TO: Ralph Hinton | Date: February 26, 1980

FROM: Gerald Boles | Subject: Indian Creek Survey

Personnel from the Water Quality and Biology Unit collected water samples from Antelope Reservoir, Indian Creek, and Little Grizzly Creek on September 28, 1979. Obviously, one sampling period is insufficient to characterize temporally varying aquatic ecosystems, but the data obtained will provide a basis on which to plan future work.

A temperature and dissolved oxygen (D.O.) profile was obtained from Antelope Reservoir from a station near the dam using a YSI meter and probe. Water samples for determination of pH, electrical conductivity (EC), alkalinity, and turbidity were collected at the surface and every three meters in depth to the bottom using a Van Dorn water sampler. Surface and bottom samples were similarly collected for mineral, nutrient, and metal analyses. At stations on Indian and Little Grizzly creeks, water temperature was measured with a hand held thermometer. Dissolved oxygen concentration was determined using the modified Winkler method with Hach reagents. Field pH was measured with a Hellige comparator. Water samples for laboratory determination of pH, EC, alkalinity, and turbidity were collected at every sampling station. Water samples for chemical analysis were collected from selected stations. Nocturnal dissolved oxygen variations were recorded in Indian Creek below Antelope Reservoir with a YSI D.O. analyzer and Rustrack recorder. Benthic macroinvertebrate samples were collected from each stream station using a kick screen with 1 041 micron mesh. Collected materials were preserved in a 10 percent formalin solution. Samples of the fungus-like filamentous growth from Indian Creek below the dam were collected and preserved in Lugol's solution. Stream station locations included the six stations sampled for fish populations in 1978 by the Department of Fish and Game Contract Services Section, and above and below Little Grizzly Creek, at the mouth of Little Grizzly Creek, and below Crescent Mills (Figure 1).

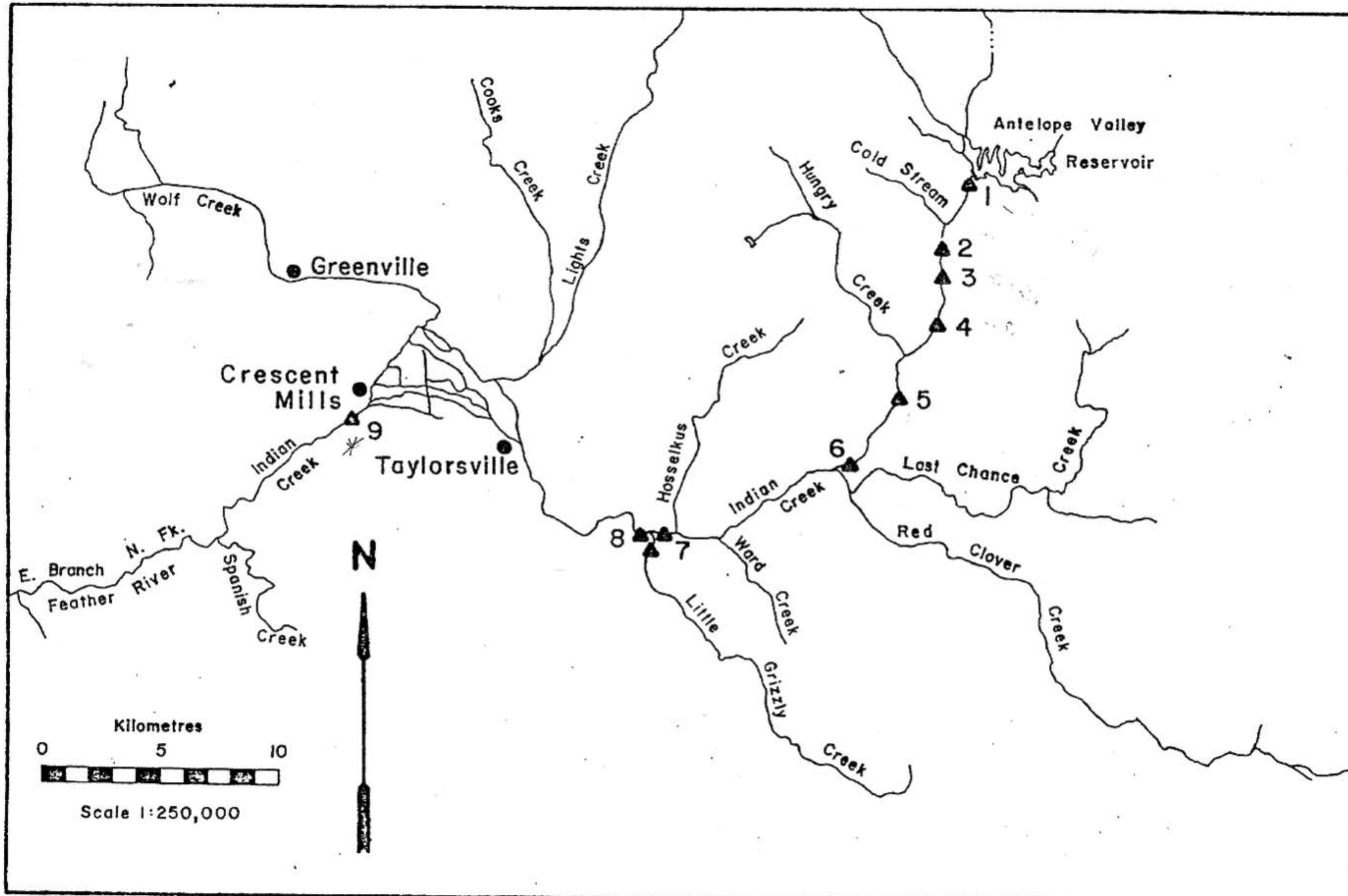


Figure 1. Water quality and benthic sampling locations along Indian Creek

The physical and chemical data obtained from Antelope Reservoir are presented in Table 1. The abrupt thermocline beginning at about 6 m (Figure 2) is due to the eroding epilimnion brought about by cooler fall air temperatures. The uptake of dissolved oxygen and liberation of carbon dioxide through decomposition of organic materials in the hypolimnion result in anoxic and slightly acidic conditions in the lower reservoir strata. The reservoir is rather low in dissolved minerals, as indicated by both the EC and dissolved mineral analyses. This low mineral constitution results in rather low buffering capabilities (alkalinity) and hardness (from Mg and Ca concentrations). Low dissolved nutrient levels ($NO_3$ + $NO_2$ and o-$PO_4$) may result from nutrient uptake by phytoplankton, but are probably in rather limited supply regardless. The dissolved iron level was found to be low in the epilimnion which is typical of many oxygenated surface waters of both lotic and lentic systems. The hypolimnetic iron level, however, is rather high, and results from increased solubility of iron due to anoxic conditions.

The water quality characteristics of Indian Creek are predominantly influenced in the upper reaches by the water quality of the hypolimnion of Antelope Reservoir, and in the middle and lower reaches by a mixture of this water source with inflow of tributary streams (Table 2). The short distance (0.6 km) from the dam to the first station is enough to allow ambient conditions to effect the water temperature, dissolved oxygen, and pH of Indian Creek. Turbulent mixing is undoubtedly the mechanism responsible for aerating the water, thereby increasing both the dissolved oxygen and pH levels. Aeration is sufficient to maintain adequate dissolved oxygen levels throughout the night, the lowest values obtained being 6.9 ppm (Figure 3). Water temperature is still undoubtedly influenced by the temperature of the hypolimnion of the reservoir, and can be expected to be higher than under natural conditions in the winter and lower than normal in the summer. The chemical constituency of the first station is essentially the same as the hypolimnion of the reservoir, except that turbidity and nitrate ($NO_3$) levels are slightly higher while iron (Fe) is slightly lower. The higher turbidity probably results from

TABLE 1

PHYSICAL/CHEMICAL ANALYSES OF ANTELOPE RESERVOIR SAMPLES
COLLECTED SEPTEMBER 27, 1979 at 1600 PST

| Depth | Temp. | D.O. | Field | lab | EC | Alk | Turb. | Hard | diss. Ca | diss. Mg | diss. Na | diss. K | diss. $SO_4$ | diss. $NO_3$+$NO_2$ | diss. o-$PO_4$ | diss. Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 17.3 | 8.0 | 8.7 | 7.5 | 91 | 46 | 1.0 | 35 | 9 | 3 | 5 | 1.6 | 0 | 0.00 | 0.00 | 0.00 |
| 1 | 16.5 | 8.0 | | | | | | | | | | | | | | |
| 2 | 16.2 | 8.0 | | | | | | | | | | | | | | |
| 3 | 16.0 | 8.0 | 8.5 | 7.7 | 92 | 44 | 0.7 | | | | | | | | | |
| 4 | 16.0 | 7.5 | | | | | | | | | | | | | | |
| 5 | 16.0 | 7.5 | | | | | | | | | | | | | | |
| 6 | 15.8 | 5.7 | 8.3 | 7.5 | 91 | 45 | 0.8 | | | | | | | | | |
| 7 | 14.2 | 1.2 | | | | | | | | | | | | | | |
| 8 | 11.0 | 0.4 | | | | | | | | | | | | | | |
| 9 | 10.0 | 0.1 | 6.5 | 7.7 | 94 | 45 | 2.1 | | | | | | | | | |
| 10 | 9.5 | 0.1 | | | | | | | | | | | | | | |
| 11 | 9.0 | 0.05 | | | | | | | | | | | | | | |
| 12 | 8.8 | 0.00 | 6.5 | 7.8 | 92 | 44 | 2.3 | | | | | | | | | |
| 13 | 8.8 | 0.00 | | | | | | | | | | | | | | |
| 14 | 8.7 | 0.00 | | | | | | | | | | | | | | |
| 15 | 8.3 | 0.00 | 6.3 | 7.6 | 93 | 43 | 2.7 | | | | | | | | | |
| 16 | 8.1 | 0.00 | | | | | | | | | | | | | | |
| 17 | 8.0 | 0.00 | | | | | | 38 | 10 | 3 | 4 | 1.5 | 1 | 0.00 | 0.02 | 1.6 |
| 17.2B | 8.0 | 0.00 | | 7.2 | 94 | 43 | 2.7 | | | | | | | | | |

Secchi depth: 1.9m

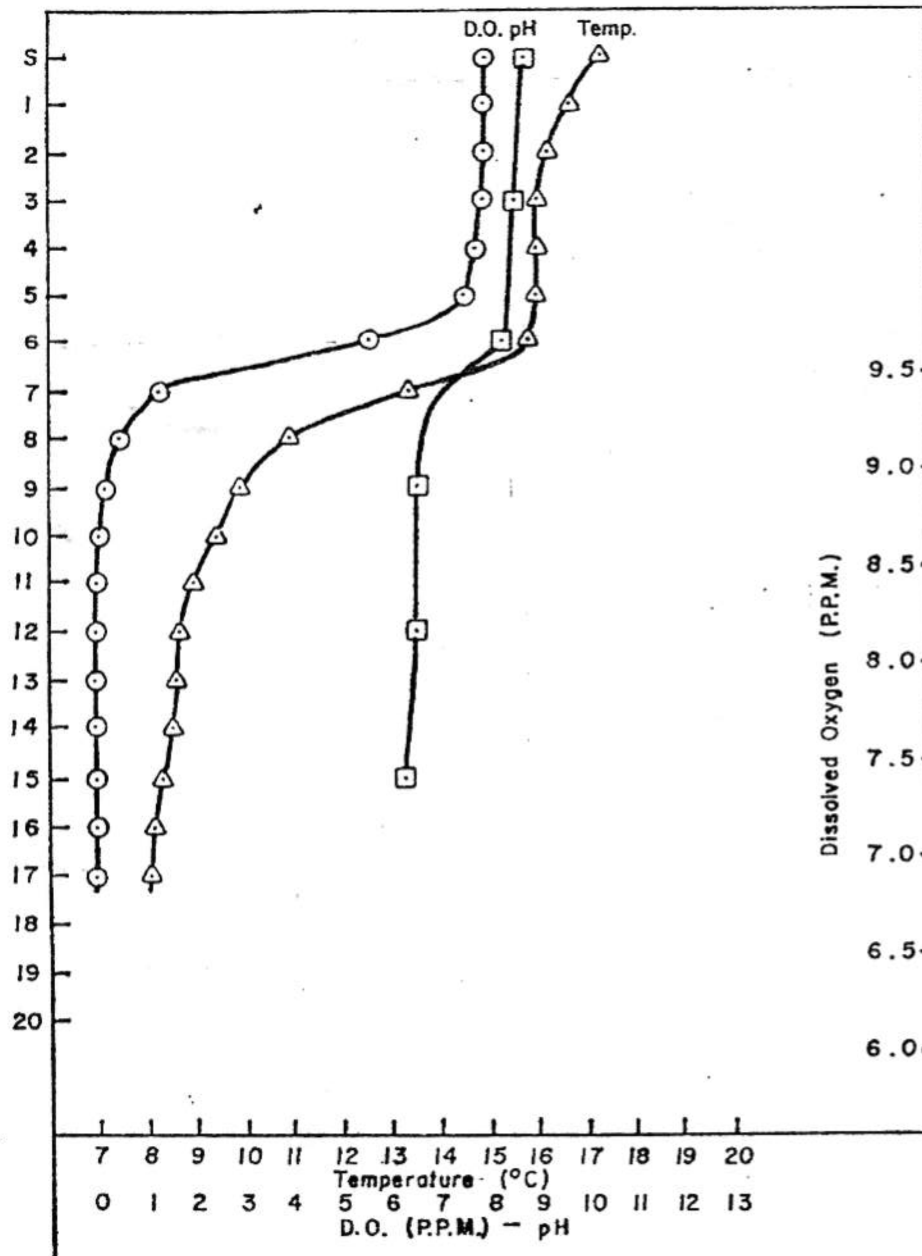


Figure 2. Dissolved oxygen (D.O.), pH, and temperature profiles from Antelope Reservoir on September 27, 1979

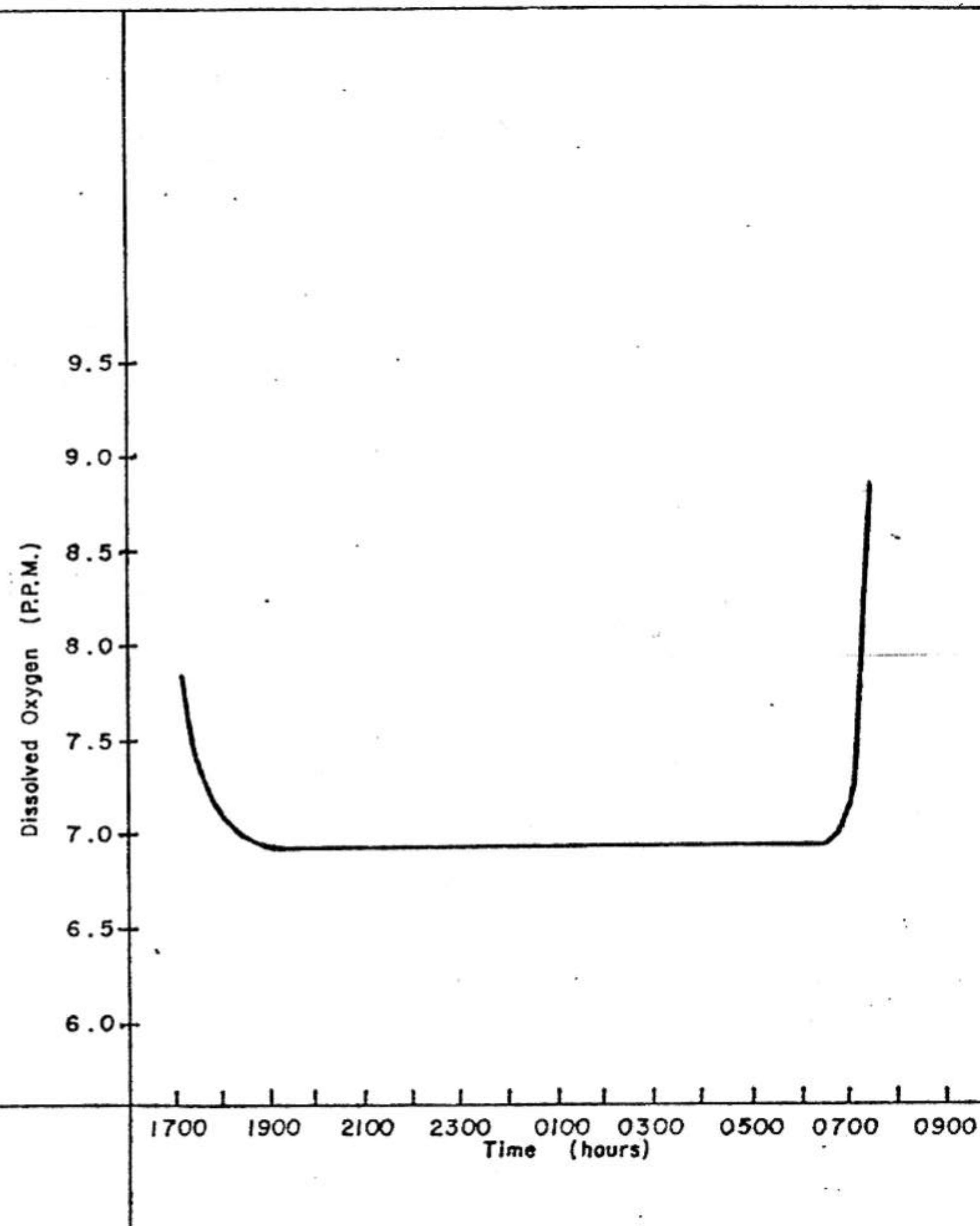


Figure 3. Nocturnal dissolved oxygen concentrations in Indian Creek below Antelope Reservoir on September 27-28, 1979

TABLE 2

PHYSICAL/CHEMICAL ANALYSES OF INDIAN CREEK AND LITTLE GRIZZLY CREEK

SAMPLES COLLECTED SEPTEMBER 28, 1979

| on | Time PST | Temp. °C | D.O. ppm | pH field | pH lab | EC µmhos/cm | Alk. mg $CaCO_3$ | Turb. FTU | Hard mg/1 as $CaCO_3$ | Ca mg/1 | Mg mg/1 | Na mg/1 | K mg/1 | $SO_4$ mg/1 | $NO_3$+$NO_2$ mg/1 | o-$PO_4$ mg/1 | Fe mg/1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| n Cr. Station 1 | 0730 | 6.4 | 8.7 | 7.0 | 7.3 | 94 | 43 | 4.0 | 38 | 10 | 3 | 5 | 1.7 | 1 | 0.03 | 0.01 | 1.2 |
| n Cr. Station 2 | 0800 | 6.5 | 9.7 | 7.2 | 7.3 | 97 | 43 | 1.1 | 38 | 10 | 3 | 5 | 1.5 | 1 | 0.45 | 0.02 | 0.87 |
| n Cr. Station 3 | 0845 | 6.5 | 10.0 | 7.3 | 7.4 | 97 | 44 | 1.4 | | | | | | 0 | 0.49 | 0.02 | 1.0 |
| n Cr. Station 4 | 0920 | 8.2 | 10.0 | 7.3 | 7.5 | 99 | 45 | 1.3 | | | | | | 0 | 0.53 | 0.02 | 1.3 |
| n Cr. Station 5 | 1000 | 9.4 | 9.8 | 7.4 | 7.5 | 98 | 45 | 1.1 | 38 | 10 | 3 | 5 | 1.6 | 4 | 0.46 | 0.02 | 1.1 |
| n Cr. Station 6 | 1030 | 12.5 | 10.0 | 7.4 | 7.7 | 139 | 64 | 0.7 | | | | | | 1 | 0.14 | 0.02 | 0.5 |
| n Cr. Station 7 | 1115 | 14.9 | 9.7 | 7.3 | 7.7 | 159 | 72 | 0.5 | 64 | 16 | 6 | 7 | 1.8 | 5 | 0.01 | 0.00 | 0.16 |
| izzly Cr. @ Mouth | 1130 | 12.8 | 9.7 | 8.1 | 8.0 | 163 | 71 | 0.4 | 72 | 22 | 4 | 4 | 0.9 | 9 | 0.00 | 0.00 | 0.02 |
| n Cr. Station 9 | 1300 | 15.3 | 8.5 | 7.2 | 8.0 | 224 | 104 | 2.2 | 88 | 22 | 8 | 11 | 1.7 | 8 | 0.01 | 0.02 | 0.10 |

iron precipitating out of solution (lowering the dissolved iron concentration), while increased nitrate levels probably result from aeration. Stations further downstream on Indian Creek become increasingly influenced in their temperature, dissolved oxygen, and pH qualities by ambient conditions, while the chemical composition is altered predominantly by tributary inflow or effluent ground water.

The attached filamentous growth was determined to be a mixture of phytoplankton species, protozoa, bacteria, and precipitated iron. The bacteria are predominantly of two types, Thiothrix and Leptothrix. The former bacterium utilizes sulfur from hydrogen sulfide ($H_2S$) in an oxidative metabolism, and is generally found in areas where one water source supplies abundant oxygen and another source supplies $H_2S$. This filamentous organism forms dense, slightly yellow-white mats. The latter bacterium is associated with iron springs and other environments where iron concentrations are high. This bacterium may play a role in the oxidation process, as they become impregnated with $Fe(OH)_3$, forming orange-brown filamentous mats. The phytoplankton, composed of species of Staurastrum, Zygnema, Closterium, Microspora, Fragilaria, Surirella, Synedra, Melosira, and Mastoglia, are mostly lentic-type species. These organisms, as well as at least some of the protozoans, undoubtedly are released from the reservoir and become caught in the tangle of filamentous bacteria.

Aquatic conditions immediately below dams are generally not suitable to support a diverse benthic macroinvertebrate fauna, and this is the case in Indian Creek (Table 3). Typical faunas in such situations consist of large numbers of a few species tolerant of such conditions, chiefly Baetis, the Chironominae, and Simulium. The factors generally responsible for the domination by a limited number of species include temperature alteration, food supply, competition, and predation. Temperatures, being warmer than normal in winter and cooler than normal in summer below reservoirs, cause many insect species to emerge when ambient conditions are not suitable for survival or reproduction, or prevent eggs from hatching since many species require near freezing temperatures followed by rapid increases before egg development occurs. The food supply

TABLE 3

BENTHIC MACROINVERTEBRATES COLLECTED FROM INDIAN CREEK DRAINAGE ON SEPTEMBER 28, 1979

| | Indian Creek | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Station 1 | | Station 2 | | Station 3 | | Station 4 | | Station 5 | | Station 6 | | Station 7 | | Station 8 | |
| | No. | Vol. | No. | Vol. | No. | Vol. | No. | Vol. | No. | Vol. | No. | Vol. | No. | Vol. | No. | Vol. |
| Ephemeroptera | | | | | | | | | | | | | | | | |
| Iron | | | | | 4 | <0.1 | | | | | | | | | | |
| Rhithrogena | | | 135 | 0.3 | 145 | 0.4 | 48 | 0.1 | 398 | 0.5 | 183 | 0.3 | 102 | 0.1 | 5 | <0.1 |
| Baetis | 65 | 0.1 | 27 | <0.1 | 22 | <0.1 | 178 | 0.3 | 38 | <0.1 | 248 | 0.3 | 81 | 0.1 | 38 | <0.1 |
| Ephemerella proserpina | | | | | | | 1 | <0.1 | | | | | | | | |
| E. micheneri | | | 5 | <0.1 | | | | | | | 183 | 0.2 | 70 | 0.1 | 5 | <0.1 |
| Paraleptophlebia | | | 16 | <0.1 | 5 | <0.1 | 5 | <0.1 | | | | | | | | |
| Plecoptera | | | | | | | | | | | | | | | | |
| Calineuria californica | | | 3 | 0.1 | 27 | 1.9 | 15 | 0.7 | 20 | 0.4 | 13 | 0.3 | 4 | 0.1 | | |
| Hesperoperla pacifica | | | 11 | 0.3 | 48 | 2.2 | 9 | 0.3 | 5 | 0.1 | | | 1 | <0.1 | | |
| Isoperla | | | 65 | 0.4 | 38 | 0.3 | 38 | 0.2 | | | 22 | 0.1 | 86 | 0.5 | 27 | 0.3 |
| Oroperla barbara | | | | | | | | | 1 | 0.1 | 3 | 0.1 | 1 | 0.1 | | |
| Hastaperla | | | 38 | 0.1 | 38 | 0.1 | 5 | <0.1 | 16 | <0.1 | | | | | | |
| Pteronarcys californica | | | 3 | 0.1 | | | 1 | 0.1 | 1 | 0.2 | | | | | | |
| Amphinemura | | | 11 | <0.1 | 5 | <0.1 | 27 | 0.1 | 11 | <0.1 | | | 5 | <0.1 | | |
| Odonata | | | | | | | | | | | | | | | | |
| Ophiogomphus bison | | | | | | | 7 | 0.1 | | | 22 | 0.5 | 3 | 1.6 | | |
| O. morrisoni | | | | | | | 1 | <0.1 | | | | | | | | |
| Coleoptera | | | | | | | | | | | | | | | | |
| Eubrianax | | | | | | | | | 1 | <0.1 | 5 | <0.1 | 5 | <0.1 | | |
| Narpus | | | 4 | <0.1 | 5 | <0.1 | 5 | <0.1 | | | 151 | 0.1 | 188 | 0.1 | 11 | <0.1 |
| Trichoptera | | | | | | | | | | | | | | | | |
| Hydropsyche | | | 651 | 2.8 | 597 | 2.8 | 194 | 1.3 | 307 | 1.7 | 1076 | 5.8 | 1970 | 9.1 | | |
| Hydroptila | | | | | | | | | | | 32 | <0.1 | 5 | <0.1 | | |
| Rhyacophila | | | | | | | | | | | | | | | 1 | <0.1 |
| Glossosoma | | | | | | | | | | | | | 22 | <0.1 | | |
| Wormaldia | | | | | | | 3 | <0.1 | | | | | | | | |
| Lepidostoma | | | | | | | | | | | 32 | <0.1 | | | | |
| Brachycentrus | | | | | | | | | | | 11 | <0.1 | | | | |
| Diptera | | | | | | | | | | | | | | | | |
| Chironominae | 81 | <0.1 | 70 | <0.1 | 54 | <0.1 | | | 11 | <0.1 | 65 | <0.1 | 145 | 0.1 | 27 | <0.1 |
| Calopsectra | | | | | | | | | | | 242 | 0.1 | 16 | <0.1 | 22 | <0.1 |
| Simulium | 867 | 0.5 | 113 | 0.1 | 16 | <0.1 | 32 | <0.1 | 5 | <0.1 | 118 | 0.1 | 7 | <0.1 | | |
| Hexatoma | | | 19 | 0.3 | 9 | 0.3 | 1 | <0.1 | 1 | <0.1 | 86 | 2.2 | 59 | 1.9 | 12 | 0.4 |
| Atherix | | | 5 | <0.1 | | | | | 12 | <0.1 | | | 5 | <0.1 | | |
| Megaloptera | | | | | | | | | | | | | | | | |
| Sialis | | | 3 | <0.1 | | | 4 | <0.1 | 1 | <0.1 | | | | | | |

immediately below reservoirs generally consists of moribund lentic plankton released from the reservoir, and high periphyton growth below the reservoir due to the usually high nutrient concentrations released from hypolimnions. This favors collector species, such as *Simulium*, and scraper species, such as *Baetis*. Because these dominant organisms feed on different materials, they do not compete with each other. This, coupled with lack of predatory species due to adverse conditions for most of these organisms, results in large populations. Ecosystems composed of so few organisms are very unstable, with benthic populations, and hence the food supply for fish, subject to large oscillations as the organisms emerge and then later repopulate via oviposition. This is especially critical when the benthic community is largely composed of *Baetis* and *Simulium*, since both emerge at about the same time of the year, leaving very little as an alternate food source until eggs hatch and larvae grow. Hydrogen sulfide ($H_2S$) odor was apparent below Antelope Dam. This substance, formed from the anoxic bacterial reduction of sulfates in the hypolimnion of the reservoir, is highly toxic to all organisms, poisoning the energy-producing cytochrome oxidase system. Fortunately, $H_2S$ is rapidly oxidized to sulfates upon exposure to oxygen and thus should cause no adverse effects in Indian Creek other than a slight odor problem from release of some gas to the atmosphere.

Conditions rapidly improve further downstream, probably due to the effects of tributary inflow and decreasing influence of reservoir releases. Species composition is fairly uniform from Station 2 through Station 7, except for uncharacteristically large populations of *Hydropsyche* at Stations 6 and 7. At certain stations, relatively large populations of one or two species cause a reduction in the species diversity index, though still at satisfactory levels. Stations 2 through 7 contain a good balance of functionally diverse organisms that leads to stability of the aquatic ecosystem through food chain stabilization.

Only the Chironominae were found in the samples collected from Little Grizzly Creek. Obviously, leachate or waste materials from historic upstream mining activities are having a significant impact on the ability of this stream to support aquatic life.

Indian Creek below Little Grizzly Creek (Station 8) is impacted from the dissolved copper and other toxic metals contained in Little Grizzly Creek water. Only about half the number of species found upstream were found at this station. Except for a single Rhyacophila found, all species were of the dominant types found upstream. This may indicate that the benthic community at this station depends on drifting organisms from upstream for colonization during periods when pollution from Little Grizzly Creek subsides.

No benthic organisms were found in the ponded water of Indian Creek below Crescent Mills (Station 9). This may be due to accumulation of toxic materials in the sediments.

On the basis of the benthic and chemical samples collected from Indian Creek in September, 1979, it can be concluded that the reach from about 3.9 km below Antelope Dam to above Little Grizzly Creek is a healthy and productive aquatic ecosystem. The area immediately below the dam suffers from the impacts commonly associated with hypolimnetic discharges from reservoirs and high water iron content. Little can be done in this reach to improve conditions short of using reservoir destratification methods to alter temperatures and reduce iron levels or construction of variable outlet structures on the dam. The extent of impacts on Indian Creek from present operations, though, probably do not justify such extravagant remedial measures. Further consideration appears to be called for concerning the extent of impacts on Indian Creek and its biota of discharges from Little Grizzly Creek.

The benthic community forms an integral component of an aquatic ecosystem but is typically ignored in stream-flow requirement studies. Benthic organisms are required as a food source for fish, especially in winter periods when other sources become unavailable, and serve as environmental monitors of even subtle perturbations. It is recommended that further in-stream flow requirement studies consider the needs of the benthic community to support a diverse and stable biota. Such studies would insure selection of flows that would provide maximum resource enhancement necessary for the perpetuation of recreation based on fisheries utilization, as well as the selection of indicator species that could be used to monitor for signs of habitat degradation.