DEPARTMENT OF NATURAL RESOURCES
Box 450
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Bureau of Fish Management
Management Report No. 23

PROCEDURES FOR CHEMICAL RECLAMATION OF SOFT WATER TROUT STREAMS

by

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SUMMARY

The procedures utilized in the chemical rehabilitation of streams are outlined in detail. Best results are obtained by maintaining 5 p.p.m. for 1 hour and 1 p.p.m. for an additional 4-5 hours. Maintenance of suitable concentrations is measured by using dissolved salt as a proportional indicator of dilution. Tables for computing required concentrations are provided. This paper succeeds a previous paper on the same subject written in 1966 (Management Report No. 5).

November, 1967

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INTRODUCTION

The control of undesirable fish in streams is often an essential and necessary procedure for attainment of quality fishing. The use of fish toxicants is an effective method of control in a flowing water system but their use is usually more complicated than techniques used on lakes. Eradication or severe reduction of undesirable populations of fish from streams with the use of rotenone is a relatively new but promising procedure. The methodology of stream reclamation with rotenone is the subject of this paper.

Presently, stream reclamation efforts are confined to low grade or marginal trout streams where problems of low productivity and limited cover are compounded by large numbers of competing species of fish. We have found that very satisfactory "put, grow, and take" trout fisheries can be established in these streams following removal of the competing species.

Basic problems encountered in stream reclamation projects include measurement of dissipation and dilution of the toxicant as it moves downstream and determination of how much additional toxicant must be added at points along the stream to keep the concentration at a level sufficient to kill the target species.

These problems arise because any bolt of toxicant moving down a stream is diluted by increased flow from springs and tributaries or it is dissipated by lateral movement into backwater areas.

The peak concentration also diminishes because of "stretchout," a term coined to describe the effects of pools and riffles in spreading the bolt of toxicant as it moves downstream. Bottom materials and particles in suspension absorb the toxicant further reducing its concentration.

Lennon (1959) reported that a solution of common salt (Na Cl) will mix somewhat the same as an emulsion of rotenone in water. Since the salt concentration can readily be determined because of its electrolitic properties, it provides an easy to use analog by which stretchout, dilution, and movement of rotenone in a flowing water situation can be measured.

Factors limiting the use of this salt technique are highly turbid waters and hard water with resistivities below 6000 ohms. Turbidity and hard water tend to increase conductivity and mask the effects of the salt. Proportionately, the salt accounts for a smaller segment of conductivity which makes it difficult to artificially drop low resistances significantly with reasonably handled quantities of salt.

PROJECT PROCEDURES

In conducting a stream reclamation project, it was found that following an outline of standardized procedures was very desirable. The following outline was developed to provide guidance for the procedure used in a project of this nature:

1. Conduct a biological survey to determine the need for the project.
2. Promote a public relations program to sell the proposed project.

3. Obtain written approval from the following:
   a. Riparian landowners, local sportsmen's clubs, and civic groups.
   b. Public Service Commission approval if required by Statutes.
4. Set a tentative date for the project.
5. Make an outline map of the project area and include all roads, trails, the stream, backwaters, and isolated pools; indicate all stations and sections.
6. Establish stations approximately one mile apart.
7. Take metered flow measurements at each station to calculate the water volume.
8. Establish a bench mark at every fifth station when flow measurements are taken.
9. Conduct salt and resistivity tests at each station above and below the point of salt introduction.
10. Calculate the toxicant requirements for each station (Table 2).
11. Calculate the volume of impoundment and toxicant requirements.
12. Set up a detoxification station if necessary.
13. Set up stations for test cages of fish.
14. Set up manpower and equipment requirements.
15. Set up post-treatment survey procedures.

METHODOLOGY

1. Determining Station Locations

Before measuring volumes of flow or running any salt tests on the stream, it is necessary to decide on station locations; points where it is anticipated that additional toxicant must be added to keep the concentration up to a lethal level.

In normal stream situations, we have found that dilution and dissipation will generally approximate 50 per cent per mile, although wide variations can be expected in some situations.

Access permitting, we have found it most convenient to select stations approximately one mile apart. This avoids the necessity of having to introduce over 15 p.p.m. toxicant at one station in order to maintain a lethal concentration of toxicant at the next downstream station.

Once fairly accessible stations have been selected and marked on the map, flows are determined and the salt and resistivity calculations are completed at the same stations where the toxicant will be added.

Bridge crossings make excellent stations when available. A station must always be established at the junction of two major tributaries.

2. Salt Calculations

Cattle salt blocks are the most common type of salt used in chemical reclamation projects. These blocks are placed at 3- to 5-feet intervals across the stream, 100- to 200-feet above the station. This is important because uneven distribution of salt concentrations will cause variations in the resistivity readings and result in unreliable calculations.

The salt blocks are weighed before introduction into the stream and again after they are removed. Another method used is to dissolve salt in water and drip the salt solution into the stream at known concentrations in parts per million.

A minimum of 50 p.p.m. of salt should be introduced into the stream but an even higher (50 to 100 p.p.m.) concentration is desirable. A salt concentration below 20 or 30 p.p.m. will not produce a measurable relationship between salt concentrations and resistance readings in waters of moderate to high resistivities (10,000 to 80,000 ohms).

Measurements of resistivity can be taken with a Model RC-7P, portable, battery-powered unit manufactured by Industrial Instruments, Inc. It is equipped with a "tuning eye" null indicator and a variable frequency pitch modulator which permits readings to be made quickly and easily. It measures resistivities of a liquid in ohms per centimeter cubed.

Water temperatures are a contributing factor in resistivity measurements. Therefore, water temperatures are recorded each time a measurement of resistivity is made. The relationship between temperature and resistivity is considered linear and amounts to a two per cent decrease in resistivity with each centigrade degree rise in temperature.

In order to standardize methods for comparing resistivities, it is common practice to correct all measurements to 25° C (77° F.) (Table 1).

Salt Resistivity Calculations

A. At Station # 1, the uppermost station:

1) Record water temperature.

2) Record resistance and correct to 77° F.

3) Introduce salt for 15 minutes at a point 200 to 300 feet upstream from Station # 1.

4) Record resistance during salt passage at Station # 1 at two to three minute intervals and correct the lowest reading to 77° F.

5) Calculate the amount of salt introduced in parts per million.

6) Compute the percentage of drop in resistance at peak salt concentration.

B. At Station # 2, one mile downstream:

1) Record temperature.

2) Record resistance and correct to 77° F. before the salt bolt arrives.

3) Record resistance at two to three minute intervals during salt passage and correct the lowest reading to 77° F.

4) Compute the following:

a) The time it takes salt to travel from Station # 1 to Station # 2 at peak salt concentration. This time interval will be used later--record it carefully.

b) The duration of peak salt concentration.

c) The maximum salt concentration in parts per million.

d) The percentage of drop in resistance at the peak salt concentration.

e) The percentage drop of salt concentration in parts per million between Stations # 1 and # 2.

Definitions and Example

1 gram of salt per 35 c.f. water = 1 (part per million)

1 gallon of pro-noxfish per 3 acre feet = 1 p.p.m.

C.F.S. x seconds x minutes = c.f.h. (cubic feet per hour)

c.f.h. ÷ 43,560 = acre feet of water per hour (A.F.)

R = resistivity

Conversion of rotenone calculations based on volume of flow.

Hypothetical Stream	Flow	Natural Resistivity
Station # 1 - Headwaters	10 c.f.s.	10,000 ohms @ 77° F.
Station # 2 - Mid-station	12 c.f.s.	9,000 ohms @ 77° F.
Station # 3 - End of area to be treated	15 c.f.s.	8,000 ohms @ 77° F.

50,000 grams of salt were dissolved above Station # 1 in 15 minutes in a flow of 10 c.f.s. of water.

10 c.f.s. x 60 seconds x 15 minutes = 9,000 c.f. of water passed through Station # 1 in 15 minutes.

Since 1 gram of salt per 35 cubic feet of H_2O = 1 p.p.m. concentration, then 9,000 c.f. of H_2O ÷ 35 = 257 grams of salt required for 1 p.p.m.

50,000 ÷ 257 = 194 p.p.m. salt added.

R. at Station # 1 is 10,000 ohms at 77° F. Addition of the original 50,000 grams of salt above Station # 1 drops R. from 10,000 ohms to 5,000 ohms.

R. at Station # 2 is 9,000 ohms at 77° F. First trace of salt recorded in two hours. R. drops to 8,400 ohms at 77° F. Peak drop in 2.5 hours is to 7,000 ohms R. at 77° F. To calculate amount of salt remaining:

$$\frac{194.0 \text{ p.p.m. of salt}}{5{,}000 \text{ ohms (loss of R at Sta. \# 1)}} = \frac{x \text{ p.p.m. of salt}}{2{,}000 \text{ ohms (loss of R at Sta. \# 2)}}$$

5,000 ohms x = 388,000 (p.p.m. - ohms)

x = 77.6 p.p.m. salt remaining at Station # 2.

77.6 p.p.m. salt = 60 % loss due to dissipation and dilution between Stations # 1 and # 2.

Station # 3. R = 8,000 ohms. Salt influence drops R to 7,000, a loss of 1,000 ohms. To calculate amount of salt remaining:

$$\frac{77.6 \text{ p.p.m. of salt}}{2{,}000 \text{ ohms (loss of R at Sta. \# 2)}} = \frac{x \text{ p.p.m. of salt}}{1{,}000 \text{ ohms (loss of R at Sta. \# 3)}}$$

2,000 x = 77,600

x = 38.8 p.p.m. salt remaining or 50 % loss between stations # 2 and # 3.

3. Stream Toxicant Calculations

We have found that the addition of rotenone at 5 p.p.m. for the first hour of operations followed by additional quantities equal to a concentration of 1 p.p.m. for an additional 4 or 5 hours will produce satisfactory fish kills when water temperatures exceed 50° F.

Addition of 1 p.p.m. for the second phase insures that toxicant will be present in the stream for an additional 6 to 10 hours at each station. This is necessary to remove hard-to-kill species such as bullheads and carp.

In order to simplify otherwise tedious calculations, we have prepared a chart (Table 2) which is attached to this report. Instructions for completing this chart are as follows:

1. In column A, record the metered flow of each station.
2. In column B, record the calculated AF/H passing the station. (c.f.s. x 3600 ÷ 43,560)
3. In column C, record the calculated number of gallons of rotenone required to treat Station # 1 at 5 p.p.m. assuming the station is run for one hour. $(\frac{AF/H}{3} \times 5) = (\frac{.82}{3})(5)$
4. In column D, record per cent loss of chemical concentration you computed from the salt and resistivity test. The loss between Stations # 1 and # 2 is recorded in per cent at Station # 1. The loss between Stations # 2 and # 3 is recorded on line 2, and so on.
5. In column E, record the difference of 100 per cent - value in column D.
6. In column F, we calculate what concentration of chemical (x) in p.p.m. is required at Station # 1 so that if 40 per cent remains, we will have 5 p.p.m. concentration at Station # 2. (40 % x = 5 p.p.m. or $x = \frac{5}{E} = 12.5$ p.p.m.)

7. In column G, we calculate how many gallons of chemical (x) are needed at Station # 1 to give the "F" value (12.5 p.p.m. at Station # 1.

$$\frac{1.38 \text{ gal.}}{5 \text{ p.p.m.}} = \frac{x \text{ gal.}}{12.5 \text{ p.p.m.}} = 5X = [(1.38)(12.5)] = [5X = CF] =$$

$$[X = \frac{CF}{5}] = 3.45 \text{ gal.}$$

8. In column H, we calculate how much chemical we need to introduce per hour at Station # 1 to keep the concentration up to 12.5 p.p.m. for an hour. At Station # 1, the H value equals G value since no chemical is coming downstream into Station # 1. At Station # 2, the H value is the difference between what is coming downstream from Station # 1 (1.65 gal.) and the total amount needed at Station # 2 (i.e. 3.3) or G-C = 3.3 - 1.65 = 1.65.

All calculations to complete the blanks under columns F, G, and H for any given station must be completed using data listed in columns C, E, F, and G for the <u>same</u> station only.

Timing The Project

It is generally desirable to time the entire project so that the chemical arrives at the detoxification point in the late morning or early afternoon. This permits the remaining daylight hours to be spent collecting the dead fish, sealing off the dam if a flowage is the lower boundary of the project, conducting detoxification operations and gathering equipment.

During the salt and resistivity test, the time needed for the chemical to move from any given station to the next downstream station was recorded (Step B. 4(a) under Salt Resistivity Calculations).

Using a copy of county plat maps showing the stream system, mark each station on the map and write the time interval between stations on the map. Then, beginning at the dam site or detoxification point, subtract the successive time intervals as you progress back up the stream system and its tributaries to the uppermost stations.

These calculations give the time that each station should be started.

We have found that in cool water streams, good kills can be achieved by little less than introducing rotenone at the rate of 5 p.p.m. for one hour followed by 1 p.p.m. for an additional 5 hours.

When the complete timing system has been completed, it is possible to assign men, chemical delivery equipment and transportation to the project stations as required.

The person planning for and thus responsible for the project should never assign himself to a specific station or task. On any project, his time is best utilized in cruising the project area, making certain that each station is started on time and running smoothly, handling public relations, directing local cooperators in dead fish pickup, and otherwise supervising the project. On projects involving over 30 miles of stream or running more than 18 hours, a reliable assistant thoroughly familiar with the entire project is essential to a successful program.

DETOXIFICATION

In soft water, a concentration of potassium permanganate equal to the concentration of rotenone will detoxify this piscicide.

In practical experience, we have never attempted a reclamation project on a stream that did not have a flowage, the dam of which could be used as a fish barrier to prevent upstream movement of rough fish from below the project area.

The flowage is drawn down as low as possible and the remaining water treated at the same time the chemical in the stream reaches the flowage. The dam is sealed off (sheet plastic is very useful to reduce seepage) and as fresh water refills the flowage, the toxicant is diluted. Only seepage through the dam is detoxified if it appears that sufficient dilution will occur in the lake prior to the time it overflows. This will depend upon volume of flow entering the lake and the size of the lake itself.

Table 4 will give guidance as to the quantity of KM_nO_4 required to detoxify various quantities of standing or flowing water. By interpolation, addition or multiplication, these tables can be expanded to provide for any eventuality.

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LITERATURE CITED

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1959. The electrical resistivity meter in fishery investigations. U. S. Fish and Wildlife Service, Spec. Sci. Report - Fish No. 287, 13 pp.

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1966. Stream reclamation procedures. Fish Management Division, Management Report No. 5, 10 pp.

TABLE 1

Temperature Factors, ft, For Use In Correcting Resistance To The Standard Temperature Of 77° F. Using the Equation $R77 = R_t / ft$*

°F.	ft	°F.	ft
38	1.711	62	1.205
39	1.683	63	1.190
40	1.657	64	1.174
41	1.631	65	1.160
42	1.606	66	1.145
43	1.580	67	1.131
44	1.555	68	1.118
45	1.532	69	1.104
46	1.509	70	1.090
47	1.486	71	1.075
48	1.464	72	1.062
49	1.443	73	1.048
50	1.421	74	1.034
51	1.400	75	1.023
52	1.380	76	1.012
53	1.361	77	1.000
54	1.342	78	0.989
55	1.323	79	0.977
56	1.305	80	0.966
57	1.288	81	0.956
58	1.271	82	0.945
59	1.254	83	0.935
60	1.237	84	0.925
61	1.221	85	0.916

* R_{77} = Specific Resistance at 77° F. R_t = Specific Resistance at known temperature; f_t = correction factor.

** Revised and Adapted from L. R. Richards, "The Diagnosis and Improvement of Saline and Alkali Solids." U. S. Department of Agriculture Regional Salinity Laboratory, 1947.

Table 2. Tabular presentation of calculations of quantities of chemical required.

Station Number	A Metered Flow in c.f.s.	B Acre Feet Per Hour $\frac{\text{c.f.s.} \times 3600}{43{,}560}$	C Gal. of Rotenone Required at This Station to Treat It at 5 p.p.m. $5(X = \frac{B}{3})$	D Dilution Loss Conc. Per Cent	E Remains Per Cent	F P.p.m. Rotenone Required at This Station to Give 5 p.p.m. at the Next Station $X = \frac{5}{E}$	G Gal. of Rotenone Required to Treat This Station at "F" p.p.m. $X = \frac{CF}{5}$	H Gal. of Rotenone That Must Be Added At This Station
1	10	.83	1.38	60	40	12.5	3.45	G 3.45
2	12	.99	1.65	50	50	10.0	3.30	G-C 1.65
3	15	1.24	2.07	60	40	12.5	5.18	G-C 3.11
4	19	1.57	2.62	20	80	6.25	3.28	G-C .66
5	20	1.65	2.75	40	60	8.33	4.58	G-C 1.83

Table 3. Tables for stream reclamation.

(Accurate within 10 per cent)

A. Quantities of rotenone required to provide desired concentrations in various stream flows.

Flow in c.f.s.	Acre Feet Per Hour	Acre Feet Per 24 Hours	Gallons of Rotenone (5%)/ Hour Required to Treat This Flow at One p.p.m.	5 p.p.m.
.5	.0412	.99	.014	.07
1.0	.0825	1.98	.028	.14
2.0	.1650	3.96	.056	.28
3.0	.2475	5.94	.084	.42
4.0	.3300	7.92	.112	.56
5.0	.4125	9.90	.140	.70
10.0	.8250	19.80	.280	1.38
15.0	1.2375	29.70	.320	2.08
20.0	1.6500	39.60	.560	2.75

B. Fractions of gallons expressed as quarts and ounces (liquid measure) rounded to the nearest whole ounces.

Fraction of One Gallon	Quarts and Liquid Ounces		
.014	0	-	2
.028	0	-	4
.056	0	-	7
.070	0	-	9
.084	0	-	11
.100	0	-	13
.14	0	-	18
.28	1	-	4
.32	1	-	9
.42	1	-	22
.56	2	-	8
.70	2	-	26

C. Quantities of antimycin required to give desired concentrations in various stream flows.

Flow in c.f.s.	Ml. or grams/hour of pure Antimycin to treat at 1 ppb.	Commercial Fintrol 1% Antimycin by weight Grams required	Liquid Antimycin 10% Antimycin in Acetone Ml. required
.5	.05	5	.5
1.0	.1	10	1.0
2.0	.2	20	2.0
3.0	.3	30	3.0
4.0	.4	40	4.0
5.0	.5	50	5.0
10.0	1.0	100	10.0
15.0	1.5	150	15.0
20.0	2.0	200	20.0

D. Quantities of antimycin required to give desired concentrations in off stream ponds or backwaters.

Acre feet standing water	Grams pure Antimycin required to treat at 1 ppb.	Commercial Fintrol 1% Antimycin by weight Grams required to yield 1 ppb.
.5	.6	60
1.0	1.2	120
2.0	2.4	240
3.0	3.6	360
4.0	4.8	480
5.0	6.0	600
10.0	12.0	1200

E. Quantities of rotenone required to give desired concentrations in off stream ponds or backwaters.

Acre feet of standing water	Gallons of Rotenone (5%) to treat at				
	1 ppm.	2 ppm.	3 ppm.	4 ppm.	5 ppm.
.5	.17	.33	.50	.68	.85
1.0	.33	.66	1.00	1.33	1.66
2.0	.66	1.33	2.00	2.64	3.30
3.0	1.00	2.00	3.00	4.00	5.00
4.0	1.33	2.66	4.00	5.32	6.60
5.0	1.66	3.30	5.00	6.60	8.30
10.0	3.30	6.60	10.00	13.20	16.50

.656 gal./AF = 2 ppm.

Table 4. Quantities of MM_nO_4 required to detoxify equal concentrations of rotenone at various stream flows and in off stream ponds or backwaters.

Acre Feet Standing Water	Pounds $KMNO_4$ Required to Treat at				
	1 p.p.m.	2 p.p.m.	3 p.p.m.	4 p.p.m.	5 p.p.m.
.5	1.37	2.73	4.11	5.47	6.84
1.0	2.73	5.46	8.19	10.92	13.65
2.0	5.46	10.92	16.38	21.84	27.30
3.0	8.19	16.38	24.57	32.76	40.95
4.0	10.92	21.84	32.76	43.68	54.60
5.0	13.65	27.30	40.95	54.60	68.25
10.0	27.30	54.60	81.90	109.20	136.50

KM_nO_4/Hour required to treat this flow at 1 p.p.m.

Flow of Stream in c.f.s.	Pounds	Grams
.5	.109	49.5
1.0	.218	99.
2.0	.436	198.
3.0	.654	297
4.0	.872	396
5.0	1.090	495
10.0	2.180	990
15.0	3.270	1485
20.0	4.360	1980

Table 5. Table of Equivalents

1 acre foot = 325,850 gallons; 43,560 cu. ft., 2,718,144 pounds water; 3,785 m.l./gal.

1 c.f.s. = 7.48 gallons/second or 448.8 gal./minute

1 gallon = 8.34 pounds or 3,800 grams

1 p.p.m. = 8.34 pounds/million gallons water

1 p.p.m. = 2.73 pounds/acre foot water

1 p.p.m. = 1241.5 grams/acre foot water or .0284 grams/cubic foot or .0038 grams/gallon or .0000623 pound/cubic foot

1 p.p.m. = .33 gallons/acre foot water

1 pound = 453.6 grams

1 ounce = 28.4 grams

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