

Prepared in cooperation with the
KANSAS WATER OFFICE

Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment



Water-Resources Investigations Report 03–4316

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By Larry M. Pope, Stacy M. Rosner, Darren C. Hoffman, and Andrew C. Ziegler

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Contents

Abstract	1
Introduction	1
Purpose and Scope	2
General Investigative Approach	3
Selection of Water-Quality Constituents	3
Selection of Time Period and Acquisition of Data	4
Data Management	7
Quality Assurance of Data	9
Summary of Available State Ambient Stream-Water-Quality Data	11
Suspended Solids	11
Fecal Coliform Bacteria	11
Ammonia	14
Nitrite Plus Nitrate	14
Phosphorus	18
Arsenic	18
Dissolved Solids	22
Chloride	22
Sulfate	26
pH	30
Limitations of State Ambient Stream-Water-Quality Data for National Assessment	30
Design of Monitoring Networks	30
Selection of Water-Quality Constituents and Criteria	34
Quantity and Comprehensiveness of Water-Quality Data	35
Summary and Conclusions	39
References Cited	41
Supplemental Information	45

Figures

1. Schematic showing general procedures and decision processes used for data acquisition, handling, and summary of State ambient stream-water-quality monitoring sites for selected water-quality constituents
2. Graphs showing relations between numbers of ambient stream-water-quality monitoring sites and selected minimum numbers of electronically available data for 10 water-quality constituents or measurements
3. Graph showing relation between the national average percentage of monitoring sites for 10 water-quality constituents or measurements and selected minimum numbers of electronically available data

Tables

1.	Water-quality constituents and physical measurements considered for summary	4
2.	Number of ambient stream-water-quality monitoring sites per State with electronically available data for at least one of the selected water-quality constituents or measurements and source of data and Internet uniform resource locator, 2001–02	5
3.	Total miles of streams in the States and percentage assessed for water-quality degradation in 1998	7
4.	Constituent or measurement descriptions and parameter codes for data retrieved from U.S. Environmental Protection Agency, U.S. Geological Survey, or State databases	8
5.	Data remark codes and descriptions and statistical summary action for remarked water-quality data from the U.S. Environmental Protection Agency STORET, U.S. Geological Survey National Water Information System, or State data-management systems	10
6.	Summary of median suspended solids concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	12
7.	Number of State ambient stream-water-quality monitoring sites with data for parameter codes of fecal coliform bacteria densities in water, 1990–98	13
8.	Summary of median fecal coliform bacteria densities in water from State ambient stream-water-quality monitoring sites, 1990–98	15
9.	Number of State ambient stream-water-quality monitoring sites with data for parameter codes of ammonia as nitrogen concentrations in water, 1990–98	16
10.	Summary of median ammonia as nitrogen concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	17
11.	Number of State ambient stream-water-quality monitoring sites with data for parameter codes of nitrate and nitrite plus nitrate as nitrogen concentrations in water, 1990–98	19
12.	Summary of median nitrite plus nitrate as nitrogen concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	20
13.	Summary of median total phosphorus concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	21
14.	Summary of median total arsenic concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	23
15.	Number of State ambient stream-water-quality monitoring sites with data for parameter codes of dissolved-solids concentrations in water, 1990–98	24
16.	Summary of median dissolved-solids concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	25
17.	Number of State ambient stream-water-quality monitoring sites with data for total and dissolved chloride concentrations in water, 1990–98	27
18.	Summary of median chloride concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	28
19.	Number of State ambient stream-water-quality monitoring sites with data for total and dissolved sulfate concentrations in water, 1990–98	29
20.	Summary of median sulfate concentrations in water from State ambient stream-water-quality monitoring sites, 1990–98	31
21.	Summary of median pH measurements in water from State ambient stream-water-quality monitoring sites, 1990–98	32
22.	Selected water-quality criteria for State ambient stream-water-quality data	35
23.	Fecal coliform bacteria criteria for primary and secondary contact recreation for streams in 50 States	36

24.	Number of State ambient stream-water-quality monitoring sites available for selected combinations of water-quality constituents per monitoring site and analyses per constituent, 1990–98	40
25.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for suspended solids, 1990–98	46
26.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for fecal coliform bacteria, 1990–98	47
27.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for ammonia as nitrogen, 1990–98	48
28.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for nitrite plus nitrate as nitrogen, 1990–98	49
29.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for total phosphorus, 1990–98	50
30.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for total arsenic, 1990–98	51
31.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for dissolved solids, 1990–98	52
32.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for chloride, 1990–98	53
33.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for sulfate, 1990–98	54
34.	Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for pH, 1990–98	55

Conversion Factors, Abbreviations, and Datum

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
microgram per liter ($\mu\text{g/L}$)	1.0	part per billion (ppb)
micrometer (μm)	0.00003937	inch (in.)
milligram per kilogram (mg/kg)	0.002	pound per ton (lb/ton)
milligram per liter (mg/L)	1.0	part per million (ppm)
milliliter (mL)	0.0338	ounce, fluid (oz)
pound per acre (lb/acre)	1.121	kilogram per hectare (kg/ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius ($^{\circ}\text{C}$) may be converted to degrees Fahrenheit ($^{\circ}\text{F}$) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32.$$

Temperature in degrees Fahrenheit ($^{\circ}\text{F}$) may be converted to degrees Celsius ($^{\circ}\text{C}$) as follows:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) / 1.8.$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

By Larry M. Pope, Stacy M. Rosner, Darren C. Hoffman, and Andrew C. Ziegler

Abstract

The investigation described in this report summarized data from State ambient stream-water-quality monitoring sites for 10 water-quality constituents or measurements (suspended solids, fecal coliform bacteria, ammonia as nitrogen, nitrite plus nitrate as nitrogen, total phosphorus, total arsenic, dissolved solids, chloride, sulfate, and pH). These 10 water-quality constituents or measurements commonly are listed nationally as major contributors to degradation of surface water. Water-quality data were limited to that electronically accessible from the U.S. Environmental Protection Agency Storage and Retrieval System (STORET), the U.S. Geological Survey National Water Information System (NWIS), or individual State databases. Forty-two States had ambient stream-water-quality data electronically accessible for some or all of the constituents or measurements summarized during this investigation. “Ambient” in this report refers to data collected for the purpose of evaluating stream ecosystems in relation to human health, environmental and ecological conditions, and designated uses. Generally, data were from monitoring sites assessed for State 305(b) reports.

Comparisons of monitoring data among States are problematic for several reasons, including differences in the basic spatial design of monitoring networks; water-quality constituents for which samples are analyzed; water-quality criteria to which constituent concentrations are compared; quantity and comprehensiveness of water-quality data; sample collection, processing, and handling; analytical methods; temporal variability in sample collection; and quality-assurance practices. Large differences among the States in number of monitoring sites precluded a general assumption that statewide water-quality conditions were represented by data from these sites. Furthermore, data from individual monitoring sites may not represent water-quality conditions at the sites because sampling conditions and protocols are unknown. Because of these factors, a high level of uncertainty exists in a national assessment of water quality.

The purpose of this report is to present a summary of electronically available State ambient stream-water-quality data for 10 selected constituents and measurements from monitoring

sites with nine or more analyses for 1990–98 and to discuss limitations for use of the data for national assessment. These analyses were statistically summarized by monitoring site and State, and the results presented in tabular format. Most of the selected constituents or measurements have U.S. Environmental Protection Agency criteria or guidelines for aquatic-life or drinking-water purposes. A significant finding of this investigation is that for a large percentage of monitoring sites in the Nation, there are insufficient data to meet U.S. Environmental Protection Agency recommendations for determining if water-quality conditions are degraded and for making informed decisions regarding total maximum daily loads.

Introduction

In 1972, Congress passed the Federal Water Pollution Control Act (Public Law 92–500), commonly referred to as the Clean Water Act (U.S. Environmental Protection Agency, 1972). This act and subsequent amendments set goals for eliminating the discharge of contaminants into the Nation’s waters, provided Federal funding for construction of municipal sewage-treatment plants, directed the States to set water-quality criteria for waters within their boundaries, and funded development of programs to control nonpoint sources of contamination. The act also directed the States to submit biannual reports to the U.S. Environmental Protection Agency (USEPA) that presented a comprehensive water-quality assessment (305(b) report) and listed the water-quality impaired (degraded) streams or stream segments (303(d) report) within the States. These reports were named after the sections in the Clean Water Act that required their preparation (U.S. Environmental Protection Agency, 1972).

In response to the provisions of the Clean Water Act, States established, modified, or enhanced their ambient stream-water-quality monitoring networks to provide the data necessary to assess stream water quality relative to State-established criteria. Data from these monitoring networks have been used to produce the biannual 305(b) and 303(d) reports to USEPA and, ultimately, to the Congress in the form of National Water Quality Inventory reports (compilation of State 305(b) reports). State

2 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

networks have been operated to meet the specific goals and objectives established by the individual States. However, a national summarization of water quality can be accomplished in one of two ways. One approach would require that the States design and execute their individual monitoring approaches using identical designs so that the results can be summed to provide a national assessment. The other would be an analytical approach (some combination of statistical and deterministic models) that combine the 50 data sets in a manner that produces inferences about water quality that take into consideration the different sampling designs. Neither of these requirements has been met to date, and thus, the data are not suitable for national assessment or State-to-State intercomparisons, even though the data sets may be highly useful for purposes of State assessments and management.

The U.S. General Accounting Office (USGAO, 2000) examined USEPA's National Water Quality Inventory reports and the adequacy of water-quality data for key water-quality decisions required by the Clean Water Act. The USGAO concluded that assessment data in State 305(b) reports are incomplete because the data do not represent all of the States' waters. Additionally, USGAO identified substantial differences among States in virtually every aspect of monitoring and assessment. These differences stem from a combination of factors including variability in the (1) water-quality criteria (including designated or beneficial uses) for determining which water is degraded; (2) types of monitoring practices used to ascertain whether or not the criteria are exceeded; and (3) procedures used to assess water-quality data for determining if water-quality conditions are degraded. Much of this variability is the result of the flexibility allowed the States by the Clean Water Act to decide which streams to assess, what uses to designate for streams, and what water-quality criteria to assign for the designated uses.

USEPA (2002a) has attempted to minimize some of these State-to-State differences through the development and recommendation of consistent methodology in network design, sampling protocols, and evaluation criteria. Targeted, statistically based (probabilistic), and geographically based sampling designs are used in some State monitoring programs to provide the water-quality information required by the Clean Water Act to evaluate potential stream-water-quality degradation relative to designated uses and appropriate water-quality criteria. When appropriate designs are used, this information also may be used to describe cause-and-effect relations, seasonal variability and time trends, mass transport, and as an aid to management decisions. However, the variability in network designs and operational characteristics, such as the distribution of sites and frequency of sampling, among the States inhibits the use of available information for comparison of results among the States.

Because of the aforementioned differences in State ambient stream-water-quality monitoring networks and programs, water-quality officials in Kansas generally questioned the validity of previous national water-quality comparisons, such as those of Hall and Kerr (1991) and Brown and Marshall (1993), produced on the basis of information presented in State 305(b)

and (or) 303(d) reports and, specifically, previous summaries of water-quality conditions in Kansas. In 2001, the U.S. Geological Survey (USGS) in cooperation with the Kansas Water Office (KWO), supported in part by the State Water Plan Fund, conducted an investigation of the comparability and representativeness of State ambient stream-water-quality databases for assessment of national water-quality conditions. However, it was beyond the scope of this investigation to evaluate the adequacy of the network designs, field and laboratory activities, and quality-assurance practices used in the various State monitoring programs. The investigation described in this report will provide additional information to support or contrast with previous investigations by the USGS that indicated data in many electronically accessible databases are of unknown quality and hydrologic context (Childress and others, 1989; Norris and others, 1992; Rinella and others, 1992).

For example, a comparison of data availability in Colorado and Ohio indicated that fewer than 15 percent of water-quality analyses met the screening criteria judged necessary for the data to be included in a consistent database suitable for addressing broad-scope water-quality questions (Norris and others, 1992). Norris and others (1992) also determined that for 12 evaluated water-quality constituents an average of only 22 percent of stream-water-quality monitoring sites in Colorado and 8 percent in Ohio had 10 or more analyses with concurrent streamflow data during 1977–84. Concurrent streamflow data are necessary for hydrologic assessment such as water-quality trend analysis and constituent transport (load) calculations. Furthermore, Norris and others (1992) concluded that, on average, less than 10 percent of the stream-water-quality monitoring sites in Colorado and Ohio yield sufficient data for determining changes in water-quality conditions.

Purpose and Scope

The purpose of this report is to present a summary of available State ambient stream-water-quality data, 1990–98, and to examine some of the characteristics of the data that would limit its use in producing a national evaluation of stream water quality. Ambient stream-water-quality data are information collected by an integrated activity for the purpose of evaluating the physical, chemical, and biological character of water ecosystems in relation to human health, environmental and ecological conditions, and designated uses. Therefore, "ambient" in this report refers to data collected for those purposes and does not mean or is it used to indicate pristine water-quality conditions. On the contrary, States may have established monitoring sites in their ambient networks for many reasons to include the documentation of stream-water-quality effects from human-related sources. These sources may be both point and nonpoint sources of contamination. Water-quality conditions determined in many or all State ambient stream networks probably are biased toward the water-quality effects generated from human-related activities because of the interest in these effects and their general pervasiveness.

The scope of this report is limited to States with electronically available water-quality data for sampling sites in their ambient stream-water-quality monitoring networks for 1990–98 (a maximum of 42 States). Water-quality data are statistically summarized by State.

State, spatial distribution of sites, or temporal distribution of streamflow samples collected at those sites. Procedures used for accounting for differences in constituents analyzed (dissolved or total constituent concentrations) and laboratory reporting methods are discussed in the “Summary of Available State Ambient Stream-Water-Quality Data” and “Quality Assurance of Data” sections of this report. A general schematic of the procedures used and assessment steps taken in the conduct of this investigation is presented in figure 1.

General Investigative Approach

The water-quality data used for the investigation described in this report were from monitoring sites representing each State’s ambient stream-water-quality monitoring network for a common time period. No attempt was made to normalize for how and why monitoring sites were selected such as targeted or probabilistic-based selection, the number of sites within each

Selection of Water-Quality Constituents

Water-quality constituents considered for summary in this report (table 1) were those most commonly responsible for

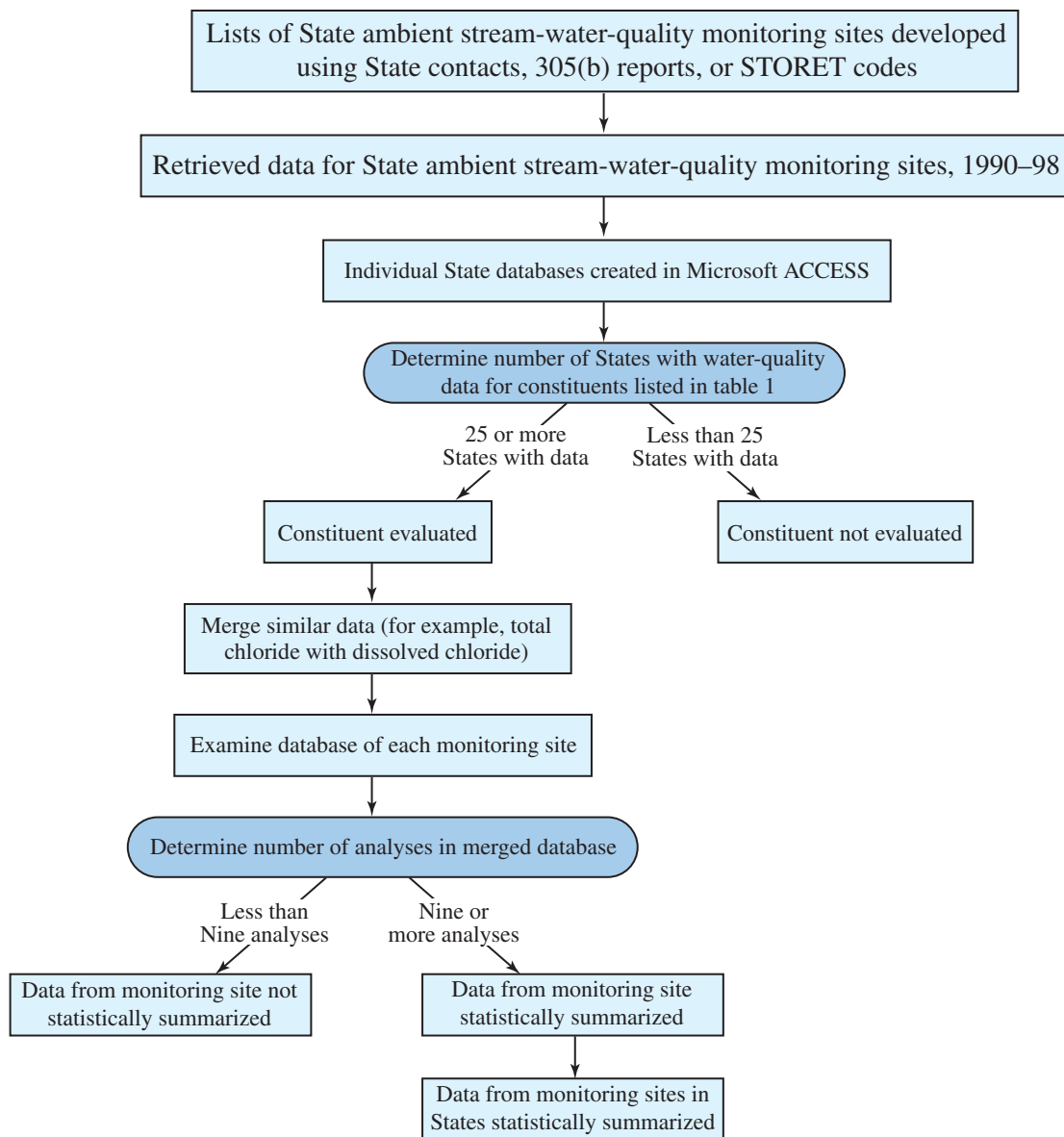


Figure 1. General procedures and decision processes used for data acquisition, handling, and summary of State ambient stream-water-quality monitoring sites for selected water-quality constituents.

4 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

Table 1. Water-quality constituents and physical measurements considered for summary.

Constituent or measurement
Sediment
Suspended solids
Bacteria
Fecal coliform
Nutrients
Ammonia as nitrogen
Nitrite plus nitrate as nitrogen
Total phosphorus
Trace elements
Arsenic
Selenium
Dissolved solids and major ions
Dissolved solids
Chloride
Sulfate
Pesticides
Alachlor
Atrazine
Physical measurements
Water temperature
pH

water-quality degradation in the Nation’s streams. In preparation for the 1998 USEPA National Water-Quality Inventory Report to Congress, States and tribes assessed 840,402 mi of rivers and streams in the Nation and determined that 35 percent of those miles (291,263 mi) were degraded with respect to some water-quality factor. Of the degraded river and stream miles in 1998, 38 percent were degraded by sediment/siltation, 36 percent by fecal bacteria, and 29 percent by nutrients (species of nitrogen and phosphorus). Smaller percentages were degraded by trace metals and pesticides. River and stream miles may have been degraded by more than one water-quality constituent (U.S. Environmental Protection Agency, 2000b).

Selection of Time Period and Acquisition of Data

The data summary period for the investigation described in this report was 1990–98. The ending date of 1998 was selected because it represented the date of closure on USEPA’s

STORET (short for STORage and RETrieval) data-management system, which traditionally has been the repository for State ambient stream-water-quality data. Currently (2004), this historical system is known as the USEPA STORET Legacy Data Center and since 1998 has been a static system; no additional data entry or update to existing data is allowed. Data submitted to USEPA after 1998 have been stored in a more modern, relational-based version of the original STORET database now (2004) known as STORET (U.S. Environmental Protection Agency, 2003a). When this investigation began in 2001, many States were not using or had not submitted post-1998 ambient stream-water-quality data into the modern STORET system; therefore, a decision was made to limit the data for the study to 1998 for consistency.

The beginning date (1990) for data used in the investigation described in this report was selected to provide a timeframe of sufficient length to produce State databases of reasonable size for statistical analysis. The purposes for which monitoring sites were selected vary among the States. Associated with these purposes are certain operational characteristics that may affect or establish the timing and frequency of water-quality sample collection. Some States have long-term monitoring sites that are sampled several to many times annually. Other States have sites that are part of a rotational network established on the basis of watersheds or geographic areas. These rotational sites may be sampled one to several times every 3 to 5 years, thereby taking several rotations to produce a database sufficient to document natural within-site water-quality variability and to produce a reasonable estimate of central tendency of this variability. Some States have a combination of these or other approaches.

An ideal data time period for a water-quality investigation such as described in this report is one that maximizes the potential for collection of water-quality samples. However, long time periods may introduce water-quality variability associated with time trends (water-quality changes over time resulting from changes in natural or human factors). Time trends at monitoring sites increase the degree of water-quality variability over a time period and reduce the prospect of commonality and comparability among monitoring sites. A 9-year (1990–98) time period was selected for the acquisition of data for the investigation described in this report. Admittedly, this time period was somewhat subjectively selected, but it was believed that a 9-year period would provide two or three sampling cycles for rotational sites and be short enough to mitigate the effect of time trends in water-quality data.

The main source of water-quality data used for the investigation described in this report was the USEPA STORET Legacy Data Center (table 2). Of the 42 States with electronically available water-quality data, 28 State databases were acquired from the Legacy system. Data were acquired for five States (Colorado, Montana, New Hampshire, North Dakota, and Utah) from the modern STORET system that currently (2004) contains the 1990–98 data, and from State-located databases for three States (Maryland, Oklahoma, and Virginia). The USGS National Water Information System (NWIS) served as the primary or ancillary source of water-quality data for seven States

Table 2. Number of ambient stream-water-quality monitoring sites per State with electronically available data for at least one of the selected water-quality constituents or measurements and source of data and Internet uniform resource locator (URL), 2001–02.

[USEPA, U.S. Environmental Protection Agency; STORET, U.S. Environmental Protection Agency STORage and RETrieval data-management system; USGS, U.S. Geological Survey; NWIS, National Water Information System; --, not available]

State	Number of sites	Source of data	Internet uniform resource locator (URL)
Alabama	49	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Alaska	--	No ambient stream-water-quality network	--
Arizona	--	State database not electronically accessible	--
Arkansas	133	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
California	--	No centralized database	--
Colorado	537	USEPA modern STORET	http://oaspub.epa.gov/storpubl/warehousemenu
Connecticut	32	USGS NWIS	http://waterdata.usgs.gov/ct/nwis/qw
Delaware	109	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Florida	874	do.	Do.
Georgia	421	do.	Do.
Hawaii	--	No ambient stream-water-quality network	--
Idaho	53	USGS NWIS	http://waterdata.usgs.gov/id/nwis/qw
Illinois	373	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Indiana	107	do.	Do.
Iowa	68	do.	Do.
Kansas	290	do.	Do.
Kentucky	89	do.	Do.
Louisiana	174	do.	Do.
Maine	--	Bioassessment ambient network only	--
Maryland	40	Chesapeake Bay Program	http://www.chesapeakebay.net/data/index.htm
Massachusetts	--	State database not electronically accessible	--
Michigan	295	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Minnesota	68	do.	Do.
Mississippi	85	do.	Do.
Missouri	44	USGS NWIS	http://waterdata.usgs.gov/mo/nwis/qw
Montana	1,114	USEPA modern STORET	http://oaspub.epa.gov/storpubl/warehousemenu
Nebraska	22	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Nevada	71	do.	Do.
New Hampshire	435	USEPA modern STORET	http://oaspub.epa.gov/storpubl/warehousemenu
New Jersey	96	USGS NWIS	http://waterdata.usgs.gov/nj/nwis/qw
New Mexico	16	do.	http://waterdata.usgs.gov/nm/nwis/qw
New York	517	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
North Carolina	19	do.	Do.
North Dakota	--	State database not electronically accessible	--
Ohio	91	USEPA modern STORET	http://oaspub.epa.gov/storpubl/warehousemenu
Ohio	42	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Oklahoma	261	Oklahoma Conservation Commission	http://www.okcc.state.ok.us
Oregon	148	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
Pennsylvania	202	do.	Do.
Rhode Island	5	USGS NWIS	http://waterdata.usgs.gov/ri/nwis/qw
South Carolina	351	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
South Dakota	100	do.	Do.
Tennessee	109	do.	Do.
Texas	980	do.	Do.
Utah	64	USEPA modern STORET	http://oaspub.epa.gov/storpubl/warehousemenu
Vermont	--	Bioassessment ambient network only	--
Virginia	1,997	Virginia Department of Environmental Quality	http://www.deq.state.va.us/water/monitoring.html
Washington	208	USEPA STORET Legacy Data Center	www.epa.gov/storpubl/legacy/gateway.htm
West Virginia	26	do.	Do.
Wisconsin	50	do.	Do.
Wyoming	47	USGS NWIS	http://waterdata.usgs.gov/wy/nwis/qw

6 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

(Connecticut, Idaho, Missouri, New Jersey, New Mexico, Rhode Island, and Wyoming). These seven States had cooperative agreements with the USGS to collect and analyze all or part of the water-quality samples for their ambient stream-water-quality monitoring networks. The repository for USGS-collected data is NWIS.

Eight States (Alaska, Arizona, California, Hawaii, Maine, Massachusetts, North Carolina, and Vermont) did not have electronically available data (table 2). Alaska and Hawaii did not have ambient stream-water-quality networks during 1990–98. Arizona, Massachusetts, and North Carolina had ambient stream-water-quality networks, but chemical and physical data were not stored in the STORET system or in a State-located database that was electronically accessible. Maine and Vermont conducted only biological water-quality assessments; therefore, they did not have data for the chemical and physical characteristics summarized during the investigation described in this report. California did not have a centralized, electronically accessible State database. Ambient stream-water-quality responsibilities in California were divided among nine Regional Water-Quality Control Boards, each of which varied as to amount, availability, and accessibility of data.

Water-quality data were acquired for ambient stream-water-quality monitoring sites in each of 42 States. Ambient stream-water-quality monitoring sites generally were those sites assessed for State 305(b) reports and were identified either through direct contact with the State agencies responsible for water-quality assessment and preparation of 305(b) reports, through information contained in 305(b) reports, or as identified in the STORET system. Water-quality data for identified monitoring sites were retrieved from the sources listed in table 2, generally, through Internet access to those sources.

State 305(b) reports provide, in part, an assessment of the number of stream miles that meet or fail water-quality criteria for designated uses. These assessments are conducted using water-quality data from many or all of the stream-water-quality monitoring sites used for the investigation described in this report. These monitoring sites, however, provide data to assess only a small percentage of the total stream miles (a combination of perennial and intermittent streams) in many States (table 3) (U.S. Environmental Protection Agency, 2000b; Appendix A–1). Percentages of assessed stream miles, reported by the States, ranged from 0 percent in Alaska to 100 percent in Hawaii, Maine, and New York with a median for all States of 20 percent. These percentages included stream miles assessed on the basis of macroinvertebrate surveys or other biological indices.

The information presented in table 3 (as reported by the States to USEPA) was not calculated consistently among the States and should be used only as a general comparison. For instance, Arizona did not include river miles on Indian lands in their estimate of total river miles; Hawaii used assessed stream miles as total miles because total miles were unknown; the percentage of stream miles assessed in Missouri was calculated on the basis of the number of perennial miles (not shown in table 3) instead of total miles; and the number of perennial stream miles

was used for the number of total miles in Virginia (U.S. Environmental Protection Agency, 2000b; Appendix A–1). In some States, intermittent streams account for a large percentage of total stream miles, particularly in the arid and semiarid western States. Water-quality conditions for intermittent streams may not be determined in many of these States; therefore, percentages of assessed stream miles calculated on the basis of total stream miles may be small in these States relative to States with fewer intermittent streams.

The number of stream miles assessed for water-quality conditions in many States is determined from an assumption that conditions at stream monitoring sites represent the conditions for some defined stream segment. This assumption imparts uncertainty in statewide water-quality assessments. If monitoring sites are to be used to assess statewide conditions, there must be a process whereby water-quality measurements are used to infer conditions throughout the network of stream reaches in the State. Although statistical methods exist that provide the means of extending these data (Smith and others, 1997; Larson and Gilliom, 2001; National Research Council, 2001), it seems that these methods have not been used by the States. Rather, the States use point (monitoring-site) data to infer conditions over some finite reach upstream and downstream from the monitoring site and then assume that they have no knowledge beyond those reaches, referring to this remaining part of the stream network as unassessed. The use of statistical or deterministic models is necessary if the monitoring data are to achieve their full utility in providing meaningful estimates of water-quality statewide or nationwide or to achieve any understanding of the uncertainty of the statewide or nationwide estimates.

The number of ambient stream-water-quality monitoring sites with data for constituents or measurements listed in table 1 varied among the States. Some of this variation may be attributed to geographical size differences among the States. State surface areas reported in this paragraph are from the U.S. Bureau of Census (2002). For example, the smaller States of Rhode Island (1,231 mi²) and Connecticut (5,544 mi²) have few monitoring sites (table 2) relative to many of the larger States such as Montana (147,046 mi²) and Texas (267,277 mi²). However, many exceptions are evident such as New York (53,989 mi²) with 19 monitoring sites and Nebraska (77,358 mi²) with 22 monitoring sites. Clearly, factors other than size determine the number of ambient stream-water-quality monitoring sites in some States. These factors may be economic, political, a limitation in surface-water resources, or, as in the case of New York, a function of monitoring-network design and operation. New York, during 1990–98, operated a monitoring network consisting of sites for both water-quality chemical and biological assessments with the major emphasis on the latter. Consequently, New York had few monitoring sites with data available for the investigation described in this report. In contrast to New York, Virginia (42,326 mi²) operated almost 2,000 ambient stream-water-quality monitoring sites during 1990–98. The number of monitoring sites indicated in table 2 represents the number with at least one analysis of any

Table 3. Total miles of streams in the States and percentage assessed for water-quality degradation in 1998 (U.S. Environmental Protection Agency, 2000b; Appendix A–1).

State	Total stream miles	Percentage assessed	State	Total stream miles	Percentage assessed
Alabama	77,274	5	Alaska	365,000	0
Arizona	90,373	5	Arkansas	87,617	10
California	211,513	8	Colorado	107,403	27
Connecticut	5,830	16	Delaware	2,509	95
Florida	51,858	10	Georgia	70,150	12
Hawaii	3,905	100	Idaho	115,595	11
Illinois	87,110	33	Indiana	35,673	24
Iowa	71,665	14	Kansas	134,338	12
Kentucky	49,105	19	Louisiana	66,294	9
Maine	31,752	100	Maryland	17,000	39
Massachusetts	8,229	18	Michigan	51,438	40
Minnesota	91,944	13	Mississippi	84,003	47
Missouri	51,978	42	Montana	176,750	10
Nebraska	81,573	5	Nevada	143,578	1
New Hampshire	10,881	24	New Jersey	6,450	59
New Mexico	110,741	4	New York	52,337	100
North Carolina	37,853	89	North Dakota	54,373	22
Ohio	29,113	10	Oklahoma	78,778	14
Oregon	114,823	47	Pennsylvania	83,260	15
Rhode Island	1,392	54	South Carolina	29,898	65
South Dakota	9,937	32	Tennessee	61,075	88
Texas	191,228	7	Utah	85,916	10
Vermont	7,099	16	Virginia	49,350	39
Washington	70,439	98	West Virginia	32,278	24
Wisconsin	57,698	40	Wyoming	108,767	87

constituent or measurement listed in table 4. Data were retrieved for a total of 10,812 sites from 42 States.

The data retrieved for this investigation came from multiple sources—STORET, NWIS, or State databases. Data for a given constituent may have been associated with one or more parameter codes that resulted from the analysis of different phases or mode of transport (total and dissolved, or whole water and filtered) or from different analytical methods. Parameter codes are the five-digit numbers that uniquely identify a chemical constituent or water-quality measurement in STORET or NWIS. A total analysis of a water-quality constituent was determined on a whole (unfiltered) water sample and included all occurrence or transport phases of the constituent as defined by the analytical laboratory method. A dissolved analysis of a water-quality constituent was determined on a filtered water sample, most commonly water filtered through a 0.45- μm pore-size filter. Data were retrieved for all available constituents or measurements listed in table 4.

The modern STORET system, however, does not distinguish water-quality constituents by parameter code. Data in the modern STORET system are organized by constituent characteristic name and cannot be retrieved by parameter code. Therefore, water-quality data acquired from modern STORET for Colorado, Montana, New Hampshire, North Dakota, and Utah were retrieved on the basis of characteristic name (suspended solids, fecal coliform, and so forth) and not by parameter codes. A total or dissolved analysis in modern STORET was identified on the basis of a sample fraction characteristic.

Data Management

Data management and selection or development of common data-summary criteria were essential components of the investigation described in this report. The management of data

8 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

Table 4. Constituent or measurement descriptions and parameter codes for data retrieved from U.S. Environmental Protection Agency, U.S. Geological Survey, or State databases.

[STORET, U.S. Environmental Protection Agency STORage and RETrieval system; NWIS, U.S. Geological Survey National Water Information System; °C, degrees Celsius; mg/L, milligrams per liter; MF, membrane filtration; M-TEC, fecal coliform agar; col/100 mL, colonies per 100 milliliters of water; M-FC, fecal coliform broth or agar; MPN, most probable number; EC, fecal coliform agar; µm, micrometer or micron; N, nitrogen; NO₃, nitrate; P, phosphorus; µg/L, micrograms per liter; As, arsenic; Se, selenium]

Constituent or measurement description	STORET/NWIS parameter code ¹
Suspended solids	
Residue, total nonfilterable, residue on evaporation at 105 °C, mg/L	00530
Solids, suspended, residue on evaporation at 180 °C, mg/L	70299
Bacteria	
Fecal coliform, MF, M–TEC, 44.5 °C, col/100 mL	31611
Fecal coliform, MF, M–FC agar, 44.5 °C, 24 hour, col/100 mL	31613
Fecal coliform, MPN, EC medium, 44.5 °C, col/100 mL	31615
Fecal coliform, MF, M–FC broth, 44.5 °C, col/100 mL	31616
Fecal coliform, MF, M–FC, 0.7-µm porosity filter, 44.5 °C, col/100 mL	31625
Nutrients	
Ammonia, dissolved, mg/L as N	00608
Ammonia, total, mg/L as N	00610
Nitrite, dissolved, mg/L as N	00613
Nitrite, total, mg/L as N	00615
Nitrate, dissolved, mg/L as N	00618
Nitrate, total, mg/L as N	00620
Nitrate, total, mg/L as NO ₃	71850
Nitrate, dissolved, mg/L as NO ₃	71851
Nitrite plus nitrate, total, mg/L as N	00630
Nitrite plus nitrate, dissolved, mg/L as N	00631
Phosphorus, total, mg/L as P	00665
Phosphorus, dissolved, mg/L as P	00666
Trace elements	
Arsenic, total recoverable in water, µg/L as As	00978
Arsenic, total, µg/L as As	01002
Selenium, total recoverable in water, µg/L as Se	00981
Selenium, total, µg/L as Se	01147
Dissolved solids and major ions	
Residue, total filterable, dried at 105 °C, mg/L	00515
Residue, total dissolved, unspecified calculation, mg/L	70294
Residue, total filterable, dried at any temperature, mg/L	70295
Residue, total filterable, dried at 180 °C, mg/L	70300
Solids, dissolved, sum of constituents, mg/L	70301
Chloride, total, mg/L	00940/none
Chloride, dissolved, mg/L	00941/00940
Sulfate, total, mg/L	00945/none
Sulfate, dissolved, mg/L	00946/00945
Pesticides	
Alachlor, dissolved, µg/L	46342
Alachlor, whole water, µg/L	77825
Atrazine, whole water, µg/L	39033
Atrazine, dissolved, µg/L	39632
Physical measurements	
Temperature, water, °C	00010
pH, standard units	00400

¹NWIS code is the same as the STORET code unless otherwise indicated. STORET codes are used in the Legacy system and State databases but are not used in the modern STORET system.

from more than 10,000 ambient stream-water-quality monitoring sites in 42 States required a relational-based data-management system to store data and to produce the site and State summaries necessary for the investigation.

Data retrieved from STORET, NWIS, or State databases were placed into a Microsoft ACCESS data-management system at the USGS office in Lawrence, Kansas. Separate ACCESS databases were created for each State. Data in each State ACCESS database consisted of ambient stream-water-quality analyses for the constituents and measurements listed in table 4. A merged database for water-quality constituents and measurements of interest (table 1) was prepared by combining data for multiple parameter codes, and the combined data for each constituent or measurement were used for statistical summary. The utility and comparability of multiple parameter codes for selected constituents and measurements for the merged database will be discussed later in the “Summary of Available State Ambient Stream-Water-Quality Data” section of this report.

Water-quality constituents or measurements from ambient stream-water-quality monitoring sites were summarized only if the site databases contained nine or more constituent analyses or measurements (fig. 1). The nine-analysis threshold was selected as a compromise between the desire to include as many ambient stream-water-quality monitoring sites per State as possible but still have enough analyses to provide an estimate of range and central tendency (median value) for each site’s data population. Additionally, nine samples represent an average of one sample per year for the selected time period (1990–98). This low threshold for data quantity is not consistent with USEPA recommendations or compatible with data quantity preferred by USGS (Hooper and others, 2001; Gilliom and others, 1995). USEPA (2002a) recommends at least 30 analyses per monitoring site for determining water-quality degradation for the 305(b) assessment cycle (2 years); however, the number of analyses required by the States for these determinations varies. For example, Kansas currently (2004) requires a minimum of 12 analyses (Kansas Department of Health and Environment, 2002). Some States require a minimum data set of 10 analyses, whereas other States, such as Nevada and Arizona, require as few as four analyses for determining degradation (U.S. General Accounting Office, 2002). Time frames within which the minimum number of samples can be collected also vary. Wyoming requires 10 samples collected over 3 years, whereas Nebraska requires 10 samples collected over 5 years (U.S. General Accounting Office, 2002). Although States generally require analysis of data collected over 1 to 3 years in determining water-quality degradation, USEPA (2002a) recommends that States analyze data over longer time periods when available.

Relative to the 30 analyses recommended by USEPA (2002a), the minimum of nine analyses required to summarize data from an ambient stream-water-quality monitoring site for the investigation described in this report is small. The potential

disadvantage of a relatively small number of analyses is the possibility that the range and central tendency in sample analyses may not be representative of the population range and central tendency in water-quality constituent concentrations or measurements at monitoring sites. The implication of this possibility is that water-quality summaries made on the basis of a few analyses may be biased.

Quality Assurance of Data

The ambient stream-water-quality merged database assembled for the investigation described in this report consists of more than 2 million individual water-quality constituent analyses or measurements from more than 10,000 monitoring sites in 42 States (table 2). An assumption was made for this investigation that the States or their cooperators had reviewed and approved the ambient stream-water-quality data prior to submission to the STORET, NWIS, or State database systems. Normal quality-assurance procedures include an examination of (1) “outlier” data values to determine erroneous or incorrectly entered data; (2) historical variability in sample collection methods; (3) accuracy, precision, and detection levels of analytical methods; (4) potential for positive or negative bias in the data sets; and (5) verification of entered data with laboratory results.

Qualitative data remark codes (table 5) were retrieved with water-quality data from the STORET or NWIS data-management systems. These remark codes document instances where analytical values are less than or greater than an analytical method or reporting limit; presumptive evidence of material (chemicals) is present but not quantifiable; bacterial enumeration is outside ideal counting ranges; or bacterial colonies are too numerous to count. There were many qualified data in the merged database used in this investigation (table 5). For instance, most chemical data values coded as “less than” an analytical method or reporting level were used for calculation of water-quality constituent median values for ambient stream-water-quality monitoring sites.

Fecal coliform bacteria densities retrieved from the STORET or NWIS data-management systems frequently were qualified “less than” or “greater than” a large range of numeric values. This range was from less than 1 to greater than several hundreds or thousands of bacteria.

Chemical concentrations or bacteria densities qualified with “less than” or “greater than” were used in calculation of median values in water from ambient stream-water-quality monitoring sites. These qualified data were ranked according to their numeric value either before (in the case of “less than”; <) or after (in the case of “greater than”; >) the corresponding non-qualified numeric values (assuming a ranking order from smallest to largest); for example, 1, 5, <10, 10, 20, 40, >40, 50, and so forth.

Table 5. Data remark codes and descriptions and statistical summary action for remarked water-quality data from the U.S. Environmental Protection Agency STORET (STORage and RETrieval), U.S. Geological Survey National Water Information System (NWIS), or State data-management systems.

[U, data used for assessment; NU, data not used for assessment]

Data remark code	Description	Statistical summary action
STORET System ¹		
A	Value reported is the mean of two or more determinations.	U
B	Results are based upon colony counts outside the acceptable range.	U
C	Calculated. Value stored was not measured directly but was calculated from other available data.	U
I	Value reported is less than the practical quantification limit and greater than or equal to the method detection limit.	U
J	Estimated.	NU
K	Off-scale low. Actual value not known but known to be less than value shown.	U
L	Off-scale high. Actual value not known but known to be greater than value shown.	U
M	Presence of material verified but not quantified. Indicates a positive detection at a level too low to permit accurate quantification.	NU
N	Presumptive evidence of presence of material.	NU
O	Sampled for, but analysis lost. Accompanying value is not meaningful for analysis.	NU
P	Too numerous to count.	NU
Q	Sample held beyond normal holding time.	U
T	Value reported is less than the criteria of detection. (<i>Best judgement value</i>).	U
U	Material was analyzed for but not detected. Value stored is the limit of detection for process in use. (<i>Added "less than" qualifier to data value</i>).	U
Z	Too many colonies were present to count (TNTC); the numeric value represents the filtration volume.	NU
\$	Calculated by retrieval software. Numerical value was neither measured nor reported in the database but was calculated from other available data during generation of the retrieval report.	U
NWIS System ²		
<	Actual value is known to be less than the value shown.	U
>	Actual value is known to be greater than the value shown.	U
A	Average value.	U
E	Estimated value.	U
M	Presence of material verified but not quantified.	NU
N	Presumptive evidence of presence of material.	NU
S	Most probable value.	U
V	Value affected by contamination.	NU
U	Analyzed for, not detected.	U

¹U.S. Environmental Protection Agency (2001a).²U.S. Geological Survey (2003).

Summary of Available State Ambient Stream-Water-Quality Data

Water-quality data for selected constituents (table 1) from ambient stream-water-quality monitoring sites in 42 States were statistically summarized. Water-quality constituents and measurements were summarized only if 25 or more States (one-half of the States) had electronically available data. Monitoring-site median values were calculated for each assessed water-quality constituent or measurement, statistically summarized by State, and presented in tabular format. Because of few data among the States for selenium, alachlor, and atrazine, these constituents were not summarized. Water temperature was not summarized because national climatic differences in water temperature make comparability among monitoring sites difficult.

Suspended Solids

Suspended solids in water samples may consist of organic or inorganic materials from sources such as decaying vegetation, algae, solids discharged by industries and municipalities, urban and agricultural runoff, soil erosion, and physical degradation of geologic formations (Mays, 1996). Suspended solids in streams can serve as a heat sink by absorbing solar radiation, which ultimately may increase water temperatures, stress aquatic organisms, and may create conditions favorable to disease in fish populations. Suspended solids also can serve as a transport mechanism for toxic water-quality constituents such as mercury, pesticides, and industrial organic compounds. When transported to and deposited in lakes or reservoirs, suspended solids can shorten the useful life of a lake or reservoir by increasing the rate of sedimentation, thereby reducing storage volume, smothering rooted vegetation, and adversely affecting the ecosystem of aquatic benthic (bottom-dwelling) organisms. Also, suspended solids in lake and reservoir water can increase turbidity, reduce the available light that reaches aquatic plants and organisms, restrict biodiversity, and inhibit photosynthesis and primary productivity (Horne and Goldman, 1994).

All States with suspended solids concentrations in water from ambient stream-water-quality monitoring sites analyzed suspended solids according to the methodology associated with parameter code 00530 (table 4) and subsequently stored those data in STORET Legacy, NWIS, or State databases under that parameter code or as “suspended solids” in the modern STORET system. Florida is the lone exception, which also had two monitoring sites with suspended solids concentrations stored under parameter code 70299. For the purpose of the summary presented in this report, it was assumed that data under both parameter codes were analytically comparable and, therefore, were merged into one database.

Forty States had electronically accessible suspended solids concentrations for water from ambient stream-water-quality monitoring sites with at least nine analyses. State medians of monitoring-site median concentrations of suspended solids

ranged from 2.0 mg/L in New Hampshire to 42.5 mg/L in Nebraska (table 6).

Fecal Coliform Bacteria

Fecal coliform bacteria are indigenous to the intestinal tract of all warmblooded animals, and their presence in stream water indicates fecal contamination and possible presence of pathogenic microorganisms, such as *entero-*, *rota*, *reovirus*, that may cause human disease, ranging from mild diarrhea to respiratory disease, meningitis, and polio (Pepper and others, 1996). Possible sources of fecal coliform bacteria contamination in streams include municipal-wastewater discharges, seepage from domestic septic systems, runoff or seepage from livestock-producing areas, and wildlife. Because of the potential human-health implications of fecal bacteria contamination, all States have implemented an ambient stream-water-quality criterion for either fecal coliform or *Escherichia coli* (*E. coli*) bacteria densities. *E. coli* is the predominant bacterium in the fecal coliform group (McKinney, 1962) and may be more indicative of fecal contamination from warmblooded animals than the fecal coliform group (Cabelli, 1977; Dufour and Cabelli, 1984). The fecal coliform bacteria group may include species of the *Klebsiella*, *Enterobacter*, and *Citrobacter* genera (Gleeson and Gray, 1997). Rasmussen and Ziegler (2003) developed site-specific relations and ratios between *E. coli* and fecal coliform bacteria such that densities of one may be used to estimate densities of the other. Historically, most States relied on the enumeration of fecal coliform bacteria as an indicator of sanitary quality particularly for the time period 1990–98. Therefore, indicator bacteria for most States consisted of the fecal coliform group in this report. In 1986, USEPA revised the ambient water-quality criteria for marine and freshwater (U.S. Environmental Protection Agency, 1986) and recommended that criteria for either *E. coli* or *Enterococci* organisms replace criteria for fecal coliform bacteria. However, many States may have been reluctant to switch from a fecal coliform criteria because of concern of long-term comparability.

Thirty-nine States had electronically accessible fecal coliform bacteria densities in water from ambient stream-water-quality monitoring sites stored in STORET Legacy, NWIS, or State databases under one or more parameter codes (table 7) or as “fecal coliform” in the modern STORET system. Although monitoring sites for most States had fecal coliform bacteria densities stored under only one parameter code (most commonly 31616), five States (Connecticut, Florida, Rhode Island, South Carolina, Virginia) had data from monitoring sites stored under two parameter codes, and Texas had data stored under three parameter codes. The division of fecal coliform bacteria densities among more than one parameter code within and among the States necessitated a data-merging procedure prior to the monitoring-site and State summaries presented in this report.

The merging procedure of ambient stream-water-quality monitoring sites with different parameter codes for fecal coliform bacteria densities was, for the most part, a simple

Table 6. Summary of median suspended solids concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	45	1.0	9.0	32.0
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	1.0	7.5	116
California	--	--	--	--
Colorado	214	<10	<10	260
Connecticut	0	--	--	--
Delaware	103	2.0	10.5	111
Florida	602	<1.0	4.0	153
Georgia	196	<1.0	9.0	37.0
Hawaii	--	--	--	--
Idaho	0	--	--	--
Illinois	11	8.0	26.0	108
Indiana	105	<4.0	19.0	93.0
Iowa	26	12.5	40.5	190
Kansas	124	5.0	33.0	108
Kentucky	60	3.0	15.0	48.5
Louisiana	171	4.0	22.0	251
Maine	--	--	--	--
Maryland	40	4.0	8.0	18.0
Massachusetts	--	--	--	--
Michigan	96	<4.0	12.0	54.1
Minnesota	63	1.2	25.0	145
Mississippi	66	1.0	13.5	140
Missouri	22	2.5	10.8	181
Montana	132	<1.0	5.2	340
Nebraska	22	5.0	42.5	254
Nevada	67	1.0	<10.0	108
New Hampshire	25	<1.0	2.0	6.5
New Jersey	65	3.0	6.0	27.0
New Mexico	219	<3.0	8.0	832
New York	19	2.0	10.0	41.0
North Carolina	--	--	--	--
North Dakota	28	<5.0	25.8	1,030
Ohio	41	<5.0	14.0	65.0
Oklahoma	182	<1.0	7.9	129
Oregon	144	<1.0	4.0	62.5
Pennsylvania	173	<2.0	6.0	26.0
Rhode Island	5	2.0	5.0	6.0
South Carolina	52	1.4	6.7	27.0
South Dakota	96	2.0	17.0	2,160
Tennessee	68	3.0	11.8	101
Texas	396	<1.0	21.0	622
Utah	64	<3.0	34.2	938
Vermont	--	--	--	--
Virginia	945	<3.0	6.5	64.0
Washington	204	1.0	5.0	114
West Virginia	26	<5.0	8.8	29.0
Wisconsin	46	3.0	10.2	56.0
Wyoming	1	13.0	13.0	13.0

¹Nine or more analyses per site.

Table 7. Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of fecal coliform bacteria densities in water, 1990–98.

[M–TEC, fecal coliform agar; M–FC, fecal coliform agar or broth; MPN, most probable number; MPF, micrometer porosity filter; --, not available]

State	Number of sites with data for parameter code ¹					Number of sites in merged database
	31611 (M–TEC)	31613 (M–FC agar)	31615 (MPN)	31616 (M–FC broth)	31625 (M–FC, 0.7 MPF)	
Alabama	--	45	--	--	--	45
Alaska	--	--	--	--	--	--
Arizona	--	--	--	--	--	--
Arkansas	--	--	--	113	--	113
California	--	--	--	--	--	--
Colorado	--	--	--	--	--	124
Connecticut	--	--	--	32	3	32
Delaware	--	--	--	--	--	0
Florida	--	108	--	268	--	372
Georgia	--	--	255	--	--	255
Hawaii	--	--	--	--	--	--
Idaho	--	--	--	--	42	42
Illinois	--	--	--	3	--	3
Indiana	--	--	--	--	--	0
Iowa	--	--	--	17	--	17
Kansas	--	--	--	249	--	249
Kentucky	--	--	--	59	--	59
Louisiana	--	--	103	--	--	103
Maine	--	--	--	--	--	--
Maryland	--	--	--	40	--	40
Massachusetts	--	--	--	--	--	--
Michigan	--	--	--	--	--	0
Minnesota	--	63	--	--	--	63
Mississippi	--	--	--	50	--	50
Missouri	--	--	--	--	39	39
Montana	--	--	--	--	--	2
Nebraska	--	--	--	22	--	22
Nevada	--	60	--	--	--	60
New Hampshire	--	--	--	8	--	8
New Jersey	--	--	--	--	5	5
New Mexico	--	--	--	--	9	9
New York	--	8	--	--	--	8
North Carolina	--	--	--	--	--	--
North Dakota	--	--	--	--	--	39
Ohio	--	--	--	40	--	40
Oklahoma	14	--	--	--	--	14
Oregon	--	83	--	--	--	83
Pennsylvania	--	--	--	53	--	53
Rhode Island	--	--	--	1	5	5
South Carolina	--	--	43	276	--	310
South Dakota	--	--	--	96	--	96
Tennessee	--	--	--	60	--	60
Texas	--	33	--	422	67	457
Utah	--	--	--	--	--	16
Vermont	--	--	--	--	--	--
Virginia	--	--	460	790	--	1,086
Washington	--	--	--	202	--	202
West Virginia	--	--	--	26	--	26
Wisconsin	--	44	--	--	--	44
Wyoming	--	--	--	--	18	18

¹See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

14 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

combining of monitoring sites into a single State database. Occasionally, however, individual water-quality samples from monitoring sites contained fecal coliform bacteria densities analyzed and stored under more than one parameter code. In these situations, densities stored under parameter code 31616 were selected in preference over densities stored under other parameter codes. Generally, densities under parameter code 31616 were the most commonly occurring for monitoring sites within the six States with multiple parameter codes for fecal coliform bacteria and, therefore, the most reasonable selection. For the purpose of summaries presented in this report, it was assumed that densities under all fecal coliform bacteria parameter codes among or within the States were analytically comparable even though there may be analytical variability between the methods associated with the different parameter codes. State medians of monitoring-site median densities of fecal coliform bacteria ranged from 19.2 col/100 mL in Colorado to 2,650 col/100 mL in Montana (on the basis of two sites) (table 8).

Ammonia

Ammonia as nitrogen (hereinafter referred to as ammonia) is a reduced form of nitrogen. Rooted aquatic plants and algae require dissolved forms of nitrogen as nutrients essential for growth and reproduction (Horne and Goldman, 1994). Compounds of nitrogen such as ammonia or the oxidized forms of nitrogen such as nitrite and nitrate are the basic building blocks for protein synthesis. However, large inputs of nitrogen compounds into the aquatic environment may cause excessive algal growth. This growth ultimately may produce taste-and-odor problems in drinking water, reduce the aesthetic and recreational value of water, and stress aquatic organisms resulting from depleted dissolved oxygen concentrations when algal blooms die.

Concentrations of ammonia ranging from 0.44 to 18.7 mg/L (uncorrected for pH) were shown to be acutely toxic to 19 freshwater invertebrate species, whereas acute toxicity among 29 fish species ranged from 0.068 to 3.78 mg/L, uncorrected for pH (U.S. Environmental Protection Agency, 1986). Concentrations of ammonia acutely toxic to fish may cause increases in respiratory activity, oxygen uptake, and heart rate; reductions in hatching success and growth and morphological development; and injury to gills, liver, and kidneys. At larger concentrations, fish may experience convulsions, coma, or death (U.S. Environmental Protection Agency, 1986). Therefore, it is desirable to mitigate the introduction of excessive ammonia.

Major nonpoint sources of ammonia include agricultural activities such as the application of synthetic fertilizers (anhydrous ammonia) and pasturing and confined feeding of livestock. Farm livestock can produce large amounts of nitrogenous organic waste (urine, manure, and organic wastes) in areas where large numbers of animals are pastured or confined. The decomposition of organic waste can release ammonia and other nutrients into the aquatic environment. Discharges from

industrial and municipal-wastewater treatment plants also may be a major point source of ammonia and other nutrients to streams in the United States.

Unionized ammonia (NH_3) readily dissolves in water to form its derivative ionic species ammonium ion (NH_4^+). Because the acid-base ionization constant for NH_4^+ is relatively large (9.26), most ammonia in water within natural environmental pH ranges (6.0 to 9.0 standard units) is present as NH_4^+ rather than NH_3 (Manahan, 1994). Analytical methods for ammonia (as nitrogen) are conducted on either a whole water sample (total ammonia analysis) or a filtered water sample (dissolved ammonia analysis). In both cases, the resultant analytical determination will represent a combined concentration of unionized and ionized forms of ammonia. However, because of the large solubility of ammonia in water at natural pH ranges and the preponderance of the dissolved ionic species (NH_4^+), analytical determinations of ammonia (as nitrogen) in whole (total) and filtered (dissolved) water samples will produce similar ammonia concentrations.

Forty-one States reported ammonia concentrations (as nitrogen) in water from ambient stream-water-quality monitoring sites (table 9). Most States reported ammonia concentrations determined from whole water samples (total ammonia; parameter code 00610) for 1990–98. Two States (Nevada and Wisconsin) reported ammonia concentrations determined only on filtered samples of water (dissolved ammonia; parameter code 00608), whereas 12 States reported both total and dissolved ammonia concentrations. Total and dissolved ammonia analyses were assumed to produce similar concentrations of ammonia in water from most monitoring sites; therefore, data for parameter codes 00608 and 00610 were combined to create merged State databases prior to the water-quality summary for ammonia. Ammonia data acquired from the modern STORET system included total and dissolved analyses for Colorado and Montana and required a similar merging procedure.

Creation of merged databases for ammonia concentrations determined in water from ambient stream-water-quality monitoring sites consisted of merging dissolved ammonia determinations into the database for total ammonia determinations. In situations where both a total and dissolved concentration existed for a water sample, the total concentration was included rather than the dissolved concentration. Total ammonia concentrations were preferred for inclusion because of the preponderance of these data among the State water-quality databases. Merged State databases (table 9) were used for the water-quality summary of ammonia presented in this report. State medians of monitoring-site median concentrations of ammonia ranged from 0.003 mg/L in Colorado to 0.46 mg/L in Rhode Island (table 10).

Nitrite Plus Nitrate

Nitrite and nitrate are inorganic oxidized forms of nitrogen produced during various stages of the nitrogen cycle (Manahan, 1994, p. 41). In most oxygenated surface water, nitrate is by far

Table 8. Summary of median fecal coliform bacteria densities in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[mL, milliliters; --, not available; <, less than; >, greater than]

State	Number of assessed monitoring sites ¹	Monitoring-site median density (colonies per 100 mL of water)		
		Minimum	Median	Maximum
Alabama	45	18.0	115	1,950
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	113	8.5	75.5	500
California	--	--	--	--
Colorado	124	<2.0	19.2	4,300
Connecticut	32	11.0	148	5,650
Delaware	0	--	--	--
Florida	372	<1.0	80.0	2,250
Georgia	255	<20.0	200	7,900
Hawaii	--	--	--	--
Idaho	42	2.0	24.0	265
Illinois	3	220	230	2,450
Indiana	0	--	--	--
Iowa	17	3.0	200	1,900
Kansas	249	<10.0	155	6,000
Kentucky	59	10.0	128	650
Louisiana	103	8.0	200	30,000
Maine	--	--	--	--
Maryland	40	4.0	265	2,300
Massachusetts	--	--	--	--
Michigan	0	--	--	--
Minnesota	63	<4.0	64.0	950
Mississippi	50	10.0	152	640
Missouri	39	4.0	57.0	1,000
Montana	2	2,260	2,650	3,040
Nebraska	22	17.0	71.2	720
Nevada	60	<10.0	20.0	3,100
New Hampshire	8	55.0	230	430
New Jersey	5	7.0	28.0	210
New Mexico	9	14.0	51.0	330
New York	8	20.0	48.0	600
North Carolina	--	--	--	--
North Dakota	39	<10.0	30.0	160
Ohio	40	72.5	235	2,700
Oklahoma	14	50.0	450	2,150
Oregon	83	<4.0	140	>600
Pennsylvania	53	10.0	60.0	1,800
Rhode Island	5	27.0	56.0	160
South Carolina	310	1.0	170	2,600
South Dakota	96	<2.0	65.0	1,100
Tennessee	60	<2.0	210	4,250
Texas	457	<3.0	106	13,000
Utah	16	2.0	40.0	750
Vermont	--	--	--	--
Virginia	1,086	<1.8	100	16,000
Washington	202	<1.0	20.8	510
West Virginia	26	<10.0	144	3,000
Wisconsin	44	<10.0	47.5	1,300
Wyoming	18	11.0	69.5	325

¹Nine or more analyses per site.

Table 9. Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of ammonia as nitrogen concentrations in water, 1990–98.

[--, not available]

State	Number of sites with data for parameter code ¹		Number of sites in merged databases
	00608 (dissolved)	00610 (total)	
Alabama	--	18	18
Alaska	--	--	--
Arizona	--	--	--
Arkansas	--	131	131
California	--	--	--
Colorado	--	--	163
Connecticut	29	24	29
Delaware	17	103	103
Florida	284	566	793
Georgia	--	283	283
Hawaii	--	--	--
Idaho	45	12	47
Illinois	--	11	11
Indiana	--	106	106
Iowa	--	39	39
Kansas	--	251	251
Kentucky	--	60	60
Louisiana	--	--	0
Maine	--	--	--
Maryland	--	40	40
Massachusetts	--	--	--
Michigan	--	70	70
Minnesota	--	66	66
Mississippi	--	58	58
Missouri	14	35	39
Montana	--	--	140
Nebraska	--	22	22
Nevada	67	--	67
New Hampshire	--	--	41
New Jersey	67	80	82
New Mexico	14	223	228
New York	--	19	19
North Carolina	--	--	--
North Dakota	--	--	55
Ohio	--	41	41
Oklahoma	--	38	38
Oregon	--	143	143
Pennsylvania	2	174	174
Rhode Island	5	5	5
South Carolina	--	337	337
South Dakota	--	96	96
Tennessee	--	65	65
Texas	90	444	446
Utah	--	--	64
Vermont	--	--	--
Virginia	67	902	957
Washington	--	204	204
West Virginia	--	26	26
Wisconsin	40	--	40
Wyoming	21	11	21

¹See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

Table 10. Summary of median ammonia as nitrogen concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[<, less than; --, not available]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	18	<0.01	<0.01	0.27
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	<.05	<.05	4.2
California	--	--	--	--
Colorado	163	<.001	.003	.12
Connecticut	29	.02	.08	.85
Delaware	103	.03	.07	.66
Florida	793	<.01	.04	3.1
Georgia	283	.02	.03	2.3
Hawaii	--	--	--	--
Idaho	47	.007	.03	.09
Illinois	11	.02	.12	.40
Indiana	106	<.10	<.10	.60
Iowa	39	.05	<.10	.11
Kansas	251	<.02	<.05	.88
Kentucky	60	<.05	<.05	.19
Louisiana	0	--	--	--
Maine	--	--	--	--
Maryland	40	.01	.03	.14
Massachusetts	--	--	--	--
Michigan	70	.01	.04	.30
Minnesota	66	<.02	.04	.22
Mississippi	58	<.10	.16	.46
Missouri	39	.01	.03	.10
Montana	140	<.01	<.01	2.9
Nebraska	22	.02	.06	.20
Nevada	67	.006	<.10	9.7
New Hampshire	41	<.01	<.10	<.10
New Jersey	82	.03	.07	.76
New Mexico	228	.02	<.10	5.3
New York	19	.008	.04	.17
North Carolina	--	--	--	--
North Dakota	55	<.01	.03	.94
Ohio	41	<.05	<.05	.48
Oklahoma	38	.01	.07	1.4
Oregon	143	<.02	.02	.31
Pennsylvania	174	<.02	.02	.74
Rhode Island	5	.03	.46	1.3
South Carolina	337	<.05	<.05	.18
South Dakota	96	<.02	<.03	10.6
Tennessee	65	<.02	.03	.23
Texas	446	<.01	<.05	.68
Utah	64	<.05	<.05	.59
Vermont	--	--	--	--
Virginia	957	.01	<.04	10.4
Washington	204	<.01	.01	2.9
West Virginia	26	<.50	<.50	<.50
Wisconsin	40	<.02	.05	.19
Wyoming	21	.02	.03	2.6

¹Nine or more analyses per site.

18 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

the most predominant ion because of the rapid oxidation of nitrite to nitrate.

Nitrate is the form of nitrogen most easily used by rooted green plants and algae and usually occurs in relatively small concentrations in uncontaminated surface water with a world average of 0.30 mg/L as nitrogen (Reid and Wood, 1976, p. 235). Larger concentrations may stimulate the growth of rooted plants or accelerate algal production to an extent that algae may produce a taste-and-odor problem in finished drinking water. Because most aquatic organisms can tolerate nitrite plus nitrate concentrations far in excess of what normally might be found even in contaminated surface water, no water-quality criteria have been established for protection of aquatic life.

Adverse human-health effects of large concentrations of nitrate (greater than 10 mg/L) in drinking water include methemoglobinemia (blue-baby syndrome) in infants (U.S. Environmental Protection Agency, 1986).

Sources of nitrite plus nitrate nitrogen in the aquatic environment are similar to those for ammonia. Point sources include municipal and industrial discharges, and nonpoint sources are mostly related to agricultural activities such as crop (fertilizer application) and livestock (manure distribution) production and urban uses such as lawn fertilizers.

Nitrite (NO_2^-) and nitrate (NO_3^-) ions are completely soluble in water (Follett, 1995). Therefore, determinations of nitrite plus nitrate as nitrogen concentrations in whole (total) or filtered (dissolved) water from ambient stream-water-quality monitoring sites generally should be comparable. Nitrite, generally, is an insignificant component of the nitrite plus nitrate determination because in most natural water nitrite is readily oxidized to nitrate (Hem, 1992).

Historically, States have reported nitrite and nitrate determinations in several ways—only nitrate, nitrite and nitrate individually, and (or) combined determinations of nitrite and nitrate (table 11). These determinations have been made on filtered and unfiltered stream-water samples. Kansas, for example, currently (2004) determines concentrations of nitrite plus nitrate as nitrogen on unfiltered water samples (parameter code 00630) but historically had reported nitrate concentrations on filtered water samples (parameter code 00618). For the purpose of this report, the representation of inorganic oxides of nitrogen in stream-water samples was concentrations of nitrite plus nitrate as nitrogen (either parameter code 00630 or 00631). In the absence of either of these determinations, however, concentrations of nitrate as nitrogen (parameter codes 00618 or 00620) or as nitrate (parameter code 71851, subsequently expressed as nitrogen in this report) were used as surrogates for nitrite plus nitrate as nitrogen determinations under the assumptions that nitrite concentrations were small (relative to nitrate concentrations) in natural stream water and that no substantial differences existed between determinations made on filtered or unfiltered water samples. Hereinafter, all determinations of nitrate or nitrite and nitrate used in this report will be referred to as nitrite plus nitrate as nitrogen.

Most of the 42 States with electronically accessible nitrite plus nitrate as nitrogen concentrations analyzed for total

concentrations (table 11). Some States, however, also analyzed for dissolved concentrations of nitrite plus nitrate either in combination with or instead of total concentrations. Because of the similarity in total and dissolved concentrations of nitrite plus nitrate as nitrogen, monitoring sites with these data were combined into merged State databases using a merge procedure identical to that used for merging ammonia data, with total concentrations having preference. State medians of monitoring-site median concentrations of nitrite plus nitrate as nitrogen ranged from 0.05 mg/L in Nevada to 5.7 mg/L in Iowa (table 12).

Phosphorus

Phosphorus is an essential nutrient for plant growth; however, in excess of critical concentrations, it may contribute to the eutrophication of surface-water resources. Eutrophication (nutrient enrichment) is characterized by an abundance of nutrients, decreases in dissolved oxygen, excess growth of algae, and an acceleration of the normal rate of ecological succession (Reid and Wood, 1976). Sources of phosphorus in surface water are similar to those previously identified for ammonia and nitrite plus nitrate as nitrogen.

Phosphorus is ubiquitous in streams in much of the Nation. Some of this occurrence is due to the natural weathering of phosphorus in soil and rock, but a large part of the phosphorus in streams is the result of human activities. These activities may include point-source discharges from municipal and industrial facilities or nonpoint-source contributions related to runoff from urban and agricultural areas. Fertilizers containing phosphorus are routinely applied in crop production, often in conjunction with nitrogen fertilizers. Phosphorus compounds also are a component of livestock manure, and the land disposal of manure from confined animal-feeding operations and pasturing of livestock establish a substantial source of nonpoint-source phosphorus to the Nation's rivers and streams (Heathwaite, 1997; Sharpley and Rekolainen, 1997; U.S. Geological Survey, 1999).

Data from 41 States were summarized for total phosphorus concentrations in water from ambient stream-water-quality monitoring sites. All phosphorus data retrieved were stored under a single parameter code (00665, table 4) or retrieved as "total phosphorus" from the modern STORET system. Therefore, a data-merge procedure was not necessary for total phosphorus concentrations. State medians of monitoring-site median concentrations of total phosphorus ranged from 0.02 mg/L in West Virginia to 0.33 mg/L in Illinois (table 13).

Arsenic

Arsenic is a nonmetallic element that has potential toxicological effects on aquatic organisms (U.S. Environmental Protection Agency, 1986). Arsenic occurs in the Earth's crust at concentrations of about 2 to 5 mg/kg and has been distributed throughout the environment by natural weathering and human activities. One distribution mechanism is the burning of fossil

Table 11. Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of nitrate and nitrite plus nitrate as nitrogen concentrations in water, 1990–98.

[--, not available]

State	Number of sites with data for parameter code ¹					Number of sites in merged database
	00618 (dissolved)	00620 (total)	00630 (total)	00631 (dissolved)	71851 ² (dissolved)	
Alabama	--	44	--	--	--	44
Alaska	--	--	--	--	--	--
Arizona	--	--	--	--	--	--
Arkansas	--	--	131	--	--	131
California	--	--	--	--	--	--
Colorado	--	--	--	--	--	210
Connecticut	--	--	24	28	--	30
Delaware	--	3	103	17	--	103
Florida	11	351	696	105	--	825
Georgia	--	--	283	--	--	283
Hawaii	--	--	--	--	--	--
Idaho	--	--	9	41	--	45
Illinois	--	--	11	--	--	11
Indiana	--	--	106	--	--	106
Iowa	--	--	39	--	--	39
Kansas	152	--	168	--	--	251
Kentucky	--	--	60	--	--	60
Louisiana	--	--	172	--	--	172
Maine	--	--	--	--	--	--
Maryland	--	--	40	--	--	40
Massachusetts	--	--	--	--	--	--
Michigan	--	51	73	28	--	85
Minnesota	--	--	66	--	--	66
Mississippi	--	--	65	--	--	65
Missouri	--	--	37	25	--	40
Montana	--	--	--	--	--	235
Nebraska	--	--	22	--	--	22
Nevada	63	--	--	--	64	64
New Hampshire	--	--	--	--	--	46
New Jersey	--	--	85	72	--	87
New Mexico	--	--	221	13	--	230
New York	--	--	19	--	--	19
North Carolina	--	--	--	--	--	--
North Dakota	--	--	--	--	--	57
Ohio	--	--	41	--	--	41
Oklahoma	--	--	³ 111	--	--	111
Oregon	--	--	143	--	--	143
Pennsylvania	1	171	--	--	--	171
Rhode Island	--	--	5	5	--	5
South Carolina	--	--	340	--	--	340
South Dakota	--	47	50	--	--	96
Tennessee	--	--	65	--	--	65
Texas	--	266	180	102	--	449
Utah	--	--	--	--	--	64
Vermont	--	--	--	--	--	--
Virginia	85	901	--	55	--	957
Washington	--	--	204	--	--	204
West Virginia	--	--	--	--	--	⁴ 24
Wisconsin	--	--	--	42	--	42
Wyoming	--	--	6	29	--	29

¹See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.²Reported nitrate as nitrate (NO₃) concentrations were converted to nitrate as nitrogen concentrations for use in this report.³Concentrations of nitrite plus nitrate as nitrogen at some monitoring sites were calculated from individual nitrite and nitrate as nitrogen concentrations.⁴No single monitoring site had nine or more analyses for any one parameter, but when merged, 24 monitoring sites had nine or more analyses of the combined parameters.

Table 12. Summary of median nitrite plus nitrate as nitrogen concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98

[--, not available; <, less than]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	44	<0.01	0.45	3.7
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	<.02	.21	8.8
California	--	--	--	--
Colorado	210	<.05	<.50	6.0
Connecticut	30	.13	.46	3.7
Delaware	103	.08	1.7	15.2
Florida	825	0	.07	9.7
Georgia	283	<.02	.26	3.5
Hawaii	--	--	--	--
Idaho	45	.06	.22	2.4
Illinois	11	.18	4.3	11.4
Indiana	106	<.10	2.5	7.2
Iowa	39	.50	5.7	11.0
Kansas	251	.04	.54	6.8
Kentucky	60	.13	.48	5.3
Louisiana	172	<.02	.16	2.2
Maine	--	--	--	--
Maryland	40	.39	1.4	5.7
Massachusetts	--	--	--	--
Michigan	85	.01	.90	9.0
Minnesota	66	<.05	.53	32.0
Mississippi	65	<.02	.16	.64
Missouri	40	.08	.47	10.5
Montana	235	0	.07	33.5
Nebraska	22	.06	1.2	1.9
Nevada	64	0	.05	3.0
New Hampshire	46	<.02	.19	.68
New Jersey	87	.10	1.1	4.4
New Mexico	230	<.04	<.10	7.2
New York	19	.18	.44	1.2
North Carolina	--	--	--	--
North Dakota	57	<.005	.08	.47
Ohio	41	.32	2.7	5.2
Oklahoma	111	.02	.24	7.1
Oregon	143	<.02	.12	4.1
Pennsylvania	171	<.04	.71	12.8
Rhode Island	5	.25	.71	.90
South Carolina	340	<.02	.18	6.5
South Dakota	96	<.10	.30	19.2
Tennessee	65	.07	.38	2.8
Texas	449	<.01	.39	29.0
Utah	64	<.02	.25	3.0
Vermont	--	--	--	--
Virginia	957	0	.19	71.7
Washington	204	<.01	.20	9.4
West Virginia	24	.16	.43	2.0
Wisconsin	42	.05	.45	4.1
Wyoming	29	.06	.16	3.3

¹Nine or more analyses per site.

Table 13. Summary of median total phosphorus concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	45	0.01	0.09	4.5
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	<.03	.07	4.7
California	--	--	--	--
Colorado	209	<.01	.05	2.7
Connecticut	32	.01	.05	.52
Delaware	103	.03	.10	.62
Florida	790	.002	.07	5.8
Georgia	283	<.02	.07	3.4
Hawaii	--	--	--	--
Idaho	44	.005	.04	.49
Illinois	11	.06	.33	2.8
Indiana	106	<.03	.10	.38
Iowa	28	.10	.20	.50
Kansas	251	.04	.15	1.9
Kentucky	60	<.005	.04	.74
Louisiana	172	.03	.15	1.0
Maine	--	--	--	--
Maryland	40	<.01	.05	.24
Massachusetts	--	--	--	--
Michigan	83	.009	.06	.35
Minnesota	63	.01	.15	3.5
Mississippi	65	.03	.08	.39
Missouri	34	.02	.05	4.1
Montana	175	<.01	.04	2.7
Nebraska	22	.02	.18	.80
Nevada	67	.01	.06	.48
New Hampshire	46	.007	.03	.12
New Jersey	82	.02	.07	.45
New Mexico	225	<.01	<.09	4.6
New York	0	--	--	--
North Carolina	--	--	--	--
North Dakota	57	<.02	.17	.64
Ohio	41	<.05	.11	1.2
Oklahoma	194	<.01	.04	.64
Oregon	141	.01	.05	.44
Pennsylvania	174	.02	.03	.64
Rhode Island	5	.02	.22	.34
South Carolina	339	<.02	.05	1.2
South Dakota	96	.01	.12	1.8
Tennessee	65	<.01	.05	.45
Texas	439	<.01	.12	4.7
Utah	64	<.01	.06	.98
Vermont	--	--	--	--
Virginia	936	.01	<.10	13.8
Washington	206	<.01	.03	3.1
West Virginia	26	<.02	.02	.14
Wisconsin	44	.03	.09	.35
Wyoming	21	.02	.05	2.4

¹Nine or more analyses per site.

22 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

fuels (particularly coal) with potential contamination of surface-water resources (Manahan, 1994). Arsenic also has been introduced into the aquatic environment through industrial discharges and use as a component in some pesticides, most of which are currently (2004) banned (Manahan, 1994). However, arsenic (roarsone) is still used as a feed additive for poultry for increased weight gain, feed efficiency, improved pigmentation, and prevention of parasites (Miller and others, 2000). Some ground water, particularly of geothermal origin, may contain relatively large natural concentrations of arsenic (Hem, 1992). Discharge of arsenic-enriched ground water may contaminate surface-water resources.

Data from 28 States were summarized for total arsenic concentrations in water from ambient stream-water-quality monitoring sites. All total arsenic data from monitoring sites with at least nine analyses had these data stored in STORET Legacy, NWIS, or State databases under parameter code 00978 (total recoverable arsenic) or parameter code 01002 (total arsenic) or as “total arsenic” in the modern STORET system. However, only Washington stored data under parameter code 00978 for a total of five monitoring sites. Total and total recoverable analyses generally are distinguished by the degree of digestion of a water/sediment sample. Total is used when the analytical procedure assures measurement of at least 95 percent of a constituent in both the dissolved and suspended phases. Total recoverable is used to represent something less than the “total” amount (less than 95 percent) (Fishman and Friedman, 1989). However, for the purpose of the summary presented in this report, it was assumed that total arsenic concentrations stored under both parameter codes were analytically comparable. Because no monitoring site in Washington contained both total and total recoverable concentrations of arsenic, a merging procedure and selection of a preferred parameter were not required. State medians of monitoring-site median concentrations of total arsenic ranged from 0.80 µg/L in Washington to 11.5 µg/L in South Dakota (table 14).

Dissolved Solids

Dissolved solids in surface water result from natural dissolution of rocks and minerals or discharges from municipal, industrial, or agricultural sources. The major constituents of dissolved solids are the cations (positively charged ions) calcium, magnesium, sodium, and potassium, and the anions (negatively charged ions) bicarbonate, carbonate, sulfate, and chloride. Natural variability in dissolved-solids concentrations depends on chemical characteristics of drainage-basin soils, composition of surficial material, and in some situations the minerals in deeper geologic strata. Larger dissolved-solids concentrations in surface water may be expected in areas underlain by ancient marine sediment containing large salt deposits (Bevans, 1989; Gillespie and Hargadine, 1994). Ground water dissolves the salt, which eventually discharges into surface water. Point-source discharges such as from industrial or municipal wastewater-treatment plants (Pope and Putnam, 1997) and

nonpoint-source discharges from areas of extensive irrigation (Klein and Bradford, 1980; Libermann and others, 1989) also may increase dissolved-solids concentrations in surface water.

Excessively large concentrations of dissolved solids may be objectionable in drinking water because of possible physiological effects, unpalatable mineral taste, and greater cost because of (1) corrosion of plumbing, boilers, or other water-transfer or utility equipment, or (2) the necessity for additional treatment to remove the ions responsible for objectionable taste or corrosion. Because dissolved solids may not be removed from source water during traditional drinking-water treatment processes, more expensive reverse osmosis procedures (Chu and others, 1986, for example) may be required to produce drinking water of desirable quality.

Twenty-nine States had electronically accessible dissolved-solids concentrations in water from ambient stream-water-quality monitoring sites (table 15). Data from monitoring sites with nine or more analyses for dissolved solids were stored in STORET Legacy, NWIS, or State databases under one or more of four parameter codes for dissolved solids (00515, 70294, 70300, 70301) or as “dissolved solids” in the modern STORET system. Although monitoring sites for most States had dissolved-solids concentrations stored under only one parameter code (most commonly 70300), Florida also had calculated dissolved-solids concentrations (parameter code 70301). For the purpose of the summary presented in this report, it was assumed that all State analytical and calculated determinations of dissolved-solids concentrations were comparable and, therefore, were merged into State databases with a common dissolved-solids parameter (table 15). During the merge process for Florida, parameter code 70300 was used in preference over parameter code 70301. State medians of monitoring-site median concentrations of dissolved solids ranged from 37.2 mg/L in Mississippi to 711 mg/L in South Dakota (table 16).

Although an assumption of comparability of State analytical and calculated results was made for the statistical summary of dissolved-solids concentrations (table 16), there may be evidence of an inconsistency in this assumption. The small median dissolved-solids concentration (37.2 mg/L) for Mississippi was determined from the medians of 46 monitoring sites that used the somewhat ambiguous parameter code 70294 (unspecified calculation). Relative to the bordering States of Alabama and Louisiana, which had median concentrations of 204 and 196 mg/L, respectively, the median for Mississippi seems anomalous and possibly the result of a lack of computational comparability (not all of the same constituents may have been included in the dissolved-solids calculation).

Chloride

Chloride ion is the most common oxidation state (-1) of the element chlorine and is the only ion of major environmental significance in the hydrologic cycle. Chloride occurs mostly in small concentrations in all natural freshwater except for those

Table 14. Summary of median total arsenic concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[<, less than; >, greater than; --, not available]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (micrograms per liter)		
		Minimum	Median	Maximum
Alabama	27	<5.0	<10.0	<10.0
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	0	--	--	--
California	--	--	--	--
Colorado	0	--	--	--
Connecticut	0	--	--	--
Delaware	20	<10.0	<10.0	<10.0
Florida	128	.57	<1.5	<10.0
Georgia	0	--	--	--
Hawaii	--	--	--	--
Idaho	0	--	--	--
Illinois	2	<1.0	1.1	1.1
Indiana	61	.30	1.5	3.2
Iowa	1	<10.0	<10.0	<10.0
Kansas	251	<1.0	4.0	<21.0
Kentucky	59	<2.0	<2.0	3.0
Louisiana	12	2.4	3.2	5.8
Maine	--	--	--	--
Maryland	0	--	--	--
Massachusetts	--	--	--	--
Michigan	48	<1.0	1.2	2.9
Minnesota	0	--	--	--
Mississippi	22	<3.0	<5.0	<5.0
Missouri	0	--	--	--
Montana	8	<1.0	>1.0	15.5
Nebraska	13	2.9	5.0	6.8
Nevada	59	<3.0	4.0	251
New Hampshire	1	<5.0	<5.0	<5.0
New Jersey	4	1.0	1.5	3.0
New Mexico	15	<1.0	<5.0	<5.0
New York	0	--	--	--
North Carolina	--	--	--	--
North Dakota	24	1.4	3.2	7.9
Ohio	41	<2.0	<2.0	4.0
Oklahoma	0	--	--	--
Oregon	0	--	--	--
Pennsylvania	31	<4.0	<4.0	<4.0
Rhode Island	1	2.0	2.0	2.0
South Carolina	0	--	--	--
South Dakota	20	<5.0	11.5	37.1
Tennessee	70	<1.0	<2.0	6.0
Texas	9	1.0	2.0	3.0
Utah	54	<5.0	<5.0	20.0
Vermont	--	--	--	--
Virginia	75	<5.0	<10.0	<10.0
Washington	5	.58	.80	3.7
West Virginia	0	--	--	--
Wisconsin	2	<10.0	<10.0	<10.0
Wyoming	0	--	--	--

¹Nine or more analyses per site.

Table 15. Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of dissolved-solids concentrations in water, 1990–98.

[°C, degrees Celsius; --, not available]

State	Number of sites with data for parameter code ¹				Number of sites in merged database
	00515 (dried at 105 °C)	70294 (unspecified calculation)	70300 (dried at 180 °C)	70301 (sum of constituents)	
Alabama	42	--	--	--	42
Alaska	--	--	--	--	--
Arizona	--	--	--	--	--
Arkansas	--	--	131	--	131
California	--	--	--	--	--
Colorado	--	--	--	--	212
Connecticut	--	--	32	--	32
Delaware	--	--	--	--	0
Florida	--	--	246	6	253
Georgia	--	--	--	--	0
Hawaii	--	--	--	--	--
Idaho	--	--	32	--	32
Illinois	--	--	--	--	0
Indiana	--	--	23	--	23
Iowa	28	--	--	--	28
Kansas	--	--	--	251	251
Kentucky	--	--	--	--	0
Louisiana	172	--	--	--	172
Maine	--	--	--	--	--
Maryland	12	--	--	--	12
Massachusetts	--	--	--	--	--
Michigan	--	--	--	--	0
Minnesota	--	--	--	--	0
Mississippi	--	46	--	--	46
Missouri	--	--	36	--	36
Montana	--	--	--	--	84
Nebraska	--	--	--	--	0
Nevada	67	--	--	--	67
New Hampshire	--	--	--	--	0
New Jersey	--	--	92	--	92
New Mexico	--	--	228	--	228
New York	--	--	19	--	19
North Carolina	--	--	--	--	--
North Dakota	--	--	--	--	52
Ohio	--	--	32	--	32
Oklahoma	--	--	--	--	0
Oregon	--	--	1	--	1
Pennsylvania	173	--	--	--	173
Rhode Island	--	--	1	--	1
South Carolina	--	--	--	--	0
South Dakota	--	--	96	--	96
Tennessee	23	--	--	--	23
Texas	--	--	284	--	285
Utah	--	--	--	--	64
Vermont	--	--	--	--	--
Virginia	82	--	--	--	82
Washington	--	--	--	--	0
West Virginia	--	--	--	--	0
Wisconsin	--	--	--	--	0
Wyoming	--	--	11	--	11

¹See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

Table 16. Summary of median dissolved-solids concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	42	45.0	204	9,790
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	30.5	144	541
California	--	--	--	--
Colorado	212	28.0	190	3,500
Connecticut	32	51.0	98.5	248
Delaware	0	--	--	--
Florida	253	2.0	201	5,960
Georgia	0	--	--	--
Hawaii	--	--	--	--
Idaho	32	29.0	214	517
Illinois	0	--	--	--
Indiana	23	167	350	476
Iowa	28	170	335	600
Kansas	251	143	435	6,250
Kentucky	0	--	--	--
Louisiana	172	44.0	196	9,360
Maine	--	--	--	--
Maryland	12	72.0	238	642
Massachusetts	--	--	--	--
Michigan	0	--	--	--
Minnesota	0	--	--	--
Mississippi	46	.02	37.2	252
Missouri	36	128	201	671
Montana	84	9.0	120	2,920
Nebraska	0	--	--	--
Nevada	67	31.5	159	2,370
New Hampshire	0	--	--	--
New Jersey	92	23.0	136	534
New Mexico	228	28.0	206	8,320
New York	19	42.0	159	438
North Carolina	--	--	--	--
North Dakota	52	158	634	2,190
Ohio	32	208	424	739
Oklahoma	0	--	--	--
Oregon	1	140	140	140
Pennsylvania	173	20.0	160	780
Rhode Island	1	74.0	74.0	74.0
South Carolina	0	--	--	--
South Dakota	96	122	711	3,540
Tennessee	23	85.5	162	262
Texas	285	62.0	507	35,100
Utah	64	98.0	437	3,450
Vermont	--	--	--	--
Virginia	82	26.5	185	773
Washington	0	--	--	--
West Virginia	0	--	--	--
Wisconsin	0	--	--	--
Wyoming	11	65.0	244	1,890

¹Nine or more analyses per site.

26 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

that receive discharge of salt-laden ground water, municipal or industrial discharges, or are affected by oceanic tides. Seawater normally contains about 19,000 mg/L of chloride (Hem, 1992).

Chloride in streams has several natural sources; the dominant source in noncoastal areas probably is the dissolution of marine salt from sedimentary rock formations, particularly evaporite deposits. In contrast, igneous rock is expected to yield little chloride to solution (Hem, 1992). Wet (precipitation) and dry (atmospheric) deposition are secondary sources of chloride to the land surface (Lynch and others, 1996). These sources would have the greatest effects in near-coastal or coastal areas where chloride had been entrained in the atmosphere during the evaporation of seawater or transported by tidal activity.

Natural concentrations of chloride may be enriched by human activities particularly those associated with urbanization. Municipal-sewage discharges may contribute chloride to streams (Phillips, 1994; Pope and Putnam, 1997). Road salt can be a major contaminant of streams in both urban and rural areas. Snowmelt runoff from roads and bridges treated with salt can transport large concentrations of sodium and chloride to streams that can change water chemistry and stress or kill aquatic organisms (U.S. Environmental Protection Agency, 1995).

The chloride ion is one of the most conservative of the major solutes in natural water and does not enter into oxidation or reduction reactions, form solute complexes with other ions, or form salts of low solubility (Hem, 1992). Therefore, concentrations of chloride determined from whole water (total analysis) samples and filtered water (dissolved analysis) samples should be similar.

An inconsistency in parameter codes exists for total and dissolved chloride concentrations between the STORET Legacy and NWIS data-management systems. The STORET Legacy parameter code for total chloride is 00940 (table 4), whereas this same code in the NWIS system represents dissolved chloride. Because of this inconsistency, parameter headings in table 17 were simplified to “Total” and “Dissolved.”

Thirty-nine States had ambient stream-water-quality monitoring sites with at least nine analyses for chloride concentrations (table 17). Most of these chloride concentrations were total analyses; however, 15 States had monitoring sites with determinations of total and (or) dissolved chloride concentrations. New Mexico had 15 monitoring sites operated by the USGS, with analyses for dissolved chloride concentrations only. Other States with USGS-operated monitoring sites with dissolved chloride concentrations only included Connecticut, Idaho, Missouri, New Jersey, Rhode Island, and Wyoming. Because of the suspected similarity in total and dissolved concentrations of chloride, total and dissolved data were combined to create merged State databases with a procedure similar to that used to combine total and dissolved ammonia concentrations previously discussed in this report except that total chloride concentrations (the most commonly reported among the States) was used in preference over dissolved concentrations. The water-quality summary for chloride was conducted on these merged State databases. State medians of monitoring-site median concentrations of chloride ranged from 0 mg/L in

Montana to 7,740 mg/L in Georgia (table 18). The exceptionally large monitoring-site median concentration for Georgia probably is due to its seven monitoring sites being located near the coast on tidal-affected streams subject to chloride fluxes from marine water.

Sulfate

Sulfate is an oxidized form of sulfur and occurs naturally in surface water as a result of weathering of metallic sulfides in igneous and sedimentary rocks. Pyrite (iron disulfide) commonly occurs in sedimentary rocks and coal deposits and can be a major source of sulfate ion when oxidized. This natural oxidation process can be enhanced due to mineral- or coal-mining operations that may expose large quantities of pyrite to weathering. Gypsum (calcium sulfate) also is a source of sulfate in sedimentary rocks (Hem, 1992).

In addition to natural sources, sulfate concentrations in streams may be increased as a result of human activities. As previously indicated, sulfate concentrations in streams in mined areas may be larger than in unmined areas because of weathering of sulfide- or sulfate-bearing minerals (Powell, 1988). Drainage water from irrigated areas, particularly in semiarid lands, may contain large sulfate concentrations as a result of leaching of solutes (Orlob and Ghorbanzadeh, 1981; Sorenson and Schwarzbach, 1991). The additional water supplied by irrigation accelerates the natural leaching process and is especially evident in areas that receive little natural precipitation. The release of sulfur dioxide during the combustion of fossil fuels (Johnson, 1986) may increase stream sulfate concentrations (Smith and Alexander, 1986). The conversion of sulfur dioxide to particulate sulfate is believed to be an aqueous-enhanced chemical reaction in the atmosphere (Lamb and others, 1987). Subsequent wet and dry deposition may increase concentrations of sulfate in surface water.

Determination of sulfate concentrations in whole (total analysis) and filtered (dissolved analysis) water samples should provide similar results because of the ionic nature and solubility of sulfate (Hem, 1992) and because most of the methods for sulfate analysis incorporate a turbidity removal step (Clesceri and others, 1998). Because of the suspected similarity in total and dissolved concentrations of sulfate, total and dissolved data were combined to create merged State databases with a procedure similar to that used to combine State total and dissolved ammonia concentrations previously discussed in this report except total sulfate concentrations (the most commonly reported among the States) was included in preference over dissolved concentrations. The water-quality summary for sulfate was conducted on these merged State databases (table 19).

An inconsistency in parameter codes exists for total and dissolved sulfate concentrations between the STORET Legacy and NWIS data-management systems. The STORET Legacy parameter code for total sulfate is 00945 (table 4), whereas this same code in the NWIS represents dissolved sulfate. Because of this inconsistency, parameter headings in table 19 were simplified to “Total” and “Dissolved.”

Table 17. Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for total and dissolved chloride concentrations in water, 1990–98.

[--, not available]

State	Number of sites with indicated analysis		Number of sites in merged database
	Total	Dissolved	
Alabama	45	--	45
Alaska	--	--	--
Arizona	--	--	--
Arkansas	131	--	131
California	--	--	--
Colorado	--	--	0
Connecticut	--	31	31
Delaware	95	--	95
Florida	600	149	653
Georgia	7	--	7
Hawaii	--	--	--
Idaho	--	35	35
Illinois	7	--	7
Indiana	15	--	15
Iowa	6	--	6
Kansas	168	152	251
Kentucky	60	--	60
Louisiana	172	--	172
Maine	--	--	--
Maryland	--	--	0
Massachusetts	--	--	--
Michigan	93	--	93
Minnesota	10	--	10
Mississippi	56	--	56
Missouri	--	35	35
Montana	48	84	132
Nebraska	22	--	22
Nevada	--	67	67
New Hampshire	12	--	12
New Jersey	--	92	92
New Mexico	116	15	131
New York	19	--	19
North Carolina	--	--	--
North Dakota	--	52	52
Ohio	40	--	40
Oklahoma	177	--	177
Oregon	--	4	4
Pennsylvania	41	--	41
Rhode Island	--	5	5
South Carolina	14	--	14
South Dakota	8	--	8
Tennessee	1	--	1
Texas	495	--	495
Utah	--	64	64
Vermont	--	--	--
Virginia	897	--	897
Washington	--	--	0
West Virginia	25	--	25
Wisconsin	47	1	47
Wyoming	--	19	19

Table 18. Summary of median chloride concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	45	3.0	12.0	5,160
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	1.9	4.8	124
California	--	--	--	--
Colorado	0	--	--	--
Connecticut	31	9.6	19.0	51.0
Delaware	95	8.0	27.0	12,900
Florida	653	1.6	23.0	4,260
Georgia	7	67.1	7,740	14,500
Hawaii	--	--	--	--
Idaho	35	.25	5.0	67.0
Illinois	7	24.8	99.6	144
Indiana	15	11.0	41.0	190
Iowa	6	21.1	22.8	23.4
Kansas	251	4.6	29.6	3,220
Kentucky	60	2.3	6.5	36.5
Louisiana	172	2.8	18.3	5,320
Maine	--	--	--	--
Maryland	0	--	--	--
Massachusetts	--	--	--	--
Michigan	93	2.0	31.5	188
Minnesota	10	7.2	12.0	25.0
Mississippi	56	0	5.6	19.7
Missouri	35	2.2	6.4	136
Montana	132	0	0	36.0
Nebraska	22	1.0	16.6	52.4
Nevada	67	0	5.6	395
New Hampshire	12	10.0	26.5	69.0
New Jersey	92	4.3	23.5	220
New Mexico	131	1.6	5.2	2,140
New York	19	3.8	18.0	96.0
North Carolina	--	--	--	--
North Dakota	52	<3.0	14.6	922
Ohio	40	10.0	36.0	162
Oklahoma	177	2.1	<10.0	1,720
Oregon	4	1.6	2.8	17.0
Pennsylvania	41	.66	10.0	63.0
Rhode Island	5	14.0	51.0	57.8
South Carolina	14	8.5	12.9	10,000
South Dakota	8	2.0	24.4	92.0
Tennessee	1	18.0	18.0	18.0
Texas	495	5.0	73.0	17,600
Utah	64	2.5	31.6	792
Vermont	--	--	--	--
Virginia	897	.6	9.5	16,700
Washington	0	--	--	--
West Virginia	25	1.6	6.0	24.4
Wisconsin	47	2.0	11.4	158
Wyoming	19	.20	4.5	140

¹Nine or more analyses per site.

Table 19. Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for total and dissolved sulfate concentrations in water, 1990–98.

[--, not available]

State	Number of sites with indicated analysis		Number of sites in merged database
	Total	Dissolved	
Alabama	--	--	0
Alaska	--	--	--
Arizona	--	--	--
Arkansas	131	--	131
California	--	--	--
Colorado	215	--	215
Connecticut	--	32	32
Delaware	--	--	0
Florida	506	144	593
Georgia	--	--	0
Hawaii	--	--	--
Idaho	--	37	37
Illinois	3	--	3
Indiana	12	--	12
Iowa	6	--	6
Kansas	168	152	251
Kentucky	--	59	59
Louisiana	172	--	172
Maine	--	--	--
Maryland	12	--	12
Massachusetts	--	--	--
Michigan	64	--	64
Minnesota	1	--	1
Mississippi	2	--	2
Missouri	--	34	34
Montana	72	91	163
Nebraska	--	--	0
Nevada	--	66	66
New Hampshire	8	--	8
New Jersey	--	92	92
New Mexico	58	59	132
New York	19	--	19
North Carolina	--	--	--
North Dakota	--	52	52
Ohio	36	--	36
Oklahoma	178	--	178
Oregon	--	--	0
Pennsylvania	174	--	174
Rhode Island	--	5	5
South Carolina	5	--	5
South Dakota	8	--	8
Tennessee	2	--	2
Texas	481	--	481
Utah	--	64	64
Vermont	--	--	--
Virginia	894	--	894
Washington	--	--	0
West Virginia	26	--	26
Wisconsin	17	--	17
Wyoming	--	19	19

Thirty-six States had ambient stream-water-quality monitoring sites with at least nine analyses for sulfate concentrations in stream water (table 19). Most of these sulfate concentrations were total analyses; however, 14 States had monitoring sites with determinations of total and (or) dissolved sulfate concentrations. Many of the monitoring sites in States with dissolved sulfate concentrations were operated by the USGS, which only analyzed for dissolved sulfate concentrations. These USGS-operated monitoring sites were in the same States as previously identified in the “Chloride” section of this report. State medians of monitoring-site median concentrations of sulfate ranged from 6.5 mg/L in New Hampshire to 232 mg/L in North Dakota (table 20).

pH

pH is a measure of the hydrogen-ion activity in a water sample and by definition is the negative base-10 logarithm of the hydrogen-ion activity ($-\log_{10} H^+$) (Hem, 1992). pH measurements of natural water serve as an indicator of acid-base equilibrium of various dissolved compounds, salts, and gases. The principal equilibrium system controlling pH in natural water is the carbonate system—carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^{-1}), and carbonate ion (CO_3^{-2}) (U.S. Environmental Protection Agency, 1986). The degree of dissociation of weak acids, bases, and salts (compounds) is affected by changes in pH that subsequently can affect the toxicological properties of those and other compounds (Franklin and others, 2000; Pyle and others, 2002). Therefore, knowledge of the pH of natural water may provide insight into the potential for detrimental effects on aquatic ecosystems.

Uncontaminated stream water generally has a pH in the range of 6.5 to 8.5 standard units (Hem, 1992) and may display diurnal fluctuations similar to those for dissolved oxygen (Simonsen and Harremoes, 1978). These diurnal pH fluctuations probably are associated with photosynthetic/respiratory processes of aquatic organisms that use dissolved carbon dioxide during the day and release it at night. Snowmelt runoff, which may increase during the warmth of the day and decrease during the cool of the night, also may produce diurnal pH fluctuations.

All 42 States with electronically accessible pH measurements in water from ambient stream-water-quality monitoring sites had these data stored in STORET Legacy, NWIS, or State databases under a single parameter code (00400, table 4) or as “pH” in the modern STORET system. Therefore, a data-merge procedure was not necessary for pH measurements. State medians of the monitoring-site median measurements of pH ranged from 6.7 standard units in Rhode Island and South Carolina to 8.2 standard units in several other States (table 21).

Limitations of State Ambient Stream-Water-Quality Data for National Assessment

The use of stream-water-quality data from State ambient monitoring networks has certain inherent limitations for producing a “picture” of national water-quality conditions. The Clean Water Act granted the States the independence to establish stream-water-quality monitoring networks to fulfill the requirements of the act and to develop monitoring procedures and protocols to satisfy unique blends of ecological, social, political, and economic conditions within each State. The very nature of this independence, however, created potential variability in the factors necessary to produce a nationally consistent water-quality assessment. These factors include (1) the basic spatial design of monitoring networks (selection of streams and location of monitoring sites); (2) water-quality constituents for which samples are analyzed; (3) water-quality criteria to which constituent concentrations are compared; (4) quantity and comprehensiveness of water-quality data; (5) sample collection, processing, and handling; (6) analytical methods; (7) temporal variability in sample collection; and (8) quality-assurance practices implemented to ensure reliability in data produced. National assessment of ambient stream-water quality using State-generated databases, therefore, consists of a compilation of 50 individual monitoring networks with varying degrees of comparability. Furthermore, in a study of water-quality assessment procedures of the Great Lake States, the Environmental Integrity Project (2004) concluded that no meaningful attempt to standardize or analyze widely disparate State approaches to water-quality assessment has been conducted and that the biannual National Water Quality Inventory reports may not present a true picture of national or regional water-quality conditions. USEPA (2004) also has recognized that many of these factors make it “...difficult to use existing data to give a complete and accurate picture of the state of U.S. surface waters to support aquatic life... .” Although a detailed evaluation of the variability among States in all these factors was beyond the resources and scope of the investigation described in this report, aspects of factors 1–4 will be discussed relative to the variability among State ambient stream-water-quality programs identified in this or previous reports.

Design of Monitoring Networks

The implementation of water-quality monitoring is a key aspect of the Clean Water Act. Monitoring forms the basis of environmental assessment, the ability to determine time trends in water quality, and provides the information required for regulatory decisions related to contaminant-load allocation (total maximum daily loads), discharge permitting, and human health. Without reliable stream-water-quality data, government agencies, the Congress, and the public can not make the informed decisions necessary to protect and conserve the Nation’s water resources.

Table 20. Summary of median sulfate concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

State	Number of assessed monitoring sites ¹	Monitoring-site median concentration (milligrams per liter)		
		Minimum	Median	Maximum
Alabama	0	--	--	--
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	2.7	9.9	181
California	--	--	--	--
Colorado	215	<5.0	41.0	1,920
Connecticut	32	5.5	11.0	31.0
Delaware	0	--	--	--
Florida	593	0	12.1	651
Georgia	0	--	--	--
Hawaii	--	--	--	--
Idaho	37	.60	17.0	120
Illinois	3	70.0	85.0	108
Indiana	12	24.0	40.0	86.5
Iowa	6	38.8	58.1	78.4
Kansas	251	10.1	81.5	2,170
Kentucky	59	5.5	31.0	290
Louisiana	172	1.4	10.7	728
Maine	--	--	--	--
Maryland	12	27.8	122	650
Massachusetts	--	--	--	--
Michigan	64	3.0	29.0	82.0
Minnesota	1	12.0	12.0	12.0
Mississippi	2	<10.0	15.4	15.4
Missouri	34	2.3	15.0	160
Montana	163	0	13.0	2,980
Nebraska	0	--	--	--
Nevada	66	0	12.5	960
New Hampshire	8	1.0	6.5	7.0
New Jersey	92	4.2	18.0	54.0
New Mexico	132	<5.0	21.6	4,700
New York	19	6.1	16.5	82.5
North Carolina	--	--	--	--
North Dakota	52	12	232	742
Ohio	36	38.0	85.2	160
Oklahoma	178	1.3	12.4	1,870
Oregon	0	--	--	--
Pennsylvania	174	4.1	28.0	348
Rhode Island	5	6.8	19.0	20.9
South Carolina	5	<10.0	<10.0	22.0
South Dakota	8	15.6	208	400
Tennessee	2	107	147	187
Texas	481	2.3	52.6	3,340
Utah	64	9.8	75.4	1,640
Vermont	--	--	--	--
Virginia	894	1.2	11.8	2,240
Washington	0	--	--	--
West Virginia	26	10.0	23.2	190
Wisconsin	17	<5.0	31.0	76.0
Wyoming	19	2.2	54.4	940

¹Nine or more analyses per site.

Table 21. Summary of median pH measurements in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available]

State	Number of assessed monitoring sites ¹	Monitoring-site median measurement (standard units)		
		Minimum	Median	Maximum
Alabama	45	5.1	7.4	7.9
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	6.2	7.3	8.2
California	--	--	--	--
Colorado	205	4.6	8.1	9.1
Connecticut	32	7.1	7.4	8.2
Delaware	103	6.5	7.2	8.0
Florida	690	3.8	7.0	8.4
Georgia	284	3.9	7.0	7.9
Hawaii	--	--	--	--
Idaho	51	7.1	8.2	8.7
Illinois	11	7.2	7.6	8.3
Indiana	101	7.4	7.8	8.2
Iowa	36	7.9	8.2	8.5
Kansas	247	6.9	8.0	8.6
Kentucky	60	6.6	7.5	8.0
Louisiana	172	5.9	7.1	8.0
Maine	--	--	--	--
Maryland	40	7.0	7.8	8.3
Massachusetts	--	--	--	--
Michigan	79	7.3	8.0	8.3
Minnesota	66	7.5	8.2	8.4
Mississippi	66	6.0	7.1	7.8
Missouri	38	7.2	7.9	8.2
Montana	276	2.8	7.6	8.8
Nebraska	22	7.9	8.1	8.3
Nevada	35	7.8	8.2	8.7
New Hampshire	55	6.1	7.0	7.6
New Jersey	89	4.3	7.6	8.3
New Mexico	211	4.6	8.2	9.0
New York	19	7.3	7.7	8.3
North Carolina	--	--	--	--
North Dakota	72	7.2	8.2	8.7
Ohio	39	7.0	8.0	8.3
Oklahoma	133	2.6	7.5	8.5
Oregon	140	6.8	7.6	8.6
Pennsylvania	174	4.6	7.4	8.3
Rhode Island	5	6.6	6.7	6.9
South Carolina	339	5.4	6.7	8.0
South Dakota	96	4.8	8.2	8.7
Tennessee	43	6.2	7.3	7.9
Texas	546	6.0	7.8	8.9
Utah	64	7.8	8.2	8.5
Vermont	--	--	--	--
Virginia	898	3.7	7.2	8.4
Washington	207	6.8	7.6	8.7
West Virginia	24	6.8	7.6	8.3
Wisconsin	38	7.1	7.9	8.6
Wyoming	36	7.6	8.2	8.6

¹Nine or more analyses per site.

Stream-water-quality monitoring data are produced from networks composed of monitoring sites (specific locations on streams) from which streamflow samples are collected over some specified interval of time. Although this is a simplistic description, monitoring networks, in practice, are composed of a complex set of operational variables that can make individual State networks functionally unique and may restrict the State-to-State comparability necessary to produce a national assessment of stream-water quality. Network operational variables include (1) the basic design option (census, judgemental or targeted, statistical or probabilistic survey), (2) type of monitoring network (physical, chemical, biological), (3) selections of streams and sampling locations on streams, and (4) temporal coverage (hour, day, week, month, or year).

Variability in network design stems from a need for States to meet State-defined water-quality management objectives, which may not be limited solely to Clean Water Act goals. Other objectives may include acquisition of data to establish water-quality criteria, determination of water-quality status and trends—including areal and temporal extent of known contamination, identification of causes and sources of water-quality problems, implementation and evaluation of water-quality management programs, and calculation of constituent transport (U.S. Environmental Protection Agency, 2003b).

These objectives are met by the States, in part, through the design of their ambient stream-water-quality monitoring networks. The census option, or monitoring of all streams and rivers within a State, is rarely, if ever, used as the sole monitoring design because of the staff and funding necessary to conduct such an ambitious effort. More commonly used in State monitoring networks are the judgemental- or statistical-based design options (U.S. General Accounting Office, 2002). The judgemental design may target monitoring-site locations or limited monitoring resources on areas with suspected or known water-quality problems or on areas that are used frequently by the public. The statistical-based option uses randomized site-selection processes to provide statistically valid information that may be extrapolated to all State water of a similar type. In reality, States may use a combination of design options to fulfill the requirements of State-defined water-quality objectives.

The type of monitoring networks used for ambient stream-water-quality assessment may vary among States. Most States use some form of physical and chemical water-quality analysis for assessment purposes to meet the objectives of the Clean Water Act. Some of these physical and chemical water-quality constituents were summarized in this report, but States often analyze for a much broader suite of constituents to include pesticides, volatile organic chemicals, and toxic contaminants. Some States (Maine and Vermont, for example) rely almost exclusively on biological monitoring, whereas others such as Illinois, Kansas, New York, and Ohio incorporate physical, chemical, and biological data into their 305(b) assessments (U.S. General Accounting Office, 2002).

The criteria and rationale used in selection of streams and sampling sites to assess may be keyed to the network design chosen by the States. For example, a substantial reliance on

statistical-survey design will dictate stream and site selection on the basis of random selection, whereas target-based designs may incorporate more professional judgement in selection of suspected or known problem areas or areas with intensive human-use activity. Other factors that may control or limit site selection include the need for point- or nonpoint-source definition, a desire to “piggy back” upon other State or Federal water programs and sites such as the USGS streamgaging network, or requests or constraints mandated from political or economic entities. The variability among States in network design, type of monitoring, and stream and site selection makes a compilation of State data into a national picture of stream-water quality problematic.

Prior to the mid-1980s, no program existed to integrate information from the local or regional scale to the national scale to provide a consistent description of water quality across the Nation and insight on the major factors that control water quality in different regions. Hirsch and others (1988) outlined a national assessment design (program) that would integrate information from a large set of hydrologic systems to provide regional and national overviews. Results from hydrologic study units would be linked together by a core set of consistent operational protocols that include (1) study approaches, (2) sample collection, processing, and handling, (3) laboratory methods and quality assurance, (4) selection of water-quality constituents, (5) collection of ancillary information pertinent to the hydrologic setting and possible cause-and-effect relations, and (6) storage of all assessment data. This proposed design evolved into the USGS National Water-Quality Assessment (NAWQA) Program.

Implemented in 1991, the purpose of the NAWQA Program is to describe the status of current water-quality conditions, long-term trends (or lack of trends) in water quality, and to identify, describe, and explain possible cause-and-effect relations for the water-quality conditions (Gilliom and others, 1995). Information from individual hydrologic study units (river basins or ground-water systems) would provide detailed descriptions of local and regional water-quality conditions, identify water-quality concerns and problem areas, and provide the consistent data necessary for national assessments (national synthesis) of priority water-quality issues such as nutrients, pesticides, volatile organic contaminants, and trace elements.

National synthesis integrates information from individual study units into multiple study-unit analyses and incorporates existing information from other agencies and researchers to produce regional- and national-scale assessments. National synthesis develops comprehensive assessments issue by issue at the national scale by comparative analysis of study-unit findings (Gilliom and others, 1995). These comparative analyses are possible only because of the consistency in assessment network design and operation among the study units. The regular accumulation of consistent and comparable water-quality assessments for some of the largest and most important hydrologic systems of the Nation provides a major contribution to the knowledge of regional and national water quality (National Research Council, 2002).

Selection of Water-Quality Constituents and Criteria

The selection of water-quality constituents for which States choose to analyze may have substantial effect on the utility of State ambient stream-water-quality data to provide a reliable national water-quality assessment. It was previously mentioned that the type of stream-water-quality monitoring (physical, chemical, biological) that States conduct may vary. This lack of commonality in monitoring practices makes direct State-to-State comparisons difficult. Not only is it difficult to make water-quality comparisons among States, but also, variability in monitoring practices within States (among monitoring sites) makes it difficult to get reliable pictures of within State water-quality conditions when the types and number of water-quality constituents vary among the sites.

USEPA (2002c) has determined that some of the most common causes of streams being listed in State 303(d) reports (degraded water quality) are the result of excessive concentrations of sediment, bacteria, nutrients, and metals. All States, however, do not analyze for the same set of water-quality constituents. For example, electronically accessible fecal coliform bacteria data were not available for Delaware, Indiana, or Michigan, seven other States had data for less than 10 monitoring sites (table 8), and total phosphorus concentrations were not available for monitoring sites in New York (table 13).

Differences in data collected among monitoring sites within States produce a skewed or biased overall assessment of water quality for the States. For example, Oklahoma had 14 monitoring sites with nine or more analyses for fecal coliform bacteria (table 8), but substantially more monitoring sites were analyzed for total phosphorus (194; table 13), chloride (177; table 17), and pH (133; table 21). Median monitoring-site densities of fecal coliform bacteria were relatively large in Oklahoma (50 to 2,150 col/100 mL; table 8), so it is possible that water at many of these sites may have been assessed as degraded, but because the 14 monitoring sites represent only a small percentage of all the sites potentially assessed, the percentage of stream miles degraded for sanitary quality may be small relative to what it may have been had more of the total number of monitoring sites been assessed. The variability in constituents analyzed among monitoring sites within a State and among the States also makes an assessment of national water-quality conditions from State databases problematic.

Most stream-water-quality constituents analyzed by States have associated criteria to measure whether the designated use of the stream is being achieved. USEPA (1999a; 1999b) has recommended water-quality criteria for aquatic-life protection for many of the constituents summarized in this report (table 22). Public drinking-water criteria (U.S. Environmental Protection Agency, 2002b) also exist for most of these constituents. USEPA currently (2004) has not implemented water-quality criteria for suspended solids, fecal coliform bacteria, or total phosphorus. States have the flexibility, however, to establish their own stream-water-quality criteria for aquatic-life protection on the basis of unique sets of conditions that include designated uses of streams, ecological characteristics such as

aquatic-life community structure, and State-determined concentration levels necessary for protection of human health through direct or indirect contact. The resulting variability in these water-quality criteria among the States reduces the potential for State-generated assessments of ambient stream-water quality to produce a national perspective of water-quality conditions.

Some water-quality constituents, such as suspended solids, do not have numeric criteria in most States. Instead, these States use a narrative criteria that generally state that the occurrence of suspended material in rivers and streams shall not be of such magnitude as to inhibit the intended use of the water and shall not have a detrimental effect on growth or reproduction of aquatic life. However, five States (Hawaii, Nevada, New Jersey, South Dakota, and Utah) do have numeric criteria for suspended solids, which range from a minimum concentration of 35 mg/L in Utah to a maximum of 158 mg/L in South Dakota (U.S. Environmental Protection Agency, 2001b). The absence of numeric criteria for most States introduces subjectivity into the water-quality assessment process and reduces the comparability of State assessments and the potential for collating these assessments into a reliable national perspective of stream-water quality.

In contrast to the absence of State numeric criteria for suspended solids, the States generally had numeric criteria for fecal coliform bacteria (table 23). Primary contact recreation criteria range from 50 (Washington) to 1,000 col/100 mL (colonies per 100 mL of water) in four States. The larger criteria, however, generally are single-sample (SS) criteria, whereas most State criteria are expressed as a geometric mean (GM). The GM is the mean of the logarithms of data transformed back to the original unit of measure and, in positively skewed or log-normally distributed data, approximates the median (Helsel and Hirsch, 1995). As defined by USEPA, a GM for bacteria is the GM of at least five samples collected in separate 24-hour periods during a 30-day period (U.S. Environmental Protection Agency, 2000a). However, few States collect the required five bacteria samples in a 30-day period necessary for calculation of a USEPA-defined geometric mean; therefore, in practice States either have not assessed streams for degradation relative to fecal bacteria, used the geometric mean of the data available or some other measure of central tendency, or compared bacteria densities to the numeric value of the geometric mean. Because few sites had more than one bacteria sample in a single 30-day period, the geometric mean for that period is the same as the single-sample value.

Fewer States have a secondary contact recreation criterion for fecal coliform bacteria than have a primary contact recreation criterion (table 23). Secondary contact recreation is defined as activities where ingestion of water is unlikely, such as fishing or wading. State criteria for secondary contact recreation range from 200 col/100 mL in five States to 5,000 col/100 mL in Ohio.

The criteria discussion for bacteria presented in this report was restricted to fecal coliform bacteria, the most common measure of sanitary quality of streams in the 1990s. However,

Table 22. Selected water-quality criteria for State ambient stream-water-quality data.

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters of water; N, nitrogen; P, phosphorus; µg/L, micrograms per liter; CMC, Criterion Maximum Concentration; CCC, Criterion Continuous Concentration; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulation (nonenforceable recommendations); HAL, Health Advisory Level; --, not available]

Water-quality constituent or measurement	U.S. Environmental Protection Agency criteria					
	Stream-water-quality goal	Aquatic life ¹		Public drinking water ²		
		CMC	CCC	MCL	SDWR	HAL
Solids, suspended, mg/L	--	--	--	--	--	--
Bacteria, fecal coliform, col/100 mL	--	--	--	0	--	--
Ammonia, total, as N, mg/L	--	³ --	⁴ --	--	--	30
Nitrite plus nitrate, total, as N, mg/L	--	--	--	10	--	--
Phosphorus, total, as P, mg/L	⁵ 0.10	--	--	--	--	--
Arsenic, total, µg/L	--	340	150	10	--	--
Solids, dissolved, mg/L	--	--	--	--	500	--
Chloride, total, mg/L	--	860	230	--	250	--
Sulfate, total, mg/L	--	--	--	--	250	--
pH, standard units	--	--	6.5–9.0	--	6.5–8.5	--

¹U.S. Environmental Protection Agency (1999a).

²Criteria apply to post-treatment water; U.S. Environmental Protection Agency (2002b).

³pH dependent; U.S. Environmental Protection Agency (1999b).

⁴pH and temperature dependent; U.S. Environmental Protection Agency (1999b).

⁵U.S. Environmental Protection Agency (1986).

USEPA (1986, 2000a) has recommended and some States have adopted the use of *Escherichia coli* (*E. coli*) bacteria as the indicator organism for sanitary quality. For example, Kansas made the switch to *E. coli* in 2003.

USEPA currently (2004) has a recommended, nonenforceable water-quality goal of 0.10 mg/L for total phosphorus in rivers and streams (U.S. Environmental Protection Agency, 1986). Ecoregion-specific criteria for total phosphorus currently (2004) are being or have been developed through a collaborative partnership between the States and USEPA. These criteria range from 0.01 to 0.128 mg/L. Information concerning this development process and resultant ecoregion-specific criteria may be found on the World Wide Web at URL <http://www.epa.gov/ost/standards/nutrient.html> (accessed July 1, 2003).

Differences in water-quality constituents analyzed and the criteria to which the resultant concentrations are compared make it difficult to use State stream-water-quality data or State water-quality assessments to produce a national picture of ambient stream-water-quality conditions (U.S. General Accounting Office, 2002). These differences are the result of

the selection of constituents that States choose to emphasize, the phase for which constituents are analyzed (total or dissolved), the designated uses that States apply to streams, and the water-quality criteria associated with these uses. Criteria differences among the States may result in different rates of stream degradation and limit State-to-State comparability. The reliance on narrative instead of numeric criteria also limits the comparability of State data or assessment results as presented in their biannual 305(b) reports. These limitations reduce the development of a reliable national water-quality assessment using these data.

Quantity and Comprehensiveness of Water-Quality Data

States vary in the quantity of ambient stream-water-quality data collected and comprehensiveness in geographical coverage of those data and type and number of constituents analyzed. This variability, in part, limits the use of State water-quality data or assessments of those data to compile a reliable picture of national water-quality conditions and restricts the capability to

Table 23. Fecal coliform bacteria criteria for primary and secondary contact recreation for streams in 50 States.

[GM, geometric mean of at least five samples collected in separate 24-hour periods during a 30-day period; SS, single sample; --, no criteria or not available]

State	Fecal coliform bacteria criteria ¹ (colonies per 100 milliliters of water)	
	Primary contact	Secondary contact
Alabama	200 (GM)	2,000 (GM)
Alaska	200 (GM)	--
Arizona	200 (GM)	1,000 (GM)
	800 (SS)	4,000 (SS)
Arkansas	200 (GM)	1,000 (GM)
California	200 (GM)	2,000 (GM)
Colorado	200 (GM)	2,000 (GM)
Connecticut	200 (GM)	--
Delaware	--	--
Florida	200 (GM)	--
Georgia	200 (GM)	1,000 (GM)
	--	4,000 (SS)
Hawaii	200 (GM)	--
Idaho	--	--
Illinois	200 (GM)	--
Indiana	--	--
Iowa	200 (GM)	--
Kansas	200 (GM)	2,000 (SS)
Kentucky	200 (GM)	1,000 (GM)
Louisiana	200 (GM)	1,000 (GM)
Maine	--	--
Maryland	--	--
Massachusetts	200 (GM)	1,000 (GM)
Michigan	--	--
Minnesota	200 (GM)	--
Mississippi	200 (GM)	2,000 (GM)
Missouri	200 (GM)	--
Montana	200 (GM)	--
Nebraska	200 (GM)	--
Nevada	200 (GM)	2,000 (GM)
New Hampshire	--	--
New Jersey	200 (GM)	--
New Mexico	200 (GM)	--
	400 (SS)	--
New York	200 (GM)	2,000 (GM)
North Carolina	200 (GM)	200 (GM)
North Dakota	200	--
Ohio	1,000 (GM)	5,000 (GM)
Oklahoma	200 (GM)	--
Oregon	126 (GM)	--
	406 (SS)	--
Pennsylvania	200 (GM)	2,000 (GM)
Rhode Island	200 (GM)	200 (GM)
South Carolina	200 (GM)	200 (GM)
South Dakota	200 (GM)	1,000 (GM)
	400 (SS)	2,000 (SS)
Tennessee	200 (GM)	--
	1,000 (SS)	--
Texas	200 (GM)	2,000 (GM)
Utah	200 (GM)	200 (GM)
Vermont	200 (GM)	--
	1,000 (SS)	--
Virginia	200 (GM)	--
	1,000 (SS)	--
Washington	50–100 (GM)	200 (GM)
West Virginia	200 (GM)	2,000 (GM)
Wisconsin	200 (GM)	--
Wyoming	200 (GM)	--

¹U.S. Environmental Protection Agency (2001b).

answer status and trends questions about the nation's stream-water quality.

An analysis of the quantity of electronically available water-quality data was conducted by determining the number of monitoring sites in each State that had selected numbers of analyses of the 10 water-quality constituents examined in this report (tables 25–34 in the “Supplemental Information” section at the back of this report). States do not necessarily analyze ambient stream-water samples for the same water-quality constituents or to the same extent. Nationally, more than 9,000 monitoring sites had one or more analysis for total phosphorus (table 29) and pH (table 34), but less than 3,500 sites had one or more analysis for total arsenic (table 30). The presence of arsenic in streams is found mostly near where it occurs naturally in soils and rocks, and the geographic variability in the natural occurrence of arsenic in soil and rocks is probably responsible for much of this difference in State emphasis on arsenic.

Relative to the number of monitoring sites with total phosphorus and pH data, other constituents showed marked reductions in the number of monitoring sites with electronically available data for 1990–98. For example, slightly less than 6,100 monitoring sites (nationally) had one or more analyses for fecal coliform bacteria (table 26), about a 33-percent reduction in the number of sites relative to those numbers of total phosphorus and pH. Much of this difference may be attributable to operational constraints in the collection and analysis of bacterial samples. Holding times (time between collection and analysis) for bacterial samples generally are short relative to many chemical constituents. These reduced holding times may increase sample transportation costs as well as staff time for collection and analysis. Increases in sample collection and analysis costs for some State programs may be offset with reductions in the number of sites at which data are collected.

In addition to differences in the number of monitoring sites with selected constituents, monitoring sites have different numbers of analyses of particular constituents (tables 25–34; fig. 2). USEPA (2002a) recommended a minimum of 30 water-quality analyses at monitoring sites for degradation assessment purposes; however, on average (for the 10 constituents evaluated in this report) only about 30 percent (fig. 3) of the monitoring sites (relative to the number with one or more analyses) examined had the quantity of electronically available data that met this minimum recommendation between 1990 and 1998. Substantial reduction in monitoring sites reduces the spatial distribution and (or) density of monitoring sites possibly to a point (1) that States may not meet the requirement of the Clean Water Act to assess all surface water (U.S. Environmental Protection Agency, 2002a), (2) that State assessments may be biased toward the water-quality characteristics of larger river systems where long-term (more samples collected) monitoring sites may predominate, or (3) that the overall quality or representativeness of the State assessment may be reduced.

The information presented in figures 2 and 3 provided some insight into the relation between the availability of monitoring sites and numbers of analyses; however, the figures do not provide information on the extent of State ambient stream-

water-quality monitoring networks and the comprehensiveness of databases relative to the modest number of commonly collected water-quality constituents assessed in this report. An effort to describe this extent and comprehensiveness was conducted by determining the number of ambient stream-water-quality sites in each State that met selected combinations of number of available constituents and minimum number of analyses of each constituent (table 24).

The first category of ambient stream-water-quality monitoring sites in table 24 (sites with 1 or more of the 10 constituents assessed in this report each with nine or more analyses) represents the maximum in available monitoring sites and, potentially, the minimum in comprehensive data requirements. The nine or more required analyses is the same summary criterion used in previous sections of this report. The other three categories are attempts to increase the overall comprehensiveness of State databases relative to the constituents summarized in this report and required either 8 or more constituents or all 10 constituents. Also required are either 9 or more analyses per constituent or 30 or more analyses per constituent. The nine-analysis criterion was chosen to represent an average of one analysis per year for the period used in this report (1990–98). The 30-analysis criterion was chosen to correspond to the minimum number of analyses recommended by USEPA (2002a) for decisions on water quality.

The number of ambient stream-water-quality monitoring sites with at least one water-quality constituent (or measurement) with nine or more analyses ranged from 5 in Rhode Island to 1,139 in Virginia (table 24). Possible reasons for this variability among the 42 States assessed were discussed in previous sections of this report. Nationally, these 42 States had 6,783 monitoring sites that met the aforementioned criteria.

Large reductions in numbers of available monitoring sites occurred as the minimum requirements for both numbers of constituents per site and number of analyses per constituent increased. The number of available monitoring sites with 8 or more of the 10 constituents assessed in this report with at least nine analyses decreased to a national total of 3,148 (decrease of 54 percent) in 37 States (table 24). Five States with data used in this report had no sites that met this data criteria, and eight States had less than 10 sites. Only 230 monitoring sites nationally (in nine States) had at least 9 analyses for all 10 constituents assessed in this report. When the USEPA minimum recommendation of 30 analyses per constituent was factored in (10 constituents each with 30 or more analyses, table 24), only 73 monitoring sites nationally (in five States) met those criteria. This analysis indicated that some State ambient stream-water-quality networks are lacking in the comprehensiveness of collected data, at least relative to the common constituents summarized in this report, and most monitoring sites in those networks do not have the number of analyses recommended by USEPA to make appropriate degradation and, ultimately, total maximum daily loads decisions.

USGAO (2002) identified differences in State approaches in identifying water-quality degraded surface water (rivers,

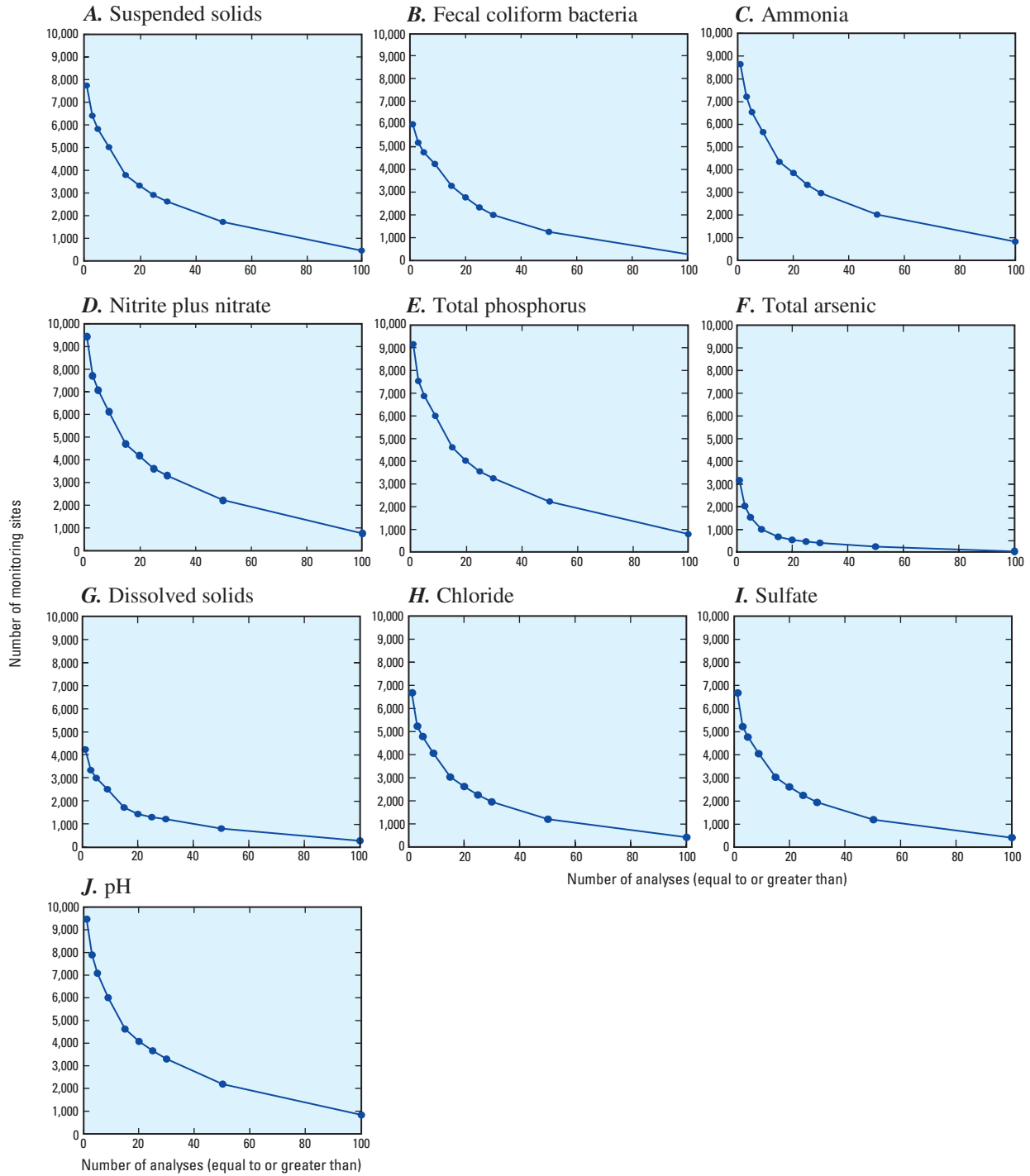


Figure 2. Relations between numbers of ambient stream-water-quality monitoring sites (nationally) and selected minimum numbers of electronically available data for 10 water-quality constituents or measurements.

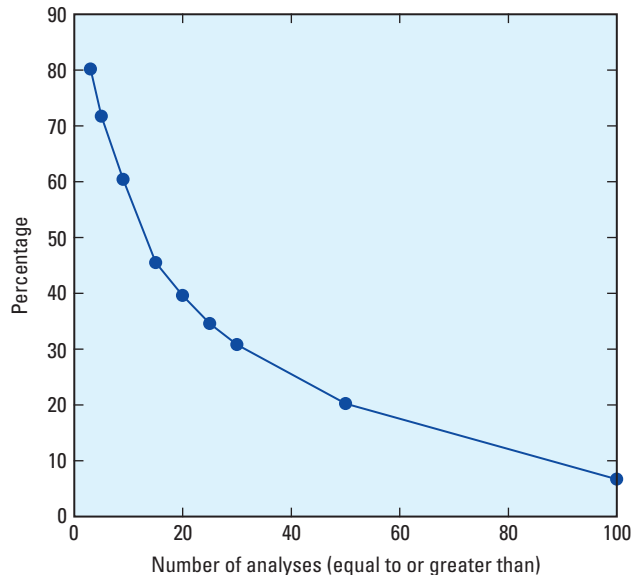


Figure 3. Relation between the national average percentage of monitoring sites for 10 water-quality constituents or measurements and selected minimum numbers of electronically available data.

streams, and lakes). Some of these differences among the States were inherent to the implementation of the Clean Water Act, which allowed USEPA, in administering the act, some flexibility for the States to develop assessment approaches that were appropriate to their specific ecological and environmental conditions. However, as noted by USGAO (2002), some of the variations in approach have no appropriate scientific basis.

Information obtained from the investigation described in this report verified some of the inconsistencies noted by USGAO (2002). Most notable is the variability in characteristics of State stream-water-quality monitoring networks such as the number of monitoring sites and water-quality analyses. Additional inconsistencies among States include numeric water-quality criteria, particularly for fecal coliform bacteria (table 23) and to a lesser degree the absence of or variability in numeric criteria for suspended solids. National monitoring is, in reality, a compilation of 50 State networks with varying degrees of comparability. Differences among the States in water-quality criteria and methodologies used in data assessment and water-quality degradation decisions restrict comparability among the States and limit the consistency needed to produce a national assessment of ambient water quality. An analysis of the extent and comprehensiveness of State ambient stream-water-quality networks for this report indicated that these networks may be lacking in the diversity of collected data and that many monitoring sites in those networks have few samples and do not have the number of analyses recommended by USEPA to make appropriate degradation and total maximum daily loads decisions.

Because of the differences and inconsistencies among State ambient stream-water-quality monitoring programs, a scientifically defensible national assessment of stream-water

quality for 1990–98 could not be made with the State databases produced for the investigation described in this report. Some efforts have been made by USEPA (2002a) to produce a more uniform system of network operations and assessment of water-quality data. However, the task is enormous and will require much coordination with and cooperation between the States and USEPA to develop common ground in collection, analysis, evaluation, and assessment of stream-water-quality data before reliable, scientifically defensible national water-quality assessments are possible.

Summary and Conclusions

Ambient stream-water-quality data were electronically acquired for 10 water-quality constituents or measurements, stored in a relational-based database (by State), and statistically summarized. The electronic availability of data varied among the States. Forty-two States had pH data from ambient stream monitoring sites, whereas only 26 States had total arsenic data. Electronically accessible data were not available for Alaska, Arizona, California, Hawaii, Maine, Massachusetts, North Carolina, and Vermont.

Data for State ambient stream-water-quality monitoring sites were retrieved for 1990–98 from the U.S. Environmental Protection Agency Storage and Retrieval System, the U.S. Geological Survey National Water Information System, or State-located databases. These data were assembled into individual State databases, and each monitoring site was assessed for the number of available analyses for 10 water-quality constituents or measurements. Monitoring sites with nine or more analyses for each of the constituents or measurements were statistically summarized, and median concentrations or measurements determined. The nine-analysis threshold was selected as a compromise between the desire to maximize spatial distribution but still have enough analyses to provide an estimate of range and central tendency (median values) for the site data population. Also, nine represented an average of one sample per year over the time period investigated. Subsequently, the median of monitoring-site medians was calculated for each constituent or measurement in each State, statistically summarized, and the result presented in tabular format.

Comparisons of monitoring data among States are problematic for several reasons, including differences in the basic spatial design of monitoring networks; water-quality constituents for which samples are analyzed; water-quality criteria to which constituent concentrations are compared; quantity and comprehensiveness of water-quality data; sample collection, processing, and handling; analytical methods; temporal variability in sample collection; and quality-assurance practices. Large differences among the States in number of monitoring sites precluded a general assumption that statewide water-quality conditions were represented by data from these sites. Furthermore, data from individual monitoring sites may not represent water-quality conditions at the sites because sampling

40 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

Table 24. Number of State ambient stream-water-quality monitoring sites available for selected combinations of water-quality constituents per monitoring site and analyses per constituent, 1990–98.

[Total number of monitoring sites in State databases (sites with one or more analyses of at least 1 of 10 constituents) were presented previously in table 2. --, not available]

State	Number of ambient stream-water-quality monitoring sites			
	With 1 or more constituents with 9 or more analyses	With any 8 or more of 10 constituents with 9 or more analyses	With all 10 constituents with 9 or more analyses	With all 10 constituents with 30 or more analyses
Alabama	45	41	0	0
Alaska	--	--	--	--
Arizona	--	--	--	--
Arkansas	131	131	0	0
California	--	--	--	--
Colorado	220	104	0	0
Connecticut	32	28	0	0
Delaware	103	0	0	0
Florida	868	405	8	0
Georgia	290	0	0	0
Hawaii	--	--	--	--
Idaho	51	21	0	0
Illinois	11	3	0	0
Indiana	106	14	0	0
Iowa	39	0	0	0
Kansas	251	251	118	40
Kentucky	61	59	0	0
Louisiana	172	105	0	0
Maine	--	--	--	--
Maryland	40	12	0	0
Massachusetts	--	--	--	--
Michigan	97	47	0	0
Minnesota	66	1	0	0
Mississippi	66	44	0	0
Missouri	40	31	0	0
Montana	334	54	0	0
Nebraska	22	13	0	0
Nevada	68	64	28	0
New Hampshire	56	8	0	0
New Jersey	96	65	0	0
New Mexico	239	115	1	1
New York	19	8	0	0
North Carolina	--	--	--	--
North Dakota	73	39	13	0
Ohio	41	40	27	6
Oklahoma	212	8	0	0
Oregon	144	1	0	0
Pennsylvania	174	63	27	24
Rhode Island	5	5	0	0
South Carolina	340	0	0	0
South Dakota	96	28	0	0
Tennessee	73	12	0	0
Texas	576	362	7	2
Utah	64	64	1	0
Vermont	--	--	--	--
Virginia	1,139	864	0	0
Washington	207	0	0	0
West Virginia	26	21	0	0
Wisconsin	48	13	0	0
Wyoming	42	4	0	0
Totals	6,783	3,148	230	73

conditions and protocols are unknown. Because of these factors, a high level of uncertainty exists in the results of this investigation.

Forty States had electronically accessible suspended solids concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of suspended solids ranged from 2.0 mg/L in New Hampshire to 42.5 mg/L in Nebraska.

Thirty-nine States had electronically accessible fecal coliform bacteria densities for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median densities of fecal coliform bacteria ranged from 19.2 col/100 mL in Colorado to 2,650 col/100 mL in Montana.

Forty-one States had electronically accessible ammonia concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of ammonia ranged from 0.003 mg/L in Colorado to 0.46 mg/L in Rhode Island.

Forty-two States had electronically accessible nitrite plus nitrate as nitrogen concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of nitrite plus nitrate as nitrogen ranged from 0.05 mg/L in Nevada to 5.7 mg/L in Iowa.

Forty-one States had electronically accessible total phosphorus concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of total phosphorus ranged from 0.02 mg/L in West Virginia to 0.33 mg/L in Illinois.

Twenty-eight States had electronically accessible total arsenic concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of total arsenic ranged from 0.80 µg/L in Washington to 11.5 µg/L in South Dakota.

Twenty-nine States had electronically accessible dissolved-solids concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of dissolved solids ranged from 37.2 mg/L in Mississippi to 711 mg/L in South Dakota.

Thirty-nine States had electronically accessible chloride concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of chloride ranged from 0 mg/L in Montana to 7,740 mg/L in Georgia.

Thirty-six States had electronically accessible sulfate concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of sulfate ranged from 6.5 mg/L in New Hampshire to 232 mg/L in North Dakota.

Forty-two States had electronically accessible pH measurements for water from ambient stream-water-quality monitoring sites. State medians of the monitoring-site median measurements of pH ranged from 6.7 standard units in Rhode Island and South Carolina to 8.2 standard units in several States.

National monitoring is, in reality, a compilation of 50 State networks with varying degrees of comparability. Differences among the States in water-quality criteria and methodologies

used in data assessment and decisions on water quality restrict comparability among the States and limit the consistency needed to produce an accurate national assessment of ambient stream-water quality. An analysis of the extent and comprehensiveness of State ambient stream-water-quality networks for this report indicated that these networks may be lacking in the diversity of collected data and that many monitoring sites in those networks have few samples and for many basic water-quality constituents do not have the number of analyses recommended (30) by the U.S. Environmental Protection Agency to make appropriate water-quality and total maximum daily loads decisions for 1990–98.

Targeted, statistically based (probabilistic), and geographically based sampling designs are used in some State monitoring programs to provide the water-quality information required by the Clean Water Act to evaluate potential stream-water-quality degradation relative to designated uses and appropriate water-quality criteria. When appropriate designs are used, this information also may be used to describe cause-and-effect relations, seasonal variability and time trends, mass transport, and as an aid to management decisions. However, the variability in network designs and operational characteristics, such as the distribution of sites and frequency of sampling, among the States prevented the use of available information for a scientifically defensible comparison of results among the States.

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42 Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

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Supplemental Information

Table 25. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for suspended solids, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	49	49	49	45	45	45	45	45	43	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	132	131	131	131	130	128	127	27
California	--	--	--	--	--	--	--	--	--	--
Colorado	347	278	262	214	75	63	52	46	28	6
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	109	109	108	103	97	86	73	58	22	0
Florida	648	642	627	602	514	431	372	300	197	94
Georgia	284	244	233	196	79	78	76	75	61	11
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	367	141	24	11	3	3	1	1	1	0
Indiana	107	106	106	105	100	91	84	83	82	0
Iowa	55	55	55	26	14	14	14	14	14	14
Kansas	161	161	153	124	46	40	40	40	14	0
Kentucky	89	88	66	60	49	46	46	45	44	27
Louisiana	172	171	171	171	152	149	148	148	99	1
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	40	40	40	40	40	40	40	40	40	38
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	261	178	166	96	72	69	65	61	39	6
Minnesota	66	65	65	63	56	51	51	50	17	0
Mississippi	84	72	71	66	58	56	19	17	10	0
Missouri	37	33	30	22	14	9	5	5	1	0
Montana	323	187	162	132	93	81	66	56	13	1
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	69	69	69	67	64	56	53	53	35	10
New Hampshire	228	114	27	25	16	0	0	0	0	0
New Jersey	74	73	70	65	33	4	0	0	0	0
New Mexico	512	415	348	219	75	31	11	1	1	0
New York	19	19	19	19	19	19	19	18	0	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	37	33	32	28	18	11	10	8	7	2
Ohio	42	42	41	41	40	40	40	40	37	10
Oklahoma	245	238	236	182	87	43	34	33	8	1
Oregon	148	148	147	144	126	119	114	98	64	12
Pennsylvania	200	196	191	173	173	173	173	171	153	8
Rhode Island	5	5	5	5	5	3	3	2	0	0
South Carolina	119	62	56	52	48	46	44	39	34	9
South Dakota	100	96	96	96	93	88	86	83	50	31
Tennessee	101	97	90	68	52	40	25	7	2	0
Texas	769	576	486	396	314	235	147	96	22	2
Utah	64	64	64	64	64	64	63	63	60	8
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,342	1,127	1,086	945	807	748	645	569	341	133
Washington	205	205	205	204	106	105	91	91	57	0
West Virginia	26	26	26	26	0	0	0	0	0	0
Wisconsin	50	49	49	46	40	36	32	29	13	5
Wyoming	1	1	1	1	1	1	1	0	0	0
Totals	7,710	6,429	5,886	5,095	3,841	3,367	2,940	2,634	1,736	456
Percentage reduction		16.6	23.7	33.9	50.2	56.3	61.9	65.8	77.5	94.1

Table 26. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for fecal coliform bacteria, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	49	49	47	45	45	45	41	41	35	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	115	115	114	113	84	72	70	70	49	0
California	--	--	--	--	--	--	--	--	--	--
Colorado	298	256	212	124	60	51	42	38	21	5
Connecticut	32	32	32	32	32	31	31	31	24	0
Delaware	1	1	0	0	0	0	0	0	0	0
Florida	458	442	427	372	260	214	169	122	75	42
Georgia	392	317	270	255	155	141	132	116	87	5
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	47	47	47	42	36	22	12	7	1	0
Illinois	37	25	7	3	3	2	1	1	1	0
Indiana	0	0	0	0	0	0	0	0	0	0
Iowa	47	33	28	17	17	16	16	16	16	0
Kansas	289	288	276	249	171	145	145	144	54	6
Kentucky	87	83	70	59	48	46	45	44	44	0
Louisiana	167	166	142	103	52	28	0	0	0	0
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	40	40	40	40	40	40	40	40	40	18
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	0	0	0	0	0	0	0	0	0	0
Minnesota	63	63	63	63	56	50	50	50	18	0
Mississippi	68	63	61	50	49	38	4	0	0	0
Missouri	43	42	42	39	39	37	34	32	16	2
Montana	4	2	2	2	1	1	0	0	0	0
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	70	68	68	60	56	55	47	37	23	0
New Hampshire	104	40	8	8	1	0	0	0	0	0
New Jersey	18	10	5	5	5	3	2	0	0	0
New Mexico	175	56	19	9	8	5	4	2	2	0
New York	13	12	10	8	1	0	0	0	0	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	69	64	57	39	23	17	11	7	3	1
Ohio	41	40	40	40	39	36	30	25	13	0
Oklahoma	22	15	14	14	4	0	0	0	0	0
Oregon	132	128	120	83	37	24	11	7	0	0
Pennsylvania	88	77	72	53	50	49	47	46	42	1
Rhode Island	5	5	5	5	5	5	5	5	5	0
South Carolina	338	337	337	310	226	203	197	192	130	5
South Dakota	100	96	96	96	88	83	74	56	47	0
Tennessee	107	99	89	60	41	32	18	3	2	0
Texas	784	659	560	457	346	251	195	140	77	11
Utah	18	16	16	16	15	12	10	6	0	0
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,420	1,195	1,151	1,086	943	834	695	584	335	83
Washington	208	208	208	202	106	105	91	89	57	0
West Virginia	26	26	26	26	0	0	0	0	0	0
Wisconsin	47	46	45	44	36	33	29	25	12	0
Wyoming	19	18	18	18	16	15	13	10	0	0
Totals	6,063	5,301	4,866	4,269	3,216	2,763	2,333	2,007	1,229	179
Percentage reduction		12.6	19.7	29.6	47.0	54.4	61.5	66.9	79.7	97.0

Table 27. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for ammonia as nitrogen, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	49	49	35	18	18	18	17	3	2	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	133	131	131	131	131	131	129	127
California	--	--	--	--	--	--	--	--	--	--
Colorado	262	232	213	163	61	54	45	40	17	0
Connecticut	29	29	29	29	29	28	28	28	24	2
Delaware	109	109	108	103	97	86	72	57	22	0
Florida	823	823	823	793	647	538	438	353	243	99
Georgia	416	382	323	283	156	147	136	126	92	22
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	49	49	49	47	33	23	19	14	7	1
Illinois	368	142	24	11	3	3	1	1	1	0
Indiana	107	106	106	106	103	93	86	85	84	0
Iowa	68	68	68	39	27	27	27	27	27	27
Kansas	289	289	281	251	169	146	145	145	89	6
Kentucky	89	88	66	60	49	46	46	45	44	24
Louisiana	0	0	0	0	0	0	0	0	0	0
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	40	40	40	40	40	40	40	40	40	40
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	248	146	127	70	65	63	55	49	14	3
Minnesota	67	67	67	66	66	65	63	52	47	0
Mississippi	81	63	63	58	51	50	6	2	1	0
Missouri	43	43	42	39	38	37	26	20	12	0
Montana	380	199	173	140	89	77	53	49	22	0
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	69	69	69	67	64	56	53	53	36	11
New Hampshire	315	156	57	41	16	7	0	0	0	0
New Jersey	95	95	95	82	70	62	49	35	3	1
New Mexico	521	427	364	228	80	35	17	6	1	0
New York	19	19	19	19	19	19	19	18	1	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	83	71	55	33	24	23	19	7	2
Ohio	42	42	41	41	40	40	40	40	37	10
Oklahoma	195	174	135	38	16	13	11	10	2	0
Oregon	148	148	147	143	126	119	115	99	64	13
Pennsylvania	201	196	192	174	174	174	174	172	169	142
Rhode Island	5	5	5	5	5	5	5	5	5	0
South Carolina	339	339	339	337	276	228	197	196	193	135
South Dakota	97	96	96	96	92	88	86	83	46	10
Tennessee	107	99	88	65	44	40	26	9	2	0
Texas	903	663	561	446	358	282	207	157	67	10
Utah	64	64	64	64	64	64	64	63	59	8
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,424	1,143	1,094	957	809	748	643	566	342	133
Washington	207	205	205	204	106	105	91	91	57	0
West Virginia	26	26	26	26	0	0	0	0	0	0
Wisconsin	49	44	43	40	35	33	27	22	9	1
Wyoming	27	22	22	21	20	15	13	10	3	0
Totals	8,615	7,194	6,525	5,618	4,341	3,851	3,316	2,942	2,020	827
Percentage reduction		16.5	24.3	34.8	49.6	55.2	61.5	65.9	76.6	90.4

Table 28. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for nitrite plus nitrate as nitrogen, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	48	48	48	44	44	44	44	44	42	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	131	131	131	131	130	129	127	17
California	--	--	--	--	--	--	--	--	--	--
Colorado	316	274	259	210	69	69	49	38	22	2
Connecticut	30	30	30	30	30	30	30	30	23	2
Delaware	109	109	108	103	97	84	72	57	20	0
Florida	839	839	838	825	678	572	487	402	264	128
Georgia	416	382	323	283	156	144	136	127	93	16
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	50	50	49	45	35	25	19	18	5	0
Illinois	368	142	24	11	3	3	1	1	1	0
Indiana	106	106	106	106	103	93	86	85	84	0
Iowa	68	68	68	39	27	27	27	27	27	27
Kansas	289	289	281	251	169	146	145	145	89	6
Kentucky	88	87	66	60	48	46	46	45	44	24
Louisiana	173	172	172	172	152	149	148	148	96	0
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	40	40	40	40	40	40	40	40	40	40
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	265	165	154	85	70	67	65	61	27	4
Minnesota	67	67	67	66	66	65	63	52	47	0
Mississippi	85	72	71	65	59	55	20	16	10	0
Missouri	44	43	43	40	37	37	34	32	14	0
Montana	880	418	347	235	165	113	72	65	29	0
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	66	66	66	64	61	54	51	51	34	10
New Hampshire	339	211	92	46	21	11	0	0	0	0
New Jersey	92	91	91	87	73	70	69	67	7	2
New Mexico	521	425	370	230	77	31	16	6	2	0
New York	19	19	19	19	19	19	19	18	1	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	83	72	57	34	25	24	19	7	2
Ohio	42	42	41	41	40	40	40	40	37	10
Oklahoma	221	197	171	111	59	38	29	28	8	1
Oregon	148	148	147	143	126	119	115	98	62	13
Pennsylvania	198	193	189	171	171	171	171	170	167	142
Rhode Island	5	5	5	5	5	5	5	5	5	0
South Carolina	340	340	340	340	301	270	226	216	209	167
South Dakota	97	96	96	96	92	88	86	83	45	0
Tennessee	106	97	88	65	43	40	26	9	2	0
Texas	889	655	571	449	331	257	181	139	72	10
Utah	64	64	64	64	64	64	63	63	60	7
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,419	1,143	1,095	957	812	749	649	568	343	134
Washington	206	205	205	204	106	105	91	90	57	0
West Virginia	24	24	24	24	0	0	0	0	0	0
Wisconsin	50	44	43	42	38	37	32	32	18	3
Wyoming	36	32	31	29	22	14	10	9	0	0
Totals	9,408	7,736	7,067	6,107	4,696	4,169	3,639	3,294	2,240	767
Percentage reduction		17.8	24.9	35.1	50.1	55.7	61.3	65.0	76.2	91.8

Table 29. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for total phosphorus, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	49	49	49	45	45	45	45	45	43	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	133	131	131	131	131	131	129	127
California	--	--	--	--	--	--	--	--	--	--
Colorado	322	274	258	209	71	61	51	45	28	6
Connecticut	32	32	32	32	31	30	30	28	25	2
Delaware	109	109	107	103	96	83	73	57	20	0
Florida	807	806	805	790	655	547	459	406	276	129
Georgia	416	382	323	283	156	147	136	126	92	21
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	50	50	49	44	39	28	22	19	7	1
Illinois	368	141	24	11	3	3	1	1	1	0
Indiana	107	106	106	106	103	93	86	85	84	0
Iowa	57	57	57	28	16	16	16	16	16	16
Kansas	289	289	281	251	169	146	145	145	89	6
Kentucky	89	88	66	60	49	46	46	45	44	26
Louisiana	173	172	172	172	152	149	148	148	98	1
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	40	40	40	40	40	40	40	40	40	40
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	272	165	155	83	69	67	65	61	28	4
Minnesota	66	65	65	63	56	51	51	51	17	0
Mississippi	85	72	71	65	59	56	20	16	10	0
Missouri	39	38	38	34	28	24	19	16	10	0
Montana	664	264	216	175	128	100	70	54	24	0
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	69	69	69	67	64	56	53	53	36	11
New Hampshire	347	220	93	46	21	15	2	0	0	0
New Jersey	95	95	93	82	71	69	66	58	7	2
New Mexico	521	426	346	225	74	33	17	10	3	0
New York	0	0	0	0	0	0	0	0	0	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	83	72	57	34	25	24	19	8	2
Ohio	42	42	41	41	40	40	40	40	34	9
Oklahoma	258	247	245	194	91	45	35	34	12	1
Oregon	148	148	146	141	126	120	116	99	64	13
Pennsylvania	201	196	191	174	174	174	174	172	169	141
Rhode Island	5	5	5	5	5	5	5	5	4	0
South Carolina	339	339	339	339	277	224	212	210	205	81
South Dakota	97	96	96	96	92	88	86	83	45	0
Tennessee	106	97	88	65	43	40	25	9	2	0
Texas	854	639	547	439	341	253	183	138	55	9
Utah	64	64	64	64	64	64	64	62	56	4
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,408	1,129	1,080	936	808	742	646	566	338	132
Washington	208	207	207	206	106	105	91	91	57	0
West Virginia	26	26	26	26	0	0	0	0	0	0
Wisconsin	50	47	46	44	39	37	34	32	18	6
Wyoming	31	28	28	21	16	10	9	7	3	0
Totals	9,148	7,557	6,891	6,015	4,604	4,030	3,558	3,244	2,197	790
Percentage reduction		17.4	24.7	34.2	49.7	55.9	61.1	64.5	76.0	91.4

Table 30. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for total arsenic, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	44	27	27	27	24	23	21	5	0	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	0	0	0	0	0	0	0	0	0	0
California	--	--	--	--	--	--	--	--	--	--
Colorado	46	2	0	0	0	0	0	0	0	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	43	22	20	20	20	19	19	17	5	0
Florida	224	175	155	128	90	65	58	48	17	6
Georgia	66	20	2	0	0	0	0	0	0	0
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	2	1	0	0	0	0	0	0	0	0
Illinois	191	51	2	2	2	1	0	0	0	0
Indiana	71	67	66	61	41	40	38	38	35	0
Iowa	1	1	1	1	1	1	1	1	1	0
Kansas	289	289	281	251	168	146	145	144	88	6
Kentucky	89	88	66	59	46	46	46	45	44	19
Louisiana	125	125	124	12	0	0	0	0	0	0
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	0	0	0	0	0	0	0	0	0	0
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	216	88	78	48	47	35	4	4	0	0
Minnesota	52	16	11	0	0	0	0	0	0	0
Mississippi	72	69	64	22	9	0	0	0	0	0
Missouri	1	0	0	0	0	0	0	0	0	0
Montana	96	9	8	8	3	3	3	3	0	0
Nebraska	17	13	13	13	0	0	0	0	0	0
Nevada	71	70	70	59	48	19	8	8	7	0
New Hampshire	213	25	16	1	0	0	0	0	0	0
New Jersey	59	28	16	4	0	0	0	0	0	0
New Mexico	323	152	42	15	3	1	1	1	1	0
New York	0	0	0	0	0	0	0	0	0	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	68	38	31	24	12	7	5	0	0	0
Ohio	42	42	41	41	26	26	21	16	7	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	1	0	0	0	0	0	0	0	0	0
Pennsylvania	41	33	32	31	31	31	30	29	22	0
Rhode Island	2	2	1	1	1	1	1	1	0	0
South Carolina	2	1	1	0	0	0	0	0	0	0
South Dakota	52	44	23	20	20	19	19	19	7	1
Tennessee	108	99	92	70	56	41	34	12	2	0
Texas	101	33	23	9	8	4	4	4	3	0
Utah	60	58	57	54	50	7	2	2	0	0
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	692	399	226	75	14	4	4	4	0	0
Washington	14	12	11	5	2	1	0	0	0	0
West Virginia	0	0	0	0	0	0	0	0	0	0
Wisconsin	4	2	2	2	1	1	1	0	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Totals	3,498	2,101	1,602	1,063	723	541	465	401	239	32
Percentage reduction		39.9	54.2	69.6	79.3	84.5	86.7	88.5	93.2	99.1

Table 31. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for dissolved solids, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	48	48	47	42	27	27	27	27	25	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	133	131	131	131	131	131	129	127
California	--	--	--	--	--	--	--	--	--	--
Colorado	317	276	262	212	75	63	51	46	28	6
Connecticut	32	32	32	32	32	32	32	32	27	2
Delaware	0	0	0	0	0	0	0	0	0	0
Florida	273	267	260	253	196	151	100	84	44	8
Georgia	0	0	0	0	0	0	0	0	0	0
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	50	50	48	32	11	9	7	6	1	0
Illinois	197	63	1	0	0	0	0	0	0	0
Indiana	30	23	23	23	21	20	20	20	19	0
Iowa	57	57	57	28	16	16	16	16	16	16
Kansas	289	289	281	251	169	146	145	144	86	6
Kentucky	1	0	0	0	0	0	0	0	0	0
Louisiana	173	172	172	172	152	149	148	148	99	1
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	12	12	12	12	12	12	12	12	12	11
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	15	0	0	0	0	0	0	0	0	0
Minnesota	0	0	0	0	0	0	0	0	0	0
Mississippi	62	49	49	46	42	8	7	4	0	0
Missouri	42	38	38	36	29	23	17	13	6	0
Montana	193	109	96	84	48	29	9	6	2	0
Nebraska	0	0	0	0	0	0	0	0	0	0
Nevada	69	69	69	67	64	56	53	53	35	10
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	95	95	95	92	76	74	73	70	7	2
New Mexico	521	424	355	228	82	39	16	5	1	0
New York	19	19	19	19	19	19	19	18	1	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	82	70	52	29	19	17	11	0	0
Ohio	38	34	33	32	29	26	24	23	20	10
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	19	4	1	1	1	0	0	0	0	0
Pennsylvania	200	195	186	173	173	172	172	171	167	37
Rhode Island	1	1	1	1	1	1	1	1	1	0
South Carolina	19	0	0	0	0	0	0	0	0	0
South Dakota	100	96	96	96	93	88	86	83	50	30
Tennessee	48	34	31	23	19	16	12	7	0	0
Texas	690	476	387	285	124	62	50	38	2	0
Utah	64	64	64	64	64	64	63	63	58	2
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	246	107	86	82	71	63	61	42	16	0
Washington	0	0	0	0	0	0	0	0	0	0
West Virginia	0	0	0	0	0	0	0	0	0	0
Wisconsin	2	0	0	0	0	0	0	0	0	0
Wyoming	23	19	13	11	7	6	6	6	1	0
Totals	4,168	3,337	3,017	2,580	1,813	1,521	1,375	1,280	853	268
Percentage reduction		19.9	27.6	38.1	56.5	63.5	67.0	69.3	79.5	93.6

Table 32. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for chloride, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	49	49	49	45	45	45	45	45	43	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	132	131	131	131	131	131	129	127
California	--	--	--	--	--	--	--	--	--	--
Colorado	22	0	0	0	0	0	0	0	0	0
Connecticut	31	31	31	31	31	31	31	31	26	2
Delaware	106	103	102	95	88	81	69	45	17	0
Florida	693	687	677	653	507	380	302	257	187	78
Georgia	10	8	8	7	7	7	7	7	7	1
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	47	47	46	35	11	10	9	7	1	0
Illinois	202	50	8	7	3	2	1	1	1	0
Indiana	32	16	15	15	15	15	15	15	14	0
Iowa	6	6	6	6	6	6	6	4	0	0
Kansas	289	289	281	251	169	146	145	145	89	6
Kentucky	89	88	66	60	51	48	48	45	44	28
Louisiana	173	172	172	172	152	149	148	148	99	1
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	0	0	0	0	0	0	0	0	0	0
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	249	173	163	93	69	66	62	58	36	3
Minnesota	17	11	11	10	9	6	6	6	5	0
Mississippi	80	65	60	56	49	49	7	3	0	0
Missouri	43	39	39	35	25	20	17	9	5	0
Montana	523	250	198	132	65	28	21	17	4	0
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	69	69	69	67	64	56	53	53	35	10
New Hampshire	209	118	32	12	1	0	0	0	0	0
New Jersey	93	93	93	92	73	71	70	67	7	2
New Mexico	507	358	233	131	52	24	18	13	3	0
New York	19	19	19	19	19	19	19	18	1	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	82	70	52	29	19	17	11	0	0
Ohio	42	42	40	40	39	38	37	35	30	3
Oklahoma	252	229	227	177	59	40	23	21	4	1
Oregon	53	6	4	4	0	0	0	0	0	0
Pennsylvania	82	66	59	41	40	40	39	39	37	3
Rhode Island	5	5	5	5	5	1	1	1	1	0
South Carolina	22	15	15	14	14	13	13	13	13	2
South Dakota	16	10	9	8	7	7	7	7	6	0
Tennessee	2	1	1	1	1	0	0	0	0	0
Texas	910	697	597	495	394	319	247	198	77	15
Utah	64	64	64	64	64	64	61	61	58	1
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,216	1,079	1,042	897	765	702	605	511	284	55
Washington	1	0	0	0	0	0	0	0	0	0
West Virginia	26	26	26	25	0	0	0	0	0	0
Wisconsin	50	49	48	47	41	39	34	33	18	4
Wyoming	25	23	22	19	18	14	13	12	7	0
Totals	6,569	5,290	4,761	4,066	3,140	2,708	2,349	2,088	1,288	342
Percentage reduction		19.5	27.5	38.1	52.2	58.8	64.2	68.2	80.4	94.8

Table 33. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for sulfate, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	0	0	0	0	0	0	0	0	0	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	132	131	131	131	131	131	129	127
California	--	--	--	--	--	--	--	--	--	--
Colorado	342	277	263	215	73	60	51	39	23	2
Connecticut	32	32	32	32	32	32	32	32	27	2
Delaware	0	0	0	0	0	0	0	0	0	0
Florida	635	622	618	593	471	364	275	199	101	25
Georgia	7	7	7	0	0	0	0	0	0	0
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	46	46	45	37		8	7	6	1	0
Illinois	220	54	3	3	3	2	1	1	1	0
Indiana	22	13	12	12	12	12	12	12	12	0
Iowa	6	6	6	6	6	6	5	0	0	0
Kansas	289	289	281	251	169	146	145	145	89	6
Kentucky	89	88	66	59	49	46	46	45	44	22
Louisiana	173	172	172	172	152	149	148	148	99	1
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	12	12	12	12	12	12	12	12	12	11
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	192	108	100	64	51	42	41	8	1	0
Minnesota	4	1	1	1	1	1	1	1	0	0
Mississippi	2	2	2	2	2	2	0	0	0	0
Missouri	42	38	38	34	24	20	17	9	5	0
Montana	614	265	240	163	98	41	30	23	3	0
Nebraska	0	0	0	0	0	0	0	0	0	0
Nevada	69	69	68	66	58	45	28	17	10	10
New Hampshire	201	43	10	8	1	0	0	0	0	0
New Jersey	93	93	93	92	74	72	71	68	7	2
New Mexico	511	364	234	132	52	24	18	13	4	0
New York	19	19	19	19	19	19	19	18	1	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	82	70	52	29	19	17	11	0	0
Ohio	42	42	41	36	33	29	26	22	19	0
Oklahoma	245	229	227	178	58	40	23	21	6	1
Oregon	30	0	0	0	0	0	0	0	0	0
Pennsylvania	201	196	192	174	174	174	174	172	169	142
Rhode Island	5	5	5	5	5	1	1	1	1	0
South Carolina	11	5	5	5	5	5	5	4	0	0
South Dakota	19	10	9	8	7	7	7	7	6	0
Tennessee	4	2	2	2	2	0	0	0	0	0
Texas	898	684	584	481	382	304	232	182	72	10
Utah	64	64	64	64	64	64	63	63	58	1
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,219	1,079	1,042	894	764	701	604	512	284	56
Washington	0	0	0	0	0	0	0	0	0	0
West Virginia	26	26	26	26	0	0	0	0	0	0
Wisconsin	20	18	18	17	12	9	9	9	6	0
Wyoming	25	23	22	19	18	16	13	12	7	0
Totals	6,652	5,218	4,761	4,065	3,043	2,603	2,264	1,943	1,197	418
Percentage reduction		21.6	28.4	38.9	54.3	60.9	66.0	70.8	82.0	93.7

Table 34. Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for pH, 1990–98.

[--, not available]

State	Number of analyses (equal to or greater than)									
	1	3	5	9	15	20	25	30	50	100
Alabama	49	49	49	45	45	45	45	45	43	0
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--
Arkansas	133	133	132	131	131	131	131	131	129	127
California	--	--	--	--	--	--	--	--	--	--
Colorado	523	360	265	205	74	63	53	45	24	4
Connecticut	32	32	32	32	32	32	32	32	27	2
Delaware	109	109	108	103	96	87	76	59	21	0
Florida	748	745	739	690	575	490	423	371	281	155
Georgia	391	377	330	284	154	146	132	122	80	8
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	51	51	51	51	48	32	24	19	9	0
Illinois	367	135	23	11	3	2	1	1	1	0
Indiana	105	105	101	101	87	82	81	80	61	0
Iowa	65	65	65	36	24	24	24	24	24	24
Kansas	289	288	280	247	169	145	145	144	76	6
Kentucky	87	84	65	60	48	47	47	45	44	15
Louisiana	173	172	172	172	152	148	148	148	84	1
Maine	--	--	--	--	--	--	--	--	--	--
Maryland	40	40	40	40	40	40	40	40	40	40
Massachusetts	--	--	--	--	--	--	--	--	--	--
Michigan	218	157	147	79	65	64	59	57	11	1
Minnesota	67	67	67	66	66	65	63	52	48	0
Mississippi	83	72	71	66	63	60	25	23	10	0
Missouri	43	42	42	38	38	36	34	32	17	2
Montana	871	411	335	276	184	125	96	81	45	5
Nebraska	22	22	22	22	22	22	22	21	0	0
Nevada	55	54	50	35	23	22	0	0	0	0
New Hampshire	429	277	136	55	21	15	5	0	0	0
New Jersey	94	94	94	89	75	74	73	70	8	2
New Mexico	527	425	360	211	65	27	14	14	5	1
New York	19	19	19	19	19	19	18	16	0	0
North Carolina	--	--	--	--	--	--	--	--	--	--
North Dakota	90	86	82	72	42	35	30	21	9	0
Ohio	41	41	41	39	38	37	35	35	24	6
Oklahoma	256	250	224	133	71	41	38	36	12	3
Oregon	148	148	147	140	126	120	116	96	63	13
Pennsylvania	200	194	188	174	174	174	174	172	166	96
Rhode Island	5	5	5	5	5	5	5	5	5	0
South Carolina	339	339	339	339	294	244	215	212	208	149
South Dakota	100	96	96	96	93	87	86	79	49	8
Tennessee	102	92	70	43	31	26	23	8	2	0
Texas	935	787	682	546	435	347	296	237	128	39
Utah	64	64	64	64	64	64	64	64	63	60
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	1,278	1,094	1,050	898	770	710	614	527	303	74
Washington	208	208	208	207	106	105	91	90	57	0
West Virginia	26	26	26	24	0	0	0	0	0	0
Wisconsin	48	44	40	38	30	28	27	27	21	5
Wyoming	43	39	36	36	31	29	25	18	6	0
Totals	9,473	7,898	7,093	6,018	4,629	4,095	3,650	3,299	2,204	846
Percentage reduction		16.6	25.1	36.5	51.1	56.8	61.5	65.2	76.7	90.1