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# Biological effects of water pollution in the Clark Fork River

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# THE BIOLOGICAL EFFECTS OF WATER POLLUTION IN THE CLARK FORK RIVER

By

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# INTRODUCTION

To rule the mountain is to rule the river -

Chinese Proverb

Mining effluent was the foremost reason for the death of the Clark Fork; control of the effluent brought about its resurrection. The river's comeback has been remarkable - stretches that only a decade ago were lifeless now support excellent trout fisheries. Yet the Clark Fork remains below its potential, its recovery not complete. Historically, the drainage has the heaviest mining activity in the state. Much of the drainage is still affected, and will be for generations. Huge quantities of tailings lie along many tributaries and the main channel, tailings laden with heavy metals and silt. Seasonal discharge fluctuations disturb these deposits, unleashing concentrations of poisonous heavy metals and suffocating silt. And if current treatment systems at Warm Springs are not maintained, great damage could occur once more.

Rarely can one find a river such as the Clark Fork, a river flowing through urban areas, confined and channelized by highways and railroads yet offering high chemical and biological quality. Along its entire length, the river provides enhanced quality of life for inhabitants of the region, because the Clark Fork has managed to avoid problems plaguing most rivers. Probably due to a predominance of agriculture, floodplain development has been minimal except in places like Hellgate

Canyon, thus reducing property damage during floods. Overgrazed streambanks are not a major problem as is usually the case in Montana; riparian habitat remains good except where channelized and riprapped. And in contrast to normal conditions, water quality improves with downstream distance. The Clark Fork and its tributaries are a valuable resource, and if their water quality and aquatic and riparian habitat improve, this value will increase commensurately. Duffield (1981) determined recreation on the Upper Clark fork and some tributaries is worth 12 to 33 million dollars annually. Agriculture, the largest water user in the drainage, uses 500,000 acre feet per year to irrigate 150,000 acres with a net depletion of half the water (Department of Health and Environmental Sciences [DHES], 1982). Many communities and some industries use the river to dispose of their effluents, generally after some pretreatment. The city of Missoula, recognizing the value of the riverfront, intends to make the Clark Fork the focus of a park stretching for miles through the city. If this section of river is maintained and its natural qualities enhanced, its economic value would be increased as a stimulus to downtown business. Fisheries data show that reproduction in this stretch is currently stifled (Peters, 1981).

Evidence of the effects of early mining operations is readily available (Van Meter, 1974; DEHES, 1982). A number of other problems allegedly degrade the Clark Fork drainage; these include poor land use practices, channelization, irrigation returns, industrial and municipal sources, streambed and riparian alteration, dewatering and enrichment (DHES, 1974); Ruffato, 1979; Johns, 1981). However, little data exists to support some of these contentions. The Soil Conservation Service

recently completed a survey (United States Department of Agriculture [USDA], 1983) of the Upper Clark Fork which indicated that over 10% of the streambank from the confluence of Warm Springs Creek and Silver Bow Creek downstream to Flint Creek suffers from mass bank wasting. According to the report, this problem was exacerbated by the flood of Spring, 1981, and may stabilize itself in three to five years.

In contrast to most drainages in Montana, the problems of the Clark Fork have arisen from point sources. These problems can be divided into two areas, heavy metals and nutrient enrichment. Heavy metals have been dumped into Silver Bow Creek for so long they are considered a non-point source problem (DHES, 1982). Since sediments bearing heavy metals have worked their way down the drainage, no "end-of-the-pipe" solution can be applied. The problem will remain until the river flushes the sediments, which will probably take decades to occur. Meanwhile, the Anaconda, Butte, Deer Lodge and Warm Springs sewage treatment plants are adding nitrogen and phosphorus to the river (DHES, 1982).

effects of early mining operations. This is readily apparent by comparing the EPA report of 1971 with the Upper Clark Fork Water Quality Inventory and Management Plan published by the Water Quality Bureau (WQB) in 1975 (U.S. EPA, 1971; Casne, Botz and Pakanyk, 1974). The primary reason for the dramatic recovery must be the installation of treatment ponds at Anaconda and Warm Springs, and to a lesser extent the treatment system installed at the Anaconda Minerals Co. (AMC) Butte operations in 1972. But to ensure the river continues to recover and reaches its biological and economic potential, we must have a complete

picture of what is affecting water quality within the drainage. The effects are usually commulative; for instance, the summer nocturnal oxygen sag plaguing the Upper Clark Fork may be the result of high water temperatures, gradient changes, increased nutrient levels, and heavy metals in streambed sediments.

Unfortunately, data concerning the Clark Fork is collected by many state or federal agencies, rarely working in cooperation or conjunction with one another. One cannot obtain all the data without extensive research, and much of it has yet to be interpreted for its ecological effects. Also, the biological and chemical quality of the Clark Fork has been changing rapidly; attempts to deal with current and anticipated problems must be based on the most recent data. AMC smelting operations have shut down, the Berkely Pit in Butte is closed, and as it fills with water it may effect water quality in the area. The most current overview on water quality in the Clark Fork uses data over six years old (Casne, Botz and Paskanyk, 1974; DHES, 1976b). Champion International (Hoerner-Waldorf) claimed these reports were outdated the moment they were published. Significantly, the WOB did not make much use of fisheries data, or discuss the likely effects of water quality problems on the fishery.

I have gathered data concerning pollution problems in the Clark Fork from several sources. Most of this information comes from the State Water Quality Bureau, Environmental Protection Agency, and the Department of Fish, Wildlife and Parks (formerly the Montana Department of Fish and Game). My purpose is to see what water quality problems have been solved, which remain, how are they affecting important stream

biota, and make recommendations for solutions or further study. In attempting to interpret water quality data in relation to biological data, one finds the water quality data to be lacking for several reasons:

1. Heavy metals and nutrient loading are the main problems in the Upper Clark Fork, but studies directly relevant to these are rarely conducted.

2. Heavy metal criteria, bioassays and sampling methods have little to do with the transport, bioaccumulation and effect of heavy metals on biota. This is undoubtedly a nation-wide problem. The literature on the subject, while voluminous, is deficient in the same areas.

3. Biological monitoring uses analytical methods which are questionable (diversity indices) and more importantly, does not utilize fisheries data which would provide more valuable information. A system-wide approach is not used.

A review of data on the Clark Fork can be confusing, since most of the studies overlap each other, and a comprehensive, coordinated approach has never been followed by state and federal agencies.

To provide the reader with some background, I have selected references from the heavy metal literature and presented them in detail. The effects of organic enrichment are not as complicated and are included in the section on enrichment.

After the literature review, I then describe water quality problems as assessed in general overviews on the Clark Fork. From these background works, I proceed to the main areas of concern, heavy metals and organic enrichment. The section on heavy metals utilizes studies concerning past and present sources of metals and their likely effects. A discussion of the WQB's biological monitoring program is included in

the enrichment section, since the program's main target is the detection of organic pollution.

A section devoted exclusively to the Milltown Dam and reservoir is presented for two reasons; the operation of this facility is the major cause of heavy metal and sediment release into the Lower Clark Fork, and as such it is a continuing source of controversy. Conclusions and recommendations complete the review.

## STUDY AREA

This report concerns the Clark Fork River from and including Silver Bow creek down to the Blackfoot River and into the Missoula Basin. Major tributaries along this stretch are Warm Springs Creek, the Little Blackfoot River, Flint Creek, Rock Creek and the Blackfoot River. Including Silver Bow Creek, this represents about 150 or more miles of river. The uppermost reaches of the Clark Fork meander constantly and are lined much of the way by willows and other brush. Parts of the river flow through irrigated pastures resulting in a loss of riparian vegetation. Downstream of Garrison, the river broadens and straightens. Two railroads and Interstate 90 were built along the Clark Fork, often channelizing the river, especially between Drummond and Missoula where the valley is very narrow.

The geology of the Clark Fork drainage is extremely varied due to glaciation, folding and faulting. These processes caused much erosion and sedimentation which yielded the valley fill of river gravel and soil. The following information is gleaned from McMurtrey, et al. (1964).

Rocks dating from the Precambrian age to the present lie below the drainage above Missoula. The Bitterroot, Blackfoot and Upper Clark Fork drainages contain Precambrian sedimentary rocks and Cenozoic fill. Mesozoic and Cenozoic extrusive rocks exist in the Upper Clark Fork and Blackfoot drainages, while Mesozoic and Cenozoic intrusive rocks are

found in the Bitterroot and Upper Clark Fork drainages. The Clark Fork, below the confluence with the Blackfoot River, contains only Precambrian sedimentary rocks. Terraces and mountain ranges border the river on both sides; the Continental Divide encloses the Upper Clark Fork on the northeast, east and south, and the Flint Creek Range does so on the west. Groundwater in the drainage generally flows toward the Clark Fork, whose floodplain is underlain with a thin layer of poorly sorted silt, sand and gravel alluvium. Sedimentary, igneous and metamorphic rocks compose the bed rock under the unconsolidated valley fill, and also form the mountains.

The semi-arid climate receives about 12" of precipitation annually; a little more than half the annual precipitation falls during May through September, with May and June being the wettest months. Most of the precipitation falls as snow in the higher elevations surrounding the valley, providing a supply of water for the Clark Fork. Summer days are pleasant, averaging around 63°F., and the nights are cool. Winters are cold; temperatures average below freezing.

## LITERATURE REVIEW OF HEAVY METAL TOXICITY

Thousands of journal articles concerning heavy metals and their effects on aquatic ecosystems have been published. With such extensive research, one would think we understand much, if not most of the biological significance of only seven or eight inorganic materials. Unfortunately, this is not the case. The reasons for this are:

1. Bioassay test results are applicable only to systems with the same water quality characteristics as used in the bioassay.
2. Almost invariably, organisms used in bioassays are exposed to only dissolved forms of the toxicant. Such bioassays ignore the significant forms of heavy metal transport.
3. Bioassays performed to determine chronic toxicity use concentrations higher than one would find in all but the most polluted drainages, and if such concentrations are found in the field, they are generally at the high levels for insufficient periods of time to cause the symptoms seen in the bioassay.
4. No work has been conducted on bioaccumulation through the food chain to see if the effects are similar to those found in tests for chronic toxicity which use the ionic form.
5. Synergistic or antagonistic effects are rarely studied, even though two or more metals are generally present in polluted streams.

6. Insufficient research has been done on the effects of long-term exposure to low levels of heavy metals.
7. System-wide effects are not known and are generally not studied.

The following section reviews literature which suffers from the problems mentioned above, but is the most relevant to the situation in the Clark Fork and the acute and chronic effects which may be occurring in it. These studies show that toxic heavy metals accumulate in the gill, liver and kidney tissue of fish, especially trout, and muscle tissue generally contains negligible amounts. Therefore, one should analyze the appropriate tissues when determining whether the fishery has been exposed to chronic levels of toxic metals.

Studies have shown that fish can accumulate heavy metals from streams that have negligible quantities present in the water column. In other words, fish accumulate heavy metals through the food chain. If so, are the effects - i.e., decreased hatchability of eggs, reduced growth and higher mortality of alevins and fry - the same as seen under lab conditions using dissolved concentrations to affect exposure? The research literature does not provide an answer, but such deletrious effects have been found to be the most sensitive under chronic conditions created in the lab. Table 1 condenses much of the data from the following journal articles.

## Copper

Benoit (1974) exposed bluegills to copper in soft water and found a dissolved level of 162 ug/1 reduced survival, retarded growth and

inhibited spawning after 22 months of exposure. No effects were seen at 77 ug/l or less. Liver, kidney and gill tissue contained significantly higher levels of copper than controls. Benoit determined the 96 hour $TL_{50}$ to be 1,100 ug/l. Larval survival was inhibited after 90 days exposure to 40 and 77 ug/l. However, no deformities were found in larvae spawned, hatched and exposed for four days at each concentration, or in those raised in control conditions and placed in experimental concentrations for 90 days.

McKim and Benoit (1971) conducted a long term study of chronic copper toxicity on brook trout (Salvelinus fontinalis). The 22 month trial under soft water conditions showed survival, growth and reproduction varied with concentration. Yearling trout exposed to 32.5 ug/l exhibited decreased weight and survival, and the number of viable eggs per female was considerably less but not statistically significant. Using eggs and alevins from experimental parents (yearlings discussed above), the authors found a level of 32.5 ug/l caused premature hatching, less active embryos, and retarded utilization of the egg yolk. all juveniles died in four months at this level of exposure. Juveniles raised at 17.4 ug/l died within eight months. Test with alevins from unexposed parents had mortality rates similar to exposed parents' offspring. For the initial 23 weeks of their growth, juvenile growth was reduced at all concentrations. After this period, fish exposed to low levels grew at the same rate or faster than control fish. The authors concluded that 9.5 ug/l of copper had no effect, and concentrations of 17.5 ug/l caused chronic toxicity. At this level of

exposure, a drastic effect on survival and growth of alevins and juveniles was noted.

Mount (1968) used the fathead minnow (Pimephales promelas) to determine chronic copper toxicity under hard water conditions. The minnows were exposed for eleven months to find the $TL_m$ (Median Tolerance Limit) for growth and reproduction. Mount found this value to be between 3% and 7% of the 96 hour $LC_{50}$ . The $TL_m$ varies with water characteristics, but these percentages can be used if the $LC_{50}$ is determined in water from the source concerned. In Mount's study the 96 hour $LC_{50}$ was 430 to 470 ug/1. Changes seen in the minnow due to the copper were behavioral; no spawning occurred at higher concentrations, although these same levels did not affect growth.

Using the brown bullhead (Ictalurus nebulosus). Brungs, Leonard and McKim (1973) determined acute and long term effects of copper exposure. Interestingly, they found copper concentrations in gill, opercle, liver and kidney tissues of chronically exposed fish did not differ from those tissues from fish that died from acute concentrations. In chronic exposures, a distinct increase in gill and liver tissue occurred at 27 ug/l and at higher concentrations, but equilibrium was achieved in these tissues within thirty days. Both the acute and chronic tests were conducted in hard water. The 96 hour $TL_{50}$ for seven month old bullheads was between 170 and 190 ug/l. The data show that when fish were exposed to sublethal concentrations first, then to lethal doses, the accumulations in gill, liver and kidney tissues were higher than in the simple acute or chronic tests.

Giles and Klaverkamp (1982) determined 400 ug/l copper was the 96 hour $LC_{50}$ for unhatched rainbow trout embryos and newly hatched alevins. Ewing, Ewing and Zimmer (1982) found channel catfish increasingly susceptible to infections from exposures of less than 25 ug/l to 1030 ug/l dissolved copper.

Zinc

Brungs (1969) determined the chronic toxicity of dissolved zinc to the fathead minnow (Pimephales promelas) under hard water conditions. He found spawning success to be most vulnerable, both in the frequency of spawning and the number of eggs per female. The eggs at all experimental concentrations were fertile and the fry exhibited no behavioral changes except at the 2800 ug/l concentration which affected spawning success, but not growth, hatching survivability, or maturation of fry.

The minnow Phoxinus phoxinus was used by Bengtsson (1974) to study the effects of zinc on growth. Bengtsson found reduced growth in yearlings and adults over a 150 day exposure period. Although the yearlings were more sensitive. After thirty days, yearlings showed reduced growth at 130 (.25 of the 96 hour $LC_{50}$), 200 and 300 ug/l compared to exposures of 50 ug/l and the control (20 ug/l). After thirty days, growth was greatly affected at the 399 ug/l exposure. The mature minnows showed growth rate differences only at the 200 and 300 ug/l levels. The adults' growth was affected more by exposure to 200 ug/l than were the yearlings. Bengtsson concludes the $TL_m$ for yearlings is 59 to 130 ug/l, and 130 to 299 ug/l for adults. He states these

values even though he realizes growth is less sensitive an indicator of toxicity than reproduction or egg mortality.

Zinc was used by Sinley, Goettl and Davies (1974) in acute an chronic tests on rainbow trout (Salmo gairdneri) conducted in hard and soft water. Their 96 hour $LC_{50}$ for soft water is 430 ug/l, and 7210 ug/l for hard water. Chronic values were determined to be between 140 and 200 ug/l in soft water, and between 330 and 640 ug/l in hard water. For the chronic test in hardwater, the authors began by exposing fingerlings (two grams) and continued exposure through sexual maturity at two years of age. Death was used as the indicator of toxicity. Based on their work, the authors concluded rainbow trout can become zinc-resistant if exposed as eyed eggs. However, reproductive behavior was not used as an indicator.

Chronic effects of zinc in soft water were studied by Holcombe, Benoit and Leonard (1979) using three generations of brook trout. Concentrations ranging from 2.6 to 534 ug/l had no apparent effect. However, separate exposures to a concentration of 1,368 ug/l reduced embryo survival and twelve week old larval survival. Another chronic exposure trial using a concentration of 1,360 ug/l reduced egg chorion strength and embryo survival. The first generation trial consisted of yearlings exposed through adult spawning. The second generation began exposure as embryos from the first generation and exposure continued through adult spawning. The third generation began exposure as offspring of the second generation and continued to the early juvenile stage. The authors conclude the Maximum Acceptable Toxicant Concentration (MATC) is between 534 and 1,360 ug/l. The 96 hour $LC_{50}$ is

2000 ug/l. The authors determined bioaccumulation levels in various tissues of these trout and found that after four weeks, no accumulation per gram tissue occurred. In the 534 ug/l concentration, zinc was accumulating after 16 weeks, and after 24 weeks at lesser concentrations. Gill, liver, kidney and opercular bone tissue accumulated the most zinc. In the first generation, muscle and brain tissue did not accumulate zinc. After being removed from experimental tanks and placed in control concentrations the gills lost 55% and the liver 59% zinc per gram tissue over a twelve week period. However, in these fish, kidney levels increases 192% over the same period. Second generation fish did not accumulate as much zinc in gill, liver and kidney tissue as the first generation, and took 52 to 93 weeks to reach peak levels.

Kormondy (1965) studied the accumulation and loss of zinc-65 in a dragonfly (Plathemis lydia). He concluded most accumulation was by surface adsorption or cation exchange. The loss of zinc from dead animals was the same as in live ones, and rates did not differ between the field and the lab. Ninety-five percent of initial accumulation remained on cast exuvia. The total uptake was found to be directly proportional to availability in the medium, and equilibrium was attained in 28 to 48 hours and was temperature independent. Another indication that cation exchange was at work in the accumulation of zinc was that small individuals - therefore with greater surface area to volume ratios - had higher accumulation factors than larger individuals.

In one of the few studies using very hard water (500 mg/l $caCO_3$). Solbe (1974) found a 48 hour $LC_{50}$ of 4760 ug/l zinc using rainbow trout.

Cadmium

Benoit, et al. (1976) exposed three generations of brook trout (Salvelinus frontinalis) to various concentrations of dissolved cadmium under soft water conditions. Starting with yearling trout, the trout were exposed for 10 months, then their offspring were exposed for two and ½ years. Offspring from this group were obtained when the second parental group was two years old. The third generation was then exposed to the early juvenile stage. The authors examined gill, liver, spleen, kidney, gonad and muscle tissue on a per gram basis. Residues in gill,liver, and kidney tissue were found to reach equilibrium (although increase with whole tissue) after 29 weeks. While the authors were unable to determine acute toxicity levels, chronic toxicity existed at 3.4 ug/l. At this concentration, males died during spawning, and growth of offspring was retarded.

Eaton (1974) also looked at dissolved cadmium toxicity, using the bluegill (Lepomis macrochirus) and hard water (200 mg/l $CaCO_3$) conditions. He found chronic toxicity at a level of 80 ug/l. Bluegills began to die after 8 months of continuous exposure to this level, and embryos developed severe abnormalities as well. Eaton found that kidney concentrations did not increase with higher exposure levels, although liver concentrations did.

Ball (1967) looked at cadmium's effect on rainbow trout under hard water conditions. His work indicated a 7 day $TL_m$ of 8 to 10 ug/l.

Largemouth bass and bluegills were used by Cearley and Coleman (1974) to study cadmium toxicity and bioaccumulation. Using moderately hard water, 50% of the bass sample died within 56 days when exposed to

concentrations of 850 ug/l and within 82 days when exposed to 80 ug/l. Bluegills experienced 50% mortality within 138 days when exposed to 850 ug/l. Two bass died when exposed to 8 ug/l, but no bluegills died. Bass and bluegills accumulated cadmium at levels higher than those in the water, with accumulations increasing with higher exposure levels. Once again, internal organs accumulated more of the toxicant than muscle tissue. After two months of exposure, an equilibrium was reached. The authors state the cause of death to be inhibition of the enzyme acetylocholinesterase, resulting in death by the paralysis of respiratory muscles or depression of the respiratory center.

The effects of cadmium on testicular tissue in brook trout was researched by Sangalang and O'Halloran (1972). In the first trial, three to four year old trout were exposed to 0, 1, 2 and 25 ug/l cadmium for twenty-four hours. The fish exposed to 25 ug/l had testes which showed marked discoloration resulting from extensive haemorrhagic necrosis. The controls showed no damage. The second trial exposed 36 trout to 10 ug/l cadmium for over twenty-one days, which was the $LT_{50}$. The authors noted similar but less extensive damage to the testes.

The acute and chronic toxicity of dissolved cadmium to the fathead minnow under hard water conditions was researched by Pickering and Gast (1972). They conducted two tests, the first using yearlings exposed for eleven months until they reached sexual maturity, the second test exposed three week old fry through sexual maturity, and then exposed their offspring as well. The cadmium concentrations used were 1, 4.5, 7.8, 13, 110 and 350 ug/l. The lower four values all yielded results similar to the control (1 ug/l). The 96 hour $TL_{50}$ was calculated to be between

30,000 and 32,000 ug/l, although the authors were not sure of these values. Other $TL_{50}$ values determined were 150 ug/l over five weeks, 89 ug/l over nine weeks, and 68 ug/l over nine months. Based on the survivability of developing embryos, the authors calculated the MATC value to be between 37 and 47 ug/l cadmium. However, hatchability of eggs produced by fish exposed to this range was similar to eggs from unexposed adults.

In a departure from normal procedure, Rowe and Massaro (1974) used gastric dosing to subject white catfish to cadmium. They noted no trend toward accumulation in muscle, bile, bone, brains or lens tissue, while once again, liver and kidney tissue were sites of accumulation.

As with other metals, cadmium has been found to be less toxic under hardwater conditions (Michibata, 1981).

## Lead

Holcombe, et al. (1976), determined the chronic effects of lead on brook trout under soft water conditions. Trout were exposed to levels ranging from 19 (control) to 474 ug/l Pb. The MATC and 96 hour $LC_{50}$ for both dissolved and total lead were calculated. The MATC was found to be between 58 and 119 ug/l total and between 39 and 84 ug/l dissolved lead. These values were based on the appearance of scoliosis in second and third generation fish, and reduced growth in twelve week old third generation trout. No effects of lead on growth, survival, spawning behavior or viability of eggs were seen in the first generation of yearling brook trout. The embryo, alevin and juvenile stages of succeeding generations were found to be most susceptible. The authors

determined lead accumulation in various tissues and found only small amounts in muscle, while the gill, liver and kidney tissues of first and second generation trout had the greatest Pb accumulation. The gills were found to lose accumulated Pb rapidly when trout were placed in a control tank. The 96 hour $LC_{50}$ for total lead was 4100 ug/l and 3362 ug/l for dissolved lead.

Mercury

Not much work has been done with chronic effects of mercury. Most investigations have centered around public health effects. Hem (1970) states unpolluted rivers have concentrations less than or equal to .1 ug/l and adsorption with various sediment components occurs. Mercury in muscle tissue is generally in the form of methyl mercury, a microbially mediated transformation. The diatom Chaetoceros costatum was found to accumulate mercury mainly by adsorption and negligible amounts through metabolic processes (Glooschenko, 1969). This indicates mercury, as with other metals, does not have to be assimilated to be passed to higher trophic levels. Rucker and Amend (1969) subjected salmonids to sublethal doses of ethyl mercury phosphate to determine sites of accumulation. Blood, liver and kidney were the sites absorbing the most mercury. The researchers found most of the mercury in muscle tissue was actually in the blood of the tissue. After the initial ten day exposure, the fish not sacrificed were placed in control water for forty-five weeks and tissue analysis was performed again. All tissues were free of mercury except for the kidney and liver tissue whose mercury levels had stabilized near their initial accumulation levels.

Johnels, et al. (1967), studying fish in field conditions, found a variance in accumulation connected with exposure levels. Fish exposed to low mercury concentrations did not accumulate more with increased weight, but fish exposed to higher levels did have positive correlations to increased weight. At amounts equaling pollution conditions, the relationship broke down again, possibly because at high dosages, some fish are able to exhibit some kind of avoidance behavior (Johnels, et al., 1967). Other studies have looked at naturally occurring levels in fish without attempting to provide information on effects (Wobeser, et al., 1970; Uthe and Bligh, 1971; Mathis and Kevern, 1975; Kronberg, 1980; Fimreite, et al., 1971).

Arsenic

Even less work has been done with arsenic except for its effect on human health. The EPA lists an acute value for fish at 4,499 ug/l, and 139 ug/l for invertebrates, but the invertebrate value includes data for *Daphnia sp.*, several species of which have been found to be especially sensitive. Other invertebrates are less sensitive than fish to arsenic. A chronic level of 170 ug/l is listed for invertebrates, higher than the acute value since this value includes data for much more resistant species of *Daphnia sp*. (EPA, ?).

pH

pH is included in this section because it has great influence on the toxicity and availability of heavy metals, as well as having toxic effects itself. According to EIFAC (1969), pH has no set limits above or below which mortality or chronic effects occur. Problems gradually

appear as the pH moves further away from the normal range. For example, pH in the 5 to 9 range is not lethal, but toxicity of many pollutants vary widely in this range. Mortalities may occur below 5.9, but productivity will certainly decline significantly below 5.0.

The effect of pH on lead toxicity was studied by Merlini and Pozzi (1977). Their results showed that at a pH of 6.0, the level of dissolved lead increased, and fish accumulated three times as much lead as at a pH of 7.5. Tissues accumulating the most lead were gills, liver and fins.

Using young rainbow trout, Hogendoorn-Roozemond, et al., (1978) found that a decrease in pH from 7.9 to 6.8 resulted in a 50 to 200 fold increase in toxicity of sodium chromate solution.

Menendez (1976) researched the chronic effects of reduced pH on brook trout by exposing eggs to pH levels of 4.5, 5.9, 5.5, 6.0, 6.5, and 7.1 (control) for eleven months He used eggs from both exposed and unexposed adults. He found pH levels below 6.5 significantly reduced embryo hatching, and growth and survival of alevins. While using water of hardness 61 to 83 mg/1 $CaCo_3$, he concluded that continuous exposure to pH below 6.5 would adversely affect brook trout populations.

Trojnar (1977), conducted a similar study with the eggs of brook trout except he did ~~no~~ use eggs from exposed adult. He achieved much higher percent hatching and survival than Menendez. He exposed the fry to different pH levels than those to which the eggs were acclimated, and found that acclimation to low pH could occur in the egg stage. Trojnar used hard water in the experimental trials.

Synergistic Effects

This area of study has been neglected. Eaton (1973) exposed fathead minnows under hard water conditions to dissolved levels of cadmium, copper and zinc for 12.5 months. He found that a lethal threshold was attained when each metal was present at a concentration of .4 or less of its individual lethal threshold.

Hiltibran (1971) used various levels of cadmium, zinc, manganese and calcium to observe the effects on oxygen and phosphate metabolism of bluegill liver mitochondria. He concluded cadmium and zinc "disrupt energy production by the inhibition of oxygen uptake within cells, and this disruption can occur at relatively low levels and can be of such severity as to cause the death of fishes, particularly the bluegill."

Transport of Heavy Metals

Gibbs (1973) studied the transport of heavy metals in stream ecosystems, using the Yukon and Amazon rivers as models. He found five mechanisms of transport:

1. Dissolved ionic species and inorganic associations.
2. Adsorption on solids.
3. Precipitation and co-precipitation on solids (metallic coatings).
4. Incorporation in solid biological materials.
5. Incorporation in crystalline structures.

Gibbs analyzed samples from the water column and suspended sediment. While the metals in solution would obviously be the most available, Gibbs determined that except for manganese, transport via

this mechanism is insignificant. This would likely be the case in western Montana as well. Inorganic materials and metallic hydroxides which require chemical activity before release are less available but much more common, according to Gibbs. Most metals were transported incorporated in crystalline structures where they would be unavailable, or precipitated and co-precipitated in metallic coatings on particles.

Enk and Mathis (1977) looked at the distribution of cadmium and lead in a stream ecosystem by studying concentrations found in sediment, fish, insects and the water column. They found similar cadmium levels in the fish and sediments, but higher levels in benthic invertebrates. Lead concentrations were similar in sediment and insects, but both had higher concentrations than fish. Generally, the trend for both metals was an increase from water to fish to sediment to insects.

Mathis and Cummings (1973) did a similar study in the Illinois River and found a similar trend in heavy metal distribution; water contained less heavy metal than fish, which contained less than sediments.

Van Hassel, Ney and Garling (1980) conducted research relevant to situations found in streams of Montana affected by mine tailings. The authors looked at levels of lead, nickel, zinc and cadmium in the water, sediment, benthic invertebrates, and fish of a softwater stream next to a highway. Although periods of high runoff were not sampled, water concentrations were within limits for unpolluted surface waters. However, lead concentrations in insects at one station were comparable to those reported from polluted, hard water Illinois streams, as were whole body concentrations of lead, cadmium and zinc in fish. A seasonal

variation was evident only in sediment samples. The authors concluded that since fish can rapidly excrete lead and zinc, "occasional pulses in stream water concentrations of heavy metals would not cause chronically elevated concentrations in Back Creek fish." The authors extend this idea to its logical conclusion:

> Water quality criteria derived from conventional laboratory bioasays and based on waterborne concentrations may be inadequate to protect aquatic life from toxicants which are accumulated from sediments. Long-term field investigations of community dynamics would more directly assay the threat to aquatic ecosystems posed by highway generated heavy metal contamination.

Mathis and Kevern (1975) studied heavy metal distribution in a eutrophic lake and concluded fish were accumulating metals from the food chain and chronic dissolved levels in the water. Once again metals were found mainly in fish and sediments, with low levels present in the water.

Further work in this area was conducted by Naminga and Wilhm (1977). They looked at heavy metals (copper, chromium, lead and zinc) in stream sediments and chironomids. While the sediment was found to act as a sink in this study as well, chrionomids had higher levels of copper, zinc and lead than the sediments, and much higher concentrations than the water. Adsorbed fractions in sediments were extracted with ammonium acetate and yielded very small amounts. Heavy metals were probably mostly associated with carbonate and iron oxides (as in Gibbs' study) due to soil types in the watershed. According to Merritt and Cummins (1978), chrionomid feeding habitats vary among species, and they could easily pick up various types of contaminated food from sediment acting as a sink for heavy metals.

Williams, et al. (1973) concluded that soluble levels were not related to flow, and metals were mainly associated with organic particles (detritus) which were resuspended in high flow periods. Metals could bioaccumulated even when water standards were being met. Therefore, the authors felt dilution is not the pollution solution. Riemer and Toth (1970) found copper to be readily adsorbed by humic acids and clays, which would settle to the bottom sediments.

## Ecosystem Effects of Heavy Metals

Patrick (1978) discusses the effects heavy metals have on aquatic systems, especially lotic systems, as reflected in changes in the diatom community structure. She points out that diatom communities are very sensitive to environmental changes, although large changes such as pollution, are required to shift a community drastically toward more tolerant species. Other factors involved include predation and competition by means of excretion products. Using vanadium, chromium and selenium, and holding constant major water chemistry components, Patrick found that trace metals can severely decrease diatom diversity and stimulate green algae growth. In her study she discovered the highest metal concentrations in biomass occurred at the highest ambient metal levels, but the greatest ratio between bioaccumulation and ambient levels occurred at low levels. Patrick pointed out a couple of important implications of her work: First, organic pollution may stimulate growth of desirable algae, resulting in higher productivity in the food web. More organic loading could stimulate a shift to undesirable (green) algae, stimulate its growth and cause a reduction of

productivity in the food web due to the undesirability of green algae to herbivores. Second, trace metals can drastically alter food webs:

> Thus, if a food web with a highly positive base of diatoms, which have high prey value, is switched to a base of green algae, a species of lesser prey value to herbivores, populations of species higher in the food web will greatly decrease because of lack of suitable food. Other species that prey upon detritus may take over, but the web will be distinctly changed.

Patrick, et al. (1969), performed studies under soft water conditions with manganese and temperature variation. The authors found temperatures over 30° C. to favor growth of green algae, and temperatures of over 35° C. favored blue-green algae. Levels of dissolved manganese less than 40 ug/l favored green and blue-green algae, while concentrations of more than 40 ug/l favored diatom growth.

Gale et al., (1973) found that mining development in previously unpolluted areas caused nuisance algal blooms to form in streams receiving effluent from mines or mills. As in the Upper Clark Fork, Cladophora sp. was one of the alga stimulated to nuisance levels. Concentrations of heavy metals in algal mass were inversely related to distance downstream from effluent sources.

The possibility of tolerance or adaptation to heavy metals or pH extremes has been raised in the literature, but more likely what occurs is the death of susceptible fish and the survival of hardier individuals. Further, the survivors are more prone to fall prey to other stresses (pollution, high temperatures, low dissolved oxygen, etc.) than fish which are not exposed to debilitating conditions through development. For example, Rahel (1981) found that flagfish exposed to high levels of zinc for a short period can recover and reproduce as

successfully as unexposed fish. Second, zinc tolerance was gained by the population through the death of weaker individuals; future generations were equally susceptible as unexposed populations. Thus, increased vigor probably accounted for survival, not genetic adaptation. Third, the survivors suffered from chronic stress which weakened their ability to withstand further stress. The implications of such work are obvious: If adaptation to toxicants like heavy metals is possible, it cannot occur quickly enough to survive anthropogenic sources from which doses arrive at relatively high rates and concentrations (Rahel, 1981).

| Metal | Biological indicator | Soft or hard water* | Threshhold level | Effect and duration of exposure | Reference |
|---|---|---|---|---|---|
| Copper | Bluegills | soft | .162 ug/l | reduced survival, retarded growth; 22 months. | Benoit, 1975 |
| | | | 40 ug/l | larval survival inhibited. 90 days, | |
| | | | 1,100 ug/l | death. 96 hour $TL_{50}$ | |
| | Brook trout | soft | 17.4 ug/l | drastic effect on survival and growth of alevins and juveniles. | McKim and Benoit, 1971 |
| | | | 9.5 ug/l | no effect level after 8 months. | |
| | Fathead minnow | hard | 14.1 - 32.9 ug/l | no spawning occurred; 11 months. | Mount, 1968 |
| | Brown bullhead | hard | 170 ug/l | death, 96 hour $TL_{50}$ | Brungs, et al., 1973 |
| | Rainbow trout | hard | 400 ug/l | death, $LC_{50}$. | Giles and Klaverkamp, 1982 |
| | Channel catfish | hard | 25 - 1030 ug/l | increasing susceptibility to invections. | Ewing, et al., 1982 |

TABLE 1. Review of literature values on heavy metal toxicity.

| | | | | | |
|---|---|---|---|---|---|
| Zinc | Fathead minnow | hard | 2800 ug/l | reduced spawning success. | Brungs, 1969 |
| | *Phoxinus phoxinus* | ? | 50 - 130 ug/l | $TL_m$ for yearlings, reduced growth. | Bengtsson, 1974 |
| | | | 130 - 200 ug/l | $TL_m$ for adults, reduced growth. | |
| | Rainbow trout | hard | 7210 ug/l | death, 96 hour $LC_{50}$. | Sinley, et al., 1974 |
| | | soft | 430 ug/l | death, 96 hour $LC_{50}$ | |
| | | hard | 330 - 640 ug/l | death, 1½ years. | |
| | | soft | 140 - 200 ug/l | death, 1½ years. | |
| | Brook trout | soft | 534 - 1360 ug/l | reduced embryo survival, embryo thru adult spawning. | Holcombe, et al., 1979 |
| | | | 2000 ug/l | death, 96 hour $LC_{50}$. | |
| | Rainbow trout | very hard | 4760 ug/l | death, 48 hour $LC_{50}$ | Solbe, 1974 |
| Cadmium | Brook trout | soft | 3.4 ug/l | death of males during spawning, retarded growth of offspring; 2 years. | Benoit, et al., 1976 |
| | Bluegills | hard | 80 ug/l | death of adults, severe abnormalities to embryos; 8 months. | Eaton, 1974 |

TABLE 1 (cont.)

| | | | | | |
|---|---|---|---|---|---|
| | Rainbow trout | hard | 8o - 100 ug/l | death, 7 day $TL_m$ | Ball, 1967 |
| | Largemouth bass<br>Bluegills | hard | 80 ug/l<br>850 ug/l | death in 82 days<br>death in 138 days | Cearlev and Coleman, 1974 |
| | Brook trout | ? | 10 ug/l | Haemorphagic necrosis in testicles ($LT_{50}$); 21 days. | Sangalang and O'Halloran, 1972 |
| | Fathead minnow | hard | 37 - 57 ug/l | death of embryos, MATC | Pickering and Gast, 1972 |
| Lead | Brook trout | hard | 58 - 119 ug/l (total) | scoliosis and reduced growth; 3 generations. | Holcombe, et al., 1976 |
| | | | 39 - 84 ug/l (diss.) | scoliosis and reduced growth; 3 generations. | |
| | | | 4100 ug/l (total) | death, 96 hour $LC_{50}$ | |
| | | | 3362 ug/l (diss.) | death, 96 hour $LC_{50}$ | |

* soft water has less than 100 mg/l $CaCO_3$,
hard water has more than 100 mg/l $CaCO_3$

TABLE 1 (cont.)

## REVIEW OF CLARK FORK RIVER WATER QUALITY

According to the State Water Quality Bureau, the Upper Clark Fork drainage has some of the worst and best quality water in the state (WQB, 1982). Silver Bow Creek remains fishless, affected by industrial and municipal effluents, and by heavy metals in mine tailings deposited during the last 100 or more years. In contrast, Rock Creek has very high quality water and supports an outstanding "Blue Ribbon" trout fishery. In spite of a history of pollution problems stemming from mining operations in the headwaters, improvements in treatment facilities at Butte and Warm Springs have resulted in a trout fishery throughout much of the Upper Clark Fork. Silver Bow Creek continues to have serious problems, mainly due to over 100 million cubic yards of old mine tailings in its floodplain. Other problems, such as effluents from storm drainages, municipalities and industry, may eventually be cleared up, but nothing within reasonable cost can be done about the mine tailings (Peckham, 1979). Thus, the Water Quality Board (WQB) classifies Silver Bow Creek is still classified E - an industrial sewer (WQB, 1982). Additionally, the WQB classifies the Clark Fork from the confluence of Warm Springs and Silver Bow creeks downstream to Cottonwood Creek, C-2 due to high sulfate concentrations. From there downstream to the Little Blackfoot River, the Clark Fork is rated C-1. The rest of the river is designated B-1. A complete explanation of the criteria used in classifying water quality can be found in the

Administrative Rules of Montana, sections 16.20.603-643. Generally, B-1 water is suitable for drinking, food processing, and growth and propagation of salmonids. C-1 and C-2 waters are not suitable for drinking and food processing, and C-2 water quality supports only marginal growth and propagation of salmonids. Nutrient loading remains a problem, mainly from municipal sources and possibly the Phosphoria Formation near Garrison. The WQB feels this has resulted in the Cladophora sp. blooms from Deer Lodge to Rock Creek. Occasionally, in times of low flow and high temperatures, this algal bloom causes low dissolved oxygen levels, creating marginal conditions for trout production (DHES, 1980).

By the time the Clark Fork enters the Missoula Valley it still suffers from municipal and industrial discharges originating in the headwaters (Butte, Anaconda, and Deer Lodge). Improvements in the Missoula Sewage Treatment Plant (STP) and the treatment system at Champion International's pulp mill in Frenchtown, plus additional flow from the Blackfoot, have reduced the effect of these two point sources to levels at which no documented degradation occurs. However, as of May 1980 the WQB felt the Champion International was adding color and possibly phenols and algal nutrients to the Clark Fork. Also, ammonia was mentioned as a potential problem below the Missoula STP, but after recent bioassays has now been declared safe (DHES, 1982). At Alberton, the river has assimilated its water quality problems and water quality is good to excellent (DHES, 1980).

The WQB stated in 1980 that temperature, suspended solids, conductance, nutrients and total dissolved solids criteria were being

exceeded in the Clark Fork (DHES, 1980). The main point sources which caused problems were the AMC operations in Butte (metals, pH) and Anaconda (sulfate, metals), and the sewage treatment facilities in Deer Lodge (nutrients). The WQB also claimed that 155 miles of the Clark Fork suffered from dewatering, but gave no supporting data. Their 1982 report did not include suspended solids, conductance or dewatering as problems, although the same problem sources were mentioned (DHES , 1982).

In previous reports on water quality in Montana (DHES, 1976a, 1975), the WQB spent much time discussing the lengths of stream sections affected by various problems. In contrast to the 1980 report, the Bureau felt in 1976 that zero miles were affected by point sources in the Upper Clark Fork while drainage total of 599 miles were affected by several problems - sedimentation (75), dewatering (110), nutrients (160), low dissolved oxygen (180), and lastly, acid mine discharge and heavy metals (84). The Lower Clark Fork had 45 miles affected by point sources and 120 miles degraded overall. In 1960, the Upper Clark Fork had 155 miles affected by point sources while the Lower Clark Fork had 153 miles so affected (DHES, 1975).

In the latest WQB assessment of statewide water quality, a new approach to problem areas was used. No longer attempting to count the miles affected by various problems, the WQB mapped problem drainages and accompanied them with a listing of the source and type of problems. Segments were identified and ranked based on an adaption of an EPA technique. The technique uses a Criteria Matrix (Table 2), although the origin of the values in the matrix is not disclosed.

TABLE 2. Water quality matrix (mg/l unless otherwise noted). Beneficial uses: 1 - cold water aquatic life; 2 - warm water aquatic life; 3 - public water supplies; 4 - primary contact recreation; 5 - irrigation; 6 - livestock watering. Taken from DHES, 1982.

| | *1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Dissolved oxygen | 7.0 | 5.0 | | | | |
| Fecal coliforms (no./100 ml) | | | | 200 | 1000 | |
| Nitrite as N | 0.05 | 0.5 | 1.0 | | | 10.0 |
| Nitrate as N | | | 10.0 | | | |
| Nitrite and nitrate as N | | | | | | 100 |
| Total ammonia | | | 0.5 | | | |
| Un-ionized ammonia | 0.02 | 0.04 | | | | |
| Total inorganic N | 0.35 | 0.35 | | | | |
| Total phosphorus | 0.05 | 0.05 | | 0.05 | | |
| Total phosphate | 0.05 | 0.05 | | 0.05 | | |
| Total dissolved solids | | | 500 | | 1200 | 1000 |
| Conductance (micromhos/cm) | | | | | 2500 | |
| Turbidity (NTU) | 10 | 50 | | | | |
| Total suspended sediment | 30 | 90 | | | | |
| Chloride | | | 250 | | 700 | |
| Sulfate | | | 250 | | | |
| Cyanide | | | 0.2 | | | |
| Magnesium | | | | | 160 | |
| Sodium | | | | | 160 | |
| Sodium adsorption ratio | | | | | 3.0 | |
| Fluoride | | | 2.4 | | 15.0 | 2.0 |
| Arsenic | 0.44 | 0.44 | 0.05 | | 0.10 | 0.20 |
| Barium | | | 1.00 | | | |
| Boron | | | | | 0.75 | 5.00 |
| Chromium VI | 0.021 | 0.021 | 0.05 | | 1.00 | |
| Iron | 1.0 | 1.0 | 0.3 | | 2.0 | |
| Manganese | | | 0.05 | | 10.0 | |
| Selenium | 0.26 | 0.26 | 0.01 | | 0.02 | 0.05 |
| Mercury | 0.004 | 0.004 | 0.002 | | | 0.010 |
| Temperature (C) | 19.4 | 26.6 | | | | |
| Temperature (F) | 67.0 | 80.0 | | | | |
| Copper | | | 1.0 | | 5.0 | 0.5 |
| Lead | | | 0.05 | | 10.0 | 0.10 |
| Zinc | | | 5.0 | | 10.0 | 25.0 |
| Cadmium | | | 0.01 | | 0.05 | 0.05 |
| Chromium III | | | 178 | | | |
| Nickel | | | 0.015 | | 2.0 | |
| Silver | | | 0.05 | | | |
| pH (minimum) | 6.5 | 6.5 | 6.5 | 6.5 | 4.5 | |
| pH (maximum) | 8.5 | 9.0 | 8.5 | 8.3 | 9.0 | |

Changes were noted for the Upper Clark Fork. Significantly, heavy metals are not longer considered a potential hazard to human health or aquatic life in the Upper Clark Fork, based on fish samples collected in 1978. Yet in the basin by basin section metals are listed as a "suspected pollutant" between Garrison and Warm Springs. The report does not mention the Milltown Dam as affecting water quality. In contrast, Graham, et al. (1981) in their report to the Bonneville Power Administration on Montana's Fish and Wildlife Mitigation Program, claim the operation of Milltown Dam degrades the water quality of the Clark Fork.

The most comprehensive reports on the Clark Fork drainage water quality compiled to date are the Water Quality Inventory and Management Plans, one each for the Upper and Lower Clark Fork (Casne, et al., 1976; DHES, 1976b). These summarized water quality studies previously completed. Casne, et al., conclude that Clark Fork River water quality is "suitable for designated beneficial uses" in the Upper Clark Fork and in the Lower Clark Fork. Improvements in municipal and industrial treatments would probably result in the Lower Clark Fork River drainage meeting (old) state water quality standards. However, one section in the Upper and tentatively one in the Lower Clark Fork is designated "water quality limited". The section from Cottonweed Creek north of Deer Lodge to the Little Blackfoot River is so designated due to excessive algal growth. From the Champion International pulp mill downstream to Alberton, organic color and phenols are considered problems until the "best practicable treatment" was completed at the pulp mill, and data demonstrating otherwise was collected.

In an aerial survey of the Upper Clark Fork conducted with the EPA in 1974, the WQB notes that the algal blooms start below Deer Lodge, getting denser toward Drummond, until the algae appears to cover the entire streambed (DHES, 1975). The growth then becomes intermittent and disappears about ten miles below Drummmond. Occasional blooms are seen below Rock Creek downstream to Bonner. Algal assay tests performed by the WQB in 1975 indicate heavy metals (zinc and copper) are probably inhibiting algal growh in the pH shack section (below the Warm Springs settling ponds), while nutrients from the Deer Lodge sewage lagoon are stimulating Cladophora sp. blooms downstream. Tests also showed that the Phosphoria Formation did not contribute more to the algal growth already present (DHES, 1975). However, the EPA also collected nutrient data in August, 1975 which show large increases in ortho and total phosphate downstream of the Phosphoria Formation, near the town of Phosphoria (DHES, 1975).

## SOURCES AND EFFECTS OF HEAVY METALS IN THE CLARK FORK RIVER

Silver Bow Creek has long been considered a biological desert and was so considered as recently as 1982 (WQB, 1982). Mining has been the cause. Wigal (1972) describes the former and current industrial treatment systems at Butte and Anaconda. Prior to 1972 the water treatment facility at Butte was a tailings pond which collected solids, and the addition of lime caused some metal precipitation in the creek. The Butte Anaconda Minerals Co. (AMC) operations released into Silver Bow Creek 7.2 million gallons per day (mgd) from their precipitation plant. This effluent was acidic and contained high levels of dissolved metals. An additional 18 mgd were dumped from the Clyde E. Weed ore concentrator. While low in heavy metals, this effluent was alkaline and very hard.

At Anaconda, 25 mgd were added to Silver Bow Creek from the AMC lime ditch, which carried plant effluents. This ditch enters Silver Bow Creek upstream of the Warm Springs settling ponds. In addition, 10 to 15 mgd from the ore concentrator, which were initially treated at AMC settling ponds, and 1 to 10 mgd of domestic effluent from the city of Anaconda, went into the settling ponds. This made an approximate total of 50 mgd treated by the pond system. Lime treatment caused additional metal precipitation in the ponds.

In October of 1972, the Butte operations installed a closed water system which decants water from the settling ponds and recycles it

through the ore concentrator. Four and half mgd of make-up water are obtained from underground mines. The new process results in 4 to 5 mgd discharged into Silver Bow Creek, down from about 25 mgd. The Continental East Pit adds an additional .01 mgd.

Anaconda was to install a pond seepage interceptor, separate treatment ponds for city sewage which would empty into Warm springs Creek or the Clark Fork, and channel the lime ditch effluents directly to the Warm Springs settling ponds. Although the area's mining and smelting operations have been drastically curtailed, enough toxic waste has been produced to degrade the Clark Fork for the forseeable future. And this is true even if the treatment ponds are maintained at Warm Springs. If they are not, a more serious degradation will ensue.

Several additional sources of heavy metals have been found polluting Silver Bow Creek (DHES, 1980). Butte's Metro STP discharges 6 to 10 mgd into Silver Bow Creek, and adds its sludge once a week. The storm sewer system in Butte contributes the area' major portion of iron, copper and zinc. A drainage ditch in the Colorado tailings area sends large amounts of heavy metals into Silver Bow Creek, indicating that groundwater is leaching metals from the tailings. The metal load at the lower pH shack is about twice what would be expected, leading to the conclusion that groundwater seepage from Warm Springs Ponds Two and Three is occurring. Conductivity data indicate this is probably the case. The Opportunity ponds are probably experiencing similar problems, resulting in seepage to Warm Springs Creek. The DHES felt that a thorough study was needed to understand the seepage problem at these settling ponds.

Several studies have documented the presence of heavy metals in the water, sediments, or fish of the Upper Clark Fork Drainage (Van Meter, 1974; Bailey, 1976; Peckham, 1979; Petersen, 1977; Ingman and Bahls, 1979), although no one seems to have established any kind of chronic effect on the productivity of the fishery. the Department of Fish, Wildlife and Parks (DFWP), in conjunction with the WQB and AMC, collected additional data in 1978 on the heavy metal content of trout taken from the Upper Clark Fork (Figure 1 shows location of sample sites).

The DFWP sampled trout from the Little Blackfoot River, and the pH shack and Williams-Tavenner section of the Clark Fork. Both of these stations are upstream of the confluence with the Little Blackfoot. Muscle tissue was analyzed for cadmium, lead, mercury, copper, zinc and arsenic. The results from the report, based on wet tissue, are shown in Table 3. Some raw data, based on dry tissue analysis, was obtained from Ken Knudsen (1981) and is presented in Table 4 since the report does not include it. Based on the available dry weight data, all sites contained different levels of mercury (F-test, @ = .01). The pH shack section yielded samples with higher levels of cadmium than Little Blackfoot or Williams-Tavenner samples, which did not differ from each other (F-test, @ = .05).

The DFWP report (Mt. DFWP, 1982) states that metals found in trout of the Upper Clark Fork are not a hazard to human or aquatic life. The levels found are certainly not indicative of a potential health problem, but the question of a hazard to aquatic life remains. As the report states, and as is clear from research literature, muscle tissue is not the

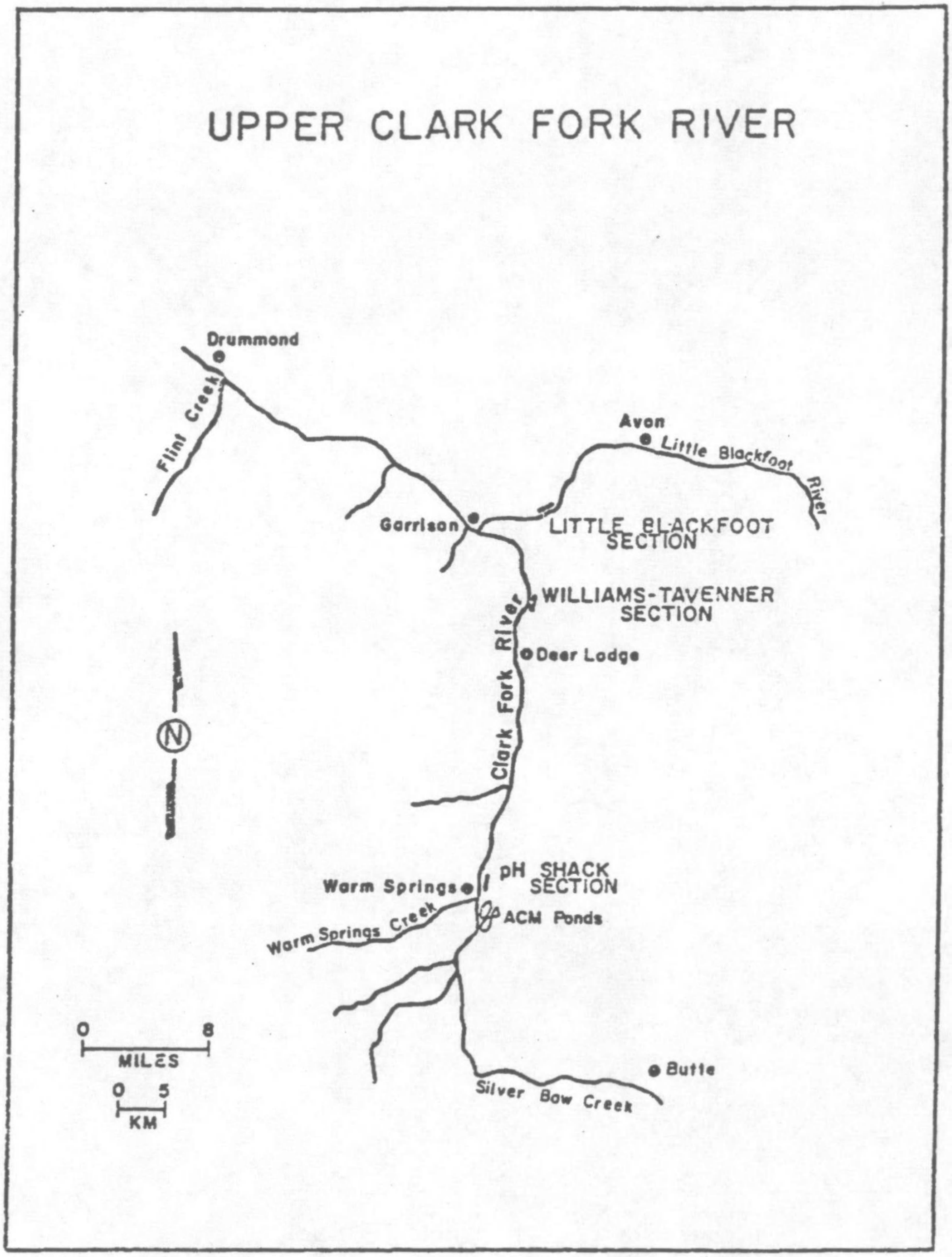



FIGURE 1. Map of the Upper Clark Fork and Little Blackfoot Rivers showing locations where brown trout were collected in 1978 for the DFWP (1982) heavy metals study.

| Location | Age Class | No. | Length (mm) | Weight (gm) | Metal concentration (ug/g) Hg | Cu | Cd | As | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| Clark Fork-pH Shack | I | 17 | 234±23 (188-272) | 136±50 (73-213) | 0.03±0.01 (0.02-0.04) | 0.10±0.27 (ND-0.83) | 0.43±0.45 (ND-1.12) | 0.16±0.08 (0.02-0.29) | 0.17±0.08 (ND-0.34) | 4.45±1.85 (1.35-7.75) |
| Clark Fork-Williams-Tavenner | | 12 | 241±15 (218-267) | 154±18 (123-195) | 0.07±0.01 (0.06-0.09) | 0.25±0.76 (ND-2.41) | 0.05±0.05 (ND-0.13) | 0.10±0.05 (0.05-0.20) | 0.08±0.10 (ND-0.25) | 4.81±1.10 (3.19-6.52) |
| Little Blackfoot | | 8 | 213±13 (198-239) | 104±14 (91-136) | 0.07±0.01 (0.05-0.08) | 0.05±0.15 (ND-0.43) | 0.21±0.23 (ND-0.56) | 0.10±0.08 (0.01-0.26) | 0.19±0.04 (0.10-0.25) | 4.85±0.68 (3.53-5.76) |
| Clark Fork-pH Shack | II | 18 | 310±33 (246-371) | 318±95 (181-599) | 0.04±0.01 (0.02-0.07) | 0.15±0.29 (ND-0.92) | 0.56±0.49 (0.06-1.36) | 0.12±0.08 (0.03-0.31) | 0.19±0.03 (0.15-0.25) | 4.15±2.04 (1.90-5.37) |
| Clark Fork-Williams-Tavenner | | 14 | 297±31 (249-343) | 286±82 (163-440) | 0.10±0.03 (0.06-0.19) | 0.03±0.07 (ND-0.24) | 0.11±0.12 (ND-0.45) | 0.08±0.04 (0.02-0.17) | 0.30±0.42 (ND-1.28) | 4.09±1.11 (2.60-6.60) |
| Little Blackfoot | | 15 | 285±23 (249-338) | 240±68 (145-404) | 0.11±0.04 (0.07-0.18) | 0.02±0.04 (ND-0.06) | 0.07±0.07 (ND-0.20) | 0.15±0.13 (0.03-0.50) | 0.17±0.13 (0.03-0.45) | 3.55±1.29 (1.49-6.89) |
| Clark Fork-pH Shack | III | 6 | 366±28 (335-414) | 508±113 (377-694) | 0.06±0.01 (0.04-0.08) | - - | 1.02±0.55 (0.22-1.41) | 0.12±0.07 (0.03-0.24) | 0.15±0.03 (0.12-0.20) | 4.63±0.74 (3.79-5.58) |
| Clark Fork-Williams-Tavenner | | 15 | 361±25 (320-406) | 531±118 (363-767) | 0.16±0.05 (0.08-0.25) | 0.12±0.15 (ND-0.43) | 0.09±0.11 (ND-0.20) | 0.05±0.04 (0.01-0.12) | 0.09±0.10 (ND-0.26) | 3.83±1.20 (1.90-6.46) |
| Little Blackfoot | | 9 | 351±30 (310-399) | 467±132 (331-690) | 0.18±0.07 (0.10-0.31) | 0.12±0.15 (ND-0.39) | 0.21±0.41 (ND-1.10) | 0.28±0.26 (0.05-0.83) | 0.24±0.12 (0.07-0.36) | 3.69±0.61 (2.88-4.89) |
| Clark Fork-pH Shack | IV | 3 | 452±58 (412-518) | 993±445 (735-1505) | 0.08±0.02 (0.03-0.10) | - - | 0.83±0.64 (0.20-1.48) | 0.01±0.02 (ND-0.03) | 0.17±0.08 (0.11-0.26) | 3.52±0.58 (3.12-4.18) |
| Clark Fork-Williams-Tavenner | | 6 | 432±38 (406-503) | 984±667 (672-1716) | 0.18±0.13 (0.05-0.41) | 0.25±0.22 (ND-0.53) | 0.41±0.57 (ND-1.26) | 0.13±0.16 (0.02-0.45) | 0.21±0.45 (ND-1.12) | 3.92±1.04 (2.65-5.20) |
| Little Blackfoot | | 6 | 439±43 (394-498) | 948±286 (721-1397) | 0.19±0.15 (0.06-0.47) | 0.28±0.37 (ND-0.97) | 0.22±0.35 (0.02-0.93) | 0.18±0.29 (0.02-0.76) | 0.17±0.09 (0.08-0.27) | 3.76±0.39 (3.37-4.34) |

TABLE 3. Means, standard deviations and ranges of length, weight, and metal concentrations in brown trout (ppm wet tissue) from two sections of the Clark Fork River and one location on the Little Blackfoot River. Refer to Fig. 1 (from Mt. DFWP, 1982).

TABLE 4. Concentrations (in ppb dry tissue) of mercury, lead and cadmium found in brown trout from the Upper Clark Fork drainage in 1978.

| | | | | | Site | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Field | Little Blackfoot | | | Field | W-T section Clark Fork | | | Field | pH shack section Clark Fork | | |
| Sample | Hg | Pb | Cd | Sample | Hg | Pb | Cd | Sample | Hg | Pb | Cd |
| LB 1 | 701 | 221 | 47 | WT 1 | 461 | - | 15* | PH 1 | 460 | 105 | 1475 |
| LB 2 | 334 | 98 | 15 | WT 2 | 594 | 167 | 59 | PH 2 | 207 | - | - |
| LB 3 | 821 | 303 | 15 | WT 3 | 514 | 124 | 55 | PH 3 | 242 | 142 | 1098 |
| LB 4 | 1071 | 330 | 137 | WT 4 | 1210 | 203 | 15* | PH 4 | 152 | 199 | 206 |
| LB 5 | 1306 | 321 | 111 | WT 5 | 505 | 220 | 46 | PH 5 | 151 | - | - |
| LB : | 688 | 303 | 15 | WT 6 | 761 | 237 | 30 | PH 6 | 153 | 156 | - |
| LB 7 | 1585 | 356 | 30 | WT 7 | 548 | 177 | 187 | PH 7 | 269 | ;43 | 197 |
| LB 8 | 1101 | 269 | - | WT 8 | 292 | 247 | 17 | PH 8 | 396 | 217 | 1075 |
| LB 9 | 2881 | 231 | 115 | WT 9 | 365 | 245 | 101 | PH 9 | 99 | 143 | 220 |
| LB 10 | 456 | 310 | 15 | WT 10 | 419 | 167 | 15* | PH 10 | 404 | 226 | 265 |
| LB 11 | 1361 | 195 | 15 | WT 11 | 455 | 168 | - | PH 11 | 150 | 245 | 1270 |
| LB 12 | 499 | 231 | 57 | WT 12 | 864 | 20* | - | PH 12 | 105 | 190 | 188 |
| LB 13 | 654 | 356 | 17 | WT 13 | 619 | 20* | 51 | PH 13 | 372 | 199 | 224 |
| LB 14 | 651 | - | - | WT 14 | 930 | 20* | 101 | PH 14 | 196 | 115 | 1407 |
| LB 15 | 839 | 336 | - | WT 15 | 397 | 20* | 161 | PH 15 | 131 | 219 | 194 |
| LB 16 | 1007 | 285 | 146 | WT 16 | 626 | - | - | PH 16 | 351 | 217 | 1361 |
| LB 17 | 856 | 338 | 15 | WT 17 | 1821 | 20* | 15* | PH 17 | 403 | 264 | 807 |
| LB 18 | 284 | 267 | - | WT 18 | 581 | 258 | 55 | PH 18 | 238 | 162 | 252 |
| LB 19 | 1096 | 472 | 21 | WT 19 | 309 | 81 | 51 | PH 19 | 161 | 199 | 88 |
| LB 20 | 389 | 454 | 1133 | WT 20 | 255 | 82 | 110 | PH 20 | 134 | 339 | 798 |
| LB 21 | 952 | 20* | 213 | WT 21 | 738 | 105 | 15* | PH 21 | 117 | 221 | - |
| LB 22 | 556 | 78 | 15 | WT 22 | 767 | 20* | 94 | PH 22 | 101 | 163 | 63 |
| LB 23 | 2204 | 114 | 79 | WT 23 | 541 | 20* | 1262 | PH 23 | 161 | 118 | 1331 |
| LB 24 | 790 | 122 | 44 | WT 24 | 444 | 20* | 22 | PH 24 | 267 | 140 | - |
| LB 25 | 1221 | 123 | 124 | WT 25 | 500 | 20* | 123 | PH 25 | 109 | 208 | 63 |
| LB 26 | 402 | 88 | 15* | WT 26 | 333 | 20* | 35 | PH 26 | 164 | 172 | 994 |
| LB 27 | 678 | 25 | 97 | WT 27 | 351 | 610 | 98 | PH 27 | 259 | 208 | 37 |
| LB 28 | 678 | 158 | 119 | WT 28 | 447 | 524 | 30 | PH 28 | 146 | 154 | 617 |
| LB 29 | 705 | 69 | 1131 | WT 29 | 357 | - | - | PH 29 | 172 | - | - |
| LB 30 | 869 | 132 | 15* | WT 30 | 935 | 273 | 15* | PH 30 | 185 | 143 | 1123 |
| LB 31 | 856 | 84 | 34 | WT 31 | 248 | 20* | 31 | PH 31 | 152 | 163 | 920 |
| LB 32 | 918 | - | - | WT 32 | 548 | 20* | 23 | PH 32 | 227 | 171 | 661 |
| LB 33 | 293 | 25 | 53 | WT 33 | 642 | 190 | 123 | PH 33 | 157 | - | - |
| LB 34 | 1339 | 185 | 79 | WT 34 | 564 | 105 | 39 | PH 34 | 174 | 137 | 33 |
| LB 35 | 457 | 159 | 35 | WT 35 | 560 | 105 | 156 | PH 35 | 149 | 198 | 58 |
| LB 36 | 376 | 62 | - | WT 36 | 1023 | 1115 | 24 | PH 36 | 112 | 207 | 145 |
| LB 37 | 471 | 73 | - | WT 37 | 306 | 694 | 15* | PH 37 | 309 | 162 | 916 |
| LB 38 | 510 | 69 | 160 | WT 38 | 457 | 21 | 43 | PH 38 | 78 | 65 | ;033 |
| LB 39 | 484 | 78 | 30 | WT 39 | 299 | 1283 | 39 | PH 39 | 119 | 225 | 145 |
| LB 40 | 325 | - | - | WT 40 | 336 | - | 120 | PH 40 | 197 | 154 | 1081 |
| LB 41 | 600 | 116 | 15* | WT 41 | 1064 | 20* | 202 | PH 41 | 132 | - | 977 |
| LB 42 | 288 | 176 | - | WT 42 | 595 | 20* | 146 | PH 42 | 126 | - | - |
| LB 43 | 457 | 140 | 105 | WT 43 | 1234 | 20* | 19 | PH 43 | 100 | - | - |
| LB 44 | 663 | 186 | 76 | WT 44 | 288 | 20* | 91 | PH 44 | 122 | 163 | 154 |
| LB 45 | 284 | 212 | 21 | WT 45 | 300 | 20* | 15* | PH 45 | 102 | - | - |
| LB 46 | 399 | 185 | 98 | WT 46 | 433 | 20* | 100 | PH 46 | 143 | 207 | 162 |
| LB 47 | 225 | 251 | - | WT 47 | 290 | 20* | - | PH 47 | 128 | 137 | - |
| LB 48 | 383 | 15* | 194 | WT 48 | 207 | 20* | 15* | PH 48 | 265 | - | - |
| LB 49 | 304 | 564 | 194 | WT 49 | 380 | 20* | 125 | PH 49 | | | |
| LB 50 | 269 | 170 | 203 | WT 50 | 353 | - | - | PH 50 | | | |

* less than (below detection limit).

appropriate tissue to analyze for evidence of exposure to heavy metals. As a result, comparison of DFWP data to literature values dealing with ecosystem or chronic effects is difficult. However, cadmium, and possibly lead and mercury, may be present at deleterious levels. At all stations, cadmium levels exceed those found by Benoit, et al. (1976) when they exposed brook trout to 3.4 ug/l Cd in soft water for 70 weeks. This was the concentration they found to cause death in spawning males and retarded the growth of offspring. The muscle tissue levels are also higher than those found by Mathis and Kevern (1975), Uthe and Bligh (1971), and Kronberg (1980) in polluted waters. Mercury in a few fish from the Williams-Tavenner section and 11 from the Little Blackfoot exceed .2 ppm, considered to be the limit for accumulation at background levels (Fimreite, et al., 1971). The .2 ppm level is also within a standard deviation of average concentrations in the III and IV year classes from these sites (Table 5). Mercury and lead concentrations found in older fish in the Little Blackfoot and the Upper Clark Fork are similar to those found in other polluted waters (Mathis and Kevern, 1975). But the effect these concentrations may have is uncertain, even for cadmium, whose bioaccumulation levels definitely represent contamination at detrimental exposures (although water quality data from the area do not reflect this).

When samples based on dry weight (Table 5) are broken down into weight or age categories, an increase in average accumulations of mercury in larger or older fish is apparent. This general pattern did not prove statistically significant except in a few comparisons which were between the extremes of the weight and age categories. The other

| AGE | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Lead** | | | | | |
| pH* | 184.8 | 186.7 | 162.5 | 124 | - |
| W-T** | 82.2 | 266.2 | 149.1 | 35 | - |
| LB*** | 189.1 | 158 | 242.6 | 212.8 | - |
| **Cadmium** | | | | | |
| pH | 489.8 | 515.8 | 973.4 | 836 | - |
| W-T | 53 | 69.8 | 65.5 | 469.3 | - |
| LB | 142.2 | 67.9 | 168.3 | 39 | 61.5 |
| **Mercury** | | | | | |
| pH | 133.1 | 173.0 | 263.3 | 364.5 | - |
| W-T | 317.4 | 465.6 | 785.8 | 624.7 | - |
| LB | 310.8 | 542.2 | 870.8 | 685 | - |

| WEIGHT | ≤ .5 | .5 ≤ x < 1.0 | 1.0 ≤ x < 2.0 | 2.0 ≤ x < 3.0 | ≥ 3.0 |
|---|---|---|---|---|---|
| **Lead** | | | | | |
| pH | 187.2 | 174.9 | 168.8 | 122.5 | - |
| W-T | 106.6 | 234.8 | 194.5 | 0 | 0 |
| LB | 178.7 | 171.9 | 254.6 | 57 | 78 |
| **Cadmium** | | | | | |
| pH | 549.8 | 639.4 | 580.1 | - | - |
| W-T | 58.5 | 63 | 135.2 | 31 | 146 |
| LB | 107.9 | 1577 | 14.7 | 22 | 79 |
| **Mercury** | | | | | |
| pH | 131.1 | 202.4 | 273.0 | 363.5 | - |
| W-T | 353.7 | 550.8 | 794 | 421.5 | - |
| LB | 362.6 | 724.7 | 1059.9 | 1237.3 | - |

* ph shack section of the Clark Fork.
** Williams-Tavenner section of the Clark Fork.
*** Little Blackfoot.

TABLE 5. Average concentrations of mercury, cadmium and lead (in ppb dry tissue) in trout from the Upper Clark Fork drainage, based on weight (lbs.) and age (years).

metals do not have this characteristic, except between the first two categories (weight or age). Two thirds of the samples show increased metal content from the first to second categories, but no other pattern is discernible based on weight or age.

Van Meter (1974) studied muscle and liver tissue from a variety of fish in the Clark Fork drainage upstream of Alberton, including the major tributaries. He looked for concentrations of cadmium, copper, lead, mercury and zinc. Samples from certain parts of the Flint Creek drainage were found to be contaminated with mercury. The source of the mercury is the tailings of the pan amalgamation method of ore processing which was used in the 19th century. Van Meter also found elevated levels of cadmium in the Little Blackfoot River, but was unable to identify a source. Table 6 shows the average concentration for each metal in the liver and muscle tissue of the six types of fish Van Meter analyzed. He also calculated liver/muscle concentration ratios (Table 6), demonstrating the tendency toward bioaccumulation in the liver. Mercury levels in tissue from the Flint Creek drainage and the Upper Clark Fork exceed the .2 ppm background level, and cadmium and copper levels found in Upper Clark Fork fish are in the range found in fish from other polluted waters (Uthe and Bligh, 1971; Mathis and Kevern, 1975). The tissue levels of mercury at Flint Creek and the Upper Clark Fork is higher than those found by DFWP rsearchers in 1978, although they found higher levels than did Van Meter in the Little Blackfoot.

Van Meter notes that the pan amalgamation method of silver ore processing caused minute globules of mercury to be discarded with the finely ground tailings. As discussed in the Quality Criteria for Water

**Average Concentrations**

| | Cadmium | | Copper | | Lead | | Zinc | | Mercury |
|---|---|---|---|---|---|---|---|---|---|
| | M* | L** | M | L | M | L | M | L | M |
| Trout | .19 | .69 | 1.47 | 11.4 | .45 | .74 | 6.3 | 38 | .15 |
| Whitefish | .2 | .65 | 3.63 | 2.51 | .84 | .37 | 8.5 | 23 | .17 |
| Sucker | .60 | .79 | .43 | 1.65 | .36 | .58 | 8.8 | 31 | .27 |
| Sculpin | | .30 | | 3.09 | | .25 | | 21 | .27 |
| Shiner | | .32 | | 1.85 | | .29 | | 25 | .13 |
| Squawfish | | .53 | | 4.45 | | .29 | | 21 | .25 |

**Average liver/muscle ratios**

| | Cadmium | Copper | Lead | Zinc |
|---|---|---|---|---|
| Trout | 7.0 | 15 | 2.5 | 5.4 |
| Whitefish | 7.1 | 4.2 | .88 | 5.6 |
| Sucker | .46 | 7.0 | 2.0 | 3.3 |

* Muscle tissue
** Liver tissue

TABLE 6. Average concentrations (in ppm wet tissue) of metals in fish tissue, and average values of liver/muscle accumulation ratios from the Upper Clark Fork drainage (from Van Meter, 1974).

(EPA, 1976), mercury is transformed into highly toxic methyl or dimethyl mercury by microbially mediated reactions. Thus, soluble mercury will be available to aquatic organisms in parts of the Flint Creek drainage as long as the tailings contain mercury. Van Meter also mentions the lack of abnormal heavy metal accumulation in fish from the Clark Fork downstream of Butte and Anaconda, however, he found no fish until twelve miles downstream of the confluence of Warm Springs and Silver Bow creeks. Thus, he had no samples from the area to analyze. Brown trout were not found until a few miles downstream of Deer Lodge. The reason for the absence of fish, according to Van Meter, was the coating of calcareous silt on the streambed which destroyed benthic invertebrate habitat. These invertebrates provide a major source of food for fish.

Ingman and Bahls (1979) conducted a water quality study in the Flint Creek Range to determine the past and present effects mining was having on water quality in the area. Interestingly, they found no problems with total or dissolved mercury levels as Van Meter did. Based on their observations, the authors conclude that very few mining-related water quality problems exist in the Flint Creek drainage. Only two streams, Douglas Creek (near Philipsburg) and the North Fork of Douglas Creek are seen by them to have severe problems due to heavy metals. Some other sections of streams are affected by mining also, but not to significant levels. Since streams flows were low the authors feel that any effect on larger order streams would be marginal. Their sampling took place from June through September of 1978. A comparison of the data put together by Ingman and Bahls, which includes their own and data previously gathered by others (except for Van Meter's), to EPA "Red

Book" criteria, points out few violations. (U.S. EPA, 1976). In a few samples, lead criteria are exceeded, and criteria for arsenic and silver are exceeded in one sample each. Sulfate levels ran high ( 100 mg/1) below some old tailings areas, but other signs of acid mine runoff are not present.

In 1970, the EPA conducted a water quality survey of the Upper Clark Fork and several tributaries (EPA, 1971). This is the only in-depth study of heavy metals in the Upper Clark Fork. The survey included the mainstream and tributaries from Warm Springs to Drummond during May to November, 1970. The purpose was to establish metal standards in the Clark Fork by comparing the then current levels with beneficial uses as defined by water quality classifications, and see if those uses were being met. If they were met, the metal levels (dissolved and total) were assumed safe and were made the standards which would theoretically protect those beneficial uses. This method of establishing standards was used due to a lack of funds to conduct bioassays, although I disagree with the EPA's statement on page 2 of their report: "This is a logical method of establishing these maximums and in many ways is superior to a laboratory approach based on bioassays," This method ignores transport and fate of heavy metals, bioaccumulation, and related ecological factors such as food, habitat or other water quality considerations which might affect stream biota. Yet this report has been the basis for heavy metals criteria in the Clark Fork.

The report refers to several major point sources of domestic and industrial wastes in the Upper Clark Fork - the city of Butte and Deer

Lodge, the state hospital at Warm Springs, and AMC operations at Butte and Anaconda. Butte was discharging 7 mgd into Silver Bow Creek from the then new secondary treatment plant. The state hospital at Warm Springs was dumping .2 mgd into the Clark Fork from a treatment lagoon. The copper precipitation facility at Butte produced effluent with a pH of about 4 and an iron content of over 2,000 mg/1. This effluent went into Silver Bow Creek at a rate of 3,000 to 4,000 gpm. Silver Bow Creek was used to transport wastes to the Warm Springs settling ponds. Lime and alkaline wastes from Anaconda were mixed with Silver Bow Creek before the settling ponds, causing either ferrous or ferric hydroxide to settle in the ponds. The ponds yielded an effluent saturated with calcium sulfate, plus total and dissolved metals. The report notes that effluent quality was variable, depending on "process fluctuations, poor pond operations, intermittent bypassing of settling ponds, and spills or shortcircuiting in the ponds, due to adverse wind or ice conditions." The EPA collected water quality data during or after several such spills; these values are reflected as maxima in their data.

For the study, water chemistry and benthic invertebrate data were collected. Fisheries data for the Clark Fork were obtained from the Sate Fish and Game Department, while tributaries were sampled qualitatively with the aid of the Fish and Game Dept.

The streambed of the Clark Fork was observed to be covered from the Warm Springs settling ponds downstream to between Dempsey and Deer Lodge. This, as Van Meter (1974) observed, was the result of calcium sulfate precipitation. Using a Surber sampler in this area, the EPA found no invertebrates; with an artificial substrate sampler,

invertebrates were collected. This points toward a habitat problem for the invertebrates, which were able to colonize only the artificial substrate.

The EPA based their findings on a beneficial use defined as trout propagation. The section from Warm Springs to Deer Lodge was classified C-$D_2$ - for marginal trout propagation - and was not meeting its goal. However, from Deer Lodge to the Little Blackfoot this goal was being met. For the B-$D_1$ classification applied downstream of the Little Blackfoot, the beneficial use was growth and propagation of trout, and downstream to at least Drummond (the downstream limit of the study) this condition was being met. Thus, in areas where trout were found, water quality was judged to be adequate. Metals criteria for the B-$D_1$ classification were taken from Drummond water samples and at Garrison for the C-$D_2$ classification. A recommendation was made to raise the C-$D_2$ classification to B-$D_1$, and remove the industrial use classification (E-F) from Silver Bow Creek.

Water Quality data collected by the EPA is presented in Tables 7, 8 and 9. As can be seen in Table 7, the Clark Fork and its tributaries have very hard water, though the Clark Fork has much harder water than the tributaries. The mainstream has lower pH, and much higher sulfate and heavy metals levels (except for mercury), all indicative of acidic mining effluent. Table 8 indicates Flint Creek and the Little Blackfoot had samples with extremely high total iron values. Possibly, the high iron content is a symptom of the historical mining disturbances at the headwater of these tributaries (Pedersen, 1977; Ingman and Bahls, 1979).

| Parameter | Warm Springs RM 483.7 No. | Warm Springs RM 483.7 Avg. | Dempsey Creek RM 470.5 No. | Dempsey Creek RM 470.5 Avg. | Deer Lodge RM 461.2 No. | Deer Lodge RM 461.2 Avg. | Tavenner Br. RM 453.8 No. | Tavenner Br. RM 453.8 Avg. | Garrison RM 444.5 No. | Garrison RM 444.5 Avg. | Drummond RM 4.7.0 No. | Drummond RM 4.7.0 Avg. | Average for tributaries |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ph | 17 | 7.2 | 17 | 7.2 | 17 | 7.2 | 17 | 7.3 | 18 | 7.4 | 10 | 7.9 | 7.8 |
| Total alkalinity, mg/l $CaCO_3$ | 16 | 47 | 16 | 92 | 17 | 109 | 17 | 123 | 17 | 120 | 10 | 150 | 159 |
| Total Hardness, mg/l | 16 | 1133 | 16 | 764 | 16 | 755 | 16 | 623 | 16 | 542 | 10 | 434 | 286 |
| Sulfate, mg/l | 3 | 1233 | 3 | 638 | 3 | 515 | 3 | 547 | 3 | 397 | 3 | 260 | 88 |
| Total Copper, ug/l | 18 | 200 | 18 | 130 | 18 | 185 | 18 | 143 | 18 | 91 | 17 | 51 | 37 |
| Dissolved Copper, ug/l | 17 | 42 | 17 | 38 | 17 | 41 | 17 | 47 | 17 | 32 | 11 | 34 | 27 |
| Total Zinc, ug/l | 18 | 810 | 18 | 333 | 16 | 584 | 18 | 286 | 18 | 173 | 18 | 119 | 50 |
| Dissolved Zinc, ug/l | 18 | 432 | 18 | 157 | 15 | 141 | 17 | 122 | 17 | 83 | 10 | 69 | 30 |
| Total Iron, ug/l | 18 | 1765 | 18 | 1280 | 18 | 2167 | 18 | 1367 | 18 | 1275 | 18 | 530 | 205 |
| Dissolved Iron, ug/l | 18 | 141 | 18 | 170 | 18 | 156 | 18 | 157 | 18 | 148 | 11 | 144 | 125 |
| Total Mercury, ug/l | 16 | .8 | 16 | .8 | 16 | .8 | 16 | .8 | 16 | .8 | 16 | .8 | 1.0 |
| Total Arsenic, ug/l | 18 | 30 | 18 | 16 | 18 | 16 | 18 | 15 | 18 | 11 | 12 | 13 | 10.3 |
| Total Cadmium, ug/l | 10 | 15 | 10 | <10 | 10 | <10 | 10 | <10 | 10 | <10 | 15 | <10 | <10 |

TABLE 7. Average water quality for Clark Fork River stations sampled by the EPA in 1971.

| Parameter | Flow Period | Warm Springs Avg. | Warm Springs Max. | Dempsey Avg. | Dempsey Max. | Deer Lodge Avg. | Deer Lodge Max. | Tavenner Ranch Bridge Avg. | Tavenner Ranch Bridge Max. | Garrison Avg. | Garrison Max. | Drummond Avg. | Drummond Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | (High) H | 6.2 | (5.9)[1] | 6.3 | (6.1) | 6.4 | (6.0) | 6.4 | (6.2) | 6.3 | (5.6) | - | - |
| | (Low) L | 7.7 | (7.1) | 7.7 | (6.9) | 7.7 | (7.1) | 7.8 | (7.5) | 8.0 | 7.7 | 8.0 | 7.7 |
| Total alkalinity, mg/l $CaCO_3$ | H | 41 | 48 | 71 | 95 | 85 | 125 | 104 | 190 | 99 | 150 | - | - |
| | L | 50 | 85 | 106 | 137 | 122 | 145 | 134 | 162 | 132 | 142 | 157 | 200 |
| Total hardness, mg/l $CaCO_3$ | H | 713 | 990 | 520 | 785 | 486 | 724 | 457 | 620 | 472 | 973 | - | - |
| | L | 1270 | 1430 | 845 | 1080 | 845 | 1950 | 679 | 900 | 566 | 720 | 434 | 620 |
| Sulfate, mg/l | H | - | - | - | - | - | - | - | - | - | - | - | - |
| | L | 1230 | 1450 | 637 | 800 | 515 | 675 | 547 | 600 | 397 | 420 | 260 | 300 |
| Total copper, ug/l | H | 130 | 220 | 233 | 420 | 408 | 1200 | 215 | 360 | 113 | 160 | - | - |
| | L | 235 | 1360 | 78 | 160 | 74 | 190 | 108 | 460 | 80 | 240 | 51 | 90 |
| Dissolved copper, ug/l | H | 31 | 50 | 29 | 40 | 47 | 70 | 34 | 60 | 26 | 40 | - | - |
| | L | 47 | 70 | 42 | 60 | 39 | 60 | 53 | 190 | 34 | 60 | 36 | 50 |
| Total zinc, ug/l | H | 420 | 720 | 487 | 960 | 1210 | 4700 | 488 | 1000 | 252 | 340 | - | - |
| | L | 1000 | 4200 | 256 | 460 | 211 | 500 | 185 | 500 | 133 | 280 | 102 | 160 |
| Dissolved zinc, ug/l | H | 278 | 580 | 115 | 170 | 127 | 230 | 112 | 220 | 65 | 130 | - | - |
| | L | 508 | 1400 | 178 | 280 | 150 | 240 | 127 | 230 | 93 | 170 | 71 | 140 |
| Total iron, ug/l | H | 1565 | 2800 | 3030 | 6800 | 5650 | 18,000 | 3250 | 7200 | 3160 | 8400 | - | - |
| | L | 1870 | 12,500 | 410 | 1500 | 424 | 1800 | 425 | 2200 | 330 | 1500 | 288 | 800 |
| Dissolved iron, ug/l | H | 118 | 160 | 156 | 220 | 188 | 320 | 173 | 280 | 138 | 180 | - | - |
| | L | 154 | 300 | 176 | 500 | 141 | 300 | 149 | 400 | 153 | 520 | 143 | 300 |

1 ( ) indicates minmums rather than maximums

TABLE 8. Average water quality conditions for high and low discharge periods in the Clark Fork River (from EPA, 1971).

Table 9, which gives average heavy metal values for high and low flows, points to some interesting situations. Normally, one would expect high concentrations of metals during high flow periods as metals are transported mainly in association with sediment and detritus. At Warm Springs, the opposite situation occurs in the case of total copper, zinc, iron and hardness, as the high flows (probably from Warm Springs Creek) were diluting the settling pond effluent. In addition, dissolved zinc was the only metal showing a drastic decrease in downstream samples. Copper and iron slightly decrease or increase downstream of Warm Springs, in both the average values for the sampling period and average values for high and low flow periods. According to the WQB, at least one tributary south of Deer Lodge has high metal content during runoff (Brown, 1982). As the EPA said in their 1971 report, no bioassays using excessive hardness levels found in the Upper Clark Fork are available.

The EPA noted a fish population increase near Dempsey, but felt the population was below its potential, and with the exception of Willow Creek, all the tributaries had better fisheries than the mainstream, and much higher numbers of invertebrates. Most likely, the fishery problem in the Upper Clark Fork below Warm Springs was due to habitat problems - a lack of food (invertebrates) from the coated streambed. The fishery increased about where the streambed ceased to be coated with calcium sulfate, although the excessively high levels of metals dumped during settling pond overflows at Warm Springs might have been sufficiently toxic to prevent a fishery for several miles downstream. At Warm Springs, average levels of zinc were in the range Sinley, et al. (1974)

| Parameter | Lost Creek No. | Lost Creek Avg. | Race Track Creek No. | Race Track Creek Avg. | Dempsey Creek No. | Dempsey Creek Avg. | Little Blackfoot No. | Little Blackfoot Avg. | Warm Springs Creek No. | Warm Springs Creek Avg. | Brook Creek No. | Brook Creek Avg. | Flint Creek No. | Flint Creek Avg. | Overall Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 6 | 8.1 | 6 | 7.4 | 4 | 7.6 | 16 | 7.4 | 10 | 8.1 | 10 | 8.2 | 10 | 7.9 | 7.8 |
| Total alkalinity, mg/l $CaCO_3$ | 6 | 173 | 6 | 89 | 4 | 158 | 16 | 121 | 10 | 201 | 10 | 205 | 10 | 164 | 159 |
| Total hardness, mg/l | 6 | 305 | 6 | 149 | 4 | 412 | 16 | 165 | 10 | 473 | 10 | 292 | 10 | 216 | 287 |
| Sulfate, mg/l | 3 | 96 | 3 | 14 | - | - | 3 | 22 | 3 | 266 | 3 | 101 | 3 | 29 | 88 |
| Total copper, ug/l | 6 | 35 | 6 | 32 | 4 | 48 | 17 | 37 | 9 | 37 | 7 | 37 | 10 | 35 | 37 |
| Dissolved copper, ug/l | 6 | 27 | 5 | 22 | 4 | 33 | 16 | 26 | 9 | 24 | 7 | 29 | 10 | 28 | 27 |
| Total zinc, ug/l | 5 | 38 | 6 | 38 | 4 | 108 | 12 | 38 | 7 | 33 | 9 | 42 | 10 | 55 | 50 |
| Dissolved zinc, ug/l | 3 | 20 | 4 | 18 | 4 | 42 | 10 | 28 | 6 | 30 | 7 | 31 | 10 | 43 | 30 |
| Total iron, ug/l | 6 | 229 | 6 | 174 | 4 | 107 | 17[1] | 796 | 10 | 188 | 10 | 258 | 11[2] | 594 | 335 |
| Dissolved iron, ug/l | 6 | 90 | 5 | 107 | 4 | 80 | 15 | 171 | 10 | 101 | 10 | 160 | 11 | 163 | 125 |
| Total mercury, ug/l | 6 | 1.5 | 6 | 1.5 | 4 | .8 | 16 | .8 | 10 | .7 | 10 | .9 | 10 | 1.0 | 1.0 |
| Total arsenic, ug/l | 6 | 28 | 6 | 5 | 4 | 7.5 | 18 | 8.5 | 10 | 4.7 | 11 | 7.3 | 11 | 11 | 10.3 |
| Total cadmium, ug/l | 6 | 10 | 6 | 10 | 4 | 10 | 10 | 10 | 10 | 10 | 8 | 10 | 8 | 10 | 10 |

1 Average includes two extremely high values obtained during high flow conditions. Average without these values would be 179 ug/l.

2 Average excludes two extremely high values obtained during high flow conditions. Average without these values would be 300ug/l.

TABLE 9. Average water quality for tributaries of the Clark Fork River (from EPA, 1971).

found to be toxic during a 1½-year bioassay. The major benefit of the Butte industrial water treatment system to fisheries below Warm Springs was probably the mitigation of spills or by-passing at the settling ponds, as the new system piped substantially less amounts of water and heavy metals into Silver Bow Creek, allowing better efficiency at the ponds.

Even with the closure of the Anaconda smelter and the Berkeley Pit in Butte, heavy metals will continue to plague the Clark Fork and especially Silver Bow Creek. The Warm Springs settling ponds must continue to function as they will remove metal-laden sediments from Silver Bow Creek and prevent them from moving downstream. Peckham (1979) found very large amounts of tailings between Butte and Gregson ($1.7 \times 10^6$ $m^3$) in the floodplain, along with an increase in total copper, iron and zinc in Silver Bow Creek as it ran by the tailings. Analyses of the floodplain tailings showed a variation in metal content, but conservative estimates indicated $9 \times 10^6$ kg copper and $18 \times 10^6$ kg zinc remain in the tailings. Peckham concludes no feasible solution to the tailings problem exists. The expense of removal would be prohibitive, and while it would reduce the leachate, larger quantities of acidic and mineralized groundwater would be released. Covering the tailings would be ineffective since groundwater leaching would still occur (Peckham, 1979).

Naturally, the treatment ponds contain large amounts of heavy metals. Based on core samples, Neher and Weisel (1977) estimated mass quantities of cadmium, chromium, copper, iron, lead and zinc are stored in Warm Springs pond WS3. At the time of their work, spills and seepage

from the ponds were still occurring. The authors found proportionally higher quantities of cadmium, copper, iron and zinc existed in the pond sediments, so one would expect these metals might be found in downstream biota more readily than lead or chromium.

In an unpublished study, James (1980) found the Clark Fork water quality below the Warm Springs settling ponds to be suffering from high zinc levels year around, and seasonally with arsenic. The seasonal fluctuation, causing effluent from the ponds to exceed standards, occurred during the cooler months, probably due to decreased efficiency of waste removal in the ponds. James also saw problems with sulfate levels below Garrison, seepage from the Opportunity pond system into Warm Springs Creek, and high nutrient levels at the lower pH shack.

## ENRICHMENT AND BIOLOGICAL MONITORING

In order to provide baseline data and systematic monitoring of water quality, the WQB instigated a series of biological water quality monitoring loops. The Clark Fork drainage is contained in two such loops; Silver Bow Creek below the Warm Springs settling ponds and the Clark Fork at Deer Lodge are in the Southwest Loop, while the Clark Fork near Milltown and at Huson is in the Northwest Loop. The first Southwest Loop was completed in 1978, the Northwest loop in 1979.

Analyses include a variety of parameters - common ions, streamflow, algal nutrients, algal assay, periphyton production, and periphyton and macroinvertebrate community structure. Samples are collected once during the spring, summer and fall. The monitoring loops, of which there are five statewide, are completed only once every four or five years due to insufficient funds. The ultimate goal of the Bureau is to translate data into a "single comprehensive, biological water quality index to simplify the ratings of streams and the evaluations of trends" (Bahls, Ingman and Horpestad, 1979).

The first Southwest loop study indicates Silver Bow Creek and the Clark Fork at Deer Lodge are phosphate limited. Algal studies show the percent relative abundance (PRA) of diatoms requiring high levels of oxygen (Achnanthes) sp.) is well above mean values for other streams in the loop. Nitrogen-loving diatoms (Nitchia sp.) have PRA values well below the mean. However, the mean autotrophic index (AI) for the two

sites, an index composed of the ratio of biomass to chlorophyll a, does show a tendency toward enrichment. The levels of ortho-phosphate and total soluble inorganic nitrogen (TSIN) are well above levels considered necessary to cause algal blooms. The number of diatom species and the diversity (d) value for the periphyton community are below average. Even though enrichment occurs in this area of the Clark Fork drainage, this is not an area suffering from severe Cladophora sp. blooms (which start below Deer Lodge) and the Clark Fork below Warm Springs supports an excellent fishery.

The macroinvertebrate analyses from these sites yielded lower than average diversity (d) values, although both have much higher than average populations of pollution intolerant insects. The Silver Bow Creek data are similar to that collected by University of Montana graduate students further downstream at Bonita; Ephemeroptera and Plecoptera are low in numbers while Trichoptera dominate. This points towards a habitat problem as noted by Van Meter in 1975.

In contrast, the Lower Clark Fork, included in the Northwest Loop, was found to be nitrogen limited (Bahls, et al., 1979). Algal productivity is lower than expected at Milltown, and very high (as expected) at Huson. More eutrophic forms of diatoms are found there than at the Upper Clark Fork sites, even though the Lower Clark Fork sites have less TSIN than upstream, and less than the recommended maximum. The oxygen-requiring diatoms Achnanthes sp. have a lower PRA at the downstream sites. Yet these sites have high d values for periphyton and macroinvertebrate communities, and numbers of diatom genera compared to the Upper Clark Fork.

At Milltown, Cladophora sp. is still a major algal component, even though levels of TSIN are much lower than upstream. Its predominance falls off at Huson, where enrichment occurs at higher levels than at Milltown.

If enrichment were the sole source of the Cladophora sp. bloom in the Upper Clark Fork, most of it should exist in the headwaters, tapering off downstream with possibly some resurgence below Missoula. Such is not the case.

Additional evidence can be found in a preliminary study by Knudsen and Hill (1978) concerning diurnal oxygen levels, nutrient loading, and algal accrual studies in the Upper Clark Fork from Deer Lodge to Huson. According to the authors, their biomass accrual data, though depleted by vandalism and not included in the report, indicate periphyton production increases with higher nutrient concentrations. Nutrient concentrations were found to be very high around Deer Lodge, decreasing to very low levels near Missoula. However, the authors note that the Gold Creek area, dominated by Cladophora sp., have low levels of nutrients and low biomass accruals. Possibly, the dominating alga efficiently removes the nutrients and ties them up in its own biomass, making them unavailable for other algae (Reed, 1978).

The most severe nocturnal oxygen sag the authors observed during their study was found at Bonita in July, 1977, a low water year. While absolute levels of dissolved oxygen dipped below six ppm and percent saturation fell to nearly 70% for 5 to 6 hours per night, this by itself would probably be insufficient to deplete the fishery to such low levels as currently exist at Bonita. Similar oxygen levels and percent

saturations are found upstream at Drummond and Deer Lodge and downstream at Turah, areas with much better fisheries. And these lower levels, plus the large range of the extremes are probably only found in low water years. Braico (1973) found similar dissolved oxygen and percent saturation levels in these areas, while Marcoux (1973) found higher ones. Although 6 and 7 ppm oxygen have been used as minima to protect fisheries, other work has shown that 5 ppm is sufficient for trout propagation (Coble, 1982).

EPA data (U.S. EPA, 1975) do not indicate tributaries cause such great improvements in main stem water quality, either by increasing dissolved oxygen, reducing metal concentrations, or reducing nutrient concentrations, to account for increased fisheries. Below the little Blackfoot the Clark Fork still has phosphate and TSIN levels above the recommended maximum. Below Rock Creek the recommended TSIN level was violated in one sample, although Rock Creek does substantially reduce concentrations of nutrients.

The USGS monitored nutrient levels along with other parameters in the Clark Fork from 1969 to 1973 (USGS, 1970-1973). Their data also show a gradual reduction in concentrations with downstream distance.

Some discussion of the characteristics and environmental requirements of Cladophora sp. is appropriate. The following information was gleaned from Whitton (1970) and Bahls (1976). Cladophora sp. is probably the most common or abundant stream alga in the world. It requires flowing water, and is generally most abundant in shallow, rapidly moving water with a substrate composed of bedrock or rocks. In temperate zones, Cladophora sp. favors a temperature range of

10-24° C., high pH, hard to very hard water, high P/N ratios, and enrichment. Although some invertebrates such as chironomids, Caenis sp. and Leuctra sp. inhabit Cladophora sp., it generally provides poor habitat for fish food.

The WQB is reviewing its biological monitoring program to determine its statistical reliability and the natural variation found in biotic communities (WQB, 1982). Sampling will then continue as time and money become available. Some problems with the program should pointed out. Due to the lengthy intervals between sampling, diatom or invertebrate communities could easily recover from perturbations in water quality, before the next sampling circuit. This is especially true of invertebrates which can be extirpated, and then recolonize quickly from upstream, downstream or tributaries.

Diversity indices used by the WQB gained much favor in the late sixties (Wilhm, 1968; Wilhm and Doris, 1966). Through their use one can treat large amounts of data, making comparisons simpler. Also, one need not be an expert taxonomist, all one needed do is distinguish between taxa. However, such indices soon came up against much criticism as a valid test for pollution stress (Moore, 1979; Godrey, 1978; Reed, 1978; Peet, 1975; Hurlbert, 1971; Eberhardt, 1969). The commonly used indices, such as the Shannon-Weaver (1963) and its variations, are actually dominance diversity indices. The value of $\underline{d}$ increases as each spécie is represented more equally in abundance. This characteristic is immediately suspect because natural ecosystems do not behave in this fashion. Therefore, such indices are relying more on species evenness and not on richness. The effect of rare species on $\underline{d}$ depends on the

number of invertebrates in the sample; they will have almost no effect when many individuals are present, and an inordinate effect when the community is small.

Much taxonomic or ecological information is ignored by the use of such indices. Species very tolerant to pollutants may be replaced by very intolerant species with no change in the interpretation of the $\underline{d}$ value. In this way, much information is lost, and not much gained per sample.

Generally, organic enrichment causes a decrease in the number of species, but an increase in the number of individuals, resulting in a simplification of the community structure. Dominance diversity indices are best at detecting this type of change, and only if it is sufficiently drastic. Subtle changes are not detected. However, simplicity is not always indicative of pollution. Reduced numbers of species and individuals will result from toxicants or inert silt. Under such conditions the presence or absence of a specie will depend on its tolerance level, but the available resources will determine its abundance. Several factors will affect the community - habitat, competition, predation, immigration, emigration, food supply, discharge and temperature fluctuations, and scouring. To use a dominance diversity index, one must assume all such factors are insignificant and that the result of pollution is a community with a reduced number of species with high populations, and that the rest of the community has become rare or has disappeared.

Nor can one depend solely on tolerance-intolerance data for macroinvertebrates. Genera contain species that have a wide range of

tolerance to organic and toxic pollutants, and macroinvertebrates are generally much more tolerant than fish anyway (Resh and Unzicher, 1975). Identification to species is a necessity when attempting to assess degradation by presence-absence methods.

Dominance diversity indices, when used to assess degradation of community structure, are only reliable for detecting drastic changes, and are not as valuable an indicator as the condition of a fishery. When such information is available, it should be used to its fullest potential. Unfortunately, fisheries data are much more time consuming and expensive to collect than invertebrate data.

Recognizing all the inherent problems of dominance diversity indices, the U.S. Forest Service has developed an alternative called the Biotic Condition Index (BCI) (Winget and Mangum, 1979). This index uses water quality, stream habitat and environmental tolerances to assess degradation. A major bonus of the BCI is that it compares a stream's condition to its own potential instead of to an ecologically unsound ideal. By using five components - total alkalinity, sulfate, substrate, stream gradient and macroinvertebrate tolerance to these four factors - the BCI accounts for much of the variability that the dominance diversity indices do not. Then a prediction can be made, based on the first four factors at a given site, on what the biotic condition should be. The actual condition is calculated based on invertebrate sampling, and the percent of the predicted value calculated. The BCI also enables prioritization of stream segments, which can save valuable time in assessing where recovery or prevention efforts would best be spent.

## THE FISHERY OF THE UPPER CLARK FORK RIVER

The fishery of the Upper clark Fork has made a remarkable recovery over the last twenty years, as evidenced by Montana Department of Fish and Game Department (now the Department of Fish, Wildlife and Parks) Job Progress Reports. General fishery surveys began in 1957 when a fisheries biologist was added to the Missoula regional office. For this reason, no data on the Clark Fork fishery exists prior to 1957.

Initially, fisheries data were collected mainly in conjunction with pollution events from the mining operations in Butte and Anaconda, or for monitoring the recovery from chronic pollution from these same sources. The first discussion of the fishery's status occurred in 1961 when the Department saw that recent severe mine pollution caused a significant fish kill in the Upper Clark Fork (Whitney and Boland, 1961). The report does not discuss the source or type of pollution, but apparently the event occurred in March of 1960.

During the pollution episode, live cages containing rainbow trout were placed in the river, apparently for the duration of the pollution episode, or until all the fish died. The cages were placed in the Clark Fork at six sites, from three miles above the Milltown Dam to 87 miles downstream of the dam. No mortality data is presented in the report, and high runoff and pollution-induced turbidity prevented direct observation of fish or insect kills. Based on whatever fish mortality

occurred in the live cages, the Department assumed a significant fish kill had occurred and fish populations in the Upper Clark Fork were probably reduced to levels too low to utilize available spawning areas. Thus, the Department closed the Clark Fork to angling from Garrison to the Milltown dam to protect surviving fish for spawning and repopulation. Upstream of Garrison the river remained open to angling because the department thought that lethal pollution would likely occur again in this area, keeping it devoid of a sustaining fishery. No successful angling was known to have occurred there in 1960, a section of river which was then classified as industrial.

The Department conducted a follow-up survey in August of 1960, to study further the effects of the March pollution event. Twenty 300' sections between Warm Springs and Missoula were elctrofished. The results indicate that upstream from Rock Creek there was no fishery. Since the Department determined that less than ten female brown trout per mile existed above Rock creek, they recommended the Garrison to Rock Creek section should remain closed for the 1961 season also.

Serious pollution occurred again when Anaconda Mineral Company (AMC) workers went on strike in 1967 and the treatment facilities at Warm Springs were shut down, causing untreated effluent to enter the Clark Fork. The department initiated another study to analyze any effects (Spence, 1968). Four sections of the river were surveyed, a 5,600' section north of Deer Lodge between the Williams-Tavenner bridge and the Clark Fork Veterinary Clinic, a 1,500' section about 1/8 mile downstream of the confluence with Dry Cottonwood Creek, a 1000' section downstream of the first county bridge over the Clark Fork below the Warm

Springs settling ponds, and a 200' section above the county bridge near Racetrack. While insufficient time between mark and recapture runs was allowed, the results of the survey revealed no fishery existed from the Warm Springs settling ponds downstream to near Dry Cottonwood Creek, roughly twelve miles of stream. As this section contained very good habitat, the Department felt the limiting factors were chemical or biological. The direct effects of the 1967 pollution could not be assessed because prior data showed no fishery existed in this section of the river anyway. The section between the Veterinary Clinic and the Williams-Tavenner bridge was found to have a brown trout population, although not a very good one.

Eight sections of the river were surveyed during 1969 and 1970, in another attempt to assess water pollution damage resulting from the AMC strike of 1967 (Spence, 1970). The sections began two miles upstream of Six Mile Creek and ranged intermittently upstream to the county bridge near the AMC pH shack. The Gold Creek to Jens section appeared to have a viable brown trout population, as did the section from the Verterinary Clinic to the Williams-Tavenner bridge. This section, surveyed during the Anaconda Company strike, was estimated to have 362 brown trout in 1967. This time, an estimate of 559 brown trout was achieved, although the estimates were not statistically different. Upstream of this section, a very poor or non-existent fishery was observed. A 5.4 mile section from the county bridge above Racetrack downstream to the next county bridge yielded only 124 trout. For over two miles below the AMC pH shack (in what has become known as the pH shack section), no fish were captured. This section had no fishery since surveillance began in

1957 (Spence, 1970). But this was better than the twelve miles of fishless river that had existed downstream of the settling ponds in 1967.

The Job Progress Report of 1971-1972 (Marcoux, 1973) states that a closed water system was scheduled to go into operation in Butte during the fall of 1972. It was hoped that the system would eliminate much of the heavy metal pollution in the Clark Fork, so the Department again surveyed the river in April 1972, downstream of the Warm Springs ponds to acquire pre-system data. The Williams-Tavenner Bridge section (1.1 miles) showed statistically fewer brown trout (at the 95% confidence level) than the 1967 or 1969 estimates. However, more whitefish were present. Due to the relative scarcity of brown trout less than 12.0" long in this area, the Department felt that spawning success may have been limited. Intergravel studies were recommended to assess spawning conditions. The Racetrack Creek section (5.4 miles) survey indicated fewer trout than were found in 1969, and the presence of whitefish, which were absent in 1969. Prior to 1969, no fish had been electro-fished in this section; in 1972 four brown trout, 3 whitefish and one longnose sucker were caught (Marcoux, 1973). The length of the section and the low number of fish captured rendered the data questionable, so the Department recommended dropping it from further study in favor of a more intensive effort on the pH shack section.

The following year, the Department again attempted to discern the effects of the June, 1967 "acid mine spill" which occurred during the strike (Peters, 1975a). The report also states the Clark Fork literally ran red downstream to Drummond on 2 January, 1972, and to Deer Lodge

on 1 March, 1972. No mention was made of this in the report covering that period. Obviously, any effect of those events would be impossible to separate from the 1967 problem.

Attempting to document the 1967 pollution, two established electrofishing sections in the Upper Clark Fork were again analyzed (Peters, 1975a). The pH shack section showed a substantial increase in brown trout, while rainbow trout, whitefish, suckers (longnose and largescale), and redsided shiners had also increased since 1969 when no fish were found. Only the data from April 1974 is appropriate for population estimates. The Department estimated population of 846 ± 305 brown trout and 979 ± 205 longnose suckers. The Department felt brown trout reproduction was occurring here for the first time in years, and the condition of the trout appeared comparable to other fish in the drainage.

Brown trout and mountain whitefish were still thriving in the Williams-Tavenner section, fifteen miles downstream of the pH shack section and three miles downstream of Deer Lodge (Peters, 1975a). The report states mountain whitefish were apparently hardest hit by the acid water in 1967, but the data do not reflect this. Insufficient data on fish populations and water quality exists to say more than the Upper Clark Fork fishery had been recovering up until 1972. The "red river" episodes of 1972 does not seem to have affected the whitefish population, but brown trout numbers declined in 1972, although the decrease was not statistically significant. According to the data presented in the report, no brown trout were collected in the fall of 1973. The report considers the increase in whitefish during the fall a

possible result of upstream spawning movement; the same should be true for brown trout populations. But the data do not indicate this.

The pH shack section was sampled again in October, 1974. The brown trout population again increased although not to statistically different levels. This time, the increase may have been a result of upstream spawning migration (Peters, 1975b).

Brown trout populations were still increasing in September of 1976 when the pH shack was next surveyed. An estimate of 1522 ± 420 was made. No estimates for other species were made, although catch per trip data show a general increase. The Williams-Tavenner Bridge section continued to show a depressed population when compared to previous populations (1969) or the pH shack section fifteen miles upstream. Condition factors in this section had decreased, especially for the larger brown trout. The Department believed sedimentation and nutrient loading may have been the cause. Local residents reported fish kills in 1973, a period of high temperatures and low flows (Vashro and Peters, 1977).

For the first time, in November of 1976, the Department decided to investigate the amount of available spawning area and its usage in the Upper Clark Fork and its tributaries. Upstream of Deer Lodge, the river appeared to be lacking in suitable substrate from deposition of calcium sulfate, ferric hydroxide and heavy metals, but below Deer Lodge the substrate was thought to be suitable. Warm Springs Creek was found to be the most important spawning tributary. This fact could account for the continually increasing population in the pH shack section while the Williams-Tavenner section does not have good numbers of trout. Dempsey,

Racetrack, Lost, Tin Cup Joe and Cottonwood Creeks all had siltation or low flow problems. The Little Blackfoot had spawning activity, but major portions of the river had been altered by bulldozers. The unaltered sections contained many more redds than the altered sections. Thus, the effective spawning areas in the Upper Clark Fork as of November 1976 appear to have been very limited from the Little Blackfoot upstream to Warm Springs Creek (Vashro and Peters, 1977).

Since 1976, the fishery of the Upper Clark Fork has developed into a good fishery below the confluence of three tributaries, Warm Springs Creek, the Little Blackfoot, and Rock Creek (Peters, 1981). Unfortunately, the most recent data are not available, but Table 10 summarizes fisheries data from the pH shack section of the Clark Fork. The dramatic increase in trout from the late sixties to the seventies is readily apparent, as is the existence of a much better fishery in the pH shack section than in shocking sections further downstream (Table 11). Table 12 summarizes data from the Williams-Tavenner section, which is a few miles downstream of Deer Lodge. The fishery seems to have recovered somewhat and now approaches numbers found in 1969.

While the fishery in the Upper Clark Fork is recognized to be enhanced by the influence of a few tributaries, very few attempts have been made to determine why the fishery suffers throughout the rest of the river. The widely held assumption is that water of high quality enters the Clark Fork from these tributaries and allows for more fish propagation. This is doubtful, because the water quality data do not show any toxicant levels that are diluted below the tributaries only to increase again several miles downstream. Any attempts at explaining the

TABLE 10. Single trip electrofishing results from the pH shack section of the Upper CLark Fork River, 1966-1977. (From Vashro and Peters, 1977.)

| Year | | Species | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Brown Trout | Mountain Whitefish | Dolly Varden | Rainbow Trout | Brook Trout | Longnose Sucker | Large-scale Sucker | Redside Shiner |
| 1967 | (summer) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | (summer) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1972 | (spring) | 4 | 3 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1972 | (fall) | 35 | 51 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1973 | (spring | 29 | 1 | 0 | 1 | 0 | 16 | 0 | 0 |
| 1973 | (fall) | 89 | 33 | 0 | 4 | 1 | 55 | 4 | 7 |
| 1974 | (spring) | 98 | 6 | 0 | 3 | 6 | 130 | 7 | 33 |
| 1974 | (fall) | 117 | 3 | 1 | 1 | 0 | 30 | 5 | 33 |
| 1976 | (fall) | 97 | 29 | 2 | 2 | 0 | 13 | 5 | 11 |
| | | per/mile | | | | | | | |
| 1977 | (spring) | 318 | | | | | | | |
| 1978 | " | 802 | | | | | | | |
| 1979 | " | 1405 | | | | | | | |
| 1980 | " | 1303 | | | | | | | |
| 1981 | " | 987 | | | | | | | |

TABLE 11. Population estimates of brown trout in the Upper Clark Fork River, 1980-1981. (From Vashro, 1982.)

| Section | Date | Size Range | Trout/Mile | 80% Confidence Interval |
|---|---|---|---|---|
| pH | 9/2/80 | 6.0-22.4 | 1514 | 1214-1787 |
| | 3/24/81 | 6.0-18.5 | 987 | 875-1099 |
| | 9/2/81 | 6.0-20.9 | 1610 | preliminary estimate |
| Williams-Tavenner | 9/3/80 | 6.0-17.2 | 249 | 198-300 |
| | 3/25/81 | 6.5-17.1 | 245 | 175-315 |
| | 9/3/81 | 6.0-16.4 | 278 | preliminary estimate |
| Phosphate | 7/29/80 | 5.0-17.6 | 315 | 272-358 |
| | 8/10/81 | 6.0-18.9 | 224 | preliminary estimate |
| Sager Lane | 8/11/81 | 6.0-17.4 | 418 | preliminary estimate |

| Species | Date | Length Range | Population Estimate | 80% C.I. |
|---|---|---|---|---|
| Mountain Whitefish | 8/69 | 10.0-16.9 | 1430 | ± 557 |
| | 4/72 | 9.0-16.9 | 2555 | ± 754 |
| | 11/72 | 10.0-17.9 | 2866 | ± 890 |
| | 11/73 | 10.0-13.9 | 4148 | ± 908 |
| | 11/73 | 14.0-18.9 | 356 | ± 109 |
| Brown Trout | 8/69 | 10.0-18.9 | 307 | ± 111 |
| | 4/72 | 9.0-18.9 | 111 | ± 36 |
| | 11/72 | 10.0-12.9 | 91 | ± 29 |
| | 11/72 | 13.0-21.9 | 83 | ± 27 |
| | 9/80 | 6.0-17.2 | 249 | ± 51 |
| | 3/81 | 6.5-17.1 | 245 | ± 70 |
| | 9/81 | 6.0-16.4 | 278 | - |

TABLE 12. Population estimates of brown trout and mountain whitefish in the Williams-Tavenner section of the Upper Clark Fork. Refer to Fig. 1. (From Peters, 1975a; Vashro, 1982.)

variations in the fishery are hampered by a lack of information on habitat quality, and heavy metals in the sediments and in the food chain.

One study conducted expressly to look at that problem was carried out by University of Montana graduate students under the supervision of Montana DFWP personnel (Barseness, et al., 1979). Fish and invertebrate surveys were made in the Clark Fork above Rock Creek at Bonita, in Rock Creek, and below Rock creek at Turah. Table 13 contains these data, and the difference in fish populations is clearly evident.

The significance of the invertebrate data lies in the biology of the insects found at each site, although one can easily see that Rock Creek is the most productive, followed by Turah and then Bonita. The researchers noted much more sedimentation at Bonita, so habitat would obviously play a large role in the difference. However, if nutrient loading were causing the depleted fishery, one might expect to find higher numbers of pollution tolerant insects in the Clark Fork, higher than in Rock Creek. Only chironomids, many species of which are pollution tolerant, are more common in the Clark Fork than in Rock Creek.

According to Merritt and Cummins (1978), almost all of the insects found at Bonita are filter feeders or collectors of detritus; the remaining few insects are predators. The other sites have a healthier mix of insects which include large numbers of primary consumers generically referred to as "scrapers", insects that rely on diatoms and other periphyton of a desirable nature. The dearth of such insects at Bonita points to lack of a food source for them. The sediment, either

TABLE 13. Insect and Fish populations taken from two stations on the Upper Clark Fork River, and one on Rock Creek (from Barsness, et al., 1979).

**Insects**

| Taxa | Turah | Rock Creek | Bonita |
|---|---|---|---|
| Plecoptera | | | |
| Perlodidae | 124 | 96 | 39 |
| Pteronarcidae | 35 | 232 | 0 |
| Perlidae | 15 | 10 | 2 |
| Chloroperlidae | 37 | 7 | 2 |
| Nemouridae | 10 | 19 | 0 |
| Ehpemeroptera | | | |
| Heptageniidae | 143 | 30 | 12 |
| Ephemerellidae | 751 | 322 | 219 |
| Baetidae | 72 | 89 | 131 |
| Siphlonuridae | 59 | 7 | 40 |
| Trichoptera | | | |
| Hydropsychidae | 193 | 1318 | 47 |
| Rhyacophilidae | 0 | 5 | 0 |
| Glossosomatidae | 0 | 13 | 0 |
| Odontoceridae | 11 | 15 | 0 |
| Diptera | | | |
| Athericidae | 12 | 87 | 81 |
| Chironomidae | 272 | 278 | 450 |
| Ceratopogonidae | 99 | 60 | 86 |
| Simuliidae | 17 | 64 | 2 |
| Tipulidae | 21 | 11 | 11 |
| Coleoptera | | | |
| Elmidae | 90 | 123 | 6 |
| Odonata | | | |
| Gomphidae | 0 | 0 | 5 |
| Lepidoptera | 2 | 0 | 0 |

**Salmonids (pop. + 80% C.I.)**

| Species | Turah | Bonita |
|---|---|---|
| Rainbow trout | 80.0 ± 85 | 5.78 ± 3.73 |
| Brown trout | 264 ± 197 | 36.9 ± 17.73 |
| Cutthroat trout | 3.45 ± 3.5 | 4.44 ± 2.14 |
| Brook trout | 5.77 ± 7.4 | 0 |

because it covers appropriate habitat, or contains toxic metals shifting the algae population toward less desirable green algae, is likely the cause. Insects such as simuliids, requiring both attachment sites and adjacent periphyton, would not do well under such conditions. Hydrophychids have been found to be indicative of organic enrichment, and ephemerellid and baetid mayflies are tolerant of heavy metals (Godfrey, 1978). These insects are major components of the insect community at Turah. Of course, synergistic effects of sedimentation and enrichment may be sufficient to deplete several taxa, without a consideration of heavy metals. Incidentally, the functional group classification developed by Merritt and Cummins (1978) is in itself a good index to water quality, and a good way to obtain information from single samples, information which is missed by diversity indices (Herricks and Cairns, 1982).

These data lend further weight to the proposition that the food chain and habitat are limiting factors to restoring a trout fishery throughout the Upper Clark Fork. Heavy metals in sediments may encourage growth of Cladophora sp. over more desirable diatoms. Nutrient loading from municipal sources (and the AMC operations) can have the same effect, but if they are not at sufficient levels to cause an algal bloom, the nutrients will still stimulate growth of the Cladophora sp. regardless of the cause of its dominance in the algal flora. The nuisance algae may be causing problems with dissolved oxygen, but insufficient data are available to be positive. If true, it would be reason to expect trout populations to drop where the blooms are heaviest.

As mentioned, the fishery is best below a few major tributaries, although the Little Black foot appears to have less effect than Warm Springs Creek or Rock Creek. This is not true below the Blackfoot River. I believe the reason for the increase in trout is the scouring action of additional flows from the tributaries, as they do not add appreciable amounts of toxicants or sediment. (Flint Creek and the Blackfoot River do have sediment problems.) The increased flow partially cleans the substrate and prevents accumulation of contaminants from upstream. If nutrient loading was the main reason for declines in the fishery, the stretch between Warm Springs Creek and Deer Lodge would have Cladophora sp. blooms and the fishery would be of po r quality. Neither is true. After the quality of the Warm Springs settling ponds' effluent was improved and the AMC upgraded its Butte operations, the substrate improved, allowing for the development of a good fishery.

If sediment is the major cause of fishery problems, then the situation should gradually improve as the sediment moves downstream until most of it accumulated in the Lower Clark Fork - where it will cause degradation to habitat. The gradient of the Clark Fork increases as it flows downstream, until it reaches Missoula (U.S.D.A, 1983); this should help prevent siltation problems. Below certain tributaries the fishery will remain better than other areas of the Clark Fork. If nutrient levels are mitigated, the algal blooms would likely diminish, thus improving the fishery. Besides the usual problem of oxygen depletion, benthic algae protects sediment from the cleansing action of river currents.

Recent work (Tada and Suzuki, 1982) indicates that not only does adsorption of heavy metals by sediment increase as particle size decreases, but the amount of organic material in the particle increases the adsorption rate. Smaller sediment particles have been found to contain more organic material, and as a result have a higher cation exchange. In fact, the amount of organic matter is more important than surface area in controlling adsorption. If true, this would allow for direct entry into the nutrient cycling pathways so crucial to lotic systems. Aquatic insects offer a good example of the amount of heavy metals in a stream system. These insects can accumulate metals from either dissolved concentrations, or directly from sediments and organic matter. Insects exposed to dissolved lead have been shown to lose the accumulated lead sooner than those exposed to lead contaminated sediments (Nehring, Nisson and Minasion, 1979).

Since the type of exposure influences the accumulation and retention of heavy metals, site-specific studies are necessary. To determine how the water quality of a stream compares to the amount of heavy metals in stream biota, one can analyze aquatic invertebrates. By comparing concentrations of metals in the water to those in the invertebrates, an accumulation factor can be calculated. The results will indicate whether water quality criteria are protecting the biota from heavy metals (Holloran, 1982), as sediments will adsorb metals from the water column. Sediments, however, do not react quickly to increased metal loads, so in most cases where metal loading is a problem, watershed runoff is a main source of mitigation - by dilution (Holloran, 1982). This apparently is not the case in the Upper Clark

Fork, where increased runoff leads to higher heavy metal concentrations (Brown, 1982). One might expect this given the amount of past mining activity and tailings in the drainage.

# THE MILLTOWN DAM

Operation of the Milltown Dam by the Montana Power Company (MPC) is the major source of heavy metals and sediment in the Lower Clark River Fork. The sediment accumulated behind the dam is released during semi-annual and major drawdowns. The sediment is the result of erosion in the Blackfoot drainage and in the flood plain of the Upper Clark Fork drainage where there are deposits of mine tailings. The tailings are the main source of heavy metals.

The dam is over seventy years old and has been modified in 1920, 1930 and 1978. Much of the original dam has been replaced by a concrete gravity dam, including a 244' section to the right of the powerhouse and in front of the old rock-filled structure, and the 152' upstream wall of the powerhouse which contains the penstocks. Four 9'x14' high sluice gates are located to the left of the powerhouse in a concrete section 52' long which rests on part of the original rock-filled dam (FERC 1979 Operation Report, App. A). The old wooden sections of the dam require the most maintenance.

According to the Federal Energy Regulatory Commission (FERC) Operation Report of 1979 (App. A), operation of the dam requires drawing down the pond twice a year to allow the addition or removal wooden flashboards. The flashboards cannot be raised or lowered while the pond is above crest level (top of the timber crib structure - elevation

3251.9). Thus the semi-annual drawdowns to crest level are necessary. With the flashboard assembly in place, the pond is raised to 3259.7'.

Major drawdowns, those over twenty feet in depth, cause the most sediment and heavy metal problems associated with the dam operation. The reason for major drawdowns seem to involve the old structures: the wooden drop gates (flashboard assembly), the wooden spillway or the rock-filled cribs. Several major drawdowns have taken place, one on March 22, 1971, another on December 22, 1972, followed by another on December 27, and one commencing January 18, 1973. A lengthy, although minor, drawdown occurred during the summer of 1981 to repair the flood-damaged spillway.

The first major drawdown for which data exist is the March 22, 1971 drawdown which lasted two weeks, several days longer than most. In all cases, data were collected by the Missoula DFWP personnel. These water quality data are located in Figures 2 and 3. Unfortunately, only two sites were sampled, one 300 yards below the dam, and another five miles below the dam. The data as presented in Job Progress Report F-12-R-17 (Marcoux, 1970) do not specify exactly when the sampling began, but apparently it started after the drawdown had begun. No upstream data, either in the Clark Fork or Blackfoot, were collected. The type of analysis used to detect the presence of heavy metals is not indicated, but given the extremely high values found, one can assume the values were total recoverable (TR). This was the method used during analysis used to detect the presence of heavy metals is not indicated, but given the extremely high values found, one can assume the values were at least total recoverable (TR). This was the method used during

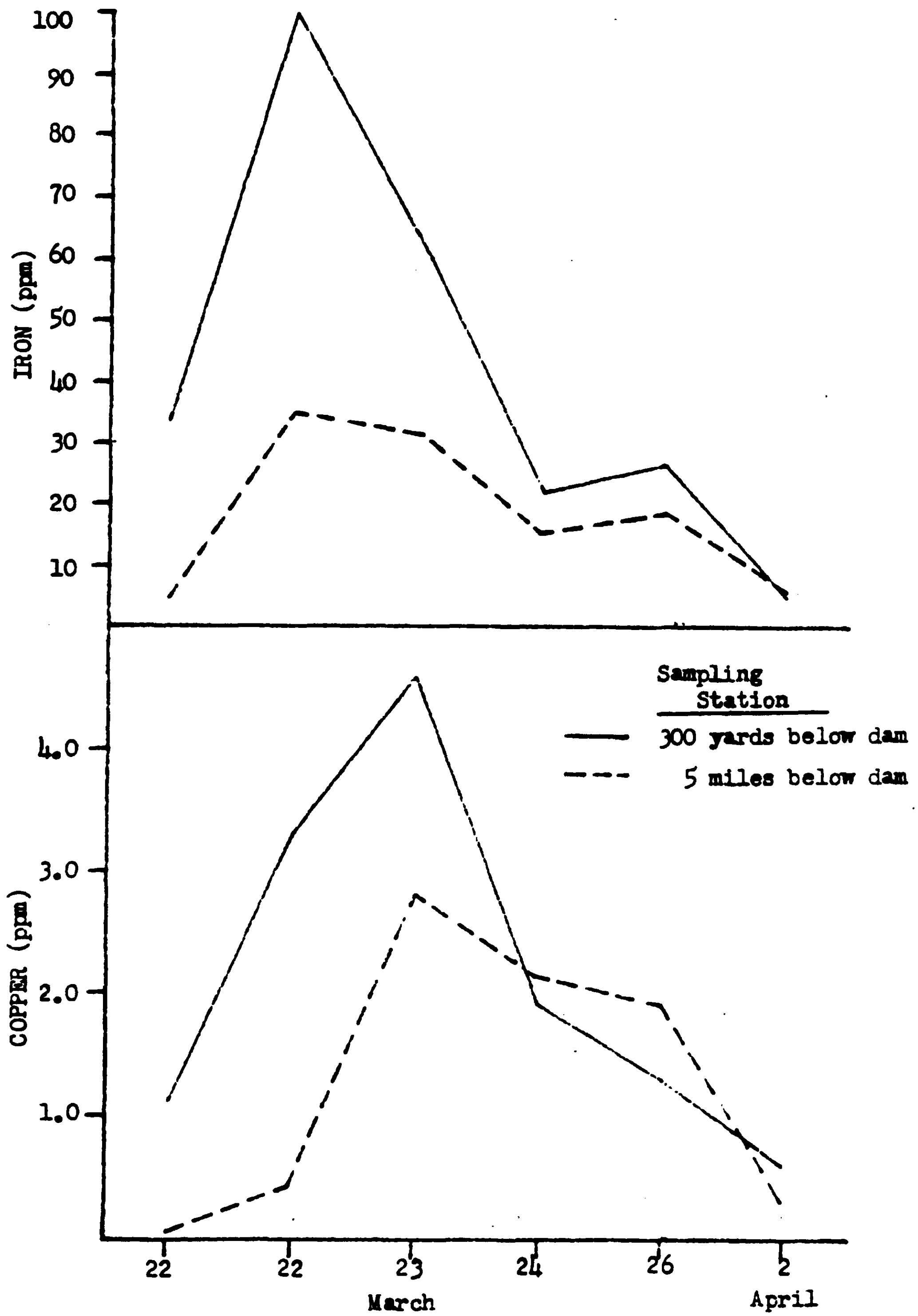



FIGURE 2. Amount of iron and copper in water samples collected from two stations downstream of Milltown Dam during the March 22, 1972 drawdown.

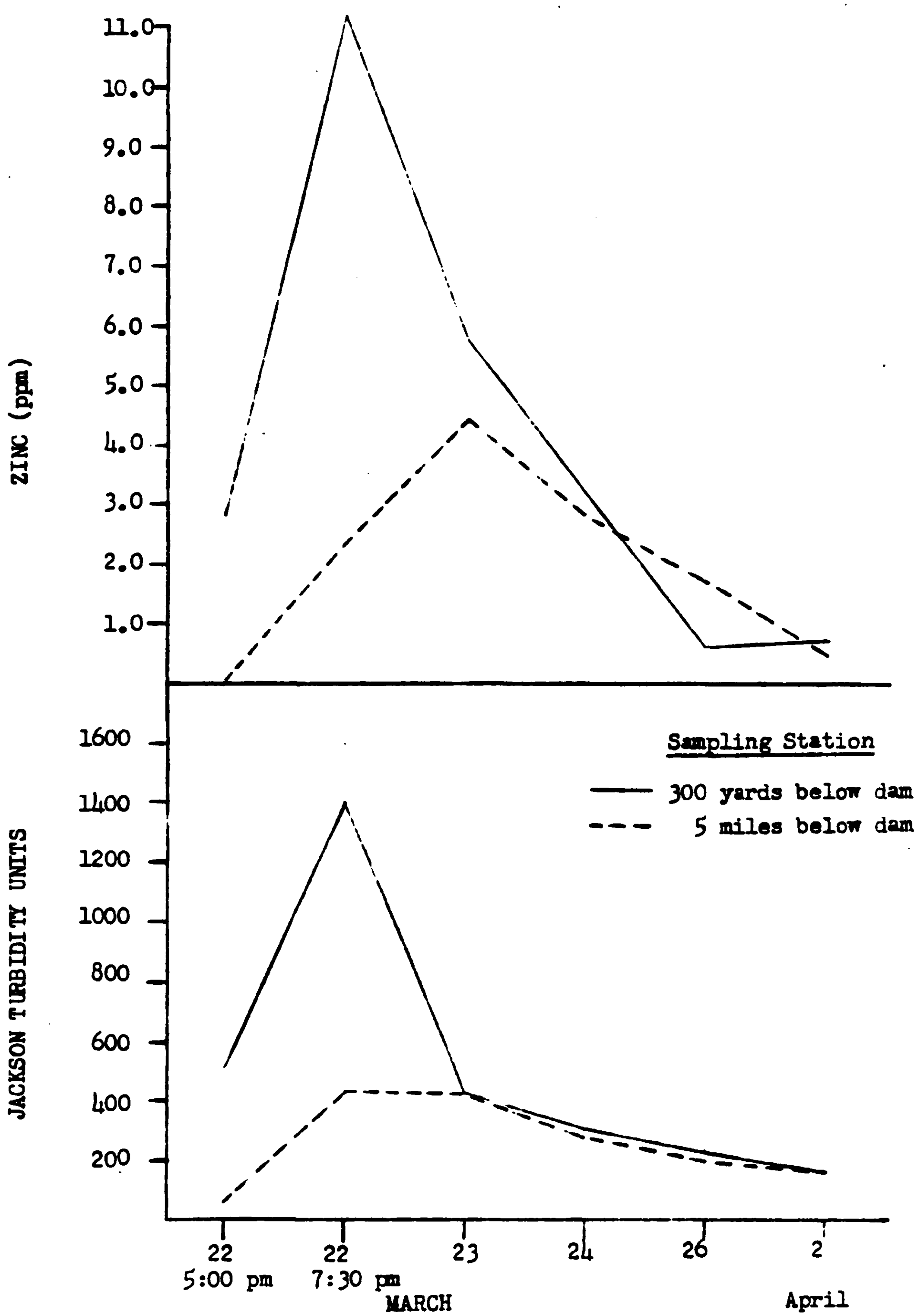



FIGURE 3. Amount of zinc and turbidity in water samples collected downstream of Milltown Dam during the March 22, 1972 drawdown.

the December 1972 drawdown, and the State Water Quality Lab performed analyses in both cases. Also, the report presents data in the form of graphs, so exact values are not apparent. However, both old and current water quality standards for the Clark Fork were exceeded by a factor of ten from the day of the drawdown until sampling ended on April 2. The maximum allowable turbidity increase was and remains five Jackson Turbidity Units. Since the exact location of the most downstream site is not given, one cannot determine if dilution from tributaries occurred. If not, the data indicate a large amount of sediment and associated heavy metals settled out between the dam and Missoula. The lack of a suitable sampling program renders much of the data inconclusive, except to say the drawdown caused large amounts of silt and heavy metals to enter the Lower Clark Fork.

During the drawdown, live cages containing catchable size (7"-9") hatchery rainbow trout were placed .5 and five miles downstream of the dam, with a control placed somewhere in the Blackfoot. The cages were placed in the rivers on March 24, the second day after the drawdown began. Within five days, 80% of the trout .5 miles downstream and 40% at the station five miles downstream of the dam died. One fish died in the control group. On the fifth day the trout were replaced with 2"-4" hatchery rainbow trout. The eighth day following the drawdown, 100% mortality occurred .5 miles downstream of the dam, while all trout five miles downstream in the Clark Fork and in the control group survived. Data are presented in Table 14. The Fish and Game Department biologist (Ron Marcoux) observed a dying brown trout (8"long) with mucus-coated gills, at the station five miles downstream of the dam. Heavy metal

TABLE 14

Mortality of caged hatchery rainbow trout during the March, 1971 Milltown Dam drawdown.

| | # fish | Number of dead trout | | | | | |
|---|---|---|---|---|---|---|---|
| 7-9" trout | in cage | 3/24 | 3/25 | 3/26 | 3/27 | 3/28 | Total |
| Clark Fork: | | | | | | | |
| .5 miles downstream | 5 | 0 | 0 | 1 | 1 | 1 | 4 |
| 5 miles downstream | 5 | 0 | 0 | 0 | 1 | 1 | 2 |
| Blackfoot: | | | | | | | |
| 3 miles upstream | 8 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2-4" trout | | 3/29 | 3/30 | 3/31 | 4/1 | 4/1 | Total |
| Clark Fork: | | | | | | | |
| .5 miles downstream | 20 | 0 | 0 | 8 | 11 | 1 | 20 |
| 5 miles downstream | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blackfoot: | | | | | | | |
| 3 miles upstream | 20 | 0 | 0 | 0 | 0 | 0 | 0 |

contamination will cause this reaction, which is either a symptom of poisoning or the cause of death. No mention is made of acclimation time for the trout or why they were not placed in the river prior to the drawdown. Acclimation does not seem to have been a factor, as only one of the control fish died during both exposures, but no controls were placed in the Clark Fork upstream of the dam. The data indicate that the drawdown caused heavy metals or sediment in the river to reach levels toxic to fish, especially the smaller size classes.

The next major drawdown for which data are available occurred December 27, 1972. This was a 16' drawdown, 8' below crest, precipitated by the collapse of part of the flashboards. The drawdown lasted eighteen hours. The Fish and Game Department can hardly be blamed for not being well prepared to monitor this drawdown as MPC informed the regional office in Missoula at 4:40 PM the day of the drawdown (Office memo from Jim Posewitz dated 29 December 1972, App. B). The time mentioned for the drawdown was 8:30 PM, but it was actually stared at 8:00. Once again pre-drawdown samples were not collected.

The Fish and Game Dept. did ask MPC to delay the drawdown twelve hours so preparations could be made to monitor the event (Posewitz, App.B). MPC said the delay was impossible to grant, but no reason was given. At the same time, MPC stated in a press release the decision to drain the dam had been made earlier in the week, and the drawdown would pose no danger to people downstream. In the same press release MPC stated the Fish and Game Dept. had been notified, yet they gave the Dept. less than four hours notice and then started the drawdown one half-hour earlier than had been stated (MPC Press Release, App. C).

Due to the lack of time prior to the drawdown, no live cages were placed in the river. Water quality data collected during this drawdown are presented in Table 15. The State Water Quality Bureau Lab performed the analyses. Unfortunately, dissolved concentrations were not recorded so comparisons to literature values for acute toxicity is not possible. Once again, turbidity standards were exceeded, as were standards for total iron, zinc, cadmium, lead and copper. The analyses of the samples yielded total recoverable values less than would be expected for total analyses, which involve a more rigorous acid digestion. Even so, the maximum instantaneous total concentration criteria were exceeded in every sample collected downstream of the dam, except for the TR cadmium sample collected 20:05 on 27 December. However, the total cadmium criterion was also exceeded in the Clark Fork in three of the five samples taken upstream of the dam, and the total lead criterion was exceeded in three of five samples from the Blackfoot. Given the history of mining in both drainages, this should not have been too surprisng. With the exception of TR lead, the heavy metals increased by a factor of ten or more downstream of the dam.

After an inspection of the dam on 27 December, MPC developed a plan to replace the decking from the "upstream and crest sections of the dam and replace them with an articulated concrete mat" (Letter from R. Whelchel to D. Willems dated 11 January 1973, App. D). This would preclude use of the flashboard structure and the need for semi-annual drawdowns. MPC stated in the same memo: "An evaluation of more complete repairs to the whole structure after runoff is also under consideration." Meanwhile the pond was held at crest level (3,251'),

| Station | Date | Time | Turbidity | Total Fe | TR Zn | TR Cd | TR Pb | TR Cu | Dissolved Solids |
|---|---|---|---|---|---|---|---|---|---|
| 1st bridge up from dam (Blackfoot River) | 12/27 | 2100 | 2.9 | .15 | .01 | .002 | .06 | .03 | .1 |
| | 12/27 | 2310 | 3.0 | .24 | .02 | .004 | .08 | .03 | .2 |
| Anaconda campground (Blackfoot River) | 12/28 | 0405 | 1.4 | .09 | .01 | .005 | .08 | .01 | .1 |
| | 12/28 | 1000 | 2.7 | .33 | .04 | .008 | .03 | .01 | .3 |
| | 12/28 | 1550 | 2.7 | .31 | .02 | .006 | .05 | <.01 | .3 |
| Clark Fork at Turah campground | 12/27 | 2035 | 3.6 | .31 | .07 | .019 | .11 | .05 | .3 |
| | 12/27 | 2255 | 3.4 | .24 | .05 | .009 | .08 | .04 | .2 |
| | 12/28 | 0350 | 4.7 | .36 | .06 | .008 | .06 | .04 | .4 |
| | 12/28 | 0930 | 4.5 | .25 | .08 | .022 | .08 | .07 | .3 |
| | 12/28 | 1610 | 3.6 | .28 | .06 | .13 | .06 | .06 | .3 |
| | 12/28 | 2015 | 88 | 7.7 | 1.31 | .011 | .23 | .48 | 7.7 |
| Clark Fork at Hughes Garden | 12/27 | 2005 | 23 | 1.4 | .21 | .01 | .14 | .55 | 1.4 |
| | 12/27 | 2220 | 28 | 2.4 | .33 | .020 | .05 | .10 | 2.4 |
| | 12/28 | 0315 | 66 | 7.1 | .93 | .023 | .07 | .42 | 7.1 |
| | 12/28 | 0900 | 25 | 2.2 | .32 | .022 | .13 | .13 | 2.2 |
| | 12/28 | 1630 | 63 | 4.9 | .65 | .021 | .06 | .45 | 4.9 |
| Clark Fork at bridge below dam | 12/27 | 2015 | 88 | 7.7 | 1.31 | .011 | .23 | .48 | 7.7 |
| | 12/27 | 2235 | 140 | 24 | 2.4 | .020 | .38 | 1.73 | 24 |
| | 12/27 | 2325 | 110 | 18.4 | 1.88 | .021 | .32 | .98 | 18.4 |
| | 12/28 | 0330 | 78 | 2.5 | .78 | .015 | .13 | .27 | 2.5 |
| | 12/28 | 0915 | 97 | 18.2 | 1.94 | .015 | .33 | 1.23 | 18.2 |
| | 12/28 | 1330 | 89 | 12.6 | 1.55 | .017 | .27 | 1.06 | 12.6 |
| | 12/28 | 1530 | 45 | 12.1 | 1.5 | .016 | .25 | .86 | 12.1 |

TABLE 15. Water quality data (ppm) from the Dec. 27, 1972 Milltown Dam drawdown.

about 8' below the top of the damaged wooden drop gates. MPC mentioned in the memo they wanted to maintain the pond between 3,248' and crest to minimize siltation during construction. No mention was made as to when work would begin.

On January 18, 1973, MPC again informed the Fish and Game Department the pond was to be lowered to 3,250' to examine the crest and make repair specifications for the contractor. The pond would then be lowered to 3,247' to study the apron for the same reason. This time MPC called Fish and Game Department headquarters in Helena at 4:45 PM, and the Missoula office was informed at 4:50 PM (Memo from Jim Posewitz to MPC dated 18 January 1973, app. E). Even though the DFWP was not given advance warning, live cages were set in the river after the drawdown began since this was a protracted drawdown. Only turbidity samples were collected (Table 16), and no pre-drawdown data were obtained. For nine days following the onset of the drawdown, turbidity standards were exceeded. Live cage data are presented in Table 17. Both wild and hatchery trout were used. A problem with control hatchery trout did occur on the Blackfoot as half of them died. However, in both cases, all the trout placed below the dam died. While not indisputable evidence, certainly a strong indication that the drawdown had acute effects on trout that could not escape the silt and heavy metals. And the caged wild trout were dying after the worst of the sedimentation had occurred.

No major drawdowns have occurred since the January 1973 event, although one has been planned since April of 1980. The State WQB has decided that MPC now needs a permit to exceed turbidity standards.

| Date | Clark Fork at Turah | Blackfoot at Anaconda Cd. | Clark Fork at Railroad trestle below dam | Clark Fork at Hughes Garden |
|---|---|---|---|---|
| 1/19 | -- | -- | 58* | -- |
| 1/20 | 2.0 | 1.5 | 40 | -- |
| 1/22 | 2.0 | 1.4 | 31 | -- |
| 1/23 | 2.3 | 1.4 | 20 | 19 |
| 1/24 | 1.8 | -- | 26 | 21 |
| 1/26 | 2.2 | 1.1 | 20 | 49 |
| 1/27 | 2.9 | 1.2 | 13 | 19 |
| 2/1 | 1.2 | 1.2 | 2.9 | 35 |
| 2/2 | 1.5 | 1.4 | 3.1 | 12 |
| 2/4 | 1.3 | 1.2 | 2.8 | 4.0 |
| 2/6 | 2.0 | 1.8 | 4.6 | -- |
| 2/8 | 1.0 | 1.0 | 8.0 | -- |
| 2/14 | 2.0 | -- | 12 | 45 |

* Jackson Turbidity units

TABLE 16. Turbidity data collected by DFWP during the Jan. 18, 1973 Milltown Dam drawdown.

| Hatchery trout Station | Number placed in cage on Jan. 24 | Number dead Jan. 24 | Jan.25 | Jan.26 | Percentage |
|---|---|---|---|---|---|
| Clark Fork at Turah | 8 | 0 | 0 | 0 | 0 |
| Blackfoot at Anaconda Campground | 8 | 0 | 4* | -- | 50 |
| Clark Fork railroad bridge below dam | 8 | 2 | 6 | -- | 100 |
| Clark Fork at Hughes Garden | 8 | 5 | 3 | -- | 100 |

| Wild trout Station | Number placed in cage on Jan. 26 | Jan. 27-29 | Jan. 30 | Jan. 31 | Feb. 1 | Feb. 2 | Feb. 4 | Feb. 6 | Feb. 8 | Feb. 9 | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Clark Fork at Turah | 4** | 0 | not checked | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blackfoot at Anaconda Campground | 4 | 0 | " | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Clark Fork railroad bridge below dam | 4 | 0 | " | 1(Ct) | 1(Ct) | 0 | 1(Ct) | 0 | 0 | 0 | 75 |
| Clark Fork at Hughes Garden | 4 | 0 | " | 1(Ct) | 0 | 1(Ct) | 2 | 0 | 0 | 0 | 100 |

* cage removed
** 3 cutthroat and one Eastern brook trout

TABLE 17. Mortality of caged hatchery rainbow trout (7-8") and caged wild trout during the 18 Jan. 1973 Milltown Dam drawdown.

Previously, no permit was deemed necessary, due to the section of the Montana Water Quality Act that states pollution from the reasonable operation of dams is considered a natural condition and water quality standards are not applicable (sec. 75-5-306, ARM, 1971). The April 1980 drawdown was to have been for the purpose of studying the dam for repairs deemed necessary by FERC (Letter from Neblett to Labrie dated 9 October 1980, App. F). Although the WQB gave MPC a section 6g turbidity permit, the drawdown was not done due to excessive runoff. Due to the magnitude of the runoff, the drawdown and inspection could not have occurred under safe conditions.

Apparently at the request of the Water Quality Bureau, MPC monitored suspended sediment levels, total and dissolved metals during a semi-annual operational drawdown in July of 1980. The drawdown began July 7 and the pond was raised four feet on July 19, signaling the end of the drawdown. The Department on Fish, Wildlife and Parks (formerly the Fish and Game Department) also collected data for turbidity, total suspended solids, and total and dissolved zinc, iron, copper and arsenic. Their data are presented in Table 18. As is readily apparent, the drawdown easily violated the current state turbidity standard of an increase of five nephelometric units (Jackson Turbidity Units). All the total recoverable values increased dramatically due to the drawdown; the dissolved levels did not. Dissolved copper, iron, arsenic and zinc standards were never breached, although the old dissolved arsenic criterion was exceeded.

MPC's heavy metal data are shown in Table 19, and Figure 4 is a map of samples sites. Although several of the old heavy metal standards

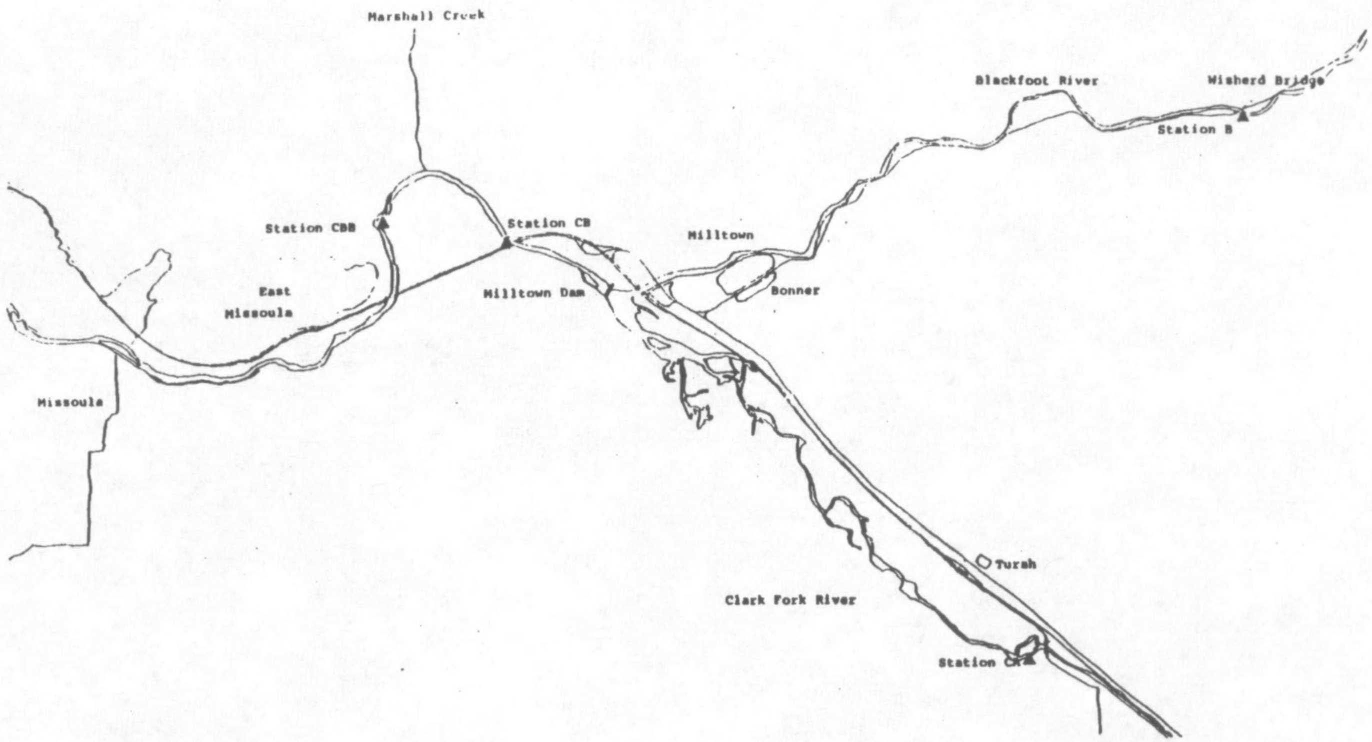



FIGURE 4. Map of the Clark Fork-Black foot River system in the vicinity of Milltown Dam showing the locations of sampling stations (▲).

| Lab No. | Sample Location | Date of Collection | Arsenic Total Recoverable | Arsenic Dissolved | Copper Total Recoverable | Copper Dissolved | Iron Total Recoverable | Iron Dissolved | Lead Total Recoverable | Lead Dissolved | Manganese Total Recoverable | Manganese Dissolved | Zinc Total Recoverable | Zinc Dissolved | Total Hardness as $CaCO_3$ mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 42964 | CB | 7/6/80 | 0.006 | -0.005 | 0.05 | -0.01 | 0.28 | -0.05 | -0.02 | -0.02 | 0.05 | -0.02 | 0.04 | -0.01 | |
| 42965 | CB-1925 | 7/7/80 | 0.045* | 0.006 | 0.27* | -0.01 | 1.97* | 0.11 | 0.03 | 0.02 | 0.54 | 0.15* | 0.41* | 0.01 | |
| 42966 | B-0940 | 7/8/80 | -0.005 | -0.005 | 0.03 | -0.01 | -0.05 | -0.05 | -0.02 | -0.02 | -0.02 | -0.02 | 0.01 | 0.01 | |
| 42967 | CA-1020 | 7/8/80 | 0.007 | 0.006 | 0.09 | -0.01 | 0.26 | -0.05 | -0.02 | -0.02 | 0.07 | -0.02 | 0.05 | 0.03 | |
| 42968 | CB-0900 | 7/8/80 | 0.043* | -0.005 | 0.37* | -0.01 | 2.35* | 0.09 | 0.04 | -0.02 | 0.57 | 0.19* | 0.55* | 0.03 | 2.63 |
| 42969 | CB-0908 | 7/9/80 | 0.028 | -0.005 | 0.28* | -0.01 | 2.15* | 0.08 | 0.05 | -0.02 | 0.38 | 0.14* | 0.35* | 0.04 | |
| 42970 | CHB-1700 | 7/9/80 | 0.018* | -0.005 | 0.17* | 0.01 | 0.88 | -0.05 | -0.02 | -0.02 | 0.20 | 0.03 | 0.08 | 0.04 | |
| 42971 | CB-0834 | 7/10/80 | 0.009 | -0.005 | 0.10* | 0.02 | 0.24 | -0.05 | 0.02 | -0.02 | 0.06 | -0.02 | 0.07 | 0.02 | |
| 42972 | CB-1130 | 7/11/80 | 0.009 | -0.005 | 0.18* | 0.05* | 0.20 | -0.05 | 0.08* | -0.02 | 0.06 | -0.02 | 0.05 | 0.01 | |
| 42973 | CB | 7/12/80 | 0.007 | -0.005 | 0.15* | 0.02 | 0.26 | -0.05 | 0.06* | -0.02 | 0.06 | -0.02 | 0.01 | -0.01 | |
| 42974 | CB-1230 | 7/13/80 | 0.006 | -0.005 | 0.09 | 0.01 | 0.14 | -0.05 | 0.05 | -0.02 | 0.04 | -0.02 | -0.01 | -0.01 | |
| 42975 | CB | 7/14/80 | -0.005 | -0.005 | -0.01 | -0.01 | 0.14 | -0.05 | -0.02 | -0.02 | 0.02 | -0.02 | 0.01 | -0.01 | |
| 42976 | CB | 7/18/80 | -0.005 | -0.005 | -0.01 | -0.01 | 0.06 | -0.05 | -0.02 | -0.02 | 0.02 | -0.02 | -0.01 | -0.01 | |

*indicates violation of old water quality standards which were applicable at the time

TABLE 18. Water quality data from the July, 1980 Milltown Dam operational drawdown collected by MPC.

TABLE 19. Department of Fish, Wildlife and Parks' water quality data from the July, 1980 operational drawdown of Milltown Dam.

| STATION | Time | Turb. (JTU) | TSS | Zinc Dis. | Zinc TR | Iron Dis. | Iron TR | Copper Dis. | Copper TR | Arsenic Dis. | Arsenic TR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Control Run 4/24/80** | | | | | | | | | | | |
| Blackfoot R.* | 1500 | 7.9 | --- | .04 | .08 | .05 | .78 | .01 | .02 | <.001 | .001 |
| CFR at Turah* | 1730 | 16.5 | --- | .07 | .11 | .08 | 1.39 | .01 | .04 | .006 | .012 |
| CFR I-90 bridge | 1630 | 6.4 | --- | .11 | .07 | .05 | .70 | .01 | .03 | .004 | .005 |
| CFR Van Buren Br. | 1830 | 6.6 | --- | .11 | .08 | .07 | .88 | .01 | .03 | .003 | .005 |
| CFR Reserve St. Br. | 1930 | 6.6 | --- | .06 | .06 | .09 | .67 | <.01 | .03 | .003 | .005 |
| **Control Run 7/6/80** | | | | | | | | | | | |
| Blackfoot R.* | 1230 | 5.0 | 15.5 | .02 | <.005 | .05 | .12 | .01 | <.01 | .002 | .001 |
| CFR at Turah* | 1520 | 6.4 | 30.3 | .008 | .04 | <.01 | .42 | .02 | .03 | .01 | .012 |
| CFR I-90 bridge | 1500 | 9.9 | 30.5 | .04 | .06 | .10 | .27 | .02 | .02 | .006 | .008 |
| CFR Van Buren Br. | 1615 | 6.2 | 23.0 | .008 | .03 | .01 | .28 | <.01 | .03 | .006 | .008 |
| CFR Reserve St. Br. | 1715 | 10.0 | 39.9 | .03 | .03 | .03 | .24 | .02 | .02 | .006 | .008 |
| **Commencement of Drawdown 7/7/80** | | | | | | | | | | | |
| Blackfoot R.* | 1430 | 3.5 | 8.4 | <.005 | <.005 | .03 | .08 | .01 | <.01 | .002 | .001 |
| CFR at Turah* | 1400 | 6.3 | 25.7 | <.005 | <.005 | .01 | .22 | .01 | .02 | .01 | .011 |
| CFR Van Buren BR. | 0100 | 30 | 157 | --- | .10 | --- | .62 | --- | .05 | --- | .011 |
| CFR Reserve St. Br. | 0115 | 20 | 75.6 | --- | .11 | --- | .90 | --- | .05 | --- | .013 |
| CFR I-90 bridge | 0900 | 240 | 906 | .008 | .88 | .07 | 5.60 | .02 | .47 | .008 | .046 |
| CFR Van Buren Br. | 1000 | 74 | 626 | .01 | .80 | .07 | 4.94 | .02 | .42 | .01 | .043 |
| CFR Reserve St. Br. | 1030 | 48 | 352 | .01 | .50 | .05 | 3.23 | .02 | .24 | .008 | .032 |
| CFR Van Buren Br. | 1315 | 47 | 421 | .005 | .58 | .06 | 2.48 | .01 | .24 | .01 | .032 |
| **Last Day of Drawdown 7/9/80** | | | | | | | | | | | |
| Blackfoot R.* | 1730 | 1.4 | 11.3 | <.005 | .01 | .11 | .10 | .01 | .01 | .001 | .001 |
| CFR at Turah* | 1700 | 5.1 | 21.5 | .03 | .03 | .23 | .35 | .03 | .03 | .010 | .010 |
| CFR I-90 Br. | 1500 | 28 | 321 | .07 | .20 | .03 | 2.43 | .01 | .17 | .007 | .020 |
| CFR Van Buren Br. | 1400 | 36 | 290 | .01 | .41 | <.01 | 2.51 | <.01 | .21 | .008 | .024 |
| CFR Reserve St. Br. | 1600 | 32 | 213 | .02 | .35 | .01 | 2.10 | .01 | .17 | .008 | .020 |

* Control stations
CFR - Clark Fork River
TSS - Total Suspended Solids
Dis. - Dissolved Solids
TR - Total Recoverable

would have been broken, none of the current standards were exceeded. Again, TR values increased more dramatically than dissolved levels with the exception of zinc and manganese whose dissolved levels rose dramatically during the drawdown. The dissolved concentrations were too low to have acute effects as indicated by comparison to literature values.

Part of the study was to determine the amount of sediment trapped behind the dam during spring runoff. The data collected by MPC (Table 20) show the dramatic increase in suspended sediment from (1) the ash from Mt. St. Helen's eruption, and (2), the semi-annual drawdown which commenced July 7. The volcano erupted May 18, but heavy rains began on 22 May and washed much of the ash into river drainages. Table 21, which indicates tons of sediment moving through the system at Bonner, shows the drawdown caused over 10,000 tons to be released during about two days.

An invertebrate and fisheries study was also attempted in coordination with the semi-annual drawdown. This study was in preparation for the next major drawdown due to occur the spring of 1981. The data for these studies were collected near the Turah Bridge of the Upper Clark Fork at the Wisherd Bridge (invertebrates) or Johnsrud section (fisheries) on the Blackfoot and at two sites downstream of the dam (Figure 4). The idea was to compare data from sites downstream of the dam to control sites in the Blackfoot and Upper Clark Fork and thus determine if a problem exists with fish or invertebrate populations attributable to the dam operation. Unfortunately, the control area on the Upper Clark Fork is not a very desirable source of data. The river

TABLE 20. Daily suspended sediment concentrations (mg/l) for the Blackfoot (B) and Clark Fork Rivers. See Fig. 4.

| Date | | B | CA | CB |
|---|---|---|---|---|
| March | 27 | 9.0 | 15.0 | 10.7 |
| April | 8 | 8.8 | 6.0 | 12.9 |
| | 10 | 8.8 | 14.2 | 6.0 |
| | 11 | 9.2 | 20.4 | 8.4 |
| | 14 | 12.7 | 19.4 | 10.0 |
| | 15 | 24 | 28.3 | 9.6 |
| | 16 | 15.8 | 38.0 | 13.0 |
| | 17 | 21 | 32.6 | 10.8 |
| | 18 | 17.6 | 29.8 | 13.4 |
| | 21 | 24.4 | 95.4 | 15.6 |
| | 22 | 27.8 | 90.0 | 20.2 |
| | 23 | 22.0 | 59.2 | 16.4 |
| | 24 | 20.8 | 52.4 | 19.2 |
| | 25 | 22.6 | 42.7 | 18.7 |
| | 28 | 35.4 | 50.6 | 54.6 |
| | 29 | 37.0 | 63.2 | 38.2 |
| | 30 | 62.4 | 52.4 | 56.0 |
| May | 1 | 48.2 | 59.8 | 46.4 |
| | 2 | 57.8 | 63.0 | 53.8 |
| | 5 | 29.0 | 81.0 | 44.8 |
| | 6 | 54.4 | 50.0 | 47.0 |
| | 7 | 42.6 | 66.8 | 48.6 |
| | 8 | 39.6 | 90.2 | 110.8 |
| | 9 | 27.4 | 130.2 | 48.6 |
| | 12 | 32.3 | 77.2 | 76.0 |
| | 13 | 30.0 | 54.8 | 56.4 |
| | 14 | 23.8 | 38.8 | 39.5 |
| | 15 | 25.4 | 38.0 | 28.0 |
| | 16 | 15.2 | 26.6 | 29.3 |
| | 27 | 342.4 | 201.0 | 196.7 |
| | 28 | 140.0 | 134.0 | 140.0 |
| | 29 | 94.0 | 96.3 | 98.3 |
| | 30 | 73.3 | 91.0 | 92.7 |
| June | 2 | 47.0 | 69.0 | 59.3 |
| | 3 | 57.3 | 97.7 | 90.0 |
| | 4 | 48.3 | 110.9 | 72.8 |
| | 5 | 44.3 | 82.5 | 73.2 |
| | 6 | 34.8 | 66.4 | 52.0 |
| | 9 | 27.6 | 63.2 | 54.4 |
| | 10 | 22.0 | 49.6 | 46.4 |
| | 11 | 29.2 | 44.0 | 38.8 |
| | 12 | 60.0 | 50.8 | 47.2 |
| | 13 | 68.0 | 88.3 | 36.3 |
| | 16 | 42.7 | 44.3 | 40.7 |
| | 17 | 60.7 | 48.7 | 44.7 |
| | 18 | 108.3 | 53.3 | 40.7 |
| June | 19 | 16.3 | 39.7 | 32.7 |
| | 20 | 4.3 | 28.3 | 32.3 |
| | 23 | 3.3 | 21.6 | 26.3 |
| | 24 | 17.7 | 39.3 | 29.3 |
| | 25 | 1.7 | 38.0 | 23.3 |
| | 26 | 1.3 | 30.3 | 19.3 |
| | 27 | 6.7 | 30.8 | 25.7 |
| | 30 | 8.3 | 23.7 | 18.7 |
| July | 2 | 715.5 | 22.7 | 18.3 |
| | 3 | 2.7 | 23.0 | 19.7 |
| | 6 | 8.0 | 21.3 | 19.3 |
| | 7 | - | - | 340.5 |
| | 8 | 9.7 | 20.0 | 234.5 |
| | 9 | - | - | 181.5 |
| | 10 | - | - | [illegible] |
| | 11 | - | - | 21.7 |
| | 12 | - | - | 22.7 |
| | 13 | - | - | [illegible] |
| | 14 | - | - | 3.3 |
| | 15 | - | - | 8.2 |
| | 16 | [illegible] | [illegible] | 9.0 |
| | 17 | - | - | 6.7 |
| | 18 | - | - | 4.0 |

| Date | | In | Out | Balance | Mean (CB) Discharge |
|---|---|---|---|---|---|
| April | 14-18 | 692 | 320 | + 372 | 2070 |
| | 21-25 | 2459 | 1007 | + 1452 | 4120 |
| | 28-2 May | 5464 | 5219 | + 245 | 7746 |
| May | 5-9 | 8093 | 8316 | - 223 | 10076 |
| | 12-16 | 4672 | 5890 | - 1218 | 9136 |
| | 19-23 | - | - | - | 8784 |
| | 27-30 | 26490 | 23500 | + 2990 | 16200 |
| June | 2-6 | 13180 | 13650 | - 470 | 14482 |
| | 9-13 | 8274 | 7400 | + 874 | 11780 |
| | 16-20 | 7340 | 6210 | + 1130 | 11940 |
| | 23-27 | 2662 | 3000 | - 338 | 8922 |
| | 30-6 July | 6563 | 1338 | + 5198 | 6533 |
| July | 7-9 | 658* | 10756 | - 10098 | 5193 |
| | 10-12 | 484* | 815 | - 331 | 4633 |
| | 13-18 | 469* | 540 | - 71 | 4108 |
| TOTALS | | 87500 | 87961 | - 488 | |

* Estimated

TABLE 21. Tons of suspended sediment moving through Milltown reservoir, reservoir sediment balance, and Clark Fork discharge (cfs) below Milltown Dam at station CB (Fig. 4) during 1980.

has been channelized by highway construction; the banks are unstable and erode frequently (Johns, 1981). Additionally, angling pressure is heavy here due to the Turah campground located in the vicinity. These problems are in addition to any other associated with the Upper Clark Fork - low dissolved oxygen, high temperatures, sediment containing heavy metals. The fisheries data collected (Table 22) reflects these condition; low fish populations above and below the dam and higher populations in the Blackfoot. While the populations above and below the dam in the Clark Fork are about the same (50+/1000'), the noteworthy aspect below the dam is the lack of young fish (smaller than 6.0"), especially brown trout. This points to a recruitment problem below the dam, probably a result of sedimentation. The Turah section appears to have similar problems, but due to the unstable channel conditions, one would expect this. So many unknown factors could be affecting the trout here that a comparison is difficult.

Through use of the Shannon-Weaver diversity index which the WQB also uses (Bahls, et al. 1979) a quick comparison can be made between sites based on aquatic invertebrate collections. Under conditions existing at the Milltown Dam, where a significant effect is expected, the use of dominance diversity indices is justified. The data are shown in Appendix G. Table 23 shows the calculated diversity (d̲) values and the mean d̲ values for each site. The results are almost what one would expect; the Blackfoot River site has the highest d̲ vlaues, the Clark Fork above the Milltown Dam has much higher values than those found at the first station below the dam. The second station below the dam exhibits some recovery, and the fall d̲ value is even higher than the

| River and Section | Species | Size Range(in.) | Fish/1000' |
|---|---|---|---|
| Clark Fork River | | | |
| Bearmouth section | brown trout | 8.0-19.9 | 7.49 |
| Bonita section | brown trout | 8.0-19.9 | 7.72 |
| | rainbow trout | 7.0-13.0 | 1.21 |
| | | | Total 8.93 |
| Turah section | brown trout | 4.0-19.9 | 51.16 |
| | rainbow trout | 9.0-13.9 | 22.72 |
| | | | Total 73.88 |
| Milltown section | brown trout | 6.0-20.9 | 14.58 |
| | rainbow trout | 6.0-16.9 | 40.21 |
| | | | Total 54.79 |
| Blackfoot River | | | |
| Johnsrud section | brown trout | 4.0-15.9 | 4.45 |
| | rainbow trout | 6.0-14.9 | 337.93 |
| | | | Total 342.38 |
| Rock Creek | | | |
| Valley Moon section | brown trout | 6.0-19.9 | 155.19 |
| | rainbow trout | 8.0-16.9 | 57.34 |
| | | | Total 212.53 |

TABLE 22. Clark Fork fisheries data (from Peters, 1981).

**Blackfoot River (B)**

| Date | 8/27/80 | | | | 10/24/80 | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | 1 | 2 | 3 | $\bar{x}$ | 1 | 2 | 3 | $\bar{x}$ |
| d value | 4.08 | 3.99 | 4.07 | 4.05 | 3.88 | 3.42 | 4.19 | 3.83 |
| e value | .54 | .66 | .69 | .63 | .59 | .50 | .68 | .59 |

**Clark Fork (CA)**

| Date | 8/27/80 | | | | 10/24/80 | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | 1 | 2 | 3 | $\bar{x}$ | 1 | 2 | 3 | $\bar{x}$ |
| d value | 3.42 | 3.40 | 3.73 | 3.52 | 3.69 | 3.64 | 3.64 | 3.66 |
| e value | .47 | .44 | .46 | .46 | .70 | .72 | .69 | .70 |

**Clark Fork (CB)**

| Date | 8/27/80 | | | | 10/24/80 | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | 1 | 2 | 3 | $\bar{x}$ | 1 | 2 | 3 | $\bar{x}$ |
| d value | 2.78 | 2.23 | 2.26 | 2.42 | 4.00 | 2.95 | 2.42 | 3.12 |
| e value | .31 | .28 | .22 | .27 | .60 | .35 | .39 | .45 |

**Clark Fork (CBB)**

| Date | 8/27/80 | | | | 10/24/80 | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | 1 | 2 | 3 | $\bar{x}$ | 1 | 2 | 3 | $\bar{x}$ |
| d value | 2.60 | 3.26 | 3.28 | 3.05 | 4.03 | 3.26 | 3.87 | 3.72 |
| e value | .35 | .45 | .45 | .42 | .66 | .54 | .57 | .59 |

TABLE 23. Diversity (d) values and equitability (e) values for 1980 MPC invertebrate data. See Figure 4 for sample site location.

fall *d* value from above the dam, although both are lower than Blackfoot River mean values. The EPA recommends always calculating the equitability value *e* along with *d* as *e* is more sensitive to degradation (Weber, 1973). Equitability values for each site were calculated according to Weber (1973) and are also shown in Table 23. These values indicated a more linear degradation between sample sites. Comparing the two control sites, the Blackfoot site had both mean values above .5, while the Clark Fork above the dam had one mean value slip below .5. The other mean value was the highest for any site. For the same sample dates, the *e* values for the Clark Fork follow an expected progression; Starting out at their peak above the dam, they dip drastically a short distance below the dam, and then recover a few miles downstream but do not regain levels found upstream. while the values of *e* for all sites reflect degraded aquatic environments (Weber, 1973), the data indicate the more degraded sites lie downstream of the dam.

During the Clark Fork flood of Spring, 1981, the dam spillway was damaged, causing MPC to perform an extended version of their summer operational drawdown. During the drawdown, the DFWP placed live cages containing wild trout in the Clark Fork, four at varying distances downstream of the dam, and one upstream at Turah. The results (Appendix H) were inconclusive mainly due to mortalities before the drawdown began on 29 July. Replication of experimental and control data was lacking as well. This drawdown, as well as a semi-annual drawdown in July, 1982, were conducted slowly to minimize siltation, in accordance with an agreement with the DFWP.

Water quality data collected by the DFWP during the 1982 summer operational drawdown are shown in Table 24. None of the parameters are high enough to break water quality standards or literature values for detrimental biological effects. Unfortunately, the data were collected only while the reservoir level was dropping. Data were not collected while the reservoir was at the reduced level, so any eroding and sloughing of sediment into the Clark Fork went unrecorded. The data do compare well to the data from Table 18 which were obtained during the summer 1980 operational drawdown. A few years of data collection will be needed to determine if the slow drawdown method is aiding the salmonid fishery downstream. Data collected by the MPC (Table 25) also indicate a slight increase in turbidity due to the drawdown. The highest increase in turbidity was during the initial phase of the drawdown; thus, erosion did not occur to any significant extent.

Based on data collected in 1980 and 1982, heavy metals do not appear to be a problem during semi-annual drawdowns. Habitat destruction caused by sedimentation is probably the worst problem that could be attributed to these drawdowns. The first semi-annual drawdown occurs in July, after peak runoff, so a good flushing effect does not cleanse the substrate. The second drawdown in the fall has even less of a flushing effect after it. The silt probably settles out over several miles, but no one has ever done any sediment studies during a major or minor drawdown, or even seen how far downstream suspended sediment levels are elevated during either type of drawdown.

The only analysis of sediment in any way connected to the Clark Fork River or the Milltown Dam, was part of a Master's thesis (Bailey,

| Parameter | Date | Blackfoot R. Wisherd Bridge | Clark Fork R. Turah | Clark Fork R. Bandmann Bridge | Clark Fork R. Reserve St. |
|---|---|---|---|---|---|
| Turbidity | 7/15 | 4.4 | 11.0 | 7.5 | 8.3 |
| | 7/16 | 3.1 | 5.7 | 6.0 | 7.0 |
| | 7/17 | 3.1 | 4.0 | 12.0 | 5.0 |
| | 7/18 | 4.2 | 4.5 | 7.5 | 21.0 |
| | 7/19 | 2.5 | 3.7 | 6.4 | 15.0 |
| Arsenic | 7/15 | .001 | .009 | .006 | .006 |
| | 7/16 | .001* | .001 | .006 | .007 |
| | 7/17 | .001 | .009 | .007 | .006 |
| | 7/18 | .001* | .010 | .009 | .009 |
| | 7/19 | .001* | .010 | .008 | .006 |
| Zinc | 7/15 | .01* | .01 | .02 | .02 |
| | 7/16 | .01* | .01* | .01 | .03 |
| | 7/17 | .01 | .01* | .02 | .01 |
| | 7/18 | .01* | .01* | .07 | .05 |
| | 7/19 | .01* | .01* | .01* | .02 |
| Copper | 7/15 | .01* | .03 | .01* | .01* |
| | 7/16 | .01* | .01* | .01 | .01* |
| | 7/17 | .01* | .01 | .02 | .01 |
| | 7/18 | .01* | .01* | .03 | .02 |
| | 7/19 | .01* | .01* | .01* | .01 |
| Iron | 7/15 | .10 | .31 | .39 | .41 |
| | 7/16 | .06 | .16 | .23 | .16 |
| | 7/17 | .06 | .12 | .24 | .20 |
| | 7/18 | .05 | .13 | .43 | .40 |
| | 7/19 | .05 | .13 | .11 | .26 |

* less than (below detection limit).

TABLE 24. Water quality data (in ppm dissolved) collected by DFWP personnel during the July, 1982 operational drawdown of Milltown Dam.

TABLE 25

MPC turbidity data from the July, 1982 operational drawdown
(EM = Clark Fork River at East Missoula; B = Blackfoot River; CA = Clark Fork upstream of dam).
NTU = Nephelometric Turbidity Units.

| Date | Time at EM | Turbidity (NTU) B | CA | EM | Daily mean[1] discharge | Reservoir level (ft.) | Floodgate position | Notes |
|---|---|---|---|---|---|---|---|---|
| 7/12 | | | | | 6280 cfs | 28.0 | | |
| 7/13 | | | | | 6070 | 28.8 | | Rain |
| 7/14 | 21:00 | | 12.5 | 13.5 | 6310 | 28.9 | | |
| 7/15 | 08:30 | 8.9 | 15.0 | 15.0 | 6580 | 28.3 | 08:00 4' | Rain previous night |
| | 14:00 | | | 14.0 | | | 12:30 3' | |
| | | | | | | | 15:30 4' | |
| 7/16 | 09:15 | 6.7 | 9.0 | 10.5 | 6010 | 27.2 | 08:00 8' | |
| | 14:00 | | 8.0 | 11.0 | | | | |
| | 20:45 | | | 10.5 | | | 10:00 6' | |
| 7/17 | 08:20 | | 7.4 | 9.7 | 5790 | 26.9 | 09:30 7' | |
| | 14:00 | | 8.0 | 11.0 | | | 11:00 8.5' | |
| | 18.45 | | 7.3 | 9.5 | | | 20:00 11.5' | |
| Drawdown started | | | | | | | | |
| 7/18 | 08:55 | 4.6 | 7.4 | 12.0 | 5460 | 26.8 | 02:00 18' | |
| | 10:00 | | | 21.0 | | | 08:00 21' | |
| | 10:15 | | | 23.0 | | | 11:15 17' | Turbidity in Clark Fork |
| | 11:00 | | | 23.0 | | | Remaining | channel in reservoir |
| | 11:15 | | | 25.0 | | | at 17' | |
| | 14:00 | | 7.4 | 20.0 | | | | |
| | 15:30 | | | 17.0 | | | | Boating and swimming at EM |
| | 16:20 | | | 13.0 | | | | |
| | 16:50 | | | 13.0 | | | | |
| | 18:00 | | | 12.0 | | | | |
| | 20:00 | | | 12.0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7/19 | 07:25 | | 7.6 | 11.0 | 5140 | 26.7 | | | |
| | 14:00 | | | 11.0 | | | 14:50 | 17.3' | Swimming at EM |
| | 16:00 | | | 11.0 | | | | | Swimming at EM |
| | 21:30 | | | 11.0 | | | 22:00 | 17.7' | |
| 7/20 | 09:00 | 4.4 | 6.2 | 11.0 | 4850 | 26.4 | 10:00 | 18.2' | |
| | 12:00 | | | 11.0 | | | 10:30 | 18.5' | |
| | 12:20 | | | 11.5 | | | | | |
| | 12:40 | | | 11.0 | | | | | |
| | 13:15 | | | 11.0 | | | | | |
| | 17:00 | | | 14.0 | | | | | |
| | | | | 11.0 | | | | | |
| | 19:45 | | | 11.0 | | | | | |
| | | | | 12.0 | | | | | |
| 7/21 | 07:40 | | | 11.8(3)[2] | 4570 | 25.8 | 08:15 | 19' | |
| | 09:30 | | | 12.5(2) | | | | | |
| | 10:30 | | | 12.0(3) | | | 13:00 | 19.5' | |
| | 11:30 | | | 14.5(2) | | | | | Samples from I-90 bridge |
| | 13:30 | | | 13.0(3) | | | | | were 13, 14 NTU at 16:00 |
| | 15:30 | | | 12.5(2) | | | | | |
| 7/22 | 07:45 | 3.9 | 7.0 | 16(2) | 4340 | 25.8 | | | |
| | 11:00 | | | 15.5(2) | | | | | |
| | 14:30 | | | 16(2) | | | | | |
| 7/23 | 12:15 | | | 14.5(2) | 4100 | 25.8 | | | 10:30 - Screens raked |
| 19:15 | 19:15 | | | 13.5(2) | | | 16:00 | 18.5' | Swimming at EM |
| 7/24 | 08:50 | 4.3 | 5.6 | 13.5(2) | 3870 | 25.8 | | | 10:00 - Screens raked |
| | 12:30 | | | 13 | | | 11:00 | 17.5' | Reservoir level at crest is 25.8', |
| | 19:30 | | | 10 | | | 17:00 | 19.5' | 25.7' is optimum for construction work on apron |

TABLE 25 (cont.)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7/25 | 08:00 | | | 13 | 3760 | | | | 10:00 - Screens raked |
| | 14:55 | | | 14 | | 26.0 | | | |
| | 19:50 | | 5.0 | 15.5(2) | | 24.3 | 20:00 | 18.7' | Rain showers |
| 7/26 | 07:20 | 4.1 | 5.5 | 13 | 3670 | 25.7 | | | |
| | 13:20 | | | 12 | | | | | Swimming at EM |
| | 21:50 | | | 13 | | | | | |
| 7/27 | 07:45 | | | 13 | 3520 | 25.7 | | | |
| | 13:40 | 4 | 4.1 | 11 | | | | | Swimming at EM |
| | | | | 12 | | | | | |
| 7/28 | 08:10 | | | 11.5 | 3380 | 25.7 | | | Slight discoloration from Clark Fork channel discharge at dam. Champion saw mill will "set up" their dam today; expect slight turbidity increase on Blackfoot. |
| | 16:20 | | | 13 | | | | | |
| 7/29 | 07:00 | | | 10.5(2) | 3010 | 25.7 | 14:00 | 14.7' | Total maximum opening for 1982 |
| | 15:10 | | 3.0 | 9.0 | | | | | |

Drawdown Finished.

1 USGS Daily mean discharge from station above Missoula on Clark Fork River. Provisional data.
2 (n) = number of samples averaged.

TABLE 25 (cont.)

1976). Bailey took eight core samples 13/18" in diameter, and 30 to 95 centimeters in length, depending on the depth of soft sediment, from Blackfoot River and Clark Fork River sediments behind the dam. Levels of cadmium and chromium were below detection limits (.05 ug/g cadmium and 2.0 ug/g chromium). The average levels of these metals found in the Clark Fork sediments were:

Copper..............50 - 7,900 ug/g

Zinc................300 - 7,900 ug/g

Manganese...........2,900 ug/g

Iron................10,500 - 43,300 ug/g

These values were high compared to Blackfoot River sediments and values Bailey found in the literature.

In 1981, MPC again proposed to perform a major drawdown of 20-22', beginning about April 6. MPC maintained that peak runoff following the drawdown would have a mitigating flushing effect, scouring away the silt deposited during the drawdown. (Memo from Zimmerman to J.A. McElwain, App. I). The purpose of the drawdown was to inspect several problem areas pointed out during the 1980 FERC dam inspection (App. F). The drawdown was to last 36 hours, commencing April 6 and ending April. 8. The pond was to have remained at its lowest level for about 8 hours. Construction repairs were planned for the semi-annual drawdown (Montana Power Company, 1981).

To perform the drawdown, MPC had to apply for a short term exemption from the turbidity standard of the Water Quality Act. The Water Quality Bureau granted the permit after a Preliminary Environmental Review (PER) and added several stipulations to the permit.

The interesting aspect of the PER is the finding that there would be a major potential environmental impact on terrestrial and aquatic biota, as well as on water quality (DHES, 1981). The discussion of these effects includes the heavy metals in the sediments behind the dam, but the permit does not allow heavy metal standards to be broken. Also, in spite of the potential major impacts, the WQB decided an Environmental Impact Statement (EIS) was unnecessary. However, the conditions placed on the permit would finally have forced MPC to consider what long term construction they would undertake to prevent the necessity of more deep drawdowns. Alternatives to flushing the sediment were considered infeasible by MPC (MPC application for short term exemption, App. M).

In slight of the imminent water quality problems and the potential effects, Trout Unlimited sued the WQB and MPC for an EIS and obtained a temporary injunction. Because the river would soon be too high to allow the inspection, MPC postponed the drawdown. One of the major arguments against the drawdown was the lack of cleansing flows due to very low snowpack conditions. Heavy rains changed what was to be a light runoff into the flood conditions which MPC and the WQB had hoped would be the mitigating factor.

The sediment releases, from either the semi-annual or deep drawdowns cause problems for aquatic biota, mainly because they occur at times of year when organisms are unaccustomed to high levels of suspended sediment. Aquatic organisms, adapted to peak discharge and sediment levels occurring simultaneously, do not cope well with high sediment levels at other times. The scouring and grinding action of the sediment will kill many organisms; even if the sediments only lay on the

stream bottom for a matter of weeks, they could seriously damage the intergravel habitat and the organisms depending upon that habitat. The deterimental effects of sedimentation have been known for a long time. To quote from a basic college text on ecology (Smith, 1974):

> Silt destroys stream habitats, changes stream bottom, covering sites for insect larvae and smothering mussels and other bottom organisms. . . . Evidence indicates that high turbidity kills fish by clogging the opercular cavities and gill filaments with silt. Because water cannot reach the gill filaments, blood aeration is impeded, and sooner or later the fish die from carbon dioxide retention, anoxemia, or both . . . silty water flowing through the gravel nests or redds of trout and salmon causes heavy mortality of eggs. Silt clogs the spaces between the gravel, reducing the water flow through the redd, and settles on the eggs. With insufficient water washing them, the eggs die from lack of oxygen. Thousands of miles of trout and salmon water have been destroyed by siltation, which more than any other cause limits the natural reproduction of these fish.

Crouse, et al. (1981), using twelve laboratory streams, measured productivity, defined by length and weight, in juvenile coho salmon. they found productivity was inversely related to the amount of fine sediment present. Increasing sedimentation suppressed fish production. Significant reductions occurred when 80-100% of the dominant particle size was embedded in sediment less than or equal to 2.0 mm in diameter. These conditions meant this size class comprised 13-26% by volume of the substrate.

The authors found a high correlation between two methods of substrate analysis; one the difficult and time consuming average geometric mean particle size method, the other a visual technique called the Substrate Score Method. The visual method assigns a score to a substrate depending on its suitability for spawning. The score is the sum of four ranks taken from a table of rankings; the first and second

most predominant particle sizes are assigned rank values, the third rank is the size of the material surrounding the predominant particle, the fourth rank concerns the level of embeddedness of the predominant particles by the particle size scored in the third rank. The authors concluded the correlation between the two types of substrate analyses was so high that the Substrate Score Method would be very valuable in field assessments of spawning areas and substate quality. Low scores indicate low productivity, high scores indicate areas where high productivity is likely.

I feel the method used in Crouse's study could be used to determine quantitatively the changes in the river bottom due to operation of the Milltown Dam. Those methods involving sampling, sieving and weighing are too time consuming for personnel of state agencies whose time and budgets are restricted. Understanding the fate of sediment released during drawdowns is crucial to comprehending effects on biota. The problems with sampling fish and invertebrate population in the Clark Fork render inefficient the time spent collecting the data. None of the proposed studies of drawdown effects involves determining the fate of the sediments.

Any easy solution does not exist. The normal, semi-annual 8' drawdowns have been detrimental, releasing thousands of tons of sediment. The occasional deep drawdowns not only dump much more sediment, they cause heavy metal contamination in excess of state standards. While no data on arsenic was ever collected during major drawdowns, recent preliminary data show high levels occur in the pore water and sediment behind the dam, as well as in the floodplain upstream

(Rice, personal communication, 1982). Neither of the two types of drawdowns occurs during peak runoff when sediment would at least be distributed much further downstream or in floodplain areas. As mentioned, aquatic biota are better adapted to siltation at that time.

Several remedies to lessen sedimentation from the operation of the dam have been proposed. I do not know the original source of the proposals, but the state has never had an engineer study the Milltown Dam and suggest alternatives, or study proposals to determine their feasibility. Specifically, current proposals, which deal mainly with deep drawdowns, are:

1. The use of suction dredges to remove accumulated sediment prior to or during the drawdown.
2. The use of dikes or cofferdams to isolate sediment banks during drawdowns.
3. Reconstruction which would eliminate operational and deep drawdowns.
4. Permanent dikes or jetties to maintain flow through the pond and move sediment along normally.
5. The do-nothing alternative.

MPC has rejected all these ideas as too expensive. The do-nothing alternative is considered infeasible as a lack of maintenance would cause inefficient operation and hazards to the plant operator. However, no catastrophic failure of the dam would be expected to result from this alternative. Therefore, MPC does not consider the do-nothing alternative endangering to public safety or welfare (Zimmerman memo, App. I). This issue was also discussed in the FERC 1979 inspection report (Appendix A). The report discusses a dam failure during a seven year flood. The only significant potential for damage would be the

condominiums and health club along the river east of Missoula. These would suffer property damage if catastrophic failure occurred, as would any low-lying structure within three to four miles downstream of the dam.

In the same report, the FERC engineer discusses the efficiency of power generation at the dam. The rating for each of the five generators with the discharge required, and the actual amount of power that was being generated at the time of inspection is:

| Unit | Discharge | Rating (kw) | Actual |
|---|---|---|---|
| 1 | 400 cfs | 600 | 390 |
| 2 | 480 " | 800 | 470 |
| 3 | 400 " | 600 | 0 |
| 4 | 400 " | 600 | 0 |
| 5 | 480 " | 800 | 590 |
| Total | 2,160 " | 3,400 | 1,450 |

The maximum capability is 3.4 megawatts, but the amount normally generated is around 1.5 megawatts. The power does ~~to~~ not go to homes in Missoula, rather it is fed into a statewide grid. An idea of the significance of the power generated by the dam was given in 1971 by Charles Pepper, then division superintendent for MPC in Missoula. Mr. Pepper was quoted in the Missoulian:

> 'If it should wash out tomorrow, as it did in 1909, sortly after it was constructed, it would not appreciably disturb the power supply in the Missoula Valley.' . . . Pepper said the power generated at the dam is 'a drop in the bucket' and 'wouldn't even carry the Bonner Mill now.' (Pederson, 1971)

A more realistic reason why MPC maintains the dam was then put forth by Mr. Pepper in the same article: "The power company feels as long as it's there you just can't wipe out a couple million dollars."

He admitted nobody "would get rich" operating the power plant. Elsewhere, the article states "power company officials admit the dam is more burden than it's worth."

> What to do about the dam?
>
> Pepper said the power company hopes to do some work on the dam and generating plant in the future to make a 'little showplace for tourists.' Although the Milltown Dam is small in comparison to most dams, Pepper said the generating equipment and water wheels inside the plant are antiques and would make an interesting sight-seeing attraction. Of course, that would mean maintaining the structure, but operational drawdowns would cease.

Mr. Pepper's comments indicate how significant the dam is compared to the problems it causes MPC and the Clark Fork.

A couple of other alternatives have been considered in the past. According to the Missoulian, 29 December 1972, MPC had intended to replace the wooden flashboards with an articulated concrete mat (Van Valkenburg, 1972). This would have made unnecessary the semi-annual drawdowns. However, the plans were tentative and were never carried out. Another Missoulian article (Curran, 1970) stated, "A MPC employee disclosed that the company is investigating the possibility of removing sediment from the holding pond later this year by dredging instead of washing to down the river."

This brings up another issue. The company has often stated the dam is a run-of-the-river operation, requiring no storage. They have also stated drawdowns are not done to remove sediment built up behind the dam. Back to Mr. Pepper:

> Generally, the silt accumulated around the water inlet is shoved through to wash downstream, causing even a greater turbidity problem. This year the silt was removed and used to

> fill in a low spot created when highway crews removed earth while building the interstate highway. (Pederson, 1971)

The statements by MPC employees indicate that silt accumulation is a problem to the operation of the dam, not just a by-product of inspection, maintenance or operational drawdowns. And the large volume of tailings in the floodplain of the Upper Clark Fork ensures the continuation of heavy metal and silt accumulation behind Milltown Dam.

During 1982, MPC was to formulate a long range plan for operation of Milltown Dam, whether to upgrade, maintain or abandon. Such plans are to include measures to mitigate adverse effects resulting from operation of the dam (Graham, et al. 1981).

One could argue that at this point Milltown Dam aids the fishery downstream by preventing large quantities of silt from reaching the Lower Clark Fork. This is somewhat faulty logic because if the sediment had been let through the system naturally, flushing flows would have mitigated most effects and deposited it behind the next dam. True, if one released silt in large amounts, much damage would occur, as is the sitation with major drawdowns. this would be the problem with abandonment of the dam - catastrophic releases of the sediment form the dam's sudden collapse or even erosion resulting from slow deterioration of the dam. Even if abandoned, the dam should be structurally maintained - probably by a major construction effort which would cause a release or sediment - or destroyed so sedimentation would occur over a short period and recovery would begin much earlier. Or the sediment would have to be removed before destroying the dam.

The slow-drawdown approach now used by MPC for semi-annual operational drawdowns <u>may</u> be a viable alternative. Time will tell. But

this still leaves major drawdowns. The only remedy for them is reconstruction of the dam, removal of the silt, or removal of the dam to prevent accumulation of the silt.

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

Even though much data on the Clark Fork does exist, one can only render conclusions with difficulty and uncertainty. We do know the Clark Fork suffers from three ills; sedimentation with associated heavy metals, nutrient loading, and infrequently, high ionic concentrations of heavy metals. But that is about all we know,

Baseline data is missing. Only three studies concerned themselves with heavy metals in sediments, and none of them were directly linked with biota in the Clark Fork. No one has started at Warm Springs Creek, moved downstream collecting appropriate data, and found what magnitude of metal loads really exists in the river. And what their effects might be. A similar study needs to be done for nitrogen and phosphorus. Without this kind of information, no one can make feasible recommendations for water quality treatment. For the heavy metals and nutrients are inexorably linked, and effective treatment must attack the most vulnerable of these two components of the system. Otherwise money and time will be wasted.

So with the excuse of insufficient data, here are my conclusions on pollution in the river and its effects on biota:

1. The trout fishery of the Upper Clark Fork remains below potential for two reasons. First, heavy metals in sediments have altered the food chain resulting in lower productivity at higher trophic

levels. A green alga, Cladophora sp., has become dominant from the toxic effect of the metals on diatoms. This green alga is not only an undesirable food source for primary herbivores, it provides little habitat for invertebrates. Detritus feeders such as hydrosychids and chironomids take over, productivity declines. Heavy metals become associated with detritus and gain direct entry into the food chain.

Second, sedimentation has reduced viable habitat and spawning areas for salmonids. Below tributaries that do not carry unreasonably large sediment loads, the substrate for invertebrates and trout is much better, and conditions for Cladophora sp. are not as good as where heavy metals are more common. Such tributaries increase the flow of the Clark Fork, helping to scour the streambed. Flint Creek is the only main tributary from the Little Blackfoot to Rock Creek, and it has sediment and heavy metal problems of its own. The fishery does not improve below it.

These two problem areas are exacerbated by nutrient loading from domestic sewage. Combined with high water temperatures in low flow years, Cladophora sp. causes dissolved oxygen levels to drop precipitously. This additional stress takes an unknown toll on an already stressed fishery. But I do not think the reduced fishery results from the nutrient loading.

2. Nothing can be done about heavy metals and sediment in the mainstream of Silver Bow Creek and the Clark Fork. Many takings remain in their floodplains, leaving no feasible technological solutions. The river will have to cleanse itself. Available data indicate acute levels are not a problem anymore. Cadmium, possibly lead and mercury, may present chronic problems for trout in sections in the Upper Clark fork, either by

themselves or synergistically with zinc. Arsenic levels may be affecting biota also, but it is too often overlooked in Clark Fork studies.

3. Milltown Dam degrades the fishery of the Lower clark Fork for at least a few, miles downstream. Major drawdowns likely cause fish kills through acute levels of heavy metals and sediment. Operational drawdowns cause chronic effects from sediment, possibly heavy metals. Sediment released during operational drawdowns is probably not as high in heavy metal content as sediment released during major drawdowns.

4. The biological monitoring program of the State Water Quality Bureau will not perform its function as it is currently designed. Changes detected by this system will be discovered too late or not at all, and only detected when very serious damage has occurred.

## Recommendations

1. An intensive study of heavy metals in the Upper Clark should be undertaken, to determine how great an effect the metal load has on biota. Concentrations of arsenic, lead, cadmium, mercury, zinc and copper should be checked in samples of water, sediments, insects, algae, and trout. Liver, kidney, and gill tissue of trout should be examined. Sampling should start below the Warm Springs settling ponds, and continue downstream, taking samples above and below major tributaries (or any suspected of metal or sediment loading) until well downstream of Milltown Dam. Substrate quality should be noted. This study will answer important questions about the benthic habitat of the Clark Fork, which is the crucial part of maintaining and promoting a quality

fishery. The study would be expensive, but not as expensive as building unnecessary treatment facilities. Data could be incorporated into a BCI (Biotic Condition Index) which would yield a good idea of the river's potential and its problems.

If the sediment and heavy metals affect the biota to a very great extent, as I believe, then tertiary treatment plants to remove nutrients would be ill-conceived. Instead, any sources of sediment, especially those bearing heavy metals, should be mitigated. This path is the more difficult - controlling the domestic sewage is mainly a problem of getting money to establish the appropriate technology. If sediment and metal sources can be controlled, flushing flows will move what remains in the river downstream, and eventually cause increased productivity. As much water as possible should remain in the river to cleanse and maintain fishery habitat.

Dilution will not prevent effects of heavy metals because the problem is not one of acute or chronic exposure via dissolved species. But rather the particulate forms, which settle to the streambed and become a chronic, long term source of metals.

2. Milltown Dam - this archaic structure should be reconstructed to do away with operational and major drawdowns, or remove it entirely and the accumulated sediment. Operational drawdowns performed at a slow rate may help mitigate some effects, but data is as yet insufficient to confirm this. This still leaves the problem of major drawdowns to be dealt with.

# APPENDIX A

## 1979 Rederal Energy Regulatory Commission Report on the Milltown Dam

DOE Form FERC-510
(7-79)

U.S. DEPARTMENT OF ENERGY

# OPERATION REPORT

COPY

TO FEDERAL ENERGY REGULATORY COMMISSION

For the period June 21, 1978, to June 11, 1979

Supervising Agency Federal Energy Regulatory Commission

Office of San Francisco Regional Engineer

Licensee The Montana Power Company Project No. 2543-MT

Name of plant Milltown (5 units totalling 3,040 kW)

Location Clark Fork River, upstream of Missoula (Waterway or reservation) Montana (State)

License issued May 1, 1965 (Expires December 31, 1993) (Date) for 27½ years.

Inspected by Edward R. Fisk Date June 11, 1979

Parts of project inspected Entire project

Memorandum report (attach additional sheets if necessary):

The project was inspected by E. R. Fisk of FERC, accompanied by Messrs. Ralph Welchel, Manager of Hydroelectric Generation Operations; Robert Perlman, Hydroelectric Design Supervisor; Gene Taylor, Assistant Manager, Hydroelectric Generation Operations; Roger Hofacker, Senior Vice President, and the Plant Supervisor, all of the Licensee. The U.S.F.S. was notified of the inspection, but did not send a representative.

The project works consist of a timber crib dam, a concrete gravity intake and dam, and a powerhouse (Photo No. 1). The plant is a run-of-the river plant with virtually no storage. The plant is connected to the Licensee's transmission system which is included in their adjacent licensed projects.

Dam

The portion of the dam to the right of the powerhouse is a concrete gravity dam, 244 feet long, constructed in front of the downstream face of the original rock-filled, timber crib dam. The next section of the dam is behind the powerhouse and forms its back wall; it is a concrete gravity section 152 feet long, 52 feet high, and 4 feet wide at its top. Through this wall pass the five 10-foot diameter steel penstocks and an exciter penstock.

Adjacent to the left of the powerhouse is a concrete sluice gate section 52 feet long. This structure rests upon part of the original rock crib dam. There

Submitted DEC 27 1979, 19

JAMES G. GAMBLE

(for) Edward R. Fisk, P.E., Civil Engineer
(Reporting officer)

are four 9-foot wide by 14-foot-high steel gates in this section. See Figures 1 and 2.

The spillway section is a timber crib, rock-filled section, 216 feet long, topped by 8-foot-high, hinged, wooden drop gates. Access to crest gates is by a steel cable suspension footbridge spanning the entire length of the spillway crest. A cableway above the bridge supports a hoist for releasing gates into open position. Gates cannot be raised (closed) while spilling.

Powerhouse

The powerhouse is a structural steel frame, brick wall building on a concrete floor, except that the back wall is formed by the downstream face of the dam. The powerhouse houses 5 generators with a total installed rated capacity of 3,040 kW. A 10-ton crane services the powerhouse.

1. Clearing

The reservoir area was clear, and additional clearing work was not needed. A service raft was overturned and drawn against the trash racks over the intakes to penstocks Nos. 3 and 4, necessitating a shutdown of those two turbines until the obstruction could be cleared. Work was in progress at the time of inspection (Photo Nos. 2 and 3).

2. Operation of the Reservoir

At the time of the inspection, the water surface elevation in the upper pool was 3257.5 feet MSL. No storage is provided at the site, and the plant is totally a river-run operation. A total of 700 cfs was being passed into Unit Nos. 1, 2, and 5 during the operations to remove the obstruction in front of Unit Nos. 3 and 4. Another 6800 cfs were being spilled directly into the stream below the dam (Photo No. 4). The highest upper pool level for the past inspection year was recorded during the period of May 2 through 25, 1979, when the water surface elevation held at 3260.0 feet MSL. The low for the same period was 3251.8 feet MSL on July 13, 1978.

The project boundary is defined as the limits covered when the reservoir level is at elevation 3264.0 feet MSL. The top of the spillway flashboards elevation is 3259.7 feet MSL.

Usable pondage behind the dam is only 300 acre-feet. The Licensee's representative stated that the pond area is heavily sedimented, resulting in practically no storage capacity.

3. Compliance With Other License Provisions

The Licensee appears to be complying with all other applicable provisions of the license.

4. Safety and Permanence of Project Works

Dam seepage appears to be negligible. An underdrain and steel diversion plate on the downstream face of the right side of the dam appear to be successfully handling the flows previously reported at that location.

The sluice operating machinery appears to be in only fair condition (Photo No. 5), although some was out of service for repair at the time of inspection. Licensee operated the sluice gate hoists in my presence, and they performed mechanically satisfactorily. An excessive amount of oil residue and earlier spillage is evident around the gate hoists, and the hoist deck has begun to accumulate a vast amount of rough storage of old machine parts, timber, and similar debris. Licensee will be advised by letter that the accumulation of improperly placed storage in this area constitutes a safety hazard to plant personnel, and it should either be removed or proper care exercised in placing for storage.

Hydraulic and electrical machinery inside the powerhouse appeared to be maintained in excellent condition (Photo No. 6).

Later complications occurred during attempts to free the raft which was obstructing the openings to Unit Nos. 3 and 4. During their attempts to close the upper intake gates to the penstocks to decrease suction on the obstruction over the trash racks, Unit No. 4 gate jammed in a partial open position. It was believed at the time to be some timber jammed in the opening. Attempts to free the gate resulted in warping the gate frame. It was also reported at the time that Unit No. 4 turbine had some debris caught in the wicket gate openings; thus the turbine could not be shut down completely, although it was taken off the line. It was believed that the pool would have to be drawn down to gain access to the trouble area, as the flows made it too hazardous for a diver to work. A follow-up telephone call was made by Mr. Fisk to Ralph Welchel on June 26, 1979, and it was found that the upper pool had been drawn down 6 feet, thus cutting the spill to 2 feet over crest, and the slide gates were lowered. The penstock to Unit 4 was drained and a short (2½-foot-long) log about 5-inches in diameter was found wedged between the vanes of the wicket gate. The slide gate was found to be undamaged, and all units were back on line.

The safety cable upstream of the dam was noted to be suspended over the stream. The resulting catenary placed the nearest point to the water surface at an estimated 3-4 feet, while near the ends it was too high to be effective. The cable was adequately marked with signs, however, and had an electric cord the full length to provide illumination at the signs (Photo No. 7).

The Licensee's attention was drawn to the problems a boater might have who was inadvertently drawn closer to the spillway. If he approached anywhere but midstream he may not even be able to reach up and grasp the cable as it would be too high. Furthermore, the concept of taking hold of an energized power cord from a boat is frightening.

A discussion was held with the Licensee, who proposed, as an alternative, to keep the catenary cable, but to suspend a horizontal cable from it, as in a suspension bridge. The signs could then be lowered to eye level. Also, as an alternative to the energized cable for local lighting, it was proposed to light the cable with shore-mounted spot lights and eliminate both the hazard of a boater grasping a weathered electric cable, and the difficulty and cost of providing adequate maintenance on the present lighting system.

The concrete training wall between the two sluice channels has now been removed (Photo No. 8).

5. Efficiency of Operation

The plant is a run-of-the-river operation with virtually no storage. All units are S. Morgan Smith, horizontal shaft, Francis turbines designed to operate under 24 feet of head.

The rated capacity and actual performance of each unit at the time of inspection is indicated in the following table:

| Unit No. | Rated | | | Actual |
|---|---|---|---|---|
| 1 | 600 kW | 400 cfs | 1.0 pf | 390 kW |
| 2 | 800 kW | 480 cfs | 1.0 pf | 470 kW |
| 3 | 600 kW | 400 cfs | 1.0 pf | 0 kW (off-line) |
| 4 | 600 kW | 400 cfs | 1.0 pf | 0 kW " |
| 5 | 800 kW | 480 cfs | 0.8 pf | 590 kW |

6. Shutdowns and Suspensions

During the past inspection year, several forced outages were experienced on Unit Nos. 2, 3, 4, and 5.

Unit 1 was down from December 15, 1978 to March 26, 1979, for a total of 101 days while the generator was being rewound. There was no power loss, as the available flows limited the number of units that could be used, and the load was shifted to an idle unit.

Unit 2 was down from May 25 to June 1, 1979, for a total of 172 hours as the result of a peavy that ran through the intake into the turbine runners. No damage to the unit was found, and it was removed and the unit returned to service. Power generation loss is estimated to be 76 MWh.

Unit 3 was down beginning on June 1, 1978 for a total of 26½ hours due to a broken oil ring. Power generation loss at that time was 12 MWh.

Unit 4 was down from December 15, 1978 to February 14, 1979, for a total of 61 days to remove a log that passed into the penstock and became lodged in the unit. No power generation loss was experienced as the load was shifted to an idle unit.

7. Additions, Betterments, Retirements, Etc.

The sluice training wall was removed in accordance with Commission Order issued August 9, 1978.

8. Needed Extensions of Project Works

None.

9. Nonproject Extensions or Additions

None.

10. Lease or Nonproject Use of Project Property

None.

11. Matters Requiring Commission Action

None.

12. Recreation, Fish and Wildlife

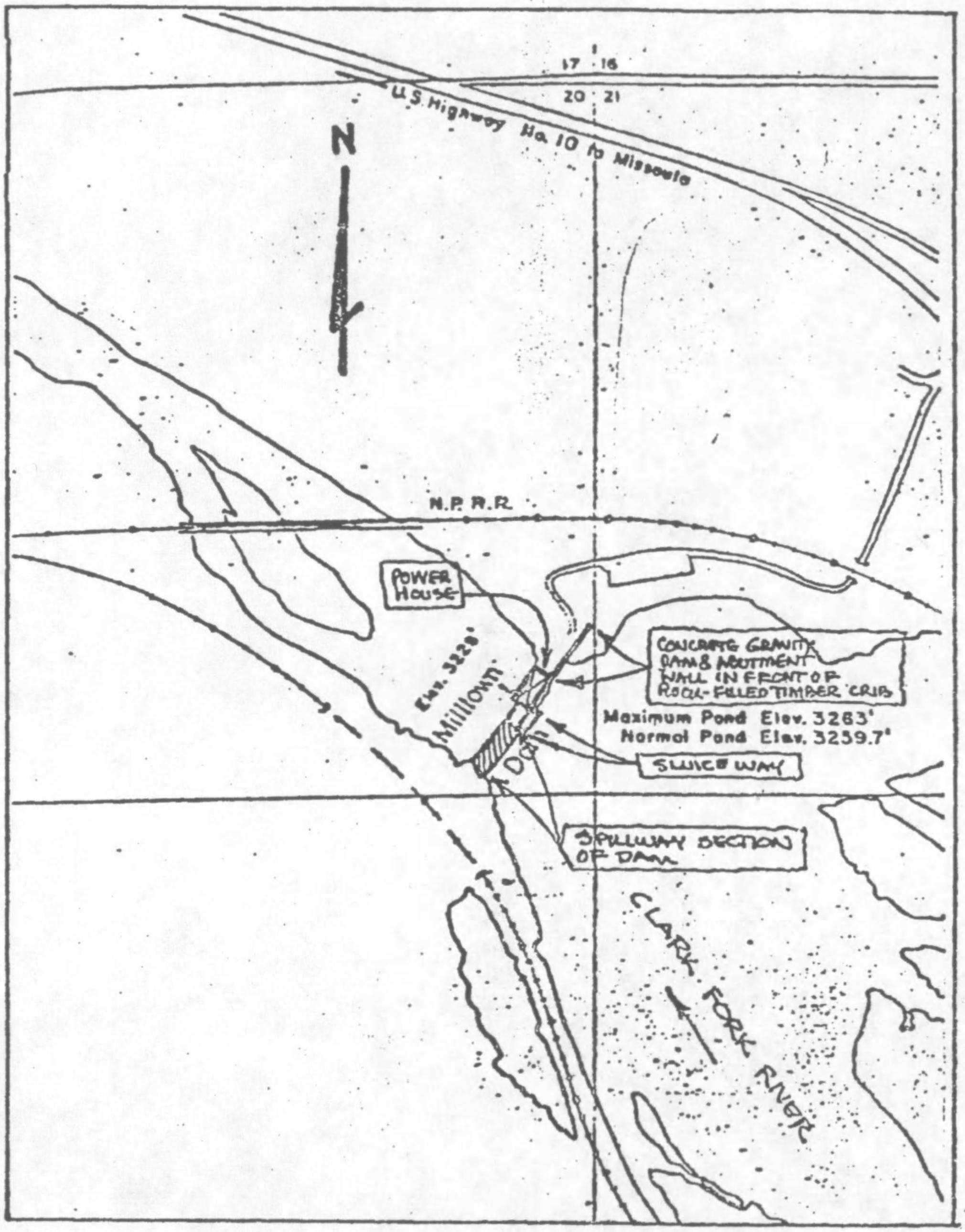
No nonproject use of the reservoir area of project property was noted. Several persons were observed fishing off the bank next to the powerhouse. However, there was no evidence of minority use of the project area. Some attempt was made by youths to gain access to a fenced, restricted area for fishing. Although they did succeed in penetrating the security area, they were observed and chased off by the Licensee's station operation crew.

The project is not subject to the requirements of Part 8, but the Licensee has voluntarily provided a project information sign which essentially conforms to the requirements of Part 8.

13. Other Matters of Interest to the Commission

Reference is made to a memorandum to the Chief, Inspections Branch from the Chief, Project Analysis Branch, dated October 26, 1978, in which reference is made under "Conclusions and Recommendations" to the possible effect to seven buildings downstream of the Milltown Project in case of a dam break during a 7-year flood. During this inspection, I searched the entire area downstream of the dam, and believe that the seven buildings referred to in the analysis were those at a small settlement approximately 3-4 miles downstream, some of which appear to be no more than 10 feet above water line. One significant change should be noted, however. Instead of 7 buildings, there now appears to be more than 14, most of which are of very recent construction. They are almost all large, expensive residences (Photo No. 9).

In the Corps of Engineers' Inventory of Dams, Vol. III, the Milltown Dam is indicated as being 10 miles from the nearest town of Missoula, population 4,886. A hazard rating of 3 is assigned, signifying a low potential hazard (minimal economic loss, involving either undeveloped land or occasional structure or agriculture). Physical inspection of all downstream areas at an elevation low enough to be threatened by any dam break, the unnamed settlement of over 14 costly residences and business places within 3-4 miles of the damsite requires reconsideration of the risk potential of this dam. Although the dam is only 28 feet high, and has virtually no storage, the proximity of the small settlement, as well as its very low elevation with reference to the normal stream water surface, suggests that a hazard rating of 1 would be more appropriate. That would be my recommendation. I can see no significant threat of loss of life, but there is a potential for a considerable amount of property damage. The Corps of Engineers, Seattle, District, will be advised of these findings.




2543-MT
MILLTOWN
GENERAL ARRANGEMENT

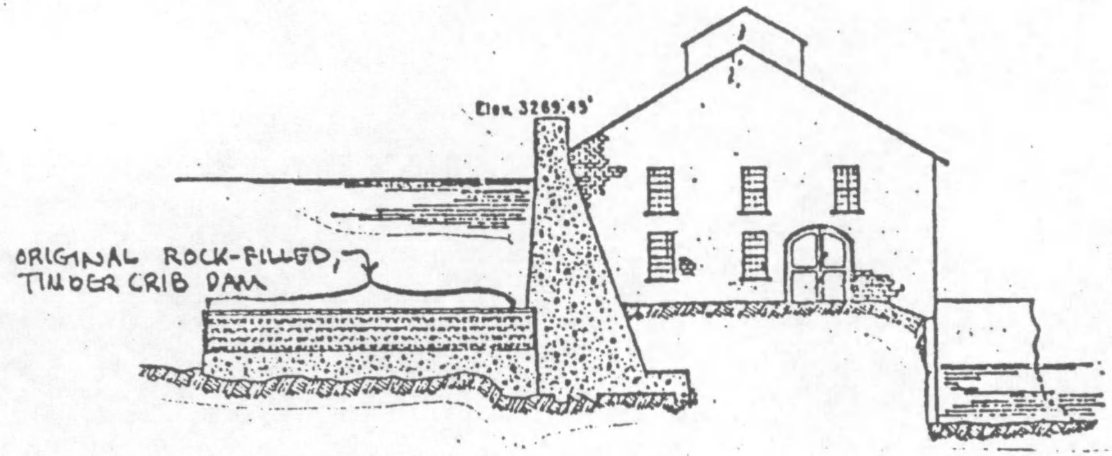
SCALE APPROX. 1" = 1030'

FIGURE 2

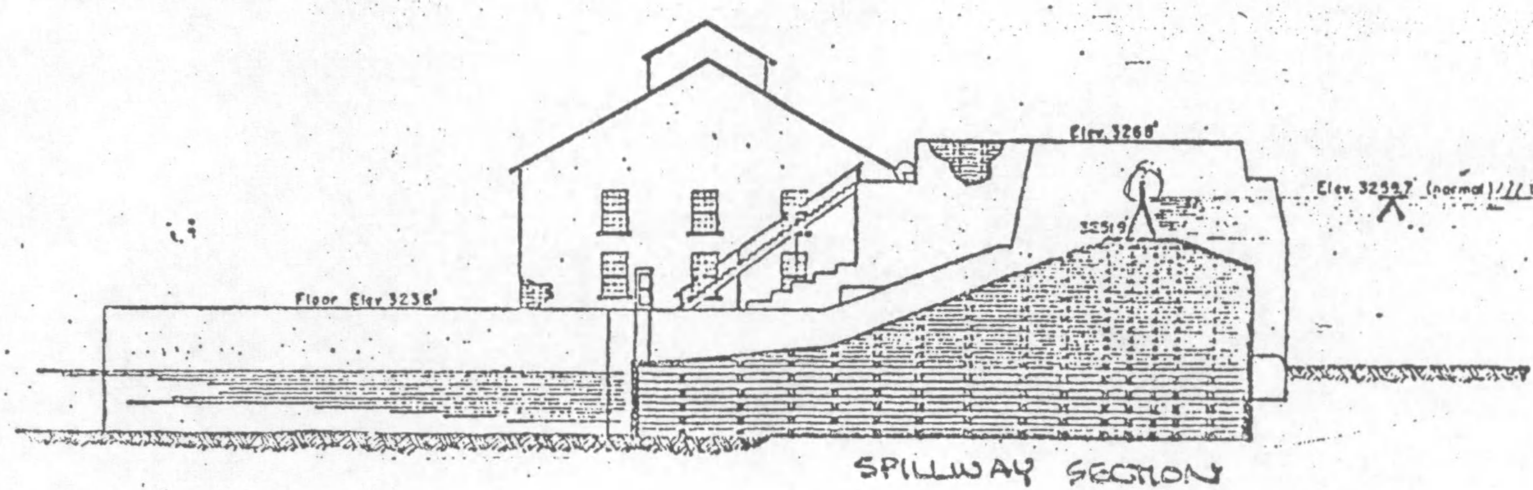
2543-MT
MILLTOWN

TYPICAL DAM SECTIONS
AT POWER HOUSE AND
AT SPILLWAY

SCALE APPROX. 1" = 32'




Elevation (looking S.W.)




Elevation (looking N.E.)

FIGURE 1

# APPENDIX B

Office memorandum from Jim Posewitz
concerning 27 Dec. 1972 Milltown reservoir drawdown.

Jim Posewitz

STATE OF MONTANA
DEPARTMENT OF FISH AND GAME
HELENA, MONTANA

Supervisor
Warden Capt.
Game Mgr.
Fish Mgr.
Dist. I. C.

*Office Memorandum*

TO : File

DATE: December 29, 1972

FROM : Jim Posewits

SUBJECT: Bonner Dam

At approximately 4:55 on December 27, Ron Marcoux called this office regarding a news release to be made by Montana Power. In essence, the news release stated that the dam at Bonner was to be drawn down 12 feet for inspection of a damaged gate that was reported by Montana Power approximately one week ago.

The news release said in part that the Department of Fish and Game had been informed of Montana Power's intention--this informing approximately consisted of bringing the news release to our regional headquarters at approximately 4:30 on the 27th.

Previous information from the Power company was that the water level of the Bonner pond was going to recede approximately 8 feet, due to the rupture in the dam. That information was conveyed to this office by Mr. Walshoe of Montana Power in Butte.

Since we were well aware that the draw down to 12 feet would cause severe sedimentation, I discussed the problem with Don Brown and Wes Woodgerd and then placed a call to Mr. Carl Anderson of the Montana Power in Butte. Essence of my conversation with Carl Anderson was a request to delay the draw down, scheduled for 8:30 p.m., at least 12 hours so that we could prepare to monitor the situation. Mr. Anderson indicated he would talk to the engineers to see if this could be accomplished.

At that point I again called Missoula, instructing Boyd Opheim to make it perfectly clear to the news media if necessary that this department did not and could not authorize anyone to exceed the water quality standards, and that we were very concerned with the sedimentation likely to be caused.

Mr. Carl Anderson later returned my phone call, saying that a delay was impossible to grant and that the draw down would commence as originally scheduled.

Attempts that evening to contact Department of Health employees Wake, Willems and Zollman were unsuccessful. Phone calls to their residences were unanswered.

At approximately noon on December 28, Carl Anderson called and said there were serious repairs to be made and that repairs would commence in approximately two weeks. We responded by concurring that it was best to refill the dam while the details of repair were learned and discussed.

JAP/sd

Montana APPENDIX C

Montana Power press release
concerning the 27 Dec. 1972 Milltown Reservoir drawdown.

Dec 27, 1972 L.S. Stenske

FOR IMMEDIATE RELEASE
From The Montana Power Company

The reservoir above Milltown dam on the Clark Fork River east of Missoula is being drained to allow close examination of the dam.

Last Friday several flashboards on top of the spillway at the dam were tripped and the reservoir was drawn down about eight feet at that time, according to the Montana Power Company, which owns and operates the facility. An examination of the structure Wednesday led to the decision to drain the pond for a thorough check later this week by Montana Power and Bechtel Company engineers.

The utility Company stressed that there is no danger to people down stream, but there is likihood some silt will be washed down stream when the water is released. Montana Power people explained that the silt comes from upstream and is deposited on the river bottom immediately above the dam. An accumulation of nearly two years sedimentation now lies on the river bottom just upstream from the dam. In 1971 the pond was drained to permit upkeep and maintenance at the dam.

The State Fish & Game Department has been notified of this latest drawdown of the pond.

# APPENDIX D

Letter from R. Whelchel to D. Willems
concerning MPC plans to deal with future drawdown
Dated 11 Jan. 1973.

*The* MONTANA POWER COMPANY

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

January 11, 1973

Mr. Don Willems, Chief
Water Quality Bureau
Cogswell Building
Helena, MT. 59601

Dear Mr. Willems:

As a follow-up to my phone conversation with Mr. Zolman, this will advise you of the problems that occurred at our Milltown Dam and our tentative plans for repair.

At approximately 6:00 AM, Friday, December 22, 1972, the center section of our flashboard assembly collapsed and about 18 of the "beartrap-type" flashboards washed away (54 foot section). A sluice gate was opened and the pond was drawn to crest elevation, 3251.9 feet, by 2:00 PM. Top of flashboards is at elevation 3259.7 feet. Shortly after 8:00 AM that same morning, I called and described our problem to Mr. Zolman of your department and Mr. Posewitz of the Fish and Game Department. Mr. Jack Elston in the San Francisco regional office of the Federal Power Commission was also notified.

With the pond at crest elevation, an inspection revealed that part of the timber cap, consisting of 10" x 12" timbers sandwiched with 2" x 12" timbers, had been washed away in that section. Siltation of the river downstream of the dam was minor during the drawdown and became negligible after a few hours.

Mr. K. V. Taylor, a consulting engineer for Engineering Managment Inc., was contacted and he agreed to fly in and inspect the damage. Mr. Taylor was responsible for the preparation of the Safety Inspection made pursuant to Part 12 of the FPC Regulations.

Tuesday evening, December 26, the pond was drawn down to approximately eight feet below crest for a detailed inspection of the main dam Wednesday by Mr. Taylor and The Montana Power Company engineers. Mr. Zolman of your department and Mr. Opheim of the Fish and Game Department

were also present. Siltation of the river was quite heavy during the eighteen hours the pond was down six feet below crest.

The inspection revealed that recent settlement has occurred in the crest of the spillway upstream of the retaining slot for the flashboard assembly. This added to ice-loading on the flashboards and caused the section of flashboards to break loose from their anchors and wash away. The timber cap and the uppermost timbers of the cribbbing are in generally poor condition and display some areas of rot.

Repair methods are currently under investigation and we intend to begin repair work as soon as weather permits to insure adequate protection of the spillway section during the spring runoff.

Currently, our plan is to remove the decking from the upstream and crest sections of the dam and replace them with an articulated concrete mat. An evaluation of more complete repairs to the whole structure after runoff is also under consideration.

Presently, the pond is being held at near elevation 3251.0 feet with virtually no siltation of the river evident downstream. During the repair program, we want to maintain the pond elevations between elevation 3248.0 and crest. Past observations have revealed that siltation is at a minimum when the pond is kept within these limits.

We will keep your department and the Fish and Game Department advised of our repair schedule as it develops. If you have any suggestions that will optimize streamflow conditions as reconstruction progresses, we will be happy to hear from you.

Sincerely yours,

Ralph Whelchel

R. A. Whelchel
Manager, Generation

RAW:mh
cc: Mr. Don Zolman, Water Quality Bureau, Helena
Mr. Jim Posewitz, Montana Fish & Game Dept., Helena
Mr. J. W. Cromer
Mr. R. A. Hofacker
Mr. R. J. Labrie/R.A. Periman
Carl Anderson
Don Gregg
C. G. Bruckner

# APPENDIX E

Memo from Jim Posewitz to MPC, dated 18 Jan. 1973.

STATE ~~OF~~ MONTANA
DEPARTMENT OF FISH AND GAME
HELENA, MONTANA

# *Office Memorandum*

TO : Montana Power Company File

DATE: January 18, 1973

FROM : Jim Posewitz

SUBJECT: Milltown Dam

Ralph Welchel, Montana Power, called at 4:05 p.m. to inform us that Milltown Dam was going to be lowered another time. The reduction in elevation was to begin this evening and proceed to elevation 3250.

When water reached that point the crest of the dam was to be surveyed to enable the company to prepare repair specifications for the contractor.

Following that survey the elevation was to be drawn to level 3247 to survey the apron for the same purpose.

Mr. Welchel called at 4:05 p.m. He called again at 4:45 p.m. when I was able to take his message. The Missoula office was informed at 4:50 p.m. and will monitor the situation for us.

JAP/sd
cc: Jim Ford
Ron Marcoux
Al Wipperman

# APPENDIX F

Letter to R. Labrie from E. Neblett
concerning FERC 1980 Milltown Dam inspection.

FEDERAL ENERGY REGULATORY COMMISSION
333 MARKET STREET, 6th FLOOR
SAN FRANCISCO, CA. 94105

October 9, 1980

Mr. Robert J. Labrie
Vice President, Engineering and Technology
Montana Power Company
40 East Broadway
Butte, Montana 59701

Dear Mr. Labrie:

Mr. Noel Folsom of this office made the annual operation inspection of your Milltown Project, FERC No. 2543, on September 9, 1980. Mr. Folsom was accompanied on the inspection by Mr. Gene Taylor from your office in Butte and Mr. Emmett Smith, Plant Superintendent at Milltown. During the inspection of the project, Mr. Folsom observed or was informed of several conditions at the site that may require corrective or investigative measures to be undertaken soon. These conditions are as follows:

(1) The concrete gravity wall which forms the right side of the dam is badly cracked. The crack apparently extends through the wall as leakage through the crack is significant. A sheet of steel plate has been bolted over the crack on the downstream side apparently in an attempt to arrest the leakage. However, the steel plate does not appear to be effective. As a direct consequence of the leakage through this crack, the foundation materials near the downstream toe of the dam, between the cracked area and the powerhouse are saturated. The crack in the wall and the saturated foundation condition could ultimately lead to an unstable structural condition along this portion of the dam.

(2) During the inspection Mr. Smith mentioned that he had observed sinkholes along the right side of the reservoir floor when the reservoir was at a low stage. If there are sinkholes, the possibility may exist of the development of a piping condition which could be detrimental to the safety of the dam. During the inspection, the water level in the reservoir was high and the bottom of the reservoir in the area of the reported sinkholes could not be clearly seen. The area downstream of the dam on the right side was closely inspected and no unusual seepage conditions were detected. Consequently, the existence of the sinkhole or any adverse effects therefrom could not be confirmed. We believe, however, that the reported sinkholes should be carefully investigated in the not too distant future.

(3) Mr. Taylor and Mr. Smith reported that the trash racks for the penstock intakes are in need of repair. Apparently, on one or more occasions debris has entered the penstock of one of the units and jammed the turbine. The turbine is then inoperative until the reservoir is drawn down and the debris removed.

I am concerned about the possible effect the reported conditions may have on the safety of the dam and the efficient operation of the project. A plan for investigation and appropriate remedial action must be developed without delay.

Accordingly, within 30 days of the date of this letter, you are requested to submit a plan to this office for the necessary work, including a schedule by which the repairs will be performed.

Sincerely,

Eugene Neblett
Regional Engineer

# APPENDIX G

Invertebrate data collected by MPC to indicate water quality in vicinity of Milltown Dam.
Refer to Figure 4 (p. ) for map of sample sites.

Station B
Numbers of invertebrates based on 3 samples.

| | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **EPHEMEROPTERA** | | | | | | | | | | |
| Ameletus | 9 | 13 | 28 | 50 | 167 | - | 3 | 1 | 4 | 13 |
| Baetis alexanderi | 11 | 2 | 7 | 20 | 67 | 80 | 28 | 44 | 152 | 506 |
| B. parvus | 1 | 2 | 4 | 7 | 23 | - | 1 | - | 1 | 3 |
| Ephemerella margarita | 3 | - | - | 3 | 10 | | | | | |
| E. spinifera | | | | | | | | | | |
| Ephemerella | | | | | | 50 | 79 | 73 | 202 | 673 |
| Epeorus | | | | | | 18 | 15 | 20 | 53 | 177 |
| Heptagenia | 11 | 2 | - | 13 | 43 | 2 | 1 | - | 3 | 10 |
| Rithrogena | 5 | 1 | 6 | 12 | 40 | 12 | - | 10 | 22 | 73 |
| Paraleptophlebia | 4 | 1 | - | 5 | 17 | 22 | - | 21 | 43 | 143 |
| Tricorythodes | 3 | - | 1 | 4 | 13 | | | | | |
| **TRICHOPTERA** | | | | | | | | | | |
| Arctiopsyche | 1 | - | - | 1 | 3 | 1 | 1 | 4 | 6 | 20 |
| Cheumatopsyche | 37 | 10 | 18 | 65 | 216 | 61 | 6 | 76 | 143 | 476 |
| Hydropsyche | 37 | 18 | 35 | 90 | 300 | 49 | 17 | 66 | 132 | 440 |
| Brachycentrus | | | | | | - | 1 | 1 | 2 | 7 |
| Ceraclea | | | | | | | | | | |
| Oecetis | | | | | | | | | | |
| Glossosoma | | | | | | 1 | - | - | 1 | 3 |
| Helicopsyche | 4 | 2 | 4 | 10 | 33 | 1 | - | 6 | 7 | 23 |
| Leucotrichia | | | | | | - | 1 | 1 | 2 | 7 |
| Hydroptila | 4 | - | - | 4 | 13 | 15 | 52 | 82 | 149 | 496 |
| Psychomyia | 213 | 49 | 84 | 346 | 1152 | 10 | 29 | 30 | 69 | 230 |
| Rhyacophila | 2 | 2 | 3 | 7 | 23 | 1 | 1 | 3 | 5 | 17 |
| **PLECOPTERA** | | | | | | | | | | |
| Acroneuria | 1 | - | - | 1 | 3 | 2 | - | 1 | 3 | 10 |
| Claassenia | | | | | | 3 | - | 2 | 5 | 17 |
| Unid. Perlidae | 6 | 2 | 10 | 18 | 60 | | | | | |
| Cultus | | | | | | 2 | 6 | - | 8 | 27 |
| Isogenoides | | | | | | | | | | |
| Unid. Perlodidae | | | | | | 12 | 14 | 23 | 49 | 163 |
| Alloperla | 1 | - | 1 | 2 | 7 | 1 | - | 2 | 3 | 10 |
| Unid. Chloroperlidae | 3 | 2 | 3 | 8 | 27 | 4 | - | 20 | 24 | 80 |
| Pteronarcys | 2 | - | - | 2 | 7 | 5 | - | 5 | 10 | 33 |
| **COLEOPTERA** | | | | | | | | | | |
| Optioservus | 17 | 4 | 22 | 43 | 143 | 5 | - | 4 | 9 | 30 |
| Zaitzevia | 5 | 1 | 21 | 27 | 90 | 1 | 1 | 1 | 3 | 10 |
| Narpus | - | - | 1 | 1 | 3 | | | | | |
| Unid. Hydrophilidae | | | | | | | | | | |
| **MEGALOPTERA** | | | | | | | | | | |
| Sialis | | | | | | | | | | |
| **ODONATA** | | | | | | | | | | |
| Ophiogomphus | | | | | | | | | | |

Station B (cont.)

| | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **LEPIDOPTERA** | | | | | | | | | | |
| *Paragyractus* | - | 5 | 1 | 6 | 20 | 1 | 4 | 9 | 14 | 47 |
| **DIPTERA** | | | | | | | | | | |
| *Atherix* | 9 | 6 | 3 | 18 | 60 | 3 | 2 | 4 | 9 | 30 |
| *Chelifera* | | | | | | 2 | 2 | 2 | 6 | 20 |
| *Hemerodromia* | | | | | | 1 | 1 | - | 2 | 7 |
| *Simulium* | | | | | | | | | | |
| Tribe Stilobezziini | | | | | | | | | | |
| *Antocha* | 12 | 2 | 5 | 19 | 63 | | | | | |
| *Limnophila* | | | | | | 9 | 10 | 20 | 39 | 130 |
| *Hexatoma* | 4 | - | - | 4 | 13 | | | | | |
| *Tipula* | 1 | 1 | - | 2 | 7 | | | | | |
| (Subfamily Chironomidae) | | | | | | | | | | |
| Thienemannimyia group | 7 | 2 | 6 | 15 | 50 | 8 | 3 | 12 | 23 | 77 |
| *Chironomus* | 1 | - | - | 1 | 3 | | | | | |
| *Cryptochironomus* | | | | | | | | | | |
| *Dicrotendipes* | | | | | | | | | | |
| *Endochironomus* | | | | | | | | | | |
| *Microtendipes* | 68 | 36 | 45 | 149 | 496 | 3 | - | 17 | 20 | 67 |
| *Paracladopelma* | | | | | | | | | | |
| *Phaenopsectra* | 6 | 1 | 1 | 8 | 27 | | | | | |
| *Polypedilum* | - | - | 1 | 1 | 3 | | | | | |
| *Micropsectra* | 64 | 6 | 42 | 112 | 373 | | | | | |
| *Paratanytarsus* | | | | | | | | | | |
| *Rheotanytarsus* | 109 | 36 | 58 | 203 | 676 | | | | | |
| *Tanytarsus* | | | | | | | | | | |
| *Corynoneura* | 1 | - | - | 1 | 3 | | | | | |
| *Cricotopus* or *Orthocladius* | 5 | 22 | 29 | 56 | 186 | 1 | 20 | 13 | 34 | 113 |
| *Cricotopus* (bicinctus group) | 89 | 30 | 58 | 177 | 589 | 1 | - | - | 1 | 3 |
| *C.* (isocladius group) | 148 | 98 | 158 | 404 | 1345 | 79 | 156 | 127 | 362 | 1205 |
| *C. nosticola* | 11 | 16 | 12 | 39 | 130 | - | - | 6 | 6 | 20 |
| *Eukiefferiella* | 2 | - | 6 | 8 | 27 | 14 | 8 | 14 | 36 | 120 |
| *Nanocladius* | 1 | - | 1 | 2 | 7 | | | | | |
| *Paraphaenocladius* | 4 | 3 | 2 | 9 | 30 | - | 1 | 2 | 3 | 10 |
| *Synorthocladius* | | | | | | | | | | |
| *Thienemanniella* | 35 | 7 | 21 | -3 | 210 | - | 10 | 17 | 27 | 90 |
| *Diamesa* | | | | | | | | | | |
| *Monodiamesa* | | | | | | | | | | |
| *Potthastia* | 2 | 2 | - | 4 | 13 | | | | | |
| *Psuedokiefferella* | - | - | 1 | 1 | 3 | | | | | |
| *Pentaneura* | 1 | - | - | 1 | 3 | | | | | |
| *Rheocricotopus* | | | | | | | | | | |
| Chironomid pupa | 83 | 33 | 57 | 173 | 576 | - | 3 | 2 | 5 | 17 |
| **GASTROPODA** | | | | | | | | | | |
| *Physa* | 14 | 11 | 9 | 34 | 113 | 1 | 3 | 3 | 7 | 23 |

Station B (cont.)

| PELECYPODA | 8/27/80 Sample # 1 | 2 | 3 | total | ind/$m^2$ | 10/24/80 Sample # 1 | 2 | 3 | total | ind/$m^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Pisidium | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| Dugesia | | | | | | 1 | - | - | 1 | 3 |
| OLIGOCHAETAE | | | | | | | | | | |
| Eiseniella | | | | | | - | - | 1 | 1 | 3 |
| Tubificidae | | | | | | | | | | |
| immature with capilliform chaeta | | | | | | | | | | |
| immature without capiliform chaeta | | | | | | | | | | |
| Rhyacodrilus | | | | | | | | | | |
| Limnodrilus | | | | | | | | | | |
| Cheatogaster | 4 | 6 | - | 10 | 33 | 1 | - | 1 | 2 | 7 |
| Ophiodonais serpentina | - | 1 | - | 1 | 3 | - | - | 4 | 4 | 13 |

Station CA
Numbers of invertebrates based on 3 samples.

| | 8/27/80 Sample # | | | | | 10/24/80 Sample # | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **EPHEMEROPTERA** | 1 | 2 | 3 | total | ind/$m^2$ | 1 | 2 | 3 | total | ind/$m^2$ |
| Ameletus | 8 | 1 | 4 | 13 | 43 | 1 | 3 | - | 4 | 13 |
| Baetis alexanderi | 23 | 21 | 42 | 86 | 286 | 5 | 5 | 18 | 28 | 93 |
| B. parvus | 4 | - | 2 | 6 | 20 | | | | | |
| Ephemerella margarita | 2 | 3 | 1 | 6 | 20 | 2 | - | 2 | 4 | 13 |
| E. spinifera | | | | | | | | | | |
| Ephemerella | | | | | | 27 | 5 | 33 | 65 | 216 |
| Epeorus | | | | | | | | | | |
| Heptagenia | 1 | 4 | 2 | 7 | 23 | | | | | |
| Rithrogena | | | | | | 2 | 2 | 9 | 13 | 43 |
| Paraleptophlebia | 1 | - | 3 | 4 | 13 | | | | | |
| Tricorythodes | 199 | 203 | 176 | 578 | 1925 | 3 | - | 2 | 5 | 17 |
| **TRICHOPTERA** | | | | | | | | | | |
| Arctiopsyche | 3 | 4 | 3 | 10 | 33 | | | | | |
| Cheumatopsyche | 1 | - | 2 | 3 | 10 | | | | | |
| Hydropsyche | 10 | 7 | 4 | 21 | 70 | 2 | - | 1 | 3 | 10 |
| Brachycentrus | | | | | | 7 | 4 | 3 | 14 | 47 |
| Ceraclea | | | | | | 1 | - | - | 1 | 3 |
| Oecetis | - | - | 1 | 1 | 3 | | | | | |
| Glossosoma | | | | | | | | | | |
| Helicopsyche | | | | | | | | | | |
| Leucotrichia | - | - | 5 | 5 | 17 | | | | | |
| Hydroptila | 15 | 1 | 28 | 44 | 147 | 36 | 6 | 52 | 94 | 313 |
| Psychomyia | 6 | 3 | 6 | 15 | 50 | | | | | |
| Rhyacophila | | | | | | | | | | |
| **PLECOPTERA** | | | | | | | | | | |
| Acroneuria | | | | | | | | | | |
| Claassenia | | | | | | | | | | |
| Unid. Perlidae | | | | | | | | | | |
| Cultus | | | | | | 2 | 5 | 10 | 17 | 57 |
| Isogenoides | 3 | 3 | 5 | 11 | 36 | - | - | 3 | 3 | 10 |
| Unid. Perlodidae | | | | | | 25 | 58 | 67 | 150 | 500 |
| Alloperla | - | - | 3 | 3 | 10 | | | | | |
| Unid. Chloroperlidae | 1 | 1 | - | 2 | 7 | - | 2 | 7 | 9 | 30 |
| Pteronarcys | | | | | | | | | | |
| **COLEOPTERA** | | | | | | | | | | |
| Optioservus | 9 | 23 | 14 | 46 | 153 | 12 | 11 | 21 | 44 | 147 |
| Zaitzevia | 1 | 3 | 3 | 7 | 23 | - | - | 1 | 1 | 3 |
| Narpus | | | | | | - | 1 | - | 1 | 3 |
| Unid. Hydrophilidae | | | | | | | | | | |
| **MEGALOPTERA** | | | | | | | | | | |
| Sialis | | | | | | - | 1 | - | 1 | 3 |
| **ODONATA** | | | | | | | | | | |
| Ophiogomphus | | | | | | | | | | |

Station CA (cont.)

| LEPIDOPTERA | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m² | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m² |
|---|---|---|---|---|---|---|---|---|---|---|
| Paragyractus | 8 | 1 | 4 | 13 | 43 | | | | | |
| **DIPTERA** | | | | | | | | | | |
| Atherix | 6 | 6 | 7 | 19 | 63 | 1 | - | - | 1 | 3 |
| Chelifera | - | 5 | 2 | 7 | 23 | 9 | 19 | 18 | 46 | 153 |
| Hemerodromia | | | | | | | | | | |
| Simulium | | | | | | | | | | |
| Tribe Stilobezziini | | | | | | - | 4 | - | 4 | 13 |
| Antocha | - | - | 1 | 1 | 3 | | | | | |
| Limnophila | 1 | - | 3 | 4 | 13 | - | 2 | 3 | 5 | 17 |
| Hexatoma | 1 | - | 1 | 2 | 7 | | | | | |
| Tipula | - | 1 | - | 1 | 3 | 2 | 3 | 1 | 6 | 20 |
| (Subfamily Chironomidae) | | | | | | | | | | |
| Thienemannimyia group | 3 | 3 | 5 | 11 | 37 | - | - | 1 | 1 | 3 |
| Chironomus | | | | | | | | | | |
| Cryptochironomus | | | | | | 1 | - | - | 1 | 3 |
| Dicrotendipes | - | 1 | 2 | 3 | 10 | | | | | |
| Endochironomus | | | | | | | | | | |
| Microtendipes | 114 | 139 | 108 | 361 | 1202 | 28 | 17 | 60 | 105 | 350 |
| Paracladopelma | 2 | 3 | 6 | 11 | 37 | - | 1 | - | 1 | 3 |
| Phaenopsectra | - | 5 | 8 | 13 | 43 | | | | | |
| Polypedilum | 3 | 33 | 31 | 67 | 223 | | | | | |
| Micropsectra | 5 | 7 | 10 | 22 | 73 | 1 | 2 | - | 3 | 10 |
| Paratanytarsus | 15 | 8 | 4 | 27 | 90 | | | | | |
| Rheotanytarsus | - | 1 | - | 1 | 3 | 2 | - | - | 2 | 7 |
| Tanytarsus | 31 | 31 | 13 | 75 | 250 | | | | | |
| Corynoneura | | | | | | | | | | |
| Cricotopus or Orthocladius | 126 | 147 | 157 | 430 | 1432 | 31 | 7 | 22 | 60 | 200 |
| Cricotopus (bicinctus group) | | | | | | | | | | |
| C. (isocladius group) | 16 | 57 | 50 | 123 | 410 | 4 | - | 5 | 9 | 30 |
| C. nosticola | | | | | | | | | | |
| Eukiefferiella | 2 | - | 4 | 6 | 20 | 11 | 1 | 9 | 21 | 70 |
| Nanocladius | | | | | | | | | | |
| Paraphaenocladius | | | | | | | | | | |
| Synorthocladius | | | | | | | | | | |
| Thienemanniella | 12 | 10 | 7 | 29 | 97 | | | | | |
| Diamesa | | | | | | 62 | 18 | 77 | 157 | 523 |
| Monodiamesa | - | - | 2 | 2 | 7 | | | | | |
| Potthastia | 27 | 14 | 13 | 54 | 180 | | | | | |
| Psuedokiefferella | 1 | - | 1 | 2 | 7 | | | | | |
| Pentaneura | | | | | | | | | | |
| Rheocricotopus | | | | | | - | 3 | - | | 10 |
| Chironomid pupa | 21 | 16 | 18 | 55 | 183 | 2 | 2 | 2 | 6 | 20 |
| **GASTROPODA** | | | | | | | | | | |
| Physa | - | 1 | - | 1 | 3 | 3 | 2 | 1 | 6 | 20 |

Station CA (cont.)

| | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ |
|---|---|---|---|---|---|
| **PELECYPODA** | | | | | |
| *Pisidium* | - | - | 1 | 1 | 3 |
| **TURBELLARIA** | | | | | |
| *Dugesia* | | | | | |
| OLIGOCHAETAE | | | | | |
| *Eiseniella* | | | | | |
| Tubificidae | | | | | |
| immature with capilliform chaeta | | | | | |
| immature without capiliform chaeta | | | | | |
| *Rhyacodrilus* | | | | | |
| *Limnodrilus* | | | | | |
| *Cheatogaster* | | | | | |
| *Ophiodonais serpentina* | 1 | - | - | 1 | 3 |

Station CB

Numbers of invertebrates based on 3 samples.

| | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m² | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m² |
|---|---|---|---|---|---|---|---|---|---|---|
| **EPHEMEROPTERA** | | | | | | | | | | |
| Ameletus | 2 | 8 | 22 | 32 | 107 | 15 | 18 | 7 | 40 | 133 |
| Baetis alexanderi | 5 | 1 | - | 6 | 20 | 6 | - | - | 6 | 20 |
| B. parvus | 1 | - | - | 1 | 3 | - | 1 | - | 1 | 3 |
| Ephemerella margarita | | | | | | | | | | |
| E. spinifera | | | | | | | | | | |
| Ephemerella | - | - | 1 | 1 | 3 | 41 | 19 | 20 | 80 | 266 |
| Epeorus | | | | | | 1 | - | - | 1 | 3 |
| Heptagenia | 6 | 3 | 5 | 14 | 47 | 4 | - | 2 | 6 | 20 |
| Rithrogena | | | | | | 2 | 1 | - | 3 | 10 |
| Paraleptophlebia | 3 | 8 | 4 | 15 | 50 | 5 | - | - | 5 | 17 |
| Tricorythodes | 8 | 21 | 19 | 48 | 160 | | | | | |
| **TRICHOPTERA** | | | | | | | | | | |
| Arctiopsyche | 1 | - | - | 1 | 3 | | | | | |
| Cheumatopsyche | 42 | 13 | 14 | 69 | 230 | 85 | 30 | 29 | 144 | 480 |
| Hydropsyche | 12 | 7 | 9 | 28 | 93 | 109 | 13 | 9 | 131 | 436 |
| Brachycentrus | | | | | | 1 | - | - | 1 | 3 |
| Ceraclea | | | | | | - | - | 1 | 1 | 3 |
| Oecetis | 7 | 2 | 3 | 12 | 40 | 10 | - | 17 | 27 | 90 |
| Glossosoma | | | | | | | | | | |
| Helicopsyche | | | | | | 1 | - | - | 1 | 3 |
| Leucotrichia | | | | | | | | | | |
| Hydroptila | 2 | - | - | 2 | 7 | 75 | 41 | 71 | 187 | 623 |
| Psychomyia | 168 | 173 | 211 | 552 | 1838 | 61 | 55 | 94 | 210 | 700 |
| Rhyacophila | | | | | | | | | | |
| **PLECOPTERA** | | | | | | | | | | |
| Acroneuria | | | | | | | | | | |
| Claassenia | | | | | | | | | | |
| Unid. Perlidae | | | | | | | | | | |
| Cultus | | | | | | 12 | 1 | - | 13 | 43 |
| Isogenoides | - | 2 | 1 | 3 | 10 | - | 1 | 3 | 4 | 13 |
| Unid. Perlodidae | | | | | | 21 | 32 | 11 | 64 | 213 |
| Alloperla | | | | | | | | | | |
| Unid. Chloroperlidae | | | | | | 4 | 6 | 2 | 12 | 40 |
| Pteronarcys | | | | | | 1 | - | - | 1 | 3 |
| **COLEOPTERA** | | | | | | | | | | |
| Optioservus | 17 | 29 | 23 | 69 | 230 | 14 | 11 | 15 | 40 | 133 |
| Zaitzevia | 2 | 1 | 3 | 6 | 20 | 2 | 1 | - | 3 | 10 |
| Narpus | | | | | | | | | | |
| Unid. Hydrophilidae | | | | | | | | | | |
| **MEGALOPTERA** | | | | | | | | | | |
| Sialis | | | | | | | | | | |
| **ODONATA** | | | | | | | | | | |
| Ophiogomphus | - | - | 1 | 1 | 3 | | | | | |

Station CB (cont.)

| LEPIDOPTERA | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m² | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m² |
|---|---|---|---|---|---|---|---|---|---|---|
| Paragyractus | 30 | 17 | 17 | 64 | 213 | 9 | 4 | 14 | 27 | 90 |
| **DIPTERA** | | | | | | | | | | |
| Atherix | | | | | | 2 | 1 | - | 3 | 10 |
| Chulifera | | | | | | 2 | 2 | - | 4 | 13 |
| Hemerodromia | | | | | | 1 | - | 1 | 2 | 7 |
| Simulium | - | 1 | - | 1 | 3 | | | | | |
| Tribe Stilobezziini | | | | | | | | | | |
| Antocha | | | | | | 8 | 2 | 2 | 12 | 40 |
| Limnophila | | | | | | 2 | - | - | 2 | 7 |
| Hexatoma | | | | | | | | | | |
| Tipula | 1 | - | - | 1 | 3 | | | | | |
| (Subfamily Chironomidae) | | | | | | | | | | |
| Thienemannimyia group | 3 | 3 | 5 | 11 | 37 | 13 | 5 | 12 | 30 | 100 |
| Chironomus | - | - | 1 | 1 | 3 | | | | | |
| Cryptochironomus | | | | | | | | | | |
| Dicrotendipes | - | - | 1 | 1 | 3 | | | | | |
| Endochironomus | 2 | - | 4 | 6 | 20 | | | | | |
| Microtendipes | 301 | 484 | 376 | 1161 | 3866 | 129 | 244 | 292 | 665 | 2214 |
| Paracladopelma | - | - | 1 | 1 | 3 | | | | | |
| Phaenopsectra | | | | | | | | | | |
| Polypedilum | - | - | 1 | 1 | 3 | - | 1 | 5 | 6 | 20 |
| Micropsectra | - | - | 4 | 4 | 13 | - | 1 | 5 | 6 | 20 |
| Paratanytarsus | 5 | 5 | 1 | 11 | 37 | | | | | |
| Rheotanytarsus | | | | | | 3 | 7 | 1 | 11 | 37 |
| Tanytarsus | 2 | - | 2 | 4 | 13 | | | | | |
| Corynoneura | | | | | | | | | | |
| Cricotopus or Orthocladius | 33 | 12 | 8 | 53 | 176 | 58 | 19 | 24 | 101 | 336 |
| Cricotopus (bicinctus group) | 14 | 22 | 2 | 38 | 127 | 17 | - | 5 | 22 | 73 |
| C. (isocladius group) | | | | | | 11 | 3 | 4 | 18 | 60 |
| C. nosticola | | | | | | | | | | |
| Eukiefferiella | 6 | - | 6 | 12 | 40 | 3 | 1 | - | 4 | 13 |
| Nanocladius | 1 | - | - | 1 | 3 | | | | | |
| Paraphaenocladius | | | | | | 4 | 3 | 1 | 8 | 27 |
| Synorthocladius | 1 | - | - | 1 | 3 | | | | | |
| Thienemanniella | | | | | | 3 | 1 | 1 | 5 | 17 |
| Diamesa | | | | | | 1 | 2 | 2 | 5 | 17 |
| Monodiamesa | 1 | 2 | 2 | 5 | 17 | | | | | |
| Potthastia | | | | | | | | | | |
| Psuedokiefferella | 2 | - | - | 2 | 7 | | | | | |
| Pentaneura | | | | | | | | | | |
| Rheocricotopus | | | | | | | | | | |
| Chironomid pupa | 5 | 2 | 1 | 8 | 27 | 3 | - | 1 | 4 | 13 |
| **GASTROPODA** | | | | | | | | | | |
| Physa | | | | | | | | | | |

Station CB (cont.)

| | 8/27/80 Sample # | | | | | 10/24/80 Sample # | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PELECYPODA** | 1 | 2 | 3 | total | ind/$m^2$ | 1 | 2 | 3 | total | ind/$m^2$ |
| *Pisidium* | | | | | | | | | | |
| **TURBELLARIA** | | | | | | | | | | |
| *Dugesia* | | | | | | | | | | |
| **OLIGOCHAETAE** | | | | | | | | | | |
| *Eiseniella* | | | | | | | | | | |
| Tubificidae | | | | | | | | | | |
| immature with capilliform chaeta | 1 | 2 | - | 3 | 10 | 6 | 8 | 15 | 29 | 97 |
| immature without capiliform chaeta | 1 | 4 | 2 | 7 | 23 | 3 | 1 | 5 | 9 | 30 |
| *Rhyacodrilus* | 1 | 6 | 1 | 8 | 27 | 2 | - | 4 | 6 | 20 |
| *Limnodrilus* | - | 6 | - | 6 | 20 | - | - | 2 | 2 | 7 |
| *Cheatogaster* | | | | | | - | - | 6 | 6 | 20 |
| *Ophiodonais serpentina* | | | | | | | | | | |

Station CBB
Numbers of invertebrates based on 3 samples.

| | 8/27/80 Sample # | | | | | 10/24/80 Sample # | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **EPHEMEROPTERA** | 1 | 2 | 3 | total | ind/$m^2$ | 1 | 2 | 3 | total | ind/$m^2$ |
| Ameletus | - | 3 | - | 3 | 10 | | | | | |
| Baetis alexanderi | 16 | 46 | 65 | 127 | 423 | 9 | 5 | 21 | 35 | 117 |
| B. parvus | - | 2 | 3 | 5 | 17 | 1 | - | - | 1 | 3 |
| Ephemerella margarita | | | | | | | | | | |
| E. spinifera | | | | | | - | - | 2 | 2 | 7 |
| Ephemerella | | | | | | 9 | 9 | 40 | 58 | 193 |
| Epeorus | | | | | | | | | | |
| Heptagenia | - | 2 | - | 2 | 7 | | | | | |
| Rithrogena | | | | | | 4 | - | 5 | 9 | 30 |
| Paraleptophlebia | | | | | | 1 | 1 | 8 | 10 | 33 |
| Tricorythodes | 1 | 1 | 3 | 5 | 17 | | | | | |
| **TRICHOPTERA** | | | | | | | | | | |
| Arctiopsyche | 1 | 2 | 4 | 7 | 23 | 1 | - | 5 | 6 | 20 |
| Cheumatopsyche | 6 | 65 | 65 | 136 | 453 | 31 | 2 | 66 | 99 | 330 |
| Hydropsyche | 33 | 101 | 134 | 268 | 892 | 76 | 13 | 196 | 285 | 949 |
| Brachycentrus | | | | | | - | - | 1 | 1 | 3 |
| Ceraclea | | | | | | | | | | |
| Oecetis | - | - | 4 | 4 | 13 | 3 | 3 | 6 | 12 | 40 |
| Glossosoma | | | | | | | | | | |
| Helicopsyche | | | | | | | | | | |
| Leucotrichia | | | | | | | | | | |
| Hydroptila | - | 1 | 1 | 2 | 7 | 18 | 23 | 30 | 71 | 236 |
| Psychomyia | 224 | 196 | 102 | 522 | 1738 | 33 | 82 | 35 | 150 | 500 |
| Rhyacophila | | | | | | 5 | - | 7 | 12 | 40 |
| **PLECOPTERA** | | | | | | | | | | |
| Acroneuria | | | | | | 1 | - | - | 1 | 3 |
| Claassenia | | | | | | | | | | |
| Unid. Perlidae | - | 1 | 1 | 2 | 7 | 3 | 2 | 3 | 8 | 27 |
| Cultus | | | | | | 2 | - | 5 | 7 | 23 |
| Isogenoides | 2 | - | 2 | 4 | 13 | - | - | 1 | 1 | 3 |
| Unid. Perlodidae | | | | | | 1 | - | 3 | 4 | 13 |
| Alloperla | | | | | | | | | | |
| Unid. Chloroperlidae | | | | | | 7 | 1 | 5 | 13 | 43 |
| Pteronarcys | - | 2 | - | 2 | 7 | | | | | |
| **COLEOPTERA** | | | | | | | | | | |
| Optioservus | 3 | 6 | 7 | 16 | 53 | - | - | 6 | 6 | 20 |
| Zaitzevia | 1 | - | - | 1 | 3 | 1 | - | - | 1 | 3 |
| Narpus | | | | | | | | | | |
| Unid. Hydrophilidae | | | | | | | | | | |
| **MEGALOPTERA** | | | | | | | | | | |
| Sialis | | | | | | | | | | |
| **ODONATA** | | | | | | | | | | |
| Ophiogomphus | | | | | | | | | | |

Station CBB (cont.)

| | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **LEPIDOPTERA** | | | | | | | | | | |
| *Paragyractus* | 39 | 58 | 26 | 123 | 410 | 17 | 20 | 7 | 44 | 147 |
| **DIPTERA** | | | | | | | | | | |
| *Atherix* | | | | | | 6 | 1 | 1 | 8 | 27 |
| *Chelifera* | 1 | - | 4 | 5 | 17 | 2 | 7 | 2 | 11 | 37 |
| *Hemerodromia* | | | | | | 2 | 6 | 4 | 12 | 40 |
| *Simulium* | | | | | | | | | | |
| Tribe Stilobezziini | | | | | | | | | | |
| *Antocha* | - | 1 | - | 1 | 3 | 22 | 46 | 27 | 95 | 316 |
| *Limnophila* | | | | | | 1 | 1 | 1 | 3 | 10 |
| *Hexatoma* | | | | | | | | | | |
| *Tipula* | | | | | | | | | | |
| (Subfamily Chironomidae) | | | | | | | | | | |
| Thienemannimyia group | 1 | - | 2 | 3 | 10 | 6 | 1 | 9 | 16 | 53 |
| *Chironomus* | | | | | | | | | | |
| *Cryptochironomus* | | | | | | | | | | |
| *Dicrotendipes* | | | | | | | | | | |
| *Endochironomus* | | | | | | | | | | |
| *Microtendipes* | 146 | 95 | 200 | 441 | 1469 | 64 | 143 | 101 | 308 | 1026 |
| *Paracladopelma* | 1 | 2 | - | 3 | 10 | | | | | |
| *Phaenopsectra* | 11 | 8 | 11 | 30 | 100 | - | | | | |
| *Polypedilum* | | | | | | | | | | |
| *Micropsectra* | - | - | 1 | 1 | 3 | | | | | |
| *Paratanytarsus* | - | 3 | 1 | 4 | 13 | | | | | |
| *Rheotanytarsus* | | | | | | - | - | 1 | 1 | 3 |
| *Tanytarsus* | | | | | | | | | | |
| *Corynoneura* | | | | | | | | | | |
| *Cricotopus* or *Orthocladius* | 34 | 35 | 33 | 102 | 340 | 28 | 20 | 55 | 103 | 343 |
| *Cricotopus* (bicinctus group) | - | 2 | 11 | 13 | 43 | | | | | |
| *C.* (isocladius group) | 7 | 14 | 10 | 31 | 103 | 16 | 12 | 36 | 64 | 213 |
| *C. nosticola* | - | 1 | 3 | 4 | 13 | - | 1 | - | 1 | 3 |
| *Eukiefferiella* | - | 3 | 2 | 5 | 17 | 2 | - | 18 | 20 | 67 |
| *Nanocladius* | | | | | | | | | | |
| *Paraphaenocladius* | 4 | 4 | 4 | 12 | 40 | 2 | 1 | 3 | 6 | 20 |
| *Synorthocladius* | | | | | | | | | | |
| *Thienemanniella* | - | 1 | 4 | 5 | 17 | - | - | 1 | 1 | 3 |
| *Diamesa* | | | | | | 29 | 17 | 32 | 78 | 260 |
| *Monodiamesa* | | | | | | | | | | |
| *Potthastia* | 2 | 3 | 1 | 6 | 20 | 1 | - | - | 1 | 3 |
| *Psuedokiefferella* | - | 3 | 1 | 4 | 13 | | | | | |
| *Pentaneura* | | | | | | | | | | |
| *Rheocricotopus* | | | | | | | | | | |
| Chironomid pupa | 6 | 8 | 6 | 20 | 67 | 2 | 2 | 5 | 9 | 30 |
| **GASTROPODA** | | | | | | | | | | |
| *Physa* | | | | | | | | | | |

Station CBB (cont.)

| PELECYPODA | 8/27/80 Sample # 1 | 2 | 3 | total | ind/m | 10/24/80 Sample # 1 | 2 | 3 | total | ind/m² |
|---|---|---|---|---|---|---|---|---|---|---|
| *Pisidium* | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| *Dugesia* | | | | | | 1 | - | - | 1 | 3 |
| OLIGOCHAETAE | | | | | | | | | | |
| *Eiseniella* | | | | | | | | | | |
| Tubificidae | | | | | | | | | | |
| immature with capilliform chaeta | 1 | - | - | 1 | 3 | | | | | |
| immature without capiliform chaeta | | | | | | | | | | |
| *Rhyacodrilus* | 1 | 1 | 1 | 3 | 10 | | | | | |
| *Limnodrilus* | | | | | | 2 | 3 | - | 5 | 17 |
| *Cheatogaster* | | | | | | - | - | 1 | 1 | 3 |
| *Ophiodonais serpentina* | 1 | 1 | 3 | 5 | 17 | 2 | 5 | 4 | 11 | 37 |

APPENDIX H

Live cage data collected by Department of Fish, Wildlife and Parks during the 1981 extended drawdown of the Milltown Reservoir.

Live cage data from the summer, 1981 extended drawdown of Milltown Reservoir.

Above dam at Turah - Eleven brown trout were placed in a live cage in the side channel above the Turah Bridge at 7:00 P.M. on 14 July. The sizes of the trout were (in inches): 4.7, 4.9, 6.2, 8.3, 9.6, 9.6, 10.1, 10.2, 10.6, 10.9, 11.5.

The following is a list of the condition of the trout as they were checked:

| | | |
|---|---|---|
| 15 July | 4:30 P.M. | All doing well |
| 16 July | 10:45 A.M. | " |
| 17 July | 10:00 P.M. | " |
| 18 July | 7:30 P.M. | " |
| 19 July | 12:30 P.M. | " |
| 20 July | 10:30 A.M. | ", increased turbidity noted starting on this day. |
| 20 July | 9:00 P.M. | " |
| 21 July | 9:30 A.M. | " |
| 21 July | 6:00 P.M. | 10 trout doing well, 1 looking tired |
| 22 July | 9:30 A.M. | 1 mortality (9.6), this fish had 3 bad sores on its ventral surface believed to be the cause of death - other 10 doing well |
| 22 July | 6:00 P.M. | All 10 doing well. |
| 23 July | 10:30 A.M. | " |
| 24 July | 11:00 A.M. | " |
| 26 July | 4:00 P.M. | " |
| 27 July | 11:45 A.M. | " |
| 28 July | 10:30 A.M. | " |
| 29 July | Live cage removed - all 10 alive and very active. They are more slender than wild fish, but appear to be a little more plump than the downstream fish. Three fish were killed to see if they had been feeding: | |

1. A 10.1" trout - no food at all in the G.I. tract, but it seemed less degenerated than the downstream fish.

2. An 8.3" trout - the G.I. tract contained three small brown items believed to be detritus - very small particles

3. A 6.2" trout - the G.I. tract was also more constricted than normal, but some food materials were present in esophygus, stomach and intestine. Mostly unidentifiable and believed to be detritus, but one baetid or siphloneurid was found. Some digested wasted could be squeezed from the intestine.

<u>East Missoula I (Yellowstone Pipeline Area)</u> - five brown trout (4.0", 4.4", 4.6", 4.8", and 5.2") were placed in a live cage in the Clark Fork here at 6:30 P.M. on 14 July. Their condition during their exposure was as follows:

| | | |
|---|---|---|
| 15 July | 11:30 A.M. | All 5 doing well. |
| 16 July | 10:15 A.M. | All 5 alive, but relatively inactive. |
| 17 July | 10:30 A.M. | Two dead (4.8" and 5.2"), the remaining 3 doing fair, no apparent reason for mortalities. |
| 18 July | 7:00 P.M. | Two more dead (4.4" and 4.6"), believed to be an acclimation problem. One remaining. |
| 19 July | noon | The one trout doing well. |
| 20 July | 10:00 A.M. | The trout doing well, turbidity increasing. |
| 20 July | 8:30 P.M. | The one trout doing well. |
| 21 July | 9:00 A.M. | " |
| 21 July | 9:30 P.M. | " |
| 22 July | 9:00 A.M. | " |
| 22 July | 7:00 P.M. | " |
| 23 July | 10:00 A.M. | " |
| 24 July | 10:30 A.M. | " |
| 26 July | 2:00 P.M. | " |
| 27 July | 11:15 A.M. | " |
| 28 July | 10:00 A.M. | " |
| 29 July | 11:30 A.M. | Removed live cage. The one surviving brown trout was still alive and very active. He was relatively slender, but was otherwise in excellent condition. The mortalities occurred before the increase in turbidity, thus the transport or change in water probably accounts for their deaths. |

East Missoula II (second live cage placed in this area of the Clark Fork) - five brown trout (7" to 9") placed in river at 6:30 P.M! on 14 July:

| | | | |
|---|---|---|---|
| | 15 July | 11:30 A.M. | Four trout escaped, one remaining. |
| | 15 July | 6:30 P.M. | Four Rock Creek brown trout added to live cage |
| | 16 July | 10:15 A.M. | All 5 doing well |
| | 17 July | 10:30 A.M. | " |
| | 18 July | 7:00 P.M. | The smallest one (7") escaped, the remaining 4 are doing well. |
| | 19 July | noon | All 4 doing well. |
| 20 | 20 July | 10:00 A.M. | All 4 doing well, turbidity increasing. |
| | 20 July | 8:30 P.M. | All 4 alive, slightly less active. |
| | 21 July | 9:00 A.M. | All 4 doing well. |
| | 21 July | 9:30 P.M. | One fish dead (8.4"), no fungus problem, gills looked fine, stomach empty, cause of death unknown, the other 3 fish look okay. |
| | 22 July | 9:00 A.M. | All 3 doing well. |
| | 22 July | 7:00 P.M. | " |
| | 23 July | 10:00 A.M. | " |
| | 24 July | 10:30 A.M. | One mortality (8.4"), bleeding from the gill and mouth region, no food in the G.I. tract. The other two trout okay. |

| | | |
|---|---|---|
| 26 July | 2:00 P.M. | Another mortality (9.2"), in bad condition. Must have died on the 25th (empty stomach). The remaining trout is doing fair, but not too active. |
| 27 July | 11:15 A.M. | Remaining trout doing well. |
| 28 July | 10:00 A.M. | " |
| 29 July | | Removed live cage. The surviving 10.2" trout was as slender as the others, but in good gneeral appearance. He had a caudal clip meaning he was from Rock Creek. He was killed and examined to see if he had been feeding. TDe G.I. tract, gill rakers, esophagus, etc. were closely examined but no trace of any food items was found. |

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Third Street and Tower Street - six brown trout (5" to 9") were placed in a live cage in the Clark Fork here at 5:50 P.M. on 14 July. Two of the trout were sick. The following is a list of their condition during their exposure to the river during the drawdown:

| | | |
|---|---|---|
| 15 July | 10:00 A.M. | The 2 sick ones died (5" and 7.5"); four remained in good shape. |
| 15 July | 7:00 P.M. | Two Rock Creek brown trout added to cage, all 6 doing well. |
| 16 July | 8:30 P.M. | All 6 doing well. |
| 17 July | 9:00 A.M. | " |
| 18 July | 5:15 P.M. | " |
| 19 July | 10:30 A.M. | All 6 doing well, but a couple are developing bad sores on their head region. |
| 20 July | 8:30 A.M. | Five doing well, 1 has a severe sore on the side of its head. Turbidity increasing. |
| 20 July | 7:30 P.M. | The trout with the growth on its head has died (7.4"); the other 5 doing well. |
| 21 July | 7:30 A.M. | All 5 doing well. |
| 21 July | 8:00 P.M. | " |
| 22 July | 7:30 A.M. | " |
| 23 July | 8:15 A.M. | " |
| 24 July | 8:45 A.M. | Four doing well, but 1 is tired and often on its side. |
| 26 July | 6:00 P.M. | Two dead (6.2" and 6.4"), and one partially eaten. No fungal growth. THeir stomachs show no sign of feeding. The remaining 3 looked fairly good. |
| 27 July | 10:00 A.M. | All 3 doing well. |
| 28 July | 8:30 A.M. | " |
| 29 July | 10:00 A.M. | Removed live cage. The remaining trout (8.9", 8.3", and 6.9") were very active. TDe fish were more slender than normal, and their fins were rather ragged. But the general health seemed good. |

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<u>Harper's Bridge</u> - five brown trout were placed in a live cage in a side channel above bridge at 5:15 P.M. on 14 July. The sizes of the trout were: 5.0, 5.4, 6.2, 7.4, 8.3. The following is a list of their condition during their exposure to Clark Fork water during the dam drawdown:

| | | |
|---|---|---|
| 15 July | 10:40 A.M. | All 5 doing well. |
| 16 July | 9:15 A.M. | " |
| 17 July | 9:30 A.M. | " |
| 18 July | 6:00 P.M. | All 5 alive, 1 with a light colored growth (possibly a fungal growth). |
| 19 July | 11:00 A.M. | The fish with the growth is dead (7.4), the remaining 4 are doing well |
| 20 July | 9:15 A.M. | All 4 doing well, turbidity increasing |
| 20 July | 8:00 P.M. | All 4 doing well |
| 21 July | 8:00 A.M. | " |
| 21 July | 8:30 P.M. | " |
| 22 July | 8:00 A.M. | " |
| 23 July | 9:00 A.M. | All 4 doing well, turbidity gradually decreasing. |
| 24 July | 9:30 A.M. | All 4 doing well. |
| 26 July | 6:45 P.M. | " |
| 27 July | 10:30 A.M. | " |
| 28 July | 9:00 A.M. | " |
| 29 July | 10:45 A.M. | Removed live cage. All four are very active and in good general health, although they are noticeably more slender than normal. |

# APPENDIX I

Memo from M. Zimmerman to J. McElwain
concerning the operation of Milltown Dam.

MEMORANDUM August 6, 1980

TO: J. A. McElwain

cc: J. J. Burke
J. Carl
R. A. Whelchel

RE: Milltown Project No. 2543: Background of the Proposed Spring Drawdown

The Montana Power Company operates the Milltown Project pursuant to License Number 2543 issued by the Federal Power Commission on June 3, 1968. Project licenses are issued subject to conditions stated in the Federal Power Act. One of these conditions is:

> (c) That the licensee shall maintain the project works in a condition of repair adequate for the purposes of navigation and for the efficient operation of said works in the development and transmission of power, shall make all necessary renewals and replacements...shall so maintain and operate said works not to impair navigation, and shall conform to such rules and regulations as the Commission may from time to time prescribe for the protection of life, health and property.

16 USCS §803(c). The Montana Power Company, therefore, has a duty to maintain the Milltown facility in a condition promoting not only efficient power generation, but protection of life, health and property as well.

The Milltown Project has been modified three times: this maintenance occurred in 1920, 1930, and 1978. Recently, it has been observed that materials sheathing the timber crib of the forebay wall will need further maintenance. In preparation for this work, it is necessary to drawdown the reservoir to permit both a detailed inspection of the forebay and exact measurements necessary to design the repair.

The drawdown was planned for mid-April, 1980; however, because the waste gates were incapable of handling the increased river flow, excessive spring runoff prevented lowering the reservoir. The reservoir was to be lowered approximately 20 feet. The elapsed time of the drawdown, inspection and refilling was not to exceed 36 hours and the river would be at its lowest level less than 8 hours. Construction deemed necessary to repair the forebay was not to be accomplished until a later semiannual drawdown where the water level would be lowered only to the crest of the spillway.

Given the infrequent lowering of the reservoir below the spillway, silt from the Clark Fork River has accumulated behind the dam. The proposed drawdown will unavoidably wash some of this silt downstream. The exact impact of the silt on water quality and aquatic life is unknown; furthermore, conclusive statements regarding potential impacts cannot be made on the basis of inadequate information presently available.

In preparation for the drawdown, The Montana Power Company undertook several significant measures. Authority to exceed state turbidity criteria was obtained from the Montana Department of Health and Environmental Sciences. Pursuant to this authority, The Montana Power Company was prepared to take precautions to minimize increases in suspended solids and turbidity associated with work activity in the Clark Fork; to minimize use of machinery in the Clark Fork; and to prevent fuel and lubricant spills.

The Montana Power Company developed a plan to determine the scope of the Project's siltation problems. The objectives of this plan (which has been implemented) are to: (1) estimate the normal amount of stream sediment during spring runoff; (2) estimate the net amount of suspended sediment passing through the reservoir during maintenance and yearly drawdowns; and (3) estimate the downstream extent of suspended sediment. The Montana Power Company, the Montana Department of Health and Environmental Sciences, and The Montana Department of Fish, Wildlife and Parks agreed on monitoring schedules and study methods to obtain data to achieve these objectives.

Collection of this data is essential. It will permit comparison of the siltation resulting from drawdowns with natural siltation during annual spring runoffs. Information thus gained will facilitate identification of the scope of an environmental problem, if one exists, and determination of an engineering solution, if one is necessary.

The necessity of periodic drawdowns is anticipated in the terms of the Milltown Project license. The introductory narrative of the Order reads:

> The State of Montana Department of Fish and Game... (now known as the Department of Fish, Wildlife and Parks) has recommended that any license for the project provide that: (1) flushing operations take place in the project reservoir during the period of spring high water so that silt which is washed out of the reservoir will not be deposited immediately downstream from the dam....

Article 29 of the Order states, further, that "Licensee... shall cooperate with Montana Fish, Game and Parks Commission in scheduling periodically the flushing by Licensee of debris from the reservoir and from the tailwater."

The proposed drawdown is designed to fulfill The Montana Power Company's statutory and license mandates. The Montana Power Company has planned a drawdown, necessary to accomplish needed maintenance, that, by coordinating the release of the reservoir waters with high-volume spring runoff river flow, will mitigate any potential environmental impact. It has initiated studies and collection of data that will provide information regarding the actual impact of the drawdown so that, if necessary, future solutions can be determined. Consistent with Article 29 of License Number 2543, The Montana Power Company has cooperated, throughout the planning and preparation for this drawdown, with the Montana Department of Fish, Wildlife and Parks and the Montana Department of Health and Environmental Sciences. This cooperation will continue.

In conclusion, then, The Montana Power Company has planned a periodic drawdown of the Milltown Project reservoir for maintenance of the dam. The plan mitigates any associated environmental impact and is the most feasible method of conducting the maintenance. In planning this drawdown, The Montana Power Company has not violated the Federal Power Act, or any other act administered by the Federal Energy Regulatory Commission.

Michael E Zimmerman

MICHAEL E ZIMMERMAN
MEZ/by
Attachments

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Ruffato, C.J. 1980. Recommendations to local government for the protection of water quality, Mineral, Missoula and Ravalli Counties. Prepared for the Five Valleys District Council, Missoula, Mt. This report is general in nature and does not contain hard data on nutrient or heavy metal loading in the Clark Fork, but does have a good discussion on problem areas such as land use, urban runoff, erosion, sedimentation and, zoning regulations, that are affecting the drainage.

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