THE EFFECTS OF HEAVY METALS ON SPECIES COMPOSITION IN A WARM-WATER STREAM

Thesis for the Degree of M. S.

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HAL FREDRIC HARRINGTON

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ABSTRACT

THE EFFECTS OF HEAVY METALS ON
SPECIES COMPOSITION IN A
WARM-WATER STREAM

By

Hal Fredric Harrington

During a two year study period, benthic macroinvertebrate composition in a warm-water stream changed markedly both in numbers and species following installation of waste treatment facilities at a metal plating plant. Oligochaete populations below the plating plant outfall decreased from 17,000/m^2 to 2000/m^2 and the species composition changed from 70% *Tubifex tubifex* to 60% *Limnodrilus* spp. in the recovery zone after new waste treatment facilities were operational. This ratio is comparable to the upstream control station. Immature tubificids comprised up to 84% of the oligochaetes at certain stations during certain sampling periods. Partial stream recovery was noted following waste-water clean-up.

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Hal Fredric Harrington

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INTRODUCTION

It is well-known that the waters of our environment are capable of receiving and purifying limited amounts of industrial and municipal wastes, and studies to determine how effective existing waste abatement programs are in keeping our environment clean must be carried out to insure the multiple use concept of our natural resources.

This study was conducted to determine the effectiveness of new treatment facilities installed at the Utilex metal plating plant, Division Hoover Ball and Bearing Company located on a warm-water stream in southern lower Michigan. The operations of the Utilex Manufacturing Company are zinc die casting and decorative plating mainly of plumbing fixtures (70% of all toilet flush handles sold in the United States are manufactured here; Dailey, 1973) and automotive fixtures. Employment is approximately 200 personnel operating two shifts, five days per week with a one week inventory shut-down in July. Treatment facilities required by the Michigan Water Resources Commission became operational in July, 1972. The river was sampled before and after treatment operations began and Garton (1968) showed severe degradation of fish and invertebrate fauna below the plant for 17 km (11 miles).

DESCRIPTION OF STUDY AREA

The Red Cedar River originates in Cedar Lake in Livingston County, flowing northwesterly approximately 73 km (45 miles) before entering the Grand River in the City of Lansing. The river has 12 major tributaries and drains approximately 1220 km^2 (472 square miles; Stevens, 1967) of both agricultural and residential land (Figure 1).

The section of river studied comprises 10 km (6 river miles) from 0.4 km (0.25 miles) above the plating plant at Garden Lane Road, to Granger Road 0.8 km (0.5 miles) above the town of Webberville. This section of river drains primarily agricultural land, comprised of both dairy and small grain farming. Man-made wastes enter the river from the Utilex Plating Plant, Division of Hoover Ball and Bearing Company and the town of Fowlerville (population 2000) in the area of study. This section of river is lined almost entirely with a minimum 15 meter greenbelt, comprised of grasses and trees.

As in many small streams, water levels can fluctuate greatly in a short period of time. River discharge at Fowlerville has varied from 1 cfs to a record 1837 cfs (Vannote, 1961; King and Ball, 1964). Elevation is approximately 268 m (880 feet) above mean sea level. The river water is relatively hard (315 ppm $CaCO_3$) and ice cover normally forms during the winter in the study area.

The plant effluent discharge (water comes from wells) has been as high as .4 mgd (million gallons/day; 1 cfs=1.55 mgd). The discharge from

Figure 1.--General area of study.

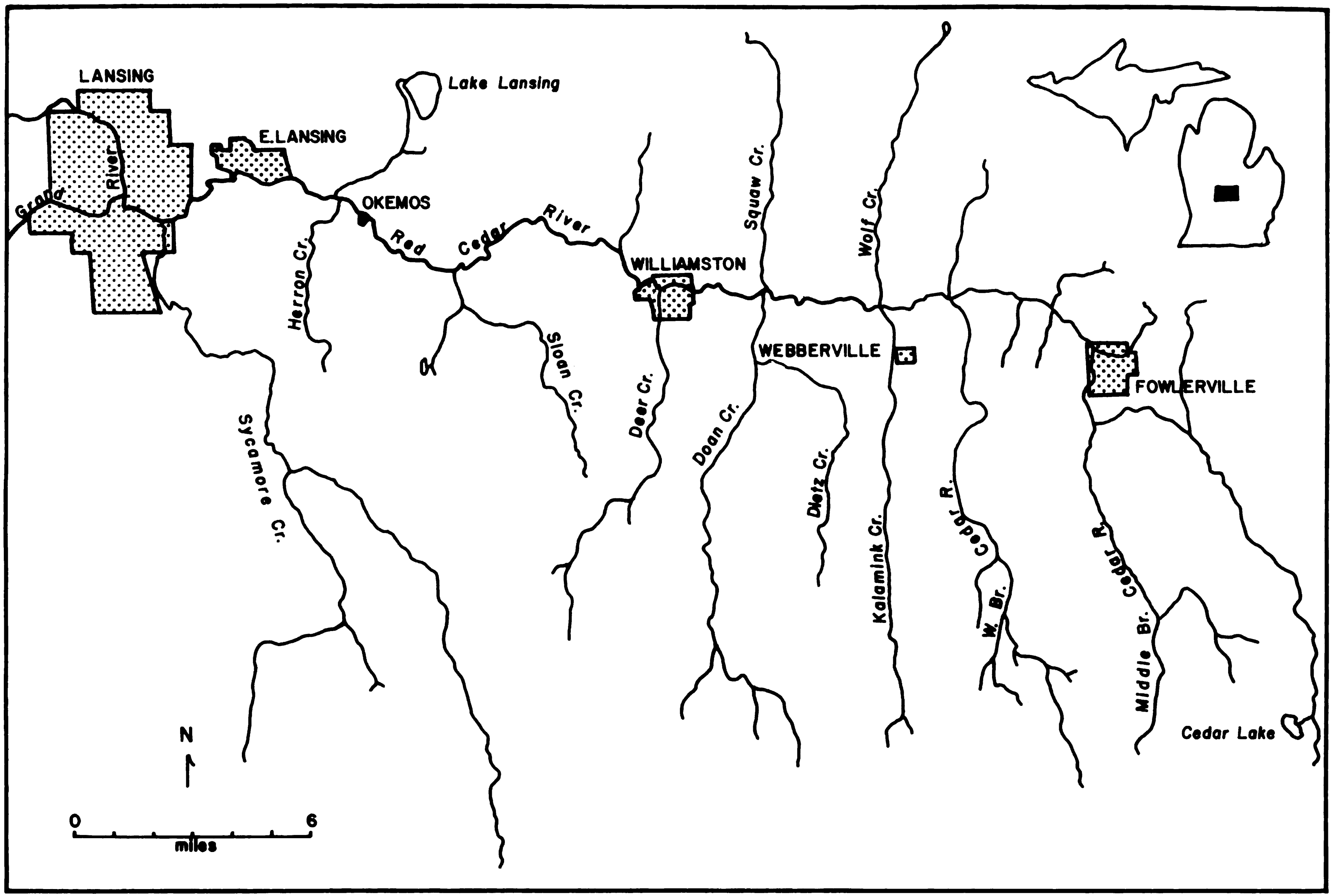

LANSING
Lake Lansing
E.LANSING
Grand
River
OKEMOS
Red Cedar River
Herron Cr.
Sloan Cr.
Sycamore Cr.
WILLIAMSTON
Squaw Cr.
Wolf Cr.
Deer Cr.
Doan Cr.
WEBBERVILLE
Dietz Cr.
Kalamink Cr.
Cedar R.
W. Br.
FOWLERVILLE
Middle Br. Cedar R.
Cedar Lake
N
0
6
miles

Figure 1

the plant can therefore comprise over 25% of the total flow of the river. This is critical since periods of low flow are normally associated with the warmest weather when metabolic rates are already high and any additional stress due to toxicants could be fatal at this time.

METHODS

Since the objective of the study was to characterize the benthic fauna following construction of waste-water treatment facilities, sampling stations were needed both above and below the plating plant. Four sampling stations were chosen (Figure 2): Station 1, 0.4 km (0.25 miles) above the outfall with a bottom type characterized by silt and detritus; Station 2, 0.4 km (0.25 miles) below the plant to allow mixing of the river water and plant effluent, with a bottom type similar to Station 1 but still upstream from the discharge drain of the Fowlerville sewage treatment plant. The treatment plant utilizes a lagoon treatment system and discharges the waste water twice yearly (spring and fall) during periods of high river discharge. Nutrient seepage through the clay lined lagoon dike into the river is believed to be slight (McCauley, 1974); Stations 3 and 4, 5 km (2.9 miles) and 9 km (5.9 miles) below the plating plant outfall respectively, were located in the zone of recovery. Bottom type in the recovery zone changes; Station 3 having a sand substrate and Station 4 a gravel substrate.

At each sampling station, four samples were taken with an Ekman grab mounted on a 1.5 m (five-foot) metal pole, sampling 236 cm^2 (36 square inches) of substrate. Transects were drawn at right angles to the river flow and the grabs were taken across the river at one meter, one-third of the width, two-thirds of the width, and one meter from the opposite bank to acquire a representative benthic sample.

Figure 2.--Sampling stations for biological survey of the Red Cedar River, Fowlerville, Michigan.

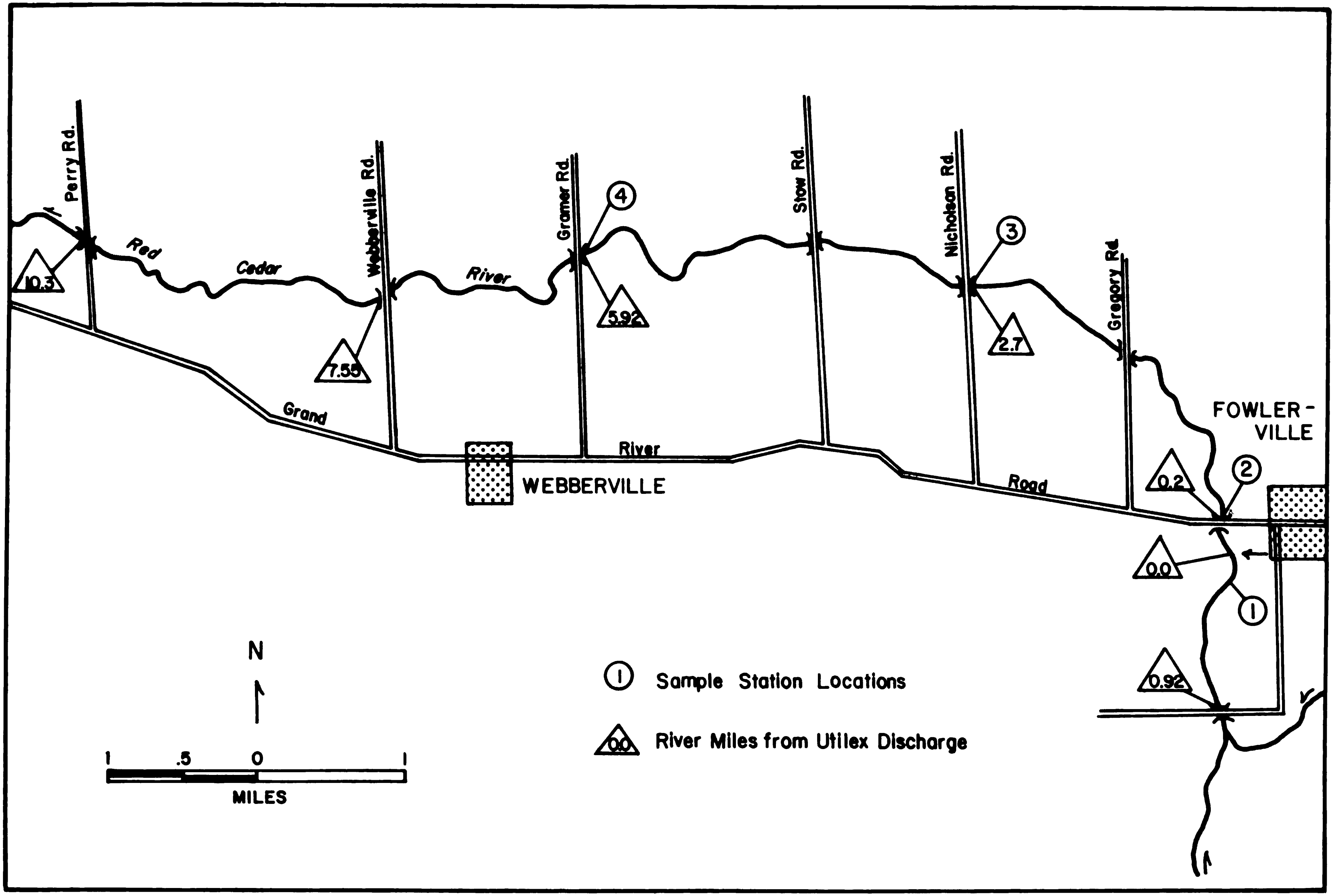

Perry Rd.
Webberville Rd.
Gramer Rd.
Stow Rd.
Nicholson Rd.
Gregory Rd.
Red Cedar River
Grand River Road
WEBBERVILLE
FOWLER-VILLE
10.3
7.55
5.92
2.7
0.2
0.0
0.92
4
3
2
1
N
1 .5 0 1
MILES
Sample Station Locations
River Miles from Utilex Discharge

Figure 2

Collected samples were then washed on a No. 30 mesh seive (0.595 mm diameter openings) stored in quart canning jars in a 5% formalin solution and returned to the laboratory. Samples were picked by hand in white enamel pans under 2X magnification. Benthic invertebrates were then identified to genera except the largest group, the tubificids, which were identified to species.

BACKGROUND

The wastes normally associated with plating industries are similar nationwide. Copper, nickel, zinc, chromium, and cyanides must be removed or reduced in amount in the waste water (Appendix B contains a complete description of methods of manufacture and waste treatment facilities).

Since the Utilex Manufacturing Company is the only industry located on the Red Cedar River, the plant's effects on the stream biota have been studied extensively since 1953 by Michigan State University researchers (Brehmer, 1956; Kevern, 1961; Rawstron, 1961; Vannote, 1961, 1963; King and Ball, 1964; King, 1963,1964; Linton and Ball, 1965) and the State of Michigan Bureau of Water Management. The climate, soil typology, and hydrology have previously been described by Stevens (1967, Appendix A).

The effect that water quality impairment has on aquatic fauna is well-known. It is generally accepted that undisturbed aquatic areas contain limited numbers of organisms per species, but the number of species is high. Conversely, in a disturbed area a large number of individuals may be present, but usually of very few species (Patrick, 1949; Gaufin and Tarzwell, 1956; Wurtz and Dolan, 1961). Water quality changes should then be reflected in a modified faunal composition (Koryak, 1972).

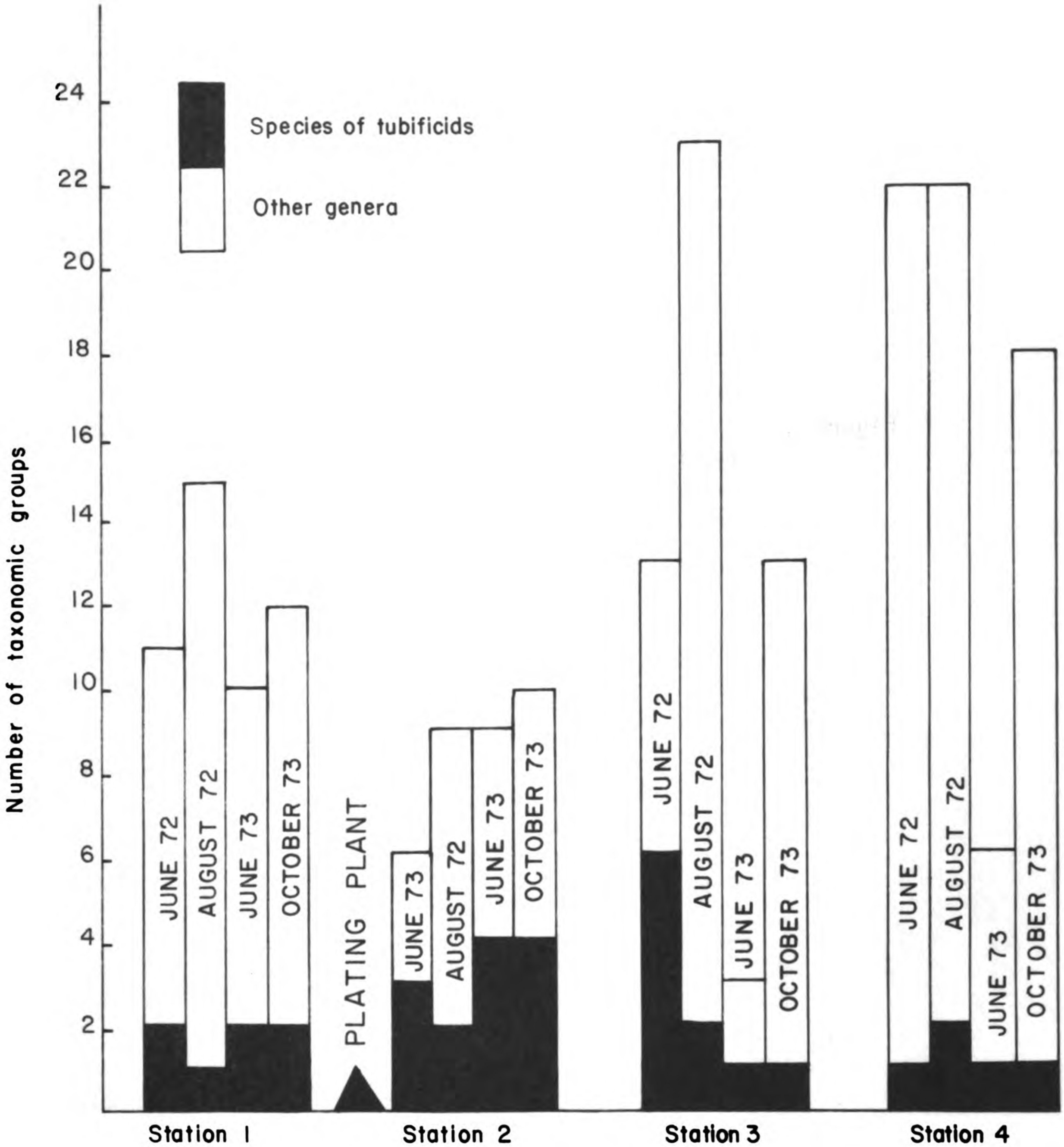
RESULTS

In June, 1972, prior to beginning of waste-water treatment processes, the number of macroinvertebrate genera occurring below the plating plant outfall were somewhat representative of a disturbed aquatic system (Figure 3). A complete listing of invertebrates found during the sampling period is given in Appendix C. Above the plating plant outfall, 11 genera were present of which two were tubificids. Of 6 genera at Station 2, 3 were tubificids, namely *Tubifex*, *Limnodrilus*, and *Peloscolex* (in decreasing order of abundance). In August, 1972, two months after treatment operation began, 15 genera were found above the plant and 9 genera were found immediately below (Figure 3). The number of tubificids below the plant had decreased to $6100/m^2$ from the previous June level of $17{,}000/m^2$ (Figure 4).

Prior to new waste-water treatment facilities, *Tubifex tubifex* led the next most abundant species, *Limnodrilus hoffmeisteri*, by a 2:1 adult ratio at Station 2. If one assumes that immature individuals are present in similar ratios as adults, immatures with capilliforms (long, hair-like structures found on *T. tubifex*), outnumber immatures without capilliforms (*L.* spp.) by an even larger ratio (3:1) in June, 1972. Station 1 had a *Tubifex*:*Limnodrilus* ratio of 1:32.

By June, 1973, one year after treatment operations began, the ratio at Station 2 was 1:1 for adults and immatures. In October of 1973

Figure 3.--Number of species of tubificids to total genera per square meter in benthic samples from the Red Cedar River.



Number of taxonomic groups
24
22
20
18
16
14
12
10
8
6
4
2
Species of tubificids
Other genera
JUNE 72
AUGUST 72
JUNE 73
OCTOBER 73
PLATING PLANT
JUNE 73
AUGUST 72
JUNE 73
OCTOBER 73
JUNE 72
AUGUST 72
JUNE 73
OCTOBER 73
JUNE 72
AUGUST 72
JUNE 73
OCTOBER 73
Station 1
Station 2
Station 3
Station 4

Figure 3

Figure 4.--Total numbers of benthic organisms per square meter at the various stations during the sampling period.

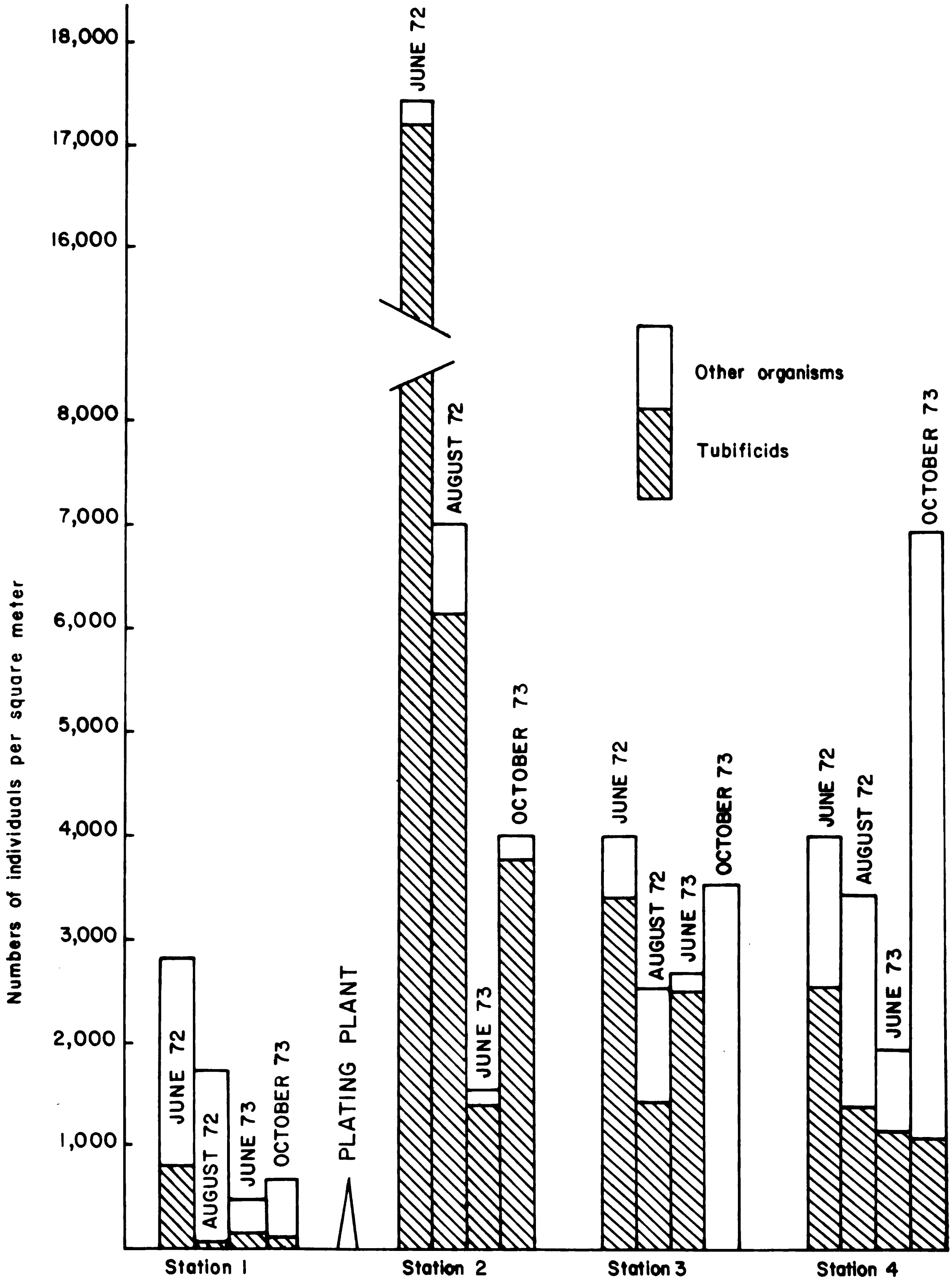

18,000
17,000
16,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
Numbers of individuals per square meter
JUNE 72
AUGUST 72
JUNE 73
OCTOBER 73
PLATING PLANT
Other organisms
Tubificids
Station 1
Station 2
Station 3
Station 4

Figure 4

the ratio changed to 1:8 for adults and 1:10 for immatures. Upstream ratios during this period ranged from 1:2 to 0.

DISCUSSION

In June, 1972, prior to treatment, 11 genera including two tubificids, were present above the outfall. Of 6 genera below the outfall, 3 were tubificids. Surber et al. (1953) studying the same area, reported only 3 genera of invertebrates, of which two were tubificids, below the outfall whereas 11 genera were found upstream. Whitley and Sikora (1970) state that Tubifex and Limnodrilus frequently are the dominant genera in polluted aquatic communities.

Using a procedure first described by King (1964), a comparison was made between the number of tubificids to total numbers of organisms (Figure 4). These data tend to show a decrease in tubificid numbers and a proportional increase in other organisms downstream from the plant discharge following treatment operations in July, 1972. An exception to the pattern was observed in June, 1973. The scarcity of "other" organisms may be explained by possible stream disruption due to significantly greater discharge in the river (three-fold calculated from USGS data) during the 40 days preceding June 1973 (u_1) sampling compared with river flow in June 1972 (u_2), ($\alpha = .01$, t test for two means, $H_1: u_1 > u_2$). High water disruption of benthic invertebrate communities was shown by Maitland (1964) in which only burrowing animals (tubificids and chironomids) were able to survive in sandy areas. Minckley (1963) found severe flooding reduced fauna near the headwaters but redistributed them downstream. This does not seem to be the case in the Red Cedar River since upstream stations contained more genera than downstream stations (Figure 3) during the high water period of June, 1973. However, at other sampling periods more genera were found downstream.

In August, 1972, two months after treatment operations began, 16 genera were found above the plant and 9 genera were found immediately below (Figure 3). The numbers of tubificids below the plant had decreased to $6100/m^2$ from the previous level of $17{,}000/m^2$ (Figure 4). Below the plating plant, personnel from the Bureau of Water Management found a similar density ($6050/m^2$) in August, 1953, during the first study of the plant effects on the river and Garton (1968) found $39{,}000/m^2$. Certain samples contained up to 84% immature tubificids (Appendix C). Large numbers of immatures are not uncommon and Kennedy (1965, 1966) found maturity time of 1 year for L. udekemianus and a 6 month to 2 year maturity time for L. hoffmeisteri. Brinkhurst (1968) states when large amounts of organic matter are present but oxygen is not greatly reduced and bacteria numbers are high, there is a parallel increase in worm numbers. However, in areas of chemical pollution, worm numbers are reduced. In organically enriched areas, concentrations as high as $400{,}000/m^2$ have been reported (Hynes, 1960).

Some difficulties were encountered during the early post-treatment operational period when effluent metal concentrations exceeded the maximum allowable Michigan limits. By June, 1973, one full year after operation of treatment facilities, water quality was considerably better though daily metal concentration discharge still exceeded the Michigan Water Resources Commission allowable limits more than 35% of the time

(Table 1). The water quality continued to improve (Table 1) and within 2 years after operations began, the monthly effluent discharge was within standards. The most frequent offender is copper, the maximum allowable level of 0.06 ppm being often exceeded. Cyanide previously detected at levels of up to 0.94 ppm (Willson, 1963) was undetectable. This improvement is crucial since even one pulse of cyanide per year could decimate the aquatic fauna necessitating a long time interval for recolonization.

Hiltunen (1967) classified tubificids from Lake Michigan according to quality of bottom environment and nutrient enrichment. All species found below the plant both before and after treatment operations were classified as being found in both polluted and unpolluted waters. Similarly, the tubificids found above the plant also fell into these same categories. Johnson and Matheson (1968) found that sediments rich in organics contained L. hoffmeisteri and T. tubifex while five other Limnodrilus species occupied the zones of less organic enrichment in Lake Ontario. Kennedy (1966) explains that the life history of L. hoffmeisteri varies with local conditions and it may be the greater breeding potential of this tubificid that has contributed to its widespread distribution and abundance.

Stream sediments below the plant apparently still contain organics from kerosene cleaning solutions since a black, sticky, floatable substance can be found in grab samples even though this emulsion cleaner has not been used since 1972. This could be an organic food supply for the dense oligochaete population.

Table 1.--Concentrations of copper and chromium in effluent samples from the Utilex plating plant at Fowlerville in ppm (Taft, personal communications, 1974).

Month	Cr max	Cu max	Cr ave	Cu ave	Days over /Operation days limitations/for month
Jan. 73	0.35*	0.40*	0.095*	0.14*	16/20
Apr. 73	0.20*	0.15*	0.059	0.069*	11/21
Nov. 73	0.03	0.15*	0.008	0.056	6/18
Jan. 74	0.04	0.10*	0.022	0.059	3/22
Apr. 74	0.04	0.06	0.016	0.041	0/22

*Equals or exceeds allowable Michigan discharge concentrations of 0.06 ppm Cu and 0.06 ppm Cr.

Water quality has apparently improved as shown by decreasing tubificid numbers and increases in other genera present below the outfall. However, with new treatment facilities in operation the question of why invertebrate genera are not similar both above and below the outfall has been raised.

Knezek et al. (1973) found high concentrations of heavy metals in the sediments (Table 2) and oil from emulsion cleaners still in the sediments of the Red Cedar River below the plant outfall. A study to determine the effects of heavy metals in the food of invertebrate detritivores is now in progress. Ten-gram leaf packs (artificial accumulations of leaves as described by Petersen and Cummins, 1974) with heavy metals adsorbed were placed in the river along with control leaf packs without adsorbed heavy metals. Adsorption of heavy metals onto leaf packs was accomplished by placing the leaf packs into the plating plant effluent for a three week time interval. The toxicity of ingested, heavy metal contaminated, leaf litter may have a detrimental effect on invertebrates colonizing the food supply. Preliminary studies have shown a significantly heavier dry weight of leaf material remaining after a given time interval in contaminated leaf packs over noncontaminated packs ($\alpha = .01$, t test, $H_1: u_1 > u_2$) reflecting reduced leaf breakdown rates of the contaminated leaves.

Mackenthun and Cooley (1952) showed copper as nontoxic to bottom dwelling organisms at a concentration of .48 mg/gm and reported concentrations as high as 10 mg/gm were needed to kill certain pollution tolerant benthic organisms (tubificids). Copper concentrations in the sediments below the plating plant were 0.52 mg/gm. Sediments analyzed

Table 2.--Total elemental composition of the Red Cedar River sediments in mg/g (From Knezek et al., 1973).

Location	Cu	Ni	Zn	Cr	Pb	Fe
Red Cedar River						
1. Sargent Road	.019	.037	.045	.023	.20	10.57
2. Van Burean	.043	.094	.086	.041	.048	15.80
Plating Plant						
3. Grand River	.52	.30	.69	.67	.061	15.57
4. Gregory	.39	.30	.31	.41	.061	15.73
5. Nicholson	.15	.15	.19	.11	.020	12.03
6. Gramer	.32	.16	.29	.29	.020	13.83
7. Meridian Road*	.013	.014	.038	.017	.015	6.04

*Meridian Road is 6 miles downstream from Gramer Road.

for all heavy metals discharged from the plating plant were summed and they totaled 2.5 mg/gm total plating plant heavy metals (Knezek, et al., 1973). Even with the possible synergistic effect of heavy metals in combination, these reported heavy metal concentrations would probably not be toxic to the tolerant species though they might affect intolerant organisms. Any heavy metal effect would probably be reflected in the artificial leaf pack study. When studies are finished, both mean weight loss of the leaf packs and invertebrate colonization of the leaves will be analyzed to determine if there is any significant difference in numbers and kinds of colonizing benthic fauna. Data are available for comparison on leaf pack weight loss under given temperature regimes in nonpolluted streams (Petersen and Cummins, 1974).

SUMMARY

Water quality has apparently improved below the plant following installation of new treatment facilities. Data supporting this hypothesis are: 1) number of genera present below the plating plant has increased; 2) number of tubificids per square meter has decreased; 3) ratio of _T_. _tubifex_ to _L_. _hoffmeisteri_ above and below the outfall is now similar ; and 4) amount of heavy metal effluent discharge has been decreased (Dailey, 1973). Improved functioning of waste treatment facilities is encouraging to all concerned. Similar studies involving benthic organism sampling should be carried out in future years to determine if waste-water discharge containing amounts of contaminants falling within recommended State levels are non-toxic over long periods of time to aquatic organisms and to determine if invertebrate communities continue to recover.

APPENDICES

APPENDIX A

DESCRIPTION OF THE RED CEDAR RIVER

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The Red Cedar River is representative of many midwestern streams receiving industrial and domestic wastes and inorganic sediments from agricultural areas (King and Ball, 1966). The stream is highly buffered and alkaline. Turbidity is low but rises sharply during periods of heavy runoff until erosion of stream deposits is exhausted (Grzenda, 1968). Dissolved oxygen pulses are common in the summer and occasionally the levels fall below 3.0 ppm. Nutrient loads are excessive although much of this material is flushed from the stream during spring floods (Ball et al., 1968). River width varies from 8 to 25 meters, total length is 89 kilometers (50.8 miles) and average gradient is 0.5 m/km (2.4 feet/mile) with elevations ranging from 263 to 301 meters above sea level (817 to 934 feet) (King and Ball, 1967).

River flow is usually highest in late spring when frozen ground and melting snow contribute more to flooding than heavy rains (Meehan, 1958). Lowest flow is usually found in the late summer months before the fall rains arrive (USGS data). A steady decrease in discharge over the last 20 years has resulted in a critical summer flow. Decreased discharge can be traced to increased well-water usage and lowered water table in the river drainage area (Stevens, 1967).

Three artificial impoundments are located on the Red Cedar River. The largest is located at Williamston, originally built to facilitate operation of a sawmill. The original dam has since been replaced and maintains a 13-foot head providing power for a frozen food and refrigeration plant (Brehmer, 1956). The other man-made dams are located in Okemos at a picnic grounds and Michigan State University at East Lansing. The dam serves as a USGS stream discharge guaging station and the supplying of cooling water for the MSU power plant.

The climate, hydrology, geology and soils have previously been described by Meehan (1958) and Stevens (1967).

APPENDIX B

MANUFACTURING OPERATIONS OF THE UTILEX PLATING PLANT

APPENDIX B

MANUFACTURING OPERATIONS OF THE UTILEX PLATING PLANT

The Utilex plating plant employs approximately 200 people operating two eight hour shifts, five days a week. The primary operations of the plant are zinc die casting and decorative plating of plumbing and automotive fixtures.

Pure zinc is purchased in ingot form and alloyed with other metals before die casting to desired shapes. After casting, the parts undergo refining operations such as trimming, machining, buffing and tumbling.

After the fixtures have been cast and refined, they are transported to the plating area and placed on racks to be carried through the plating operation. The plating sequence, diagramed in Figure B-1 is as follows. The fixtures are first cleaned in one set of emulsion cleaners to remove dirt and residues from buffing and machining operations. Wastes from this operation flow to the emulsion waste pit and are later moved to an outside waste pit. After the emulsion cleaner, the fixtures go through two sets of detergent cleaners with a clear water rinse in between to remove the spray cleaner. After the second detergent cleaner comes one electrocleaner. In these cleaners, the fixtures are made the anode or cathode and an electric current is set up through an alkaline solution. The cleaning is brought about by the chemical action of the

Figure B-1.--Plating sequence at Utilex plating plant.

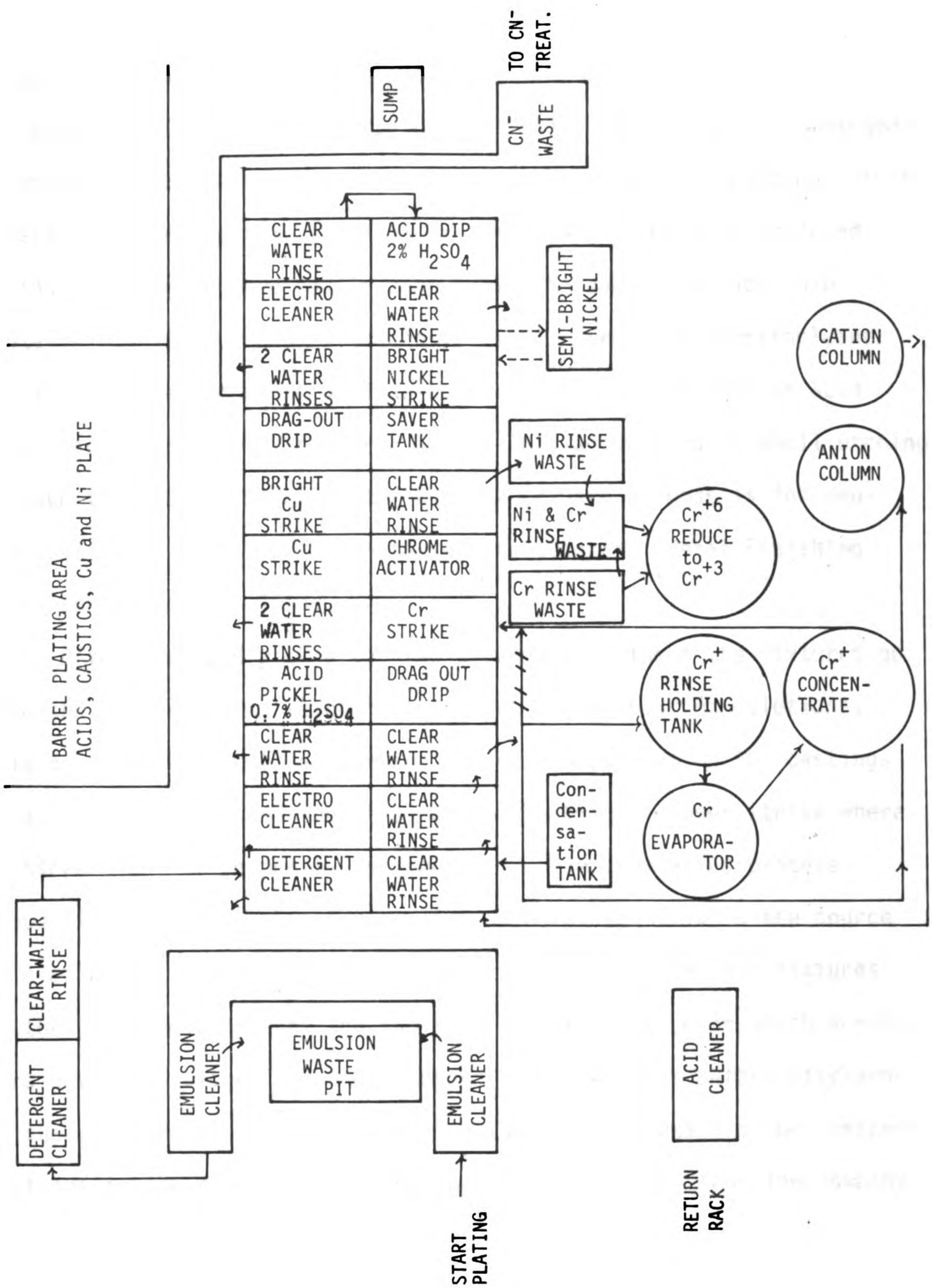
TO CN⁻ TREAT.
SUMP
CN⁻ WASTE
CLEAR WATER RINSE
ACID DIP 2% H_2SO_4
ELECTRO CLEANER
CLEAR WATER RINSE
SEMI-BRIGHT NICKEL
2 CLEAR WATER RINSES
BRIGHT NICKEL STRIKE
DRAG-OUT DRIP
SAVER TANK
Ni RINSE WASTE
CATION COLUMN
ANION COLUMN
BRIGHT Cu STRIKE
CLEAR WATER RINSE
Ni & Cr RINSE WASTE
Cr^{+6} REDUCE to Cr^{+3}
Cu STRIKE
CHROME ACTIVATOR
Cr RINSE WASTE
2 CLEAR WATER RINSES
Cr STRIKE
ACID PICKEL 0.7% H_2SO_4
DRAG OUT DRIP
Cr^+ RINSE HOLDING TANK
Cr^+ CONCENTRATE
CLEAR WATER RINSE
CLEAR WATER RINSE
ELECTRO CLEANER
CLEAR WATER RINSE
Con-den-sa-tion TANK
Cr EVAPORATOR
DETERGENT CLEANER
CLEAR WATER RINSE
BARREL PLATING AREA
ACIDS, CAUSTICS, Cu and Ni PLATE
CLEAR-WATER RINSE
DETERGENT CLEANER
EMULSION CLEANER
EMULSION WASTE PIT
EMULSION CLEANER
ACID CLEANER
START PLATING
RETURN RACK

Figure B-1

alkali in conjunction with the mechanical action of vigorous hydrogen gas evolution (Richards, 1946). Cathode and anode may be interchanged by an electrical switch during the process but with zinc castings it is generally preferred that the zinc be the anode as any film produced during cleaning is more easily removed in the subsequent acid dip (Metal Finishing Guidebook Directory, 1960). From the electrocleaner the fixtures pass through a clear-water rinse and then into an acid pickle solution of 0.7% sulfuric acid. This acid produces small etching to make the plating stick better but the primary purpose is for neutralization of the alkali from the electrocleaners (Metal Finishing Guidebook Directory, 1960).

After the acid pickle and two clear-water rinses the fixtures go into the copper strike which is the first of the plating solutions. This copper strike puts a thin initial coat of copper on the castings to avoid blistering and then they go to the bright copper strike where a thicker coat of copper is applied by the electroplating process. Copper is applied in a copper cyanide solution and this is the source of cyanide wastes. Following the bright copper strike, the fixtures go through a holding tank and two clear-water rinses over which scrubbers have been placed to remove copper from the fumes before discharge to the atmosphere since previously, rains would increase copper concentrations in the river by flushing copper contaminants from the company roof (Taft, 1974). The copper rinse water is sent to a special cyanide treatment tank before release to the river.

Next comes another electro-cleaner and clear-water rinse and then a 2% sulfuric acid dip. After another rinse the automotive fixtures go into a semi-bright nickel strike to meet specifications and increase rust resistance. These fixtures then go to the bright nickel strike where all other fixture racks continued from the clear-water rinse.

Following nickel plating the fixtures go through a saver tank and then one clear-water rinse. The fixtures then go to a chromic acid activator to prevent chrome burn (turns fixtures white) and then into the chromium plating vats and a layer of chrome is applied to produce the finished product. The most suitable chrome compound for electro-deposition is chromic acid, CrO_3^-, used in aqueous solution with small additions of other substances (Richards, 1946). The chrome bath concentration was dropped 10 ounces without affecting the product and at the same time reducing the chrome concentration in the waste-water.

All process and cooling water is obtained from the company's well. Water is used within the plant to cool die casting machines and air compressors. This die cast cooling water flows to the settling ponds.

Processing waste water is generated from three various line processes illustrated in Figure B-1 (modified from WRC report of Nov. 20, 1972). All non-metallic rinses occurring at the beginning of the plating line flow directly to a neutralizing mixing tank. Cyanide is removed in the two rinses following copper plating and the rinse water is sent to one of a pair of concrete cyanide treatment tanks along with any spilled matter.

The two tanks are filled on an alternate basis and the full tank is treated by the addition of sodium hypochlorite to oxidize the cyanide ion (CN^-) to carbon dioxide and nitrogen. These wastes are retained approximately one day and discharged when residual chlorine is positive. Nickel rinses flow directly into the clarifier and chrome wastes are recycled unless a breakdown occurs.

Hexevalent chrome is recovered since it costs approximately nine times as much for chemicals to reduce Cr^{+6} to Cr^{+3} with sodium bisulfite and sulfuric acid. However, this system is still present in the plant for use when the chrome recovery unit is not operational. Chrome recovery unit operates by distilling off the excess water and leaving chromic acid which then goes to a holding reservoir to be analyzed and returned to the working bath (Figure B-2). If chromium wastes are collected, batch treatment takes place with the addition of sulfuric acid to lower the pH and then sodium bisulfite to reduce hexevalent chromium and increase the pH thus precipitating the trivalent chromium.

The non-metallic rinse water neutralizes the overflow clarifier effluent in the mixing tank. Sodium hypochlorite and sodium hydrosulfite are available for emergency mixing in the tank if further treatment is required.

The four settling lagoons (50,000 to 100,000 gallons) used by Utilex are normally operated in the fashion listed in Figure B-3. Periodically these are cleaned by private contractors to remove the sludge build-up (Garton, 1968; WRC report, November 1972; Dailey, 1973; Taft, 1974).

The rated capacity, types and amounts of chemicals used are listed in Table B-1.

Figure B-2.--Schematic diagram of waste treatment flow at the Utilex plating plant, Fowlerville, Michigan.

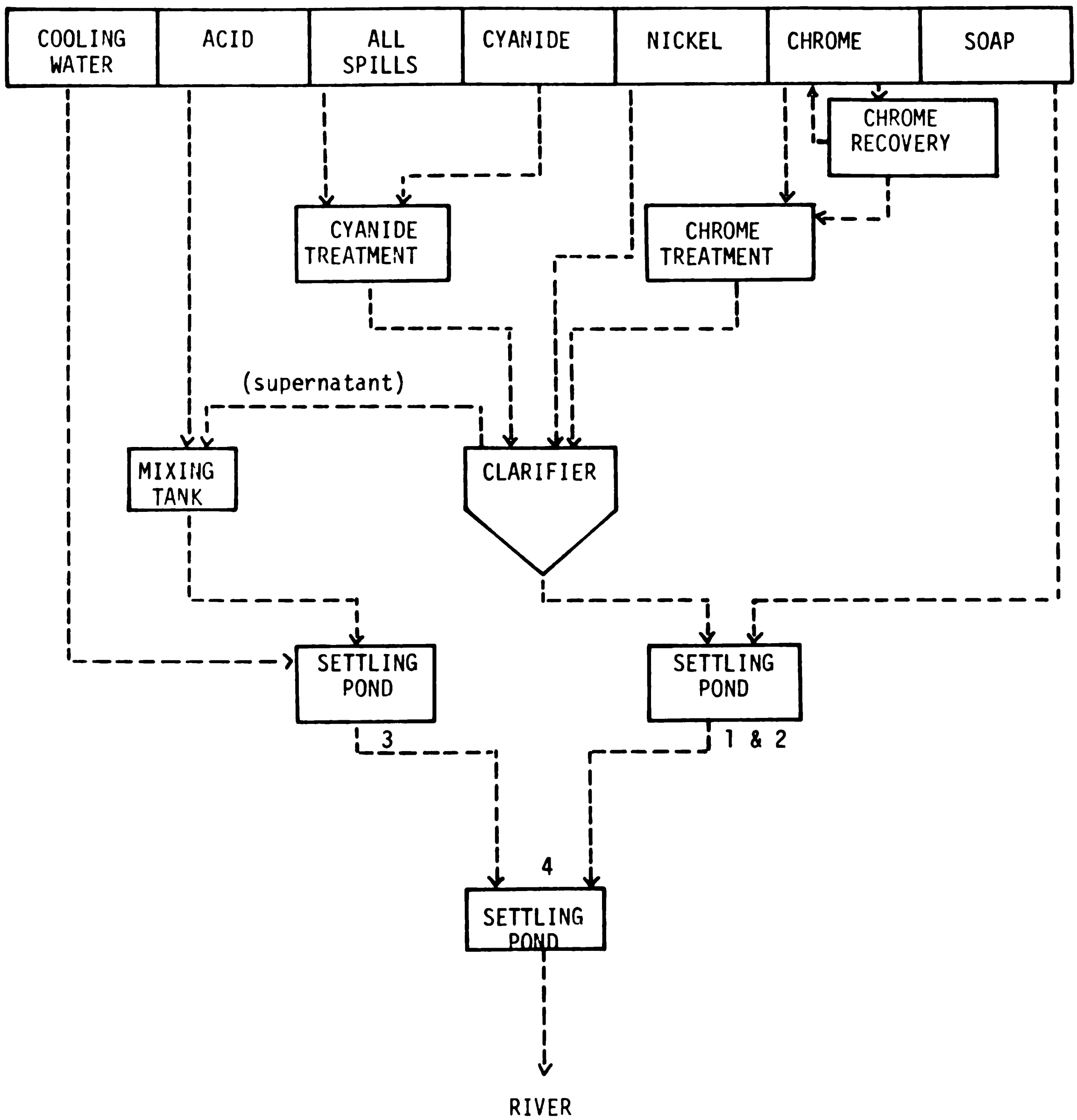
COOLING WATER
ACID
ALL SPILLS
CYANIDE
NICKEL
CHROME
SOAP
CHROME RECOVERY
CYANIDE TREATMENT
CHROME TREATMENT
(supernatant)
MIXING TANK
CLARIFIER
SETTLING POND
SETTLING POND
3
1 & 2
4
SETTLING POND
RIVER

Figure B-2

Figure B-3.--Site layout of the Utilex plating plant.

UTILEX
HOOVER BALL BEARING
FOWLERVILLE

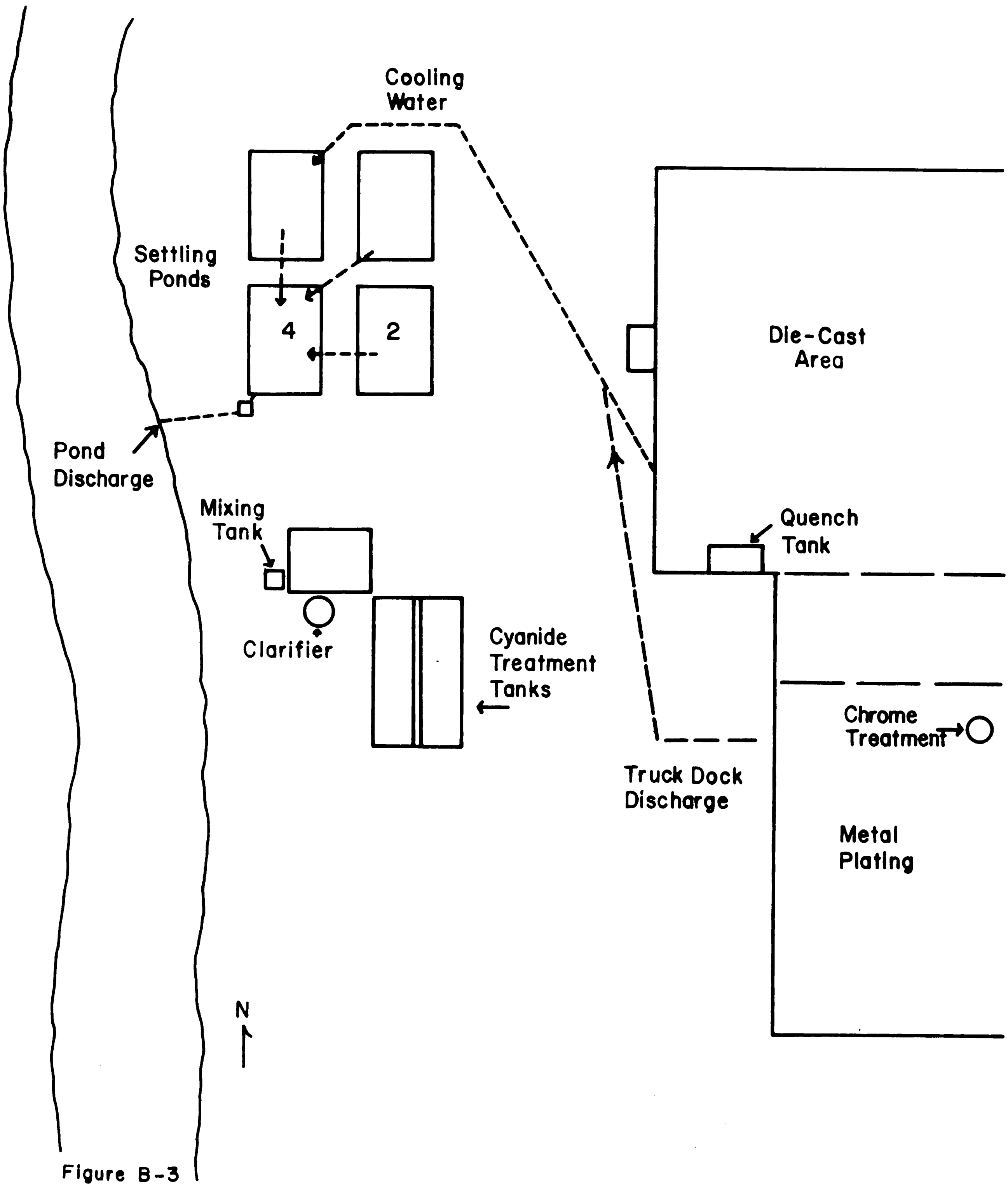

Figure B-3

Table B-1.--Chemicals used in the treatment of waste-water at Utilex Plating Plant, Fowlerville, Michigan (Taft, 1974).

Treatment facility	Capacity	Chemicals	Amount
Cyanide treatment	15,000 gpd	sodium hypochlorite	200 lbs/day
		caustic soda	
		sulfuric acid	
Chrome destruct	15 gpm	sulfuric acid	10 gpd
		sodium bisulfite	400 lbs/day
Clarifier	150 gpm	dolomitic lime	200 lbs/day
		caustic soda	315 lbs/day
		sodium hydrosulfide	15 lbs/day
		ferrous sulfate	15 lbs/day
		polymer Aldoa 350	5 lbs/day

APPENDIX C

INVERTEBRATES OF THE RED CEDAR RIVER SAMPLED IN 1972 AND 1973

Table C-1.--Invertebrates of the Red Cedar River Sampled in 1972 and 1973.

	A	B	C	D	No./m^2
STATION 1					
June 72*					
Tubificidae		14	23		822
Limnodrilus udekemianus		4	--		
L. hoffmeisteri		8	20		
Immatures w/o capilliforms		1	3		
Imm. w/cap.		1	--		
Elmidae					
Dubiraphia		10	6		356
Ceratopogonidae		7	3		222
Polycentropidae					
Polycentropus		1	--		22
Coenagrioidae					
Amphiagrion		1	--		22
Caenidae					
Ceanis		--	1		22
Libellulidae					
Paltothemis		1	--		22
Dytischidae unidentifiable		1	--		22
Chironomidae		45	13		1289
Microtendipes		32	7		
Clinotanypus		13	6		
					2777
June 73					
Tubificidae	3	3	--	6	133
L. hoffmeisteri	--	1	--	1	
Tubifex tubifex	--	--	--	1	
Imm. w/o cap.	2	2	--	4	
Imm. w/cap.	1	--	--	--	
Tabanidae					
Chrysops	--	1	--	2	33
Ceratopogonidae	--	2	--	1	33
Leptoceridae					
Oecetis	--	1	--	--	11
Pyralidae					
Parargyractis	--	1	--	--	11

*June 1972 sample containers A and D unavailable for analysis

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 1--June 1973--continued					
Chironomidae	1	10	3	1	177
Polypedilum	1	--	--	--	
Harnischia	--	2	2	--	
Microtendipes	--	6	1	1	
Ablabesmyia	--	2	--	--	
					398
August 72					
Tubificidae	--	--	6	--	66
L. hoffmeisteri	--	--	4	--	
Imm. w/o cap.	--	--	2	--	
Elmidae					
Dubiraphia	6	2	4	4	177
Tabanidae					
Chrysops	1	--	3	--	44
Polycentropidae					
Polycentropus	8	--	8	--	177
Sialidae					
Sialis	3	--	6	2	121
Amphipod					
Hyalella	--	3	--	14	188
Leptoceridae					
Oecetis	1	--	--	--	11
Libellulidae					
Paltothemis	--	--	--	1	11
Baetidae unidentifiable	--	--	1	--	11
Chironomidae	29	23	15	16	922
Tanypus	5	8	1	1	
Clinotanypus	6	--	5	9	
Procladius	8	13	5	1	
Tanytarsus	3	1	1	1	
Tribelos	5	1	3	3	
Microtendipes	2	--	--	1	
					1728
October 73					
Tubificidae	--	1	5	2	88
L. hoffmeisteri	--	--	2	--	
Lumbricidae	--	1	--	--	
Imm. Limnodrilus spp.	--	--	--	1	
Imm. w/o cap.	--	--	3	1	

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 1--October 1973--continued					
Amphipod					
Hyalella	--	7	3	--	111
Elmidae					
Dubiraphia	--	1	4	4	100
Ceratopogonidae	1	--	3	5	100
Sialidae					
Sialis	2	2	--	--	44
Polycentropidae					
Polycentropus	--	1	--	--	11
Pyradidae					
Parargyractis	--	--	1	--	11
Chironomidae	4	3	3	3	144
Microtendipes	2	1	1	1	
Cryptochironomus	1	--	1	--	
Ablabesmyia	--	--	--	2	
Tanytarsus	1	2	1	--	
					609

STATION 2

(Prior to Treatment Plant Operation)

June 72

	A	B	C	D	No./m^2
Tubificidae	390	292	284	590	17,266
T. tubifex	7	9	13	5	
L. hoffmeisteri	4	5	3	4	
Imm. w/o cap.	26	11	7	24	
Imm. w/cap.	41	45	60	45	
Peloscolex multisetosis	--	1	1	--	
Ceratopogonidae	1	--	--	--	11
Chironomidae	2	2	--	2	67
Procladius	1	2	--	2	
Cryptochironomus	1	--	--	--	
					17,344

June 73

	A	B	C	D	No./m^2
Tubificidae	44	26	31	21	1355
L. hoffmeisteri	6	2	1	2	
T. tubifex	6	1	1	1	
P. multisetosis	2	1	--	--	

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 2--June 1973--continued					
L. udekemianus	1	--	--	--	
Imm. w/o cap.	22	14	15	11	
Imm. w/cap.	7	8	14	7	
Coenagrionidae					
Amphiagrion	--	--	--	3	33
Polycentropidae					
Polycentropus	--	--	--	2	22
Amphipod					
Hyalella	--	--	--	2	22
Planaridae					
Dugesia	--	--	--	1	11
Isopod	--	--	--	1	11
					1454
August 72					
Tubificidae	279	29	85	156	6112
L. hoffmeisteri	5	3	4	6	
Imm. w/o cap.	19	16	33	23	
Imm. w/cap.	16	10	13	16	
Tabanidae					
Chrysops	--	--	--	1	11
Elmidae					
Dubiraphia	--	--	--	1	11
Haliplidae					
Peltodytes	--	--	--	1	11
Coenagrionidae unidentifiable	--	--	1	2	33
Planariidae					
Dugesia	--	--	--	4	44
Erpobdellidae					
Erpobdella	--	--	2	--	22
Chironomidae					
Procladius	12	12	27	16	744
					6988
October 73					
Tubificidae	50	60	208	8	3721
L. hoffmeisteri	3	3	2	2	
P. multisetosis	1	--	3	--	
Ilyodrilus templetoni	1	--	2	--	
Imm. w/o cap.	15	16	30	4	
Imm. w/cap.	--	--	4	1	
T. tubifex	--	1	--	1	

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 2--October 1973--continued					
Amphipod					
Hyalella	1	--	--	1	22
Elmidae					
Dubiraphia	--	1	--	--	11
Tabanidae					
Chrysops	--	--	--	1	11
Chironomidae	1	1	--	10	133
Procladius	1	1	--	8	
Ablabesmyia	--	--	--	2	
Coenagrionidae					
Amphiagrion	--	--	--	5	55
					3953
STATION 3					
June 72					
Tubificidae	60	152	42	49	3363
L. hoffmeisteri	8	11	11	18	
L. udekemianus	--	1	1	2	
T. tubifex	1	2	--	--	
I. templetoni	--	1	--	--	
L. claparedianus	--	1	--	1	
P. multisetosis	--	1	--	--	
Imm. w/o cap.	36	40	9	18	
Imm. w/cap.	6	7	18	7	
Ceratopogonidae	--	--	1	3	44
Coenagrionidae					
Amphiagrion	--	--	--	2	22
Gyrinidae					
Dineutus	1	--	--	--	11
Chironomidae	12	3	1	30	511
Clinotanypus	6	--	--	16	
Procladius	6	1	--	10	
Harnischia	--	--	1	4	
Chironomus	--	2	--	--	
					3951

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 3--continued					
June 73					
Tubificidae	5	109	65	55	2570
L. hoffmeisteri	3	36	18	12	
Imm. w/o cap.	2	42	33	43	
Chironomidae	1	--	3	--	44
Clinotanypus	1	--	--	--	
Tanytarsini	--	--	3	--	
					2614
August 72					
Tubificidae	9	29	19	71	1420
L. hoffmeisteri	3	5	6	22	
L. udekemianus	1	--	--	--	
Imm. w/o cap.	5	16	13	38	
Dytiscidae					
Hydrovatus	--	--	--	1	11
Gyrinidae					
Dineutus	--	--	--	1	11
Simuliidae					
Simulium	--	1	--	--	11
Leptoceridae					
Oecetis	7	4	1	4	177
Baetidae unidentifiable	1	--	--	--	11
Coenagrionidae					
Chromagrion	7	--	--	--	77
Sialidae					
Sialis	--	--	--	3	33
Haliplidae					
Peltodytes	--	--	--	1	11
Hydropsychidae					
Cheumatopsyche	--	--	--	7	77
Libellulidae					
Paltothemis	--	--	--	1	11
Amphipod					
Hyalella	20	--	--	--	222
Chironomidae	7	3	6	25	455
Cryptochironomus	--	--	2	--	
Ablabesmyia	--	1	--	--	
Clinotanypus	1	1	--	8	
Tanytarsus	2	--	--	2	

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 3--August 1972--continued					
Polypedilum	2	1	--	--	
Tribelos	1	--	1	2	
Cricotopus	--	--	2	1	
Procladius	1	--	--	8	
Endochironomus	--	--	1	3	
Conchapelopia	--	--	--	1	
					2527
October 73					
Tubificidae	--	--	--	1	11
L. hoffmeisteri	--	--	--	1	
Amphipod					
Hyalella	5	3	1	18	300
Ceratopogonidae	--	1	--	--	11
Hydropsychidae					
Cheumatopsyche	--	1	--	--	11
Coenagrionidae					
Amphiagrion	--	1	--	3	55
Chromagrion	--	1	--	--	
Hydrophilidae					
Berosus	--	--	1	--	11
Sialidae					
Sialis	--	--	--	2	22
Libellulidae					
Paltothemis	--	--	--	1	11
Chironomidae	12	13	28	52	1165
Clinotanypus	7	7	13	22	
Tribelos	2	--	6	16	
Cricotopus	3	6	--	14	
Chironomus	--	--	9	--	
Glossiponiidae					
Helobdella fusca	--	--	--	1	
					1597
STATION 4					
June 72					
Tubificidae	--	40	115	72	2522
L. hoffmeisteri	--	6	12	6	
Imm. w/o cap.	--	15	22	13	

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 4--June 1972--continued					
Leptoceridae					
Oecetis	--	--	2	--	22
Elmidae					
Dubiraphia	8	--	16	--	267
Haliplidae					
Peltodytes	--	--	1	3	44
Dytiscidae					
Hydroporus	1	--	3	1	55
Coenagrionidae					
Amphiagrion	--	3	2	--	55
Ceratopogonidae	5	1	7	1	155
Caenidae					
Caenis	1	--	--	--	11
Limnephilidae					
Platycentropus	1	--	--	--	11
Hydropsychidae					
Cheumatopsyche	2	--	1	0	33
Polycentropidae					
Polycentropus	--	--	2	--	22
Corixidae adult	--	--	--	1	11
Sphaeridae	--	6	--	1	77
Limpet	--	--	1	--	11
Crayfish	--	--	--	1	11
Chironomidae	22	4	23	14	700
Cryptochironomus	15	2	3	5	
Polypedilum	2	--	8	1	
Cricotopus	--	1	2	--	
Tanypus	--	--	2	--	
Procladius	--	--	2	--	
Ablabesmyia	2	--	--	1	
Chironomus	3	1	6	3	
Harnischia	--	--	--	4	
					4007
June 73					
Tubificidae	14	16	23	49	1132
L. hoffmeisteri	9	11	14	14	
Imm. w/o cap.	5	5	9	11	
Coenagrionidae unidentifiable	1	1	3	--	55
Tabanidae					
Chrysops	1	--	--	--	11

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 4--June 73--continued					
Amphipod					
Hyalella	1	--	25	--	287
Crayfish	--	--	35	--	388
Chironomidae	1	1	3	--	55
Clinotanypus	1	1	3	--	
					1928
August 72					
Tubificidae	66	--	25	32	1365
L. hoffmeisteri	4	--	4	6	
L. udekemianus	1	--	--	--	
Imm. w/o cap.	22	--	21	26	
Chironomidae	7	--	55	18	888
Tanytarsus	1	--	8	1	
Microtendipes	--	--	2	--	
Cryptochironomus	1	--	16	8	
Polypedilum	1	--	3	--	
Tribelos	1	--	6	--	
Chironomus	2	--	8	2	
Ablabesmyia	1	--	3	2	
Procladius	--	--	9	5	
Elmidae					
Dubiraphia	--	5	3	3	121
Hydroptilidae					
Neotrichia	--	2	1	--	33
Sialidae					
Sialis	1	1	1	--	33
Caenidae					
Caenis	--	1	--	2	33
Leptoceridae					
Oecetis	--	3	5	--	88
Hydropsychidae					
Cheumatopsyche	--	--	--	2	22
Haliplidae					
Peltodytes	--	--	1	--	11
Agrionidae					
Agria	--	--	1	--	11
Amphipod					
Hyalella	2	2	52	6	689
Glossiponiidae					
Placobdella montifera	--	1	--	--	11

continued

TABLE C-1--continued

	A	B	C	D	No./m^2
Station 4--August 72--continued					
Sphareidae	--	2	--	--	22
Astacidae	--	1	--	--	11
Diptera pupae	--	3	2	--	55
					3393
October 73					
Tubificidae	1	19	19	59	1088
L. hoffmeisteri	--	4	5	5	
Imm. w/o cap.	1	15	14	17	
Chironomidae	13	51	55	9	1420
Conchapelopia	--	1	3	1	
Cryptochironomus	3	--	4	1	
Polypedilum	2	6	2	--	
Tribelos	1	3	3	2	
Microtendipes	2	8	18	1	
Procladius	1	--	--	2	
Pseudochironomus	--	1	--	--	
Clinotanypus	4	6	3	2	
Elmidae					
Dubiraphia	11	43	26	3	921
Hydropsychidae					
Cheumatopsyche	3	2	--	--	55
Ceratopogonidae	1	5	4	--	110
Sialidae					
Sialis	1	3	1	--	55
Coenagrionidae					
Amphiagrion	1	--	--	--	11
Agrionidae					
Agria	1	--	--	--	11
Caenidae					
Caenis	--	7	1	--	88
Dytiscidae					
Hydroporus	--	1	--	--	11
Amphipod					
Hyalella	216	19	5	49	3207
					6977

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