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TOXICITY OF MAGNIFLOC 573C ALONE AND THE EFFECTS OF SUSPENDED
SOLIDS ADDITION TO JUVENILE COHO, CHINOOK SALMON, AND RAINBOW TROUT

by

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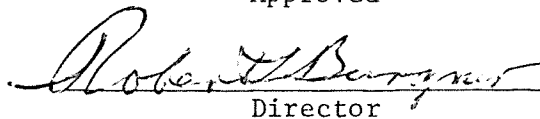

Director

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SUMMARY

During construction of the Washington Public Power Supply System's Nuclear Projects 3 and 5, sited near Satsop, Washington, runoff water will be treated in an erosion and sedimentation control system prior to discharge to the Chehalis River. Magnifloc 573C has been suggested as a substance to reduce the suspended solids concentrations in the discharge from these ponds. A series of 96-hr static bioassays was conducted to determine the effects of Magnifloc 573C alone and in combination with suspended solids on yearling coho salmon (Oncorhynchus kisutch), 0-age coho, 0-age chinook salmon (O. tshawytscha), and 0-age rainbow trout (Salmo gairdneri). Test concentrations of Magnifloc and suspended solids were designed around the planned operational levels of 0.1 to 0.7 $\mu\text{l/l}$ Magnifloc and suspended solids of about 100 mg/l. The 96-hr LC50 values (for Magnifloc only) for all 0-age fish were not significantly different and ranged from 0.62 to 0.93 $\mu\text{l/l}$. LC50 values were not established for the yearling coho, but response indicated that they were more resistant. At 1.0 $\mu\text{l/l}$ Magnifloc, the toxicity was reduced by addition of 10 mg/l (or more) suspended solids, but at higher concentrations of about 7.0 $\mu\text{l/l}$ Magnifloc, the addition of 100 mg/l of suspended solids did not significantly reduce toxicity. Because the operational concentration of 0.1 to 0.7 $\mu\text{l/l}$ Magnifloc (required to meet the water quality standard of 50 mg/l suspended solids) is near the 96-hr LC50 value, Magnifloc should be used with extreme caution.

INTRODUCTION

The Washington Public Power Supply System (WPPSS) plans to build two 1242 MW(e) nuclear-fuel steam electric power plants (WPPSS Nuclear Projects No. 3 and 5) near the junction of the Satsop and Chehalis rivers in southwestern Washington (Fig. 1). During the construction period, an erosion and sedimentation control system (Fig. 2) will be built to collect storm runoff water from the construction area; this will reduce the suspended solids in the water discharged to receiving streams. The control system consists of several large collecting and settling basins with an approximate surface area of 17 acres.

Under U.S. Environmental Protection Agency (EPA) rules and regulations (Federal Register, 1973), a National Pollutant Discharge Elimination System (NPDES) permit, implemented by the State of Washington, is required for the discharge from the erosion and sedimentation control system. To qualify for this permit, WPPSS must meet an effluent standard of suspended solids not to exceed 50 mg/l. The erosion and sedimentation control system can effectively reduce peak suspended solid loads to about 100 mg/l without any treatment other than natural settling. However, to meet the EPA standard of 50 mg/l it will be necessary to use a flocculent or polyelectrolyte to further reduce the suspended solids.

Ebasco Services Incorporated, New York, performed a series of column settling tests (using soils from the plant site) to determine which of several commercially available polyelectrolytes would be most suitable for this site. Magnifloc 573C was selected as the most effective in clarifying the water at an expected range of concentration from 0.1 to 0.7 $\mu\text{l/l}$.¹

¹These values can be converted to mg/l by using the specific gravity value of 1.14 to 1.18 for Magnifloc.

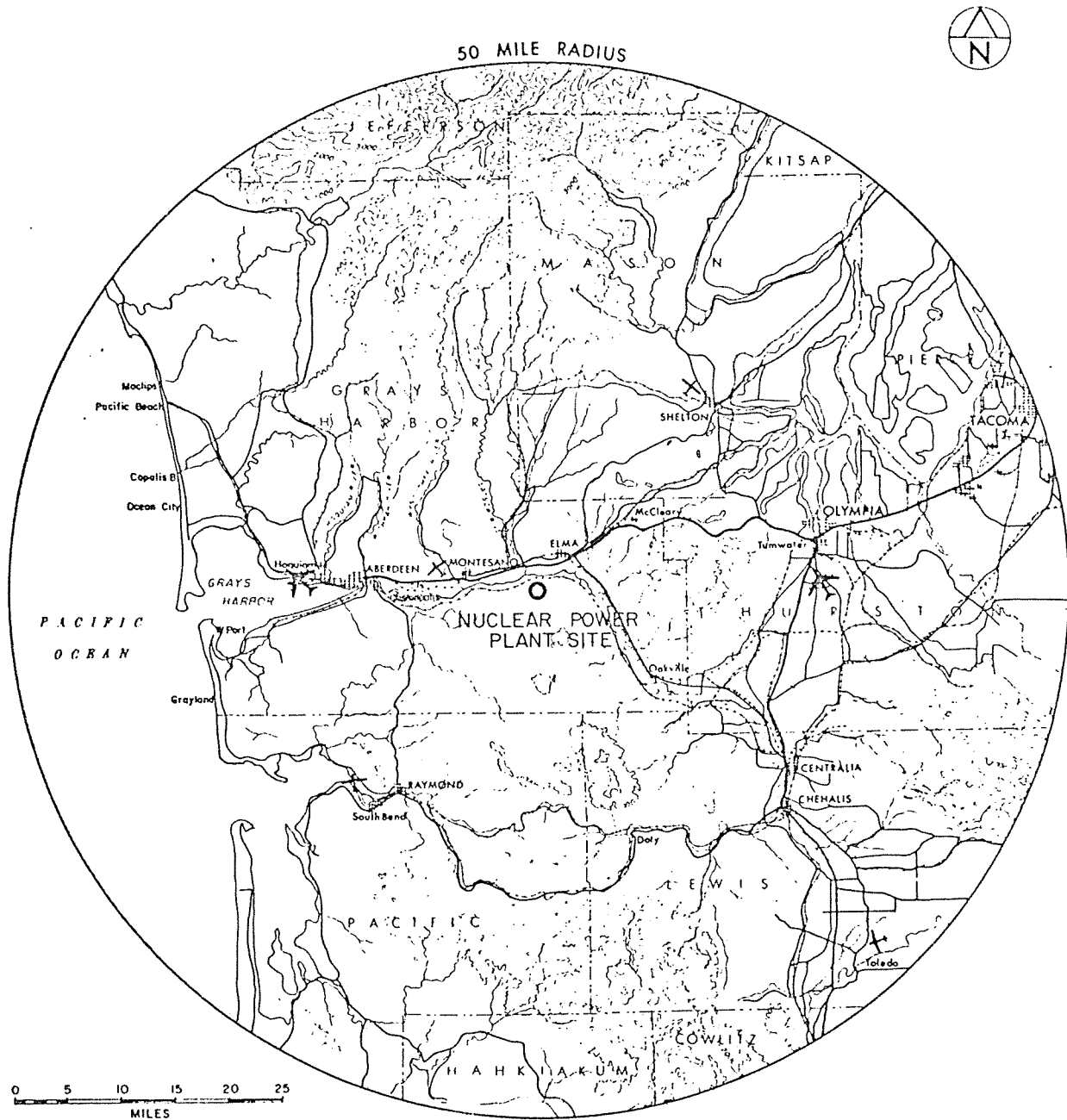


Fig. 1. The proposed site in a regional setting.

Source: United States Nuclear Regulatory Commission, 1975.

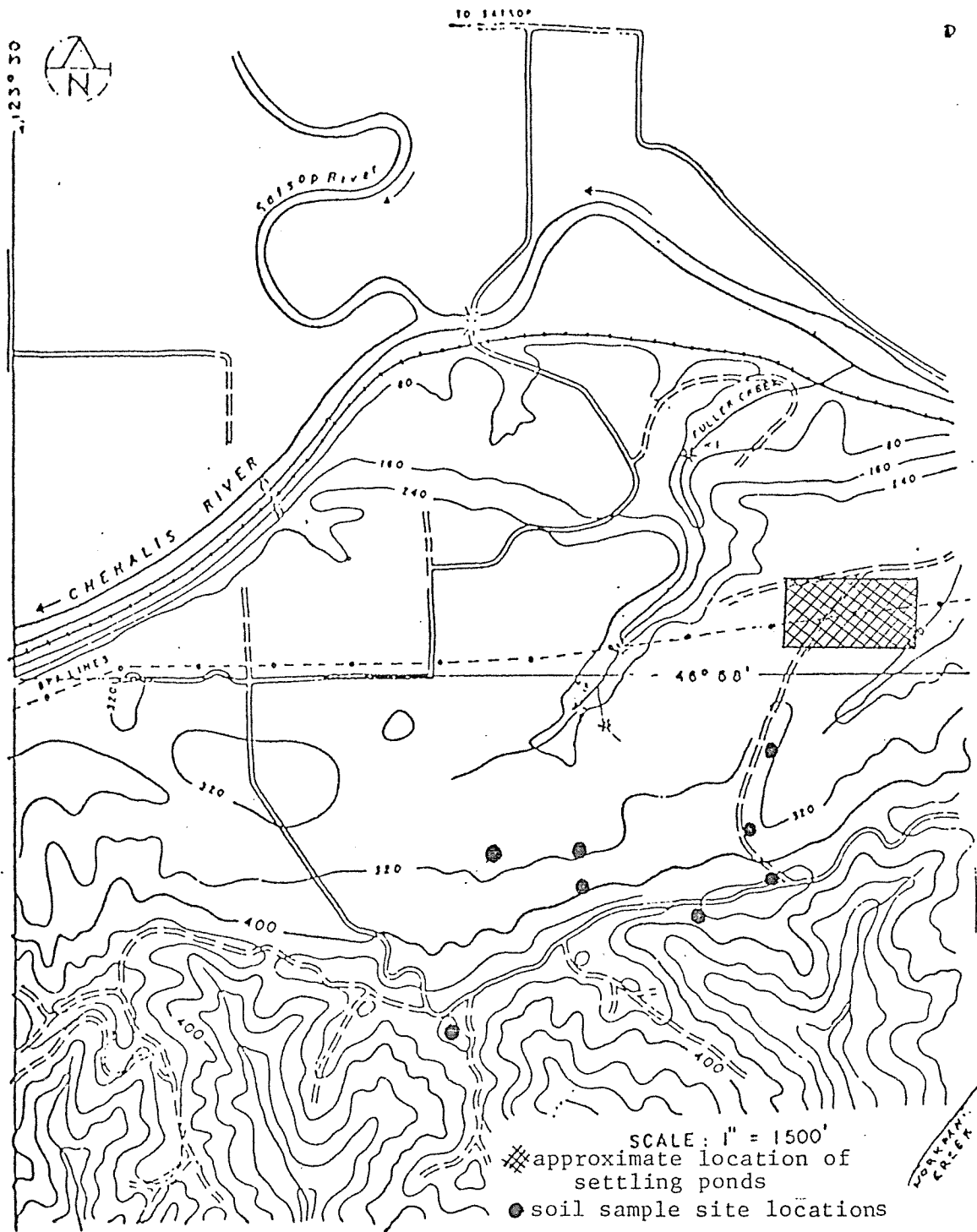


Fig. 2. Soil sample site locations - Washington Public Power Supply System Nuclear Project No. 3.

Source: U.S.G.S. Topographic Map, 1953
Malone Quadrangle.

Studies on polyelectrolytes in general, have shown them to be acutely toxic at 0.3 to 200 mg/l, depending on the particular polyelectrolyte and the test species (Biesinger, et al., 1976). Bionomics, Inc. (1971), using static bioassays, determined that the 96 hr LC₅₀ values for juvenile rainbow trout (Salmo gairdneri) and juvenile bluegill (Leopomis macrochirus) exposed to Magnifloc 573C were 0.39 and 0.16 mg/l, respectively.

The tests by Biesinger, et al. (1976), and Bionomics, Inc. (1971), were mainly performed without any addition of suspended solids. Theoretically, the toxicity of a polyelectrolyte to fish should diminish when particulate matter is present because the polyelectrolyte adsorbs to the particle, and settles out of solution. Biesinger, et al. (1976), observed this effect in their tests when the toxicity of Superfloc 330 to Daphnia sp. was significantly reduced with the addition of food particles to the test containers. Olson, et al. (1973), Brocksen (1971), and McDonald (1971, as quoted by Biesinger, et al., 1976) found similar reductions in toxicity to rainbow trout when suspended solids were present. Furthermore, Olson, et al., found that the gills of rainbow trout held in turbid waters showed "rather severe proliferation of the gill lamellae which resulted in fusion of the lamellae". This was attributed either to direct irritation by the suspended solids or to NH₃ build-up in the test tank. When fish were exposed to turbid waters that had been clarified with polyelectrolytes, he found "mostly normal gill lamellae", thus suggesting some possible benefits from this treatment. Additionally, Olson found that trout were more active and responded better to feeding in the clarified water.

Although Bionomics demonstrated that Magnifloc 573C was toxic, the relationship between this particular polyelectrolyte at various concentrations and various concentrations of suspended solids was not studied. Therefore, the Fisheries Research Institute (FRI) conducted this series of acute bioassays to determine the toxicity of Magnifloc 573C and its interactions with suspended solids.

MATERIALS AND METHODS

Standard 96-hr static bioassays (EPA, 1975) were used to evaluate the toxicity of Magnifloc 573C alone and in combination with suspended solids. The bioassays were conducted at FRI, University of Washington, Seattle, Washington, from January 25 to March 25, 1977.

Test Species

Table 1 describes the four groups of juvenile salmonids that were used as test subjects. Two age groups, 0-age and yearling coho salmon, 0-age chinook salmon, and 0-age rainbow trout were selected because they are economically important and are found seasonally in the vicinity of the planned discharge (U.S. Nuclear Regulatory Commission, 1975; Washington Department of Fisheries, 1975).

All fish were fed five times weekly with Oregon Moist Pellets (Moore-Clarke, Inc., LaConner, Washington) of appropriate size. Fish were not fed 48 hr prior to testing. In all tests, the body weight to volume ratio was 1.0-1.5 gm/l.

Table 1. Test species used for Magnifloc 573C bioassays

<u>Species</u>	<u>Stage of development</u>	<u>Source of fish</u>
Coho salmon (<u>Oncorhynchus kisutch</u>)	Yearling	Washington State Department of Fisheries, Simpson Hatchery; Satsop River
Coho salmon	0-age	College of Fisheries, University of Washington, Seattle, Washington
Chinook salmon (<u>Oncorhynchus tshawytscha</u>)	0-age	"
Rainbow trout (<u>Salmo gairdneri</u>)	0-age	Washington State Department of Game Puyallup Trout Hatchery, Puyallup, Washington

Test Containers

Two types of test containers were employed. The yearling coho were tested in large glass aquaria (31 x 38 x 58 cm) which contained 40 liters of test solution. Smaller fish were tested in glass jars containing 3 liters of test solution. Before testing began, all jars were thoroughly washed, rinsed with water followed by 5% nitric acid, water, acetone, and water. Between each series of tests, the containers were washed and rinsed with water followed by acetone followed by water. The large aquaria were aerated with capillary pipets attached to tygon tubing (two per aquarium). In the small jars, a preliminary test showed that aeration had no significant effect on test results (Appendix 1), so all further studies were performed without aeration. In all tests without aeration, dissolved oxygen values in the test containers were found to be 5.0 mg/l or greater.

Soil Samples

Soil samples from eight different locations on the Satsop plant site (Fig. 2) were collected by Envirosphere personnel. The samples were mixed to form a composite which would be representative of soil types that are expected to be washed into the sedimentation ponds. The composite sample was transported to FRI where it was sifted through a 1/8-inch plastic screen to further enhance mixing and to obtain a more uniform consistency.² Between tests, the soil samples were held at room temperature in sealed plastic bags. This maintained the soil in a moist condition roughly similar to the condition in which it arrived at FRI.

² A detailed description of the types of soils in the vicinity of the power plant site can be found in the final environmental statement (U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, 1975).

Diluent Water and Water Quality Parameters

Lake Washington water at ambient temperature was used as diluent water and for the water bath surrounding the test chambers. This water was also used for holding fish prior to testing.

On the first day of each test a sample of lake water was analyzed for pH, alkalinity, hardness, and suspended solids (Table 2). Table 3 describes the method or instrumentation used for each of these analyses. Dissolved oxygen concentrations were also monitored during tests to confirm that adequate levels (5 mg/l or greater) were present. The measuring instrument was a Yellow Springs Instrument Corporation oxygen meter and probe.

Characteristics of Magnifloc 573C

Table 4 shows the characteristics of Magnifloc 573C as described by the American Cyanamid Company; Wayne, New Jersey.

The pH value of Magnifloc was less than the diluent water. Therefore, preliminary tests were conducted to determine the effect of various concentrations of Magnifloc on pH in the diluent water. At the levels of usage in these bioassays, no significant change in pH was observed.

Test Procedures

In the tests run in the large aquaria, the following procedure was used:

Each aquarium was filled with 40 liters of lake water, and appropriate amounts of soil were added. Test concentrations of suspended solids in each bioassay experiment were not measured directly but were estimated indirectly. To estimate the ratio of soils needed to obtain a given suspended solids solution, a preliminary test was conducted in which a certain amount of soil was added to a given volume of water and the resulting suspended solids

Table 2. Summary of test conditions for 13 bioassays

Test no.	Start date	Fish species	No. of fish	Mean \pm SD length cm*	Mean \pm SD weight g*	Mean temp. °C	pH	Alkalinity (ppm as CaCO ₃)	Hardness (ppm as CaCO ₃)	Range of concentration Magnifloc (µl/l) †	Suspended solids (mg/l) ††
1	2-28-77	Coho 0-age	120	3.45 \pm 0.2	0.16 \pm 0.03	8.0	7.3	26	36	.03-2.0	0
2	2-21-77	Chinook 0-age	168	4.10 \pm 0.19	0.75 \pm 0.14	8.0	7.1	35	33	0.2 -7.0	0
3	3-21-77	Rainbow trout 0-age	120	3.83 \pm 0.58	0.46 \pm 0.08	7.9	6.9	31	36	0.6 -3.0	0
4A	1-25-77	Coho yearling	180	10.7 \pm 1.23	11.4 \pm 4.19	7.9	7.0	25	34	.005 -1.0	0.10
4B	1-31-77	Coho yearling	180	11.8 \pm 1.30	13.3 \pm 3.88	7.4	6.75	31	35	.005 -1.0	1.0
4C	2- 7-77	Coho yearling	165	12.3 \pm 1.88	13.4 \pm 4.30	8.1	7.6	26	33	.005 -1.0	10-50
4D	2-14-77	Coho yearling	90	12.7 \pm 1.57	14.2 \pm 3.92	8.3	7.6	19	37	.05 -1.0	100
5	3- 7-77	Coho 0-age	144	3.49 \pm 0.23	0.22 \pm 0.03	8.0	7.3	20	36	0.5 -1.0	10-100
6	2-14-77	Chinook 0-age	186	4.30 \pm 0.22	0.62 \pm 0.07	8.3	7.6	19	37	.25 -1.0	10-100
7	3-14-77	Rainbow trout 0-age	144	4.22 \pm 0.20	0.37 \pm 0.06	7.9	7.3	27	34	.5 -1.0	10-100
8	3-21-77	Coho 0-age	84	3.59 \pm 0.25	0.29 \pm 0.03	7.9	6.9	31	36	1.0	10-50
9	3-28-77	Coho 0-age	126	4.07 \pm 0.35	0.32 \pm 0.06	10.3	7.1	30	33	1.0	10-50
10	2-28-77	Chinook 0-age	60	4.70 \pm 0.30	0.64 \pm 0.07	8.0	7.3	26	36	7.0	10-50
Totals			1,767							.005 -7.0	0.1-100

*Based on measurements of approximately 20 fish.

†Can be converted to mg/l by using the specific gravity value of 1.14 to 1.18 for Magnifloc.

††Background average of suspended solids in lake water was 1.20 mg/l with a range of 1.08-1.88 mg/l.

Table 3. Methods or instrumentation for water quality analysis

Parameter	Method or instrumentation
pH	Corning Model 12 pH meter
Alkalinity	Methyl orange procedure listed in Methods of Chemical Analysis of Water and Wastes (EPA, 1971)
Hardness	Calculated according to formulas listed in Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1971). The calcium and magnesium values that are required for these formulas were determined with a Perkin-Elmer 290 atomic absorption spectrophotometer
Temperature	A thermometer with a precision of $\pm 0.1^{\circ}\text{C}$
Suspended Solids	In Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1971)

Table 4. Characteristics of Magnifloc 573C (American Cynamid Company;
Wayne, New Jersey)

Appearance: amber liquid
Specific Gravity: 1.14-1.18

Viscosity: 175-350
(25°C, cps)

pH: 5-6

Solubility: Infinitely soluble in water

Chemical

Reactivity: Non-reactive

General

Description: "A liquid cationic flocculent which works effectively
as a primary coagulant in raw water clarification."

concentration was determined. The ratio of soil weight to suspended solids concentration was approximately 135:1. After mixing, Magnifloc 573C was added with capillary micropipettes. (In tests with smaller fish in the 4-liter jars, the Magnifloc was not added directly, but instead a stock solution with Magnifloc at 1.0 ml/l was made and appropriate amounts of this solution were added to the jars.) Concentrations of Magnifloc were calculated on a volume basis using $\mu\text{l}/\text{l}$.³ The solutions were mixed again and allowed to settle for 45-60 min. To avoid exposing fish to any settled-out soil and Magnifloc, the supernatant water was siphoned into another aquarium, and fish were placed in these test chambers. Two groups (replicates) were tested at each concentration. Fifteen fish were used per tank in the larger aquaria. Six fish were tested per aquarium in the smaller jars (Appendix 2). During any particular test series, 60 to 186 fish were used (Table 2) with a total of 1,767 used during the entire study. Death of the test fish was used as the criterion for evaluation of toxicity. Fish were considered to be dead when they ceased active opercle movements and failed to respond to gentle prodding with a glass rod. Observations were always made at 24-hr intervals. Additional observations were made at intermediate times to record the approximate time of death of each fish. At each observation, dead fish were removed from the test containers.

Test concentrations of suspended solids were based on amounts that might be found on the site (0-100 mg/l) and on restrictions associated with the WPPSS discharge permit (50 and 100 mg/l). The range of concentrations of Magnifloc was based on (1) levels of expected usage (0.1-0.7 $\mu\text{l}/\text{l}$), and (2)

³This was roughly equivalent to mg/l, but to obtain a more exact conversion, the $\mu\text{l}/\text{l}$ value can be multiplied by a specific gravity value of 1.14-1.18 to give mg/l.

the approximate concentration needed to establish a 96-hr LC50 value, as determined from previous bioassays with Magnifloc (Bionomics, 1971).

The 96-hr LC50⁴ values were calculated (for Magnifloc alone) by using the BMD03S computer program developed at the University of California at Los Angeles (Dixon, 1970). This program takes the percent mortality at 96 hrs for each test concentration and calculates the concentration at which 50% mortality would be expected to be observed. Confidence limits for the LC50 values were computed by methods of Litchfield & Wilcoxon (1959) and Finney (1964, 1971) as modified for computerized analysis (K. Pierson, personal communication).

Specific Bioassays

Several combinations of Magnifloc, soils, and species were tested (Table 2). Tests 1, 2, and 3 were designed to determine the 96-hr LC50 of Magnifloc alone with three different species of 0-age fish. Tests 4 A-C were actually one series of tests with larger yearling fish which were conducted over several weeks. The purpose of these tests and tests 5, 6, and 7 was to observe the response of fish at the concentrations of Magnifloc and suspended solids projected for the Satsop site. Tests 8, 9, and 10 were designed to provide additional information on the effects of suspended solids additions on Magnifloc toxicity.

⁴The LC50 is the concentration at which 50% of the test organisms are dead (Sprague, 1969).

RESULTS AND DISCUSSION

Toxicity of Magnifloc 573C Alone

Figures 3, 4, and 5 show the time-mortality curves for both the observations made at 24-hr intervals and those made at intermediate times.⁵ Appendix 2 presents all the raw data for the 24-hr interval observations. Observations made between the 24-hr points appear on the time mortality curves, but are not summarized in Appendix 2.

Figures 6, 7, and 8 show the same data as in Figures 3, 4 and 5, respectively, when the 96-hr percent mortalities at each concentration are transformed to a log-probit scale. The BMD03S program calculates a regression line for these points from which an LC50 value is determined. Confidence limits are also indicated. Any points which have an arrow attached are values which are either greater than 98% mortality, or less than 2% mortality.

Figures 9 through 14 show the time-mortality curves for Tests 4 through 10. No data transformation to log-probit scale was performed with these tests because they were designed to estimate toxicity at anticipated levels of suspended solids and/or Magnifloc which would occur on the site. They were not designed to estimate an LC50 value.

Test 1: 0-Age Coho

Mortalities began at approximately 24-hr (Fig. 3) and most mortalities occurred by 80-hr. No mortalities occurred at 0.8 µl/l or less. This

⁵The points on each line represent the combined percentage of mortalities for both replicates at that observation (e.g., if n=6 for each replicate and 2 fish were dead in one and 3 fish in the other, the point on the graph would appear as:

$$\frac{2(\text{dead}) + 3(\text{dead})}{12 \text{ total}} = \frac{5}{12} = 42\% \text{ mortality for that particular observation}$$

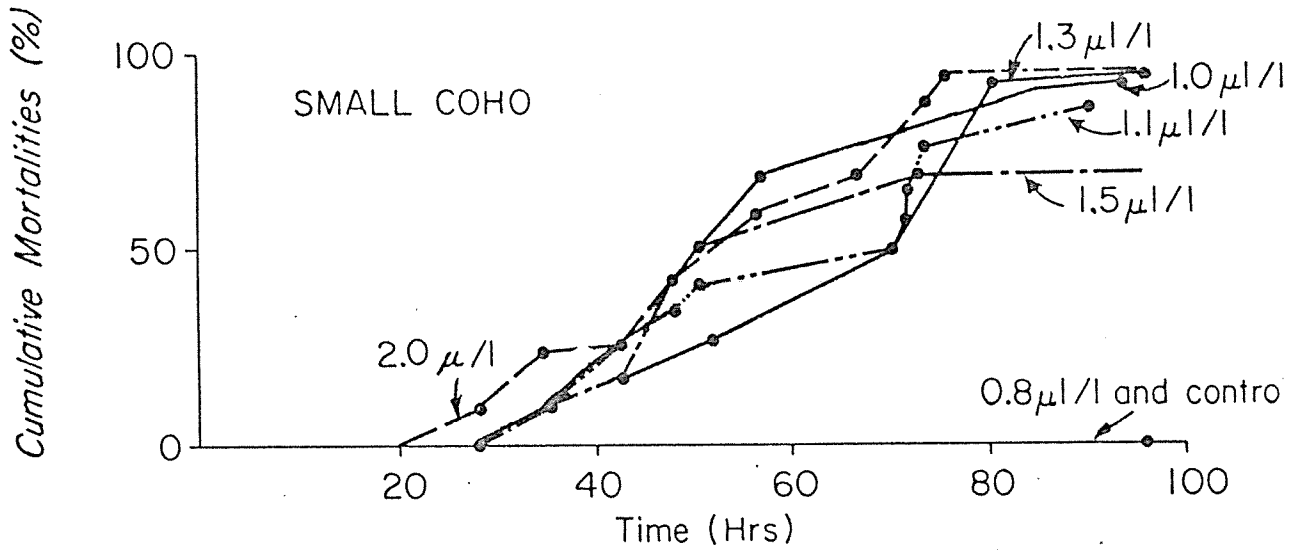


Fig. 3. Results of Test 1 showing time-mortality curves for 0-age coho exposed to Magnifloc 573C (only).

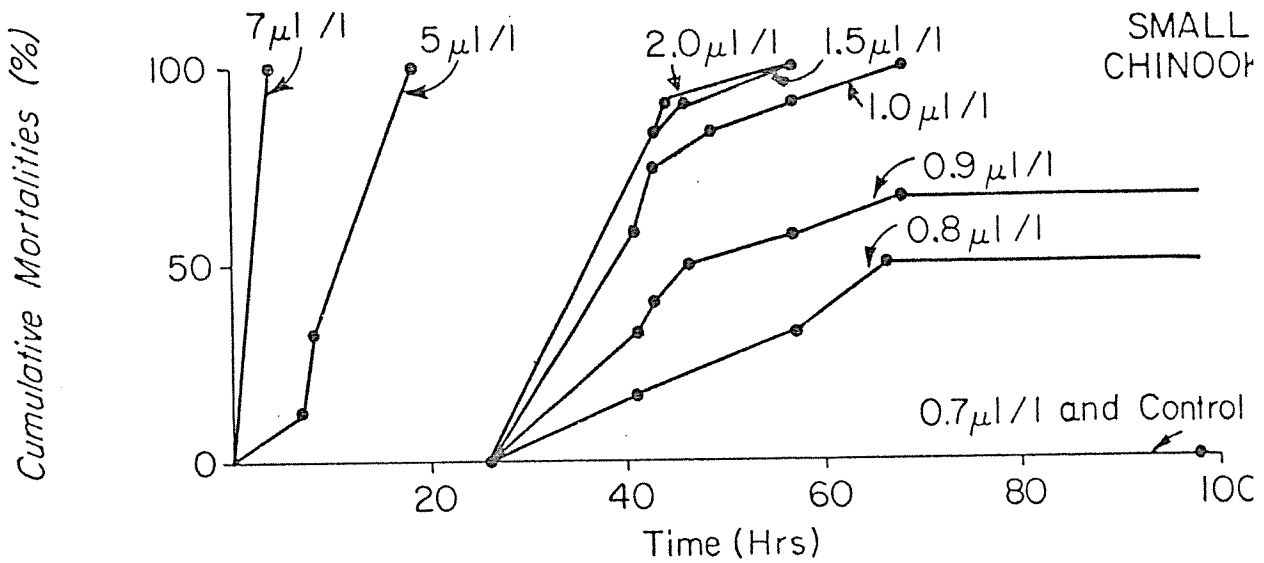


Fig. 4. Results of Test 2 showing time-mortality curves for 0-age chinook exposed to Magnifloc 573C (only).

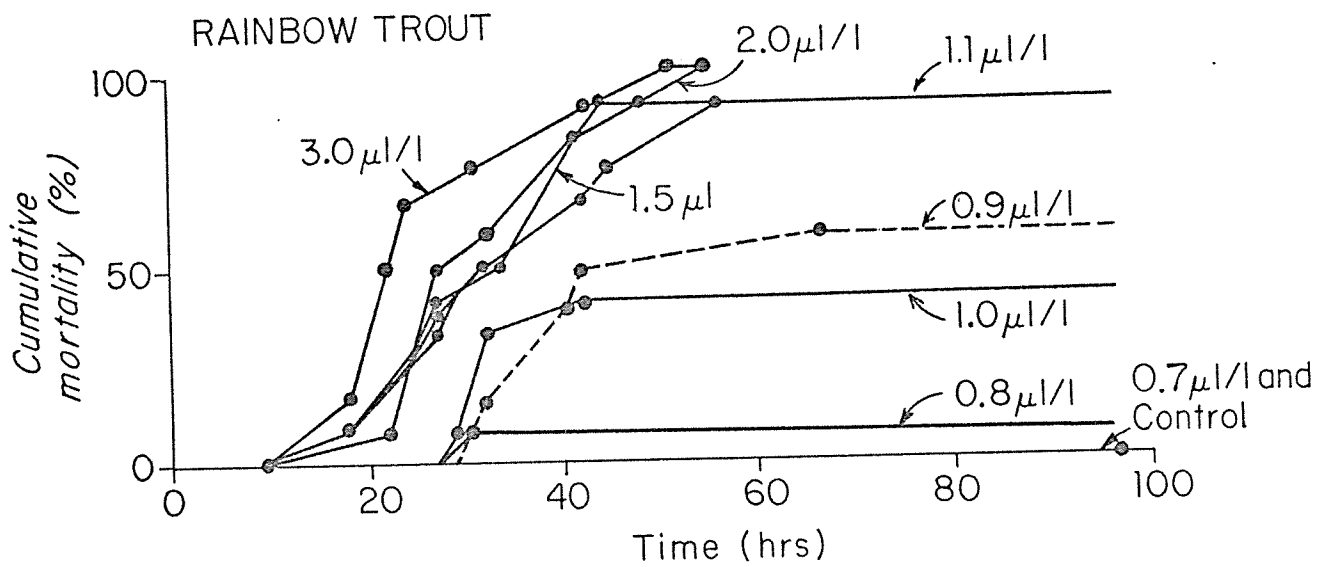


Fig. 5. Results of Test 3 showing time-mortality curves for 0-age rainbow trout exposed to Magnifloc 573C (only).

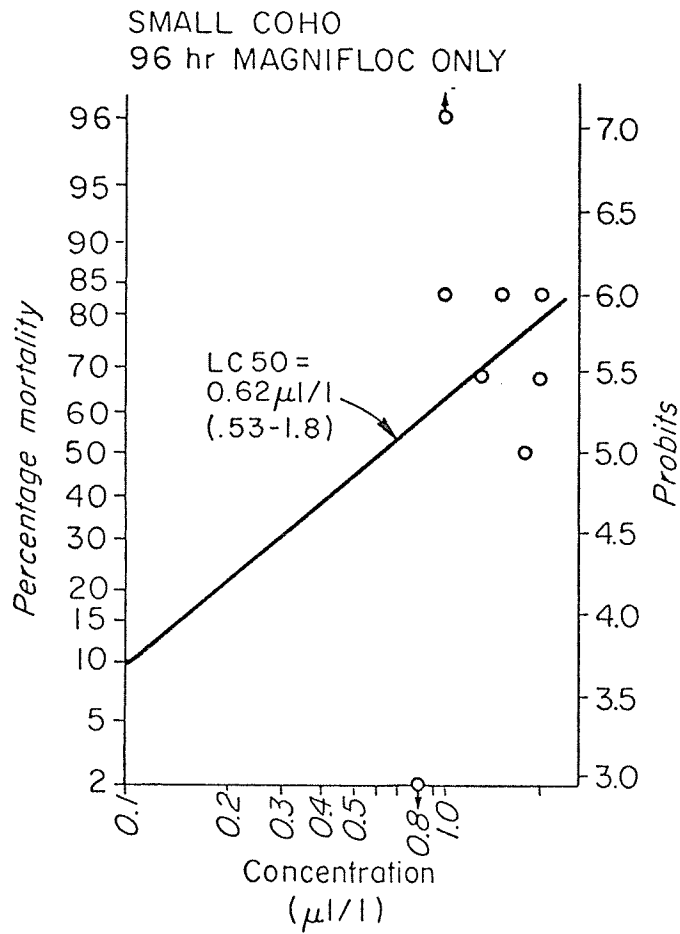


Fig. 6. Transformed data from Fig. 3 showing the 96-hr LC50 value and its confidence limits for 0-age coho exposed to Magnifloc 573C.

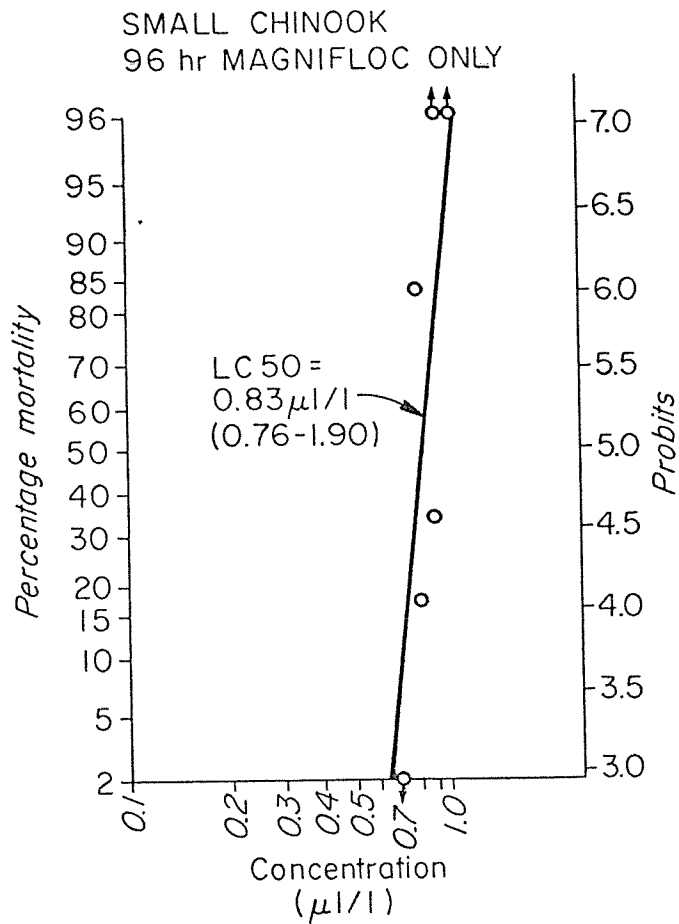


Fig. 7. Transformed data from Fig. 4 showing the 96-hr LC50 value and its confidence limits for 0-age chinook exposed to Magnifloc 573C.

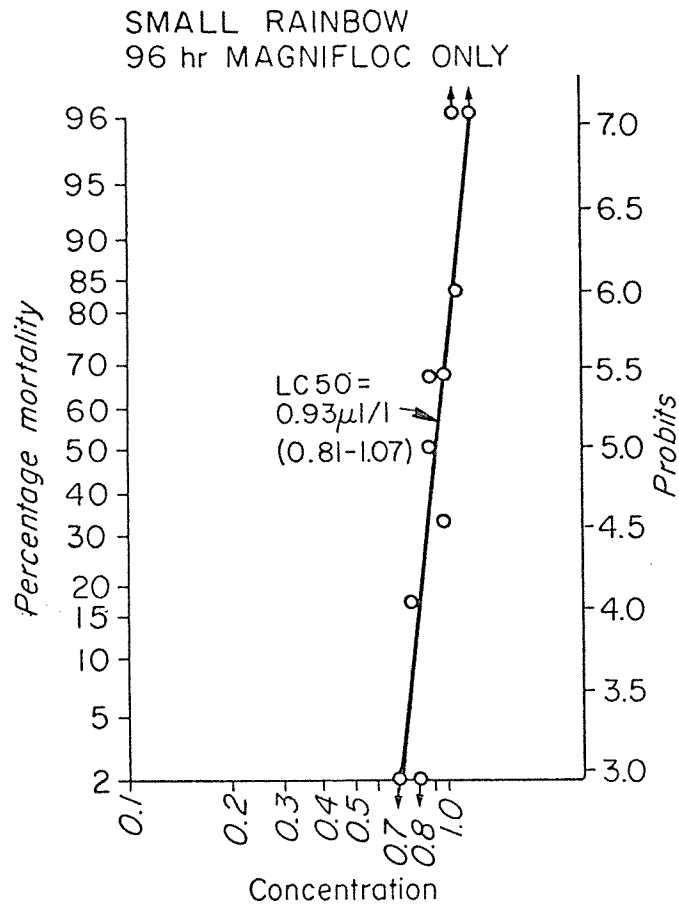


Fig. 8. Transformed data from Fig. 5 showing the 96-hr LC50 value and its confidence limits for 0-age rainbow trout exposed to Magnifloc 573C.

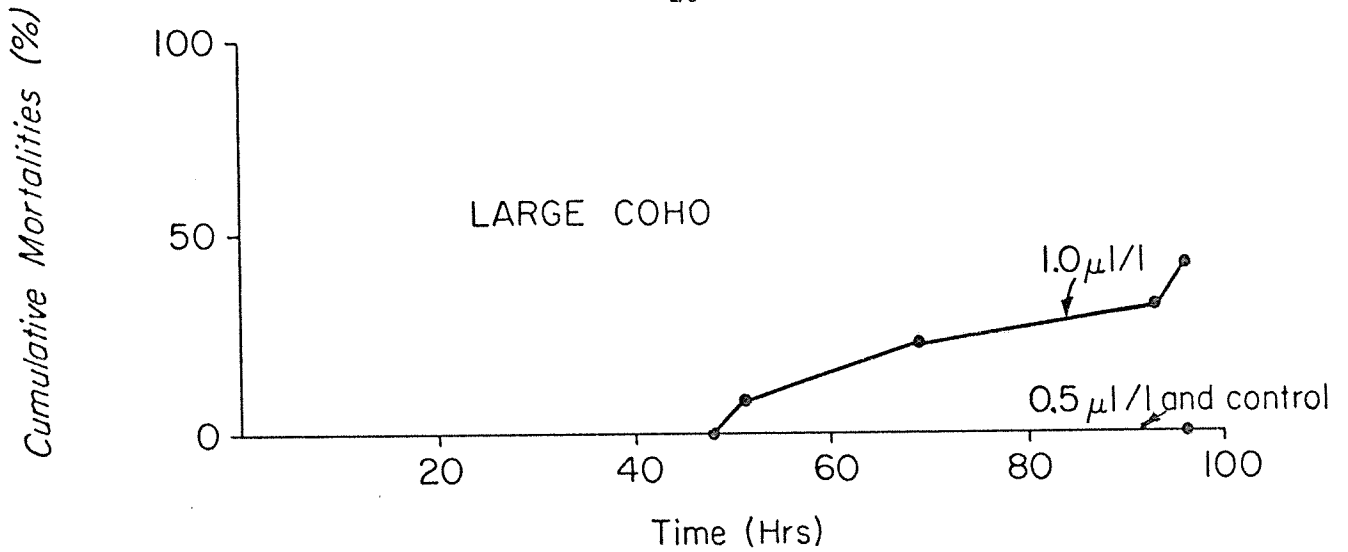


Fig. 9.. Results of Test 4 showing time-mortality curve for yearling coho exposed to Magnifloc 573C. In addition to values shown on the graph, these fish were also exposed to combinations of Magnifloc 573C and suspended solids of .005, .05, and .25 ml/l and 0.1, 1.0, and 50 and 100 mg/l, respectively. No mortalities occurred in these additional bioassays (see Appendix-Tests 4A-4C).

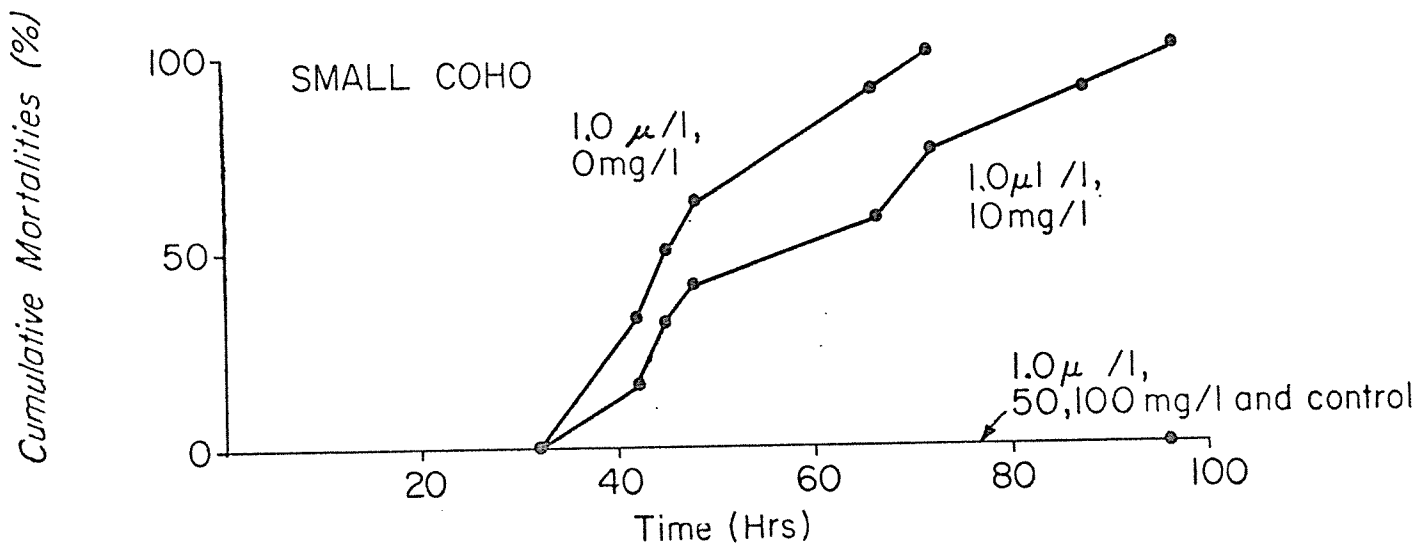


Fig. 10. Results of Test 5 showing time-mortality curve for 0-age coho exposed to Magnifloc 573C ($\mu\text{l}/\ell$) and suspended solids (in mg/ℓ). Additional combinations of (at concentrations less than those shown) of Magnifloc 573C and suspended solids can be found in Appendix 2-Test 5. No mortalities occurred in these additional tests.

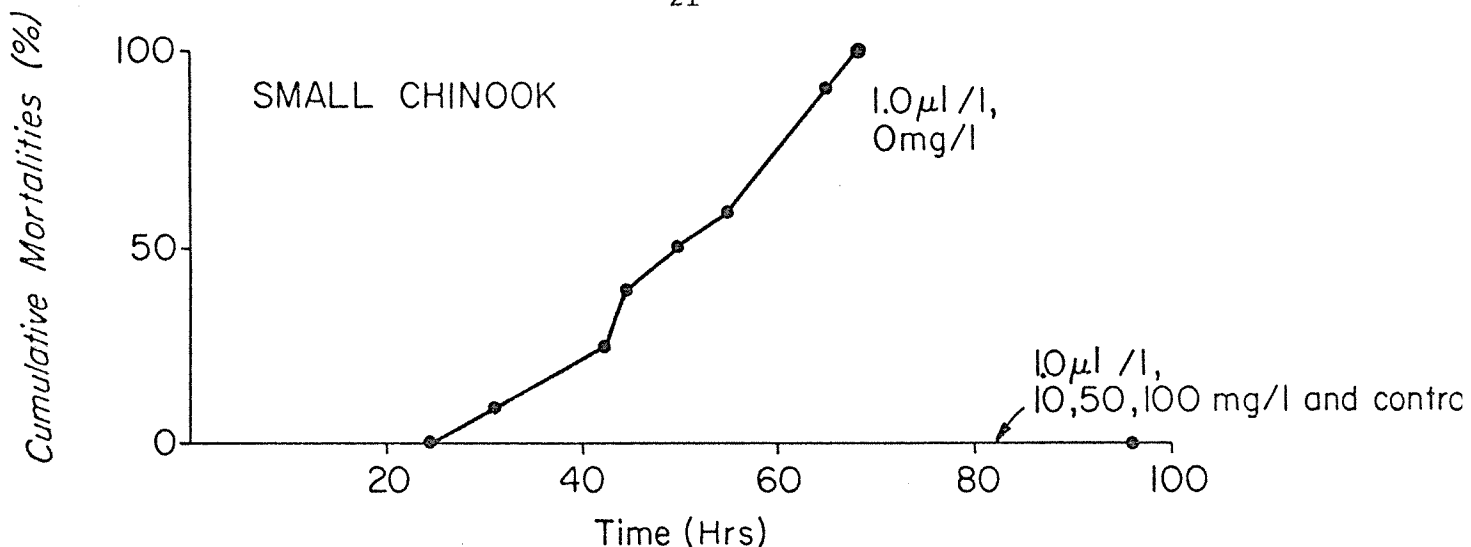


Fig. 11. Results of Test 6 showing time-mortality curve for 0-age chinook exposed to Magnifloc 573C (μ l/l) and suspended solids (in mg/l). Additional combinations (at concentrations less than those shown) of Magnifloc 573C and suspended solids can be found in Appendix 2-Test 6. No mortalities occurred in these additional tests.

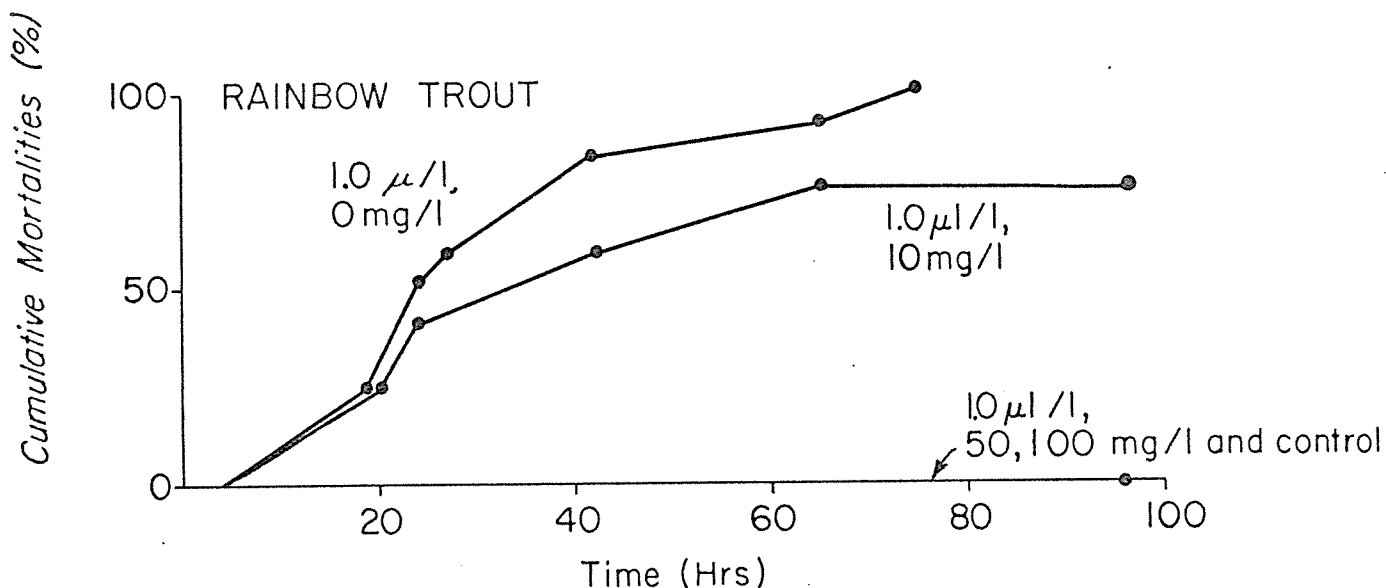


Fig. 12. Results of Test 7 showing time-mortality curve for 0-age rainbow trout exposed to Magnifloc 573C (in μ l/l) and suspended solids (in mg/l). Additional combinations (at concentrations less than those shown) of Magnifloc 573C and suspended solids can be found in Appendix 2-Test 7. No mortalities occurred in these additional tests.

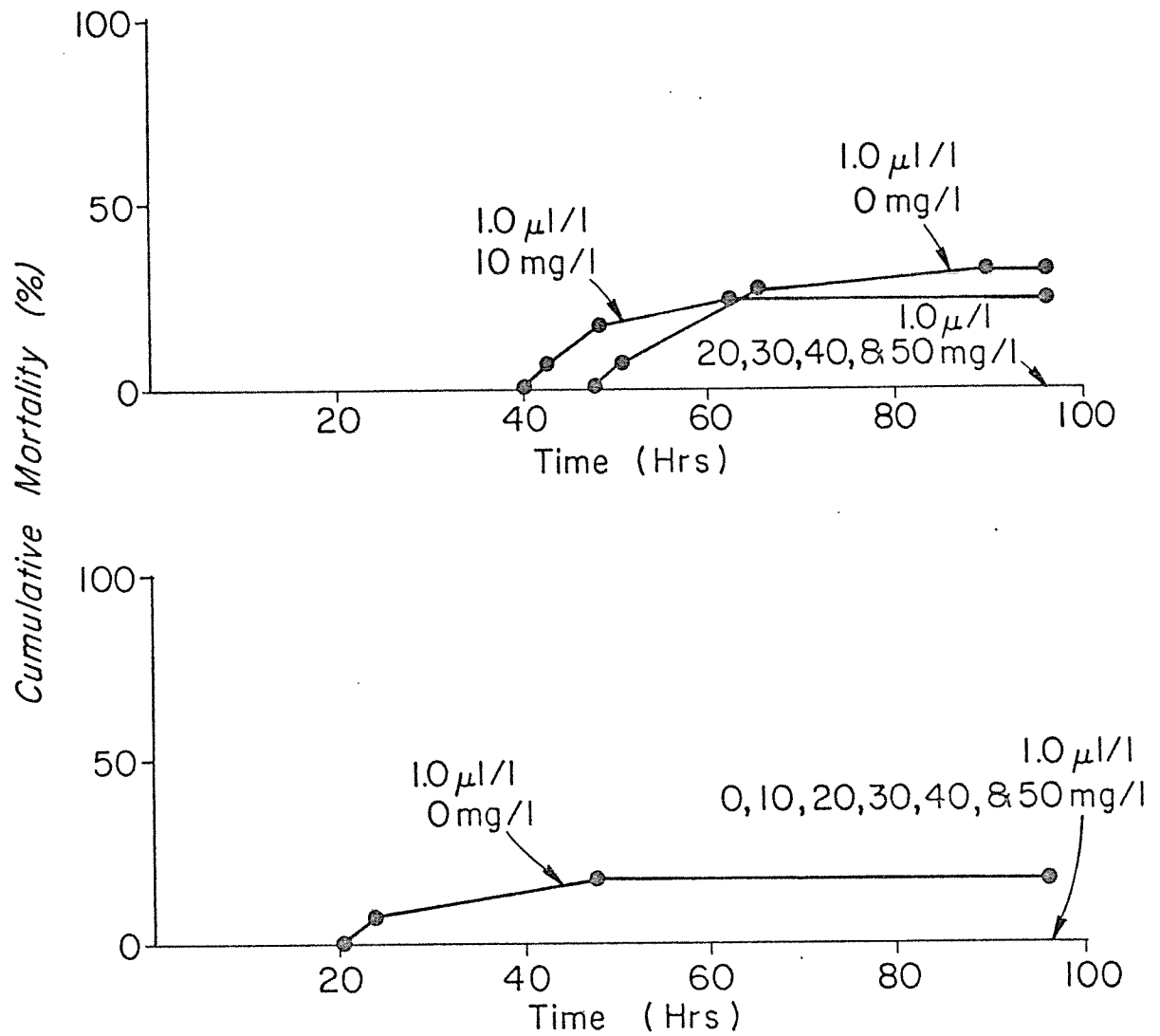


Fig. 13 (top) Results of Test 8 showing time-mortality curve for 0-age chinook exposed to Magnifloc 573C (in $\mu\text{l}/\ell$) and suspended solids (in mg/ℓ).
 (bottom) Results in Test 9 showing time-mortality curve for 0-age chinook exposed to Magnifloc 573C (in $\mu\text{l}/\ell$) and suspended solids (in mg/ℓ).

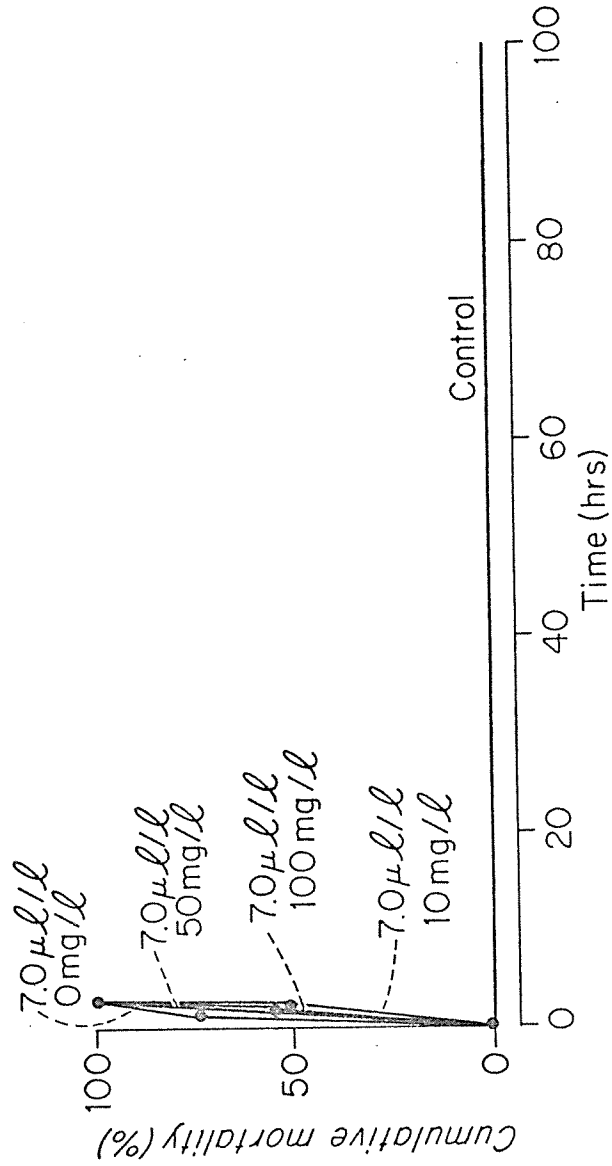


Fig. 14. Results of Test 10 showing time-mortality curve for 0-age coho exposed to Magnifloc 573C (in µl/l) and suspended solids (in mg/l).

indicated a threshold concentration above which the test fish were unable to tolerate Magnifloc. If continuous flow tests had been used for these bioassays, this threshold concentration probably would have been lower, as Biesinger (1976) found in other bioassays with polyelectrolytes.

Prior to death, fish would display muscle spasms throughout the entire body. This was accompanied by loss of equilibrium. Frequently, fish would recover from this condition for several hours and appear "normal." However, the condition would again return and the fish eventually died.

Some overlapping of curves did appear with slightly greater mortalities occurring at 1.0 $\mu\text{l/l}$ and 1.1 $\mu\text{l/l}$ than at 1.5 $\mu\text{l/l}$. This may be attributed largely to biological variation among individuals.

The 96-hr LC50 was 0.62 $\mu\text{l/l}$ (Fig. 6) which is within the range of expected levels of usage.

Dissolved oxygen values in the tests (and in all other tests where no supplemental aeration was used) ranged from near-saturation values of 10.5 to 11.0 ppm at the beginning of the test and from 5.5 to 7.0 ppm at the end. These values were adequate for healthy maintenance of fish (Committee on Water Quality, 1973).

Test 2: 0-Age Chinook

The response by the small chinook was similar to the coho response except that mortalities (for concentrations $\leq 2.0 \mu\text{l/l}$) began around 30 hrs and were complete by 60 hrs (Fig. 4). No mortalities occurred at concentrations below 0.8 $\mu\text{l/l}$. Signs of distress at concentrations of 2.0 $\mu\text{l/l}$ or less prior to death were the same as those of the small coho. At the 5.0 and 7.0 $\mu\text{l/l}$ concentrations, mortalities were very rapid and 100% mortality occurred at 3 hr with 7 $\mu\text{l/l}$ and at 18 hr with 5 $\mu\text{l/l}$. Signs of distress were different at these higher concentrations. Muscle spasms were rarely observed, but large

amounts of mucus were found on the gills, indicating irritation of these tissues. A closer examination of the gills showed that after 96 hr of exposure to 7 $\mu\text{l/l}$ of Magnifloc, there was necrosis of the gill filaments and lamellae. Also, hemorrhage from the filamental capillaries was widespread. At a lower concentration of 1.2 $\mu\text{l/l}$, possible edema and limited necrosis of the gills were apparent but at 0.5 $\mu\text{l/l}$ Magnifloc, no visible lesions on the gills could be observed. Examination of other tissues throughout the fish (even to 7 $\mu\text{l/l}$) showed no significant changes from controls.

The confidence limits for the 96-hr LC50 overlapped with those of the coho, and therefore, the LC50 values were not significantly different.

Test 3: 0-Age Rainbow Trout

The rainbow trout response was similar to the coho and chinook (Fig. 8), both in approximate time of first observed mortalities (of concentrations around 2.0 $\mu\text{l/l}$ or less) and in signs of distress (muscle spasms). The 3.0 $\mu\text{l/l}$ concentration was the highest concentration tested and no attempt was made to determine if a very rapid response (such as that found with chinook at 5 and 7 $\mu\text{l/l}$) would have occurred at higher concentrations. No response was observed at concentrations below 0.8 $\mu\text{l/l}$. The 96-hr LC50 was not significantly different from either the coho or the chinook.

Effects of Suspended Solids on Magnifloc 573C Toxicity

Test 4: Yearling Coho

The only mortalities that occurred with the yearling coho were with Magnifloc only at 1.0 $\mu\text{l/l}$ (Fig. 9). No mortalities occurred at Magnifloc concentrations below 1.0 $\mu\text{l/l}$ and when 10 mg/l or greater suspended solids were included in the test container at 1.0 $\mu\text{l/l}$ Magnifloc, no mortalities

occurred. Only 5 of 15 fish died in one of the replicates at 1.0 $\mu\text{l/l}$ Magnifloc (with no suspended solids additions). Thus, it appeared that the tolerance of larger coho to Magnifloc was greater than the other groups of test fish.

Test 5: 0-Age Coho

The results of the small coho tests with Magnifloc and suspended solids were similar to the large coho except that nearly 100% mortality was found at 1.0 $\mu\text{l/l}$ of Magnifloc only (Fig. 10). A mortality of 100% was observed with Magnifloc at a concentration of 1.0 $\mu\text{l/l}$ in combination with 10 mg/l suspended solids, but with the same Magnifloc concentration at suspended solids concentrations of 50 or 100 mg/l, no mortalities were observed.

Test 6: 0-Age Chinook

The results were slightly different from previous results. As with the coho, total mortality occurred at 1.0 $\mu\text{l/l}$ Magnifloc only (Fig. 11). However, when 10 mg/l or more of suspended solids were added to concentrations of Magnifloc of 1.0 $\mu\text{l/l}$ or less, no response was observed.

Test 7: 0-Age Rainbow Trout

The response in these bioassays was similar to that of the small coho. Mortalities occurred at 1.0 $\mu\text{l/l}$ Magnifloc only and with 1.0 $\mu\text{l/l}$ of Magnifloc with 10 mg/l suspended solids (Fig. 12). No mortalities were observed at suspended solids concentrations greater than these values.

Tests 8, 9, and 10 (added coho and chinook tests)

Tests 8 and 9 (with 0-age chinook) verified previous results: With Magnifloc only, at 1.0 $\mu\text{l/l}$, some mortality occurred, and 10 mg/l suspended solids did not offer protection (Fig. 13). However, at 20 mg/l or more, no mortalities were evident. In test 9, very few mortalities occurred even at 1.0 $\mu\text{l/l}$ Magnifloc only. These fish were slightly larger because of growth

between tests and may have been somewhat less sensitive than smaller fish used in previous tests. Natural biological variance may have also accounted for the differences from previous results. Test 10 showed that the lower toxicity associated with increased suspended solids was not apparent at 7.0 $\mu\text{l/l}$ Magnifloc. Even at 100 mg/l suspended solids, no significant decrease in mortality occurred. One hundred percent mortality was observed in all tanks, except controls, within 4 hrs of exposure (Fig. 14).

GENERAL DISCUSSION

Magnifloc Only, LC50

One tentative plan for operation of the sedimentation and control system ponds calls for a continuous fixed injection of Magnifloc into the effluent from the ponds at a concentration of 0.1-0.7 mg/l regardless of the concentration of suspended solids. Thus, Magnifloc may be injected when suspended solids concentrations are minimal (≤ 10 mg/l). Therefore, the LC50 values obtained in the bioassays using Magnifloc (only) become an important "bench mark".

The LC50 (96-hr) values for all of the small salmon tested were essentially the same (0.62-0.93 $\mu\text{l/l}$) because confidence limits on all of these values overlapped. The larger coho were more resistant but further tests would be needed to determine the degree of difference (the tests with the larger coho were designed with respect to operational values and not to determine an LC50). Bionomics, Inc. (1971), found a 96-hr LC50 of 0.16 $\mu\text{l/l}$ with rainbow trout and 0.39 with bluegill (Lepomis macrochirus). Although these values were smaller than those found in our tests, the concentrations were in the same general range. Thus, at the expected concentrations to be used (0.1 to 0.7 $\mu\text{l/l}$), there is a real potential for

toxicity to occur, especially at the higher concentrations. Furthermore, these tests were all based on acute responses and long-term effects are unknown. If an application factor of 1/10 the 96-hr LC50 value (Committee on Water Quality Criteria, 1973) is considered, then the operational level of 0.1-0.7 $\mu\text{l}/\text{l}$ exceeds the "safe level" for discharge.

Another factor to consider is the possibility of accidental over-dosage. As demonstrated with the small chinook tests at 5.0 and 7.0 $\mu\text{l}/\text{l}$, the lethality increases substantially, with all fish dead in 4 hrs at the 7.0 $\mu\text{l}/\text{l}$ concentration.

Magnifloc and Suspended Solids

The addition of suspended solids did reduce toxicity at 1.0 $\mu\text{l}/\text{l}$ of Magnifloc, but at the higher concentrations (7.0 $\mu\text{l}/\text{l}$) the reduction was not evident, at least not at levels to be expected at the plant site. At 1.0 $\mu\text{l}/\text{l}$ Magnifloc, 20 mg/l suspended solids was enough to decrease or eliminate acute toxic effects. However, at 7.0 $\mu\text{l}/\text{l}$ Magnifloc, even 100 mg/l did not significantly reduce toxicity. Thus, again, if application factors (e.g., 1/10 of the 96-hr LC50) are considered, or an accidental spill occurs, there is a potential for adverse effects (a fish kill).

Although some caution will be necessary in using Magnifloc because of its potential toxicity, several factors at the Satsop plant would tend to reduce this potential. These are as follows:

1. If a mixing zone is allowed in calculating toxicity of the discharge, "safe levels" of Magnifloc in the receiving water should be realized, because the Magnifloc would be diluted and dispersed below toxic levels.

2. If no accidental spill occurs, and suspended solids concentrations are at least 10 mg/l or greater, safe use of Magnifloc (at 0.1 to 0.7 μ l/l) may be possible. Envirosphere Company personnel have indicated that it is unlikely that suspended solids concentrations in the storm water runoff during construction will be less than 50 mg/l, and thus, Magnifloc will probably not be injected at suspended solids concentrations less than this.

3. If the Magnifloc dosing apparatus is designed so that injection of the flocculent is adjusted to suspended solids concentrations, the potential for toxicity decreases further.

In reference to item 1, other studies on polyelectrolytes have shown that little or no toxicity can be detected when the polyelectrolyte is dispersed, i.e., diluted by the receiving water (Smith and Nightingale, personal communication). Whether a similar situation would occur with Magnifloc is not definitely established for the field situation at the Satsop site. However, the results from this study would tend to support such an argument because no acute toxicity was detected at concentrations slightly lower than the expected dosage.

Items 2 and 3 (above) are directly related to the results found in this study and previous studies (Biesinger, et al., 1976; Olson, et al., 1973) which show that toxicity is decreased when suspended solids are added.

Another question does arise and that is whether Magnifloc (or any other polyelectrolyte) should be required at the Satsop site. To consider this question, some background information is necessary. First, the highest suspended solids concentrations in the erosion and sedimentation control system will coincide with the occurrence of rain storms. The

Chehalis and Satsop rivers will also have their highest suspended solids concentrations during the same general period. The values for suspended solids concentrations in the Chehalis (at Porter, from EPA Storet Retrieval Data, September 27, 1974) are 195 mg/l maximum value and 125 mg/l mean value. If the control system can achieve a value of 100 mg/l or less even during a 10-year peak storm, then the discharge would probably be less turbid than the receiving water, even without using Magnifloc. It may not be reasonable to risk the use of Magnifloc to clarify the water even further.

In addition to the above question, the effects of suspended solids at 50 and 100 mg/l must be considered. No mortalities occurred in these tests at either 50 or 100 mg/l of suspended solids only. In fact, other studies and reviews have shown that many more times that amount would be needed to show an effect, depending on the type of suspended sediment. Martin, et al. (1976), found that the 96-hr LC50 for juvenile chum salmon (Oncorhynchus keta) exposed to suspended sediments was approximately 1,000 mg/l. Mortensen, et al. (1976), concluded that a variety of factors influence the toxicity of suspended sediments. These include such factors as chemical composition, grain size, etc. Thus, it is difficult to determine an overall "safe" suspended solids concentration because each site has its own characteristic composition of suspended solids. To determine this "safe" level of suspended solids for the Satsop site, more tests would be needed to establish an LC50 value.

RECOMMENDATIONS

1. Magnifloc 573C should be used with caution and at suspended solids concentrations of at least 10 mg/l and preferably larger when dosed at concentrations of 0.1 to 0.7 μ l/l.

2. The dosing apparatus should be adjusted to suspended solids concentrations. If levels fall to 50 mg/l or less, Magnifloc should not be injected.

3. Chronic bioassays, live-box studies at the site, behavioral studies, and the determination of residual polyelectrolytes after addition of suspended solids should all be considered as possible additional studies to ensure that Magnifloc causes no adverse effects at the Satsop site.

4. Young salmonids can survive in 100 mg/l suspended solids without any problem; thus, the risk of using Magnifloc to reduce the suspended solids must be balanced by the relatively non-toxic effects of low suspended solids.

5. Other polyelectrolytes should be studied for consideration as alternative types of treatment. These should include both non-ionic and anionic forms of polyelectrolytes.

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APPENDIX TABLES

1 and 2

Appendix I. Results of preliminary test to determine if supplemental aeration significantly affected bioassay results. Test species: 0-age chinook average length - 3.8 cm, average weight - 0.41 gm
N = 60 fish

Fish/tank	Magnifloc ($\mu\text{l/l}$)	24 hr	48 hr	72 hr	96 hr	
aeration	6	0	0	0	0	
	6	0.05	0	0	0	
	6	0.25	0	0	0	
	6	0.5	0	4	6	6
	6	1.0	0	3	6	6
non-aeration	6	0	0	0	0	
	6	0.05	0	0	0	
	6	0.25	0	0	0	
	6	0.5	0	3	6	6
	6	1.0	0	4	6	6

The test results were not significantly different. Therefore, no aeration was used in the tests with small jars and 0-age salmon rainbow trout. Supplemental aeration was only used with the yearling coho. Dissolved oxygen values ranged from 10.5-11 ppm at the beginning and end of the tanks where aeration was used and from 10.5-11 ppm at the beginning and 6.5-7.0 at the end of tests with non-aeration.

Appendix II. Results of Tests 1 through 10 with Magnifloc 573C.

Test No. 1

Start date: Feb. 28, 1977

Test fish: Small coho

Mean length: 3.45 cm

Mean weight: 0.16 g

No. test tanks: 20

N = 120 fish

Water source: Lake Washington

Temp. 8.0°C

Fish/tank	Concentration		Number dead (cumulative)				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	0	0.3	0	0	0	0	0
6	0	0.3	0	0	0	0	0
6	0	0.5	0	0	0	0	0
6	0	0.5	0	0	0	0	0
6	0	0.6	0	0	0	0	0
6	0	0.6	0	0	0	0	0
6	0	0.8	0	0	0	0	0
6	0	0.8	0	0	0	0	0
6	0	1.0	0	1	4	6	6
6	0	1.0	0	2	5	5	5
6	0	1.1	0	3	3	6	6
6	0	1.1	0	2	6	6	6
6	0	1.3	0	0	4	6	6
6	0	1.3	0	1	4	4	4
6	0	1.5	0	1	4	5	5
6	0	1.8	0	1	2	3	3
6	0	2.0	0	2	5	6	6
6	0	2.0	0	3	4	6	6

Test No. 2

Start date: Feb. 21, 1977

Test fish: Small chinook

No. test tanks: 28

Water source: Lake Washington

Average test temperature: 8.0°C

Mean length: 4.10 cm

Mean wet weight: 0.75

N = 168 fish

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	0	.20	0	0	0	0	0
6	0	.20	0	0	0	0	0
6	0	.30	0	0	0	0	0
6	0	.30	0	0	0	0	0
6	0	.40	0	0	0	0	0
6	0	.40	0	0	0	0	0
6	0	.50	0	0	0	0	0
6	0	.50	0	0	0	0	0
6	0	.60	0	0	0	0	0
6	0	.60	0	0	0	0	0
6	0	.70	0	0	0	0	0
6	0	.70	0	0	0	0	0
6	0	.80	0	0	1	1	1
6	0	.80	0	2	5	5	5
6	0	.90	0	4	6	6	6
6	0	.90	0	2	2	2	2
6	0	1.0	0	4	5	5	5
6	0	1.0	0	5	6	6	6
6	0	1.5	0	5	6	6	6

Test No. 2 cont'd

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	1.5	0	6	6	6	6
6	0	2.0	0	5	6	6	6
6	0	2.0	0	6	6	6	6
6	0	5.0	6	6	6	6	6
6	0	5.0	6	6	6	6	6
6	0	7.0	6	6	6	6	6
6	0	7.0	6	6	6	6	6

Test No. 3

Start date: March 21, 1977

Test fish: Rainbow Trout Mean length: 3.83 cm Mean wet weight: 0.46 g

No. test tanks: 20 N = 120 fish

Water source: Lake Washington

Average test temperature: 7.9°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	0	0.6	0	0	0	0	0
6	0	0.6	0	0	0	0	0
6	0	0.7	0	0	0	0	0
6	0	0.7	0	0	0	0	0
6	0	0.8	0	0	0	0	0
6	0	0.8	0	1	1	1	1
6	0	0.9	0	1	3	5	5
6	0	0.9	0	3	3	3	3
6	0	1.0	0	0	2	2	2
6	0	1.0	1	4	4	4	4
6	0	1.1	2	5	6	6	6
6	0	1.1	0	4	5	5	5
6	0	1.5	2	5	5	5	5
6	0	1.5	1	6	6	6	6
6	0	2.0	2	6	6	6	6
6	0	2.0	1	5	6	6	6
6	0	3.0	6	6	6	6	6
6	0	3.0	3	5	6	6	6

Test No. 4A

Start date: Jan. 25, 1977

Test fish: Large coho

Mean length: 10.7 cm

Mean wet weight: 11.4 g

No. test tanks: 12

Water source: Lake Washington

N = 180 fish

Average test temperature: 7.9°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
15	0	0	0	0	0	0	0
15	0	.005	0	0	0	0	0
15	0	.05	0	0	0	0	0
15	0	.25	0	0	0	0	0
15	0	.50	0	0	0	0	0
15	0	1.0	0	0	3	5	5
15	.10	0	0	0	0	0	0
15	.10	.005	0	0	0	0	0
15	.10	.05	0	0	0	0	0
15	.10	.25	0	0	0	0	0
15	.10	.50	0	0	0	0	0
15	.10	1.0	0	0	0	0	0

Test No. 4B

Start date: Jan. 31, 1977

Test fish: large coho Mean length: 11.8 cm Mean wet weight: 13.3 g

No. test tanks: 12 N = 180 fish

Water source: Lake Washington

Average test temperature: 7.35°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (µl/l)	24 hr	48 hr	72 hr	96 hr	
15	0	0	0	0	0	0	0
15	0	.005	0	0	0	0	0
15	0	.05	0	0	0	0	0
15	0	.25	0	0	0	0	0
15	0	.50	0	0	0	0	0
15	0	1.0	0	0	0	0	0
15	1.0	0	0	0	0	0	0
15	1.0	.005	0	0	0	0	0
15	1.0	.05	0	0	0	0	0
15	1.0	.25	0	0	0	0	0
15	1.0	.50	0	0	0	0	0
15	1.0	1.0	0	0	0	0	0

Test No. 4C

Start date: Feb. 7, 1977

Test fish: large coho

Mean length: 12.3 cm

Mean wet weight: 13.4 g

No. test tanks: 11

N = 165 fish

Water source: Lake Washington

Average test temperature: 8.1°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
15	0	0	0	0	0	0	0
15	10	.005	0	0	0	0	0
15	10	.05	0	0	0	0	0
15	10	.25	0	0	0	0	0
15	10	.50	0	0	0	0	0
15	10	1.0	0	0	0	0	0
15	50	0	0	0	0	0	0
15	50	.05	0	0	0	0	0
15	50	.25	0	0	0	0	0
15	50	.50	0	0	0	0	0
15	50	1.0	0	0	0	0	0

Test No. 4D

Start date: Feb. 14, 1977

Test fish: Large coho

No. test tanks: 6

Water source: Lake Washington

Average test temperature: 8.3°C

Mean length: 12.7 cm Mean wet weight: 14.2 g

N = 90 fish

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
15	0	0	0	0	0	0	0
15	100	0	0	0	0	0	0
15	100	1.0	0	0	0	0	0
15	100	.50	0	0	0	0	0
15	100	.25	0	0	0	0	0
15	100	.05	0	0	0	0	0

Test No. 5

Start date: March 7, 1977

Test fish: Small coho

Mean length: 3.49 cm

Mean wet weight: 0.22 g

No. test tanks: 24

N = 144 fish

Water source: Lake Washington

Average test temperature: 8.0°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	10	0	0	0	0	0	0
6	10	0	0	0	0	0	0
6	50	0	0	0	0	0	0
6	50	0	0	0	0	0	0
6	100	0	0	0	0	0	0
6	100	0	0	0	0	0	0
6	0	0.5	0	0	0	0	0
6	0	0.5	0	0	0	0	0
6	10	0.5	0	0	0	0	0
6	10	0.5	0	0	0	0	0
6	50	0.5	0	0	0	0	0
6	50	0.5	0	0	0	0	0
6	100	0.5	0	0	0	0	0
6	100	0.5	0	0	0	0	0
6	0	1.0	0	4	5	5	5
6	0	1.0	0	3	6	6	6

Test No. 5 cont'd

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	10	1.0	0	3	5	6	6
6	10	1.0	0	2	4	6	6
6	50	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	100	1.0	0	0	0	0	0
6	100	1.0	0	0	0	0	0

Test No. 6

Start date: Feb. 14, 1977

Test fish: Small chinook Mean length: 4.30 cm Mean wet weight: 0.62 g

No. test tanks: 31 N = 186 fish

Water source: Lake Washington

Average test temperature: 8.3°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	0	.25	0	0	0	0	0
6	0	.50	0	0	0	0	0
6	0	.50	0	0	0	0	0
6	0	1.0	0	1	6	6	6
6	0	1.0	0	3	6	6	6
6	10	0	0	0	0	0	0
6	10	0	0	0	0	0	0
6	10	.25	0	0	0	0	0
6	10	.25	0	0	0	0	0
6	10	.50	0	0	0	0	0
6	10	.50	0	0	0	0	0
6	10	1.0	0	0	0	0	0
6	10	1.0	0	0	0	0	0
6	50	0	0	0	0	0	0
6	50	0	0	0	0	0	0
6	50	.25	0	0	0	0	0
6	50	.25	0	0	0	0	0

Test No. 6 cont'd

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	50	.50	0	0	0	0	0
6	50	.50	0	0	0	0	0
6	50	1.00	0	0	0	0	0
6	50	1.00	0	0	0	0	0
6	100	0	0	0	0	0	0
6	100	0	0	0	0	0	0
6	100	.25	0	0	0	0	0
6	100	.25	0	0	0	0	0
6	100	.50	0	0	0	0	0
6	100	.50	0	0	0	0	0
6	100	1.0	0	0	0	0	0
6	100	1.0	0	0	0	0	0

Test No. 7

Start date: March 14, 1977

Test fish: Rainbow trout Mean length: 4.22 cm Mean wet weight: 0.37 g

No. test tanks: 24 N = 144 fish

Water source: Lake Washington

Average test temperature: 7.9°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (µl/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	10	0	0	0	0	0	0
6	10	0	0	0	0	0	0
6	50	0	0	0	0	0	0
6	50	0	0	0	0	0	0
6	100	0	0	0	0	0	0
6	100	0	0	0	0	0	0
6	0	0.50	0	0	0	0	0
6	0	0.50	0	0	0	0	0
6	10	0.50	0	0	0	0	0
6	10	0.50	0	0	0	0	0
6	50	0.50	0	0	0	0	0
6	50	0.50	0	0	0	0	0
6	100	0.50	0	0	0	0	0
6	100	0.50	0	0	0	0	0
6	0	1.0	5	5	5	6	6
6	0	1.0	1	5	6	6	6
6	10	1.0	1	2	4	4	4
6	10	1.0	4	5	5	5	5

Test No. 7 cont'd

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	50	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	100	1.0	0	0	0	0	0
6	100	1.0	0	0	0	0	0

Test No. 8

Start date: March 21, 1977

Test fish: Small coho Mean length: 3.51 cm Mean wet weight: 0.29 g

No. test tanks: 14 N = 84 fish

Water source: Lake Washington

Average test temperature: 7.9°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	0	1.0	0	0	2	2	2
6	0	1.0	0	0	1	2	2
6	10	1.0	0	2	3	3	3
6	10	1.0	0	0	0	0	0
6	20	1.0	0	0	0	0	0
6	20	1.0	0	0	0	0	0
6	30	1.0	0	0	0	0	0
6	30	1.0	0	0	0	0	0
6	40	1.0	0	0	0	0	0
6	40	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0

Test No. 9

Start date: March 28, 1977

Test fish: Small coho Mean length: 4.02 cm Mean wet weight: 0.32 g

No. test tanks: 21 N = 126 fish

Water source: Lake Washington

Average test temperature: 10.3°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (µl/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	1.0	1	0	0	0	1
6	0	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	50	1.0	0	0	0	0	0
6	40	1.0	0	0	0	0	0
6	40	1.0	0	0	0	0	0
6	30	1.0	0	0	0	0	0
6	30	1.0	0	0	0	0	0
6	30	1.0	0	0	0	0	0
6	30	1.0	0	0	0	0	0
6	20	1.0	0	0	0	0	0
6	20	1.0	0	0	0	0	0
6	20	1.0	0	0	0	0	0
6	20	1.0	0	0	0	0	0
6	10	1.0	0	1	0	0	0
6	10	1.0	0	0	0	0	0
6	10	1.0	0	0	0	0	0
6	10	1.0	0	0	0	0	0

Test No. 10

Start date: Feb. 28, 1977

Test fish: Small chinook Mean length: 4.71 cm Mean wet weight: 0.64 g

No. fish/tank: 6 N = 60 fish

No. test tanks: 10

Water source: Lake Washington

Average test temperature: 8.0°C

Fish/tank	Concentration		Cumulative Mortality				Total dead
	Solids (mg/l)	Magnifloc (μ l/l)	24 hr	48 hr	72 hr	96 hr	
6	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6	0	7.0	6	0	0	0	6
6	0	7.0	6	0	0	0	6
6	10	7.0	6	0	0	0	6
6	10	7.0	6	0	0	0	6
6	50	7.0	6	0	0	0	6
6	50	7.0	6	0	0	0	6
6	100	7.0	6	0	0	0	6
6	100	7.0	6	0	0	0	6