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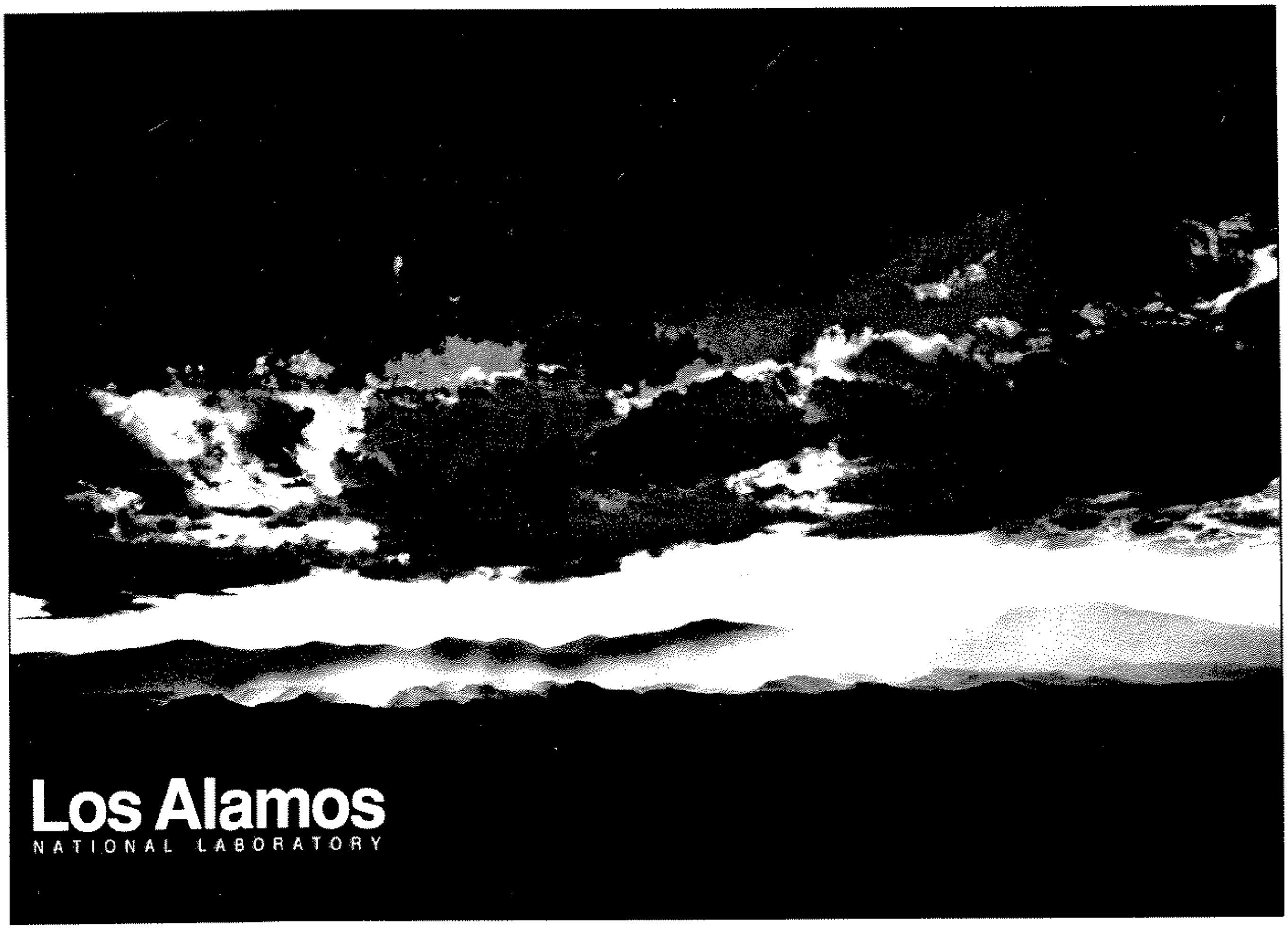
Saul Cross, Leonard Sandoval, and Thomas Gonzales



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1 INTRODUCTION

Los Alamos National Laboratory (LANL) has conducted studies of the geohydrology, water chemistry, and radiochemistry at springs and streams along the Rio Grande downslope from Laboratory property since 1970 (Purtymun,et. al 1980). Forming a portion of LANL's water quality monitoring system, these studies seek to determine if hazardous materials are transported by water beyond LANL boundaries.

In recent years, members of LANL's ESH-18 group and personnel from the New Mexico Environment Department's Department of Energy Oversight Bureau (NMED OB) have combined sampling efforts along the Rio Grande in White Rock Canyon. NMED OB and LANL personnel simultaneously collect separate water and sediment samples. The eventual analytic results are made available to both groups for comparison and comment.

The Ecological Studies Team (EST) of ESH-20 (Environmental Assessments and Report Evaluations) first systematically sampled the streams discharging into the Rio Grande in September 1994. EST collected aquatic invertebrates, measured physical and chemical parameters, and conducted habitat assessments up-canyon from 3 major stream confluences with the river. These invertebrate collections were never identified due to large sample sizes and lack of funding.

In April and September of 1995, EST conducted more detailed sampling along the Rio Grande, in conjunction with ESH-18 – NMED OB sampling trips. On these dates, aquatic invertebrate collections were made up-canyon from the 3 stream confluences and at 6 springs near the Rio Grande. Physical and chemical parameters were measured at all locations, and habitats were assessed at each of the streams. EST sampled the resident aquatic invertebrate communities at all 9 sites in April 1995 and September 1995.

Physical parameters (water temperature, dissolved oxygen, pH, and conductivity) of the canyon streams were monitored, simultaneously with the collection of aquatic macroinvertebrates. In reviewing these measures, this report refers to many environmental quality ratings developed by Battelle Columbus Laboratories (Battelle 1972). Battelle outlined a comprehensive and interdisclipinary Environmental Evaluation System, which uses physical, chemical, and biological parameters to assess possible environmental impacts of water resource projects.

Water temperature directly influences the physiological functions such as metabolism, growth, emergence, and reproduction of aquatic organisms (Anderson and Wallace 1984). Because water absorbs greater amounts of oxygen at lower temperatures, temperature is inversely related to oxygen solubility. While aquatic organisms can tolerate wide fluctuations in pH and conductivity, a change in water temperature of a single degree Celsius can have a significant impact (Lehmkuhl 1979).

The pH scale measures acidity and basicity with low values indicative of acidity, middle values (around 7.0) indicatative of neutrality, and high values indicatative of basicity. A departure of ±1 from the normal pH is considered to be insignificant to aquatic macroinvertebrates (Lehmkuhl 1979). The normal pH of natural surface waters in the United States ranges from 6.5 to 9.0 (Canter and Hill 1979). In general, acidic waters limit species richness, evenness, and abundance. Some aquatic organisms, such as mayflies, are very sensitive to low pH, which can be caused by accidental acid spills or acid rain deposition.

Depressed oxygen environments often indicate the presence of organic wastes. The amount of dissolved oxygen (DO) in water has a direct and immediate effect on invertebrates using tracheal gills for respiration (such as the larvae of mayflies, caddisflies, and stoneflies). Oxygen is present in the atmosphere at levels greater than 200,000 parts per million (ppm), but its maximum value in water is only 15 ppm (Eriksen et al. 1984). Although aquatic insects require more oxygen for metabolism at elevated temperatures, less is available due to decreased solubility (Gaufin et al. 1974). Certain life cycle stages (such as emergence) of aquatic invertebrates 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).

Conductivity measures the ability of water to carry an electrical current and reflects the concentration of ionized substance in water. The conductivity of potable water in the United States ranges from 50 to 1,500 micro-mhos per centimeter (µmho/cm), while 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 can be obtained by multiplying the conductivity by a factor of 0.66. The upper limit of TDS that aquatic organisms can tolerate ranges from 5,000 to 10,000 mg/l (Battelle 1972).

In general, monitoring only the physical and chemical characteristics of water provides little information on conditions before the sampling date. Failure of chemical criteria to protect aquatic life has necessitated incorporating biological criteria into water resource management (Karr 1991). Shifts in the numbers of individuals, species, and functional feeding groups present may 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). Changes in macroinvertebrate communities thus reflect water quality over a much longer period than chemical monitoring.

Aquatic macroinvertebrates have been used extensively as water quality indicators. The term "macroinvertebrate" refers to invertebrates large enough to be seen with the unaided eye, and this report uses the terms "macroinvertebrate" and "invertebrate" interchangeably. These organisms, especially the stream-dwelling insects, are well suited to this purpose due to their

- abundance in virtually all freshwater streams,
- small size and total immersion in the water environment,
- relatively sedentary life styles, making them good indicators of local conditions,
- differential sensitivities to various types of impairment, including non-point source pollution,
- life cycles that are frequently at least one-year long, allowing moderately long-term detection of past disturbance, and
- relative ease of collection and identification to family or genus level.

Many early water-quality investigators compiled extensive indicator species lists and attempted to measure species-specific tolerances to pollution (Beck 1955). These methods are prone to erroneous interpretations since species-level identification is difficult to ascertain, tolerances of some species vary greatly under differing environmental conditions, and "intolerant" species may be found in polluted areas due to drift, i.e., transport by water currents. Use of a biotic index overcomes these problems by permitting higher level identifications and weighting taxa according to the numbers present. Indices of species richness, evenness, and diversity have been developed to allow numerical comparisons of whole communities. Unpolluted environments have greater species richness, evenness, and diversity than polluted environments, which tend to be dominated by relatively few intolerant species.

2 ENVIRONMENTAL SETTING

2.1 General Setting

LANL is located in north-central New Mexico approximately 105 km (65 mi) north of Albuquerque and 48 km (30 mi) northwest of Santa Fe (Fig. 1). The dominant physical feature in the LANL area is the Pajarito Plateau, an apron of volcanic rock stretching 32 – 40 km (20 – 25 mi) north-south and 8 – 16 km (5 – 10 mi) east-west. The 2380 m (7800 ft) high plateau slopes gently eastward toward the Rio Grande from the edge of the Jemez Mountains. At 1890 m (6200 ft), the plateau has been cut into a series of cliffs extending to the Rio Grande River at 1646 m (5400 ft). Intermittent streams flowing southeastward dissect the plateau into a number of finger-like, narrow mesas separated by deep canyons.

The plateau bedrock is of Bandelier Tuff, a formation deposited during volcanic eruptions in the Jemez Mountains approximately 1.1 to 1.4 million years ago. The tuff overlays other volcanic materials that are underlain by the conglomerate of the Puye Formation. This conglomerate intermixes with Chino Mesa basalts along the Rio Grande.

White Rock Canyon is approximately 16 km (25 mi) long and has been formed by downcutting of the Rio Grande through basaltic rocks of the Chino Mesa. As it flows through this canyon, the Rio Grande decreases in elevation from approximately 1680 m (5510 ft) at the Otowi Bridge to approximately 1620 m (5315 ft) at Frijoles Canyon (Purtyman, et. al 1980).

The area has a semiarid, temperate, montane climate. Summer temperatures typically range from 10°C – 27°C (50°F – 80°F) during a 24-hour period (Bowen 1990). Winter temperatures generally range from about -9 – 10°C (15 – 50°F) during a 24-hour period. The annual precipitation in the vicinity ranges from 33 – 46 cm (13 – 18 in.), much of it falling during summer rain showers in July and August.

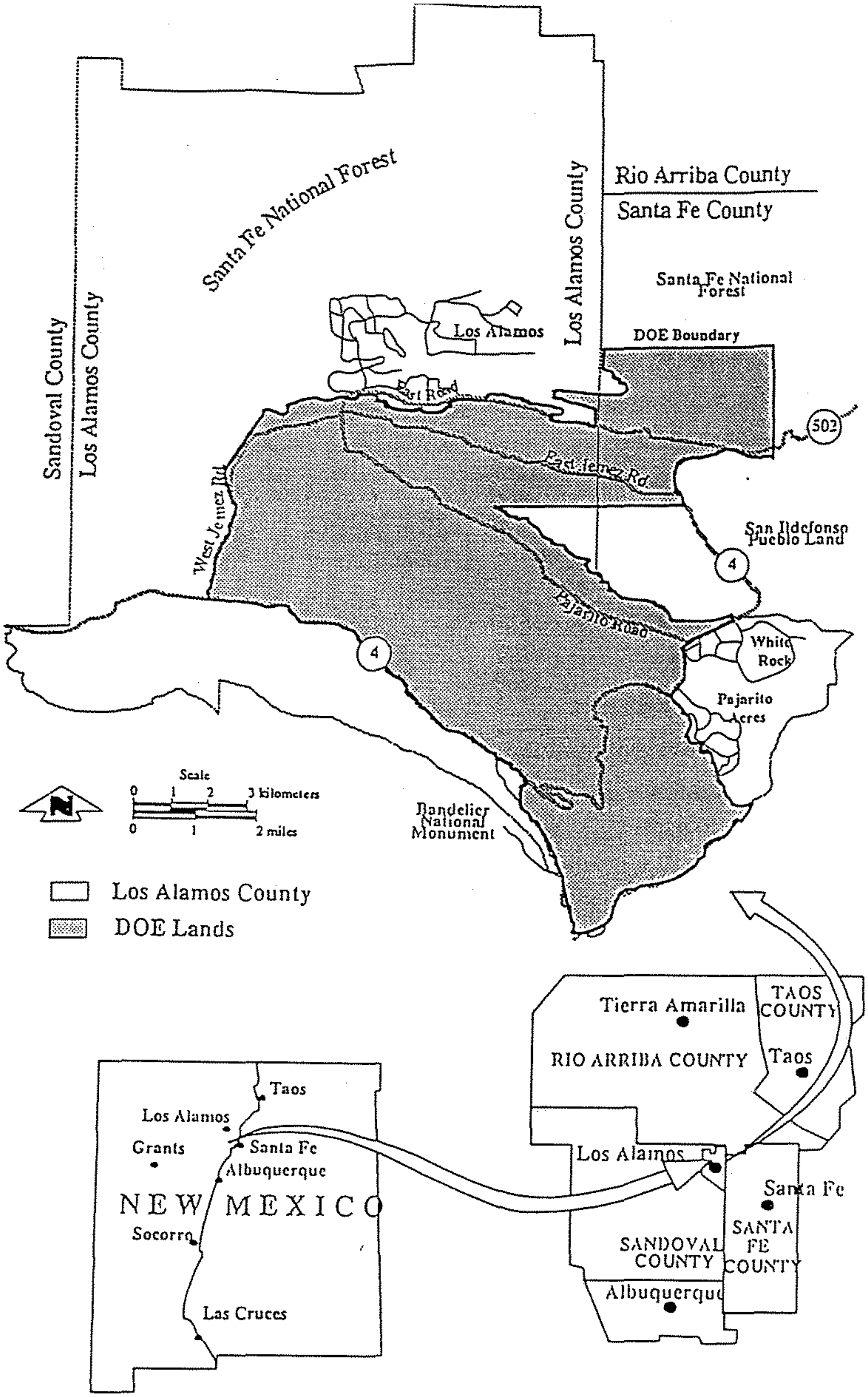

Figure 1. Map of Los Alamos County and LANL

2.2 General Description of Streams

The eastern edge of the Pajarito Plateau lies along the westen edge of White Rock Canyon. In the LANL area, the plateau is drained by Los Alamos, Sandia, Mortandad, Pajarito, Water, Ancho, Chaquihui, and Frijoles Canyons (Fig. 2). Only two canyons draining LANL property have perennial flows that reach the Rio Grande: Pajarito and Ancho Canyons. The base flow in these canyons is maintained from springs discharging near the Rio Grande. The entire length of Frijoles Canyon is contained within Bandelier National Monument, but it provides a convenient reference for Pajarito and Ancho Canyons. The base flow in Frijoles Canyon originates in a series of headwater springs located about 13 km (20 mi) west of the Rio Grande on the eastern edge of the Jemez Mountains (Purtyman, et. al 1980).

2.3 General Description of Springs

Twenty of the twenty-seven springs and seeps along White Rock Canyon are located on the western side of the Rio Grande. These western springs discharge ground water from the uppper surface of the Los Alamos main aquifer (Purtyman, et. al 1980). Some of these springs are underwater during high river flows, and the present study investigated the 6 largest and most accessible of the western springs.

3 METHODOLOGY

3.1 Habitat Evaluation

The US Environmental Protection Agency (EPA) has developed a series of measures to assess aquatic habitat qualityin stream riffle and run areas (Plafkin, et al. 1989). According to their relative influence on stream habitat, the 8 habitat parameters (Appendix A) are divided into 3 groups:

- primary — bottom substrate instream cover, embeddedness, and flow (not measured in this study);
- secondary — channel alteration, bottom scouring and deposition, and pool riffle and run ratio;
- tertiary — bank stability, bank vegetative stability, and streamside cover.

The groups are scored so that primary parameters receive the greatest weight and tertiary parameters the least. Each parameter is assigned a score from a table of values, with

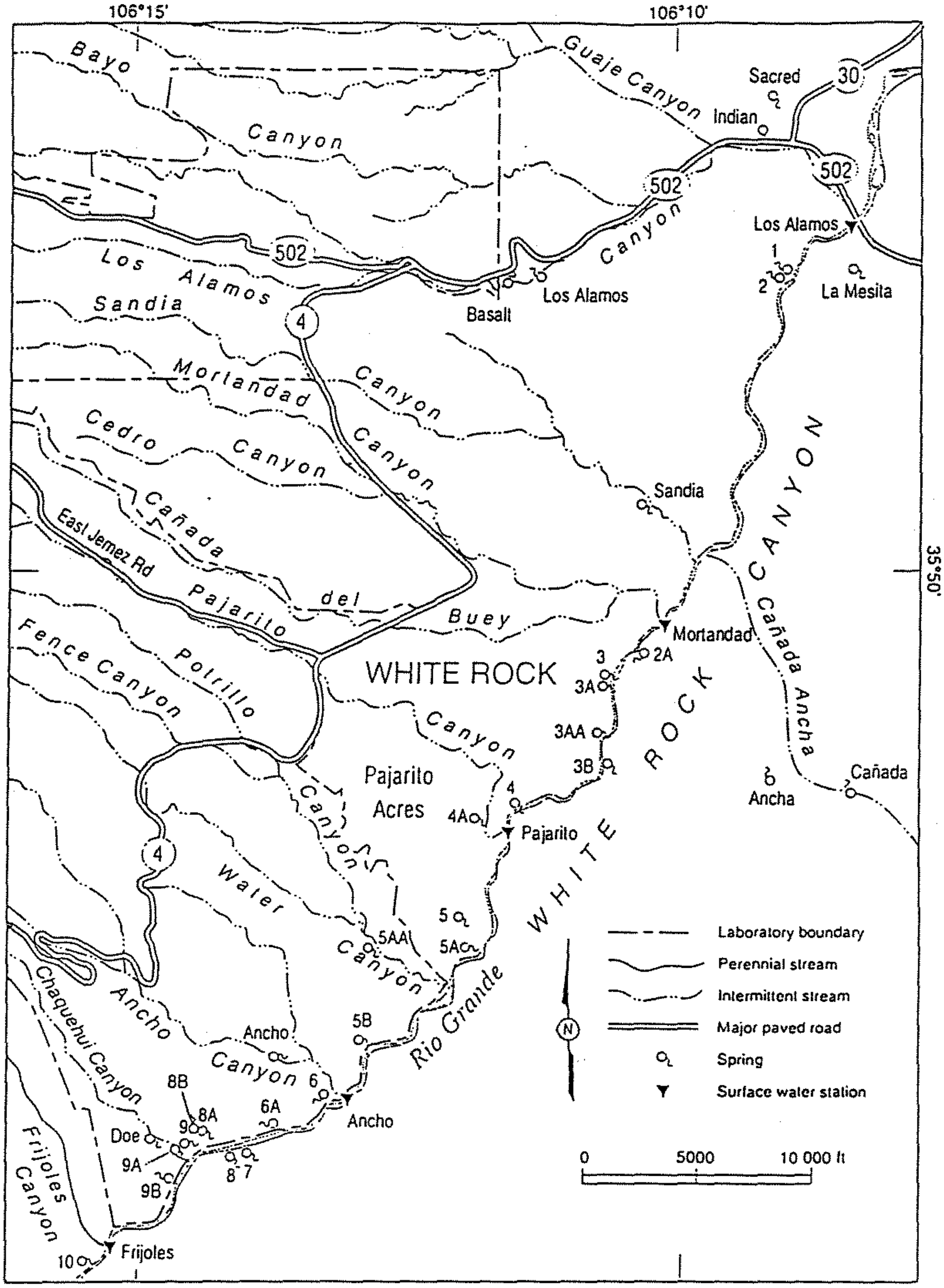

Figure 2. Map of White Rock Canyon and Canyons of the Pajarito Plateau

(from Purtymun, et al. 1980)

higher scores reflecting higher quality habitat. The scores are then summed to yield an overall numerical habitat assessment. This sum is not intended to directly translate into narrative categories of habitat quality. Instead, the score provides a means of combining several habitat parameters into a single value that provides a comparative method to evaluate stream habitat.

EPA recommends that a single individual perform all comparative habitat assessments to standardize any prejudices and/or preferences that may influence the scoring. Therefore, Saul Cross personally conducted all habitat assessments at all sampling sites and on all sampling dates. Flow rates were not measured, and this parameter was discarded from the summations.

3.2 Water Quality Parameters

Stream parameters of water temperature, pH, DO, and conductivity of streams were measured with instruments calibrated daily in accordance with the manufacturers' specifications. All measurements were taken at least 3 times, and the averaged values are reported. If a measurement differed greatly from the others taken at a site, 1 or 2 further measurements were taken and the average computed from all 4 or 5 values.

Water temperature was measured in degrees Celsius with the temperature probe of a Yellow Springs Instrument model 57 DO meter. All pH measurements were taken with an Oakton pH/mV/°C meter set to the hundredths scale. Conductivity was measured with a VWR digital conductivity meter which displays the conductivity in units of µmhos/cm.

DO was measured in units of mg/l with a Yellow Springs Instrument model 57. DO is temperature and altitude dependent. To correct for altitude, the calibration readings were multiplied by 0.82, the compensation value for 1645 m (5264 ft). The percent saturation was calculated by dividing the corrected DO reading by the saturation value at the appropriate water temperature.

Personnel from New Mexico'sEnvironment Department recorded parameters of water temperature, conductivity, DO, and pH at the spring sources. They used an Orion pH meter model 290A to measure both pH and temperature, and an Orion conductivity meter model 124.

3.3 Aquatic Macroinvertebrates

Aquatic macroinvertebrates were collected (see Appendix B for complete listing) at the same time that water quality parameters were measured and habitat assessments were recorded. Flow regimes required different sampling techniques to be employed in the streams as opposed to the springs. Collected debris and invertebrates were placed in a 500-ml Nalgene bottle labelled with the collection site and the collection date. Aquatic nets were closely inspected and any clinging invertebrates were added to the sample bottle. Once collected, all invertebrate samples were preserved in 70% ethanol and taken to the lab for analysis.

3.3.1 Stream Sampling

The streams had considerably more flow than the springs (except for Spring 3A), permitting quantitative sampling. Sampling occurred in areas with cobble substrates in stream riffles subjectively determined to be the best available habitats. Aquatic invertebrates were collected from the streams with a Surber sampler, a quantitative sampling device widely used in stream studies. After firmly positioning the 1 sq ft frame against the stream bottom, the substrate enclosed by the frame was agitated. Clinging and attached invertebrates were dislodged and carried by the stream current into the 900 micron mesh net. A scrub brush was used to remove resistant invertebrates from rocks in the sample area. Larger rocks were visually inspected to ensure that no invertebrates had been overlooked.

3.3.2 Spring Sampling

The low flows at the springs prevented the use of a Surber sampler or any other standard quantitative sampling device. In April 1995, aquatic invertebrate samples were collected with a small aquarium net from various points along the water course. Because these collections were made haphazardly, we could not reliably compare total numbers of invertebrates. In September 1995, the sampling protocol for springs was standardized to allow more valid comparisons. Each spring discharge was sampled for 5 seconds at 3 separate locations, subjectively chosen to represent a variety of the best available habitats. The 3 sub-samples from each spring were composited into a single sample container for analysis.

3.3.3 Laboratory Protocols

In the lab, the ethanol preservative was carefully poured into a sorting tray and checked for invertebrates. The ethanol was then poured into a disposal container labelled as containing hazardous waste. After adding water to the Nalgene bottle, the sample was poured into white plastic trays. Pickers separated invertebrates from the organic detritus and rocks present in the sample. Invertebrates were placed in scintillation vials of 70% ethanol to await identification. All trays were checked under 10-power magnification before their contents were discarded.

A Bausch and Lomb Stereozoom dissecting binocular microscope was used to accomplish identifications. A trained entomologist identified specimens using standard references, including Baumann et al. 1977, Edmunds 1976, Merritt and Cummins 1984, Pennak 1978, and Wiggins 1977. Specimens were identified to genus when possible and stored in vials of 70% ethanol in the EST invertebrate collection. Identifications were confirmed by local aquatic invertebrate experts: Gerald Z. Jacobi of New Mexico Highlands University or Daniel McGuire of McGuire Consulting. All macroinvertebrates collected in this study were archived in EST's permanent collection.

3.3.4 Invertebrate Analysis

Several measures of aquatic macroinvertebrates, or metrics, have been incorportated into this paper. The strength of such a "multimetric" assessment is its ability to integrate and evaluate data from individual, population, community, and ecosystem levels. The metrics are not intended to be exclusive measures, and overlap occurs between number of individuals and density, EPT index and EPT percentage, and other community composition measures. This study did not attempt to establish a reference site or condition. Instead, the spring and stream sommuntities are analyzed separately permitting site comparisons.

To understand community balance, EST counted and calculated the <u>number of taxa, number of individuals, dominant taxa, and percent contribution of dominant taxon</u> for each sample. In general, higher numbers of taxa and lower percent contribution of dominant taxon indicate better water quality. Quantitative sampling in the larger streams permitted a density calculation, expressed in numbers of invertebrates per m^2. Densities and numbers of individuals are somewhat ambiguous in that high numbers may indicate a population bloom of tolerant invertebrates or a well-adjusted community at, or near, its carrying capacity. These parameters must be interpreted in terms of other measures, such as a biodiversity index and the Community Tolerance Index.

In all samples, we tried to ensure that no taxon 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 per 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.

A biodiversity index was calculated for each site on each sampling date using the equation discussed by Wilhm (1967):

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

where D = the taxa diversity index

S = the number of taxa

N = the number of individuals

The derived number reflects the site's taxa richness and evenness. A diversity index value of less than 1 indicates heavy pollution, between 1 and 3 indicates moderate pollution, and greater than 3 indicates 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.

Metrics of EPT (Ephemeroptera or mayflies, Plecoptera or stoneflies, and Trichoptera or caddisflies) reflect the health of a waterway. These aquatic insect orders are generally sensitive to assorted pollutants. The EPT index is the number of EPT taxa within a sample, and it usually increases with increasing water quality.

The EPT/All invertebrates metric is a ratio of EPT individuals to all macroinvertebrates collected, expressed as a percentage. Good biotic condition is reflected in communities having substantial representation in the sensitive EPT groups (Plafkin, et al. 1989). Many species of Chironomids (midges) are tolerant of pollutants, and a high percentage for the Chironomidae/All invertebrate ratio generally indicates environmental stress.

The Insects/All invertebrates metric compares total numbers of individuals collected in a sample. Many non-insect aquatic invertebrates can tolerate more degraded conditions, as higher levels of solubilized metals, than can aquatic insects. This ratio must be carefully interpreted because the relatively constant temperatures and possible lack of predators and/or competitors in springs may favor of non-insect invertebrates. The ratio should be interpreted in conjunction with other metrics, especially the Community Tolerance Quotient.

Recent studies have emphasized the importance of community structure in evaluating water quality (Gaufin and Tarzwell 1956; Hilsenhoff 1977; Schwenneker and Hellenthal 1984; and Jacobi 1989, 1990, 1992). Examination of macroinvertebrate functional feeding groups provides an understanding of community structure and complexity. Insects are the dominant group in most streams; and aquatic research has therefore concentrated on this widespread arthropod class.

When feeding, aquatic insects select organic particles primarily due to their size rather than their origin. Thus, the familiar trophic (feeding) categories of herbivore, carnivore, and omnivore have little application to aquatic macroinvertebrates. To more accurately describe the trophic relations of aquatic insects, a series of functional feeding groups, or trophic categories, has been developed (Cummins and Merritt 1984). These categories are determined by feeding mechanism (Table 1). See Appendix A for a listing of functional feeding groups for aquatic insects collected in this study.

Table 1. Aquatic Insect Functional Feeding Groups

Functional Group	Dominant Food
Collector-filterers	Water-borne fine particulate organic matter
Collector-gatherers	Sedimentary fine particulate organic matter
Shredders	Coarse particulate organic matter
Scrapers	Attached algae and associated material
Predators	Engulfers or piercers feeding on living animal tissue

The Scraper/Filtering collector functional group metric can detect imbalances due to an overabundance of a particular food source. Scrapers increase with increased abundance of diatoms and decrease as filamentous algae and aquatic mosses increase. Filtering collectors increase with increased filamentous algae and aquatic mosses because these provide good attachment sites. The organic enrichment often responsible for overabundance of filamentous algae also provides fine particulate organic matter utilized by the filterers (Plafkin, et al. 1989).

The Community Tolerance Quotient (CTQ) index was developed to assess the impacts of nonpoint source pollution in the western United States (Winget and Mangum 1979). This system has been previously used in the Jemez Mountains to effectively evaluate stream quality (Jacobi 1989, 1990, and 1992) and provides a more complete and accurate basis for site comparison than the EPT index. Tolerance quotients for aquatic invertebrate taxa range from 6 (the most sensitive) to 108 (the least sensitive) and are based upon tolerances to alkalinity, sulfates, and sedimentation (see Appendix D for the tolerance quotients of insects collected in this study). The CTQ is computed using the formula

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

where x = number of individuals within a species

t = tolerance value of a taxon (found in a published table of values)

n = total number of organisms in the sample

4 RESULTS

4.1 Springs

The data collected at each spring is reported on a standardized data sheet to facilitate comparisons. All data sheets are comprised of sections on location, elevation, topographic situation, spring description, surrounding vegetation, water quality parameters, and aquatic invertebrates. Water quality parameter tables include estimated flow and measurements of pH, water temperature, conductivity, and alkalinity. Aquatic invertebrate metrics include number of taxa, number of individuals, dominant taxon, percent contribution of dominant taxon, Wilhm's biodiversity index, EPT index, EPT/all invertebrates, Chironomidae/all invertebrates, insects/all invertebrates, scrapers/(scrapers + filtering collectors), and the Community Tolerance Quotient. The elevations and topographic information in the description sections are taken from Purtyman, et. al (1980). The latitude and longitude coordinates were supplied by NMED OB personnel. The data from all springs is reviewed in the Conclusions Section.

4.1.1 Spring 3

Location: Longitude 106° 10' 42.04"; latitude 35° 49' 10.02"

Elevation: Source at 1695 m (5560 ft).

Topographic situation: Source at gravel terrace above river.

Description: The water flowed for approximately 73 m (80 yds) and split into 4 small rivulets, which flowed over exposed rock surfaces before joining the Rio Grande. The upper area was an open meadow of rush and watercress. In April, some cow manure was observed near the stream.

Surrounding vegetation: New Mexico olive and one-seed juniper were the dominant trees and provided much shading. The watercourse was surrounded by a thick understory of grasses and forbs. Many mosses and hydrophytes, including large amounts of watercress, occurred in the stream.

Water quality parameters (taken at source):

Field parameter	10 April 1995	11 September 1995
pH	7.89	7.58
Water temperature	19.1°C	20.2°C
Conductivity	199.3 μmho/cm	203 μmho/cm
Alkalinity	5.56 mg/L	Not taken.
Estimated flow	9 gal/min	12.5 gal/min

Spring 3 had the relatively high conductivity readings, only slightly.

Aquatic invertebrates:

Invertebrate metric	10 April 1995	11 September 1995
Number of taxa	23	14
Number of individuals	908	245
Dominant taxon	*Hyalella* scuds	*Hyalella* scuds
Percent contribution of dominant taxon	39.0%	38.0%
Wilhm's biodiverity index	3.38	2.36
EPT index	5	3
EPT/All invertebrates	22.0%	29.4%
Chironomidae/All invertebrates	4.7%	0%
Insects/All invertebrates	48.1%	51.4%
Scrapers/(Scrapers + filtering collectors)	90.2%	76.0%
Community Tolerance Quotient	85.7	64.3

Compared to the other springs, Spring 3 was characterized by low numbers of taxa and individuals in September, low percentages of Chironomids, high percentages of scapers compared to filtering collectors, low percentages of aquatic insects, and the lowest CTQs. The low CTQs are due to high numbers of *Helicopsyche borealis* (in April and September) and *Wormaldia* sp. (in September) caddisflies. It is unclear why a more developed community is not present at this spring. This was the only spring or stream having the same dominant taxa in April and September.

4.1.2 Spring 3A

Location: Longitude 106° 10' 41.64"; latitude 35° 49' 7.41"

Elevation: Source at 1695 m (5560 ft).

Topographic situation: Source at gravel terrace above river.

Description: This spring feeds a small clear pool where the uprushing water creates a flurry of air bubbles. The adjacent narrow channel has a substrate of mixed sized rocks. Much of the 70 m (75 yd) watercourse is shaded and much of the channel has a sandy substrate. At its confluence with the Rio Grande, the flow was significantly reduced in April, but strong in September.

Surrounding vegetation: New Mexico olive and one-seed juniper grow along the channel. Large amounts of watercress and mosses occur in the stream.

Water quality parameters (taken at source):

Field parameter	10 April 1995	11 September 1995
pH	7.82	7.54
Water temperature	19.7°C	20.0°C
Conductivity	184.5 μmho/cm	186 μmho/cm
Alkalinity	7.68 mg/L	Not taken.
Estimated flow	32.5 gals/min	27.5 gal/min

Spring 3A had the highest flows of all springs, comparable to that of Ancho stream. The highest alkalinity reading recorded was here in April.

Aquatic invertebrates:

Invertebrate metric	10 April 1995	11 September 1995
Number of taxa	14	14
Number of individuals	221	356
Dominant taxon	*Hydropsyche* caddisflies	*Hyalella* scuds
Percent contribution of dominant taxon	29.9%	49.2%
Wilhm's biodiverity index	2.41	2.21
EPT index	5	1
EPT/All invertebrates	50.2%	6.2%
Chironomidae/All invertebrates	3.2%	0%
Insects/All invertebrates	75.6%	18.5%
Scrapers/(Scrapers + filtering collectors)	26.7%	66.0%
Community Tolerance Quotient	96.4	96.7

Compared to the other springs, Spring 3A was characterized by the lowest numbers of taxa, the lowest biodiversities, low percentages of Chirononmids, and very different vernal and autumnal community compositions.

4.1.3 Spring 5

Location: Longitude 106° 11' 48.06"; latitude 35° 47' 21.05"

Elevation: Source at 1698 m (5569 ft).

Topographic situation: Source at gravel terrace on steep slope above river.

Description: The springhead substrate contained cobbles, but most of the drainage had a sandy substrate. The upper 100 yds (90 m) had an overstory of juniper and a sandy substrate. The lower drainage passed through a steep grade and had a dirt substrate with scattered large rocks.

Surrounding vegetation: The dominant overstory near the stream was composed of New Mexico olive, juniper, and tamarisk. Watercress grew in the stream. Cow manure and the effects of heavy trampling were observed near the stream.

Water quality parameters (taken at source):

Field parameter	10 April 1995	12 September 1995
pH	7.84	7.42
Water temperature	20.6°C	20.9°C
Conductivity	181.5 µmho/cm	208 µmho/cm
Alkalinity	7.48 mg/L	Not taken.
Estimated flow	7.5 gal/min	7.5 gal/min

The highest conductivity reading at a spring was recorded at Spring 5 in September.

Aquatic invertebrates:

Invertebrate metric	10 April 1995	12 September 1995
Number of taxa	18	21
Number of individuals	649	367
Dominant taxon	*Simulium* blackflies	*Hyalella* scuds
Percent contribution of dominant taxon	54.1%	51.5%
Wilhm's biodiverity index	2.63	3.39
EPT index	1	1
EPT/All invertebrates	3.9%	0.5%
Chironomidae/All invertebrates	28.6%	16.1%
Insects/All invertebrates	94.3%	45.5%
Scrapers/(Scrapers + filtering collectors)	0%	1.1%
Community Tolerance Quotient	106.2	106.2

Compared to the other springs, Spring 5 was characterized by the lowest EPT values, very different vernal and autumnal community compositions, the highest percentages of the dominant taxa, low numbers of scrapers compared to filtering collectors, and the highest CTQs. These measures indicate that Spring 5 has a variable habitat or that some habitat component inhibits the establishment of a stable community.

4.1.4 Spring 8A

Location: Longitude 106° 14' 16.63"; latitude 35° 45' 51.75"

Elevation: Source at 1682 m (5517 ft).

Topographic situation: Source at seep in channel on canyon wall.

Description: The upper 100 yds (92 m) was a steep drainage with many small clear ponds that were partially filled with fine sediments. The shaded substrate consisted of rock and sand, and a frog was observed in the stream. The lower 50 yds (46 m) passed through a dead juniper zone and contained several disconnected stagnant pools.

Surrounding vegetation: The dominant trees along the stream are New Mexico olive and junipers. Smaller amounts of ponderosa pine, large oaks, and seep willow are also present. The stream contained watercress and another aquatic plant with pinnately odd and dissected leaves.

Water quality parameters (taken at source):

Invertebrate parameter	11 April 1995	13 September 1995
pH	8.28	6.47
Water temperature	Not taken.	20.3°C
Conductivity	119 μmho/cm	143 μmho/cm
Alkalinity	4.72 mg/L	Not taken.
Estimated flow	3.5 gal/min	7.5 gal/min

The highest and lowest pH values recorded at a spring occurred at Spring 8A, as well as the lowest conductivity and alkalinity.

Aquatic invertebrates:

Invertebrate metric	11 April 1995	13 September 1995
Number of taxa	21	22
Number of individuals	654	329
Dominant taxon	Ostracods	*Baetis* mayflies
Percent contribution of dominant taxon	37.0%	46.8%
Wilhm's biodiverity index	3.08	3.62
EPT index	5	5
EPT/All invertebrates	38.5%	61.4%
Chironomidae/All invertebrates	3.2%	6.1%
Insects/All invertebrates	60.6%	77.2%
Scrapers/(Scrapers + filtering collectors)	70.2%	72.7%
Community Tolerance Quotient	82.0	76.2

Compared to the other springs, Spring 8A was characterized by consistently high numbers of taxa, high biodiversities, high EPT measures, low percentages of Chironomids, and low CTQs. These measures indicate that Spring 8A provides high quality habitat and supports a well established community.

4.1.5 Spring 9A

Location: Longitude 106° 14' 29.69"; latitude 35° 45' 48.18"

Elevation: Source at 1684 m (5524 ft).

Topographic situation: Source at seep area on canyon wall.

Description: The upper area had marshy areas and a sandy bottom eith some rocks. The stream had a fairly steep gradient and several pools. In September, a slight flow continued for 20 yds (18 m) passed through pools paritally filled with sediments in a dead juniper zone. The lowest 50 yds (45 m) was a 2 ft (0.6 m) deep channel containing high amounts of sand and mud, large rocks, and a few cobbles.

Surrounding vegetation: The dominant trees were New Mexico olive, oak, and junipers. Few plants, including some watercress, occurred in the water, perhaps due to heavy grazing by cattle. Grasses grew on the sides of the stream channel, which supported few shrubs. Sedges and many cow tracks occurred in marshy spots.

Water quality parameters (taken at source):

Field parameter	11 April 1995	29 September 1995
pH	7.49	7.04
Water temperature	19.6°C	20.2°C
Conductivity	124.1 μmho/cm	126.5 μmho/cm
Alkalinity	4.72 mg/L	Not taken.
Estimated flow	2.5 gal/min	4.5 gal/min

The lowest alkalinity recorded at a spring occurred at Spring 9A in April.

Aquatic invertebrates:

Invertebrate metric	**11 April 1995**	**13 September 1995**
Number of taxa	24	17
Number of individuals	503	249
Dominant taxon	*Micropsectra* midges	*Rheotanytarsus* midges
Percent contribution of dominant taxon	29.6%	32.5%
Wilhm's biodiverity index	3.70	3.08
EPT index	6	3
EPT/All invertebrates	9.7%	18.1%
Chironomidae/All invertebrates	35.0%	48.9%
Insects/All invertebrates	80.3%	72.3%
Scrapers/(Scrapers + filtering collectors)	18.2%	10.5%
Community Tolerance Quotient	107.8	94.9

Compared to the other springs, Spring 9A was characterized by a low number of individuals, the highest EPT index (in April), high percentages of Chironomids, and high CTQs. These measures indicate that Spring 9A provides high quality habitat.

4.1.6 Doe Spring

Location: Longitude 106° 14' 34.75"; latitude 35° 45' 52.64"

Elevation: Source at 1707 m (5560 ft).

Topographic situation: Source at seep area in channel and canyon wall.

Description: In the upper 100 yds (92 m), the small stream formed a series of clear pools up to 2 ft (0.6 m) deep within a channel of large rocks. Few cobbles were present in the channel, and the substrate was primarily sand. The lower 220 yds (200 m) was a dry channel with large boulders and filled pools.

Surrounding vegetation: The dominant tree was New Mexico olive with a scattering of junipers and oaks. At the lower end, Apache plume was the dominant shrub. A small amount of watercress occurred in the upper channel, but few plants grew in the lower half of the stream. Some areas were choked by green algae.

Water quality parameters (taken at source):

Field parameter	12 April 1995	13 September 1995
pH	7.90	7.41
Temperature	16.1°C	16.2°C
Conductivity	123.6µmho/cm	140.0 µmho/cm
Estimated flow	3 gal/min (combined)	3 gal/min (combined)

Aquatic invertebrates:

Invertebrate metric	12 April 1995	13 September 1995
Number of taxa	17	26
Number of individuals	162	496
Dominant taxon	*Callibaetis* mayflies	*Simulium* blackflies
Percent contribution of dominant taxon	49.4%	39.9%
Wilhm's biodiverity index	3.14	4.03
EPT index	5	5
EPT/All invertebrates	62.3%	38.1%
Chironomidae/All invertebrates	22.8%	3.2%
Insects/All invertebrates	95.1%	88.5%
Scrapers/(Scrapers + filtering collectors)	89.5%	10.2%
Community Tolerance Quotient	85.6	81.5

Compared to the other springs, Doe Spring was characterized by the highest number of individuals during September's standardized sampling, the highest biodiversity, high EPT measures, and the highest percentages of aquatic insects. These measures indicate that Doe Spring supported the best developed and most diverse spring community sampled. The low CTQ indicates that the habitat has been of high quality long enough for the present community to establish itself.

4.2 Streams

The data collected in each stream is reported on a standardized data sheet to facilitate comparisons. All data sheets are comprised of sections on location, stream description, surrounding vegetation, water quality parameters, and aquatic invertebrates. Water quality parameter tables include estimated flow and measurements of pH, water temperature, conductivity, dissolved oxygen, oxygen saturation, and the total habitat assessment score. Aquatic invertebrate measures include number of taxa, number of individuals, dominant taxon, percent contribution of dominant taxon, Wilhm's biodiversity index, EPT index, EPT/all invertebrates, Chironomidae/all invertebrates, insects/all invertebrates, scrapers/(scrapers + filtering collectors), and the CTQ. The data from all streams is discussed in the Conclusions Section.

4.2.1 Lower Pajarito Canyon (Pajarito Springs)

Location (at river): Longitude 106° 11' 66"; latitude 35° 48' 17"

Description: Lower Pajarito Canyon has a consistently strong flow. The stream is fairly open with large rocks in the waterway. In April, numerous bullfrog tadpoles occurred in a large sheltered pool at the confluence with the Rio Grande. In the fall, one adult bullfrog and several fish were seen in the pool.

Surrounding vegetation: A thicket of short willows and an occassional tamarisk grows near the Rio Grande confluence. Upstream, the scattered dominant trees are Russian olive, New Mexico olive, and one-seed juniper. The streambank is well vegetated and some watercress grows in the water.

Water quality parameters:

Field parameter	10 April 1995	10 September 1995
pH	8.29	7.95
Water temperature	18.1°C	22.0°C
Conductivity	221 µmho/cm	209 µmho/cm
Dissolved oxygen	7.75 mg/L	6.65 mg/l
Oxygen saturation	81.8%	76.1%
Estimated flow	300 gal/min	Not estimated.
Habitat assessment	100	94

Compared to the other streams, Pajarito had the highest conductivities, the highest average habitat assessment scores, and a consistently large flow. It appears to provide high quality habitat for aquatic invertebrates.

Aquatic invertebrates: The Pajarito aquatic samples were collected 130 yds (120 m) above the confluence with the Rio Grande. Many hydroptilid caddisfly larvae were observed in vesicles of large rocks both within and adjacent to the sampling area. These caddisflies construct cases that tightly adhere to the rock surface and were not collected. However, estimates of their numbers were included in all aquatic invertebrate calculations.

Invertebrate metric	**10 April 1995**	**11 September 1995**
Number of taxa	19	20
Number of individuals	149	337
Density (per sq m)	1603	3626
Dominant taxon	*Heterlimnius* beetle larvae	*Hydropsyche* caddisflies
Percent contribution of dominant taxon	29.5%	24.0%
Wilhm's biodiverity index	3.60	3.26
EPT index	8	9
EPT/All invertebrates	32.9%	54.0%
Chironomidae/All invertebrates	3.4%	0.3%
Insects/All invertebrates	96.0%	79.2%
Scrapers/(Scrapers + filtering collectors)	89.8%	39.6%
Community Tolerance Quotient	98.8	95.2

Compared to the other streams, Pajarito Springs was characterized by high numbers of taxa and biodiversities, both very similar to those in Ancho. Pajarito had the lowest percent dominant taxa, the highest EPT indices, and high numbers of scrapers compared to filtering collectors. All of these measures indicate that Pajarito supports a well-developed community and provides high quality aquatic habitat.

4.2.2 Ancho Canyon

Description: The stream has cut a channel to 6 ft (1.8 m)through alluvium near the river. For 50 yds (46 m) above the confluence, there was no shade and large amounts of filamentous algae in the stream. The streambed here had large unstable rocks in the sandy substrate and pools choked with sand. The next 70 yds (64 m) was a zone of dead junipers from the ponding of water behind Cochiti dam. The upper area had a few scattered willows, which increased with distance upstream, and a sandy substrate for 150 yds (137 m) with many rocks in the channel. The entire lower portion of the Ancho stream (220 yds or 200 m) had deep sand depositions. In April, signs of over-grazing included cow manure in the stream, trampling of young vegetation, muddied water, and browsed willows. We saw 5 adult cattle and 3 calves near one of the heavily used pools. In fall, no evidence of cattle was seen, and the willows seemed to be recovering.

Surrounding vegetation: The lower floodplain contained large amounts of tansy mustard and summer cypress with little vegetational diversity. The stream contained few hydrophytes, but there was some watercress.

Water quality parameters: The April invertebrate sample was collected approximately 220 yds (200 m) above the confluence with Rio Grande, just before the stream abruptly narrows. The September invertebrate sample was collected approximately 200 yds (183 m) above the river, in the willow area.

Field parameter	11 April 1995	11 September 1995
pH	8.63	8.22
Water temperature	17.9°C	24.1°C
Conductivity	155 µmho/cm	162 µmho/cm
Dissolved oxygen	7.9 mg/l	7.65 mg/l
Oxygen saturation	81.7%	90.9%
Estimated flow	37.5 gal/min	Not estimated.
Habitat assessment	65	33

Compared to the other streams, Ancho had the highest pH readings, the lowest conductivities, the highest average oxygen saturation, and the lowest flow by far. The extremely low habitat assessment scores indicate that the aquatic habitat is marginal.

Aquatic invertebrates: In April, the area of the stream had a sandy substrate, except for the small rock riffle that was sampled.

Invertebrate metric	**11 April 1995**	**28 September 1995**
Number of taxa	21	19
Number of individuals	532	102
Density (per sq m^2)	5724	1098
Dominant taxon	*Baetis* mayflies	*Hydropsyche* caddisflies
Percent contribution of dominant taxon	37.8%	23.5%
Wilhm's biodiverity index	3.19	3.89
EPT index	5	5
EPT/All invertebrates	56.4%	68.6%
Chironomidae/All invertebrates	6.6%	6.9%
Insects/All invertebrates	92.5%	97.1%
Scrapers/(Scrapers + filtering collectors)	50.1%	33.7%
Community Tolerance Quotient	81.1	78.3

Compared to the other streams, Ancho was characterized by high numbers of taxa and biodiversities, both very similar to those in Pajarito Springs. Ancho also had the highest density (in April) of aquatic invertebrates collected, moderate dominant taxa percentages, the highest EPT percentages, and the lowest CTQs. All of these measures indicate that Ancho supports a well established community and provides high quality aquatic habitat. Although the overall habitat is marginal, communities residing in the small riffle areas are remarkably diverse.

4.2.3 Frijoles Canyon

Description: The stream has cut a channel to 8 ft (2.5 m) deep through the soft alluvium near the river. In April, sands had settled out in pools and slower reaches. Many bare spots along the stream were easily erodable and provide a source of further sedimentation. In September, the system had been flushed out by rains, and the substrate consisted of varied cobbles with some sediments. The dead juniper zone extended 250 yds (230 m) above the confluence with the Rio Grande. No signs of recent cattle activity were observed on either date.

Surrounding vegetation: The floodplain is heavily dominated by summer cypress, with some tansy mustard and nettles. The dead juniper zone extended approximately 350 yds (320 m) above the confluence with the Rio Grande. Above the dead zone, there are a few scattered trees, mostly New Mexico olive, Ponderosa pine, cottonwood, and oak. Several boxelders and willow grow on the grassy stream banks. Apache plume grows in thick clumps in drier sites away from the stream. The stream contains little algae. In April, the water in the lower stream 400 yds (365 m) was milky due to runoff.

Water quality parameters:

Field parameter	12 April 1995	12 September 1995
pH	7.98	7.97
Water temperature	8.5°C	14.1°C
Conductivity	116 µmho/cm	124 µmho/cm
Dissolved oxygen	10.1 mg/l	8.0 mg/l
Oxygen saturation	86.3%	77.6%
Estimated flow	300 gal/min	Not estimated.
Habitat assessment	71	97

Compared to the other streams, Frijoles had the lowest pH readings, lowest temperatures, and lowest conductivities. This is the longest drainage sampled and it contains a high volume of discharge. Past impacts, including high nitrogen loads and over-grazing, may continue to affect this reach of the stream.

Aquatic invertebrates: Little organic matter was collected in the April sample. The April sample was collected at the edge of the dead juniper zone, and the September sample was collected 300 yds (275 m) above the river within the dead zone.

Invertebrate metric	12 April 1995	12 September 1995
Number of taxa	5	15
Number of individuals	97	217
Density (per sq m)	1044	2335
Wilhm's biodiverity index	0.87	2.60
Dominant taxon	*Simulium* blackflies	*Baetis* mayflies
Percent contribution of dominant taxon	75.3%	37.8%
EPT index	3	7
EPT/All invertebrates	23.7%	63.1%
Chironomidae/All invertebrates	0%	0.9%
Insects/All invertebrates	99.0%	99.1%
Scrapers/(Scrapers + filtering collectors)	23.2%	71.2%
Community Tolerance Quotient	98.2	77.8

Compared to the other streams, Frijoles had the lowest number of taxa (in April), the highest dominant taxa percentages, the lowest biodiversity indices, the highest percentages of insects, and variable scrapers to filtering collector ratios. Despite the low biodiversity values, the CTQs were intermediate and lower than those of Pajarito, which appears to offer better much habitat.

5 CONCLUSIONS

5.1. Springs

When compared to higher-order streams, springs have greater physical and chemical stability (Glazier 1991). The sampled springs were similiar in physical and chemical parameters variation between April and September (Table 2) in that the pH of each dropped by approximately 0.5 unit (except Spring 8A which dropped 1.8 units), the water temperature remained fairly constant with a slight increase, all conductivities displayed a slight rise, and the estimated flows remained similiar.

Table 2. Average 1995 Physical and Chemical Spring Parameters

Month*, Parameter	3	3A	5	8A	9A	Doe	Average
A, pH	7.89	7.82	7.84	8.28	7.49	7.90	7.87
S, pH	7.58	7.54	7.42	6.47	7.04	7.41	7.24
A, Water temperature (°C)	19.1	19.7	20.6	Not taken.	19.6	16.1	18.8
S, Water temperature (°C)	20.2	20.0	20.9	20.3	20.2	16.2	19.6
A, Conductivity (µmho/cm)	199.3	184.5	181.5	119	124.1	123.6	155.3
S, Conductivity (µmho/cm)	203	186	208	143	126.5	140.0	167.8
A, Alkalinity (mg/l)	5.56	7.68	7.48	4.72	4.72	Not taken.	6.03
A, Estimated flow (gpm)	9	32.5	7.5	3.5	2.5	3	9.7
S, Estimated flow (gpm)	12.5	27.5	7.5	7.5	4.5	3	10.4

Most springs had moderate numbers of taxa (Table 3) and biodiversities (Spring 3A was low). The EPT indices and percentages varied greatly between seasons. Streams had widely different percentages of Chironomids (0 to 48.9), insects (18.5 to 95.1), and scrapers compared to filtering collectors (0 to 90.2). Wilhm's biodiversity indices varied greatly by season and were not as correlated with CTQs as expected.

Table 3. 1995 Spring Invertebrate Parameters

Month*, Parameter	**3**	**3A**	**5**	**8A**	**9A**	**Doe**	**Average**
A, Number of taxa	23	14	18	21	24	17	19.5
S, Number of taxa	14	14	21	22	17	26	19
A, Number of individuals	908	221	649	654	503	162	516
S, Number of individuals	245	356	367	329	249	496	340
A, Percent dominant taxa	39.0%	29.9%	54.1%	37.0%	29.6%	49.4%	39.8%
S, Percent dominant taxa	38.0%	49.2%	51.5%	46.8%	32.5%	39.9%	43.0%
A, Wilhm's biodiversity index	3.38	2.41	2.63	3.08	3.70	3.14	3.06
S, Wilhm's biodiversity index	2.36	2.21	3.39	3.62	2.90	4.03	3.12
A, EPT index	5	5	1	5	6	5	4.5
S, EPT index	3	1	1	5	3	5	3.0
A, EPT/All invertebrates	22.0%	50.2%	3.9%	38.5%	9.7%	62.3%	31.1%
S, EPT/All invertebrates	29.4%	6.2%	0.5%	61.4%	18.1%	38.1%	25.6%
A, Chironomidae/All invertebrates	4.7%	3.2%	28.6%	3.2%	35.0%	22.8%	16.2%
S, Chironomidae/All invertebrates	0%	0%	16.1%	6.1%	48.9%	3.2%	12.4%
A, Insects/All invertebrates	48.1%	75.6%	94.3%	60.6%	80.3%	95.1%	75.7%
S, Insects/All invertebrates	51.4%	18.5%	45.5%	77.2%	72.3%	88.5%	58.9%
A, Scrapers/(Scrapers + filtering collectors)	90.2%	26.7%	0%	70.2%	18.2%	89.5%	49.1%
S, Scrapers/(Scrapers + filtering collectors)	76.0%	66.0%	1.1%	72.7%	10.5%	10.2%	39.4%
A, Community tolerance quotient	85.7	96.4	106.2	82.0	107.8	85.6	94.0
S, Community tolerance quotient	64.3	96.7	106.2	76.2	94.9	81.5	86.6

* A = April
S = September

5.2 Streams

The streams all showed a seasonal decline in pH, an increase in water temperature, and fairly constant conductivities (Table 4). Flows at Pajarito and Frijoles were similar, but Ancho had considerably less discharge. Dissolved oxygen saturation values were similar, but much lower than expected. Most habitat assessment scores displayed large seasonal inter-stream variability.

Table 4. Average 1995 Physical and Chemical Stream Parameters

Month,* Parameter	Pajarito	Ancho	Frijoles	Average
A, pH	8.29	8.63	7.98	8.30
S, pH	7.95	8.22	7.97	8.05
A, Water temperature (°C)	18.1	17.9	8.5	14.8
S, Water temperature (°C)	22.0	24.1	14.1	20.1
A, Conductivity (µmho/cm)	221	155	116	164
S, Conductivity (µmho/cm)	209	162	124	165
A, Dissolved oxygen (mg/l)	7.75	7.9	10.1	8.58
S, Dissolved oxygen (mg/l)	6.65	7.65	8.0	7.43
A, Oxygen saturation	81.8%	81.7%	86.3%	83.3%
S, Oxygen saturation	76.1%	90.0%	77.6%	81.5%
A, Estimated flow (gpm)	300	37.5	300	212.5
A, Habitat assessment	100	65	71	78.6
S, Habitat assessment	94	33	97	74.6

* A = April
S = September

The numbers of individuals and densities varied greatly at each stream (Table 5) and probably indicate differences in micro-habitats rather than trends. Wilhm's biodiversity values were considerably higher at Pajarito and Ancho than at Frijoles, even though the CTQ is higher at Pajarito than at Frijoles. Percent dominant taxa were roughly similar at all sites, except Frijoles in April when 73 *Simulium* blackflies overwhelmed other community components, producing an extremely low biodiversity. EPT percentages were higher in September in all streams, and Chironomids never formed a significant portion of the communities. The percentage of insects was always high although scrapers compared to filtering collectors varied greatly and unpredictably.

Table 5. 1995 Stream Invertebrate Parameters

Month*, Parameter	Pajarito	Ancho	Frijoles	Average
A, Number of taxa	19	21	5	15
S, Number of taxa	20	19	15	18
A, Number of individuals	149	532	97	259
S, Number of individuals	337	102	217	219
A, Density (sq m)	1603	5724	1044	2790
S, Density (sq m)	3626	1098	2335	2353
A, Percent dominant taxa	29.5%	37.8%	75.3%	47.5%
S, Percent dominant taxa	24.0%	23.5%	37.8%	28.4%
A, Wilhm's biodiversity index	3.60	3.19	0.87	2.55
S, Wilhm's biodiversity index	3.26	3.89	2.60	3.25
A, EPT index	8	5	3	5.3
S, EPT index	9	5	7	7
A, EPT/All invertebrates	32.9%	56.4%	23.7%	37.7%
S, EPT/All invertebrates	54.0%	68.6%	63.1%	61.9%
A, Chironomidae/All invertebrates	3.4%	6.6%	0.0%	3.3%
S, Chironomidae/All invertebrates	0.3%	6.9%	0.9%	2.7%
A, Insects/All invertebrates	96.0%	92.5%	99.0%	95.8%
S, Insects/All invertebrates	79.2%	97.1%	99.1%	91.8%
A, Scrapers/(Scrapers + filtering collectors)	89.8%	50.1%	23.2%	54.4%
S, Scrapers/(Scrapers + filtering collectors)	39.6%	33.7%	71.2%	48.2%
A, Community tolerance quotient	98.8	81.1	98.2	92.7
S, Community tolerance quotient	95.2	78.3	77.8	83.8

* A = April
S = September

5.3 Summary

Although all springs and stream showed a decline in pH between April and September, the streams displayed less variation. The springs had much more consistent water temperatures. Flow at the highest volume spring (27.5 gallons/minute at Spring 3A) approached flow at the lowest volume stream (37.5 gallons/minute at Ancho), but few other similarities were noted between the two classes of waterways.

Despite very different sampling techniques, the average number of taxa collected in springs and streams is remarkably similar. Percent dominant taxa were high at all locations (except possibly Pajarito) and the dominant taxa was different seasonally at every location except at Spring 3 (Table 6). Wilhm's biodiversity indices were reasonably high (except at Frijoles in April, at Spring 3A in April and September, and at Spring 3 in September) for these first order waterways. The streams had higher EPT measures, lower percentages of Chironomids, and higher percentages of insects than did the springs. Average percentages of scrapers to filtering collectors and CTQs were roughly similar for springs and streams, although CTQS tended to be slightly lower at all locations in September. Based on this limited sampling, the highest quality aquatic communities were found in Spring 3, Spring 8A, Doe Spring, Pajarito, and Ancho.

It is unfortunate that aquatic invertebrate samples have not been previously collected at these locations. Eighteen invertebrate samples collected at different seasons do not provide enough data to firmly support many conclusions. However, a few observations may be tentatively advanced:

- pH values of both springs and streams appear to decrease between spring and autumn,
- the springs have more stable temperature regimes than do the streams,
- great variations in flow rates exist between individual springs and streams,
- aquatic habitats vary greatly between the streams and seasonally,
- the dominant taxa frequently changes seasonally in both springs and streams,
- differences between invertebrate samples may obscure differences in site densities, and
- despite variations in community compositions, most of the springs and streams appear capable of supporting well-developed aquatic communities.

Table 6. Dominant Taxa of Springs and Streams by Season

Location	**April taxa**	**April percentage**	**September taxa**	**September percentage**
Spring 3	*Hyallela* scuds	39.0%	*Hyalella* scuds	38.0%
Spring 3A	*Hydropsyche* caddisflies	29.9%	*Hyalella* scuds	49.2%
Spring 5	*Simulium* blackflies	54.1%	*Hyalella* scuds	51.5%
Spring 8A	Ostracods	37.0%	*Baetis* mayflies	46.8%
Spring 9A	*Micropsectra* midges	29.6%	*Rheotanytarsus* midges	32.5%
Doe Spring	*Callibaetis* mayflies	49.4%	*Simulium* blackflies	39.9%
Pajarito stream	*Heterlimnius* beetles	29.5%	*Hydropsyche* caddisflies	24.0%
Ancho stream	*Baetis* mayflies	37.8%	*Hydropsyche* caddisflies	23.5%
Frijoles stream	*Simulium* blackflies	75.3%	*Baetis* mayflies	37.8%

Continued sampling of the aquatic invertebrate communities residing in the streams and springs along White Rock Canyon is required to conclusively document and analyze community structures, seasonal trends, and differences between individual springs and streams. It is recommended that aquatic sampling be conducted during each future hydrological sampling trip. Such sampling would provide a valuable component to the water quality assessments conducted at these sites for approximately the last 20 years.

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APPENDIX A: HABITAT ASSESSMENT FIELD DATA SHEET
(from Plafkin, et al. 1989)

HABITAT ASSESSMENT FIELD DATA SHEET

Habitat Parameter	Category			
	Excellent	Good	Fair	Poor
1. *Bottom substrate/ available cover[a]	Greater than 50% rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability less than desirable. 6-10	Less than 10% rubble gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. Embeddedness[b]	Gravel, cobble, and boulder particles are between 0 and 25 % surrounded by fine sediment 16-20	Gravel, cobble, and boulder particles are between 25 and 50 % surrounded by fine sediment 11-15	Gravel, cobble, and boulder particles are between 50 and 75 % surrounded by fine sediment 6-10	Gravel, cobble, and boulder particles are over 75 % surrounded by fine sediment 0-5
3. ≤0.15 cms (5cfs) - *Flow at rep. low flow[a]	Cold >0.05 cms (2 cfs) Warm >0.15 cms (5 cfs) 10-20	0.03-0.05 cms (1-2 cfs) 0.05-0.15 cms (2-5 cfs) 11-15	0.01-0.03 cms (.5-1 cfs) 0.03-0.05 cms (1-2 cfs) 6-10	<0.01 cms (.5 cfs) <0.03 cms (1 cfs) 0-5
or >0.15 cms (5cfs) - Velocity/depth	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present. 16-20	Only 3 of the 4 habitat categories present (missing riffles or runs receive lower score than missing pools). 11-15	Only 2 of the 4 habitat categories present (missing riffles/runs receive lower score). 6-10	Dominated by one velocity/depth category (usually pool). 0-5
4. * Channel alteration[a]	Little or no enlargement of islands or point bars, and/or no channelization. 12-15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled w/silt; and/or embankments on both banks. 4-7	Heavy deposits of fine material, increased bar development; most pools filled w/silt; and/or extensive channelization. 0-3
5. Bottom scouring and deposition[a]	Less than 5% of the bottom affected by scouring and deposition. 12-15	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools. 8-11	30-50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools. 4-7	More than 50% of the bottom changing nearly year long. Pools almost absent due to deposition. Only large rocks in riffle exposed. 0-3

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[a] From Ball 1982.

[b] From Platts et al. 1983.

Note: * = Habitat parameters not currently incorporated into BIOS.

HABITAT ASSESSMENT FIELD DATA SHEET (cont.)

Habitat Parameter	Category			
	Excellent	Good	Fair	Poor
6. Pool/riffle, run/bend ratio[a] (distance between riffles divided by stream width)	5-7. Variety of habitat. Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles. Bends provide habitat. 8-11	15-25. Occassional riffle or bend. Bottom contours provide some habitat. 4-7	>25. Essentially a straight stream. Generally all flat water or shallow riffle. Poor habitat. 0-3
7. Bank stability[a]	Stable. No evidence of erosion or bank failure. Side slopes generally <30%. Little potential for future problem. 9-10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40% on one bank. Slight potential in extreme floods. 6-8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% on some banks. High erosion potential during extreme high flow. 3-5	Unstable. Many eroded areas. Side slopes >60% common. "Raw" areas frequent along straight sections and bends. 0-2
8. Bank vegetative stability[b]	Over 80% of the streambank surfaces covered by vegetation or boulders and cobble. 9-10	50-79% of the streambank surfaces covered by vegetation, gravel or larger material. 6-8	25-49% of the streambank surfaces covered by vegetation, gravel, or larger material. 3-5	Less than 25% of the streambank surfaces covered by vegetation, gravel, or larger material. 0-2
9. Streamside cover[b]	Dominant vegetation is shrub. 9-10	Dominant vegetation is of tree form. 6-8	Dominant vegetation is grass or forbes. 3-5	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2
Column Totals	____	____	____	____

Score ____________

APPENDIX B: MACROINVERTEBRATE COLLECTED AT SPRINGS AND STREAMS IN 1995

Insects:

Order	Family	Genus species	Location (season)*
Plecoptera (stoneflies)	Nemouridae	*Amphinemura banksi*	F(f)
	Perlidae	*Hesperoperla pacifica*	F(f)
	Perlodidae	*Isoperla*	F(s)
	Pteronarcyidae	*Pteronarcella badia*	F(f)
Ephemeroptera (mayflies)	Baetidae	*Baetis tricaudatus*	3(s), 3A(s), 8A(b), 9A(b), Doe(b), A(b), F(b), P(b)
	Baetidae	*Callibaetis*	8A(s), Doe(b)
	Heptageniidae	*Epeorus longimanus*	F(s)
	Tricorythidae	*Tricorythodes minutus*	A(s), P(f)
Odonata (damselflies and dragonflies)	Calopterygidae	*Hataerina*	3(s), A(s), P(s)
	Coenagrionidae	*Argia*	3(b), 3A(b), 5(b), 8A(b), 9A(b), Doe(f), A(b), P(b)
	Corduliidae	*Neurocordulia*	8A(s)
	Lestidae	*Archilestes*	3A(f), A(f), P
	Libellulidae	*Libellula?*	8A(f), 9A(f), Doe(f), P(f)
Hemiptera (true bugs)	Gerridae	*Gerris*	Doe(b)
	Naucoridae	*Ambrysus mormon*	3(b), 3A(b), 8A(b), 9A(s), A(b), P(f)
	Saldidae		8A(f), Doe(f)
	Veliidae	*Microvelia*	A(b)
	Veliidae	*Rhagovelia*	A(f)
Trichoptera (caddisflies)	Brachycentridae	*Brachycentrus americana*	F(f)
	Helicopsychidae	*Helicopsyche borealis*	3(b), 3A(b), 9A(s), Doe(f), A(b), F(f), P(f)
	Hydropsychidae	*Cheumatopsyche*	3(f), P(b)
	Hydropsychidae	*Hydropsyche oslari*	3(s), 3A(s), A(b), P(b), F(f)
	Hydroptilidae		3A(s)

Order	Family	Genus species	Location (season)*
	Hydroptilidae	*Alisotrichia*	P(b)
	Hydroptilidae	*Hydroptila*	8A(f), A(f)
	Hydroptilidae	*Leucotichia*	P(s)
	Hydroptilidae	*Ochrotrichia*	9A(f)
	Hydroptilidae	*Stactobiella*	8A(f), 9A(s), P(f)
	Limnephilidae	*Hesperophylax*	8A(s), 9A(s), Doe(s)
	Limnephilidae	*Limnephilus*	Doe(s)
	Philopotamidae	*Chimarra*	9A(s), Doe(f), A(b)
	Philopotamidae	*Wormaldia*	3(b), 3A(s), 8A(b), 9A(f), P(b)
	Polycentropodidae	*Polycentropus*	8A(b), Doe(b)
	Rhyacophilidae	*Rhyacophila coloradensis*	F(f)
	Sericostomatidae	*Gumaga*	5(s), 9A(s)
Lepidoptera (butterflies and moths)	Pyralidae	*Petrophila*	3(s), A(s), P(b)
Coleoptera (beetles)	Dryopidae	*Helichus*	8A(f), 9A(s), Doe(f)
	Dytiscidae		5(s), 8A(s), Doe(s)
	Dytiscidae	*Agabus*	Doe(f)
	Dytiscidae	*Rhantus*	Doe(f)
	Elmidae	*Heterelmis*	3(f), 3A(f), 8A(f), 9A(f), A(f)
	Elmidae	*Heterlimnius corpulentus*	3(s), 3A(s), P(s)
	Elmidae	*Microcylloepus*	3(b), 3A(b), 9A(s), P(b)
	Elmidae	*Narpus*	F(f)
	Elmidae	*Optioservus*	F(f)
	Elmidae	*Zaitzevia*	3A(f), F(f)
	Gyrinidae	*Gyrinus*	8A(s), Doe(s)
	Hydrophilidae		3(s), 3A(s), 5(f), Doe(s)
Diptera (true flies)	Ceratopogonidae	*Bezzia*	5(s), 8A(s), 9A(s)
	Ceratopogonidae	*Culicoides?*	5(f)
	Chironomidae	Type M	9A(s)
	Chironomidae, Chironomini	*Cryptotendipes*	A(f)
	Chironomidae, Chironomini	*Pseudochironomus*	9A(f)
	Chironomidae, Macropelopini		5(s)

Order	Family	Genus species	Location (season)*
	Chironomidae, Orthocladiinae		3(s), 5(s), 8A(s), 9A(s), A(s), P(s)
	Chironomidae, Orthocladiinae	*Corynoneura*	5(b), 8A(b), 9A(f), A(f)
	Chironomidae, Orthocladiinae	*Orthocladius*	A(s), F(f), P(s)
	Chironomidae, Orthocladinae	*Cricotopus*	5(f), 8A(f)
	Chironomidae, Orthocladinae	*Labrundinia*	5(f), 8A(f), 9A(f)
	Chironomidae, Orthocladinae	*Orthocladius*	3(s), Doe(f)
	Chironomidae, Orthocladinae	*Parametriocnemus*	5(f), 9A(f), Doe(f)
	Chironomidae, Orthocladinae	*Phaenopsectra?*	Doe(f)
	Chironomidae, Tanypodinae	*Ablabesmyia*	Doe(f)
	Chironomidae, Tanypodinae	*Procladius*	5(s), Doe(f)
	Chironomidae, Tanypodinae	*Thienemannimyia*	3(s), 8A(f), 9A(b), Doe(b), A(b)
	Chironomidae, Tanypodinae	*Zavrelimyia*	Doe(f)
	Chironomidae, Tanytarsini	*Micropsectra*	3(s), 3A(s), 5(s), 9A(s), Doe(s), P(s)
	Chironomidae, Tanytarsini	*Rheotanytarsus*	3(s), 5(b), 8A(f), 9A(f), Doe(f), A(b), F(f), P(f)
	Culicidae	*Culex*	Doe(f)
	Dixidae	*Dixa*	8A(s), 9A(b)
	Empididae		A(f)
	Empididae	*Chelifera*	9A(s)
	Muscidae		5(f)
	Psychodidae	*Maruina*	5(f), P(s)
	Simulidae	*Simulium*	3(b), 3A(b), 5(b), 8A(b), 9A(b), Doe(f), A(b), F(b), P(f)
	Stratiomyidae		3(b)
	Tipulidae		3(s)
	Tipulidae	*Hexatoma*	5(s)
	Tipulidae	*Holorusia*	5(f)

Order	Family	Genus species	Location (season)*
	Tipulidae	*Limnoia*	5(f), 8A(f)
	Tipulidae	near *Limnophila*	5(f)
	Tipulidae	*Tipula*	5(f)
	Tipulidae	*Tipula* B	8A(s), 9A(s)

* s = spring (April)
f = fall (September)
b = both spring and fall

Non-insects invertebrates:

Phylum	Sub-phylum of family	Genus species	Location (season)*
Annelida	Hirudinea		A(s)
	Megadrilli		3A(f), 8A(f), Doe(f)
	Naididae		5(f), A(s)
	Oligochaeta, Lumbriculidae		3(s), 3A(f), 5(s), 9A(s), Doe(s), A(s), F(s)
	Oligochaeta, Tubificidae		3(f), 3A(b), Doe (s)
Crustacea	Amphipoda, Talitridae	*Hyalella azteca*	3(b), 5(b), P(b)
	Amphipoda, Gammaridae	*Gammarus*	9A(b)
	Ostracoda		5(b), 8A(f), 9A(b), Doe(b)
Mollusca	Gastropoda, Lymnaeidae	*Lymnaea*	8A(s)
Mollusca	Gastropoda, Physidae	*Physella gyrina*	3(b), 3A(f), 8A(b), Doe(b), A(b), F(f)
Mollusca	Gastropoda, Sphaeriidae	*Pisidium*	3A(b), 5(f),8A(s), P(s)
Nematoda			5(s), P(s)
Nematomorpha			F(f)
Platyhelminthes	Turbellaria		3(b), 3A(b), 5(f), 8A(b), 9A(b), Doe(f), A(b), P(b)

* s = spring (April)
f = fall (September)
b = both spring and fall

APPENDIX C: FUNCTIONAL FEEDING GROUPS OF COLLECTED INSECTS

Order	Family	Genus species	Functional Feeding Group*
Plecoptera (stoneflies)	Nemouridae	*Amphinemura banksi*	Sh, Cg
	Perlidae	*Hesperoperla pacifica*	Pr
	Perlodidae	*Isoperla*	Pr, Cg
	Pteronarcyidae	*Pteronarcella badia*	Sh, Pr
Ephemeroptera (mayflies)	Baetidae	*Baetis tricaudatus*	Cg, Sc
	Baetidae	*Callibaetis*	Cg
	Heptageniidae	*Epeorus longimanus*	Cg, Sc
	Tricorythidae	*Tricorythodes minutus*	Cg
Odonata (damselflies and dragonflies)	Coenagrionidae	*Argia*	Pr
	Corduliidae	*Neurocordulia*	Pr
	Lestidae	*Archilestes*	Pr
	Libellulidae	*Libellula?*	Pr
Hemiptera (true bugs)	Gerridae	*Gerris*	Pr
	Naucoridae	*Ambrysus mormon*	Pr
	Saldidae		Pr
	Veliidae	*Microvelia*	Pr
	Veliidae	*Rhagovelia*	Pr
Trichoptera (caddisflies)	Brachycentridae	*Brachycentrus americana*	Cf, Sc
	Helicopsychidae	*Helicopsyche borealis*	Sc
	Hydropsychidae	*Cheumatopsyche*	Cf
	Hydropsychidae	*Hydropsyche oslari*	Cf
	Hydroptilidae	*Hydroptila*	Pi, Sc
	Hydroptilidae	*Leucotichia*	Sc, Cg
	Hydroptilidae	*Ochrotrichia*	Cg, Pi
	Limnephilidae	*Hesperophylax*	Sh, He
	Limnephilidae	*Limnephilus*	Sh&He, Cg
	Philopotamidae	*Chimarra*	Cf
	Philopotamidae	*Wormaldia*	Cf
	Polycentropodidae	*Polycentropus*	Pr, Cf, Sh

Order	Family	Genus species	Functional Feeding Group*
	Rhyacophilidae	*Rhyacophila coloradensis*	Pr
	Sericostomatidae	*Gumaga*	Sh
Lepidoptera (butterflies and moths)	Pyralidae	*Petrophila*	Sc
Coleoptera (beetles)	Dryopidae	*Helichus*	Sh, Cg
	Dytiscidae	*Agabus*	Pr
	Dytiscidae	*Rhantus*	Pr
	Elmidae	*Heterelmis*	Cg, Sc
	Elmidae	*Heterlimnius corpulentus*	Cg, Sc
	Elmidae	*Microcylloepus*	Sh
	Elmidae	*Narpus*	Sh
	Elmidae	*Optioservus*	Sc, Cg
	Elmidae	*Zaitzevia*	Sc, Cg
	Gyrinidae	*Gyrinus*	Pr
Diptera (true flies)	Ceratopogonidae	*Bezzia*	Pr
	Ceratopogonidae	*Culicoides?*	Pr, Cg
	Chironomidae, Chironomini	*Cryptotendipes*	Cg(?)
	Chironomidae, Chironomini	*Pseudochironomus*	Cg
	Chironomidae, Macropelopini		Cg
	Chironomidae, Orthocladiinae		Cg
	Chironomidae, Orthocladiinae	*Corynoneura*	Cg
	Chironomidae, Orthocladiinae	*Orthocladius*	Cg
	Chironomidae, Orthocladinae	*Cricotopus*	Sh, Cg
	Chironomidae, Orthocladinae	*Labrundinia*	Pr
	Chironomidae, Orthocladinae	*Orthocladius*	Cg
	Chironomidae, Orthocladinae	*Parametriocnemus*	Cg
	Chironomidae, Orthocladinae	*Phaenopsectra?*	Sc, Cg
	Chironomidae,	*Ablabesmyia*	Co

Order	**Family**	**Genus species**	**Functional Feeding Group***
	Tanypodinae		
	Chironomidae, Tanypodinae	*Procladius*	Pr, Cg
	Chironomidae, Tanypodinae	*Thienemannimyia*	Cg, Sc
	Chironomidae, Tanypodinae	*Zavrelimyia*	Pr
	Chironomidae, Tanytarsini	*Rheotanytarsus*	Cf
	Dixidae	*Dixa*	Cg
	Empididae	*Chelifera*	Pr, Cg
	Psychodidae	*Maruina*	Sc, Cg
	Simulidae	*Simulium*	Cf
	Stratiomyidae		Cf
	Tipulidae	*Hexatoma*	Pr
	Tipulidae	*Holorusia*	Sh
	Tipulidae	*Limnoia*	Sh
	Tipulidae	near *Limnophila*	Pr
	Tipulidae	*Tipula*	Sh&He, Cg, Sc, Pr
	Tipulidae	*Tipula* B	Sh&He, Cg, Sc, Pr

* Cf = Collector filterer
Cg = Collector gatherers
He = Herbivore
Pi = Piercers
Pr = Predators
Sc = Scrapers
Sh = Shredders

APPENDIX D: TOLERANCE QUOTIENTS OF COLLECTED MACROINVERTEBRATES

Insects:

Order	Family	Genus species	Tolerance quotient
Plecoptera (stoneflies)	Nemouridae	*Amphinemura banksi*	6
	Perlidae	*Hesperoperla pacifica*	18
	Perlodidae	*Isoperla*	48
	Pteronarcyidae	*Pteronarcella badia*	24
Ephemeroptera (mayflies)	Baetidae	*Baetis tricaudatus*	72
	Baetidae	*Callibaetis*	72
	Heptageniidae	*Epeorus longimanus*	21
	Tricorythidae	*Tricorythodes minutus*	108
Odonata (damselflies and dragonflies)	Coenagrionidae	*Argia*	108
	Lestidae	*Archilestes*	108
	Libellulidae	*Libellula?*	72
Hemiptera (true bugs)	Gerridae	*Gerris*	72
	Naucoridae	*Ambrysus mormon*	72
	Veliidae	*Microvelia*	72
	Veliidae	*Rhagovelia*	72
Trichoptera (caddisflies)	Brachycentridae	*Brachycentrus americana*	24
	Helicopsychidae	*Helicopsyche borealis*	18
	Hydropsychidae	*Cheumatopsyche*	108
	Hydropsychidae	*Hydropsyche oslari*	108
	Hydroptilidae		108
	Hydroptilidae	*Alisotrichia*	108
	Hydroptilidae	*Hydroptila*	108
	Hydroptilidae	*Leucotichia*	108
	Hydroptilidae	*Ochrotrichia*	108
	Hydroptilidae	*Stactobiella*	108
	Limnephilidae	*Hesperophylax*	108
	Philopotamidae	*Chimarra*	24
	Philopotamidae	*Wormaldia*	24
	Polycentropodidae	*Polycentropus*	72
	Rhyacophilidae	*Rhyacophila*	18

Order	Family	Genus species	Tolerance quotient
		coloradensis	
	Sericostomatidae	*Gumaga*	72
Lepidoptera (butterflies and moths)	Pyralidae	*Petrophila*	72
Coleoptera (beetles)	Dytiscidae (all)		72
	Elmidae		108
	Gyrinidae	*Gyrinus*	108
	Hydrophilidae		72
Diptera (true flies)	Ceratopogonidae	*Bezzia*	108
	Ceratopogonidae	*Culicoides?*	108
	Chironomidae (all)		108
	Culicidae	*Culex*	108
	Dixidae	*Dixa*	108
	Empididae (all)		108
	Muscidae		108
	Psychodidae	*Maruina*	36
	Simulidae	*Simulium*	108
	Stratiomyidae		108
	Tipulidae		72
	Tipulidae	*Hexatoma*	36
	Tipulidae	*Holorusia*	72
	Tipulidae	*Tipula*	36
	Tipulidae	*Tipula* B	36

Non-insects invertebrates:

Phylum	Sub-phylum of family	Genus species	Tolerance quotient
Annelida	Hirudinea		108
	Oligochaeta, Lumbriculidae		108
	Oligochaeta, Tubificidae		108
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