LA-UR- 96-3684

Title: **AQUATIC MACROINVERTEBRATES AND WATER QUALITY OF SANDIA CANYON, LOS ALAMOS NATIONAL LABORATORY, 1995**

Author(s): **Saul Cross and Heidie Nottelman**

Submitted to:

Los Alamos
NATIONAL LABORATORY

Form No. 836 R5
ST 2629 10/95

Aquatic Macroinvertebrates and Water Quality

of Sandia Canyon,

Los Alamos National Laboratory, 1995

by Saul Cross and Heidi Nottelman

Biology Team, ESH-20, LANL

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

AQUATIC MACROINVERTEBRATES AND WATER QUALITY OF SANDIA CANYON, LOS ALAMOS NATIONAL LABORATORY, 1995

by

Saul Cross
and Heidi Nottelman

ABSTRACT

The Biology Team of ESH-20 (the Ecology Group) at Los Alamos National Laboratory (LANL) has collected samples from the stream within Sandia Canyon since the summer of 1990. These field studies measure water quality parameters and collect aquatic macroinvertebrates from sampling sites within the upper canyon stream. Reports by Bennett (1994) and Cross (1994, 1995a) discuss previous aquatic studies in Sandia Canyon. This report updates and expands the previous findings.

The Biology Team collected water quality data and aquatic macroinvertebrates monthly at three sampling stations within Sandia Canyon in 1995. The two upstream stations occur near a cattail (*Typha latifolia*) dominated marsh downstream from outfalls that discharge industrial and sanitary waste effluent into the stream, thereby maintaining year-round flow. The third station is approximately 1.5 miles downstream from the outfalls within a mixed conifer forest.

All water chemistry parameters measured in Sandia Canyon during 1995 fell within acceptable State limits and scored in the "good" or "excellent" ranges when compared to an Environmental Quality Index. However, aquatic macroinvertebrates habitats have been degraded by widespread erosion, channelization, loss of wetlands due to deposition and stream lowering, scour, limited acceptable substrates, LANL releases and spills, and other stressors. Macroinvertebrate communities at all the stations had low diversities, low densities, and erratic numbers of individuals. These results indicate that although the stream possesses acceptable water chemistry, it has reduced biotic potential. The best developed aquatic community occurs at the sampling station with the best habitat and whose downstream location partially mitigates the effects of upstream impairments.

---

1 INTRODUCTION

1.1 Previous Aquatic Biological Sampling within Sandia Canyon

In the summer of 1990, an accidental spill from the environmental tank at the TA-3 power plant released at least 3,785 liters (1,000 gallons) of concentrated sulfuric acid into upper Sandia Canyon. The Biology Team was asked to review the impacts of this spill and began regular monitoring of the Sandia wetland at this time (Bennett 1994). The Team initiated a study to assemble baseline information on the aquatic environment in Sandia Canyon and to determine if the environment was affected by industrial and sanitary waste discharges. Simultaneously with monitoring chemical and physical conditions of the stream monthly, the Team collected aquatic invertebrates. These samples were used to evaluate the effects of LANL discharges on aquatic biological communities in upper Sandia Canyon.

1.2 Physical and Chemical Parameters

In a report for the Bureau of Reclamation (Battelle 1972), Battelle Columbus Laboratories outlined a comprehensive and interdisciplinary Environmental Evaluation System (EES). This EES uses physical, chemical, and biological parameters to assess possible environmental impacts of water resource projects. This report refers to many of the environmental quality ratings developed by Battelle. The Biology Team measured water temperature, dissolved oxygen, pH, and conductivity at each sampling station monthly.

Water temperature directly influences aquatic organisms' physiological functions such as metabolism, growth, emergence, and reproduction (Wallace and Anderson 1996). Temperature is inversely related to oxygen solubility because water absorbs greater amounts of oxygen at lower temperatures. While aquatic organisms can tolerate wide fluctuations in pH and conductivity, a change in water temperature of a single degree Celsius can be significant (Lehmkuhl 1979).

Depressed oxygen environments often indicate the presence of organic wastes. The amount of dissolved oxygen (DO) in water has direct and immediate effect on invertebrates using tracheal gills for respiration (as the larvae of dragonflies, mayflies, caddisflies, and stoneflies). Oxygen is present in air at levels greater than 200,000 ppm, but its maximum value at saturation in water is only 15 ppm (Eriksen et al. 1996). Although aquatic insects require more oxygen for metabolism at elevated temperatures, less is available due to decreased solubility (Gaufin et al. 1974). Certain stages in the life cycle of aquatic invertebrates, such as emergence, will not occur unless sufficient oxygen is present (Bell 1971). Cold-water mayflies and stoneflies cannot tolerate DO concentrations much below 5 mg/l (Nebeker 1972).

Acid waters are characterized by low species diversity and low productivity. Acidity and basicity of water are measured by the pH scale, with low values (0 – 6) indicating acidity, middle values (around 7.0) indicating neutrality, and high values (8 – 14) indicating basicity. Some aquatic organisms, as mayflies, are extremely sensitive to low pH, which can be caused by accidental acid spills or acid rain deposition. The normal pH of natural surface waters ranges from 6.5 to 9.0 (Canter and Hill 1979).

Conductivity measures the ability of water to carry an electrical current, and it reflects the concentrations of ionized substance in water. The conductivity of potable water in the United States ranges from 50 to 1,500 micro-mhos per centimeter (μmhos/cm), and the conductivity of industrial waste may be as high as 10,000 μmhos/cm. A rough approximation of the total dissolved solids (TDS) of freshwater in mg/l is obtained by multiplying the conductivity by 0.66. The upper limit of TDS that aquatic organisms can tolerate ranges from 5,000 to 10,000 mg/l (Battelle 1972).

1.3 Aquatic Macroinvertebrates

Aquatic macroinvertebrates are extensively utilized as water quality indicators. A macroinvertebrate is an invertebrate that is visible to the unaided eye. This report uses the terms macroinvertebrate, aquatic macroinvertebrate, invertebrate, and aquatic invertebrate interchangeably. These organisms, especially the stream-dwelling insects, are well suited as water quality indicators due to their

- small size and total immersion in the aquatic environment;
- relatively sedentary nature;
- abundance in virtually all streams;
- range of sensitivities to stress and contaminants;
- life cycles, which are frequently of at least one-year duration, allowing long-term detection of past disturbance; and
- relative ease of collection and identification to family or genus level.

In general, monitoring only the physical and chemical characteristics of waters provides little information of conditions prior to the sampling date. In contrast, changes in macroinvertebrate communities indicate water quality over a much longer period (Rosenberg et al. 1986). The failure of chemical criteria to protect aquatic life has necessitated incorporation of biological criteria into water resource management planning (Karr 1991). Shifts in the numbers of individuals and community species composition indicate prior disturbances. These disturbances could result from infrequent discharges of waste that might remain undetected through a water quality monitoring program that did not incorporate biological data (Weber 1973).

Biological assessments facilitate the comprehension of ecosystem processes and health, allowing management to make informed decisions and to take appropriate actions (ITFMWQ 1994). According to the Intergovernmental Task Force on Monitoring Water Quality (1992), objectives of an aquatic biological monitoring program should include

- defining status and trends,
- identifying existing and emerging problems,
- providing information to support development and implementation of policies and programs for water-resource management,
- evaluation of program effectiveness, and
- response to emergencies.

2 ENVIRONMENTAL SETTING

2.1 General Setting

Upper Sandia Canyon occurs within the boundaries of Los Alamos National Laboratory (LANL). The 111-km^3 (43-mi^2) Laboratory site is located in north-central New Mexico on the Pajarito Plateau, approximately 120 kilometers (80 miles) north of Albuquerque and 40 km (25 mi) west of Santa Fe (Fig. 1). In the LANL region, the eastern edge of the Pajarito Plateau descends to the Rio Grande in White Rock Canyon. The Rio Grande flows in a southwesterly direction along the easternmost boundary of LANL. Most LANL industrial developments are confined to the mesa tops, which range in elevation from a maximum of 2,400 m (7,800 ft) along the western boundary to about 1,900 m (6,200 ft) at their eastern terminus above the Rio Grande. The canyons within LANL boundaries can be as deep as 300 m (1,000 ft) below the mesa top. LANL is divided into Technical Areas (TAs) that are used for administration and support function buildings, experimental and research areas, waste disposal areas, roads, and utility corridors. However, these uses account for only a small part of LANL's total land area,

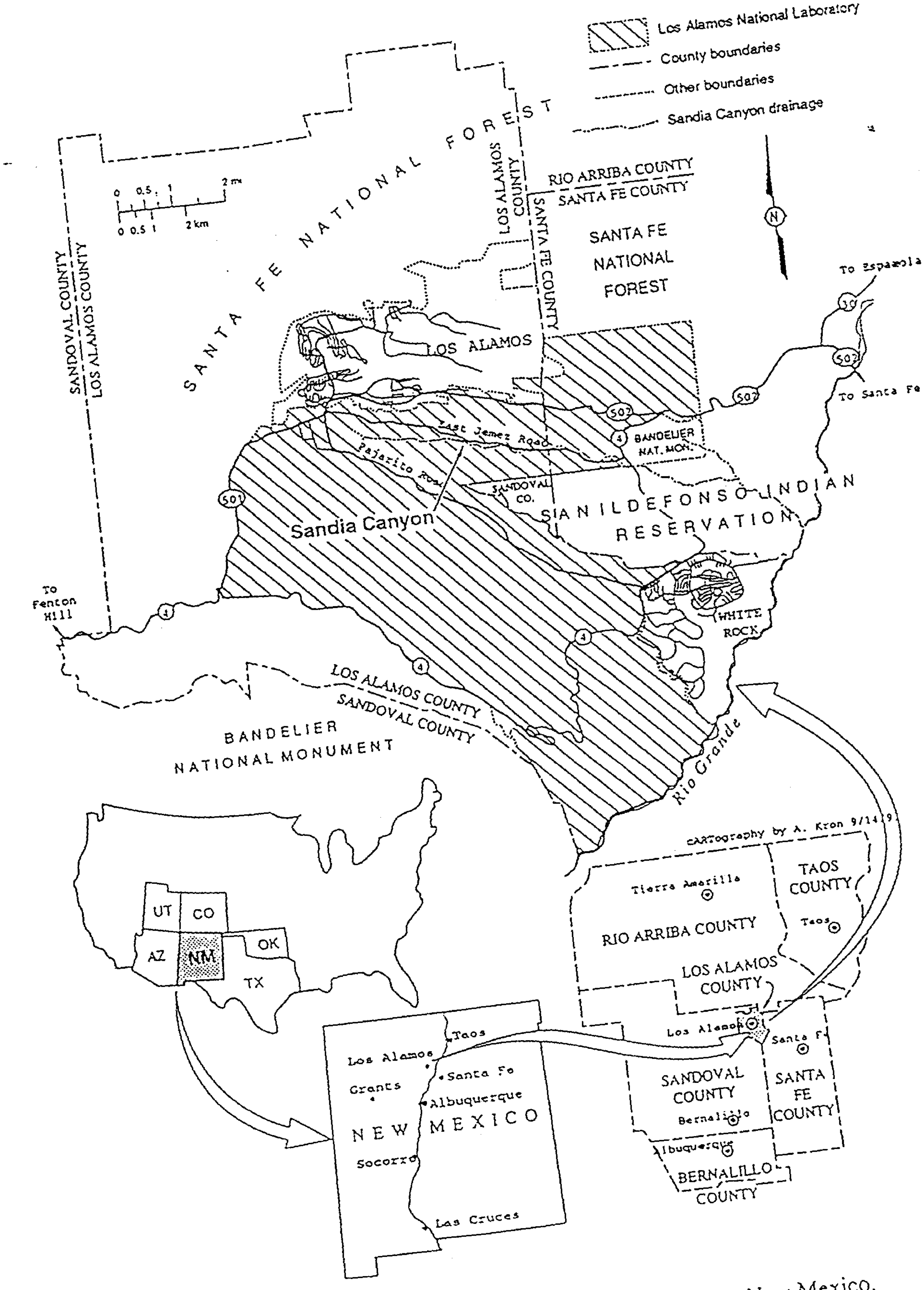


Fig. 1. Location of Los Alamos National Laboratory, New Mexico.

and the remainder is reserved as buffer zones and potential sites for future development (EPG 1996).

Most of the mesas in the Los Alamos area are formed from Bandelier Tuff, which includes ash fall, ash fall pumice, and rhyolite tuff. The tuff, ranging from nonwelded to welded, is more than 300 m (1,000 ft) thick in the western part of the Plateau and thins to about 80 m (260 ft) eastward above the Rio Grande. It was deposited as a result of major eruptions in the Jemez Mountains about 1.2 to 1.6 million years ago. The tuff overlaps onto the Tschicoma Formation, which consists of older volcanics that form the Jemez Mountains. In the central and eastern edge along the Rio Grande, the tuff is underlain by the conglomerate of the Puye Formation. Chino Mesa basalts intermix with the conglomerate along the river. These formations overlay the sediments of the Santa Fe Group, which extend across the Rio Grande Valley and are more than 1,000 m (3,300 ft) thick (EPG 1996).

LANL has a semiarid, temperate mountain climate. The average high temperature in July from 1961 through 1990 was 27°C (81°F), and the average high temperature in January was 4°C (40°F). The average low temperature in July from 1961 through 1990 was 13°C (55°F), and the average low temperature in January was -8°C (17°F). Daily temperature fluctuations average 13°C (23°F), a result of LANL's high elevation and a dry, clear atmosphere, which allows high insolation during the day and rapid radiative losses at night (EPG 1996).

The average annual precipitation is 48 cm (18.7 in), and the first five years of the 1990's are considered to be normal rainfall years. Approximately 36 percent of the annual precipitation normally occurs during July and August. Runoff from late summer thundershowers flows through the various canyons, supplementing ground water in the shallow alluvium. Winter precipitation falls primarily as snow with accumulations of about 150 cm (59 in) (EPG 1996). The monthly totals of precipitation from nearest meteorological station in TA-6 are shown in Fig. 2.

2.2 Description of Sandia Canyon

The head of Sandia Canyon is near the University House in TA-3, and the canyon extends approximately 18.5 km (11.5 moles) southeastward to the Rio Grande. The drainage basin is approximately 13.5 square kilometers (5.6 square miles). The initial 7.5 km (4.7 miles) of the canyon occurs on LANL property. Industrial effluents from LANL activities maintain a year-round stream flow in upper Sandia Canyon. The lower canyon has seasonal flows, and stream water reaches the Rio Grande an estimated 6 – 20 days a year due to storm events and snowmelt.

The National Wetlands Inventory conducted by the U.S. Fish and Wildlife Service identified three types of wetlands or water systems within Sandia Canyon (Cowardin 1979). The upper stretch is a "persistent artificially flooded, palustrine wetland." East of LANL property, the wetland area changes to a "temporarily flooded palustrine wetland" type. The stream's lowest stretch is an "intermittent, temporarily flooded, riverine steam bed" (Cowardin 1979). The National Wetland Inventory map of Sandia Canyon is shown in Fig. 3.

Biology Team monitoring was conducted in the upper canyon area, near an open cattail (*Typha latifolia*) marsh and in a narrow stream reach with an overstory of mixed conifer. These areas occur downgradient from TA-3 and have received effluent discharges

Fig. 2. 1995 monthly precipitation totals for the upper Sandia Canyon area.

IN PREPARATION

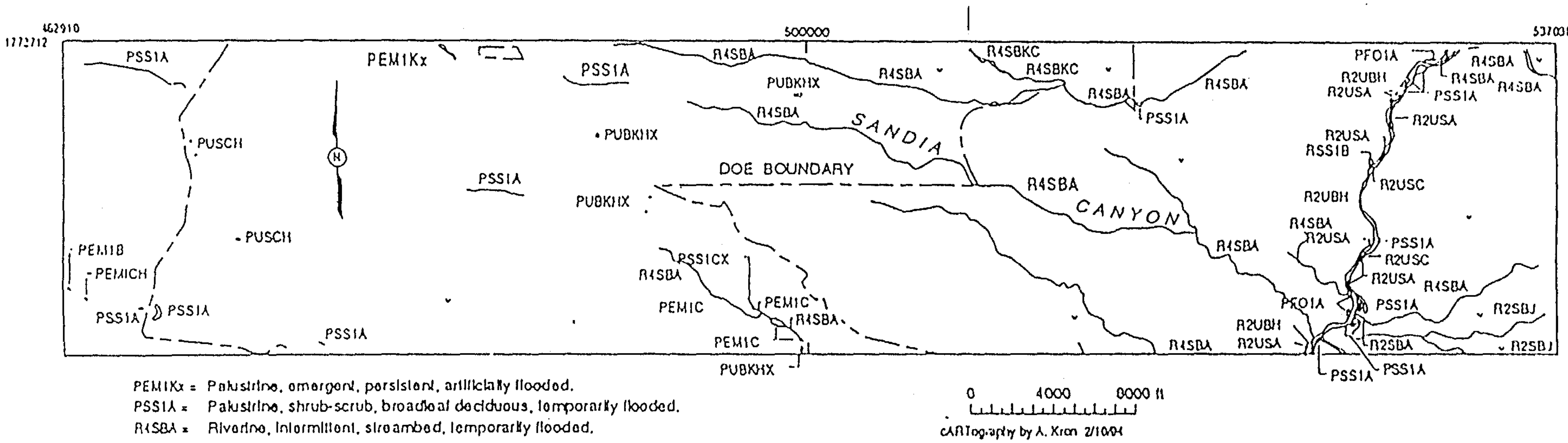


Fig. 2. National Wetland Inventory map for Sandia Canyon, Los Alamos County, New Mexico (developed by U.S. Fish and Wildlife Service).

from LANL operations since the early 1950's. A perennial stream flow is currently maintained primarily by discharges from cooling towers below the TA-3 power plant, recirculated water from the Sanitary Waste Systems Consolidation (SWSC) plant, and storm water diversions from TA-3 roads, buildings, and parking lots. A large culvert underneath a demolition landfill empties water from the TA-3 power plant, diverted storm water, and several low-volume LANL outfalls into the head of the canyon. The SWCS Outfall 13S discharges excess reuse water on a southern hillside, approximately 40 m (125 ft) from the culvert. Waters from both points of discharge commingle in the channel that has cut through soft sediments near the center of the canyon.

2.3 Description of the Study Sites

In 1990, the Biology Team began to monitor sampling stations within Sandia Canyon's artificially flooded, palustrine wetland. The locations of these stations have been changed during the years to allow data collection at different wetland sites. In 1995, the lowest station was moved approximately 2.4 km (1.5 mi) downstream to provide data on conditions within the montane stream that drains the upper cattail marsh.

Each sampling station consists of an approximately 10-m (33-ft) stream reach, and specific sampling sites are alternated within the reach to allow macroinvertebrate populations sufficient re-establishment time after sample collection. All sampling stations are designated by the letters "SC" followed by a number indicating their relative positions along the stream, with lower numbers occurring farther upstream (Fig. 4). In 1995, the Biology Team monitored three sampling stations within Sandia Canyon by taking monthly measurements of water quality parameters and collections of aquatic invertebrates.

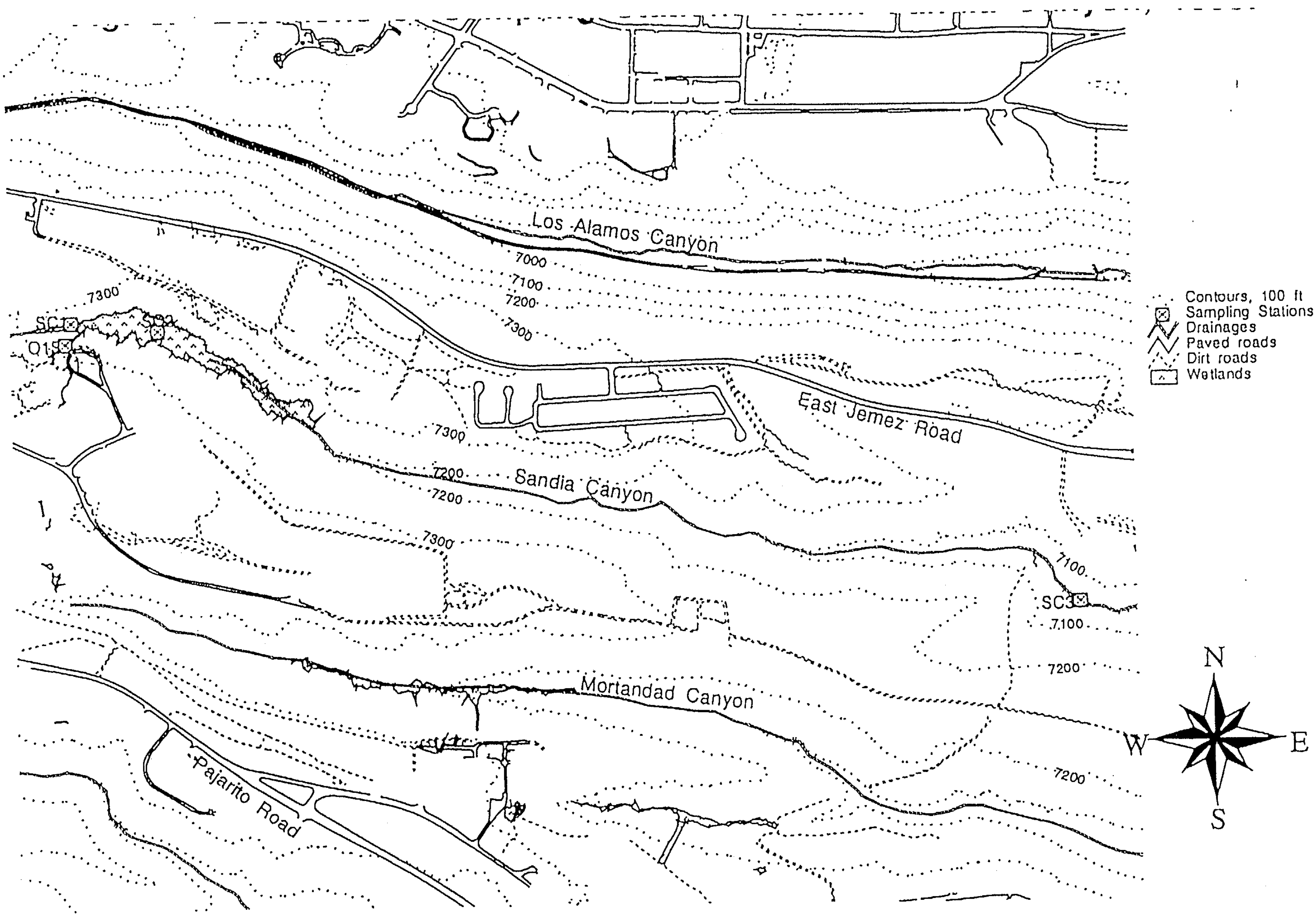


Fig. 3 1995 Locations of Sampling Stations within Sandia Canyon.

SC1 is located on the south side of the stream across from the Los Alamos County landfill. It is at an approximate elevation is 2520 m (7200 ft) above sea level and roughly 16 m (50 ft) downstream from the main effluent culvert. This site receives discharges from the SWSC outfall on the southern hillside above it and from upstream outfalls and storm water diversions through the culvert. The vegetation along the southern streambank is a thick monotypic stand of tall (1.8 m or 6 ft) cattails (*Typha latifolia*). The northern streambank vegetation consists primarily of redtop (*Agrostis alba*) with smaller amounts of sow's ear (Sonchus asper), and various other forbs. Several ponderosa pine (*Pinus ponderosa*), Gambel's oak (*Quercus gambelii*), Douglas-fir (*Pseudotsuga menziesii*) trees, and Russian olive (Eleagnus *angustifolia*) trees occur upstream, but SC3 has no true overstory, although surrounding cattails provide some shade.

Debris, including asphalt and concrete from the demolition landfill and wind-borne trash from the County sanitary landfill, occurs in the stream channel at SC1. The surrounding hillsides are unvegetated raw areas capable of massive erosion during storm events. Sedimentation fences have been erected to prevent additional debris from entering the channel, but numerous gaps occur in the fencing, especially in the sections bounding the County sanitary landfill. The stream bed is heavily sedimented with silts and sands, but suitable habitat for aquatic invertebrates exists as large gravels, cobbles, and stacked rocks. Water is usually about 0.15 m (0.5 ft) deep, although the channel is approximately 1.6 m (5 ft) deep. Frequent flooding occurs at SC1 primarily due to sudden storm water discharges during thunderstorms, which erodes the unconsolidated substrate and redeposits it downstream.

At an approximate elevation of 2520 m (7200 ft) above sea level, SC2 is about 100 m (330 ft) downstream from SC1. The streamside vegetation consists primarily of cattails, redtop, and thistle, with smaller amounts of gumweed (*Grindelia aphanactis*), sweet clover (*Melilotus* sp.), sage, Canada wildrye, and dandelion (*Taraxacum officinale*). Ponderosa pine and Gambel's oak grow along the canyon walls, but no overstory occurs at this sampling station. SC2 is beside a series of shifting sand bars, and the channel banks are less than 0-.3 m (1 ft) high. Immediately upstream from SC2, a large stand of cattails extends across most of the level canyon bottom and the stream becomes less channelized. Aquatic invertebrate habitat is marginal due to stream bank instability, high rates of erosion, and the loose substrates.

Previously, the farthest downstream sampling station occurred near the end of the cattail area. In 1995, the Biology Team wanted to collect information on the biological health of the stream beyond the upper marsh. For that reason, SC3 was established approximately 2.4 km (1.5 mi) downstream from the head of Sandia Canyon. This sampling station occurs in a deep (12 m or 40 ft) and narrow (15 m or 50 ft) section of the canyon thickly shaded by white fir (*Abies concolor*), Gambel's oak, Doug-fir (*Pseudotsuga menziesii*), and chokecherry (*Prunus virginiana*). The approximate elevation at SC3 is 2150 m (7050 ft). Along the stream channel, the understory vegetation consists largely of redtop (*Agrostis alba*) with smaller amounts of wild raspberry (*Rubus strigosus*), James geranium (*Geranium caespitosum*), Wood's rose (*Rosa woodsii*), Mexican dropseed (*Muhlenbergia mexicana*), liverworts, and mosses. Streamside cover is much greater in this area than near the upper sampling sites, and this causes cooler and more consistent water temperatures. The water is usually about 0.15 m (0.5 ft) deep, and the stream channel is approximately 1.5 m (5 ft) wide and 0.5 m (1.5 ft) deep. SC3 provides the best aquatic invertebrate habitat of all the Sandia sampling stations due to shading, more frequent riffle areas, and less sand and silt (although much is present due to upstream erosion and subsequent deposition) covering a rocky substrate.

3 DISTURBANCES WITHIN SANDIA CANYON

In addition to the impacts of routine effluent discharges, the hydrology of Sandia Canyon has been affected by the nearby rubble landfill and Los Alamos County sanitary landfill, accidental chemical spills, and cumulative habitat degradation.

3.1 Rubble Landfill

The rubble landfill was started in 1986 as an alternate disposal site for clean rubble. Presently, the landfill bridges the upper canyon's western margin and towers above the cattail dominated wetland. In previous years, large amounts of fill, sediments, and pieces of rubble, including asphalt, eroded into the wetland during heavy storm events and snow melt. In February 1995, a dirt road was cut from the landfill summit to the culvert at the head of the canyon. Large quantities of fine sediments quickly eroded into the wetland along this roadway. A poorly designed sedimentation fence blew out during a storm event in July and fine materials continued to wash into the stream. Subsequently, two remedial actions were undertaken to minimize the impact of the rubble landfill on the wetland area: a retention pond was excavated at the base of the landfill and the sedimentation fence was reinforced to prevent further erosion into the wetland during storms and runoff. Both efforts were successful in containing materials that would otherwise fall and/or erode into the stream channel and be carried into the wetland. However, large pieces of concrete and asphalt that had previously fallen into the stream channel still occur. The introduction of asphalt (an oil-based product) into a wetland area violates U.S. Environmental Protection Agency regulations.

3.2 County Landfill

The county landfill occurs immediately to the north of upper Sandia Canyon and extends 1.2 km (0.75 mi) along the top of Los Alamos Mesa. The landfill receives Los Alamos County business and residential refuse as well as sanitary refuse from LANL. Fill material erodes off the landfill, down the steep northern canyon wall, and into the wetland area. The introduction of this material has raised a portion of the upper northern wetland far enough above the water table to eliminate its wetland vegetation. In addition, paper trash and other debris fall or blow into the canyon.

During 1995, a series of sedimentation fences to contain eroding sediments from the sanitary landfill was erected, reinstalled, or repaired. In September and October of 1995, several ill-considered roadways were cut along the northern slope above the upper cattail area. The sedimentation fences, particularly the sections by the head of the canyon, were not anchored properly and did little to prevent continued erosion. The road cuts increased erosion by baring the soil and providing corridors for runoff and precipitation. The September cuts also exposed previously buried trash cells, increasing the amount of loose litter that entered the wetland. As of the writing of this report (September 1996), these problems have not been resolved.

A wetland expert hired to assess the current condition of LANL wetlands wrote, "...the operations of the Los Alamos County (LAC) Sanitary Landfill paralleling the north side of the Sandia Creek have created massive, steep high walls of relatively unstable, unvegetated, erodible, granular material. Considering the presence of large, recently deposited sediment fans within the Sandia Creek floodplain, it is apparent that these slopes are a ready source of large volume sediment inputs to the creek system. Apparent existing efforts to check erosive deposition by hay bales, sediment fences, and the spraying of polymer stabilizers on the barren slopes have not been sufficiently effective to prevent major sediment flows onto the floodplain" (Newling 1995).

3.3 Accidental Spills and Over-Chlorination

During the summer of 1990, 3,785-5,300 liters (1,000-1,400 gallons) of sulfuric acid spilled from the TA-3 power plant environmental tank into the cattail-dominated wetland in upper Sandia Canyon. At this time, the Biology Team established sampling stations to assess the spill's impact on biota and biological function. The Biology Team surveyed the stream channel immediately after the spill for aquatic macroinvertebrates, and no specimens were found at any sample location. However, aquatic macroinvertebrate communities began to reestablish within one month. Recovery was first observed at the sampling station farthest downstream.

During midsummer 1992, another spill discharged chlorine from the sewage treatment plant into Sandia Canyon. Subsequent investigation revealed a significant decline in the number of stream macroinvertebrates. By the end of summer, the numbers of macroinvertebrates had nearly returned to normal.

Heavy metals and polychlorinated biphenyls (PCBs) are believed to occur within the deeper sediments of Sandia Canyon. LANL's Environmental Restoration program has conducted preliminary tests to determine the nature and extent of this contamination. A former storage site for electrical equipment located upslope from the main drainage leading to Sandia Canyon had one "hot spot" of PCBs measuring 30,000 parts per million (ppm). The current Environmental Protection Agency acceptable limit for PCBs in the environment is 1 ppm.

In 1995, members of the New Mexico Environmental Department noted over-chlorination of discharges from the sanitary Outfall 13S that feeds into Sandia Canyon. This water is pumped from the SWCS station in Cañada del Buey for reuse at various LANL sites. It was chlorinated to protect workers from potential contamination that could result from accidental exposure to treatment facility discharges. In April 1995, a sodium thiosulfate pump was installed to dechlorinate the water prior to its discharge into Sandia Canyon. The Biology Team began monitoring chlorine levels monthly at Outfall 13S in April 1995 to document compliance with the State limit of 1 ppm free chlorine.

3.4 Overall Habitat Degradation

According to a recent Department of Energy compliance investigation of LANL wetlands (Kubic 1993), "The wetland at the head of Sandia Canyon has been, and continues to be, adversely impacted by chemical releases and other LANL activities associated with TA-3. Efforts should be made to prevent further disturbance of this wetland."

A properly functioning wetland provides increased water retention, storm and flood abatement, groundwater recharge, sediment trapping, pollutant filtering, and wildlife habitat (Hill 1994). However, the wetland in Sandia Canyon is not functioning properly, primarily due to anthropogenic stresses. These stressors include:

- high sedimentation loads from the Los Alamos County landfill and the LANL rubble dump;
- urbanization and paving of the watershed producing flooding, channelization and scour, and lowering the wetland water table;
- headcutting within the wetland resulting in mass erosion;
- excessive levels of chlorination in discharges to the upper canyon;
- thermal pollution from cooling tower discharges;
- asphalt and trash in the stream;
- previous sewer line work, which failed to restore the area to its natural contours and failed to revegetate disturbed areas properly; and
- loss of potential aquatic and wildlife habitat due to sedimentation, channelization, low plant diversity, and senescent cattails.

4 METHODOLOGY

4.1 Water Quality Parameters

The Biology Team began to monitor chlorine discharges into Sandia Canyon in April 1995. These tests were conducted at the Outfall O1S point of discharge, on the south rim of the head of Sandia Canyon. A LaMotte digital colorimeter model 1100 measured the amount of free chlorine in ppm. The Biology Team conducted monthly chlorine sampling at the same time as other physical-chemical parameters were measured and aquatic invertebrates were collected.

The Biology Team measured the water temperature, pH, dissolved oxygen, and conductivity of the stream in Sandia Canyon monthly at three sampling stations. All measurements were taken with instruments in accordance with all the manufacturer's specifications. Each instrument was calibrated on the same day that it was used in the field. All measurements were taken three times, and the average value was used in computations.

All pH measurements were taken with an Orion SA 250 pH meter or an Orion model 230 pH meter. Temperature measurements were taken with a Yellow Springs Instrument model 57 dissolved oxygen (DO) meter in degrees Celsius. DO was measured with the same Yellow Springs Instrument model 57. The DO meter was calibrated by multiplying the reading by a factor of 0.78 to compensate for the elevation in upper Sandia Canyon, which is about 2180 m (7200 ft). Conductivity measurements were taken with a Van Waters Rogers digital conductivity meter which displays conductivity in units of μmhos/cm. Total dissolved solids were estimated by multiplying the conductivity readings by 0.66 (Battelle 1972).

4.2 Erosion Measurements

The Biology Team placed erosion stakes in side drainages along upper Sandia Canyon to monitor the extent of erosion. Erosion stakes consisted of metal fence posts and were placed along four side drainages along upper Sandia Canyon. On the north side of the canyon, the Biology Team had noted significant amounts of coarse material deposition due to erosion from the steep-sided and unvegetated Los Alamos County sanitary landfill. Drainages along the south side of the canyon were more characteristic of natural drainages in the area and were used as controls. Each stake line consisted of three posts set in the center of the drainages. Each line began 10 meters (33 ft) from the stream edge or from the edge of live cattails. The posts were spaced 10 meters (33 ft) apart and monitored monthly.

On the north side, N-1 was established below the southwest corner of the Los Alamos County sanitary landfill. It crossed a former wetland area that had been elevated and dried out due to thick deposits of coarse materials. N-2 was placed below another Los Alamos County sanitary landfill blow-out area near the end of the cattail marsh. On the south side, S-1 was established in a more natural drainage channel as a control station. S-2 was placed in the most heavily sedimented drainage on the south side of upper Sandia Canyon, which received runoff from TA-3 parking lots and buildings.

4.3 Aquatic Macroinvertebrate Sampling

Aquatic macroinvertebrates were collected monthly at the same time that water quality parameters were measured. The Biology Team used a 0.09-m^2 (1- ft^2) Surber sampler with a mesh size of 1000 microns to collect macroinvertebrates because it allows density calculations. The sampler consists of a square metal frame that supports two side-flaps with a conical net between them. The frame was positioned firmly against the substrate in a riffle area that was subjectively judged to provide the best available habitat in the vicinity. The net trailed downstream and captured dislodged invertebrates that the current swept into it. Large rocks within the metal frame were shaken and then scrubbed with a brush to remove clinging macroinvertebrates. The substrate was agitated to a depth of several inches, so that burrowing invertebrates would also be collected.

All captured aquatic invertebrates were placed in labeled scintillation vials containing 70% ethanol and taken to the Biology Team's lab. The samples and collection data were logged into the Biology Team Aquatic Data Book upon return to the invertebrate lab. Trained sorters separated invertebrates from associated debris, placing the collected invertebrates in labeled vials containing 70% ethanol to await identification. Macroinvertebrates were identified by Dan McGuire, an expert in the taxonomically difficult Chironomidae (midge) family and non-insect aquatic invertebrates.

Organisms were identified with an American Optics Stereo-star-zoom dissecting microscope and an American Optics Model 150 compound microscope for slide samples. Identification of specimens was accomplished using taxonomic references for North American macroinvertebrates including Baumann et al. 1977, Edmunds et al. 1976, Merritt and Cummins 1996, Thorpe and Covich 1991, and Wiggins 1978. Organisms were identified to species or genus when possible, and archived in the permanent Biology Team invertebrate collection in vials containing 70% ethanol.

4.4 Aquatic Macroinvertebrate Analysis

Many early water quality investigators compiled extensive species indicator lists to measure species-specific tolerances to pollution. This method is prone to erroneous interpretations since species-level identification is difficult to ascertain, tolerances of some species vary greatly under different environmental conditions, and "intolerant" species may occur in polluted waters due to drift, i.e. transport by water currents.

Recent studies have emphasized the importance of community structure in evaluating water quality (Gaufin and Tarzwell 1956; Hilsenhoff 1977; and Schwenneker and Hellenthal 1984). Diversity indices have been developed to allow numerical comparisons of whole macroinvertebrate communities. Unpolluted environments have higher taxa diversity index values than polluted environments, which tend to be dominated by relatively few tolerant species. The Biology Team reviewed macroinvertebrate densities and population distributions by sampling station. Invertebrate habits (modes of existence) and functional feeding groups were also examined to further elucidate community trends.

The Community Tolerance Quotient (CTQ) index was developed to assess the impacts of non-point source pollution in the western United States (Winget and Magnum 1979). This system has been previously used in the Jemez Mountains to effectively evaluate stream quality (Jacobi 1989, 1990, and 1992; Cross 1994, 1995a, and 1995b) and provides a more thorough and accurate basis for site comparisons than the PET (Plecoptera, Ephemeroptera, and Trichoptera) index. Tolerance quotients for aquatic macroinvertebrate taxa range from 6 (the most sensitive) to 108 (the least sensitive) and are based upon tolerances to alkalinity, sulfates, and sedimentation. The CTQ is computed using the formula

$$CTQ = \Sigma(xt)/n$$

where
x = number of individuals of a taxon,
t = tolerance value of a taxon (found in a published table), and
n = total number of organisms in the sample.

The Biology Team attempted to ensure that taxa were not counted twice; and if a counting error occurred, it was due to under-counting rather than over-counting. Therefore, we only counted one taxon in a sample for the following cases:

- different life stages of a taxon present,
- specimen(s) keyed to the family level and another specimen(s) in the same family identified to a lower level, and
- possible different instars of a genus assigned separate descriptive, rather than taxonomic, identifications.

The diversity index was calculated monthly for each sampling station using the equation discussed by Wilhm (1967):

$$D = (S-1)/\ln N$$

where D = the taxa diversity index,
S = the number of taxa, and
N = the number of individuals.

Despite the simplicity of Wilhm's equation, this diversity index usually provides an accurate measure of a site's taxa richness (number of taxa present) and evenness (distribution of individuals in differing taxa). A diversity index less than 1 is usually indicative of heavy pollution, between 1 and 3 is usually indicative of moderate pollution, and greater than 3 is usually indicative of clean water. However, biodiversity values for low-order montane streams are notoriously low and should not be compared to higher-order and lower elevation streams. Nonetheless, Wilhm's equation is useful in detecting differences between sampling stations in adjacent reaches of a montane stream, such as found in upper Sandia Canyon.

5 RESULTS AND DISCUSSION

5.1 Water Quality Measurements

This section refers to many State standards for water quality as listed in the *State of New Mexico Standards for Interstate and Intrastate Streams* for 1995. This document (State of New Mexico 1995) is published yearly by the Water Quality Control Commission in Santa Fe. These listed standards have been established to sustain and protect existing or attainable uses of water in the State. The 1995 document states, "These general standards apply at all times, unless a specified standard is provided elsewhere in this document, to all surface waters of the State." However, the specific standards that apply to waters originating within and/or flowing through LANL property have not yet

(September 1996) been resolved. This report refers to several of the 1995 standards, particularly those of a high quality coldwater fishery, which is the State's most stringent standard for nonpotable water.

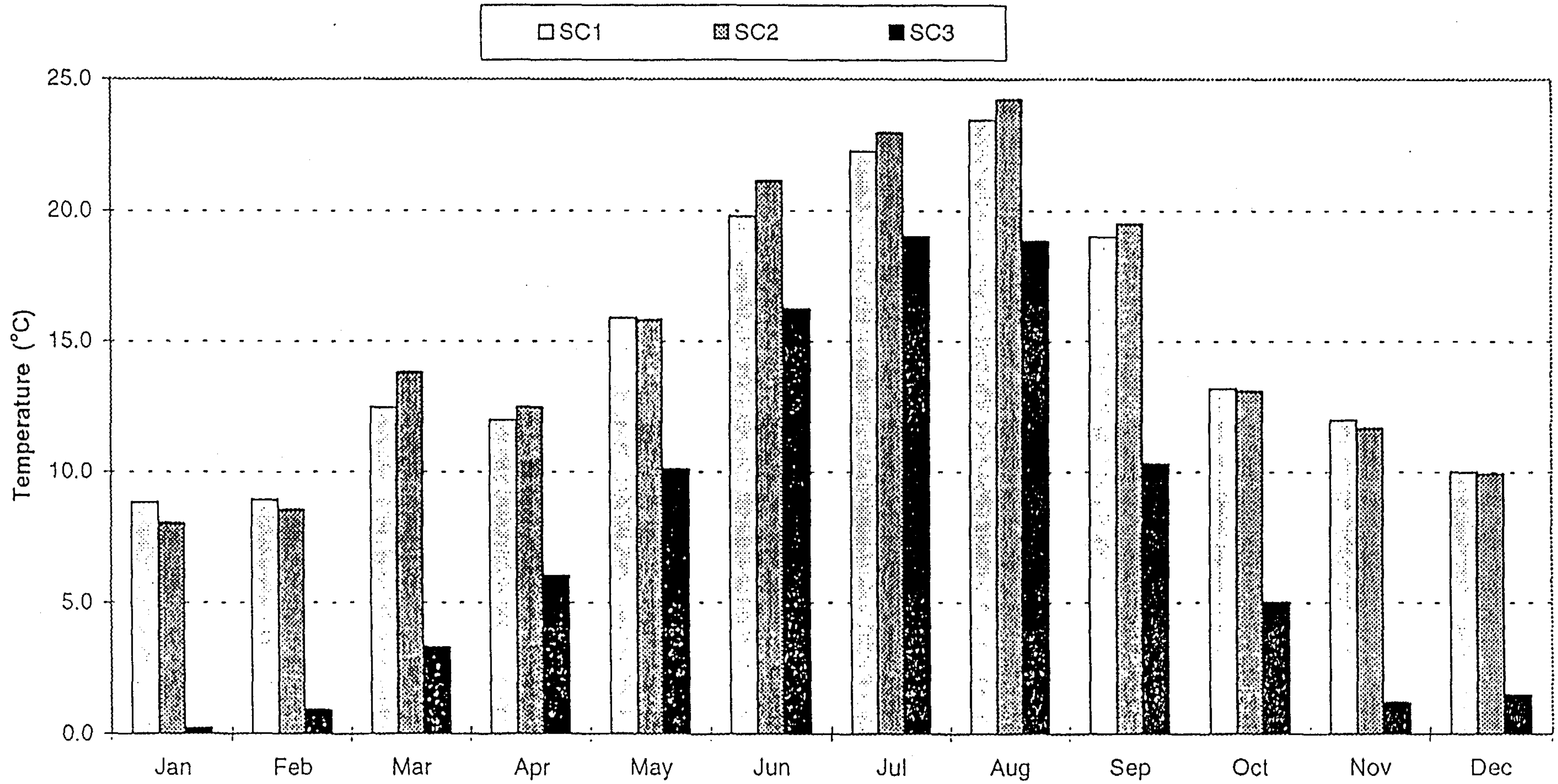
5.1.1 Temperature. Fig. 5 shows the monthly temperatures from each sample station in degrees Celsius. SC1 receives effluent from the TA-3 steam plant that is normally discharged at temperatures higher than the natural stream temperature; and the annual averages were highest (14.8°C or 58.6°F and 15.1°C or 59.2°F) at the two upstream stations (Table 1). The monthly temperatures were similar at SC1 and SC2, the greatest difference being only 1.3°C or 2.3°F. The average temperature at SC3, which is much farther downstream and very shaded, was significantly lower at 7.7°C or 45.9°F. The temperature at SC3 was always lower than the upstream stations, and it was much lower during the fall and winter months. No recorded temperatures were in excess of current State of New Mexico standards for a marginal coldwater fishery (State of New Mexico 1995).

Table 1. 1995 Water Quality Parameter Annual Averages for Sandia Canyon Sampling Stations.

Sampling Station	Water Temperature (°C)	pH	Dissolved Oxygen (mg/l)	Percent of Oxygen Saturation	Conductivity (µmhos/cm)	TDS (mg/l)
SC1	14.8	8.0	7.4	72%	590.0	389.4
SC2	15.1	8.0	7.8	77%	583.3	384.9
SC3	7.7	8.1	9.2	75%	685.4	452.4

5.1.2 pH. Monthly pH measurements ranged from 7.49 to 8.62, and Fig. 6 displays the pH readings from the three sampling stations. Some months are omitted from Fig. 6 because the Biology Team's pH meter was inoperative. Monthly readings and annual averages (Table 1) were similar for all stations, the greatest monthly difference being 0.58.

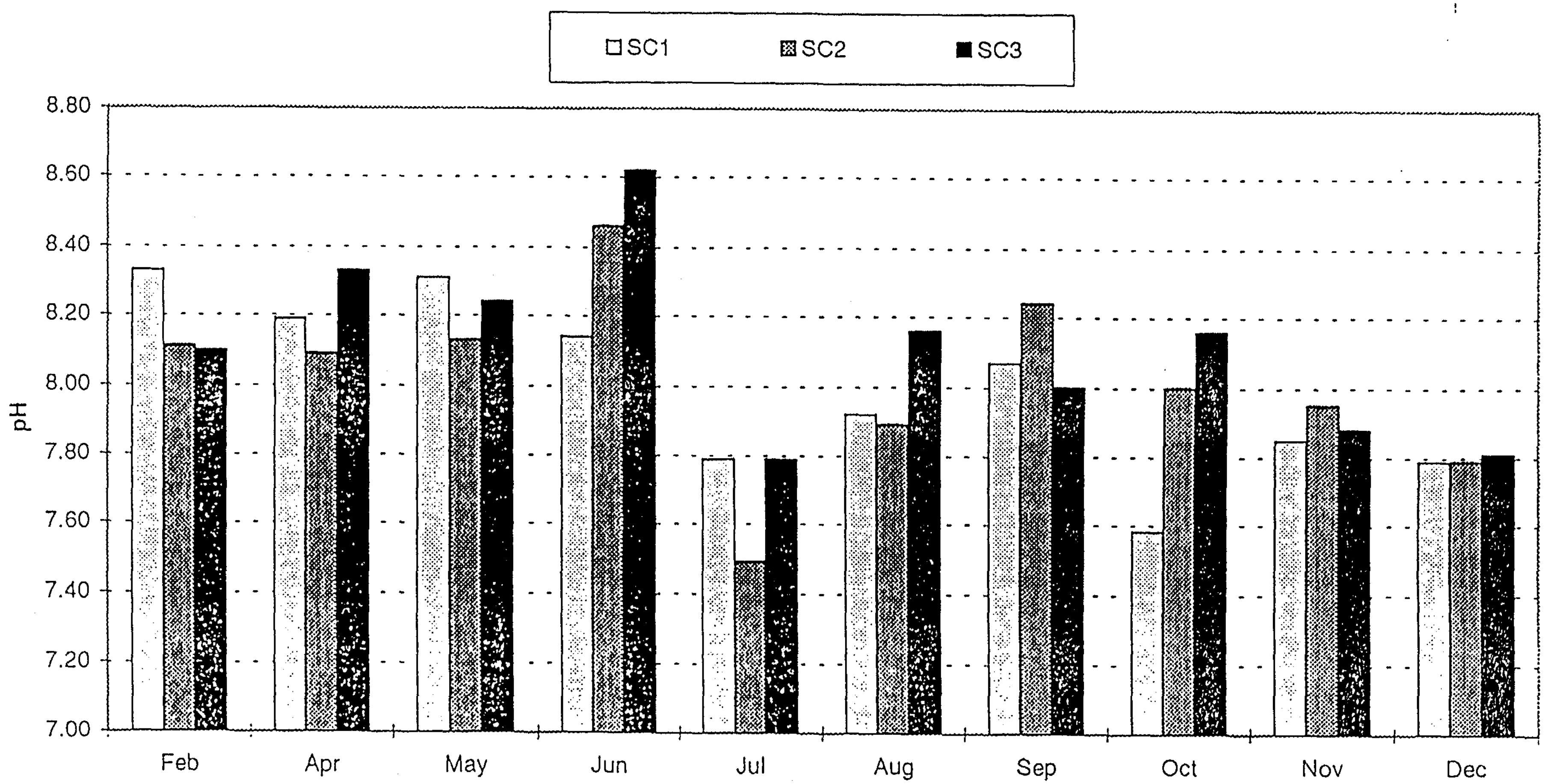
1995 Monthly Water Temperature in Sandia Canyon



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SC1	8.8	8.9	12.5	12.0	15.9	19.8	22.2	23.4	19.0	13.2	12.0	10.0
SC2	8.0	8.5	13.8	12.5	15.8	21.1	22.9	24.2	19.5	13.1	11.7	9.9
SC3	0.2	0.9	3.3	6.0	10.1	16.2	19.0	18.8	10.3	5.0	1.2	1.5

Fig. 4

1995 Monthly pH in Sandia Canyon



	Feb	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SC1	8.33	8.19	8.31	8.14	7.79	7.92	8.07	7.58	7.85	7.79
SC2	8.11	8.09	8.13	8.46	7.49	7.89	8.24	8.00	7.95	7.79
SC3	8.10	8.33	8.24	8.62	7.79	8.16	8.00	8.16	7.88	7.81

Fig. 5

All monthly values fall within the "excellent" range of the Environmental Quality Index based on pH (Battelle 1972; Fig. 7). All monthly readings also fell within the State of New Mexico standards for high quality coldwater fisheries (State of New Mexico 1995).

5.1.3 Dissolved Oxygen and Oxygen Percent Saturation. In 35 of 36 measurements, the DO readings fell within the State of New Mexico standards for high quality coldwater fisheries (State of New Mexico 1995). The single reading below the State standards was within the standards for warmwater fisheries and occurred in July, one of the hottest months when dissolved oxygen concentrations tend to be lowest. The highest annual average DO (9.2 mg/l) occurred at SC3, while the lowest (7.4 mg/l) was at SC1 (Table 1). SC3 also had the highest monthly readings of all stations in 10 of 12 months (Fig. 8). This is due to SC3's much lower temperatures, which allows more oxygen to dissolve in the water.

Oxygen percent saturation reflects oxygen availability to invertebrates. Recorded monthly values ranged from 65% to 92% (Fig. 9). Annual averages ranged from 72% to 77% (Table 1), all of which are rather low. The stream in Sandia Canyon has few riffles and consequently little mixing of air and water, resulting in low oxygen saturations. Underwater algal respiration releases oxygen into waterways, but algae are not abundant at or near any of the sampling stations. Rainfall could cause periodic increases in oxygen saturation, but the more typical low values could limit aquatic invertebrate diversity.

Fig. 10 displays a functional curve relating oxygen percent saturation to an Environmental Quality Index (Battelle 1972). All monthly saturations fell within Battelle's "excellent" or "good" categories.

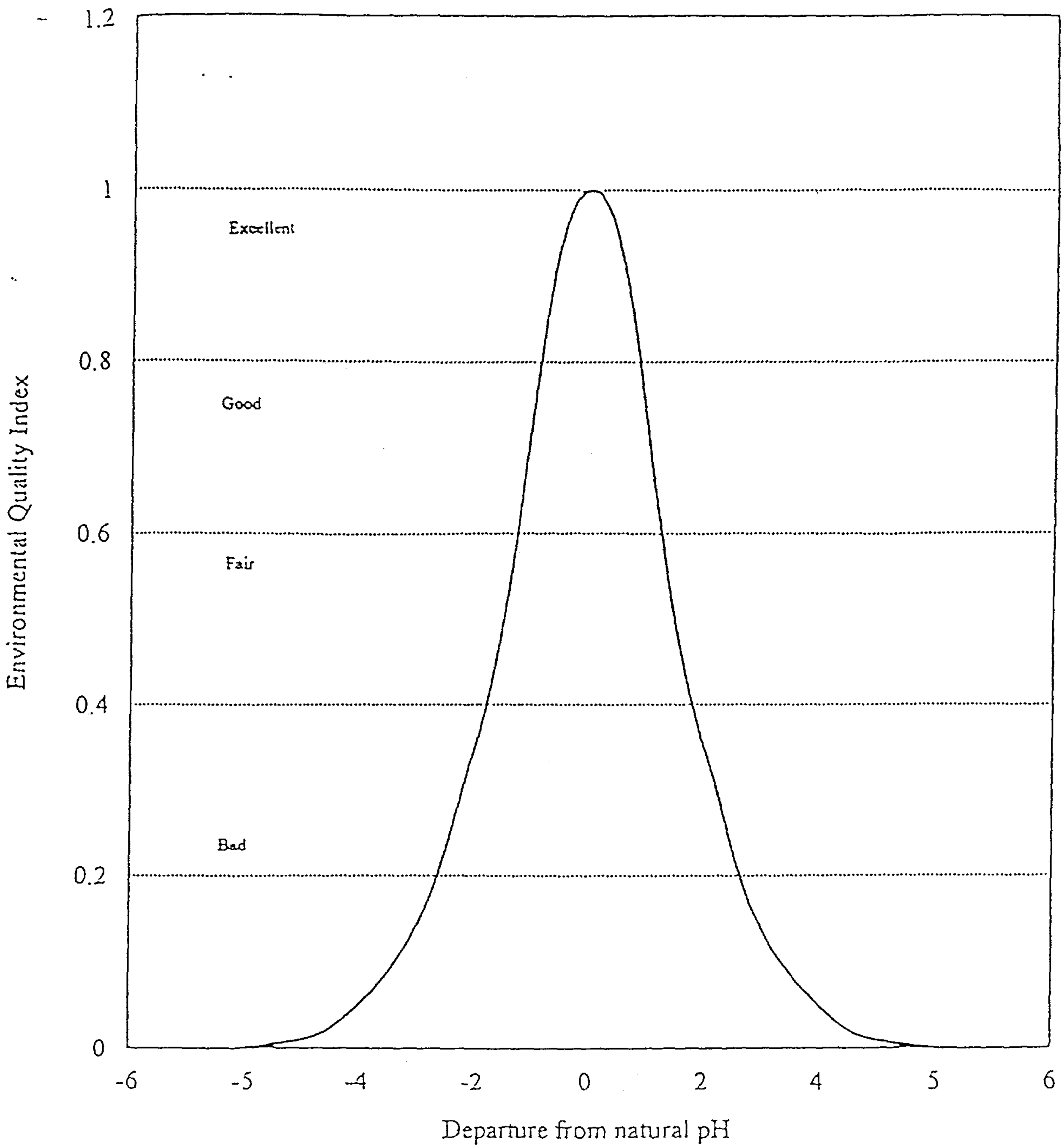
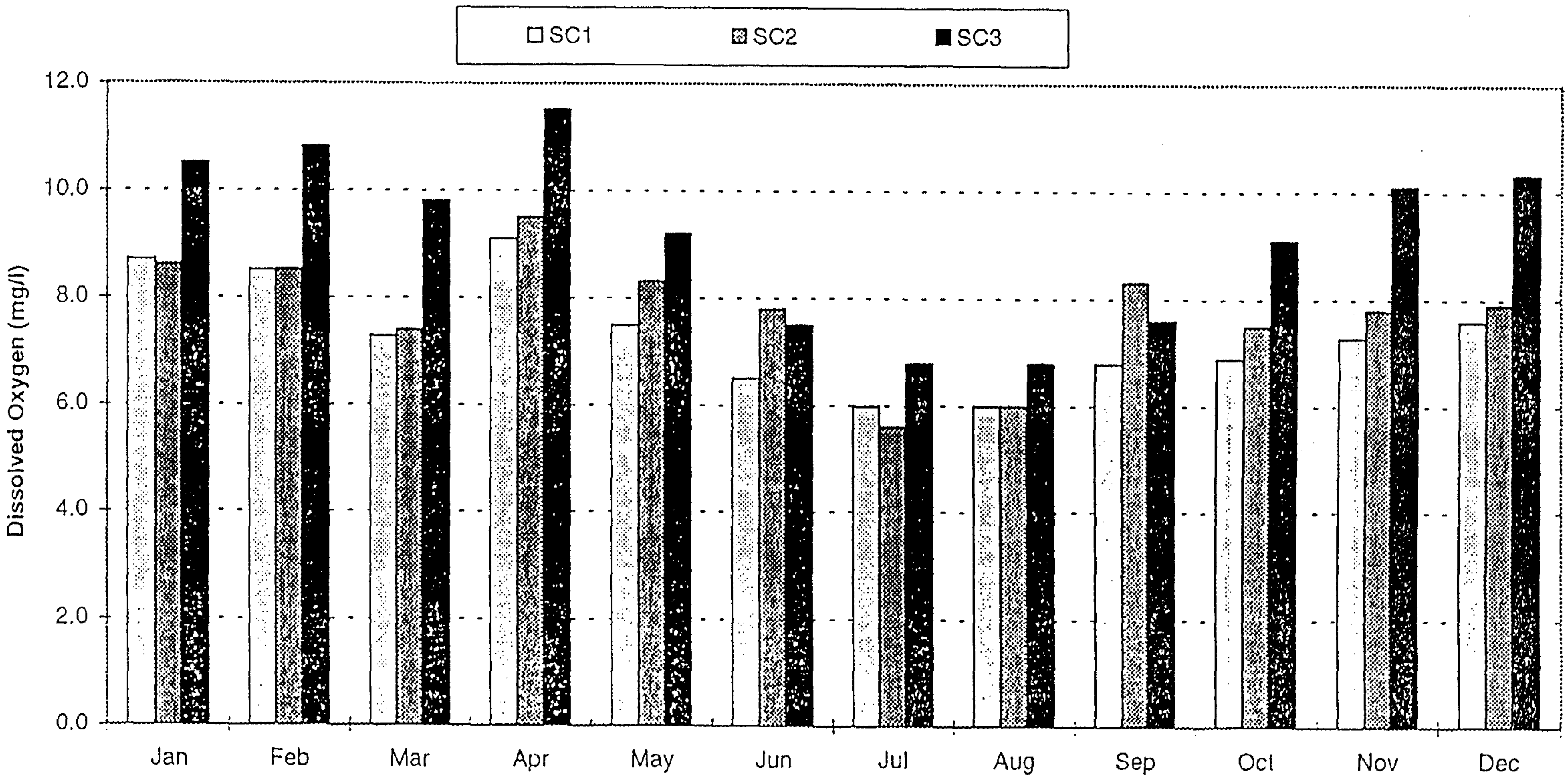


Fig. 6. Departure from natural pH versus an Environmental Quality Index (Battelle, 1972).

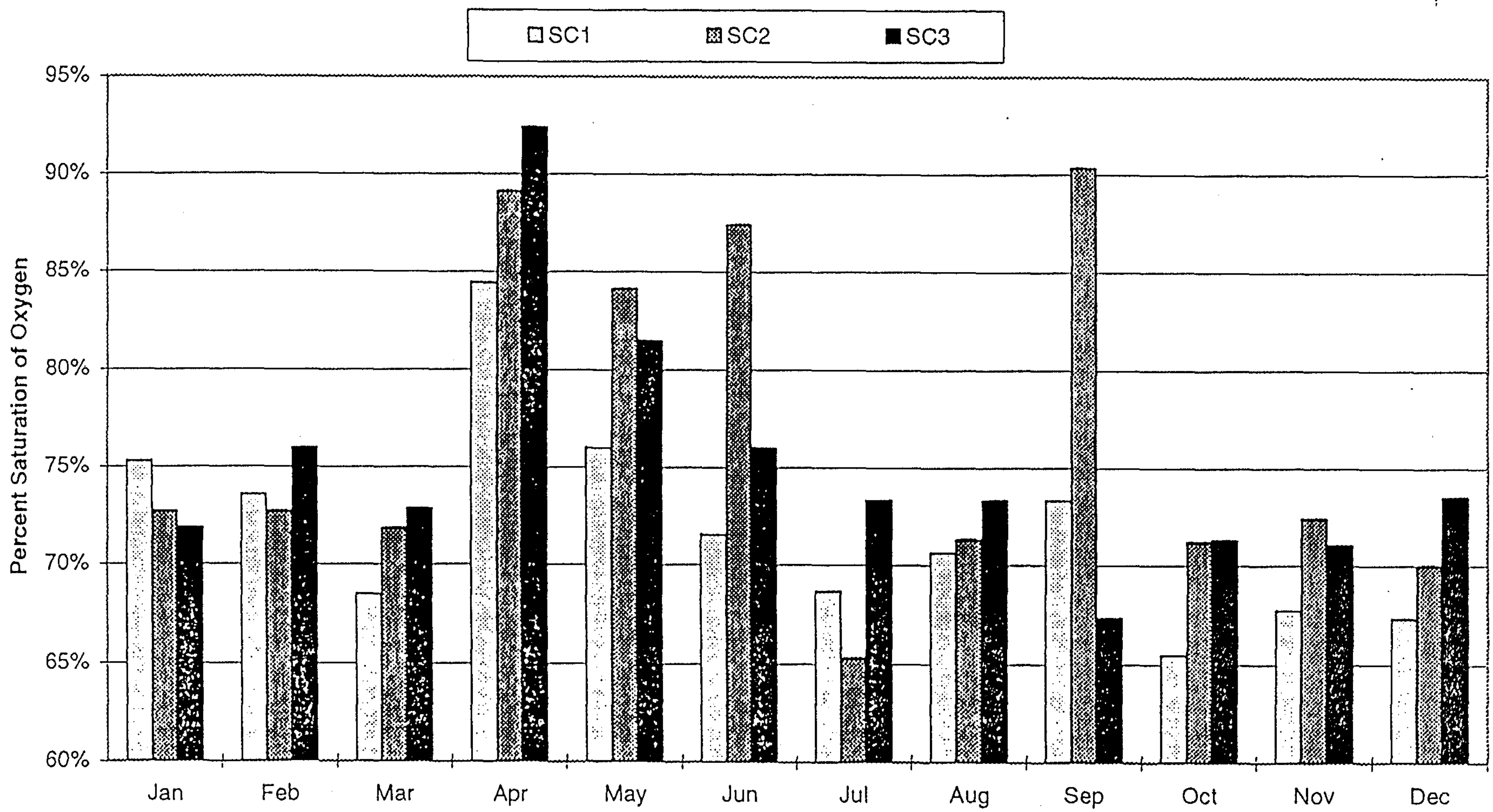
1995 Monthly Dissolved Oxygen in Sandia Canyon



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SC1	8.7	8.5	7.3	9.1	7.5	6.5	6.0	6.0	6.8	6.9	7.3	7.6
SC2	8.6	8.5	7.4	9.5	8.3	7.8	5.6	6.0	8.3	7.5	7.8	7.9
SC3	10.5	10.8	9.8	11.5	9.2	7.5	6.8	6.8	7.6	9.1	10.1	10.3

Fig. 7

1995 Monthly Oxygen Percent Saturation in Sandia Canyon



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SC1	75%	74%	68%	84%	76%	72%	69%	71%	73%	65%	68%	67%
SC2	73%	73%	72%	89%	84%	87%	65%	71%	90%	71%	72%	70%
SC3	76%	76%	73%	92%	81%	76%	73%	73%	67%	71%	71%	73%

Fig. 8

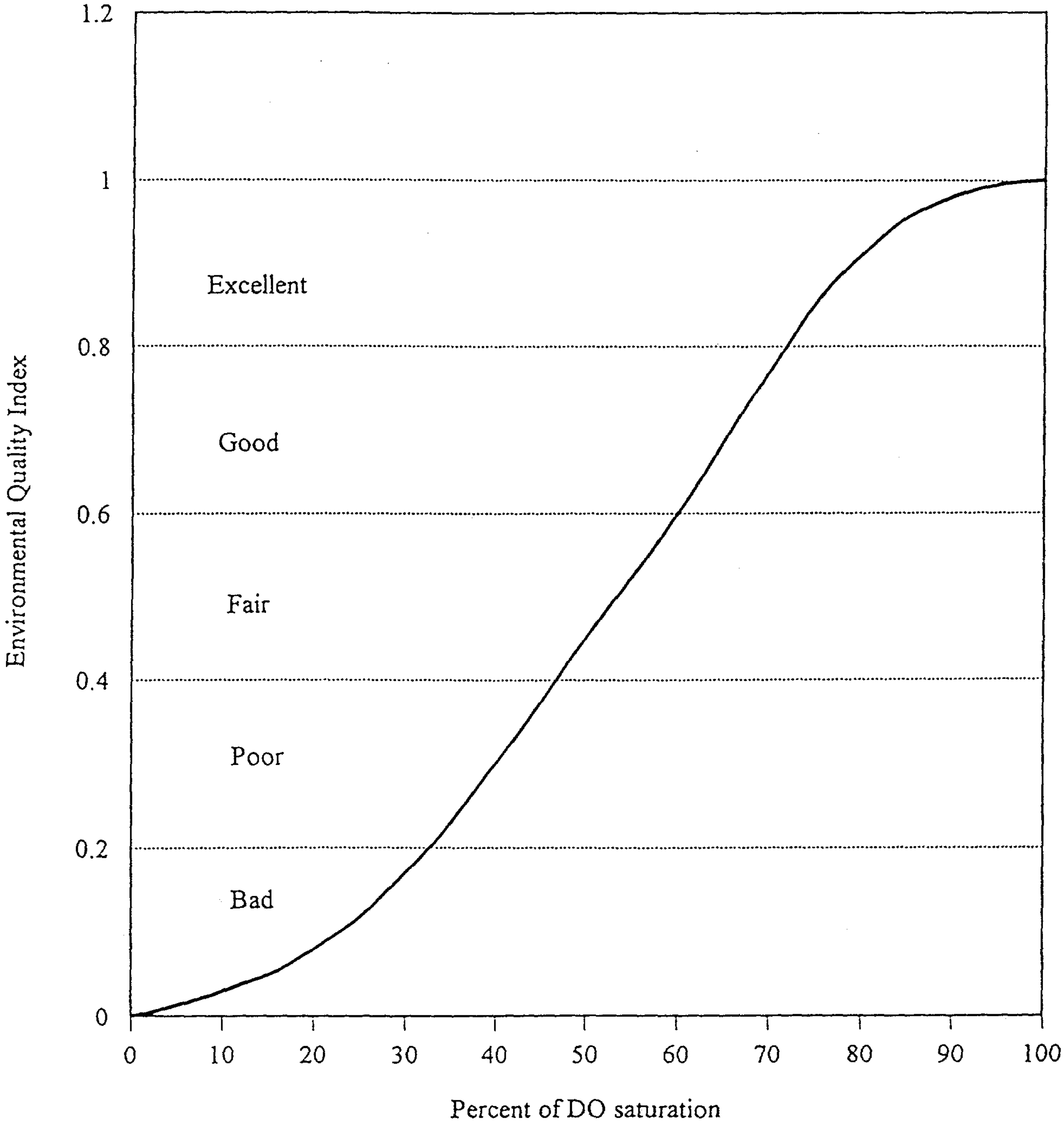


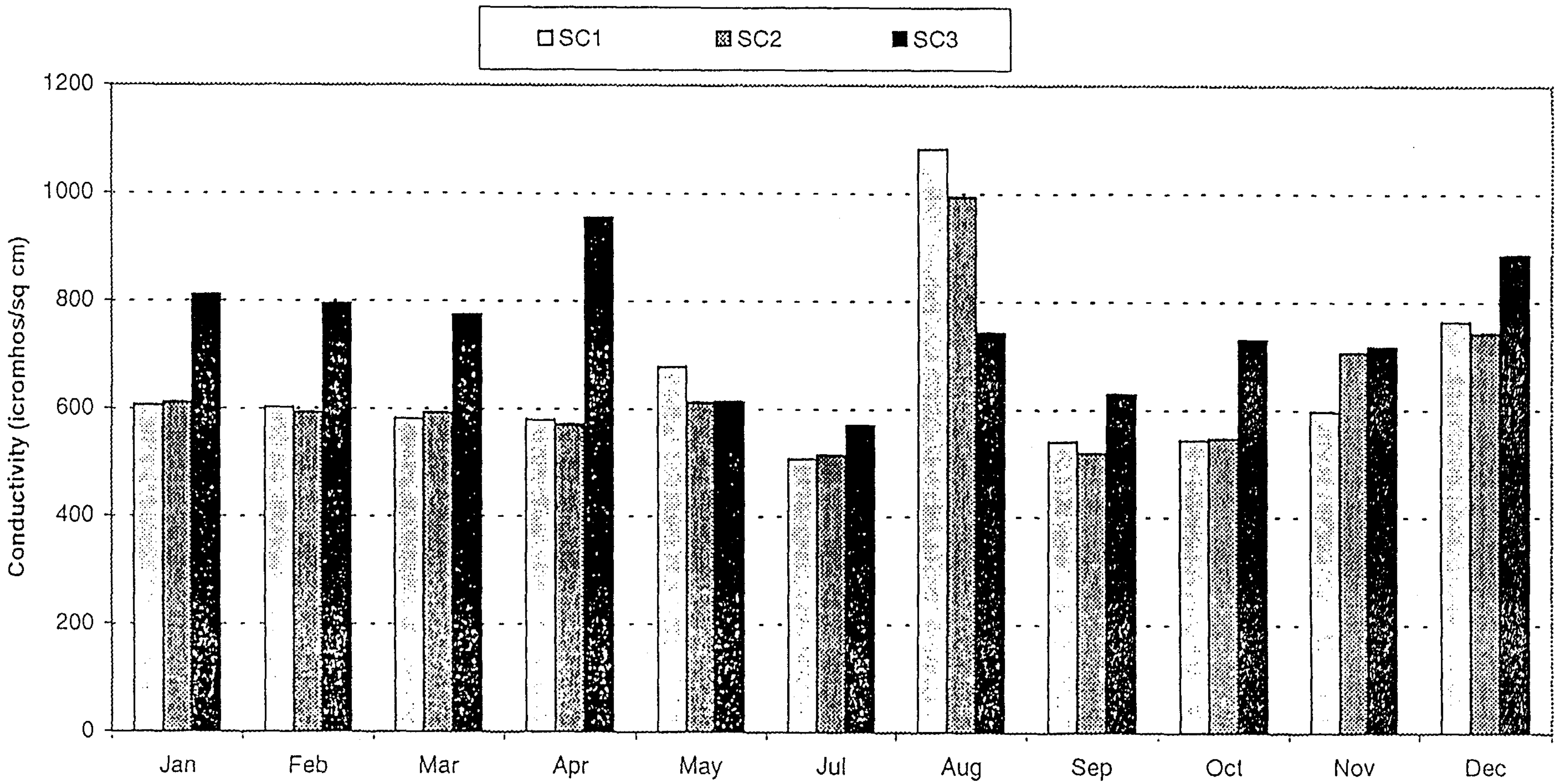
Fig. 9. Percent of DO saturation versus an Environmental Quality Index (Battelle, 1972).

5.1.4 Conductivity and Total Dissolved Solids. Monthly conductivity readings in µmhos/cm are displayed in Fig. 11 and annual averages are presented in Table 1. The measurements were highest at SC3 in 9 of 12 months, possibly due to ionized substances in the tuff that naturally erodes into the stream or from decomposing cattails. The highest reading (1081 at SC1 in August) was probably due to LANL operations, but it posed no threat to the aquatic biota and quickly dissipated with distance downstream. Aquatic organisms can generally tolerate TDS concentrations as high as 5000 mg/l, a concentration nearly five times higher than the highest concentration recorded during 1995. All conductivity readings were within the range specified by the State of New Mexico for high-quality coldwater fisheries (State of New Mexico 1995).

A rough approximation of TDS in milligrams per liter of freshwater is obtained by multiplying the conductivity readings by 0.66. Fig. 12 illustrates monthly TDS concentrations from the three stations and Table 1 lists the annual averages. All 1995 TDS measurements fall within the "excellent" range of the Environmental Quality Index developed by Battelle (Fig. 13).

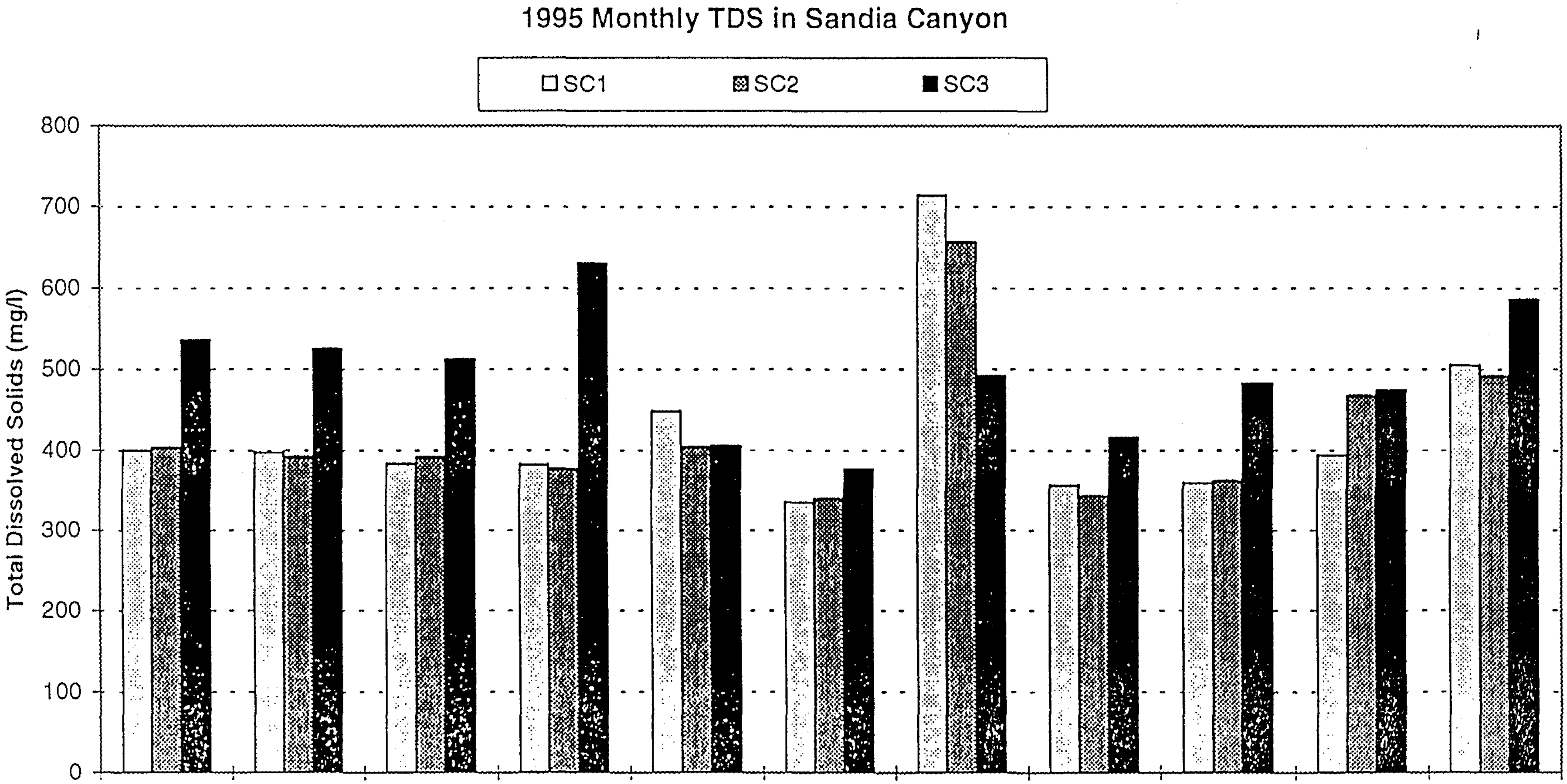
5.1.5 Chlorine. In recent years, the Biology Team noted a strong smell of chlorine at Outfall 13S during monthly sampling at Sandia Canyon. The New Mexico Environment Department determined that sanitary discharges from this outfall contained chlroine exceeding the maximum allowable limit of 1 ppm (equivalent to 1 mg/l). The Biology Team began to monitor chlorine concentration in discharges from Outfall 13S in early April 1995. The first measurement taken (2.2 mg/l) exceeded the State limit (Table 2). On 20 April 1995, a sodium thiosulfate pump was installed to dechlorinate the water prior to

1995 Monthly Conductivity in Sandia Canyon



	Jan	Feb	Mar	Apr	May	Jul	Aug	Sep	Oct	Nov	Dec
SC1	606	602	581	579	678	508	1081	540	544	597	764
SC2	610	592	592	570	611	514	994	519	547	707	743
SC3	811	794	775	955	613	570	743	629	730	717	888

Fig. 9



	Jan	Feb	Mar	Apr	May	Jul	Aug	Sep	Oct	Nov	Dec
SC1	400	397	383	382	447	335	713	356	359	394	504
SC2	403	391	391	376	403	339	656	343	361	467	490
SC3	535	524	512	630	405	376	490	415	482	473	586

Fig. 10

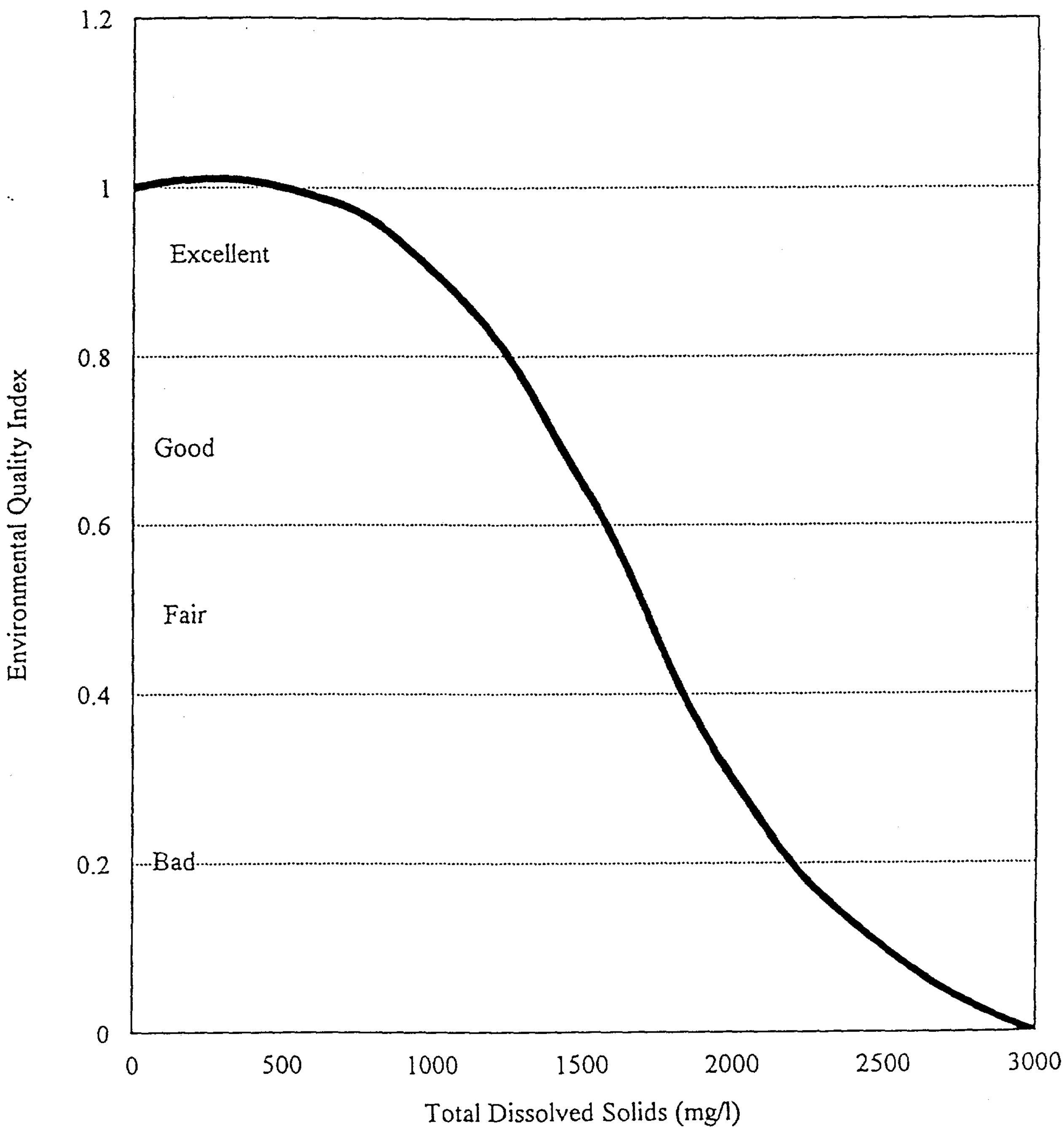


Fig. 12. TDS (mg/l) versus an Environmental Quality Index (Battelle, 1972).

its discharge from the outfall. Since that time, the highest chlorine reading taken by the Biology Team at Outfall 13S was 0.21 mg/l in June 1995. To date, the dechlorination equipment appears to be effectively limiting the chlorine levels from Outfall 13S.

Table 2. 1995 Chlorine Levels (mg/l) at Outfall O1S in Sandia Canyon.

April	June	July	Aug.	Sept.	Nov.	Dec.
2.2	0.21	0.03	0.02	0.02	0.04	0.02

5.1.6 Erosion Stakes. Erosion monitoring stakes were installed in four lines within upper Sandia Canyon in late summer of 1995. These stakes are intended to provide long-term data on patterns of erosion and deposition within drainages that feed into the canyon. Stake N-1C was removed during blading that scooped out a shallow catchment pond at the head of the drainage containing line N-1. The pond and installation of jute matting on the road surface in September greatly reduced monthly land surface differences in this line.

Table 3 lists the differences in land surface as measured by the heights of exposed stakes. Positive (depositional) or negative (erosional) changes both indicate an unstable landscape that will eventually impact the nearby stream. Therefore, the monthly change averages were computed using absolute values. Such limited data permits few conclusions; but it is noteworthy that the southern control lines had a higher average monthly change (0.7 cm) than did the northern experimental lines (0.6 cm).

5.2 Aquatic Macroinvertebrate Analysis

5.2.1 Total Numbers and Taxa Collected. A total of 3,178 macroinvertebrates of 40 taxa (Appendix A) were collected from the three Sandia Canyon sampling stations during 1995. As in previous years, the greatest number of aquatic invertebrates were collected at SC3 (Table 4). The fixed-area Surber sampler permitted the Biology Team to compute

Table 3. 1995 Monthly Erosion Stake Changes (cms) in Sandia Canyon.

Line	Sep.	Oct.	Nov.	Dec.	Average monthly change
N-1A	-2.6	+0.2	-0.4	+2.4	1.4
N-1B	-0.8	-0.9	+0.3	-0.3	0.6
N-2A	+0.6	-0.2	+0.5	0.0	0.3
N-2B	-0.3	+0.1	-0.4	+0.1	0.2
N-2C	-2.6	+1.2	-1.0	+0.1	0.6
S-1A	NA	-0.3	-0.3	+0.2	0.3
S-1B	NA	+0.2	+0.2	-0.6	0.3
S-1C	NA	-0.4	+0.4	+0.3	0.4
S-2A	-1.6	-0.3	-0.1	-0.4	0.6
S-2B	-0.1	+0.6	-2.4	+0.8	1.0
S-2C	-2.2	+0.4	+2.0	-1.6	1.6

average density of Sandia macroinvertebrates for the first time. Only SC3 had a density comparable to those of 1995 sampling stations (1820, 1517, and 1812) within Guaje Canyon, a natural stream adjacent to LANL property (Cross 1995b). SC3 also had the highest number of taxa due to its greater distance from LANL operations and landfills, denser shading that produces colder and more stable water temperatures, higher dissolved oxygen content, and prevalence of riffles.

Table 4. 1995 Summary Analysis of Macroinvertebrates Collected in Sandia Canyon.

Sampling Station	Number of Individuals Collected	Average Density (individuals/m^2)	Number of Taxa	Biodiversity Index	CTQ
SC1	435	403	24	1.46	95.0
SC2	698	646	25	1.49	89.3
SC3	2045	1893	30	1.72	84.7

In 1995, all macroinvertebrates were identified by Dan McGuire, a recognized expert in the Chironomid (midge) family. His identification of 12 Chironomid genera further elucidates aquatic community structure within the canyon. Many of these Sandia

Canyon Chironomid taxa had been previously isolated into distinct groups by differences in head morphology, setae, prolegs, and other characteristic features (Cross 1994 and 1995a). However, the differences in total taxa recorded from sampling stations during 1993 (36 taxa), 1994 (36 taxa), and 1995 (40 taxa) are due to "new" Chironomid taxa identified by McGuire.

5.2.2 Population Distributions. The average numbers of macroinvertebrates collected at a station varied greatly, with SC3 having 3 – 4 times the number of individuals as the other two stations (Fig. 14). Population distributions reflect community stability by examining monthly variances. One method compares the number of macroinvertebrates collected at a station during its most populous months to its annual total. More than half of the aquatic invertebrates collected at all sampling stations were collected during only two months or 17% of the sampling season (Table 5).

Table 5. 1995 Monthly Averages, Totals, and TMPM* Numbers of Macroinvertebrates for Sandia Canyon.

Station	Average Number Collected Monthly	Total Number Collected	Number Collected in TMPM*	TMPM*/Total
1	36.3	435	283	65.1%
2	58.2	698	432	61.9%
3	170.4	2045	1521	74.4%

*** Two Most-Populous Months**

Localized population explosions routinely occur in streams because invertebrate egg hatches occur during favorable conditions. In November and December, high numbers of individuals were found at all three stations (Fig. 14). The highest numbers of individuals collected in a month occurred at SC3 in November (642) and December (879). However,

1995 Monthly Individual Macroinvertebrates Collected in Sandia Canyon

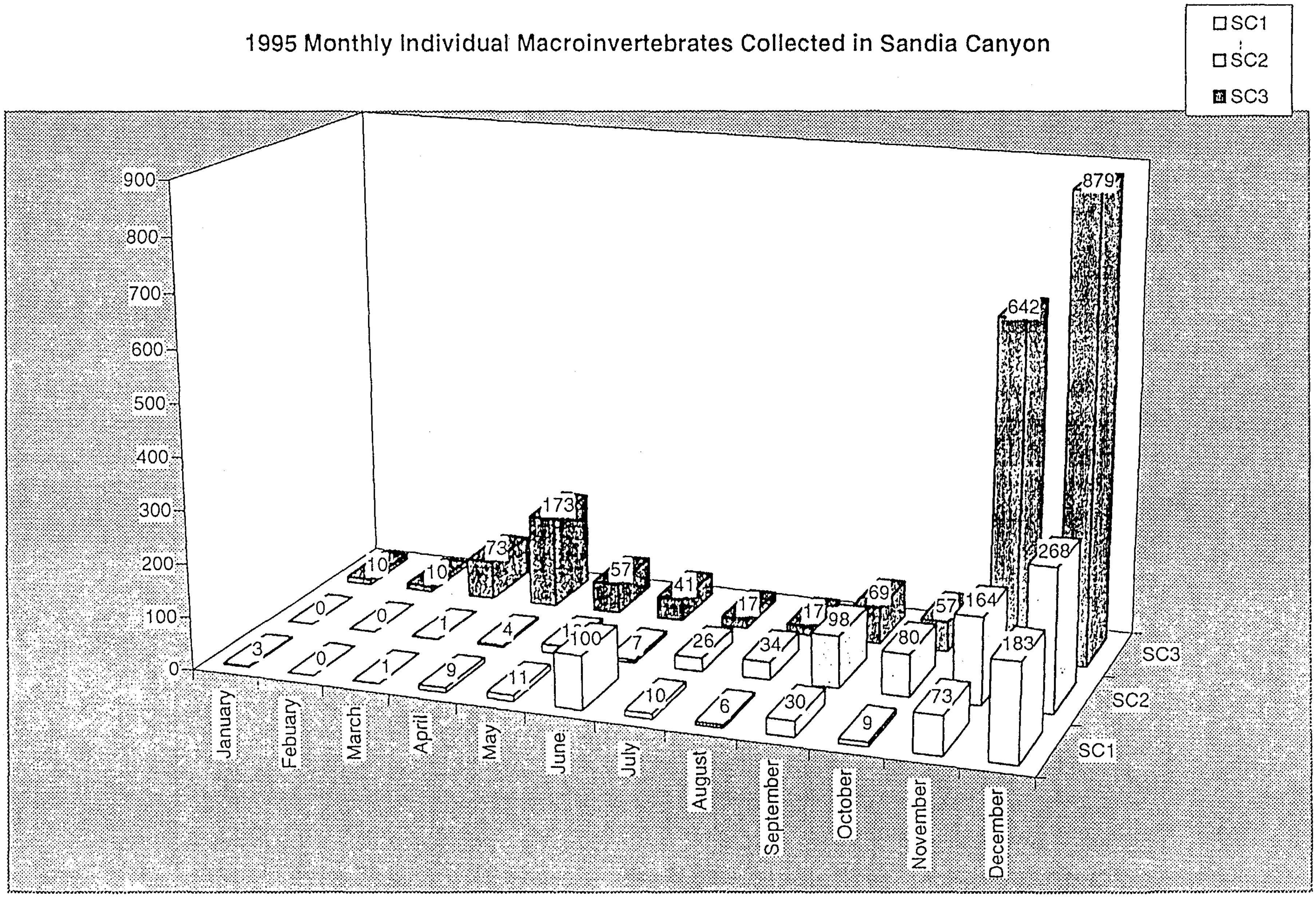


Fig. 12

baetid mayflies accounted for 72% of November's total and 62% of December's total. These two months accounted for 74.4% of the invertebrates collected at SC3 during 1995.

Another measure of population distributions is determination of the number of months that no aquatic invertebrates were collected at a sampling station. During 1995, no macroinvertebrates were found at SC1 once (9% of the samples) and at SC2 twice (17% of the samples). In contrast, macroinvertebrates were collected at SC3 every month. The relatively stability of SC3 is because it experiences

- much less flooding due to its location below the cattail marsh,
- less scour due to a more stable substrate, and
- greater colonization by adult invertebrates due to its greater accessibility.

5.2.3 Community Structure. Familiar trophic categories of herbivore, carnivore, and omnivore are not very applicable to macroinvertebrates. Aquatic invertebrates select food sources primarily due to particle size, rather than food origin. Merritt and Cummins (1996) have developed a series of functional feeding groups or trophic categories to describe trophic relationships among aquatic insects (Table 6). These categories are based on feeding mechanism, instead of food origin.

A natural and balanced aquatic ecosystem usually contains representatives of the various functional feeding groups. Appendix B lists the functional feeding groups of the aquatic insects collected in Sandia Canyon. The only poorly represented functional feeding group at all sites were the shredders. SC3 had the most shredders, primarily the caddisfly *Hesperophylax*, due to greater amounts of decomposing plant material in this reach of the stream. At all sites, the primary collector filterer was the caddisfly *Hydropsyche oslari*, which accounted for almost all individuals of this functional feeding group. All other

Table 6. Functional Feeding Groups and Modes of Existence of Aquatic Insects.
(adapted from *An Introduction to the Aquatic Insects of North America*,
Merritt and Cummins, 1996)

Functional Feeding Group	Dominant Food
Collectors	Decomposing fine particulate matter
Piercers	Fluids from living plant and algae cells
Predators	Living animal tissue
Scrapers	Attached algae and associated material
Shredders	Living or decomposing plant tissue, coarse particulate organic matter

Mode of Existence	Description
Burrowers	Inhabit fine sediments, construct burrows, tunnel into plants
Climbers	Live on vegetation, can move vertically
Clingers	Attach to surfaces in stream riffle areas
Divers	Adapted for surface swimming, and diving
Skaters	On the surface of water
Sprawlers	On the surface of floating substrate or fine sediments
Swimmers	Cling to submerged objects, swims short distances

functional feeding groups were well represented by a variety of taxa at all sampling sites.

Within a balanced aquatic community of a natural aquatic ecosystem, macoinvertebrates occur all available microhabitats and utilize a variety of food resources. Appendix B lists the functional feeding group and mode of existence for the macroinvertebrates collected in this study (Table 6). Although frequently seen on the water's surface within Sandia Canyon, skaters are poorly represented because they are not usually collected with a Surber sampler. Divers were scarce at all stations, but swimmers, clingers, climbers, and burrowers were well represented at all stations, indicating a fairly balanced community.

5.2.4 Biodiversity. Monthly biodiversity indices (Fig. 15) and annual averages (Table 4) were calculated for each sampling station (Appendix C). Although low, the 1995 biodiversity values were higher than those of 1994 (Cross 1995a). These numbers reflect

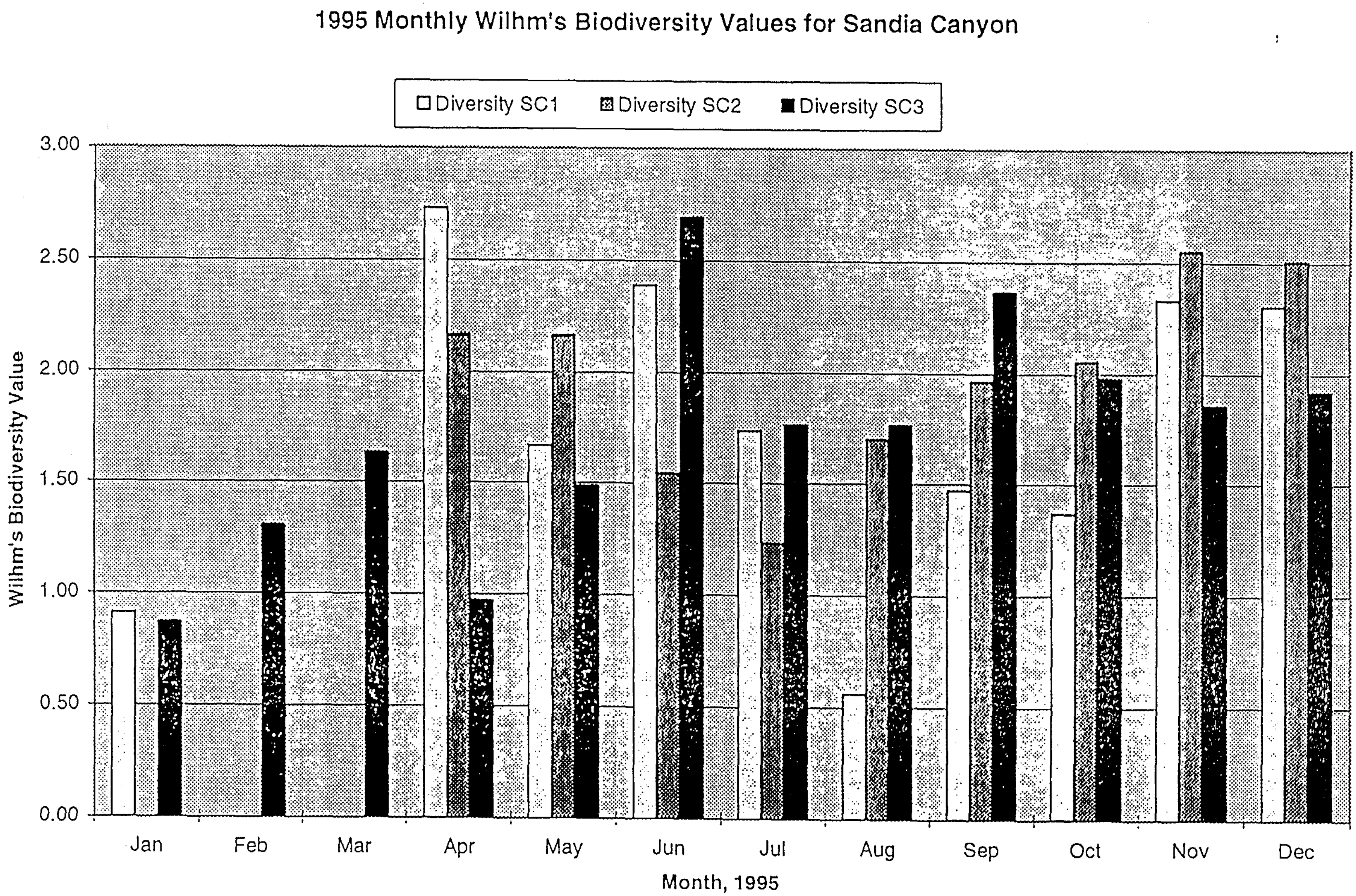

1995 Monthly Wilhm's Biodiversity Values for Sandia Canyon
Diversity SC1
Diversity SC2
Diversity SC3
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Wilhm's Biodiversity Value
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month, 1995

Fig. 11

the dominance of a few species, especially of Baetid mayflies (Table 5), and the fact that Sandia Canyon is a low-order montane stream. SC3 had higher biodiversity values than SC1 or SC2 due to its greater distance from LANL operations and landfills, denser shading that produces colder and more stable water temperatures, higher dissolved oxygen content, and prevalence of riffles.

5.2.5 Community Tolerance Quotients. Tolerance quotients for each taxa collected in Sandia Canyon during 1995 are listed in Appendix A. The values decrease with increasing distance from the head of the canyon indicating that downstream habitats are more favorable. SC3 has the most tolerant community, with a CTQ of 84.7 (Table 4), indicating that this is the least stressed site. This value is somewhat misleading because it is due in large part to the high number of Baetid mayflies found in November and December at this station. The genus *Baetis* has a tolerance quotient of 72, which appears inordinately low to biologists familiar with northern New Mexico aquatic invertebrates.

6 CONCLUSIONS

Despite widespread habitat degradation and high amounts of sedimentation, all physical and chemical tests conducted within the upper Sandia Canyon stream indicate a healthy waterway. The vast majority of water chemistry tests done in Sandia Canyon in 1995 were within the standards set by New Mexico for coldwater fisheries (The exceptions were a single dissolved oxygen reading during July and water temperature readings that all fell within the range for warmwater fisheries). Chlorine levels from Outfall 13S discharges have been within State limits since dechlorination equipment was installed in April 1995. All monthly pH and conductivity measured fall within State limits set for coldwater fisheries, and all pH and TDS measurements were within the "excellent" range as defined by Battelle's Environmental Quality Index. All oxygen percent saturation values were within Battelle's "excellent" or "good" ranges.

Although many physical and chemical parameters indicate a healthy stream, the waterway's biotic potential is limited by the effects of widespread erosion, channelization, loss of wetlands due to deposition and stream lowering, scour, limited acceptable substrates, LANL releases and spills, and other stressors. Low biodiversities and the high TMPM percentages at all sites demonstrate that the aquatic communities in Sandia Canyon are somewhat unstable. SC1 and SC2 are exposed to the synergistic effects of habitat degradation much more than SC3, and those stations have lower densities of macroinvertebrates, fewer taxa, reduced biodiversity, higher CTQs, and more unstable communities than SC3.

ACKNOWLEDGMENTS

Field and laboratory personnel included Saul Cross (field leader and aquatic entomologist), Leonard Sandoval (UGS), Tom Gonzales (UGS) and Jesse Davila (HS co-op). Dan McGuire identified all aquatic macroinvertebrates collected in Sandia Canyon during 1995. Saul Cross and Heidi Nottelman analyzed the data and compiled the manuscript. As senior author, I commend Heidi's enthusiasm and dedication to detail in the preparation of this report. ESH-18 (LANL's Water Quality and Hydrology Group) funded this study in cooperation with ESH-20 (LANL's Ecology Group).

REFERENCES

Battelle, Columbus Laboratories, "Environmental Evaluation System for Water Resources Planning" Bureau of Reclamation, U.S. Department of Interior, Contract Number 14-06-D-1782, Columbus, Ohio (1972).

Baumann, R. W., Gaufin, A. R., and Surdick, R. F., *The Stoneflies (Plecoptera) of the Rocky Mountains*, American Entomological Society at the Academy of Natural Sciences, Philadelphia, Pennsylvania (1977).

Bell, Henry, "Effect of Low pH on the Survival and Emergence of Aquatic Insects" in *Water Research*, Vol. 5, pp. 313-319, Pergamon Press (1971).

Bennett, Kathryn, "Aquatic Macroinvertebrates and Water Quality Monitoring of Sandia Canyon," Los Alamos National Laboratory report, LA-12738 (1994).

Canter, L. W., and Hill, L. G., *Handbook of Variables for Environmental Impact Assessment*, Ann Arbor Science Publishers, Inc., Michigan (1979).

Cowardin, L. M.,, Carter, V., Glet, F. C., and E. T. LaRoe, *Classification of Wetlands and Deep Water Habitats of the United States*, U. S. Fish and Wildlife Service, Washington, D.C., Publication No. FWS/OBS-79/31 (1979).

Cross, Saul, "Aquatic Macroinvertebrates and Water Quality of Sandia Canyon, Los Alamos National Laboratory", Los Alamos National Laboratory report, LA-12734-SR (1994).

Cross, Saul, "Aquatic Macroinvertebrates and Water Quality of Sandia Canyon, Los Alamos National Laboratory, November 1993 to October 1994", Los Alamos National Laboratory report, LA-12971-SR (1995a).

Cross, Saul, "Aquatic Macroinvertebrates and Water Quality in Guaje and Los Alamos Canyons" in *Ecological Baseline Studies in Los Alamos and Guaje Canyons, County of Los Alamos, New Mexico*, compiled by T. Foxx, Los Alamos National Laboratory report, LA-13065-MS (1995b).

Edmunds, G. F., Jensen, S. L., and Berner, L., *The Mayflies of North and Central America*, University of Minnesota Press, Minneapolis, Minnesota (1976).

EPG: Environmental Protection Group, *Environmental Surveillance at Los Alamos during 1994*, LANL report LA-13047-ENV (July 1996).

Eriksen, C. H., V. H. Resh, and G. A. Lamberti, "Aquatic Insect Respiration," pp. 29-40 in *An Introduction to the Aquatic Insects of North America*, third edition, edited by R. W. Merritt and K. W. Cummins, Kendall/Hunt Publishing Company, Dubuque, Iowa (1996).

Gaufin, A. R., Clubb, Robert, and Newell, Robert, "Studies on the Tolerance of Aquatic Insects to Low Oxygen concentrations," *Great Basin Naturalist*, Vol. 34, No. 1, pp. 45-59 (1974).

Gaufin, A. R. and Tarzwell, C. M., "Aquatic Macro-Invertebrate Communities as Indicators of Organic Pollution in Lytle Creek," *Sewage and Industrial Waste*, Vol. 28, No. 7, pp. 906-924 (1956).

Hilsenhoff, W., "The Use of Arthropods to Evaluate Water Quality of Streams", Technical Bulletin No. 100, Department of Natural Resources, Madison, Wisconsin 53707 (1977).

Hill, B. H., *Dynamics of Wetlands: New Approaches to Assessing Wetland Structure and Function*, a Journal of the North American Benthological Society Technical Information Workbook (1994).

Intergovernmental Task Force on Monitoring Water Quality, *Ambient Water-Quality Monitoring in the United States: First Year Review, Evaluation, and Recommendations*, report to the Office of Management and Budget (1992).

ITFMWQ: Intergovernmental Task Force on Monitoring Water Quality, *The Strategy for Improving Water-quality Monitoring in the United States* (Draft 1994).

Jacobi, Gerald Z., "Benthic Macroinvertebrate Assessment of Several Small Streams -- Implementation of the 1987 Santa Fe National for Ecology Team Plan, ," U. S. for Ecology Team Service, Santa Fe National for Ecology Team, Santa Fe, New Mexico, Contract # 43-8379-0-0327 (1989).

Jacobi, Gerald Z., "Benthic Macroinvertebrate Assessment of Several Small Streams -- Implementation of the 1987 Santa Fe National for Ecology Team Plan, second survey," U. S. for Ecology Team Service, Santa Fe National for Ecology Team, Santa Fe, New Mexico, Contract # 43-8379-0-0327 (1990).

Jacobi, Gerald Z., "Benthic Macroinvertebrate Assessment of Several Small Streams -- Implementation of the 1987 Santa Fe National for Ecology Team Plan, 1990 survey," U. S. for Ecology Team Service, Santa Fe National for Ecology Team, Santa Fe, New Mexico, Contract # 43-8379-0-0327 (1992).

Karr, J. R., "Biological Integrity: a Long-Neglected Aspect of Water Resource Management", Ecological Applications, 1:66-84 (1991).

Kubic, C., "Multi-Media Compliance Investigation", Department of Energy report (1993).

Lehmkuhl, D. M., "Environmental Disturbance and Life Histories: Principles and Examples," *Journal of the Fisheries Research Board of Canada*, Vol. 36, pp. 329-334 (1979).

Merritt, R. W. and Cummins, K. W., eds., *An Introduction to the Aquatic Insects of North America*, 3rd edition, Kendall/Hunt Publishing Company, Dubuque, Iowa (1996).

Nebeker, A. V., "Effect of Low Oxygen Concentration on Survival and Emergence of Aquatic Insects," *trans. Amer. Fish Soc.*, No. 4, pp. 675-679 (1972).

Newling, C. J., letter to ESH-20 on the current condition of LANL wetlands (19 July 1995).

Rosenberg, D. M., H. V. Danks, and D. M. Lehmkuhl, "Importance of Insects in Environmental Impact Assessments," *Environmental Management*, Vol. 10, No. 6, pp. 773-783 (1986).

Schwenneker, Bruce W. and Ronald A. Hellenthal, "Sampling Considerations in Using Stream Insects for Monitoring Water Quality," *Environmental Entomology*, Vol. 13, No. 3 (1984).

State of New Mexico, "Standards for Interstate and Intrastate Streams," New Mexico Water Quality Control Commission, Santa Fe, New Mexico (1995)

Thorpe, J. H. and A. P. Covich, eds., *Ecology and Classification of North American Freshwater Invertebrates*, Academic Press (1991).

Wallace, J. B. and N. H Anderson, "Habitat, Life History, and Behavioral Adaptations of Aquatic Insects, " pp. 41-73 in *An Introduction to the Aquatic Insects of North America*, third edition, edited by R. W. Merritt and K. W. Cummins, Kendall/Hunt Publishing Company, Dubuque, Iowa (1996).

Weber, C. I., "Biological Field and Laboratory Methods for Measuring the Quality of Surface waters and Effluents," National Environmental Research Center, Cincinnati, Ohio, PB-227-183, pp. 70-109 (1973).

Wiggins, G. B., *Larvae of the North American Caddisfly Genera (Trichoptera)*, University of Toronto Press (1978).

Wilhm, J. L., "Comparison of Some Diversity Indices Applied to Populations of Benthic Macroinvertebrate in a Stream Receiving Organic Waste," *Journal WPCF*, Vol. 39, No. 10, Part 1, pp. 1673-1683 (1967).

Winget, R. N., and Magnum, F. A., *Biotic Condition Index: Integrated Biological, Physical, and Chemical Stream Parameters for Management, Intermountain Region,* U. S. Department of Agriculture, Forest Service, Ogden, Utah (1979).

APPENDIX A

MACROINVERTEBRATE TAXA COLLECTED IN SANDIA CANYON DURING 1995 AND THEIR TOLERANCE QUOTIENTS

AQUATIC INSECTS:

Order	Family (genus)	Species	Station	TQ
Coleoptera	Dryopidae adult	*Helicus*	3	72
	Dytiscidae	*Agabus*	1, 2, 3	72
	Elmidae	*Optioservus*	3	108
	Elmidae	*Heterlimnus*	1	108
	Hydrophilidae		2	72
Collembola			3	
Diptera	Ceratopogonidae	*Bezzia*	2	108
	Chironomidae	*Cardiocladius*	2	108
	Chironomidae	*Cricotopus*	2	108
	Chironomidae	*Pagastia*	1, 2	108
	Chironomidae	*Tvetenia*	1, 2, 3	108
	Chironomidae	*pupa*	1	108
	(Chironominae)			
	Chironomidae	*Diamesa*	1, 2, 3	108
	(Diamesinae)			
	Chironomidae	*pupa*	1, 2	108
	(Orthocladinae)			
	Chironomidae	*Paraphaenocladius*	1, 2, 3	108
	(Orthocladinae)			
	Chironomidae	*Eukiefferiella*	1, 2, 3	108
	(Orthocladinae)			
	Chironomidae	*Chaetocladius*	1, 2, 3	108
	(Orthocladinae)			
	Chironomidae	*Orthocladius*	2, 3	108
	(Orthocladinae)			
	Chironomidae	*Brillia*	3	108
	(Orthocladinae)			
	Chironomidae	*Parametriocnemus*	1, 2	108
	(Orthocladinae)			
	Chironomidae	*Thienemannimyia*	1, 2, 3	108
	(Thanypodinae)			
	Empididae	*Chelifera*	1, 2	95
	Ephydridae	*pupa*	2	108
	Muscidae		1, 2	108

Order	Family (genus)	Species	Station	TQ
	Muscidae	*Limnophora*	1, 2, 3	108
	Simulidae	*Simulium*	1, 2, 3	108
	Tabanidae		3	108
	Tipulidae	*Antocha*	3	24
	Tipulidae	*Dicranota*	1, 3	24
	Tipulidae	*Limonia*	3	24
	Tipulidae	*Tipula*	3	36
Ephemeroptera	Baetidae	*Baetis (tricaudatus)*	1, 2, 3	72
	Tricorythidae	*Tricorythodes*	2	108
Lepidoptera	Pyralidae		3	108
	Pyralidae	*Petrophila*	1	108
Odonata	Aeshnidae	*Aeshna*	3	72
	Aeshnidae	*Boyeria*	1, 2, 3	72
	Coenagrionidae	*Argia*	1, 2, 3	108
Plecoptera	Nemouridae	*Podmosta*	3	6
	Nemouridae	*Amphinemura/Male*	3	6
Trichoptera	Hydropsychidae	*Hydropsyche oslari*	1, 2, 3	108
	Limnephilidae		3	108
	Limnephilidae	*Hesperophylax*	3	108

AQUATIC NON-INSECTS:

Phylum	Class (subclass)	Family	Station	TQ
Annelida	Oligochaeta	Lumbriculidae	1, 2, 3	108
		Naididae	1	108
		Tubificidae	1, 2	8
Arthropoda	Crustracea		3	108
	(Ostracoda)			

APPENDIX B

FUNCTIONAL FEEDING GROUPS AND MODES OF EXISTENCE OF AQUATIC COLLECTED IN SANDIA CANYON DURING 1995

Order	Family (Subfamily)	Genus	Feeding Group	Mode of Existence
Coleoptera	Dryopidae adult	*Helicus*	sc, cg	cg
	Dytiscidae	*Agabus*	pr	sw, dv
	Elmidae	*Optioservus*	sc, cg	cg
	Elmidae	*Heterlimnus*	sc, cg	cg
	Hydrophilidae		cg	sw, dv
Collembola			cg	sk
Diptera	Ceratopogonidae	*Bezzia*	pr	bu
	Chironomidae	*Cardiocladius*	pr	bu, cg
	Chironomidae	*Cricotopus*	sh, cg	cg, bu
	Chironomidae	*Pagastia*	cg, sc	sp
	Chironomidae	*Tvetenia*	cg	sp
	Chironomidae	*pupa*	cg, cf	bu, cg
	(Chironominae)			
	Chironomidae	*Diamesa*	cg, sc	sp
	(Diamesinae)			
	Chironomidae	*pupa*	cg	sp,bu
	(Orthocladinae)			
	Chironomidae	*Paraphaenocladius*	cg	sp
	(Orthocladinae)			
	Chironomidae	*Eukiefferiella*	cg, sc, pr	sp
	(Orthocladinae)			
	Chironomidae	*Chaetocladius*	cg	sp
	(Orthocladinae)			
	Chironomidae	*Orthocladius*	cg	sp,bu
	(Orthocladinae)			
	Chironomidae	*Brillia*	sh, cg	bu
	(Orthocladinae)			
	Chironomidae	*Parametriocnemus*	cg	sp
	(Orthocladinae)			
	Chironomidae	*Thienemannimyia*	pr	sp
	(Thanypodinae)			
	Empididae	*Chelifera*	pr	sp,bu
	Ephydridae	*pupa*	cg,sh,sc,pr	sp,bu
	Muscidae		pr	sp

Order	Family	Genus	Feeding Group	Mode of Existence
	Muscidae	*Limnophora*	pr	bu
	Simulidae	*Simulium*	cf	cg
	Tabanidae		pr	sp, bu
	Tipulidae	*Antocha*	cg	cg
	Tipulidae	*Dicranota*	pr	sp,bu
	Tipulidae	*Limonia*	sh	sp,bu
	Tipulidae	*Tipula*	sh, cg	bu
Ephemeroptera	Baetidae	*Baetis*	cg, sc	sw, cb, cg
	Tricorythidae	*Tricorythodes*	cg	sp, cg
Lepidoptera	Pyralidae		sh	cb, cb-sw, bu
	Pyralidae	*Petrophila*	sc	cg
Odonata	Aeshnidae	*Aeshna*	pr	cb
	Aeshnidae	*Boyeria*	pr	cb-sp
	Coenagrionidae	*Argia*	pr	cg, cb-sp
Plecoptera	Nemouridae	*Podmosta*	sh, cg	sp, cg
	Nemouridae	*Amphinemura/Malenka*	sh, cg	sp-cg
Trichoptera	Hydropsychidae	*Hydropsyche*	cf	cg
	Limnephilidae		sc, sh, cg	cb-sp-cg
	Limnephilidae	*Hesperophylax*	sh	sp

Mode of Existence Abbreviations:

bu = burrower
cb = climber
cg = clinger
dv = diver
sk = skater
sp = sprawler
sw = swimmer

Functional Feeding Group Abbreviations:

cf = collector filterers
cg = collector gatherers
pr = predators
sc = scrapers
sh = shredders

APPENDIX C

MONTHLY NUMBERS OF INDIVIDUALS, NUMBERS OF TAXA, AND THE BIODIVERSITY INDICES FOR SANDIA CANYON, 1995

Month, Station	Number of Individuals	Number of Taxa	Biodiversity Index
Jan, SC1	3	2	0.91
Jan, SC2	0	0	NA
Jan, SC3	10	3	0.87
Feb, SC1	0	0	NA
Feb, SC2	0	0	NA
Feb, SC3	10	4	1.30
Mar, SC1	1	1	NA
Mar, SC2	1	1	NA
Mar, SC3	73	8	1.63
Apr, SC1	9	7	2.73
Apr, SC2	4	4	2.16
Apr, SC3	173	6	0.97
May, SC1	11	5	1.67
May, SC2	16	7	2.16
May, SC3	57	7	1.48
Jun, SC1	100	12	2.39
Jun, SC2	7	4	1.54
Jun, SC3	41	11	2.69
Jul, SC1	10	5	1.74
Jul, SC2	26	5	1.23
Jul, SC3	17	6	1.76
Aug, SC1	6	2	0.56
Aug, SC2	34	7	1.70
Aug, SC3	17	6	1.76
Sep,SC1	30	6	1.47
Sep, SC2	98	10	1.96
Sep, SC3	69	11	2.36
Oct, SC1	9	4	1.37
Oct, SC2	80	10	2.05
Oct, SC3	57	9	1.98
Nov, SC1	73	11	2.33
Nov, SC2	164	14	2.55
Nov, SC3	642	13	1.86
Dec, SC1	183	13	2.30
Dec, SC2	268	15	2.50
Dec, SC3	879	14	1.92