WATER RESOURCES RESEARCH, VOL. 34, NO. 9, PAGES 2401–2405, SEPTEMBER 1998

Data from selected U.S. Geological Survey national stream water quality monitoring networks

Richard B. Alexander,[1] James R. Slack,[1] Amy S. Ludtke,[2] Kathleen K. Fitzgerald,[1] and Terry L. Schertz[2]

Abstract. A nationally consistent and well-documented collection of water quality and quantity data compiled during the past 30 years for streams and rivers in the United States is now available on CD-ROM and accessible over the World Wide Web. The data include measurements from two U.S. Geological Survey (USGS) national networks for 122 physical, chemical, and biological properties of water collected at 680 monitoring stations from 1962 to 1995, quality assurance information that describes the sample collection agencies, laboratories, analytical methods, and estimates of laboratory measurement error (bias and variance), and information on selected cultural and natural characteristics of the station watersheds. The data are easily accessed via user-supplied software including Web browser, spreadsheet, and word processor, or may be queried and printed according to user-specified criteria using the supplied retrieval software on CD-ROM. The water quality data serve a variety of scientific uses including research and educational applications related to trend detection, flux estimation, investigations of the effects of the natural environment and cultural sources on water quality, and the development of statistical methods for designing efficient monitoring networks and interpreting water resources data.

1. Introduction

This note describes a comprehensive collection of water quality and quantity data compiled by the U.S. Geological Survey (USGS) during the past 30 years for streams and rivers of the United States. The data, now available in a two CD-ROM set and accessible over the World Wide Web, include measurements for 122 physical, chemical, and biological properties of water collected using nationally consistent methods at 680 monitoring stations, quality assurance information that describes the sample collection agencies, laboratories, analytical methods, and estimates of laboratory measurement error, and information on selected cultural and natural characteristics of the station watersheds. All data are easily accessed by using enclosed browsing and retrieval software on the CD-ROMs.

The data are from two USGS national stream water quality networks: the Hydrologic Benchmark Network (HBN) and the National Stream Quality Accounting Network (NASQAN) (see Figure 1). Watersheds from these networks represent a diverse set of climatic, physiographic, and cultural characteristics. The HBN, consisting of 63 stations in small, minimally disturbed watersheds, provides data for investigating naturally induced changes in streamflow and water quality and the effects of airborne substances on water quality. The watersheds range in size from 5 to 5200 km^2, with a median drainage basin size of 148 km^2. The HBN steadily grew from three stations in 1962 to 57 in 1968, and continued to operate with slightly more than 50 stations through 1996. NASQAN, consisting of 618 stations in larger, more culturally influenced watersheds, provides data on ambient water quality conditions in major U.S. rivers and streams. Drainage basins range in size from 3 to 3 million km^2, with a median drainage basin size of 10,400 km^2. NASQAN was initiated in 1973 to address national and regional needs for comprehensive water quality monitoring that was prompted by the enactment of water pollution control legislation during the 1960s and 1970s, including the Water Quality Act of 1965 and the Clean Water Act of 1972 [*Briggs and Ficke*, 1977]. Stations were located near the outlets of major watersheds (i.e., hydrologic cataloging units [see *Seaber et al*., [1987]) to describe spatial variability in water quality and quantify long-term changes in chemical concentrations and flux. The number of stations rapidly grew from 51 in 1973 to 345 in 1975 with continued increases to 513 in 1980. These levels remained steady through 1986 with reductions to about 400 stations during 1987–1992, after which the number of stations declined to about 140 in 1995. Beginning in 1996, NASQAN was redesigned to more intensively monitor a wider range of water properties, including pesticides and trace elements, at 39 stations in four of the largest U.S. drainage basins [*Hooper et al*., 1997]. Water quality sampling was discontinued at HBN stations in 1997. The water quality data on CD-ROM span the years 1962–1995 for HBN and 1973–1995 for NASQAN. Network expenditures through 1995 totaled about $130 million in 1997 dollars.

Data from these USGS networks serve a variety of research and educational uses. The data provide some of the best available historical information for describing national water quality conditions and trends, investigating and illustrating the effects of the natural environment and human activities on water quality, and supporting research and development of new methods for interpreting stream water quality data. Example uses of the data include the analysis of trends in water quality [*Smith et al*., 1987; *Schertz*, 1990; *Hay and Campbell*, 1990; *Lettenmaier et al*., 1991], the estimation of rates of chemical

[1]U.S. Geological Survey, Reston, Virginia.
[2]U.S. Geological Survey, Denver, Colorado.

Paper number 98WR01530.

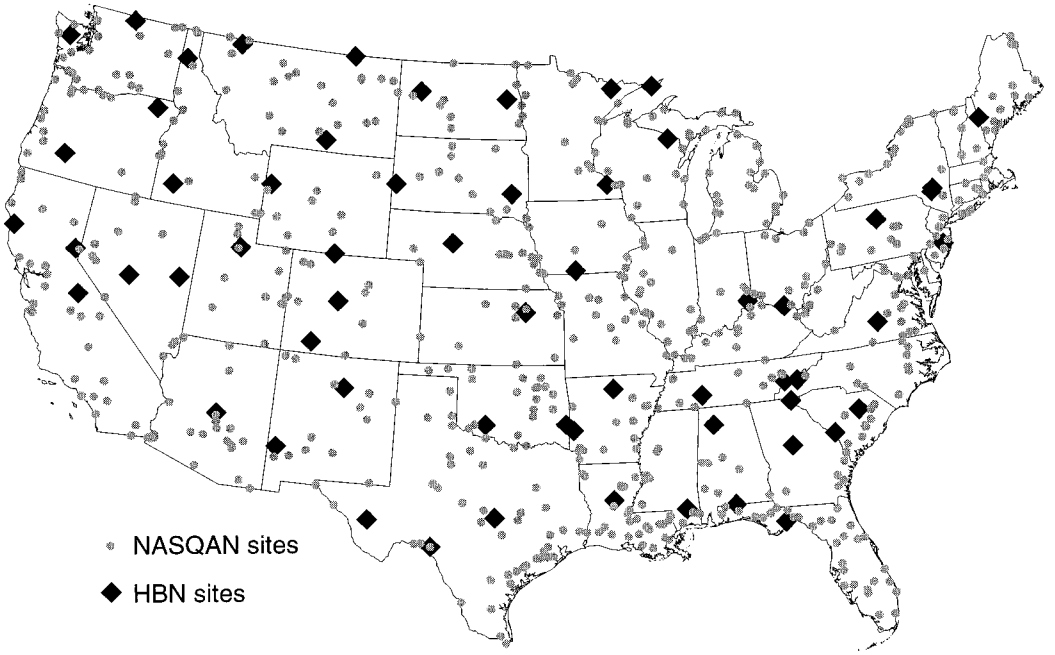

Figure 1. Stream monitoring locations in the National Stream Quality Accounting Network (NASQAN) and the Hydrologic Benchmark Network (HBN) for the conterminous United States. Monitoring sites located outside the conterminous United States for NASQAN include 13 in Alaska, eight in Hawaii, six in Puerto Rico, and one in Guam; HBN sites include one in Alaska and Hawaii. (Modified from *Alexander et al*. [1996b].)

flux from major watersheds [*Smith et al*., 1993; *Alexander et al*., 1996a], and the investigation of relations of water quality to streamflow [*Smith et al*., 1982], climatic, physiographic, and geologic factors [*Biesecker and Leifeste*, 1975; *Peters*, 1984; *Lucey and Goolsby*, 1993; *Alexander et al*., 1996a; *Clow et al*., 1996], and anthropogenic pollutant sources, such as agricultural fertilizers, livestock wastes, atmospheric deposition, and wastewater discharges from sewage treatment plants [*Smith and Alexander*, 1986; *Kramer et al*., 1986; *Smith et al*., 1987; *Crawford and Wangsness*, 1991; *Smith et al*., 1993, 1997]. The data have also served as baseline information for developing and illustrating many statistical methods for analyzing water resources data [*Hirsch et al*., 1982; *Hirsch and Slack*, 1984; *Helsel and Gilliom*, 1986; *Helsel and Cohn*, 1988; *Hirsch et al*., 1991; *Alexander et al*., 1993; *Smith et al*., 1997]. The data should provide excellent support for developing and evaluating new statistical methods for interpreting water quality and quantity data, especially methods that can be applied at the regional and national levels.

2. Data Characteristics

The network data on CD-ROM include regularly collected measurements for 122 physical, chemical, and biological properties of water made during more than 60,000 visits to stream-monitoring sites. Field measurements include instantaneous streamflow, turbidity, water temperature, specific conductance, *p*H, alkalinity, dissolved oxygen, percent saturation dissolved oxygen, and the pathogenic indicators fecal coliform bacteria and fecal streptococci bacteria. Measurements of instantaneous streamflow are available for the times of water quality sampling; continuous streamflow records (i.e., daily mean values) are also available for most stations. Laboratory measurements include major ions, *p*H, specific conductance, nutrients, organic carbon, radiochemicals, suspended sediment, periphyton, phytoplankton, and inorganic trace elements. Monitoring of several constituents began after the initial start of the networks; these include radiochemicals (1975 at all HBN and a subnetwork of 53 NASQAN stations), fecal bacteria (1976), organic carbon (dissolved and suspended in 1977), and alkalinity (field determinations in 1985). Several constituents were discontinued prior to 1995 including periphyton (1980), organic carbon (1981), phytoplankton (1981), whole water (i.e., unfiltered) analyses of inorganic trace elements (1982), and selected dissolved inorganic trace elements (1991). The dissolved trace elements arsenic, beryllium, cadmium, chromium, copper, lead, mercury, and zinc were discontinued in 1991 because of evidence of sample contamination [*Windom et al*., 1991; *Horowitz et al*., 1994]. The results of USGS investigations of trace element sample contamination [*Horowitz et al*., 1994] are included in the CD-ROM database to provide guidance in using the dissolved trace element data.

The frequency of water quality sampling commonly ranges from quarterly to monthly, with differences occurring by network, constituent, and time period. A change from monthly to bimonthly and quarterly sampling occurred in 1982 at NASQAN stations following major budget reductions. Most HBN stations changed from monthly to quarterly sampling beginning in 1983. Selected constituents such as radiochemicals were sampled biannually in both networks. For NASQAN the number of annual water quality analyses rose rapidly to nearly 200,000 in 1975, peaked at about 300,000 in 1980, and then declined to about 150,000 in 1983. These levels continued until 1991, when the number of analyses steadily declined to about 50,000 in 1995. For HBN the number of annual analyses increased to about 11,000 in 1968 and fluctuated between 10,000 and 15,000 through 1995.

Standard methods of sample collection, processing, and field and laboratory measurement have been used throughout the operation of the national networks (see *Alexander et al*. [1996b] for a listing of references and descriptions of selected methods). All physical, chemical, and biological measurements were made on water column samples with the exception of periphyton measurements, which reflect substrate conditions. Depth- and width-integrated sample-collection techniques were used to ensure adequate representation of the stream cross section. In preparing water samples for transport to the laboratory, bottles were filled from a "splitting" device to ensure proper mixing of stream subsamples. Fecal bacteria samples were taken as a surface "grab" sample from the centroid of streamflow and analyzed using membrane filter techniques. Samples analyzed for "dissolved" chemical species were pumped through a 0.45 μm pore size filter. Inorganic trace element samples were stabilized with nitric acid. Nutrient samples were chilled, and from 1980 to 1994 were treated with the biocide preservative mercuric chloride. Protocols specified that all samples were to be promptly transported to USGS laboratories.

Quality assurance information on network protocols and historical data on the sample collection agencies, laboratories, analytical methods, and laboratory measurement error (i.e., bias and variance) are provided on the CD-ROMs to assist in the proper use of the ambient water quality data. This information can help identify occasional changes in field and laboratory methods that may affect the use and interpretation of the ambient stream data. Estimates of the laboratory measurement error associated with the ambient data are available for 34 chemical constituents (nutrients, major ions, and inorganic trace elements), based on regular measurements of quality control reference samples (about 200–350 samples per year) from 1985 to 1995 that were collected as part of the USGS Blind Sample Program.

The CD-ROMs also provide additional supporting information on the history and purpose of the national networks, characteristics of the water quality, streamflow, and quality assurance/quality control data, selected cultural and natural characteristics of the watersheds, and a bibliography that references more than 160 publications on methods, network operations, and national, regional, and local interpretations of the data. Information on watershed characteristics include estimates of 1987 land cover [*U.S. Soil Conservation Service*, 1989] and 1990 population [*U.S. Bureau of Census*, 1991] compiled by intersecting digital watershed boundaries with counties and census units, respectively, in a geographic information system.

3. Data Access

The water quality data and supporting information were assembled in an easy-to-use format on two CD-ROMs [*Alexander et al*., 1996b]. All data are stored in ASCII form on the "ASCII" disc. The data can be browsed by executing the supplied Hypertext Markup Language (HTML) software from a Web browser (note that transfer of data to hard disc is accomplished by enabling the browser downloading option such as "save as"). Alternatively, the data may be directly accessed via other user-supplied software, including word processor or spreadsheet. The data architecture and file formats are fully documented in conveniently accessible files. A second disc, the "DOS" disc, includes software (operational on Windows systems) that is capable of browsing text files (all files except for daily streamflow) and retrieving and printing data according to user-specified criteria. The water quality data are geographically identified by river name, station location, state, county, and hydrologic drainage basin, all of which may be used to query and print the data. Quality assurance information that identifies changes in network operations and sampling and analytical methods is organized in easy-to-use tables with HTML links to supporting documentation. All other supporting information, including descriptions of the characteristics of the networks and bibliographic references, is also accessible through HTML links.

The CD-ROM two-disc set may be purchased from the USGS Branch of Information Services, Box 25286, Denver, Colorado 80225-0286 (1-800-435-7627). Web access is provided to the contents of the "ASCII" disc at ⟨URL http://wwwrvares.er.usgs.gov/wqn96/⟩. This Web site also includes a description of the contents and data architecture for the "ASCII" and "DOS" discs, a "frequently asked questions" page, an information fact sheet, and additional information about purchasing the discs and related publications.

4. Scientific Uses of the Data

The water quality data have a variety of scientific uses, serving both research and educational applications related to trend detection, flux estimation, investigations of the effects of the natural environment and cultural sources on water quality, and the development of statistical methods for designing efficient monitoring networks and interpreting water resources data. A few example uses of the data are highlighted here. NASQAN monitoring of the outlets of the major coastal tributaries of the United States (approximately 150 rivers) provides historical data for estimating the flux of dissolved constituents from the continent to important estuarine and coastal marine ecosystems [e.g., *Alexander et al*., 1996a]. The mass transport of silica, nutrients, and organic carbon from the continent is especially relevant to current research on coastal marine eutrophication [*National Research Council*, 1993] and regional and global estimation of carbon and nutrient budgets [*Maybeck*, 1982; *Galloway et al*., 1996; *Stallard*, 1998]. The data also provide a comprehensive archive of water quality measurements during a period when considerable changes, brought about in part by regulatory actions, occurred in terrestrial and atmospheric sources of water pollutants in the United States. This archive can be used to test hypotheses about past water quality changes in relation to changes in anthropogenic sources and provides a baseline for comparisons with water quality data collected in the future. In addition, the data can be used to investigate the effects of climatic variability on water quality through analyses of relations between water quality and streamflow [e.g., *Alexander et al*., 1996a; *Biesecker and Leifeste*, 1975]. Finally, there are water quality assessment needs [e.g., *Smith et al*., 1997] related to the design of efficient monitoring networks, especially at the regional and national levels, that the data can support. These include the development of statistical methods, which optimally determine the sampling frequencies and the number and location of monitoring locations that satisfy the objectives of load estimation, trend analysis, or predictive water quality models.

The data on CD-ROM also provide educators and students at levels ranging from high school through graduate school with an excellent opportunity to investigate many of the re-

search topics noted previously, as well as more fundamental relations in stream water quality. The data can be used to illustrate and explore the influence of cultural activities and the natural environment on water quality by examining relations of water quality concentrations and flux to land cover, population, watershed size, and streamflow characteristics and by observing variations in water quality over different temporal scales (e.g., seasonal, interannual). These uses are enriched by the diversity of river and watershed characteristics represented in the database.

5. Summary

This note describes a nationally consistent and well-documented collection of water quality data compiled during the past 30 years for streams and rivers in the United States by the U.S. Geological Survey (USGS) and now available on CD-ROM and accessible over the World Wide Web. The data include stream quantity and quality data collected at 680 monitoring stations, quality assurance information, and estimates of selected cultural and natural characteristics of the station watersheds, all of which are easily accessed by using the enclosed browsing and retrieval software. The data are from two national networks that include watersheds with diverse climatic, physiographic, and cultural characteristics. The Hydrologic Benchmark Network (HBN), consisting of 63 stations in small, minimally disturbed watersheds, provides data for investigating naturally induced changes in streamflow and water quality and the effects of airborne substances on water quality. The National Stream Quality Accounting Network (NASQAN), consisting of 618 stations in larger, more culturally influenced watersheds, provides data on ambient water quality conditions in major U.S. rivers and streams. The water quality data on CD-ROM span the years 1962–1995 for HBN and 1973–1995 for NASQAN. The data serve a variety of scientific uses, including research and educational applications related to trend detection, flux estimation, investigations of the effects of the natural environment and cultural sources on water quality, and the development of statistical methods for designing efficient monitoring networks and interpreting water quality and quantity data, especially methods that can be applied at the regional and national levels.

Acknowledgments. We would like to thank Jim Loftis of Colorado State University and Percy Pacheco of NOAA for their helpful improvements to the manuscript. We thank Janice Ward, William Battaglin, Richard Coupe, and Randy Parker of the USGS for earlier reviews of the contents of the CD-ROMs. We are also indebted to many others at the USGS, who provided technical support in the production of these discs. Finally, we extend a special thanks to Richard Smith and Gregory Schwarz of the USGS, whose collaboration on analyses of NASQAN and HBN data over the years made the release of these CD-ROMs possible.

References

Alexander, R. B., R. A. Smith, and G. E. Schwarz, Correction of stream quality trends for the effects of laboratory measurement bias, *Water Resour. Res*., *29*, 3821–3833, 1993.

Alexander, R. B., P. S. Murdoch, and R. A. Smith, Streamflow-induced variations in nitrate flux in tributaries to the Atlantic coastal zone, *Biogeochemistry*, *33*, 149–177, 1996a.

Alexander, R. B., J. R. Slack, A. S. Ludtke, K. K. Fitzgerald, and T. L. Schertz, Data from selected U.S. Geological Survey national stream water-quality monitoring networks (WQN), *U.S. Geol. Surv. Digital Data Ser*., *DDS-37*, 1996b.

Biesecker, J. E., and D. K. Leifeste, Water quality of hydrologic bench marks—An indicator of water quality in the natural environment, *U.S. Geol. Surv. Circ*., *460-E*, 1975.

Briggs, J. C., and J. F. Ficke, Quality of rivers of the United States, 1975 water year—Based on the National Stream Quality Accounting Network (NASQAN), *U.S. Geol. Surv. Open File Rep*., *78-200*, 1977.

Clow, D. W., M. A. Mast, and D. H. Campbell, Controls on surface water chemistry in the Upper Merced River basin, Yosemite National Park, California, *Hydrol. Processes*, *10*, 727–746, 1996.

Crawford, C. G., and D. J. Wangsness, Effects of advanced wastewater treatment on the quality of the White River, Indiana, *Water Resour. Bull*., *27*, 769–779, 1991.

Galloway, J. N., R. W. Howarth, A. F. Michaels, S. W. Nixon, J. M. Prospero, and F. J. Dentener, Nitrogen and phosphorus budgets of the North Atlantic Ocean and its watersheds, *Biogeochemistry*, *35*, 3–25, 1996.

Hay, L. E., and J. P. Campbell, Water quality trends in New Jersey streams, *U.S. Geol. Surv. Water Resour. Invest. Rep*., *90-4046*, 1990.

Helsel, D. R., and T. A. Cohn, Estimation of descriptive statistics for multiply censored water quality data, *Water Resour. Res*., *24*, 1997–2004, 1988.

Helsel, D. R., and R. J. Gilliom, Estimation of distributional parameters for censored trace level water quality data, 2, Verification and applications, *Water Resour. Res*., *22*, 147–155, 1986.

Hirsch, R. M., and J. R. Slack, A nonparametric trend test for seasonal data with serial dependence, *Water Resour. Res*., *20*, 727–732, 1984.

Hirsch, R. M., J. R. Slack, and R. A. Smith, Techniques of trend analysis for monthly water quality data, *Water Resour. Res*., *18*, 107–121, 1982.

Hirsch, R. M., R. B. Alexander, and R. A. Smith, Selection of methods for the detection and estimation of trends in water quality, *Water Resour. Res*., *27*, 803–813, 1991.

Hooper, R. P., D. A. Goolsby, D. A. Rickert, and S. W. McKenzie, NASQAN—A program to monitor the water quality of the nation's large rivers, *U.S. Geol. Surv. Fact Sheet*, *FS-055-97*, 1997.

Horowitz, A. J., C. R. Demas, K. K. Fitzgerald, T. L. Miller, and D. A. Rickert, U.S. Geological Survey protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water, *U.S. Geol. Surv. Open File Rep*., *94-539*, 1994.

Kramer, J. R., A. W. Andren, R. A. Smith, A. H. Johnson, R. B. Alexander, and G. Ohlert, Streams and lakes, in *Acid Deposition: Long-term Trends*, pp. 231–299, Natl. Acad. Press, Washington, D. C., 1986.

Lettenmaier, D. P., E. R. Hooper, C. Wagoner, and K. B. Faris, Trends in stream quality in the continental United States, 1978–1987, *Water Resour. Res*., *27*, 327–339, 1991.

Lucey, K. J., and D. A. Goolsby, Effects of climatic variations over 11 years on nitrate-nitrogen concentrations in the Raccoon River, Iowa, *J. Environ. Qual*., *22*, 38–46, 1993.

Maybeck, M., Carbon, nitrogen, and phosphorus transport by world rivers, *Am. J. Sci*., *282*, 401–450, 1982.

National Research Council, *Managing Wastewater in Coastal Urban Areas*, Comm. on Wastewater Manage. for Coastal Urban Areas, Natl. Acad. Press, Washington, D. C., 1993.

Peters, N. E., Evaluation of environmental factors affecting yields of major dissolved ions of streams in the United States, *U.S. Geol. Surv. Water Supply Pap*., *2228*, 1984.

Schertz, T. L., Trends in water-quality data in Texas, *U.S. Geol. Surv. Water Resour. Invest. Rep*., *89-4178*, 1990.

Seaber, P. R., F. P. Kapinos, and G. L. Knapp, Hydrologic unit maps, *U.S. Geol. Surv. Water Supply Pap*., *2294*, 1987.

Smith, R. A., and R. B. Alexander, Correlations between stream sulphate and regional SO_2 emissions, *Nature*, *322*, 722–724, 1986.

Smith, R. A., R. M. Hirsch, and J. R. Slack, A study of trends in total phosphorus measurements at NASQAN stations, *U.S. Geol. Surv. Water Supply Pap*., *2190*, 1982.

Smith, R. A., R. B. Alexander, and M. G. Wolman, Water quality trends in the nation's rivers, *Science*, *235*, 1607–1615, 1987.

Smith, R. A., R. B. Alexander, and K. J. Lanfear, Stream water quality in the conterminous United States—Status and trends of selected indicators during the 1980's, in *National Water Summary 1990–91*: *Hydrologic Events and Stream Water Quality*, edited by R. W. Paulson et al., *U.S. Geol. Surv. Water Supply Pap*., *2400*, pp. 111–140, 1993.

Smith, R. A., G. E. Schwarz, and R. B. Alexander, Regional interpre-

tation of water quality monitoring data, *Water Resour. Res*., *33*, 2781–2798, 1997.

Stallard, R. F., Terrestrial sedimentation and the carbon cycle: Coupling weathering and erosion to carbon burial, *Global Biogeochemical Cycles*, *12*, 231–257, 1998.

Windom, H. L., J. T. Byrd, R. G. Smith, and F. Huan, Inadequacy of NASQAN data for assessing metal trends in the nation's rivers, *Environ. Sci. Technol*., *25*, 1137–1142, 1991.

U.S. Bureau of Census, Census of population and housing 1990—Public Law 94-71 data on CD-ROM, Washington, D. C., 1991.

U.S. Soil Conservation Service, Summary report 1987—National resources inventory, *U.S. Soil Conserv. Serv. Stat. Bull*., *790*, Washington, D. C., 1989.

R. B. Alexander, K. K. Fitzgerald, and J. R. Slack, U.S. Geological Survey, 413 National Center, Reston, VA 20192.

A. S. Ludtke and T. L. Schertz, U.S. Geological Survey, Denver Federal Center, Building 53, Denver, CO 80225.

(Received November 17, 1997; revised May 1, 1998;
accepted May 5, 1998.)