | .00 | + |
| Phosphorus, dissolved | 25 | 747,200 | .38 | .06 | + | 566 | .42 | .03 | + |
| Cadmium, total recoverable | 27 | 156 | .84 | .00 | + | 195 | .86 | .00 | None |
| Copper, total recoverable | 38 | 275 | .83 | .00 | + | 152 | .82 | .00 | None |
| Lead, total recoverable | 45 | 52,785 | .62 | .00 | + | 2,370 | .64 | .00 | + |
| Zinc, total recoverable | 44 | 948 | .76 | .00 | + | 189 | .72 | .00 | + |
| Storm runoff | 47 | 206 | .93 | .00 | + | NA | NA | NA | NA |

showed that even though local regression equations may provide a better fit to observed values, the equations may not have the smallest root mean squared error.

The MAP used to adjust each regional-regression equation was selected according to the guidelines described by Hoos and Sisolak (1993). The guidelines are a series of conditional statements that lead to either (1) a regression (designated R-P) that uses only predicted constituent loads if predicted and observed constituent loads are positively correlated and biased or (2) a regression (designated R-P+nV) that uses predicted constituent loads and explanatory variables if a correlation and (or) bias do not exist. The n in the R-P+nV regression equals the number of explanatory variables used in the regression. Hoos and Sisolak showed that minimizing the standard error of estimate was not a valid criterion for selecting the best regression technique.

The selected MAP's were applied to predictions from both the stepwise and three-variable equations (table 9). The general forms of the detransformed MAP equations are for the R-P:

$$P_{ai} = \beta_o' \times P_{ui}^{\beta_u'} \times BCF' \qquad (2)$$

and for the R-P+nV:

$$P_{ai} = \beta_o' \times P_{ui}^{\beta_u'} \times (\chi_1')^{\beta_1'} \times (\chi_2')^{\beta_2'} \ldots (\chi_n')^{\beta_n'} \times BCF' \qquad (3)$$

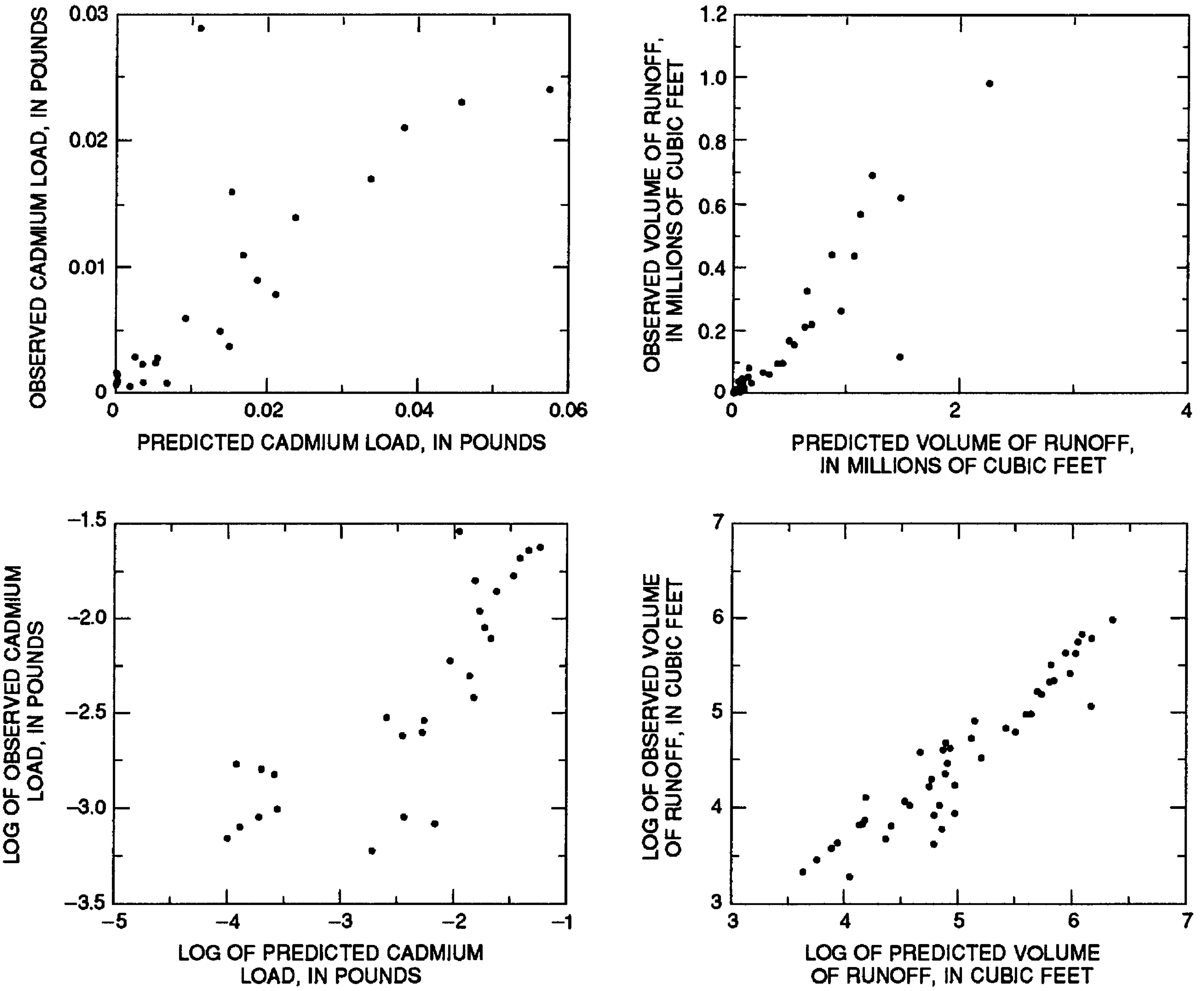


**Figure 5.** Observed load of total recoverable cadmium in stormwater and volume of runoff as a function of predicted load and volume, Maricopa County, Arizona. Loads and volumes were predicted using the stepwise equation of Driver and Tasker (1990).

where

$P_{ai}$ = the adjusted storm-runoff load or volume at unmonitored site *i*;

$P_{ui}$ = the unadjusted storm-runoff load or volume;

$\chi_1', \chi_2', \chi_n'$ = explanatory variables used in the adjusted regression equations;

$\beta_o', \beta_u', \beta_1', \beta_2', \beta_n'$ = regression coefficients for the adjusted regression equations;

$BCF'$ = bias-correction factor for the adjusted regression equations.

Correlations were computed between loads and the following explanatory variables: TRN, DA, IA, residential land use (LUR), commercial land use (LUC), industrial land use (LUI), undeveloped land use (LUN), storm duration (DRN), antecedent dry days (ANT) and maximum 5-minute rainfall intensity (MAX5). ANT and MAX5 were not used in the regional-regression equations. ANT and MAX5 correlated with DS, TKN, or CD at a level of 15 percent (table 10) and could account for some

**Table 9.** Calibration-error statistics for adjusting regional-regression equations with local data, Maricopa County, Arizona

[Constituent loads are in pounds, and storm runoff is in cubic feet per second. R-P, regression of observed against predicted value; R-P+nV, regression of observed against predicted value and explanatory variables. Simple, model-adjustment procedure is inappropriate, therefore a simple estimation technique should be used. NA, not applicable]

| Variable | Stepwise equation | | | Adjusted correlation coefficient | Three-variable equation | | | Adjusted correlation coefficient |
|---|---|---|---|---|---|---|---|---|
| | Model-adjustment procedure | Standard error of estimate, in log units | Standard error of estimate, in percent | | Model-adjustment procedure | Standard error of estimate, in log units | Standard error of estimate, in percent | |
| Chemical oxygen demand | R-P | 0.437 | 132 | 0.48 | R-P | 0.399 | 115 | 0.57 |
| Suspended solids | R-P | .611 | 250 | .47 | R-P | .627 | 266 | .44 |
| Dissolved solids | R-P+nV | .279 | 71 | .69 | R-P | .296 | 77 | .85 |
| Nitrogen, total | R-P | .430 | 130 | .50 | R-P | .340 | 92 | .69 |
| Nitrogen, ammonia plus organic, total | R-P+nV | .310 | 82 | .59 | R-P | .362 | 100 | .72 |
| Phosphorus, total | R-P | .577 | 220 | .37 | R-P | .416 | 122 | .67 |
| Phosphorus, dissolved | R-P | .405 | 118 | .16 | R-P | .418 | 124 | .10 |
| Cadmium, total recoverable | R-P | .278 | 71 | .75 | R-P+nV | .214 | 52 | .63 |
| Copper, total recoverable | R-P | .452 | 140 | .70 | Simple | NA | NA | NA |
| Lead, total recoverable | R-P | .671 | 314 | .32 | R-P | .619 | 258 | .42 |
| Zinc, total recoverable | R-P | .415 | 122 | .61 | R-P | .430 | 129 | .58 |
| Storm runoff | R-P | .259 | 65 | .88 | NA | NA | NA | NA |

of the differences between observed and predicted loads. A level of 15 percent was used because of the small amount of local data available for correlation analysis. The R-P+nV regressions for DS, TKN, and CD were computed using only data from drainage basins monitored by the USGS because data on ANT and MAX5 were not available from the City of Phoenix.

Urban land uses did not correlate strongly with constituent loads (table 10). This lack of correlation is consistent with the observations that most constituents in stormwater are not significantly different between various urban land uses. DA and LUN were the most common variables that correlated with constituent loads. The lack of correlation of TRN with most constituent loads was unexpected, because runoff and constituent loads depend on rainfall. Additional data may show the physical significance of TRN, even though the available data indicates that this explanatory variable generally is not significant.

Explanatory variables that were significantly correlated at a level of 15 percent were used in developing a local regression equation for BOD. The local regression equation for BOD was computed using a stepwise regression analysis of the log-transformed observed loads, DA, and LUN. The best regression, using Mallows' Cp (Helsel and Hirsch, 1992) as the criterion, used only DA as the explanatory variable.

The MAP's greatly reduced the standard errors of the regional-regression equations (compare columns 3 and 7 of table 8 with columns 4 and 8 of table 9). The decision to use either the adjusted stepwise or adjusted three-variable equations for each constituent generally was made on the basis of

**Table 10.** Explanatory variables that were correlated with observed constituent loads and volume of storm runoff at a level of 15 percent, Maricopa County, Arizona

[Constituent loads are in pounds, and storm runoff is in cubic feet. ANT, antecedent dry days; DA, drainage area, in square miles; Land use and impervious area, in percent; IA, impervious area; LUC, commercial land use; LUN, undeveloped land use; LUR, residential land use; LUI, industrial land use; MAX5, maximum 5-minute rainfall intensity, in inches per hour; TRN, total storm rainfall. Numbers in parentheses indicate number of samples used in correlations with ANT and MAX5]

| Variable | Explanatory variables | Number of samples |
|---|---|---|
| Chemical oxygen demand | ANT, DA, IA, LUC, LUN | 39 (24) |
| 5-day biological oxygen demand | ANT, DA, LUN | 40 (22) |
| Suspended solids | ANT, DA, IA, LUC, LUN, LUR, MAX5 | 42 (25) |
| Dissolved solids | ANT, DA, LUN | 42 (25) |
| Nitrogen, total | ANT, DA, LUC, LUN | 31 (23) |
| Nitrogen, ammonia plus organic, total | ANT, DA, LUN | 39 (25) |
| Phosphorus, total | ANT, DA, IA,LUN | 39 (25) |
| Phosphorus, dissolved | DA, LUN | 25 (25) |
| Cadmium, total recoverable | DA, DRN, IA, LUC, LUI, LUN, MAX5 | 27 (12) |
| Copper, total recoverable | DA, IA, LUC, LUN | 38 (20) |
| Lead, total recoverable | DA, IA, LUC, LUN, LUR, MAX5, TRN | 45 (27) |
| Zinc, total recoverable | ANT, DA, LUN, MAX5, TRN | 44 (27) |
| Storm runoff | DA, DRN, LUN, TRN | 47 (27) |

simplicity. Adjustments of the three-variable equations were selected to estimate most constituent loads because they require only TRN, DA, and IA as explanatory variables to compute $P_u$ and commonly used the R-P regression. Adjustments of the three-variable equations had smaller or about equal standard errors than the more complicated stepwise equations. Adjustment of the stepwise equation using the R-P regression for CD was selected because adjustment of the three-variable equation required the more complicated R-P+nV method and was computed using a smaller range in basin characteristics and smaller data set. Adjustments of the stepwise equations using the R-P regression for CU and RUN were used because adjustments of the three-variable equations were not possible. The selected adjusted equations for estimating constituent loads are listed in table 11. The standard error of the adjusted equations was higher (from 65 to 266 percent, table 12) for most constituents than the standard error reported by Driver and Tasker (1990, table 2).

### Load Estimates for Phoenix, Surrounding Municipalities, and Major Drainage Basins

The equations in table 11, land-use data, and municipality and drainage-basin boundaries were used to estimate constituent loads for each municipality and major drainage basin. The land-use and boundary data were obtained from the FCDMC and stored in a geographic-information system (GIS). A GIS is a data-base management system that can be used to store map information and to analyze and quantify relations between different maps. Each municipality and major drainage basin was subdivided into sections of 640 acres or less so that equations could be applied to each section. This area was selected because 640 acres is about equal to the area of two drainage basins monitored by the City of Phoenix and the mean area of drainage basins used in the adjustment procedures.

Each land-use type was assumed to be represented by a specific percentage of impervious area (Flood Control District of Maricopa County, 1993). The amount of each land use and impervious area in each of the sections was quantified using GIS. Noncontributing areas, such as lakes and canals, areas with agricultural land use, and areas within a municipality but not part of the municipality were excluded from all computations. The Phoenix area has many dry wells and retention basins; however, data on their locations and contributing areas are not available. Constituent

**Table 11.** Summary of regression equations selected for estimating storm-runoff constituent loads and volumes for Phoenix and surrounding municipalities

[Equation: $((Bo \times (TRN^{B1}) \times (DA^{B2}) \ldots \times BCF)^{B10}) \times (Bo\ adjusted) \times (BCF\ adjusted)$. Constituent values are in pounds, and storm runoff is in cubic feet. Bo, regression coefficient that is the intercept of the regression model; BCF, bias correction factor in the stepwise or three-variable regression model; Bo adjusted, the regression coefficient that is the intercept of the adjusted regression model; B10, the regression coefficient that is the slope of the adjusted regression model; BCF adjusted, the bias correction factor in the adjusted regression model. Dashes indicate variable is not used in equation]

| Variable | Bo | Total storm rainfall, in inches (TRN) | Drainage area, in square miles (DA) | Impervious area[1] in percent (IA) | Land use, in percent |  |  | Storm intensity, in inches (INT) | Mean annual rainfall, in inches (MAR) | BCF | B10 | Bo adjusted | BCF adjusted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Industrial[1] (LUI) | Commercial[1] (LUC) | Undeveloped[1] (LUN) |  |  |  |  |  |  |
| Chemical oxygen demand | 407 | 0.626 | 0.710 | 0.379 | ------- | ------ | ------- | ------- | ------- | 1.518 | 0.826 | 1.881 | 1.670 |
| 5-day biological oxygen demand | 117.5 | ------ | .382 | ------ | ------- | ------ | ------- | ------- | ------- | 3.042 | ------- | ------ | ------ |
| Suspended solids | 1,778 | .867 | .728 | .157 | ------- | ------ | ------- | ------- | ------- | 2.367 | .950 | .431 | 1.967 |
| Dissolved solids | 20.7 | .637 | 1.311 | 1.180 | ------- | ------ | ------- | ------- | ------- | 1.249 | .688 | 7.326 | 1.220 |
| Nitrogen, total | 20.2 | .825 | 1.070 | .479 | ------- | ------ | ------- | ------- | ------- | 1.258 | .679 | 1.197 | 1.255 |
| Nitrogen, ammonia plus organic, total | 13.9 | .722 | .781 | .328 | ------- | ------ | ------- | ------- | ------- | 1.722 | .947 | .421 | 1.304 |
| Phosphorus, total | 1.725 | .884 | .826 | .467 | ------- | ------ | ------- | ------- | ------- | 2.130 | .931 | .352 | 1.377 |
| Phosphorus, dissolved | .540 | .976 | .795 | .573 | ------- | ------ | ------- | ------- | ------- | 2.464 | .435 | .127 | 1.446 |
| Cadmium, total recoverable | .039 | .845 | .753 | ------ | 0.138 | 0.248 | -0.374 | ------- | ------- | 1.244 | 1.144 | .781 | 1.201 |
| Copper, total recoverable | .141 | .807 | .590 | ------ | .424 | .274 | -.061 | 0.928 | ------- | 1.502 | 1.237 | .536 | 1.562 |
| Lead, total recoverable | .162 | .839 | .808 | .744 | ------- | ------ | ------- | ------- | ------- | 1.791 | .815 | .110 | 2.244 |
| Zinc, total recoverable | .320 | .811 | .798 | .627 | ------- | ------ | ------- | ------- | ------- | 1.639 | .800 | .442 | 1.421 |
| Storm runoff | 1,123,052 | 1.016 | .916 | .677 | ------- | ------ | ------- | ------- | -1.312 | 1.299 | .963 | .491 | 1.154 |

[1] Add 1 to the value for impervious area, industrial land use, and commercial land use for use in the equation; add 2 to the value for undeveloped land use.

**Table 12.** Summary statistics of regression equations for estimating storm-runoff constituent loads and volumes for Phoenix and surrounding municipalities

| Variable | Number of samples | Adjusted correlation coefficient | Standard error of estimate, in percent | Method |
|---|---|---|---|---|
| Chemical oxygen demand | 39 | 0.57 | 115 | R-P 3-variable |
| 5-day biological oxygen demand | 40 | .20 | 241 | Local |
| Suspended solids | 42 | .44 | 266 | R-P 3-variable |
| Dissolved solids | 42 | .85 | 77 | R-P 3-variable |
| Nitrogen, total | 31 | .69 | 92 | R-P 3-variable |
| Nitrogen, ammonia plus organic, total | 39 | .72 | 100 | R-P 3-variable |
| Phosphorus, total | 39 | .67 | 122 | R-P 3-variable |
| Phosphorus, dissolved | 25 | .10 | 124 | R-P 3-variable |
| Cadmium, total recoverable | 27 | .75 | 71 | R-P 13-variable |
| Copper, total recoverable | 38 | .70 | 140 | R-P 13-variable |
| Lead, total recoverable | 45 | .42 | 258 | R-P 3-variable |
| Zinc, total recoverable | 44 | .58 | 129 | R-P 3-variable |
| Storm runoff | 47 | .88 | 65 | R-P 13-variable |

loads presented in this report therefore could be overestimated.

Confidence intervals measure the accuracy of constituent-load estimates. The confidence intervals represent the probability that the true (but unknown) mean of each constituent load is within a certain range and is represented by:

$$\left(\frac{1}{T}\right)P_{ai} < Y_i < (T)P_{ai} \qquad (4)$$

where

$Y_i$ = true (but unknown) value of the response variable at unmonitored site $i$;

$T$ is calculated as follows:

$$\log(T) = t_{\left(\frac{\alpha}{2},\, n-p\right)} \times SEP_i \qquad (5)$$

where

$t_{\left(\frac{\alpha}{2},\, n-p\right)}$ = critical value of the t-distribution for n-p degrees of freedom;

$n$ = number of observations in the calibration data set;

$p$ = number of explanatory variables plus 1; and

$SEP_i$ = standard error of prediction, expressed in log units, for adjusted estimate.

For the R-P regression:

$$SEP_i = \sqrt{SE^2_{R-P}\left(1 + u_i\left(U_i'U_i\right)^{-1}u_i'\right)} \qquad (6)$$

where

$SE_{R-P}$ = standard error of estimate (in log units) for the R-P regression equation;

$u_i$ = a (1 x 2) row vector containing 1 as the first element, and the value for the single explanatory variable, $P_{ui}$, evaluated (in log units) for unmonitored site $i$, augmented by a 1 as the first element; and

$U_i$ = a (n x 2) matrix containing 1 as the first column, and the values for the single explanatory variable, $P_u$, evaluated (in log units) for all n sites in the R-P calibration set, in the second column.

For any storm, the constituent load for a municipality is equal to the sum of estimates of all sections that comprise the municipality. The confidence interval for the sum is computed by summing the variance of estimates, in real units, and taking the square root to obtain the SEP (Gary Tasker, research hydrologist, USGS, written commun., May 1994). The steps for summing variances are described in the following equations:

$$VAR_i = (2.306 \times SEP_i)^2 \tag{7}$$

$$CV_i = \sqrt{e^{var_i} - 1} \tag{8}$$

$$VAR_{i,real} = (CV_i \times P_{ai})^2 \tag{9}$$

$$VAR_{sum} = \Sigma_{i=1}^{n} VAR_{i,real} \tag{10}$$

$$SEP_{sum} = \sqrt{VAR_{sum}} \tag{11}$$

$$T = t_{\left(\frac{\alpha}{2}, n-p\right)} \times SEP_{sum} \tag{12}$$

where

$VAR_i$ = variance of estimate, in log (base e) units, at unmonitored site *i*;

$CV_i$ = coefficient of variation;

$VAR_{i,real}$ = variance of estimate, in real units;

$VAR_{sum}$ = variance for the sum of estimates; and

$SEP_{sum}$ = standard error of estimate for the sum.

The procedure for computing constituent loads, confidence intervals, and confidence intervals of a sum, described by equations 1 through 12, apply to an individual storm with a fixed TRN value. The constituent loads for a mean summer, winter, or spring storm are estimated from mean TRN values, which have standard deviations that need to be taken into consideration. The constituent loads of mean summer, winter, and spring storms were estimated using rainfall statistics for 1954 to 1990 and procedures described by Gilroy and others (1990). Mean seasonal and mean annual constituent loads also were estimated. The steps for using mean TRN values with the R-P adjustment to estimate loads for a mean storm, mean seasonal loads, and mean annual loads at an unmonitored site are described by the following equations:

$$\log(P_{ai}) = se^2/2 + B_o + B_1 \times \log(P_{ui}) + (B_1^2 \times (C_1 \times rsd)^2)/2 \tag{13}$$

$$Load_{i,total} = N_{storms} \times e^{(\log(P_{ai}))} \tag{14}$$

$$Load_{i,mean} = (Load_{i,total})/N_{years} \tag{15}$$

where

$\log(P_{ai})$ = adjusted constituent load for an individual storm, in log (base e) units, estimated using a mean TRN value at unmonitored site *i*;

$se$ = standard deviation of residuals from the R-P regression, in log (base e) units;

$B_o$ = intercept of the R-P regression;

$B_1$ = slope of the R-P regression;

$C_1$ = regression coefficient for TRN from the regional-regression equations;

$rsd$ = standard deviation, in log (base e) units, of mean TRN value;

$Load_{i,\,total}$ = total constituent load for the period of record;

$N_{storms}$ = total number of storms for a season or year for the period of record;

$Load_{i,\,mean}$ = mean seasonal or annual constituent load.

$N_{years}$ = number of years in the period of record; and

The steps for computing the standard error and variance of the mean-constituent loads at an unmonitored site are described as follows:

$$\Phi = (C_1 \times rsd)^2 \times (sdbl)^2/2 \qquad (16)$$

$$\Lambda = (B_1 + (P_{ui} - xbar) / (C_1 \times rsd)^2)^2 / (sdbl)^2 \qquad (17)$$

$$\Omega = (1 - (se^2)/(m-2))^{m-2} \times (1 - 2 \times (se^2)/(m-2))^{-(m-2)/2} \qquad (18)$$

$$\rho = \Omega(1 - 2 \times \Phi) \times (1 - 4 \times \Phi)^{-0.5} \qquad (19)$$

$$MSE_i = \rho \times e^{((se^2)/m + 4 \times \Phi^{2((\Lambda)} / (((1 - 4 \times \Phi) \times (1 - 2 \times \Phi)))} \qquad (20)$$

$$VAR_{P_{ai}} = (e^{\log(P_{ai})})^2 \times (MSE_i - 1) \qquad (21)$$

$$VAR_{i,\,mean} = (Load_{i,\,mean})^2 \times (MSE_i - 1) \qquad (22)$$

$$RMSE_i = 100 \times \sqrt{(MSE_i - 1)} \qquad (23)$$

where

$sdbl$ = standard deviation of the slope of the R-P regression;

$xbar$ = mean of unadjusted predictions used in R-P regression;

$m$ = number of observed values used in R-P regression;

$MSE_i$ = mean standard error of estimate at unmonitored site $i$;

$VAR_{P_{ai}}$ = variance of event-mean constituent load;

$VAR_{i,\,mean}$ = variance of seasonal or annual constituent load; and

$RMSE_i$ = root mean square error, in percent.

Equations 13 through 23 and mean TRN values were used to estimate mean storm, mean seasonal, and mean annual loads and variances for each constituent, except BOD, for each section in a municipality (tables 13 through 19). Constituent loads for each section were summed, and equations 10, 11, and 12 were used to compute confidence intervals for these sums. The equation for estimating BOD load is similar to the R-P regression except that DA is the independent variable instead of the unadjusted load from the regional-regression equations. The BOD regression (table 11) and equations 4 through 12 were used to estimate loads for the municipalities because BOD load depends on DA, a fixed value, and not a mean TRN. Storm-frequency data (table 2) were used to estimate mean seasonal and annual BOD loads. BOD loads are the same for each season because the same number of storms occur in each season.

Runoff from summer monsoons and winter cold fronts contribute to the annual constituent loads in Phoenix and the surrounding areas. Both types of storms have a mean TRN value of 0.46 in., but monsoons have a larger standard deviation (table 2). Either type of storm can occur during spring (April through June); storms during this period have a mean storm TRN value of 0.36 in. Mean TRN values and standard deviations were

**Table 13.** Estimated constituent loads of a mean summer storm for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 33,500 | 29,400 | 31,400 | 217,000 | 168,000 | 192,000 | 11,500 | 10,500 | 11,000 | 997 | 871 | 934 |
| Gilbert | 15,700 | 13,200 | 14,400 | 107,000 | 74,900 | 91,000 | 4,520 | 3,940 | 4,230 | 455 | 378 | 416 |
| Glendale | 39,200 | 34,100 | 36,600 | 272,000 | 210,000 | 241,000 | 14,600 | 13,100 | 13,900 | 1,220 | 1,060 | 1,140 |
| Guadalupe | 1,210 | 631 | 919 | 9,370 | 2,070 | 5,720 | 323 | 213 | 268 | 35.0 | 18.4 | 26.7 |
| Mesa | 95,300 | 87,200 | 91,200 | 663,000 | 565,000 | 614,000 | 36,300 | 33,700 | 35,000 | 2,980 | 2,730 | 2,850 |
| Paradise Valley | 13,900 | 11,500 | 12,700 | 107,000 | 72,200 | 89,800 | 3,670 | 3,230 | 3,450 | 430 | 354 | 392 |
| Peoria | 35,600 | 28,500 | 32,000 | 260,000 | 170,000 | 215,000 | 16,100 | 13,100 | 14,600 | 1,180 | 914 | 1,050 |
| Phoenix | 302,000 | 287,000 | 295,000 | 2,220,000 | 2,030,000 | 2,120,000 | 112,000 | 107,000 | 109,000 | 9,730 | 9,240 | 9,480 |
| Scottsdale | 98,500 | 91,900 | 95,200 | 882,000 | 780,000 | 831,000 | 23,800 | 22,100 | 23,000 | 3,100 | 2,890 | 3,000 |
| Tempe | 39,600 | 34,100 | 36,900 | 264,000 | 198,000 | 231,000 | 16,900 | 15,100 | 16,000 | 1,260 | 1,090 | 1,180 |
| Tolleson | 3,500 | 2,560 | 3,030 | 22,800 | 12,000 | 17,400 | 968 | 779 | 873 | 95.6 | 70.6 | 83.0 |
| Youngtown | 1,730 | 1,030 | 1,380 | 12,300 | 4,030 | 8,180 | 511 | 366 | 439 | 49.4 | 29.9 | 39.6 |

**Table 13.** Estimated constituent loads of a mean summer storm for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 1,330 | 1,170 | 1,250 | 334 | 293 | 318 | 69.0 | 49.4 | 59.2 | 0.504 | 0.412 | 0.458 |
| Gilbert | 609 | 510 | 560 | 152 | 122 | 137 | 36.1 | 24.2 | 30.2 | .164 | .131 | .148 |
| Glendale | 1,640 | 1,430 | 1,540 | 421 | 354 | 388 | 77.4 | 53.4 | 65.4 | .826 | .648 | .737 |
| Guadalupe | 46.6 | 25.1 | 35.8 | 12.0 | 5.60 | 8.82 | 3.14 | .392 | 1.77 | .00935 | .00580 | .00758 |
| Mesa | 4,020 | 3,700 | 3,860 | 1,020 | 917 | 970 | 176 | 138 | 157 | 1.73 | 1.48 | 1.60 |
| Paradise Valley | 582 | 483 | 533 | 140 | 111 | 125 | 28.2 | 17.4 | 22.8 | .190 | 0.148 | .169 |
| Peoria | 1,590 | 1,250 | 1,420 | 423 | 312 | 368 | 69.5 | 40.7 | 55.1 | .626 | .436 | .531 |
| Phoenix | 13,200 | 12,600 | 12,900 | 3,270 | 3,070 | 3,170 | 517 | 449 | 483 | 6.04 | 5.49 | 5.76 |
| Scottsdale | 4,270 | 4,010 | 4,140 | 929 | 850 | 889 | 184 | 155 | 170 | 1.44 | 1.26 | 1.35 |
| Tempe | 1,690 | 1,470 | 1,580 | 452 | 378 | 415 | 72.7 | 46.7 | 59.7 | .932 | .735 | .833 |
| Tolleson | 126 | 94.4 | 110 | 32.6 | 22.6 | 27.6 | 8.93 | 4.24 | 6.58 | .0457 | .0294 | .0375 |
| Youngtown | 83.5 | 48.1 | 65.8 | 17.2 | 9.46 | 13.4 | 4.44 | .963 | 2.70 | .0207 | .0123 | .0165 |

**Table 13.** Estimated constituent loads of a mean summer storm for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean |
| Chandler | 31.0 | 24.5 | 27.7 | 71.9 | 57.4 | 64.7 | 102 | 88.8 | 95.7 | 25,100 | 5,310 | 15,200 |
| Gilbert | 10.3 | 7.28 | 8.79 | 36.9 | 26.8 | 31.8 | 45.1 | 37.2 | 41.1 | 15,300 | 1,400 | 8,350 |
| Glendale | 34.6 | 24.6 | 29.6 | 99.9 | 76.7 | 88.3 | 119 | 102 | 110 | 30,500 | 7,340 | 18,900 |
| Guadalupe | .407 | .203 | 0.305 | 3.18 | 0.969 | 2.07 | 3.54 | 1.80 | 2.67 | 2,180 | –1,250 | 467 |
| Mesa | 77.6 | 64.2 | 70.9 | 239 | 201.7 | 220 | 289 | 261 | 275 | 65,700 | 28,100 | 46,900 |
| Paradise Valley | 4.71 | 3.70 | 4.20 | 30.1 | 21.7 | 25.9 | 38.1 | 31.2 | 34.6 | 14,100 | –314 | 6,910 |
| Peoria | 30.2 | 19.3 | 24.8 | 97.9 | 63.9 | 80.9 | 112 | 86.9 | 99.7 | 27,500 | 5,160 | 16,300 |
| Phoenix | 269 | 239 | 254 | 716 | 649 | 682 | 890 | 839 | 864 | 94,700 | 46,500 | 70,600 |
| Scottsdale | 56.3 | 48.0 | 52.2 | 180 | 154 | 167 | 241 | 220 | 231 | 98,500 | 48,600 | 73,500 |
| Tempe | 52.9 | 41.4 | 47.2 | 110 | 84.1 | 97.0 | 128 | 109 | 118 | 25,900 | 3,960 | 14,900 |
| Tolleson | 4.05 | 2.27 | 3.16 | 9.00 | 5.10 | 7.05 | 10.4 | 7.47 | 8.94 | 4,510 | –1,270 | 1,620 |
| Youngtown | .680 | .397 | .538 | 4.79 | 1.87 | 3.33 | 5.29 | 3.07 | 4.18 | 2,670 | –1,340 | 667 |

**Table 14.** Estimated constituent loads of a mean winter storm for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 34,300 | 30,000 | 32,200 | 231,000 | 177,000 | 204,000 | 11,700 | 10,600 | 11,200 | 1,020 | 894 | 960 |
| Gilbert | 16,100 | 13,400 | 14,800 | 114,000 | 78,900 | 96,500 | 4,600 | 4,010 | 4,300 | 468 | 388 | 428 |
| Glendale | 40,200 | 34,800 | 37,500 | 290,000 | 221,000 | 256,000 | 14,900 | 13,300 | 14,100 | 1,250 | 1,080 | 1,170 |
| Guadalupe | 1,240 | 641 | 941 | 10,100 | 2,060 | 6,070 | 329 | 217 | 273 | 36.2 | 18.8 | 27.5 |
| Mesa | 97,600 | 89,200 | 93,400 | 706,000 | 598,000 | 652,000 | 36,900 | 34,300 | 35,600 | 3,070 | 2,800 | 2,930 |
| Paradise Valley | 14,300 | 11,800 | 13,000 | 115,000 | 75,900 | 95,300 | 3,730 | 3,280 | 3,510 | 443 | 363 | 403 |
| Peoria | 36,500 | 29,100 | 32,800 | 278,000 | 179,000 | 228,000 | 16,400 | 13,400 | 14,900 | 1,220 | 937 | 1,080 |
| Phoenix | 310,000 | 294,000 | 302,000 | 2,360,000 | 2,150,000 | 2,250,000 | 114,000 | 109,000 | 111,000 | 10,000 | 9,490 | 9,750 |
| Scottsdale | 101,000 | 94,100 | 97,500 | 938,000 | 826,000 | 882,000 | 24,200 | 22,500 | 23,400 | 3,190 | 2,970 | 3,080 |
| Tempe | 40,700 | 34,800 | 37,700 | 281,000 | 209,000 | 245,000 | 17,200 | 15,400 | 16,300 | 1,300 | 1,110 | 1,210 |
| Tolleson | 3,590 | 2,620 | 3,100 | 24,300 | 12,600 | 18,500 | 985 | 792 | 888 | 98.5 | 72.3 | 85.4 |
| Youngtown | 1,780 | 1,050 | 1,420 | 13,200 | 4,120 | 8,680 | 521 | 372 | 446 | 50.9 | 30.5 | 40.7 |

**Table 14.** Estimated constituent loads of a mean winter storm for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 1,390 | 1,220 | 1,300 | 366 | 310 | 338 | 70.6 | 49.7 | 60.1 | 0.550 | 0.444 | 0.497 |
| Gilbert | 636 | 530 | 583 | 162 | 128 | 145 | 36.9 | 24.3 | 30.6 | .180 | .141 | .160 |
| Glendale | 1,710 | 1,490 | 1,600 | 448 | 375 | 412 | 79.2 | 53.7 | 66.4 | .902 | .697 | .800 |
| Guadalupe | 48.9 | 25.8 | 37.4 | 12.9 | 5.82 | 9.36 | 3.26 | .327 | 1.80 | .0103 | .00618 | .00822 |
| Mesa | 4,190 | 3,840 | 4,020 | 1,090 | 971 | 1,030 | 180 | 139 | 159 | 1.88 | 1.60 | 1.74 |
| Paradise Valley | 608 | 502 | 555 | 149 | 117 | 133 | 28.9 | 17.4 | 23.1 | .208 | .158 | .183 |
| Peoria | 1,660 | 1,300 | 1,480 | 451 | 329 | 390 | 71.3 | 40.7 | 56.0 | .685 | .468 | .577 |
| Phoenix | 13,800 | 13,100 | 13,400 | 3,470 | 3,250 | 3,360 | 527 | 454 | 491 | 6.57 | 5.94 | 6.25 |
| Scottsdale | 4,450 | 4,170 | 4,310 | 987 | 900 | 944 | 188 | 157 | 172 | 1.56 | 1.36 | 1.46 |
| Tempe | 1,770 | 1,530 | 1,650 | 481 | 400 | 440 | 74.5 | 46.8 | 60.6 | 1.02 | .792 | .904 |
| Tolleson | 132 | 97.9 | 115 | 34.8 | 23.8 | 29.3 | 9.19 | 4.18 | 6.69 | .0502 | .0312 | .0407 |
| Youngtown | 87.5 | 49.6 | 68.5 | 18.4 | 9.88 | 14.2 | 4.60 | 0.889 | 2.74 | .0228 | .0130 | .0179 |

**Table 14.** Estimated constituent loads of a mean winter storm for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 34.0 | 26.6 | 30.3 | 75.1 | 59.6 | 67.4 | 106 | 92.0 | 99.3 | 25,100 | 5,310 | 15,200 |
| Gilbert | 11.3 | 7.87 | 9.59 | 38.6 | 27.7 | 33.2 | 46.8 | 38.5 | 42.7 | 15,300 | 1,400 | 8,350 |
| Glendale | 38.1 | 26.6 | 32.3 | 104 | 79.6 | 92.0 | 124 | 105 | 115 | 30,500 | 7,340 | 18,900 |
| Guadalupe | .446 | .219 | .333 | 3.33 | .985 | 2.16 | 3.69 | 1.85 | 2.77 | 2,180 | –1,250 | 467 |
| Mesa | 85.0 | 69.7 | 77.4 | 250 | 210 | 230 | 301 | 271 | 286 | 65,700 | 28,100 | 46,900 |
| Paradise Valley | 5.16 | 4.01 | 4.58 | 31.4 | 22.6 | 27.0 | 39.6 | 32.3 | 35.9 | 14,100 | –314 | 6,910 |
| Peoria | 33.2 | 20.8 | 27.0 | 102 | 66.1 | 84.3 | 117 | 89.8 | 103 | 27,500 | 5,160 | 16,300 |
| Phoenix | 294 | 261 | 278 | 747 | 675 | 711 | 924 | 870 | 897 | 94,700 | 46,500 | 70,600 |
| Scottsdale | 61.7 | 52.2 | 56.9 | 188 | 160 | 174 | 250 | 229 | 239 | 98,500 | 48,600 | 73,500 |
| Tempe | 58.1 | 44.8 | 51.4 | 115 | 87.2 | 101 | 133 | 112 | 123 | 25,900 | 3,960 | 14,900 |
| Tolleson | 4.47 | 2.43 | 3.45 | 9.42 | 5.27 | 7.34 | 10.8 | 7.71 | 9.28 | 4,510 | –1,270 | 1,620 |
| Youngtown | .745 | .429 | .587 | 5.02 | 1.92 | 3.47 | 5.52 | 3.16 | 4.34 | 2,670 | –1,340 | 667 |

**Table 15.** Estimated mean summer constituent loads for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 220,000 | 193,000 | 206,000 | 1,420,000 | 1,100,000 | 1,260,000 | 75,800 | 68,700 | 72,300 | 6,550 | 5,720 | 6,130 |
| Gilbert | 103,000 | 86,400 | 94,700 | 703,000 | 492,000 | 59,7000 | 29,700 | 25,900 | 27,800 | 2,990 | 2,480 | 2,730 |
| Glendale | 258,000 | 224,000 | 241,000 | 1,790,000 | 1,380,000 | 1,580,000 | 96,100 | 86,100 | 91,100 | 8,010 | 6,940 | 7,480 |
| Guadalupe | 7,930 | 4,150 | 6,040 | 61,500 | 13,600 | 37,600 | 2,120 | 1,400 | 1,760 | 230 | 121 | 175 |
| Mesa | 626,000 | 572,000 | 599,000 | 4,360,000 | 3,710,000 | 4,030,000 | 238,000 | 221,000 | 230,000 | 19,600 | 17,900 | 18,700 |
| Paradise Valley | 91,500 | 75,600 | 83,500 | 706,000 | 474,000 | 590,000 | 24,100 | 21,200 | 22,600 | 2,820 | 2,320 | 2,570 |
| Peoria | 234,000 | 187,000 | 210,000 | 1,710,000 | 1,120,000 | 1,410,000 | 106,000 | 86,300 | 96,100 | 7,760 | 6,000 | 6,880 |
| Phoenix | 1,980,000 | 1,890,000 | 1,940,000 | 14,600,000 | 13,300,000 | 14,000,000 | 734,000 | 705,000 | 719,000 | 63,900 | 60,700 | 62,300 |
| Scottsdale | 647,000 | 604,000 | 625,000 | 5,790,000 | 5,120,000 | 5,460,000 | 156,000 | 145,000 | 151,000 | 20,300 | 19,000 | 19,700 |
| Tempe | 260,000 | 224,000 | 242,000 | 1,730,000 | 1,300,000 | 1,520,000 | 111,000 | 99,400 | 105,000 | 8,300 | 7,130 | 7,720 |
| Tolleson | 23,000 | 16,800 | 19,900 | 149,000 | 79,100 | 114,000 | 6,360 | 5,120 | 5,740 | 628 | 463 | 545 |
| Youngtown | 11,400 | 6,790 | 9,080 | 81,000 | 26,400 | 53,700 | 3,360 | 2,400 | 2,880 | 324 | 196 | 260 |

**Table 15.** Estimated mean summer constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 8,750 | 7,700 | 8,220 | 2,260 | 1,920 | 2,090 | 453 | 324 | 389 | 3.31 | 2.70 | 3.01 |
| Gilbert | 4,000 | 3,350 | 3,680 | 998 | 800 | 899 | 237 | 159 | 198 | 1.08 | .862 | .971 |
| Glendale | 10,800 | 9,410 | 10,100 | 2,770 | 2,330 | 2,550 | 508 | 351 | 430 | 5.42 | 4.26 | 4.84 |
| Guadalupe | 306 | 165 | 236 | 79.1 | 36.8 | 57.9 | 20.6 | 2.58 | 11.6 | .0614 | .0381 | .0498 |
| Mesa | 26,400 | 24,300 | 25,300 | 6,720 | 6,020 | 6,370 | 1,150 | 906 | 1,030 | 11.3 | 9.73 | 10.5 |
| Paradise Valley | 3,820 | 3,170 | 3,500 | 917 | 731 | 824 | 185 | 114 | 150 | 1.25 | .969 | 1.11 |
| Peoria | 10,400 | 8,230 | 9,320 | 2,780 | 2,050 | 2,420 | 456 | 268 | 362 | 4.11 | 2.87 | 3.49 |
| Phoenix | 86,700 | 82,700 | 84,700 | 21,500 | 20,200 | 20,800 | 3,400 | 2,950 | 3,172 | 39.6 | 36.0 | 37.8 |
| Scottsdale | 28,000 | 26,300 | 27,200 | 6,100 | 5,580 | 5,840 | 1,210 | 1,020 | 1,110 | 9.44 | 8.28 | 8.86 |
| Tempe | 11,100 | 9,650 | 10,400 | 2,970 | 2,480 | 2,720 | 478 | 307 | 392 | 6.12 | 4.83 | 5.47 |
| Tolleson | 832 | 620 | 726 | 214 | 148 | 181 | 58.6 | 27.8 | 43.2 | .300 | .193 | .246 |
| Youngtown | 548 | 316 | 432 | 113 | 62.1 | 87.7 | 29.1 | 6.32 | 17.7 | .136 | .0806 | .108 |

**Table 15.** Estimated mean summer constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean |
| Chandler | 204 | 161 | 182 | 204 | 161 | 182 | 204 | 161 | 182 | 204 | 161 | 182 |
| Gilbert | 67.7 | 47.8 | 57.8 | 67.7 | 47.8 | 57.8 | 67.7 | 47.8 | 57.8 | 67.7 | 47.8 | 57.8 |
| Glendale | 228 | 162 | 195 | 228 | 162 | 195 | 228 | 162 | 195 | 228 | 162 | 195 |
| Guadalupe | 3.33 | 1.64 | 2.48 | 3.33 | 1.64 | 2.48 | 3.33 | 1.64 | 2.48 | 3.33 | 1.64 | 2.48 |
| Mesa | 510 | 422 | 466 | 510 | 422 | 466 | 510 | 422 | 466 | 510 | 422 | 466 |
| Paradise Valley | 30.9 | 24.3 | 27.6 | 30.9 | 24.3 | 27.6 | 30.9 | 24.3 | 27.6 | 30.9 | 24.3 | 27.6 |
| Peoria | 198 | 127 | 163 | 198 | 127 | 163 | 198 | 127 | 163 | 198 | 127 | 163 |
| Phoenix | 1,770 | 1,580 | 1,670 | 1,770 | 1,580 | 1,670 | 1,770 | 1,580 | 1,670 | 1,770 | 1,580 | 1,670 |
| Scottsdale | 370 | 315 | 343 | 370 | 315 | 343 | 370 | 315 | 343 | 370 | 315 | 343 |
| Tempe | 433 | 334 | 384 | 433 | 334 | 384 | 433 | 334 | 384 | 433 | 334 | 384 |
| Tolleson | 26.6 | 14.9 | 20.8 | 26.6 | 14.9 | 20.8 | 26.6 | 14.9 | 20.8 | 26.6 | 14.9 | 20.8 |
| Youngtown | 4.46 | 2.61 | 3.54 | 4.46 | 2.61 | 3.54 | 4.46 | 2.61 | 3.54 | 4.46 | 2.61 | 3.54 |

**Table 16.** Estimated mean winter constituent loads for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 256,000 | 224,000 | 240,000 | 1,720,000 | 1,320,000 | 1,520,000 | 87,600 | 79,300 | 83,500 | 7,650 | 6,670 | 7,160 |
| Gilbert | 120,000 | 100,000 | 110,000 | 85,1000 | 589,000 | 720,000 | 34,300 | 29,900 | 32,100 | 3,490 | 2,890 | 3,190 |
| Glendale | 300,000 | 260,000 | 280,000 | 2,160,000 | 1,650,000 | 1,910,000 | 111,000 | 99,400 | 105,000 | 9,370 | 8,090 | 8,730 |
| Guadalupe | 9,250 | 4,780 | 7,020 | 75,200 | 15,300 | 45,300 | 2,450 | 1,620 | 2,040 | 270 | 140 | 205 |
| Mesa | 728,000 | 665,000 | 697,000 | 5,260,000 | 4,460,000 | 4,860,000 | 275,000 | 256,000 | 266,000 | 22,900 | 20,900 | 21,900 |
| Paradise Valley | 106,000 | 87,700 | 97,100 | 856,000 | 566,000 | 711,000 | 27,800 | 24,500 | 26,200 | 3,300 | 2,710 | 3,000 |
| Peoria | 272,000 | 217,000 | 245,000 | 2,080,000 | 1,330,000 | 1,700,000 | 122,000 | 99,600 | 111,000 | 9,070 | 6,990 | 8,030 |
| Phoenix | 2,310,000 | 2,190,000 | 2,250,000 | 17,600,000 | 16,000,000 | 16,800,000 | 848,000 | 814,000 | 831,000 | 74,600 | 70,800 | 72,700 |
| Scottsdale | 752,000 | 702,000 | 727,000 | 7,000,000 | 6,160,000 | 6,580,000 | 180,000 | 168,000 | 174,000 | 23,800 | 22,200 | 23,000 |
| Tempe | 303,000 | 260,000 | 282,000 | 2,100,000 | 1,560,000 | 1,830,000 | 128,000 | 115,000 | 121,000 | 9,710 | 8,310 | 9,010 |
| Tolleson | 26,700 | 19,500 | 23,100 | 182,000 | 94,000 | 138,000 | 7,350 | 5,900 | 6,630 | 734 | 539 | 637 |
| Youngtown | 13,300 | 7,850 | 10,600 | 98,800 | 30,800 | 64,800 | 3,890 | 2,770 | 3,330 | 380 | 228 | 304 |

**Table 16.** Estimated mean winter constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 10,400 | 9,090 | 9,730 | 2,730 | 2,310 | 2,520 | 526 | 371 | 449 | 4.10 | 3.31 | 3.71 |
| Gilbert | 4,740 | 3,960 | 4,350 | 1,210 | 959 | 1,080 | 276 | 182 | 228 | 1.34 | 1.05 | 1.20 |
| Glendale | 12,800 | 11,100 | 11,900 | 3,350 | 2,800 | 3,070 | 590 | 401 | 496 | 6.73 | 5.20 | 5.96 |
| Guadalupe | 364 | 193 | 279 | 96.3 | 43.4 | 69.8 | 24.4 | 2.44 | 13.4 | .0766 | .0461 | .0613 |
| Mesa | 31,300 | 28,700 | 30,000 | 8,110 | 7,240 | 7,680 | 1,340 | 1,040 | 1,190 | 14.0 | 11.9 | 13.0 |
| Paradise Valley | 4,540 | 3,740 | 4,140 | 1,110 | 877 | 993 | 216 | 130 | 173 | 1.55 | 1.18 | 1.37 |
| Peoria | 12,400 | 9,700 | 11,000 | 3,360 | 2,460 | 2,910 | 532 | 304 | 418 | 5.11 | 3.49 | 4.30 |
| Phoenix | 103,000 | 97,800 | 100,000 | 25,900 | 24,300 | 25,100 | 3,930 | 3,390 | 3,660 | 49.0 | 44.3 | 46.6 |
| Scottsdale | 33,200 | 31,100 | 32,200 | 7,360 | 6,710 | 7,040 | 1,400 | 1,170 | 1,290 | 11.7 | 10.2 | 10.9 |
| Tempe | 13,200 | 11,400 | 12,300 | 3,590 | 2,980 | 3,280 | 556 | 349 | 452 | 7.59 | 5.90 | 6.75 |
| Tolleson | 988 | 730 | 859 | 260 | 177 | 218 | 68.6 | 31.2 | 49.9 | .374 | .233 | .304 |
| Youngtown | 653 | 370 | 511 | 138 | 73.7 | 106 | 34.3 | 6.63 | 20.5 | .170 | .0968 | .134 |

**Table 16.** Estimated mean winter constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 253 | 198 | 226 | 560 | 445 | 502 | 795 | 686 | 740 | 133,000 | 80,400 | 106,000 |
| Gilbert | 84.5 | 58.7 | 71.6 | 288 | 207 | 247 | 350 | 287 | 318 | 76,900 | 40,100 | 58,500 |
| Glendale | 284 | 198 | 241 | 778 | 594 | 686 | 925 | 786 | 856 | 163,000 | 102,000 | 132,000 |
| Guadalupe | 3.33 | 1.64 | 2.48 | 24.9 | 7.35 | 16.1 | 23.2 | 11.8 | 17.5 | 7,800 | −1,270 | 3,270 |
| Mesa | 634 | 520 | 577 | 1,860 | 1,560 | 1,710 | 2,240 | 2,020 | 2,130 | 378,000 | 279,000 | 328,000 |
| Paradise Valley | 38.5 | 29.9 | 34.2 | 234 | 168 | 201 | 295 | 241 | 268 | 67,500 | 29,300 | 48,400 |
| Peoria | 248 | 155 | 202 | 764 | 493 | 629 | 873 | 670 | 771 | 144,000 | 84,800 | 114,000 |
| Phoenix | 2,200 | 1,950 | 2,070 | 5,570 | 5,040 | 5,300 | 6,890 | 6,490 | 6,690 | 558,000 | 430,000 | 494,000 |
| Scottsdale | 460 | 389 | 424 | 1,400 | 1,200 | 1,300 | 1,870 | 1,700 | 1,790 | 581,000 | 449,000 | 515,000 |
| Tempe | 433 | 334 | 384 | 857 | 651 | 754 | 994 | 840 | 917 | 134,000 | 75,500 | 104,000 |
| Tolleson | 33.3 | 18.1 | 25.7 | 70.3 | 39.3 | 54.8 | 80.9 | 57.5 | 69.2 | 19,000 | 3,690 | 11,300 |
| Youngtown | 5.56 | 3.20 | 4.38 | 37.4 | 14.3 | 25.9 | 41.1 | 23.6 | 32.4 | 9,980 | −634 | 4,670 |

**Table 17.** Estimated constituent loads of a mean spring storm for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 31,900 | 28,000 | 30,000 | 218,000 | 166,000 | 192,000 | 11,000 | 9,940 | 10,400 | 954 | 832 | 893 |
| Gilbert | 15,000 | 12,500 | 13,700 | 108,000 | 73,700 | 90,700 | 4,300 | 3,750 | 4,020 | 435 | 361 | 398 |
| Glendale | 37,400 | 32,400 | 34,900 | 274,000 | 207,000 | 240,000 | 13,900 | 12,400 | 13,200 | 1,170 | 1,010 | 1,090 |
| Guadalupe | 1,150 | 598 | 876 | 9,580 | 1,830 | 5,700 | 307 | 203 | 255 | 33.6 | 17.5 | 25.5 |
| Mesa | 90,800 | 83,000 | 86,900 | 665,000 | 560,000 | 612,000 | 34,500 | 32,000 | 33,300 | 2,850 | 2,600 | 2,730 |
| Paradise Valley | 13,300 | 10,900 | 12,100 | 108,000 | 70,800 | 89,600 | 3,490 | 3,070 | 3,280 | 412 | 338 | 375 |
| Peoria | 34,000 | 27,100 | 30,500 | 263,000 | 166,000 | 215,000 | 15,300 | 12,500 | 13,900 | 1,130 | 871 | 1,000 |
| Phoenix | 288,000 | 274,000 | 281,000 | 2,220,000 | 2,020,000 | 2,120,000 | 106,000 | 102,000 | 104,000 | 9,300 | 8,830 | 9,060 |
| Scottsdale | 93,900 | 87,600 | 90,700 | 883,000 | 774,000 | 829,000 | 22,600 | 21,000 | 21,800 | 2,960 | 2,760 | 2,860 |
| Tempe | 37,800 | 32,400 | 35,100 | 266,000 | 196,000 | 230,000 | 16,000 | 14,400 | 15,200 | 1,210 | 1,040 | 1,120 |
| Tolleson | 3,340 | 2,440 | 2,890 | 23,000 | 11,700 | 17,400 | 920 | 740 | 830 | 91.6 | 67.2 | 79.4 |
| Youngtown | 1,650 | 981 | 1,320 | 12,600 | 3,760 | 8,160 | 486 | 348 | 417 | 47.3 | 28.4 | 37.9 |

**Table 17**. Estimated constituent loads of a mean spring storm for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 1,300 | 1,130 | 1,210 | 344 | 290 | 317 | 66.1 | 46.4 | 56.2 | 0.529 | 0.421 | 0.475 |
| Gilbert | 592 | 494 | 543 | 152 | 120 | 136 | 34.6 | 22.7 | 28.6 | .173 | .134 | .153 |
| Glendale | 1,590 | 1,390 | 1,490 | 422 | 351 | 387 | 74.2 | 50.1 | 62.1 | .902 | .697 | .800 |
| Guadalupe | 45.6 | 24.0 | 34.8 | 12.2 | 5.38 | 8.80 | 3.06 | .304 | 1.68 | .00995 | .00578 | .00787 |
| Mesa | 3,910 | 3,580 | 3,740 | 1,020 | 911 | 967 | 168 | 130 | 149 | 1.81 | 1.52 | 1.67 |
| Paradise Valley | 567 | 467 | 517 | 140 | 110 | 125 | 27.0 | 16.2 | 21.6 | .201 | .150 | .175 |
| Peoria | 1,540 | 1,210 | 1,380 | 426 | 308 | 367 | 66.9 | 37.8 | 2.35 | .661 | .442 | .552 |
| Phoenix | 12,800 | 12,200 | 12,500 | 3,260 | 3,050 | 3,160 | 493 | 425 | 459 | 6.30 | 5.66 | 5.98 |
| Scottsdale | 4,150 | 3,880 | 4,020 | 929 | 845 | 887 | 176 | 147 | 161 | 1.50 | 1.30 | 1.40 |
| Tempe | 1,650 | 1,420 | 1,530 | 453 | 374 | 414 | 69.8 | 43.6 | 56.7 | .979 | .751 | .865 |
| Tolleson | 123 | 91.0 | 107 | 32.8 | 22.2 | 27.5 | 8.60 | 3.91 | 6.25 | .0486 | .0293 | .0390 |
| Youngtown | 64.0 | 38.7 | 51.3 | 17.4 | 9.18 | 13.3 | 4.30 | .828 | 2.57 | .0222 | .0121 | .0171 |

**Table 17.** Estimated constituent loads of a mean spring storm for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 32.8 | 25.4 | 29.1 | 83.2 | 65.1 | 74.2 | 99.2 | 85.5 | 92.4 | 25,100 | 5,310 | 15,200 |
| Gilbert | 11.0 | 7.48 | 9.22 | 36.0 | 25.8 | 30.9 | 43.6 | 35.8 | 39.7 | 15,300 | 1,400 | 8,350 |
| Glendale | 36.9 | 25.3 | 31.1 | 97.3 | 74.0 | 85.7 | 115 | 98.0 | 107 | 30,500 | 7,340 | 18,900 |
| Guadalupe | .432 | .208 | .320 | 3.11 | .908 | 2.01 | 3.44 | 1.71 | 2.58 | 2,180 | –1,250 | 467 |
| Mesa | 82.1 | 66.7 | 74.4 | 233 | 195 | 214 | 280 | 252 | 266 | 65,700 | 28,100 | 46,900 |
| Paradise Valley | 4.98 | 3.84 | 4.41 | 29.3 | 21.0 | 25.1 | 36.8 | 30.0 | 33.4 | 14,100 | –314 | 6,910 |
| Peoria | 32.2 | 19.7 | 26.0 | 95.7 | 61.3 | 78.5 | 109 | 83.4 | 96.2 | 27,500 | 5,160 | 16,300 |
| Phoenix | 284 | 250 | 267 | 696 | 628 | 662 | 860 | 809 | 834 | 94,700 | 46,500 | 70,600 |
| Scottsdale | 59.5 | 49.9 | 54.7 | 176 | 149 | 162 | 233 | 213 | 223 | 98,500 | 48,600 | 73,500 |
| Tempe | 56.1 | 42.8 | 49.5 | 107 | 81.1 | 94.1 | 124 | 105 | 114 | 25,900 | 3,960 | 14,900 |
| Tolleson | 4.34 | 2.28 | 3.32 | 8.79 | 4.89 | 6.84 | 10.1 | 7.17 | 8.63 | 4,510 | –1,270 | 1,620 |
| Youngtown | .721 | .408 | .565 | 4.69 | 1.77 | 3.23 | 5.14 | 2.93 | 4.04 | 2,670 | –1,340 | 667 |

**Table 18.** Estimated mean spring constituent loads for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 35,400 | 31,000 | 33,200 | 242,000 | 184,000 | 212,000 | 12,200 | 11,000 | 11,600 | 1,060 | 922 | 989 |
| Gilbert | 16,600 | 13,900 | 15,200 | 119,000 | 81,600 | 100,000 | 4,760 | 4,150 | 4,460 | 482 | 400 | 441 |
| Glendale | 41,400 | 35,900 | 38,700 | 303,000 | 229,000 | 266,000 | 15,400 | 13,800 | 14,600 | 1,290 | 1,120 | 1,200 |
| Guadalupe | 1,280 | 663 | 971 | 10,600 | 2,020 | 6,320 | 340 | 225 | 282 | 37.2 | 19.4 | 28.3 |
| Mesa | 101,000 | 92,000 | 96,300 | 737,000 | 621,000 | 679,000 | 38,200 | 35,500 | 36,900 | 3,160 | 2,880 | 3,020 |
| Paradise Valley | 14,700 | 12,100 | 13,400 | 120,000 | 78,400 | 99,200 | 3,860 | 3,400 | 3,630 | 456 | 374 | 415 |
| Peoria | 37,600 | 30,000 | 33,800 | 291,000 | 184,000 | 238,000 | 17,000 | 13,800 | 15,400 | 1,250 | 965 | 1,110 |
| Phoenix | 319,000 | 303,000 | 311,000 | 2,460,000 | 2,230,000 | 2,350,000 | 118,000 | 113,000 | 115,000 | 10,300 | 9,780 | 10,000 |
| Scottsdale | 104,000 | 97,000 | 100,000 | 977,000 | 858,000 | 918,000 | 25,000 | 23,300 | 24,200 | 3,280 | 3,060 | 3,170 |
| Tempe | 41,900 | 36,000 | 38,900 | 294,000 | 217,000 | 256,000 | 17,800 | 15,900 | 16,800 | 1,340 | 1,150 | 1,240 |
| Tolleson | 3,700 | 2,700 | 3,200 | 25,500 | 13,000 | 19,200 | 1,020 | 820 | 920 | 101 | 74.5 | 88.0 |
| Youngtown | 1,830 | 1,090 | 1,460 | 13,900 | 4,160 | 9,040 | 539 | 385 | 462 | 52.5 | 31.4 | 42.0 |

**Table 18.** Estimated mean spring constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 1,440 | 1,260 | 1,350 | 382 | 322 | 352 | 73.2 | 51.4 | 62.3 | 0.587 | 0.467 | 0.527 |
| Gilbert | 657 | 547 | 602 | 169 | 133 | 151 | 38.3 | 25.2 | 31.8 | .192 | .148 | .170 |
| Glendale | 1,770 | 1,540 | 1,650 | 468 | 389 | 429 | 82.2 | 55.5 | 68.9 | .962 | .733 | .848 |
| Guadalupe | 50.5 | 26.6 | 38.5 | 13.5 | 5.96 | 9.75 | 3.39 | .337 | 1.86 | .0110 | .00641 | .00872 |
| Mesa | 4,330 | 3,970 | 4,150 | 1,130 | 1,010 | 1,070 | 186 | 144 | 165 | 2.00 | 1.69 | 1.85 |
| Paradise Valley | 628 | 517 | 573 | 155 | 122 | 139 | 30.0 | 18.0 | 24.0 | .222 | .166 | .194 |
| Peoria | 1,710 | 1,340 | 1,520 | 472 | 341 | 406 | 74.2 | 41.9 | 58.0 | .732 | .490 | .611 |
| Phoenix | 14,200 | 13,500 | 13,900 | 3,620 | 3,380 | 3,500 | 547 | 470 | 509 | 6.98 | 6.27 | 6.63 |
| Scottsdale | 4,600 | 4,300 | 4,450 | 1,030 | 936 | 983 | 195 | 163 | 178. | 1.66 | 1.44 | 1.55 |
| Tempe | 1,820 | 1,570 | 1,700 | 502 | 415 | 458 | 77.4 | 48.4 | 62.9 | 1.08 | .832 | .959 |
| Tolleson | 137 | 101 | 119 | 36.4 | 24.6 | 30.5 | 9.53 | 4.33 | 6.93 | .0539 | .0324 | .0432 |
| Youngtown | 70.9 | 42.8 | 56.9 | 19.3 | 10.2 | 14.8 | 4.77 | .918 | 2.84 | .0246 | .0134 | 0.0190 |

**Table 18.** Estimated mean spring constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 36.4 | 28.1 | 32.2 | 92.2 | 72.2 | 82.2 | 110 | 94.8 | 102 | 44,500 | 16,400 | 30,400 |
| Gilbert | 12.2 | 8.29 | 10.2 | 39.8 | 28.6 | 34.2 | 48.3 | 39.6 | 44.0 | 26,500 | 6,870 | 16,700 |
| Glendale | 40.8 | 28.1 | 34.4 | 108 | 82.0 | 94.9 | 128 | 108 | 118 | 54,200 | 21,500 | 37,800 |
| Guadalupe | .479 | .230 | .355 | 3.45 | 1.00 | 2.23 | 3.81 | 1.90 | 2.85 | 3,360 | –1,490 | 933 |
| Mesa | 91.0 | 73.9 | 82.4 | 258 | 216 | 237 | 310 | 279 | 294 | 120,000 | 67,300 | 93,800 |
| Paradise Valley | 5.52 | 4.25 | 4.88 | 32.5 | 23.2 | 27.9 | 40.8 | 33.3 | 37.0 | 24,000 | 3,600 | 13,800 |
| Peoria | 35.7 | 21.8 | 28.8 | 106 | 67.9 | 87.0 | 121 | 92.4 | 106 | 48,500 | 16,900 | 32,700 |
| Phoenix | 314 | 277 | 296 | 771 | 696 | 734 | 953 | 896 | 925 | 175,000 | 107,000 | 141,000 |
| Scottsdale | 66.0 | 55.3 | 60.6 | 194 | 165 | 180 | 258 | 235 | 247 | 182,000 | 112,000 | 147,000 |
| Tempe | 62.2 | 47.4 | 54.8 | 119 | 89.8 | 104 | 137 | 116 | 127 | 45,400 | 14,300 | 29,900 |
| Tolleson | 4.81 | 2.53 | 3.67 | 9.74 | 5.42 | 7.58 | 11.2 | 7.94 | 9.57 | 7,330 | –848 | 3,240 |
| Youngtown | .799 | .452 | .626 | 5.19 | 1.96 | 3.58 | 5.69 | 3.25 | 4.47 | 4,170 | –1,500 | 1,340 |

**Table 19.** Estimated mean annual constituent loads for Phoenix and surrounding municipalities

[Units for all estimates are in pounds]

| City | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | | Total nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 501,000 | 459,000 | 480,000 | 3,260,000 | 2,740,000 | 3,000,000 | 173,000 | 162,000 | 167,000 | 14,900 | 13,600 | 14,300 |
| Gilbert | 233,000 | 207,000 | 220,000 | 1,590,000 | 1,250,000 | 1,420,000 | 67,300 | 61,500 | 64,400 | 6,760 | 5,980 | 6,370 |
| Glendale | 585,000 | 533,000 | 559,000 | 4,090,000 | 3,430,000 | 3,760,000 | 219,000 | 203,000 | 210,000 | 18,200 | 16,600 | 17,400 |
| Guadalupe | 17,000 | 11,100 | 14,000 | 128,000 | 50,600 | 89,100 | 4,630 | 3,530 | 4,080 | 494 | 323 | 409 |
| Mesa | 1,430,000 | 1,350,000 | 1,390,000 | 10,100,000 | 9,050,000 | 9,570,000 | 545,000 | 519,000 | 532,000 | 45,000 | 42,300 | 43,700 |
| Paradise Valley | 206,000 | 182,000 | 194,000 | 1,590,000 | 1,210,000 | 1,400,000 | 54,700 | 50,200 | 52,500 | 6,380 | 5,600 | 5,990 |
| Peoria | 525,000 | 452,000 | 489,000 | 3,830,000 | 2,880,000 | 3,360,000 | 238,000 | 207,000 | 222,000 | 17,400 | 14,600 | 16,000 |
| Phoenix | 4,580,000 | 4,420,000 | 4,500,000 | 34,100,000 | 32,100,000 | 33,100,000 | 1,690,000 | 1,640,000 | 1,660,000 | 148,000 | 142,000 | 145,000 |
| Scottsdale | 1,490,000 | 1,420,000 | 1,450,000 | 13,500,000 | 12,400,000 | 13,000,000 | 358,000 | 341,000 | 349,000 | 46,900 | 44,800 | 45,800 |
| Tempe | 591,000 | 534,000 | 563,000 | 3,950,000 | 3,260,000 | 3,600,000 | 252,000 | 234,000 | 243,000 | 18,900 | 17,100 | 18,000 |
| Tolleson | 51,000 | 41,500 | 46,200 | 328,000 | 215,000 | 271,000 | 14,200 | 12,300 | 13,300 | 1,400 | 1,140 | 1,270 |
| Youngtown | 24,700 | 17,500 | 21,100 | 171,000 | 83,600 | 128,000 | 7,410 | 5,930 | 6,670 | 706 | 506 | 606 |

**Table 19.** Estimated mean annual constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total organic nitrogen plus ammonia | | | Total phosphorus | | | Dissolved phosphorus | | | Total recoverable cadmium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 20,100 | 18,500 | 19,300 | 5,230 | 4,690 | 4,960 | 1,000 | 798 | 900 | 7.74 | 6.74 | 7.24 |
| Gilbert | 9,140 | 8,120 | 8,630 | 2,290 | 1,970 | 2,130 | 520 | 397 | 458 | 2.52 | 2.16 | 2.34 |
| Glendale | 24,800 | 22,600 | 23,700 | 6,400 | 5,690 | 6,050 | 1,120 | 870 | 994 | 12.6 | 10.7 | 11.6 |
| Guadalupe | 664 | 441 | 553 | 172 | 103 | 138 | 41.2 | 12.6 | 26.9 | .139 | .100 | .120 |
| Mesa | 61,200 | 57,800 | 59,500 | 15,700 | 14,600 | 15,100 | 2,580 | 2,190 | 2,380 | 26.7 | 24.0 | 25.4 |
| Paradise Valley | 8,730 | 7,700 | 8,210 | 2,100 | 1,800 | 1,960 | 402 | 290 | 346 | 2.91 | 2.44 | 2.67 |
| Peoria | 23,600 | 20,200 | 21,900 | 6,320 | 5,140 | 5,730 | 986 | 688 | 838 | 9.43 | 7.37 | 8.40 |
| Phoenix | 202,000 | 196,000 | 199,000 | 50,400 | 48,400 | 49,400 | 7,700 | 6,990 | 7,340 | 94.1 | 88.1 | 91.1 |
| Scottsdale | 65,200 | 62,400 | 63,800 | 14,300 | 13,400 | 13,900 | 2,730 | 2,430 | 2,580 | 22.3 | 20.4 | 21.3 |
| Tempe | 25,500 | 23,200 | 24,400 | 6,860 | 6,080 | 6,470 | 1,040 | 773 | 907 | 14.2 | 12.1 | 13.2 |
| Tolleson | 1,870 | 1,540 | 1,700 | 483 | 377 | 430 | 124 | 75.7 | 100 | .683 | 0.504 | .593 |
| Youngtown | 1,180 | 817 | 1,000 | 249 | 167 | 208 | 59.1 | 23.0 | 41.0 | .307 | .214 | .261 |

**Table 19.** Estimated mean annual constituent loads for Phoenix and surrounding municipalities—Continued

| City | Total recoverable copper | | | Total recoverable lead | | | Total recoverable zinc | | | Biological oxygen demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Chandler | 475 | 405 | 440 | 1,080 | 934 | 1,010 | 1,540 | 1,400 | 1,470 | 283,000 | 204,000 | 244,000 |
| Gilbert | 156 | 123 | 140 | 543 | 438 | 490 | 673 | 591 | 632 | 161,000 | 106,000 | 134,000 |
| Glendale | 525 | 416 | 470 | 1,480 | 1,240 | 1,360 | 1,790 | 1,610 | 1,700 | 349,000 | 256,000 | 302,000 |
| Guadalupe | 5.93 | 3.75 | 4.84 | 43.4 | 20.5 | 32.0 | 50.0 | 32.1 | 41.0 | 14,300 | 613 | 7,470 |
| Mesa | 1,200 | 1,050 | 1,120 | 3,600 | 3,200 | 3,400 | 4,380 | 4,090 | 4,230 | 826,000 | 675,000 | 751,000 |
| Paradise Valley | 72.1 | 61.2 | 66.7 | 443 | 356 | 399 | 568 | 497 | 533 | 140,000 | 81,700 | 111,000 |
| Peoria | 452 | 334 | 393 | 1,420 | 1,070 | 1,250 | 1,660 | 1,400 | 1530 | 306,000 | 217,000 | 262,000 |
| Phoenix | 4,200 | 3,880 | 4,040 | 10,900 | 10,200 | 10,500 | 13,600 | 13,000 | 13,300 | 1,220,000 | 1,030,000 | 1,130,000 |
| Scottsdale | 873 | 783 | 828 | 2,720 | 2,440 | 2,580 | 3,650 | 3,440 | 3,550 | 1,280,000 | 1,080,000 | 1,180,000 |
| Tempe | 811 | 686 | 748 | 1,630 | 1,360 | 1,500 | 1,920 | 1,720 | 1,820 | 283,000 | 195,000 | 239,000 |
| Tolleson | 59.8 | 40.5 | 50.2 | 129 | 88.4 | 108.7 | 153 | 122 | 138 | 37,500 | 14,400 | 25,900 |
| Youngtown | 10.0 | 7.03 | 8.54 | 66.4 | 36.2 | 51.3 | 75.8 | 52.8 | 64.3 | 18,700 | 2,660 | 10,700 |

calculated by using log-transformed rainfall data from Sky Harbor Airport from 1954 to 1990 and by specifying the number of hours without rainfall to differentiate storms. Varying the time between storms by 50 percent had little effect on the mean TRN and storm frequency. Varying the time between storms had a large effect on storm duration; however, storm duration is not used in the regression equations. The maximum 24-hour intensity that has a 2-year recurrence interval (INT) is 1.44 in. (Sabol and others, 1990) and the mean annual rainfall is 7.11 in. (National Oceanic and Atmospheric Administration, 1990; table 1, this report). INT and MAR are required to estimate CU and RUN.

Loads for a mean storm and mean seasonal loads for summer and winter (tables 13, 14, 15, and 16) differ because, although cold fronts and monsoons have the same mean TRN, summer monsoons have a larger standard deviation. Loads for a mean storm and mean seasonal loads for spring storms were estimated using the mean TRN value of 0.36 in. (tables 17 and 18). Mean annual constituent loads were estimated by summing mean seasonal constituent loads (table 19).

Volumes of runoff for a mean storm, mean seasonal, and mean annual volumes of runoff also were estimated (tables 20 and 21). Estimates were made by assuming that rainfall at Sky Harbor Airport represents the entire Phoenix area. The eastern part of Phoenix, however, seemed to get more rainfall than other areas during this study. Orographic effects of the surrounding mountains could be a significant factor influencing the areal distribution of storm characteristics, mean annual rainfall, and constituent loads.

Localized areas seem to contribute a large proportion of the constituent loads and were identified in several municipalities by analyzing the distribution of constituent loads per unit area (unit-constituent load). The unit-constituent loads were calculated by dividing constituent loads for a mean storm by section area to normalize load estimates; the unit-constituent load depends primarily on percentage of impervious area. The relative proportion of constituent loads from areas within a city was determined by associating the unit-constituent load of a section with a quartile and by analyzing the areal distribution of quartiles (figs. 6–9). Quartiles are the percentage of values equal to or less than the indicated values: the 0 to 25th quartile is the smallest 25 percent of the values; 25th to 50th quartile means 50 percent of the values are larger and 25 percent are smaller; 50th to 75th quartile means 25 percent of the values are larger and 50 percent are smaller; and 75th to 100th quartile is the largest 25 percent of the values. Sections that are associated with the same quartile indicate areas that contribute about the same amount of constituent loads per unit area.

Sections assigned to the 50th to 75th quartile and 75th to 100th quartile that are contiguous indicate localized areas that contribute a large proportion of constituent loads, and may require special consideration in managing urban stormwater. The cities of Chandler, Mesa, Paradise Valley, and Peoria had the most distinct areas where sections with large unit-constituent loads are contiguous. These localized areas typically are associated with sections that have about 40 percent or more impervious area and have industrial, commercial, and high-density residential land use. The other municipalities either are too small for analysis to be meaningful (Guadalupe and Youngtown) or had sections in the 50th to 75th and 75th to 100th quartile that were small and (or) were not contiguous. The lack of large, contiguous areas in the 50th to 75th and 75th to 100th quartiles indicates that constituent loads are, in general, uniformly distributed in Gilbert, Glendale, Phoenix, Scottsdale, Tempe, and Tolleson.

Annual constituent loads also were estimated for major drainage basins in the study area (fig. 10, table 22) to determine which drainage basins discharge the most constituents to rivers in the Phoenix area and to identify the drainage basins that are most affected by urban stormwater. Constituent-load estimates for major drainage basins were made assuming that the adjusted regression equations apply to sections that are undeveloped and that there is no storage within a drainage basin. Comparisons of constituent concentrations between different land uses (fig. 4; table 7) and accuracy of the RUN equation for drainage basins with a small percentage of impervious area indicates that the equations can be used in undeveloped parts of the study area.

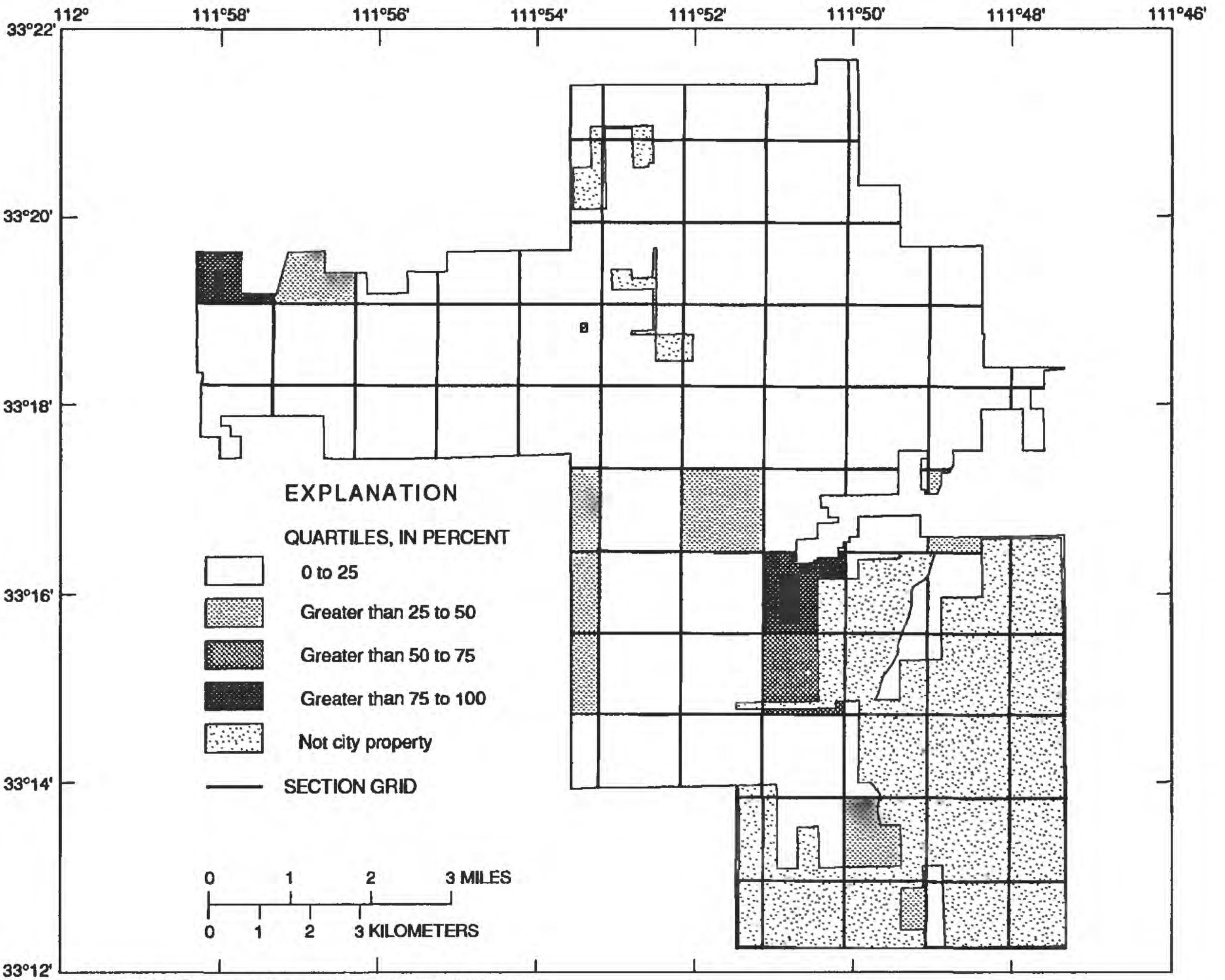
Urbanized drainage basins have the largest estimated unit-constituent loads of the major drainage basins in the study area. The large

**Table 20.** Estimated volume of runoff for a mean storm and mean seasonal volumes of runoff for Phoenix and surrounding municipalities

| City | Volume of runoff for a mean storm, in cubic feet | | | Mean seasonal volume of runoff, in cubic feet | | |
|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95-percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean |
| **Summer storms** | | | | | | |
| Chandler | 12,800,000 | 11,700,000 | 12,200,000 | 84,000,000 | 76,600,000 | 80,300,000 |
| Gilbert | 5,220,000 | 4,600,000 | 4,910,000 | 34,300,000 | 30,200,000 | 32,200,000 |
| Glendale | 16,100,000 | 14,500,000 | 15,300,000 | 106,000,000 | 95,500,000 | 101,000,000 |
| Guadalupe | 375,000 | 252,000 | 314,000 | 2,460,000 | 1,650,000 | 2,060,000 |
| Mesa | 39,700,000 | 37,100,000 | 38,400,000 | 260,000,000 | 244,000,000 | 252,000,000 |
| Paradise Valley | 4,540,000 | 4,010,000 | 4,270,000 | 29,800,000 | 26,400,000 | 28,100,000 |
| Peoria | 17,200,000 | 14,300,000 | 15,800,000 | 113,000,000 | 93,900,000 | 103,000,000 |
| Phoenix | 125,000,000 | 121,000,000 | 123,000,000 | 822,000,000 | 792,000,000 | 807,000,000 |
| Scottsdale | 29,300,000 | 27,600,000 | 28,400,000 | 192,000,000 | 181,000,000 | 187,000,000 |
| Tempe | 18,100,000 | 16,400,000 | 17,300,000 | 191,000,000 | 108,000,000 | 113,000,000 |
| Tolleson | 1,090,000 | 889,000 | 989,000 | 7,150,000 | 5,840,000 | 6,490,000 |
| Youngtown | 571,000 | 415,000 | 493,000 | 3,750,000 | 2,730,000 | 3,240,000 |
| **Winter storms** | | | | | | |
| Chandler | 14,000,000 | 12,700,000 | 13,400,000 | 104,000,000 | 94,800,000 | 99,600,000 |
| Gilbert | 5,720,000 | 5,000,000 | 5,360,000 | 42,700,000 | 37,300,000 | 40,000,000 |
| Glendale | 17,600,000 | 15,800,000 | 16,700,000 | 106,000,000 | 95,500,000 | 101,000,000 |
| Guadalupe | 413,000 | 272,000 | 332,000 | 2,460,000 | 1,650,000 | 2,060,000 |
| Mesa | 43,400,000 | 40,500,000 | 41,900,000 | 324,000,000 | 302,000,000 | 313,000,000 |
| Paradise Valley | 4,540,000 | 4,010,000 | 4,270,000 | 37,100,000 | 32,600,000 | 34,800,000 |
| Peoria | 18,900,000 | 15,500,000 | 17,200,000 | 141,000,000 | 116,000,000 | 128,000,000 |
| Phoenix | 137,000,000 | 132,000,000 | 134,000,000 | 1,020,000,000 | 981,000,000 | 1,000,000,000 |
| Scottsdale | 32,000,000 | 30,000,000 | 31,000,000 | 239,000,000 | 224,000,000 | 232,000,000 |
| Tempe | 19,800,000 | 17,800,000 | 18,800,000 | 148,000,000 | 133,000,000 | 141,000,000 |
| Tolleson | 1,190,000 | 965,000 | 1,080,000 | 8,910,000 | 7,200,000 | 8,050,000 |
| Youngtown | 628,000 | 449,000 | 538,000 | 4,690,000 | 3,350,000 | 4,020,000 |
| **Spring storms** | | | | | | |
| Chandler | 13,600,000 | 12,300,000 | 12,900,000 | 15,100,000 | 13,600,000 | 14,300,000 |
| Gilbert | 5,560,000 | 4,820,000 | 5,190,000 | 6,160,000 | 5,350,000 | 5,750,000 |
| Glendale | 17,100,000 | 15,300,000 | 16,200,000 | 19,000,000 | 17,000,000 | 18,000,000 |
| Guadalupe | 404,000 | 259,000 | 332,000 | 447,000 | 287,000 | 367,000 |
| Mesa | 42,100,000 | 39,100,000 | 40,600,000 | 46,600,000 | 43,400,000 | 45,000,000 |
| Paradise Valley | 4,830,000 | 4,210,000 | 4,520,000 | 5,350,000 | 4,670,000 | 5,010,000 |
| Peoria | 18,300,000 | 15,000,000 | 16,600,000 | 20,300,000 | 16,600,000 | 18,400,000 |
| Phoenix | 132,000,000 | 127,000,000 | 130,000,000 | 147,000,000 | 141,000,000 | 144,000,000 |
| Scottsdale | 31,000,000 | 29,000,000 | 30,000,000 | 34,400,000 | 32,200,000 | 33,300,000 |
| Tempe | 19,300,000 | 17,200,000 | 18,200,000 | 21,400,000 | 19,100,000 | 20,200,000 |
| Tolleson | 1,160,000 | 929,000 | 1,040,000 | 1,290,000 | 1,030,000 | 1,160,000 |
| Youngtown | 613,000 | 430,000 | 521,000 | 679,000 | 476,000 | 578,000 |

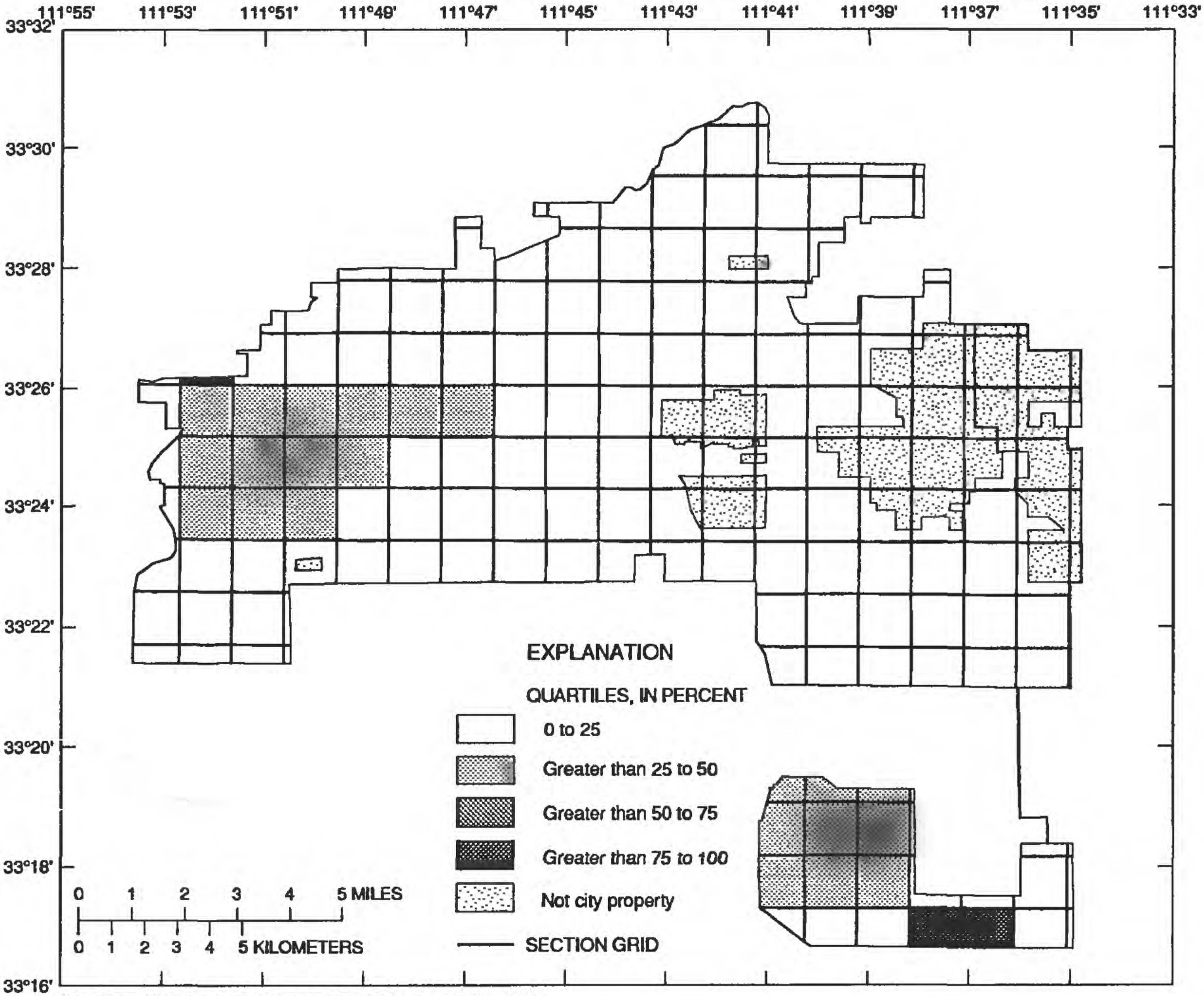
**Table 21.** Estimated mean annual volume of runoff for Phoenix and surrounding municipalities

| City | Mean annual volume of runoff, in cubic feet | | | City | Mean annual volume of runoff, in cubic feet | | |
|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean |
| Chandler | 200,000,000 | 188,000,000 | 194,000,000 | Peoria | 266,000,000 | 234,000,000 | 250,000,000 |
| Gilbert | 81,400,000 | 74,600,000 | 78,000,000 | Phoenix | 1,980,000,000 | 1,930,000,000 | 1,950,000,000 |
| Glendale | 252,000,000 | 235,000,000 | 243,000,000 | Scottsdale | 461,000,000 | 442,000,000 | 451,000,000 |
| Guadalupe | 5,650,000 | 4,310,000 | 4,980,000 | Tempe | 284,000,000 | 265,000,000 | 274,000,000 |
| Mesa | 624,000,000 | 596,000,000 | 610,000,000 | Tolleson | 16,800,000 | 14,600,000 | 15,700,000 |
| Paradise Valley | 70,800,000 | 65,000,000 | 67,900,000 | Youngtown | 8,680,000 | 6,980,000 | 7,830,000 |



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection, Zone 12, and
Arizona State Land Department digital data, 1:100,000, 1993
Universal Tranverse Mercator projection, Zone 12

**Figure 6.** Distribution of unit-constituent loads in stormwater for the City of Chandler. Unit-constitiuent loads (constituent load per unit area) were calculated for each section, and each section was associated with quartiles between the minimum (0 to 25 quartile) and maximum (greater than 75 to 100 quartile) unit load.



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection, Zone 12, and
Arizona State Land Department digital data, 1:100,000, 1993
Universal Tranverse Mercator projection, Zone 12

**Figure 7.** Distribution of unit-constituent loads in stormwater for the City of Mesa. Unit-constitiuent loads (constituent load per unit area) were calculated for each section, and each section was associated with quartiles between the minimum (0 to 25 quartile) and maximum (greater than 75 to 100 quartile) unit load.

unit-constituent loads of urbanized drainage basins are due mostly to the large volumes of runoff from impervious areas. The major drainage basins were ranked by the unit loads of each constituent, and the mean ranking was used to compare constituent loads from the basins (table 23). The drainage basins with the largest unit-constituent loads are mostly urbanized and are adjacent to the Salt, New, and Agua Fria Rivers. The proximity of these drainage basins to the Salt, New and Agua Fria Rivers indicates that these rivers could be receiving larger constituent loads than would have occurred before urbanization.

## Event-Mean Constituent Concentrations

Driver and Tasker (1990) developed regional-regression equations for event-mean constituent concentrations using the same independent variables as in the stepwise equations for constituent loads. Driver and Tasker did not develop a set of regression equations using three variables for constituent concentrations. Log-transformed values of predicted and observed event-mean constituent concentrations were significantly and positively correlated at a level of

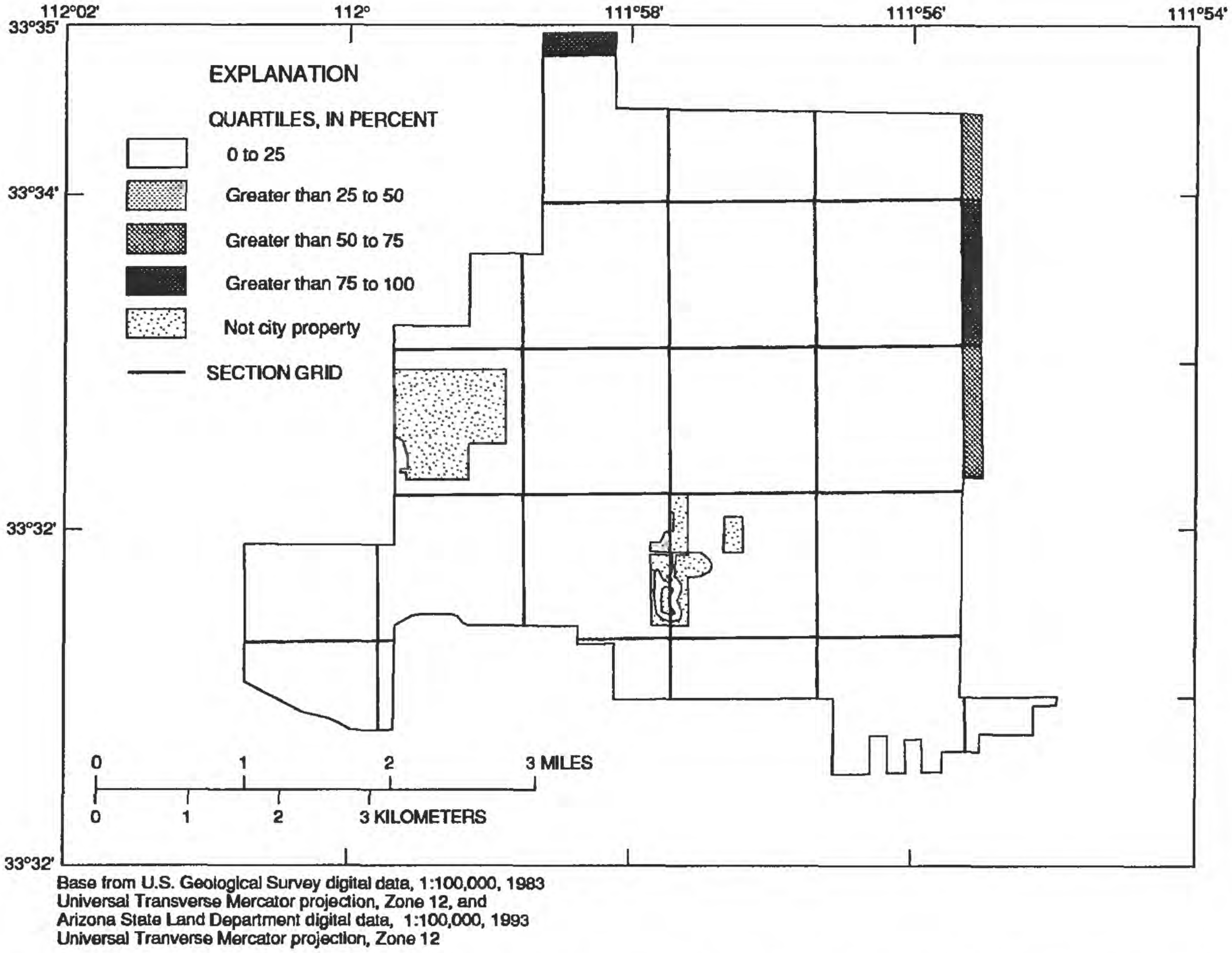


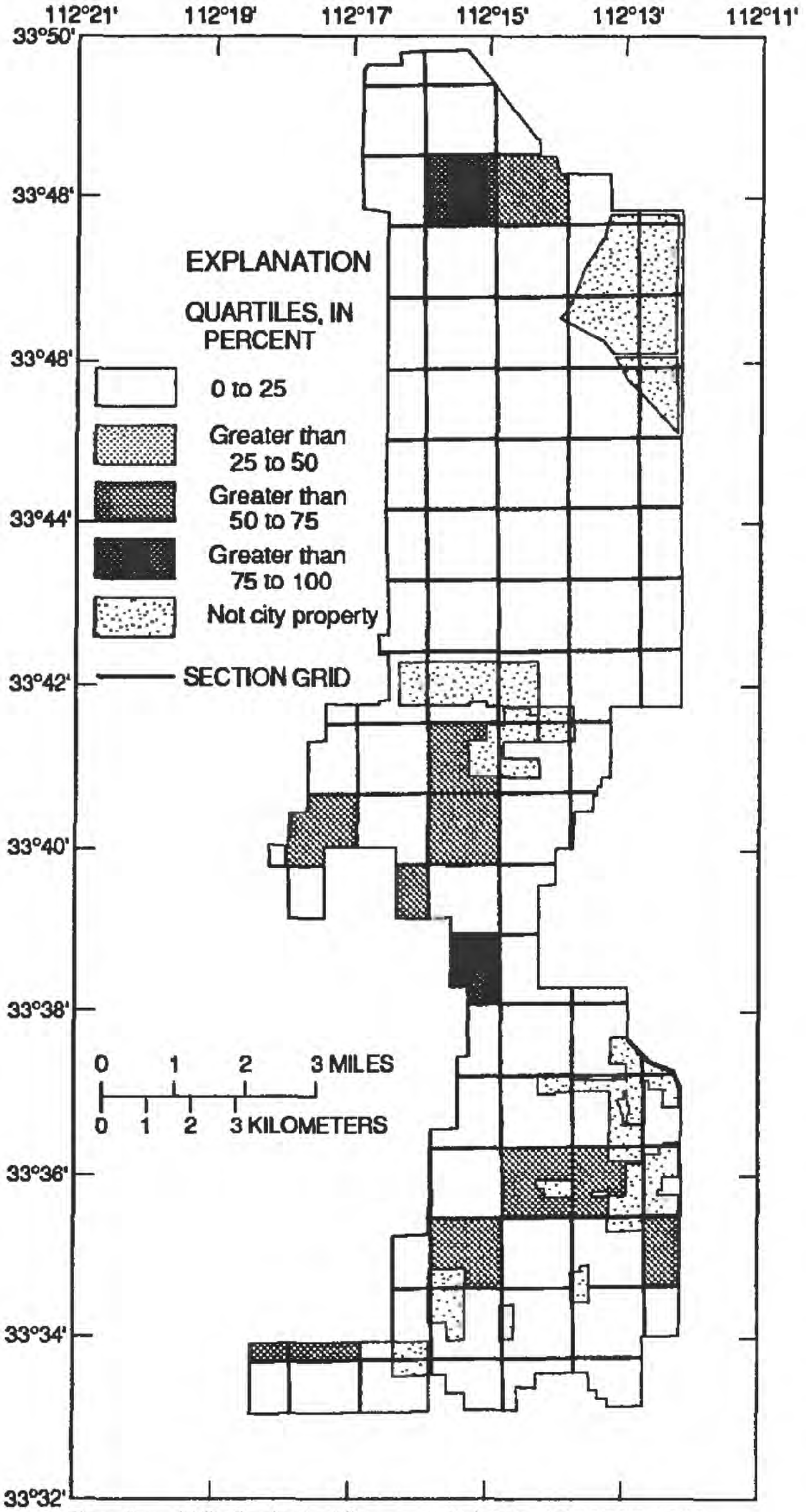
**Figure 8.** Distribution of unit-constituent loads in stormwater for the City of Paradise Valley. Unit-constitiuent loads (constituent load per unit area) were calculated for each section, and each section was associated with quartiles between the minimum (0 to 25 quartile) and maximum (greater than 75 to 100 quartile) unit load.

5 percent for only four of the constituents. In addition, there was a poor linear relation between untransformed observed and predicted values in contrast to constituent-load values. In general, the regional-regression equations overestimated event-mean constituent concentrations and had standard errors that were unacceptably high for direct application to the study area.

The MAP's of Hoos and Sisolak (1993) were used to modify the regional-regression equations for event-mean constituent concentrations. The MAP's that provided the least error in predicting constituent concentrations were either the R-P or R-P+nV adjustments. The MAP's reduced the standard error of estimate by about 20 to 3,300 percent. The regression residuals, however, were not homoscedastic. Lack of homoscedasticity and the poor linear relation between predicted and observed values violates the underlying assumptions of linear regression; therefore, the best estimators for event-mean constituent concentrations in the study area probably are the mean values (table 6).

## SUMMARY

From October 1991 to October 1993, stormwater was sampled in the metropolitan Phoenix area from five drainage basins with residential, light industrial, heavy industrial, commercial, and undeveloped land uses;

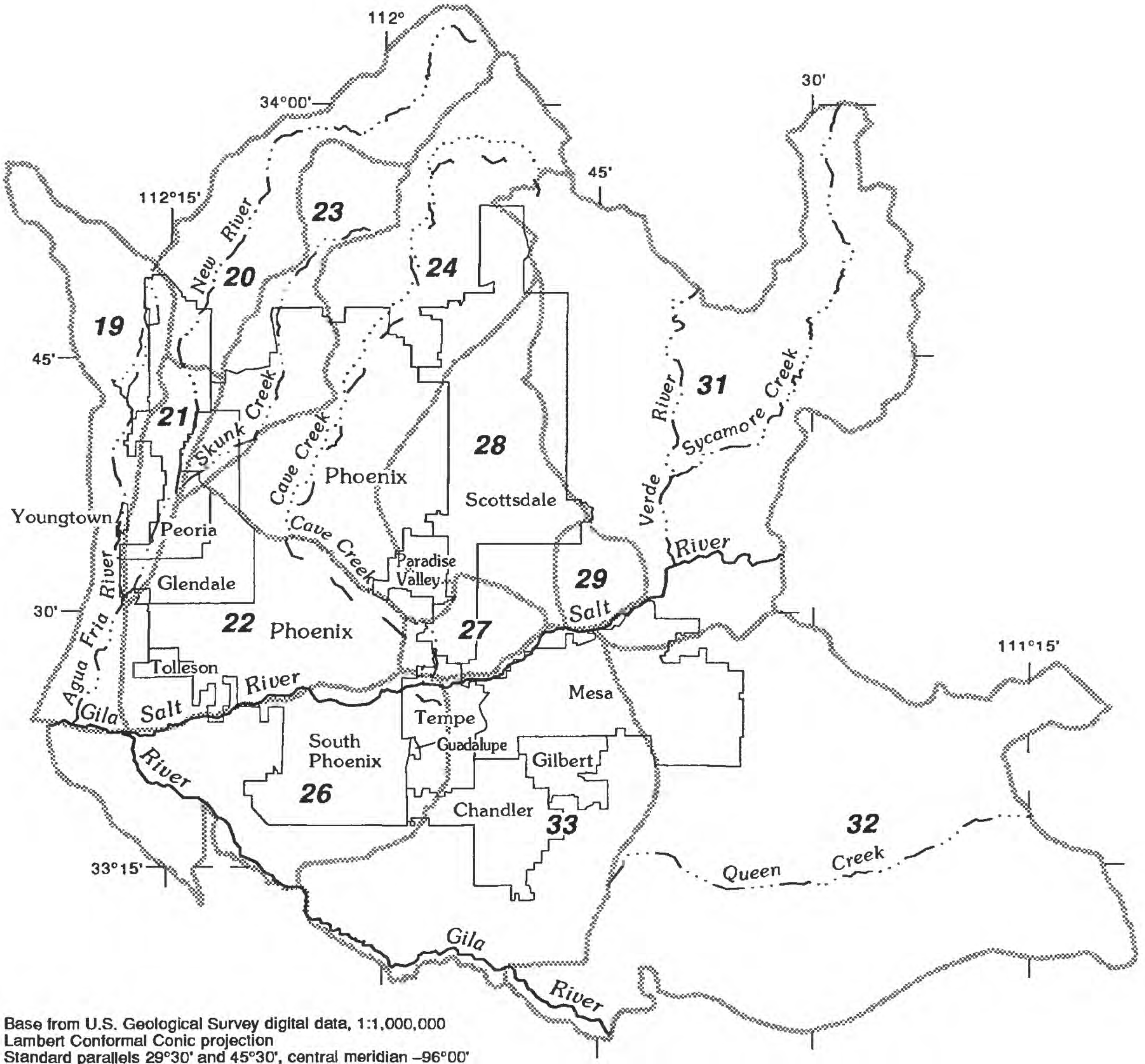


Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection, Zone 12, and
Arizona State Land Department digital data, 1:100,000, 1993
Universal Tranverse Mercator projection, Zone 12

**Figure 9.** Distribution of unit-constituent loads in stormwater for the City of Peoria. Unit-constitiuent loads (constituent load per unit area) were calculated for each section, and each section was associated with quartiles between the minimum (0 to 25 *quartile*) and maximum (greater than 75 to 100 quartile) unit load.

streamflow was sampled from the Salt River. Stormwater also was sampled from seven drainage basins with residential, industrial, commercial, and mixed land use in 1992 by the City of Phoenix. Initial runoff from several sites typically was black in color from oil and grease, particulates from ground-up tires, or other sources. Specific-conductance values commonly decreased during storms; the decreasing values indicated that most soluble constituents were washed from exposed surfaces in the initial runoff or that constituents were diluted. Event-mean concentrations of most constituents measured in stormwater generally were log-normally distributed, commonly varied by an order of magnitude, and were similar for most land uses. The largest event-mean concentrations of constituents were from the drainage basin with heavy industrial land use; this basin also had the largest event-mean concentration of suspended solids of the urban drainage basins studied. Most event-mean constituent concentrations were positively correlated with suspended-solids concentrations; percent impervious area was negatively correlated with suspended-solids concentrations. The dependence of constituent concentrations on suspended-solids concentrations makes it difficult to separate the effects of land use on urban stormwater chemistry from percentage of impervious area. Instantaneous concentrations of most constituents measured in streamflow from the Salt River were within the range of concentrations measured in stormwater from urban drainage basins. Event-mean concentrations of chemical oxygen demand and biological oxygen demand, oil and grease, and counts of fecal bacteria were greater in urban stormwater than in streamflow.

Organochlorine pesticides, semivolatile compounds, and volatile organic compounds were seldom detected in urban stormwater and were not detected in streamflow or stormwater from the drainage basin with undeveloped land use. The insecticides DDT and DDE were measured in stormwater samples from the drainage basins with heavy industrial, residential, and commercial land use at concentrations of 0.04 to 1.1 μg/L. DDT and its degradation product DDE could be from insecticides applied in the 1950's and 1960's when most of the land in the metropolitan Phoenix area was used for agriculture or could be present as byproducts from the manufacturing of other organochlorine pesticides. Semivolatile and volatile organic compounds were detected in 7 of 30 samples and were detected in samples from the light industrial and commercial drainage basins, which indicates that these compounds were not significant in stormwater.



Base from U.S. Geological Survey digital data, 1:1,000,000
Lambert Conformal Conic projection
Standard parallels 29°30' and 45°30', central meridian –96°00'
Watershed drainage basins from Arizona Department of Water Quality

0 5 10 15 20 MILES

0 5 10 15 20 KILOMETERS

EXPLANATION

19 WATERSHED BOUNDARY—Number is identifier (Source: Flood Control District of Maricopa County)

| | |
|---|---|
| ***19*** Lower Agua Fria | ***27*** Lower Indian Bend |
| ***20*** Upper New River | ***28*** Upper Indian Bend |
| ***21*** Lower New River | ***29*** Evergreen |
| ***22*** Lower Arizona Canal Diversion Channel | ***31*** Lower Verde |
| ***23*** Skunk Creek | ***32*** Lower East Maricopa Flood |
| ***24*** Upper Arizona Canal Diversion Channel | ***33*** Upper East Maricopa Flood |
| ***26*** South Mountain | |

**Figure 10.** The major drainage basins in the Phoenix area.

**Table 22.** Estimated mean annual constituent loads for major drainage basins in Phoenix and surrounding municipalities

[Units for all estimates are in pounds. ACDC, Arizona Canal Diversion Channel]

| Drainage basin (from figure 10) | Chemical oxygen demand | | | Suspended solids | | | Dissolved solids | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Upper New River | 700,000 | 670,000 | 685,000 | 8,140,000 | 7,400,000 | 7,770,000 | 64,400 | 61,800 | 63,100 |
| Upper ACDC | 2,700,000 | 2,600,000 | 2,650,000 | 23,900,000 | 22,400,000 | 23,200,000 | 703,000 | 678,000 | 690,000 |
| Lower Verde | 2,520,000 | 2,470,000 | 2,500,000 | 30,000,000 | 28,600,000 | 29,300,000 | 223,000 | 218,000 | 220,000 |
| Skunk Creek | 770,000 | 734,000 | 752,000 | 7,880,000 | 7,120,000 | 7,500,000 | 110,000 | 105,000 | 108,000 |
| Lower Agua Fria | 940,000 | 896,000 | 918,000 | 8,780,000 | 8,020,000 | 8,400,000 | 180,000 | 170,000 | 175,000 |
| Upper Indian Bend | 1,420,000 | 1,340,000 | 1,380,000 | 12,400,000 | 11,300,000 | 11,800,000 | 369,000 | 352,000 | 360,000 |
| Lower New River | 427,000 | 389,000 | 408,000 | 3,330,000 | 2,800,000 | 3,060,000 | 126,000 | 117,000 | 122,000 |
| Lower ACDC | 2,410,000 | 2,290,000 | 2,350,000 | 15,600,000 | 14,100,000 | 14,900,000 | 1,090,000 | 1,050,000 | 1,070,000 |
| Evergreen | 162,000 | 150,000 | 156,000 | 2,020,000 | 1,680,000 | 1,850,000 | 11,000 | 10,300 | 10,700 |
| Lower Indian Bend | 1,070,000 | 816,000 | 943,000 | 3,020,000 | 2,470,000 | 2,750,000 | 172,000 | 158,000 | 165,000 |
| Lower East Maricopa Flood | 2,670,000 | 2,590,000 | 2,630,000 | 26,200,000 | 24,700,000 | 25,400,000 | 519,000 | 499,000 | 509,000 |
| Upper East Maricopa Flood | 2,380,000 | 2,280,000 | 2,330,000 | 17,800,000 | 16,400,000 | 17,100,000 | 792,000 | 764,000 | 778,000 |
| South Mountain | 1,700,000 | 1,630,000 | 1,660,000 | 14,800,000 | 13,600,000 | 14,200,000 | 438,000 | 419,000 | 428,000 |

| Drainage basin | Total nitrogen | | | Total organic nitrogen plus ammonia | | | Total phosphorus | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean | Upper 95-percent confidence level | Lower 95-percent confidence level | Mean |
| Upper New River | 21,900 | 21,000 | 21,400 | 31,200 | 29,900 | 30,600 | 5,530 | 5,260 | 5,390 |
| Upper ACDC | 86,900 | 83,700 | 85,300 | 121,000 | 117,000 | 119,000 | 27,100 | 25,800 | 26,400 |
| Lower Verde | 79,800 | 78,100 | 79,000 | 114,000 | 112,000 | 113,000 | 19,900 | 19,400 | 19,600 |
| Skunk Creek | 24,100 | 22,900 | 23,500 | 33,900 | 32,300 | 33,100 | 6,660 | 6,270 | 6,460 |
| Lower Agua Fria | 28,400 | 27,100 | 27,700 | 39,600 | 37,800 | 38,700 | 8,270 | 7,750 | 8,010 |
| Upper Indian Bend | 45,400 | 43,100 | 44,300 | 63,000 | 60,000 | 61,500 | 14,200 | 13,340 | 13,800 |
| Lower New River | 13,100 | 11,900 | 12,500 | 18,000 | 16,400 | 17,200 | 4,320 | 3,840 | 4,080 |
| Lower ACDC | 77,200 | 73,300 | 75,200 | 104,000 | 99,400 | 102,000 | 28,200 | 26,500 | 27,400 |
| Evergreen | 4,990 | 4,630 | 4,810 | 7,160 | 6,640 | 6,900 | 1,200 | 1,100 | 1,160 |
| Lower Indian Bend | 13,800 | 12,300 | 13,000 | 18,600 | 16,800 | 17,700 | 490 | 4,280 | 4,590 |
| Lower East Maricopa Flood | 84,300 | 81,600 | 83,000 | 118,000 | 115,000 | 116,000 | 24,300 | 23,300 | 23,800 |
| Upper East Maricopa Flood | 73,700 | 70,600 | 72,100 | 101,000 | 96,800 | 98,800 | 24,700 | 23,400 | 24,100 |
| South Mountain | 53,300 | 50,900 | 52,100 | 73,800 | 70,700 | 72,200 | 16,600 | 15,600 | 16,100 |

**Table 22.** Estimated mean annual constituent loads for major drainage basins in Phoenix and surrounding municipalities—Continued

| Drainage basin | Dissolved phosphorus | | | Total recoverable cadmium | | | Total recoverable copper | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean |
| Upper New River | 1,370 | 1,270 | 1,320 | 6.93 | 6.69 | 6.81 | 317 | 301 | 309 |
| Upper ACDC | 4,730 | 4,300 | 4,520 | 37.6 | 35.2 | 36.4 | 1,550 | 1,420 | 1,490 |
| Lower Verde | 4,810 | 4,620 | 4,720 | 25.9 | 25.5 | 25.7 | 1,160 | 1,120 | 1,140 |
| Skunk Creek | 1,480 | 1,340 | 1,410 | 7.05 | 6.77 | 6.91 | 296 | 280 | 288 |
| Lower Agua Fria | 1,900 | 1,710 | 1,800 | 9.96 | 9.32 | 9.64 | 571 | 510 | 540 |
| Upper Indian Bend | 2,520 | 2,200 | 2,360 | 18.4 | 17.1 | 17.8 | 715 | 653 | 684 |
| Lower New River | 832 | 655 | 743 | 7.28 | 6.00 | 6.64 | 223 | 186 | 205 |
| Lower ACDC | 4,070 | 3,500 | 3,780 | 69.1 | 63.2 | 66.2 | 3,060 | 2,730 | 2,890 |
| Evergreen | 332 | 296 | 314 | 1.64 | 1.54 | 1.59 | 74.0 | 67.2 | 70.6 |
| Lower Indian Bend | 840 | 625 | 733 | 10.8 | 8.69 | 9.75 | 385 | 312 | 348 |
| Lower East Maricopa Flood | 5,000 | 4,640 | 4,820 | 27.2 | 26.2 | 26.7 | 1,340 | 1,260 | 1,300 |
| Upper East Maricopa Flood | 4,380 | 3,910 | 4,140 | 42.0 | 38.9 | 40.5 | 1,900 | 1,740 | 1,820 |
| South Mountain | 3,160 | 2,820 | 2,990 | 22.4 | 20.7 | 21.6 | 1,310 | 1,180 | 1,250 |

| Drainage basin | Total recoverable lead | | | Total recoverable zinc | | | Volume of runoff, in cubic feet | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean | Upper 95–percent confidence level | Lower 95–percent confidence level | Mean |
| Upper New River | 739 | 676 | 707 | 1,230 | 1,170 | 1,200 | 118,000,000 | 114,000,000 | 116,000,000 |
| Upper ACDC | 5,100 | 4,710 | 4,900 | 6,840 | 6,530 | 6,680 | 904,000,000 | 876,000,000 | 890,000,000 |
| Lower Verde | 2,540 | 2,420 | 2,480 | 4,330 | 4,220 | 4,270 | 415,000,000 | 407,000,000 | 411,000,000 |
| Skunk Creek | 1,060 | 956 | 1,010 | 1,590 | 1,500 | 1,550 | 171,000,000 | 165,000,000 | 168,000,000 |
| Lower Agua Fria | 1,550 | 1,380 | 1,470 | 2,150 | 2,020 | 2,090 | 242,000,000 | 231,000,000 | 237,000,000 |
| Upper Indian Bend | 2,710 | 2,440 | 2,570 | 3,610 | 3,400 | 3,500 | 476,000,000 | 457,000,000 | 466,000,000 |
| Lower New River | 943 | 781 | 862 | 1,180 | 1,060 | 11,240 | 153,000,000 | 142,000,000 | 148,000,000 |
| Lower ACDC | 6,700 | 6,100 | 6,400 | 7,950 | 7,510 | 7,730 | 1,210,000,000 | 1,160,000,000 | 1,180,000,000 |
| Evergreen | 150 | 129 | 139 | 261 | 240 | 250 | 22,400,000 | 21,500,000 | 21,900,000 |
| Lower Indian Bend | 1,170 | 954 | 1,060 | 1,390 | 1,230 | 1,310 | 183,000,000 | 168,000,000 | 176,000,000 |
| Lower East Maricopa Flood | 4,200 | 3,880 | 4,040 | 5,980 | 5,730 | 5,850 | 714,000,000 | 692,000,000 | 703,000,000 |
| Upper East Maricopa Flood | 5,440 | 4,990 | 5,220 | 6,830 | 6,490 | 6,660 | 933,000,000 | 902,000,000 | 917,000,000 |
| South Mountain | 3,260 | 2,950 | 3,110 | 4,320 | 4,090 | 4,200 | 554,000,000 | 533,000,000 | 543,000,000 |

**Table 23.** Ranking of the major drainage basins in the Phoenix area by unit-constituent loads

[Rankings are listed in ascending order. Ranks were computed for each constituent, and the mean rank was computed for the drainage basin. ACDC, Arizona Canal Diversion Channel]

| Drainage basin | Drainage area, in square miles | Mean rank |
|---|---|---|
| Upper New River | 126.3 | 3 |
| Upper ACDC | 313 | 7 |
| Lower Verde | 506.4 | 1 |
| Skunk Creek | 110 | 4 |
| Lower Agua Fria | 115 | 6 |
| Upper Indian Bend | 154.6 | 8 |
| Lower New River | 33.6 | 10 |
| Lower ACDC | 137 | 13 |
| Evergreen | 30.8 | 2 |
| Lower Indian Bend | 25 | 12 |
| Lower East Maricopa Flood | 371.2 | 5 |
| Upper East Maricopa Flood | 187 | 11 |
| South Mountain | 183.3 | 9 |

Loads for a mean storm, mean seasonal, and mean annual loads of 12 constituents and volumes of runoff were estimated for municipalities in the study area. Constituent loads were estimated by using data collected in the study area to adjust regional-regression equations for local application. Most of the adjusted equations required three explanatory variables (total rainfall, drainage area, and percentage of impervious area) to estimate constituent loads and had standard errors that were from 65 to 266 percent. Land-use data and a geographic-information system were used with the adjusted equations to estimate constituent loads and volume of runoff from each municipality, to evaluate the areal distribution of constituent loads, and to identify areas that are contributing a large proportion of the total loads. The distribution of pollutant loads in the municipalities of Chandler, Mesa, Paradise Valley, and Peoria indicates that there are localized areas contributing a large proportion of the annual constituent loads. Constituent loads seem to be evenly distributed in other municipalities.

Regional-regression equations for estimating event-mean constituent concentrations also were adjusted. The equations, however, were not linear and residuals were not homoscedastic; therefore, the best estimates of the event-mean constituent concentrations measured in stormwater probably are the mean values.

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# SELECTED WATER-QUALITY DATA FOR FLOW-WEIGHTED COMPOSITE AND INSTANTANEOUS SAMPLES OF STORMWATER AND STREAMFLOW

## UNITED STATES DEPARTMENT OF INTERIOR – GEOLOGICAL SURVEY - MULTIPLE STATION ANALYSES

[Mgal/d, million gallons per day; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius; mm, millimeters; mg/L, milligrams per liter; cols./100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; dashes indicate no data; <, less than; >, greater than; K, based on non-ideal colony count]

| Station number | Date | Time | Dis-charge, inst. (cubic feet per second) | Storm water flow (Mgal/d) | Precipi-tation total inches/ storm | Maximum 5-minute precipi-tation intensity (inches) | Elapsed time of storms (hours) | Dry days before precipi-tation event (days) | Number of sam-pling points (count) | Spe-cific con-duct-ance (µS/cm) | Specific con-duct-ance lab (µS/cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | 0005 | 10 | ----- | ----- | ----- | ----- | ----- | 1 | 880 | 880 |
| | 01-04-93 | 1630 | 8,600 | ----- | ----- | ----- | ----- | ----- | 27 | 607 | 620 |
| | 01-12-93 | 1910 | 47,800 | ----- | ----- | ----- | ----- | ----- | 5 | 500 | 496 |
| | 02-11-93 | 0900 | 25,500 | ----- | ----- | ----- | ----- | ----- | 10 | 309 | 299 |
| 09512184 | 11-10-91 | 1957 | 7.7 | 0.22 | 0.48 | 0.05 | 2.3 | 13.0 | 1 | 80 | 97 |
| | 12-10-91 | 2036 | 16 | 0.17 | 0.46 | 0.19 | 10.0 | 29.0 | 1 | ----- | 178 |
| | 12-18-91 | 0546 | 0.97 | 0.13 | 0.56 | 0.02 | 8.8 | 7.0 | 1 | 109 | 81 |
| | 03-08-92 | 0716 | 2.1 | 0.15 | 0.35 | 0.04 | 5.6 | 1.0 | 1 | 194 | 139 |
| | 03-27-92 | 0602 | 2.7 | 0.32 | 0.51 | 0.03 | 5.8 | 18.0 | 1 | 97 | 87 |
| | 05-20-92 | 1341 | -------- | ----- | ----- | ----- | ----- | ----- | --- | ----- | ----- |
| | 05-20-92 | 1348 | 5.0 | 0.29 | 0.28 | 0.09 | 2.7 | 1.0 | 1 | 128 | 164 |
| | 05-20-92 | 1350 | -------- | ----- | ----- | ----- | ----- | ----- | --- | ----- | ----- |
| | 05-20-92 | 1412 | -------- | ----- | ----- | ----- | ----- | ----- | --- | ----- | ----- |
| | 05-20-92 | 1424 | -------- | ----- | ----- | ----- | ----- | ----- | --- | ----- | ----- |
| | 05-20-92 | 1436 | -------- | ----- | ----- | ----- | ----- | ----- | --- | ----- | ----- |
| | 08-05-92 | 0841 | 32 | 0.30 | 0.44 | 0.16 | 2.7 | 6.0 | 1 | 93 | 90 |
| 09512190 | 08-24-92 | 1430 | 16,500 | ----- | ----- | ----- | ----- | ----- | 15 | 406 | 384 |
| | 09-02-92 | 1055 | 1,140 | ----- | ----- | ----- | ----- | ----- | 8 | 761 | 774 |
| 09512200 | 01-12-92 | 0032 | 163 | 1.4 | 0.60 | 0.15 | 3.0 | 6.0 | 1 | 75 | 88 |
| | 02-07-92 | 1524 | 128 | 0.77 | 0.41 | 0.10 | 19.8 | 3.0 | 1 | ----- | ----- |
| 09512403 | 12-10-91 | 2113 | 3.0 | 0.08 | 0.60 | 0.08 | 11.0 | 11.0 | 1 | 163 | 170 |
| | 12-18-91 | 0733 | 1.2 | 0.10 | 0.25 | 0.01 | 12.0 | 7.0 | 1 | 177 | 185 |
| | 02-07-92 | 0445 | 0.28 | 0.01 | 0.18 | 0.02 | 5.5 | 17.0 | 1 | ----- | ----- |
| | 03-02-92 | 1327 | 1.8 | 0.05 | 0.23 | 0.08 | 17.6 | 18.0 | 1 | 266 | 258 |
| | 03-08-92 | 1439 | 0.63 | 0.05 | 0.41 | 0.02 | 13.0 | 1.0 | 1 | 159 | 200 |
| | 03-27-92 | 0400 | -------- | ----- | ----- | ----- | ----- | ----- | 1 | 215 | ----- |
| | 07-11-92 | 0105 | 2.0 | 0.09 | 0.53 | 0.03 | 3.3 | 4.0 | 1 | 169 | 223 |
| | 08-22-92 | 0926 | 2.3 | 0.04 | 0.37 | 0.13 | 2.1 | 14.0 | 1 | 150 | 188 |
| | 12-08-92 | 0713 | 2.7 | 0.13 | 0.88 | 0.05 | 6.7 | 41.0 | 1 | 129 | ----- |
| 09513700 | 10-27-91 | 0909 | 1.7 | 0.07 | 0.52 | 0.13 | 3.1 | 57.0 | 1 | 87 | 73 |
| | 11-29-91 | 2332 | 0.33 | 0.03 | 0.34 | 0.05 | 10.2 | 15.0 | 1 | 99 | 138 |
| | 12-10-91 | 1817 | 18 | 0.40 | 0.72 | 0.28 | 7.8 | 11.0 | 1 | 76 | 70 |
| | 02-07-92 | 0320 | 0.83 | 0.08 | 0.38 | 0.02 | 8.9 | 47.0 | 1 | 52 | 55 |
| | 03-27-92 | 0333 | 0.65 | 0.06 | 0.34 | 0.02 | 8.0 | 50.0 | 1 | 76 | 87 |
| | 08-22-92 | 2221 | 0.96 | 0.05 | 0.40 | 0.11 | 21.9 | 17.0 | 1 | 175 | 92 |
| 09513885 | 12-04-92 | 0523 | 1.2 | 0.05 | 0.68 | 0.02 | 12.7 | 36.0 | 1 | 82 | 47 |
| | 01-06-93 | 2103 | 0.82 | 0.03 | 0.44 | 0.02 | 24.1 | 3.0 | 1 | 99 | 44 |
| | 02-08-93 | 1941 | 1.7 | 0.06 | 0.76 | 0.02 | 19.5 | 18.0 | 1 | 130 | 49 |
| | 03-26-93 | 1557 | 2.0 | 0.02 | 0.22 | 0.09 | 4.5 | 45.0 | 1 | 894 | 170 |
| | 08-24-93 | 2343 | 2.1 | 0.02 | 0.29 | 0.07 | 2.0 | 16.0 | 1 | 104 | 121 |
| | 10-06-93 | 1231 | 1.2 | 0.03 | 0.39 | 0.06 | 11.7 | 22.0 | 1 | 80 | 133 |

| Station number | Date | pH water whole field (standard units) | pH water whole lab (standard units) | Temperature water (°C) | Barometric pressure (mm of Hg) | Oxygen, dissolved (mg/L) | Oxygen, dissolved (percent saturation) | Oxygen demand, chemical (high level) (mg/L) | Oxygen demand, biochemical, 5-day (mg/L) | Coliform, fecal, 0.7 um-mf (cols./100 mL) | Streptococci fecal, kf agar (cols./100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | 8.9 | 8.5 | 13.0 | ----- | ------ | ----- | 25 | --------- | ---------- | ----------- |
| | 01-04-93 | 7.9 | 8.1 | 13.0 | 720 | 10.2 | 103 | 17 | 7.0 | ---------- | 540 |
| | 01-12-93 | 8.2 | 8.0 | 12.0 | 730 | 8.1 | 79 | 39 | <5.0 | 290 | 1,300 |
| | 02-11-93 | 8.0 | 8.1 | 11.0 | 725 | 8.7 | 83 | 13 | <5.0 | 100 | 230 |
| 09512184 | 11-10-91 | 7.5 | 6.8 | 18.0 | 729 | 8.2 | 91 | 69 | <5.0 | 5,700 | 8,800 |
| | 12-10-91 | ---- | 7.6 | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 12-18-91 | 7.6 | 6.6 | 15.0 | 731 | 8.3 | 86 | 300 | 200 | 4,500 | K12,000 |
| | 03-08-92 | 8.0 | 8.0 | 16.5 | 727 | 8.9 | 96 | 53 | <5.0 | 5,000 | 4,400 |
| | 03-27-92 | 7.0 | 7.6 | 17.5 | 725 | 7.9 | 87 | 87 | 60 | 2,500 | 5,500 |
| | 05-20-92 | ---- | ---- | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 05-20-92 | 6.5 | 6.7 | ----- | 724 | 6.9 | 96 | 120 | 18 | 1,400 | 27,000 |
| | 05-20-92 | ---- | ---- | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 05-20-92 | ---- | ---- | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 05-20-92 | ---- | ---- | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 05-20-92 | ---- | ---- | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 08-05-92 | 8.0 | 7.6 | 26.0 | 731 | 7.2 | 93 | 93 | 100 | >6,000 | K11,000 |
| 09512190 | 08-24-92 | 7.3 | 7.9 | ----- | 732 | 5.6 | ----- | 33 | 10 | 3,000 | 3,400 |
| | 09-02-92 | 8.1 | 8.3 | 25.5 | 730 | 5.9 | 76 | 12 | 30 | 450 | 48 |
| 09512200 | 01-12-92 | 8.3 | 7.5 | 7.5 | 720 | 7.3 | 64 | 59 | 20 | 2,500 | 9,800 |
| | 02-07-92 | ---- | 8.1 | ----- | ----- | ------ | ----- | 21,000 | --------- | ---------- | ----------- |
| 09512403 | 12-10-91 | 8.4 | 7.9 | 17.5 | 727 | 7.3 | 80 | 4,300 | 3,600 | 3,100 | K22,000 |
| | 12-18-91 | 7.8 | 7.2 | 16.0 | 730 | 9.0 | 95 | 520 | 270 | K11,000 | K26,000 |
| | 02-07-92 | ---- | ---- | ----- | ----- | ------ | ----- | -------- | --------- | ---------- | ----------- |
| | 03-02-92 | 9.0 | 7.8 | 17.0 | 730 | 8.5 | 92 | 340 | 8.5 | 5,500 | 6,500 |
| | 03-08-92 | 8.7 | 7.9 | 17.0 | 731 | 7.6 | 82 | 590 | 31 | 5,800 | 6,600 |
| | 03-27-92 | 7.9 | ---- | 17.5 | 730 | 8.5 | 93 | -------- | --------- | K9,500 | 8,500 |
| | 07-11-92 | 8.4 | 7.5 | 28.0 | 732 | 7.1 | 95 | 180 | 33 | 4,500 | 9,800 |
| | 08-22-92 | 8.8 | 7.8 | 27.5 | 732 | 5.9 | 78 | 180 | 21 | 5,800 | 4,200 |
| | 12-08-92 | 7.8 | ---- | 12.5 | 730 | 10.2 | 100 | 110 | 12 | 4,500 | K15,000 |
| 09513700 | 10-27-91 | 7.2 | 7.8 | 25.0 | 723 | 6.5 | 83 | 140 | 12 | 4,600 | 1,000 |
| | 11-29-91 | 7.3 | 7.5 | 10.0 | 724 | 10.0 | 93 | 150 | 55 | 5,800 | 1,700 |
| | 12-10-91 | 7.9 | 7.6 | 15.0 | 727 | 9.8 | 102 | <10 | 30 | 2,600 | K12,000 |
| | 02-07-92 | 7.1 | 7.4 | 14.5 | 727 | 8.7 | 89 | 60 | <5.0 | 970 | 2,600 |
| | 03-27-92 | 7.9 | 7.4 | 16.5 | 725 | 8.8 | 95 | 120 | 65 | 2,700 | 8,500 |
| | 08-22-92 | 7.2 | 6.8 | 30.0 | 729 | 5.7 | 79 | 150 | 18 | >6,000 | 1,900 |
| 09513885 | 12-04-92 | 6.9 | 7.2 | 14.5 | 730 | 10.0 | 102 | 97 | 16 | K8,000 | 6,700 |
| | 01-06-93 | 6.8 | 6.8 | 12.0 | 725 | 8.6 | 84 | 97 | 66 | 2,700 | K12,000 |
| | 02-08-93 | 6.3 | 6.5 | 16.0 | 730 | 8.2 | 87 | 180 | 9.0 | 2,300 | 5,200 |
| | 03-26-93 | 6.5 | 6.7 | 22.0 | 725 | 5.6 | 67 | 330 | 63 | K41,000 | K21,000 |
| | 08-24-93 | 6.5 | 6.6 | 27.0 | 730 | ------ | ----- | 160 | 30 | ---------- | K130 |
| | 10-06-93 | 7.0 | 6.4 | 25.0 | 732 | ------ | ----- | 210 | 33 | K400 | K670 |

## UNITED STATES DEPARTMENT OF INTERIOR – GEOLOGICAL SURVEY - MULTIPLE STATION ANALYSES

| Station number | Date | Calcium dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium, dissolved (mg/L as K) | Bicarbonate water Wh it field (mg/L as $HCO_3$) | Bicarbonate water Dis it field (mg/L as $HCO_3$) | Carbonate water Wh it field (mg/L as $CO_3$) | Carbonate water Dis it field (mg/L as $CO_3$) | Alkalinity Wat Wh Tot it field (mg/L as $CaCO_3$) | Alkalinity Wat Dis Tot it field (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | 43 | 20 | 100 | ------ | ---- | ---- | -- | -- | ---- | 150 |
| | 01-04-93 | 37 | 12 | 63 | 3.0 | 150 | 130 | 0 | 0 | 123 | 107 |
| | 01-12-93 | 29 | 8.3 | 54 | 2.8 | 128 | 109 | 0 | 0 | 105 | 89 |
| | 02-11-93 | 27 | 8.6 | 19 | 2.0 | ---- | 116 | -- | 0 | ---- | 95 |
| 09512184 | 11-10-91 | 9.1 | 1.2 | 4.7 | 2.0 | 20 | 20 | 0 | 0 | 17 | 16 |
| | 12-10-91 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 12-18-91 | 8.6 | 1.0 | 4.0 | 1.5 | 25 | ---- | 0 | -- | 21 | ---- |
| | 03-08-92 | 13 | 1.5 | 8.2 | 2.1 | 41 | 32 | 0 | 0 | 34 | 27 |
| | 03-27-92 | 8.1 | 0.90 | 3.5 | 1.6 | 29 | 23 | 0 | 0 | 24 | 19 |
| | 05-20-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 05-20-92 | 13 | 1.8 | 12 | 3.4 | 29 | 24 | 0 | 0 | 24 | 19 |
| | 05-20-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 05-20-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 05-20-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 05-20-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 08-05-92 | 8.7 | 1.0 | 3.9 | 1.6 | 48 | 25 | 0 | 0 | 39 | 21 |
| 09512190 | 08-24-92 | 32 | 11 | 29 | 2.8 | 179 | ---- | 0 | -- | 147 | ---- |
| | 09-02-92 | 40 | 11 | 87 | 3.6 | 139 | 138 | 0 | 0 | 114 | 113 |
| 09512200 | 01-12-92 | 11 | 0.85 | 0.90 | 4.3 | 40 | ---- | 0 | -- | 33 | ---- |
| | 02-07-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| 09512403 | 12-10-91 | 13 | 1.5 | 8.9 | 3.3 | ---- | ---- | -- | -- | ---- | ---- |
| | 12-18-91 | 16 | 1.9 | 9.3 | 3.5 | 78 | 46 | 0 | 0 | 64 | 38 |
| | 02-07-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 03-02-92 | 23 | 3.0 | 15 | 5.3 | 278 | 39 | 0 | 0 | 228 | 32 |
| | 03-08-92 | 16 | 2.1 | 11 | 4.3 | 261 | 49 | 0 | 0 | 214 | 40 |
| | 03-27-92 | ----- | ------- | -------- | ------ | ---- | ---- | -- | -- | ---- | ---- |
| | 07-11-92 | 18 | 2.2 | 11 | 6.7 | 105 | 38 | 0 | 0 | 86 | 31 |
| | 08-22-92 | 16 | 1.7 | 8.2 | 4.5 | 229 | 34 | 0 | 0 | 188 | 28 |
| | 12-08-92 | 12 | 2.0 | 7.5 | 2.9 | 127 | ---- | 0 | -- | 104 | ---- |
| 09513700 | 10-27-91 | 9.3 | 0.78 | 1.8 | 1.7 | 46 | 22 | 0 | 0 | 38 | 18 |
| | 11-29-91 | 14 | 1.6 | 7.1 | 2.0 | 34 | 36 | 0 | 0 | 28 | 29 |
| | 12-10-91 | 7.6 | 0.80 | 1.5 | 1.2 | 156 | 23 | 0 | 0 | 128 | 19 |
| | 02-07-92 | 6.7 | 0.63 | 2.2 | 1.0 | 22 | 23 | 0 | 0 | 18 | 19 |
| | 03-27-92 | 12 | 0.97 | 2.3 | 1.6 | 34 | 26 | 0 | 0 | 28 | 22 |
| | 08-22-92 | 13 | 0.96 | 2.1 | 1.4 | 30 | 30 | 0 | 0 | 24 | 24 |
| 09513885 | 12-04-92 | 4.6 | 0.54 | 1.4 | 0.90 | 13 | 12 | 0 | 0 | 11 | 10 |
| | 01-06-93 | 4.9 | 0.53 | 1.5 | 0.70 | 16 | 16 | 0 | 0 | 13 | 13 |
| | 02-08-93 | 4.9 | 0.66 | 1.7 | 0.70 | 12 | 12 | 0 | 0 | 10 | 10 |
| | 03-26-93 | 15 | 1.7 | 12 | 1.7 | 59 | 32 | 0 | 0 | 48 | 26 |
| | 08-24-93 | 11 | 1.4 | 5.7 | 1.5 | 26 | 17 | 0 | 0 | 21 | 14 |
| | 10-06-93 | 13 | 2.0 | 8.4 | 1.7 | 29 | 26 | 0 | 0 | 24 | 21 |

| Station number | Date | Alkalinity lab (mg/L as $CaCO_3$) | Sulfate, dissolved (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Silica, dissolved (mg/L as $SiO_2$) | Solids, residue at 180°C dissolved (mg/L) | Residue total at 105°C suspended (mg/L) | Nitrogen, nitrite total (mg/L as N) | Nitrogen, $NO_2$+$NO_3$ total (mg/L as N) | Nitrogen, ammonia total (mg/L as N) | Nitrogen, ammonia + organic total (mg/L as N) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | ------- | 72 | 150 | 7.1 | 491 | 9 | -------- | ------- | -------- | ------ |
| | 01-04-93 | 132 | 38 | 92 | 16 | 347 | 47 | -------- | ------- | -------- | 0.30 |
| | 01-12-93 | 92 | 26 | 83 | 15 | 292 | 318 | <0.050 | ------- | 0.390 | 0.60 |
| | 02-11-93 | 98 | 20 | 21 | 15 | 180 | 149 | <0.050 | ------- | <0.100 | 0.30 |
| 09512184 | 11-10-91 | 25 | 8.3 | 6.6 | 1.7 | 57 | 57 | 0.050 | 0.770 | 0.770 | 1.9 |
| | 12-10-91 | ------- | ------ | ------ | ----- | ----- | 680 | -------- | --------- | -------- | ------ |
| | 12-18-91 | 26 | 6.3 | 4.5 | 2.2 | 92 | 10 | 0.080 | 0.690 | 0.380 | 1.0 |
| | 03-08-92 | 31 | 13 | 10 | 2.1 | 89 | 142 | 0.060 | 1.60 | 0.220 | 0.60 |
| | 03-27-92 | 28 | 4.0 | 5.2 | 1.4 | 44 | 108 | 0.080 | 0.460 | 0.610 | 1.1 |
| | 05-20-92 | ------- | ------ | ------ | ----- | ----- | 438 | -------- | ------- | -------- | ------ |
| | 05-20-92 | 36 | 10 | 17 | 2.1 | 116 | 167 | 0.080 | 0.950 | 1.10 | 2.4 |
| | 05-20-92 | ------- | ------ | ------ | ------ | ----- | 266 | -------- | ------- | -------- | ------ |
| | 05-20-92 | ------- | ------ | ------ | ------ | ----- | 208 | -------- | ------- | -------- | ------ |
| | 05-20-92 | ------- | ------ | ------ | ------ | ----- | 140 | -------- | ------- | -------- | ------ |
| | 05-20-92 | ------- | ------ | ------ | ------ | ----- | 136 | -------- | ------- | -------- | ------ |
| | 08-05-92 | 49 | 4.4 | 5.3 | 1.6 | 63 | 564 | 0.040 | 0.810 | 0.380 | 1.4 |
| 09512190 | 08-24-92 | 34 | ------ | ------ | 17 | 225 | 720 | 0.020 | 0.150 | 0.030 | 0.30 |
| | 09-02-92 | 120 | 41 | 140 | 15 | 445 | 3 | <0.010 | <0.050 | 0.030 | <0.20 |
| 09512200 | 01-12-92 | 40 | 7.2 | 1.6 | 2.0 | 35 | 365 | 0.110 | 1.40 | 0.230 | 2.0 |
| | 02-07-92 | 38 | ------ | ------ | ------ | ----- | 3,390 | 0.030 | 0.590 | 0.070 | 1.6 |
| 09512403 | 12-10-91 | 79 | 12 | 13 | ------ | 110 | 925 | 0.200 | 1.70 | 0.250 | 2.3 |
| | 12-18-91 | 79 | 9.7 | 10 | 3.3 | 122 | 316 | 0.080 | 2.00 | 0.140 | 1.7 |
| | 02-07-92 | ------- | ------ | ------ | ------ | ----- | ------- | -------- | ------- | -------- | ------ |
| | 03-02-92 | 42 | 20 | 27 | 3.0 | 158 | 1,120 | 0.070 | 4.70 | 0.410 | 2.6 |
| | 03-08-92 | 64 | 11 | 14 | 4.5 | 112 | 1,480 | 0.110 | 1.70 | 0.070 | 3.0 |
| | 03-27-92 | ------- | ------ | ------ | ------ | ----- | ------- | -------- | ------- | -------- | ------ |
| | 07-11-92 | 74 | 9.2 | 17 | 4.5 | 138 | 586 | 0.050 | 2.60 | 0.750 | 3.8 |
| | 08-22-92 | 75 | 9.1 | 13 | 4.2 | 121 | 1,430 | 0.040 | 2.10 | 0.390 | 2.2 |
| | 12-08-92 | 95 | 5.3 | 9.1 | 3.4 | 70 | 1,030 | 0.120 | 1.80 | 0.130 | 1.0 |
| 09513700 | 10-27-91 | 49 | 3.2 | 2.8 | 1.4 | 59 | <1 | 0.080 | 0.720 | 0.630 | 2.3 |
| | 11-29-91 | 41 | 7.3 | 12 | 3.9 | 100 | 92 | 0.060 | 1.50 | 0.890 | 1.7 |
| | 12-10-91 | 120 | 3.0 | 2.3 | 1.9 | 51 | 910 | 0.080 | 0.620 | 0.170 | 2.2 |
| | 02-07-92 | 21 | 2.0 | 1.0 | 2.6 | 46 | 3 | 0.040 | 0.420 | 0.480 | 0.90 |
| | 03-27-92 | 32 | 3.6 | 2.5 | 2.4 | 64 | 117 | 0.060 | 0.650 | 0.520 | 1.2 |
| | 08-22-92 | 2.7 | 6.8 | 2.1 | 3.2 | 105 | 118 | 0.040 | 1.00 | 0.980 | 1.9 |
| 09513885 | 12-04-92 | 11 | 3.2 | 1.7 | 1.0 | 46 | 22 | 0.060 | 0.550 | 1.70 | 2.6 |
| | 01-06-93 | 15 | 3.0 | 1.1 | 1.8 | 33 | 240 | -------- | ------- | -------- | 1.3 |
| | 02-08-93 | 14 | 4.6 | 1.6 | 1.1 | 38 | 144 | -------- | ------- | -------- | 1.6 |
| | 03-26-93 | 32 | <0.10 | 8.1 | 1.4 | 164 | 337 | -------- | ------- | -------- | 4.7 |
| | 08-24-93 | 23 | 12 | 5.8 | 1.1 | 126 | 42 | 0.020 | 0.780 | 1.20 | 3.4 |
| | 10-06-93 | 23 | 17 | 8.1 | 1.4 | 165 | 40 | 0.030 | 1.10 | 1.00 | 4.9 |

| Station number | Date | Phosphorus, total (mg/L as P) | Phosphorus, dissolved (mg/L as P) | Phosphorus, ortho total (mg/L as P) | Arsenic, total (µg/L as As) | Barium, dissolved (µg/L as Ba) | Beryllium, dissolved (µg/L as Be) | Cadmium, total recoverable (µg/L as Cd) | Cadmium, dissolved (µg/L as Cd) | Chromium, total recoverable (µg/L as Cr) | Copper, total recoverable (µg/L as Cu) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | ------- | ------- | ------- | 7 | 50 | <0.5 | <1 | <1.0 | 8 | 3 |
| | 01-04-93 | 0.090 | 0.030 | ------- | 8 | 40 | <0.5 | <1 | <1.0 | 8 | 6 |
| | 01-12-93 | 0.430 | 0.060 | ------- | 9 | 27 | <0.5 | <1 | <1.0 | 15 | 25 |
| | 02-11-93 | 0.200 | 0.060 | ------- | 8 | 24 | <0.5 | <1 | <1.0 | 6 | 13 |
| 09512184 | 11-10-91 | 0.330 | 0.210 | ------- | 3 | 23 | 1 | <1 | <1.0 | 5 | 30 |
| | 12-10-91 | ------- | ------- | ------- | 8 | --- | ----- | 2 | ----- | 44 | ---- |
| | 12-18-91 | 0.190 | 0.110 | ------- | 3 | 35 | <0.5 | <1 | <1.0 | 3 | ---- |
| | 03-08-92 | 0.150 | 0.070 | ------- | 4 | 25 | <0.5 | <1 | <1.0 | 7 | 10 |
| | 03-27-92 | 0.140 | 0.110 | ------- | 2 | 19 | <0.5 | <1 | <1.0 | 4 | 72 |
| | 05-20-92 | ------- | ------- | ------- | --- | --- | ----- | 2 | ----- | 17 | 90 |
| | 05-20-92 | 0.260 | 0.210 | ------- | 4 | 35 | 0.7 | 1 | <1.0 | 8 | 50 |
| | 05-20-92 | ------- | ------- | ------- | --- | --- | ----- | 1 | ----- | 7 | 50 |
| | 05-20-92 | ------- | ------- | ------- | --- | --- | ----- | <1 | ----- | 7 | 47 |
| | 05-20-92 | ------- | ------- | ------- | --- | --- | ----- | <1 | ----- | 7 | 49 |
| | 05-20-92 | ------- | ------- | ------- | --- | --- | ----- | <1 | ----- | 5 | 44 |
| | 08-05-92 | 0.260 | 0.130 | ------- | 6 | 13 | <0.5 | 1 | <1.0 | 15 | 55 |
| 09512190 | 08-24-92 | 0.080 | ------- | ------- | 13 | --- | ----- | <1 | ----- | 25 | 300 |
| | 09-02-92 | 0.030 | 0.010 | ------- | 1 | 44 | <0.5 | <1 | <1.0 | 1 | 2 |
| 09512200 | 01-12-92 | 0.760 | 0.180 | ------- | 4 | 11 | <0.5 | <1 | <1.0 | 14 | 27 |
| | 02-07-92 | 0.530 | ------- | ------- | 7 | --- | ----- | 2 | ----- | 120 | 210 |
| 09512403 | 12-10-91 | 0.960 | 0.110 | ------- | 10 | --- | ----- | 2 | ----- | 47 | ---- |
| | 12-18-91 | 0.720 | 0.100 | ------- | 8 | 21 | <0.5 | 1 | <1.0 | 20 | ---- |
| | 02-07-92 | ------- | ------- | ------- | 21 | --- | ----- | 6 | ----- | 89 | 320 |
| | 03-02-92 | 0.850 | 0.140 | ------- | 16 | 34 | <0.5 | 4 | <1.0 | 25 | 200 |
| | 03-08-92 | 1.70 | 0.090 | ------- | 16 | 14 | 0.6 | 4 | <1.0 | 3 | 200 |
| | 03-27-92 | ------- | ------- | ------- | --- | --- | ----- | --- | ----- | --- | ---- |
| | 07-11-92 | 1.10 | 0.230 | ------- | 2 | 28 | <0.5 | 2 | <1.0 | 25 | 50 |
| | 08-22-92 | 0.650 | 0.180 | ------- | 14 | 24 | <0.5 | 3 | <1.0 | 52 | 160 |
| | 12-08-92 | 0.510 | 0.170 | ------- | 11 | 15 | <0.5 | <2 | 2.0 | 34 | 100 |
| 09513700 | 10-27-91 | 0.430 | 0.180 | ------- | 5 | 11 | <0.5 | 1 | <1.0 | 12 | 33 |
| | 11-29-91 | 0.190 | 0.120 | ------- | 4 | 15 | <0.5 | <1 | <1.0 | 10 | ---- |
| | 12-10-91 | 0.680 | 0.100 | ------- | 14 | 10 | <0.5 | 1 | <1.0 | <1 | ---- |
| | 02-07-92 | 0.110 | 0.080 | ------- | 3 | 6 | <0.5 | <1 | <1.0 | 4 | 7 |
| | 03-27-92 | 0.150 | 0.120 | ------- | 3 | 14 | 0.8 | <1 | <1.0 | 6 | ---- |
| | 08-22-92 | 0.140 | 0.030 | ------- | 2 | 16 | <0.5 | <1 | <1.0 | 8 | 14 |
| 09513885 | 12-04-92 | 0.220 | 0.200 | ------- | 2 | 6 | 0.8 | <1 | <1.0 | 3 | 9 |
| | 01-06-93 | 0.160 | 0.050 | ------- | 3 | 6 | <0.5 | <1 | <1.0 | 4 | 8 |
| | 02-08-93 | 0.180 | 0.070 | ------- | 1 | 7 | <0.5 | <1 | 3.0 | 11 | 13 |
| | 03-26-93 | 0.380 | 0.240 | ------- | 4 | 21 | <0.5 | <1 | <1.0 | 11 | 26 |
| | 08-24-93 | 0.800 | 0.580 | 0.390 | 2 | 10 | 0.6 | <1 | <1.0 | 3 | 13 |
| | 10-06-93 | 0.750 | 0.630 | 0.370 | 2 | 16 | <0.5 | <1 | <1.0 | 2 | 17 |

| Station number | Date | Copper, dis-solved (µg/L as Cu) | Iron, total recov-erable (µg/L as Fe) | Iron, dis-solved (µg/L as Fe) | Lead, total recov-erable (µg/L as Pb) | Lead, dis-solved (µg/L as Pb) | Lithium dis-solved (µg/L as Li) | Manga-nese, dis-solved (µg/L as Mn) | Mercury total recov-erable (µg/L as Hg) | Molyb-denum, dis-solved (µg/L as Mo) | Nickel, total recov-erable (µg/L as Ni) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | <10 | ------- | <3 | <1 | <10 | 61 | 1 | <0.10 | 10 | 2 |
| | 01-04-93 | <10 | ------- | 9 | 3 | <10 | 42 | 2 | <0.10 | <10 | 4 |
| | 01-12-93 | <10 | ------- | 58 | 22 | <10 | 35 | 2 | <0.10 | <10 | 21 |
| | 02-11-93 | <10 | ------- | 70 | 7 | <10 | 13 | 4 | <0.10 | <10 | 10 |
| 09512184 | 11-10-91 | 10 | ------- | 38 | 18 | <10 | 5 | 45 | 0.10 | <10 | 13 |
| | 12-10-91 | ----- | ------- | ---- | 130 | ----- | --- | --- | 0.20 | ----- | 63 |
| | 12-18-91 | <10 | ------- | 39 | 15 | <10 | <4 | 24 | <0.10 | <10 | 5 |
| | 03-08-92 | <10 | ------- | 15 | 12 | <10 | 7 | 17 | <0.10 | <10 | 9 |
| | 03-27-92 | 10 | ------- | 23 | 11 | <10 | <4 | 26 | <0.10 | <10 | 6 |
| | 05-20-92 | ----- | 9,200 | ---- | 71 | ----- | --- | --- | ------- | ----- | 38 |
| | 05-20-92 | 20 | ------- | 80 | 33 | <10 | 9 | 70 | 0.10 | <10 | 20 |
| | 05-20-92 | ----- | 4,500 | ---- | 41 | ----- | --- | --- | ------- | ----- | 22 |
| | 05-20-92 | ----- | 3,200 | ---- | 32 | ----- | --- | --- | ------- | ----- | 17 |
| | 05-20-92 | ----- | 3,300 | ---- | 32 | ----- | --- | --- | ------- | ----- | 17 |
| | 05-20-92 | ----- | 2,900 | ---- | 28 | ----- | --- | --- | ------- | ----- | 13 |
| | 08-05-92 | <10 | ------- | 67 | 50 | <10 | 4 | 17 | 0.10 | <10 | 33 |
| 09512190 | 08-24-92 | ----- | ------- | ---- | 27 | ----- | --- | --- | <0.10 | ----- | 49 |
| | 09-02-92 | <10 | ------- | 4 | <1 | <10 | 55 | <1 | <0.10 | <10 | 2 |
| 09512200 | 01-12-92 | <10 | ------- | 11 | 10 | <10 | <4 | <1 | <0.10 | <10 | 12 |
| | 02-07-92 | ----- | ------- | ---- | 150 | ----- | --- | --- | <0.10 | ----- | 100 |
| 09512403 | 12-10-91 | ----- | ------- | ---- | 230 | ----- | --- | --- | <0.10 | ----- | 58 |
| | 12-18-91 | 10 | ------- | 20 | 120 | <10 | 4 | 11 | <0.10 | <10 | 23 |
| | 02-07-92 | ----- | ------- | ---- | 620 | ----- | --- | --- | <0.10 | ----- | 120 |
| | 03-02-92 | 20 | ------- | 32 | 430 | <10 | 8 | 21 | <0.10 | <10 | 53 |
| | 03-08-92 | 10 | ------- | 81 | 380 | 10 | 10 | 17 | <0.10 | <10 | 95 |
| | 03-27-92 | ----- | ------- | ---- | ----- | ----- | --- | --- | ------- | ----- | ---- |
| | 07-11-92 | 20 | ------- | 140 | 210 | <10 | 7 | 34 | <0.10 | <10 | 40 |
| | 08-22-92 | 20 | ------- | 140 | 300 | <10 | 7 | 15 | 0.20 | <10 | 68 |
| | 12-08-92 | <10 | ------- | 170 | 170 | <10 | 5 | 13 | <0.10 | <10 | 68 |
| 09513700 | 10-27-91 | <10 | ------- | 35 | 51 | <10 | <4 | 34 | <0.10 | <10 | 17 |
| | 11-29-91 | <10 | ------- | 32 | 23 | <10 | <4 | 43 | <0.10 | <10 | 11 |
| | 12-10-91 | <10 | ------- | 36 | 99 | <10 | <4 | 6 | <0.10 | <10 | 35 |
| | 02-07-92 | <10 | ------- | 31 | 8 | <10 | <4 | 20 | <0.10 | <10 | 4 |
| | 03-27-92 | <10 | ------- | 19 | 19 | <10 | <4 | 29 | <0.10 | <10 | 8 |
| | 08-22-92 | <10 | ------- | 66 | 28 | 10 | <4 | 46 | <0.10 | <10 | 10 |
| 09513885 | 12-04-92 | <10 | ------- | 41 | 3 | <10 | <4 | 57 | <0.10 | 10 | 5 |
| | 01-06-93 | <10 | ------- | 27 | 8 | <10 | <4 | 28 | <0.10 | <10 | 5 |
| | 02-08-93 | <10 | ------- | 27 | 12 | <10 | <4 | 47 | <0.10 | <10 | 13 |
| | 03-26-93 | 10 | ------- | 110 | 27 | <10 | <4 | 140 | <0.10 | <10 | 23 |
| | 08-24-93 | 10 | ------- | 150 | 7 | <10 | <4 | 140 | <0.10 | <10 | 7 |
| | 10-06-93 | 10 | ------- | 210 | 8 | <10 | <4 | 160 | <0.10 | <10 | 9 |

| Station number | Date | Nickel, dis-solved (µg/L as Ni) | Sele-nium, total (µg/L as Se) | Silver, total recov-erable (µg/L as Ag) | Silver, total recov-erable (µg/L as Ag) | Silver, dis-solved (µg/L as Ag) | Stron-tium, dis-solved (µg/L as Sr) | Vana-dium, dis-solved (µg/L as V) | Zinc, total recov-erable (µg/L as Zn) | Zinc, dis-solved (µg/L as Zn) | Carbon, organic total (mg/L as C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | <10 | <2 | <1 | ------- | 2.0 | 600 | 7 | <10 | <3 | 7.3 |
| | 01-04-93 | <10 | <2 | <1 | <0.500 | <1.0 | 370 | <6 | <10 | <3 | 4.8 |
| | 01-12-93 | <10 | <2 | <1 | <0.500 | <1.0 | 230 | <6 | 50 | <3 | 13 |
| | 02-11-93 | <10 | <2 | <1 | <0.500 | <1.0 | 220 | <6 | <10 | <3 | 6.7 |
| 09512184 | 11-10-91 | <10 | <1 | <1 | <1.00 | <1.0 | 55 | <6 | 120 | 37 | 18 |
| | 12-10-91 | ----- | <2 | <1 | <5.00 | ----- | ----- | --- | 560 | --- | --------- |
| | 12-18-91 | <10 | <2 | <1 | <2.00 | <1.0 | 120 | <6 | 110 | 22 | 63 |
| | 03-08-92 | <10 | <2 | <1 | <1.00 | <1.0 | 88 | <6 | 80 | 9 | 12 |
| | 03-27-92 | <10 | <2 | <1 | <1.00 | <1.0 | 44 | <6 | 100 | 19 | 20 |
| | 05-20-92 | ----- | --- | --- | -------- | ----- | ----- | --- | 600 | --- | --------- |
| | 05-20-92 | <10 | <2 | <1 | <1.00 | <1.0 | 85 | 6 | 270 | 59 | 54 |
| | 05-20-92 | ----- | --- | --- | -------- | ----- | ----- | --- | 440 | --- | --------- |
| | 05-20-92 | ----- | --- | --- | -------- | ----- | ----- | --- | 300 | --- | --------- |
| | 05-20-92 | ----- | --- | --- | -------- | ----- | ----- | --- | 320 | --- | --------- |
| | 05-20-92 | ----- | --- | --- | -------- | ----- | ----- | --- | 290 | --- | --------- |
| | 08-05-92 | <10 | 1 | <1 | <0.500 | <1.0 | 50 | <6 | 290 | 7 | 20 |
| 09512190 | 08-24-92 | ----- | <2 | <1 | 2.50 | ----- | ----- | --- | 120 | --- | 9.5 |
| | 09-02-92 | <10 | <2 | <1 | <0.500 | <1.0 | 310 | <6 | <10 | <3 | 4.9 |
| 09512200 | 01-12-92 | <10 | <2 | <1 | <10.0 | <1.0 | 50 | <6 | 60 | <3 | 17 |
| | 02-07-92 | ----- | <2 | 3 | -------- | ----- | ----- | --- | 390 | --- | 210 |
| 09512403 | 12-10-91 | ----- | <2 | <1 | -------- | ----- | ----- | --- | 450 | --- | 1,100 |
| | 12-18-91 | <10 | <2 | <1 | <2.00 | <1.0 | 170 | <6 | 230 | 5 | 120 |
| | 02-07-92 | ----- | <2 | <1 | -------- | ----- | ----- | --- | 980 | --- | --------- |
| | 03-02-92 | <10 | <2 | <1 | <1.00 | <1.0 | 210 | 6 | 690 | <3 | 65 |
| | 03-08-92 | <10 | <2 | <1 | <1.00 | <1.0 | 140 | 6 | 720 | 7 | 130 |
| | 03-27-92 | ----- | --- | --- | -------- | ------ | ----- | --- | ----- | --- | --------- |
| | 07-11-92 | <10 | <2 | <1 | <1.00 | <1.0 | 140 | 10 | 310 | 8 | 52 |
| | 08-22-92 | <10 | <1 | <1 | <0.500 | <1.0 | 120 | 9 | 680 | 4 | 74 |
| | 12-08-92 | <10 | <2 | <1 | <0.500 | <1.0 | 82 | <6 | 340 | <3 | 21 |
| 09513700 | 10-27-91 | <10 | <1 | <1 | <1.00 | <1.0 | 47 | <6 | 170 | 12 | 34 |
| | 11-29-91 | <10 | <2 | <1 | <2.00 | 1.0 | 73 | <6 | 110 | 15 | 36 |
| | 12-10-91 | <10 | <2 | <1 | <2.00 | <1.0 | 55 | <6 | 250 | 8 | 46 |
| | 02-07-92 | <10 | <2 | <1 | <0.500 | <1.0 | 32 | <6 | 30 | 8 | 14 |
| | 03-27-92 | <10 | <2 | <1 | <1.00 | 1.0 | 53 | <6 | 80 | 12 | 36 |
| | 08-22-92 | <10 | <2 | <1 | <0.500 | <1.0 | 49 | 8 | 100 | 18 | 48 |
| 09513885 | 12-04-92 | <10 | <2 | <1 | <0.500 | <1.0 | 27 | <6 | 90 | 59 | 26 |
| | 01-06-93 | <10 | <2 | <1 | <1.00 | <1.0 | 28 | <6 | 90 | 25 | 21 |
| | 02-08-93 | <10 | <2 | <1 | <0.500 | <1.0 | 31 | <6 | 110 | 27 | 29 |
| | 03-26-93 | 10 | <2 | <1 | <1.00 | <1.0 | 91 | 11 | 270 | 56 | 96 |
| | 08-24-93 | <10 | <1 | <1 | <0.500 | <1.0 | 63 | 9 | 180 | 140 | 47 |
| | 10-06-93 | <10 | 1 | <1 | <0.500 | <1.0 | 83 | 10 | 280 | 260 | 76 |

| Station number | Date | Cyanide, total (mg/L as Cn) | Cyanide, total (mg/L as Cn) | Phenols, total (µg/L) | Oil and grease, total recover-able gravimetric (mg/L) | Aldrin, total (µg/L) | Aroclor, 1254 PCB total (µg/L) | P, P' DDE, total (µg/L) | P, P' DDT, total (µg/L | Dieldrin, total (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | --------- | ---------- | ------- | <1 | -------- | ------ | ------- | ------- | --------- |
| | 01-04-93 | <0.010 | <0.010 | <1 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 01-12-93 | <0.010 | <0.010 | 1 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 02-11-93 | <0.010 | <0.010 | 1 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| 09512184 | 11-10-91 | <0.010 | <0.010 | 4 | 3 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 12-10-91 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| | 12-18-91 | <0.010 | <0.010 | 14 | 3 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 03-08-92 | <0.010 | <0.010 | 4 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 03-27-92 | <0.010 | <0.010 | 7 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 05-20-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| | 05-20-92 | <0.010 | <0.010 | 10 | 2 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 05-20-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| | 05-20-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| | 05-20-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| | 05-20-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| | 08-05-92 | <0.010 | <10.0 | 16 | 6 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| 09512190 | 08-24-92 | <0.010 | <0.010 | 2 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 09-02-92 | <0.010 | 0.012 | <1 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| 09512200 | 01-12-92 | <0.010 | <0.010 | <1 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 02-07-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------- | ------- | --------- |
| 09512403 | 12-10-91 | <0.010 | ---------- | 5 | <1 | -------- | ------ | ------- | ------- | --------- |
| | 12-18-91 | <0.010 | <0.010 | <1 | <1 | <0.040 | <0.1 | 0.14 | <0.10 | <0.020 |
| | 02-07-92 | <0.010 | ---------- | 8 | <1 | -------- | ------ | ------- | ------- | --------- |
| | 03-02-92 | <0.010 | <0.010 | 1,900 | 2 | <0.040 | 0.3 | 0.67 | 0.10 | <0.020 |
| | 03-08-92 | <0.010 | <0.010 | 8 | 2 | <0.040 | 0.3 | 1.1 | <0.10 | <0.020 |
| | 03-27-92 | --------- | ---------- | ------- | --- | -------- | ------ | ------ | ------- | --------- |
| | 07-11-92 | <0.010 | <10.0 | 6 | 6 | <0.040 | <0.1 | 0.35 | <0.10 | <0.020 |
| | 08-22-92 | <0.010 | <0.010 | 9 | 1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 12-08-92 | <0.010 | <0.010 | 8 | 2 | <0.040 | <0.1 | 0.40 | 0.10 | <0.020 |
| 09513700 | 10-27-91 | <0.010 | <0.010 | 7 | 8 | <0.040 | <0.1 | 0.07 | <0.10 | <0.020 |
| | 11-29-91 | <0.010 | <0.010 | 5 | 2 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 12-10-91 | <0.010 | <0.010 | 2 | 3 | <0.040 | <0.1 | 0.50 | <0.10 | 0.040 |
| | 02-07-92 | <0.010 | <0.010 | <1 | <1 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 03-27-92 | <0.010 | <0.010 | 6 | 1 | <0.040 | <0.1 | 0.04 | <0.10 | <0.020 |
| | 08-22-92 | <0.010 | <0.010 | 12 | 9 | <0.040 | <0.1 | <0.04 | <0.10 | <0.20 |
| 09513885 | 12-04-92 | 0.020 | <0.010 | 33 | 2 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 01-06-93 | <0.010 | <0.010 | ------- | 5 | <0.040 | <0.1 | <0.04 | <0.10 | <0.020 |
| | 02-08-93 | <0.010 | <0.010 | 12 | 5 | <0.040 | <0.1 | 0.05 | <0.10 | <0.020 |
| | 03-26-93 | 0.010 | <0.010 | 21 | 5 | <0.040 | <0.1 | 0.15 | <0.10 | <0.020 |
| | 08-24-93 | --------- | ---------- | 7 | 2 | <0.040 | <0.1 | <0.04 | <0.10 | <0.20 |
| | 10-06-93 | 0.010 | <0.010 | 29 | 1 | --------- | ------ | ------- | ------- | --------- |

| Station number | Date | Benzo (B) fluorsnthene, total (µg/L) | Benzo (g,h,I) perylene, total (µg/L) | Chrysene, total (µg/L) | Diethyl Phthalate, total (µg/L) | Bis (2-ethylhexyl) phthalate, total (µg/L) | Fluoranthene, total (µg/L) | Indeno (1,2,3-cd) pyrene, total (µg/L) | Methylene chloride, total (µg/L) | Phenol, total (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ----- |
| | 01-04-93 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | ----- | <5.0 |
| | 01-12-93 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | ----- | <5.0 |
| | 02-11-93 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | ----- | <5.0 |
| 09512184 | 11-10-91 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 12-10-91 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 12-18-91 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 03-08-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 03-27-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 05-20-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 05-20-92 | <10.0 | <10.0 | <10.0 | <5.0 | 9.0 | 7.0 | 27.0 | <0.2 | <5.0 |
| | 05-20-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 05-20-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 05-20-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 05-20-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 08-05-92 | <10.0 | 16.0 | <10.0 | <5.0 | 5.0 | <5.0 | 17.0 | <0.2 | <5.0 |
| 09512190 | 08-24-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 09-02-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | ----- | <5.0 |
| 09512200 | 01-12-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 02-07-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| 09512403 | 12-10-91 | ------ | ------- | ------- | ------ | ------ | ------ | ------- | <0.2 | ------ |
| | 12-18-91 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 02-07-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | <0.2 | ------ |
| | 03-02-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 03-08-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | 0.2 | <5.0 |
| | 03-27-92 | ------- | ------- | ------- | ------ | ------ | ------ | ------- | ----- | ------ |
| | 07-11-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 08-22-92 | <10.0 | <10.0 | <10.0 | <5.0 | 5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 12-08-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| 09513700 | 10-27-91 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 11-29-91 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 12-10-91 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 02-07-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 03-27-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| | 08-22-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | <5.0 |
| 09513885 | 12-04-92 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | <5.0 | <10.0 | <0.2 | 7.0 |
| | 01-06-93 | <10.0 | <10.0 | <10.0 | <5.0 | <5.0 | 5.0 | <10.0 | <0.2 | <5.0 |
| | 02-08-93 | 14.0 | <10.0 | 13.0 | <5.0 | 8.0 | 13.0 | <10.0 | <20 | <5.0 |
| | 03-26-93 | 16.0 | <10.0 | 17.0 | <5.0 | 8.0 | 18.0 | <10.0 | <20 | <5.0 |
| | 08-24-93 | 19.0 | <10.0 | 14.0 | <5.0 | <5.0 | 16.0 | <10.0 | <1.0 | <5.0 |
| | 10-06-93 | ------- | ------ | ------- | ------ | ------ | ------ | ------- | <5.0 | ------ |

| Station number | Date | p-Isopropyltoluene water whole rec (µg/L) | Methyl ether tert-butyl Wat Unf rec (µg/L) | Pyrene, total (µg/L) | Toluene, total (µg/L) | Pseudocumene water unfiltered rec (µg/L) | Styrene, total (µg/L) | Xylene water unfiltered rec (µg/L) | Quality assurance data indicator code | Sampling method codes |
|---|---|---|---|---|---|---|---|---|---|---|
| 09512165 | 12-31-92 | ------- | ------- | ------ | ------ | ------- | ------ | ------- | --- | 30 |
| | 01-04-93 | ------- | ------- | <5.0 | ------ | ------- | ------ | ------- | --- | 10 |
| | 01-12-93 | ------- | ------- | <5.0 | ------ | ------- | ------ | ------- | --- | 10 |
| | 02-11-93 | ------- | ------- | <5.0 | ------ | ------- | ------ | ------- | --- | 10 |
| 09512184 | 11-10-91 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 10 | 30 |
| | 12-10-91 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| | 12-18-91 | <0.20 | 1.2 | <5.0 | 0.3 | <0.20 | 0.5 | 0.20 | --- | 30 |
| | 03-08-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 03-27-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 40 | 30 |
| | 05-20-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| | 05-20-92 | 0.70 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 05-20-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| | 05-20-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| | 05-20-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| | 05-20-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| | 08-05-92 | <0.20 | <1.0 | 11.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| 09512190 | 08-24-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | 10 |
| | 09-02-92 | ------- | ------- | <5.0 | ------ | ------- | ------ | ------- | --- | 10 |
| 09512200 | 01-12-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 02-07-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | --- |
| 09512403 | 12-10-91 | <0.20 | 1.0 | ----- | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 12-18-91 | <0.20 | 1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 30 | 30 |
| | 02-07-92 | <0.20 | <1.0 | ----- | <0.2 | <0.20 | <0.2 | <0.20 | --- | --- |
| | 03-02-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 30 | 30 |
| | 03-08-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 03-27-92 | ------- | ------- | ----- | ------ | ------- | ------ | ------- | --- | 30 |
| | 07-11-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 08-22-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | 0.20 | --- | 30 |
| | 12-08-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| 09513700 | 10-27-91 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 30 | 30 |
| | 11-29-91 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 10 | 30 |
| | 12-10-91 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 10 | 30 |
| | 02-07-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| | 03-27-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | 10 | 30 |
| | 08-22-92 | <0.20 | <1.0 | <5.0 | <0.2 | <0.20 | <0.2 | <0.20 | --- | 30 |
| 09513885 | 12-04-92 | <0.20 | 2.5 | <5.0 | 0.2 | 0.30 | <0.2 | 0.30 | --- | 30 |
| | 01-06-93 | <0.20 | 1.0 | <5.0 | 0.2 | <0.20 | <0.2 | 0.20 | --- | 30 |
| | 02-08-93 | <20 | <100 | 10.0 | <20 | <20 | <20 | <20 | 10 | 30 |
| | 03-26-93 | <20 | <100 | 13.0 | <20 | <20 | <20 | <20 | --- | 30 |
| | 08-24-93 | <1.0 | <5.0 | 11.0 | <1.0 | <1.0 | <1.0 | <1.0 | 40 | 30 |
| | 10-06-93 | <5.0 | <25 | ----- | <5.0 | <5.0 | <5.0 | <5.0 | --- | 30 |