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Stephen P. Mosley, Director

LAKE RENOVATION

PROCEDURES MANUAL

By

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TABLE OF CONTENTS

LIST OF APPENDICES

I. INTRODUCTION

The Idaho Department of Fish and Game uses chemical renovation of waters as a fishery management tool to reduce or eliminate undesirable fish species. Eliminating nongame fish or undesirable fish, such as stunted yellow perch, frees up food and space for desirable sport fish. The nutrients recycled into the lake from the decomposition of these unwanted fish also stimulates an increase in available food. The result is improved survival of restocked fish, extraordinary growth, and better fishing within one to two years following treatment. The benefits may last 5 to 10 years or more. It is often impossible to achieve a total elimination of undesirable species, and illegal reintroductions occasionally take place. Consequently, repeat renovations may be appropriate for some waters. However, we have successfully eliminated undesirable fish from some high mountain lakes, and Utah chubs were removed from Magic Reservoir in 1960 and have not re-established. Even though lakes and streams which are renovated may revert back to pre-renovation conditions in a period of time, chemical renovation is still a very useful, cost-effective, and successful management tool for small to moderate size lakes and reservoirs. Fishing use may increase as much as 100-fold or more on waters following renovation.

The toxicant of choice is rotenone, which kills fish and some aquatic invertebrates at application concentrations which are not harmful to man or other animals. However, rotenone powder or liquid formulations can create discomfort or health problems during shipping, handling and application. Safety precautions will be discussed in this manual. Rotenone is a naturally occurring nonsystemic, selective piscicide. It kills fish by blocking oxygen transfer at the cellular level, thus suffocating them. Appendix A, providing information from Lennon et al. (1971) and a California Environmental Impact Report (California Department of Fish and Game 1985), should provide fish managers with enough information to answer most questions from the public about its recent history, toxicity, safety, and formulation. A U.S. Fish and Wildlife Service pamphlet, "Better Fishing Through Management' by Sousa et al. (no date), is available (in a Question-Answer format) to help with the most common questions from the public.

The Department has treated hundreds of waters since 1948. This Procedures Manual has been developed to facilitate the planning and execution of renovation projects and to eliminate or at least reduce considerably the potential for accidental fish losses downstream of the planned treatment area. It provides a synopsis of applicable rotenone information, and presents procedures to be implemented by Department personnel on any lake renovation.

An historical review of Idaho renovation projects (dates, places, target species, species restocked, toxicants) is included in:Appendix G. The State Fishery Manager must apply to the Regional Federal Aid Coordinator for any projects on reservoirs and lakes greater than 100 surface acres that have not been treated before. This table will provide ready access for that information. An Environmental Assessment (EA) will be needed for previously untreated waters that exceed 100 acres.

This manual will eventually incorporate procedures for use of other toxicants and stream treatment procedures. The Department has used only rotenone for many years, and no complex stream systems have been treated since Salmon Falls Creek in 1960.

II. RENOVATION PROCEDURES

A. Determination of the Need to Renovate

In a survey of opinions and preferences of Idaho Anglers (Reid 1989), two-thirds of all respondents listed trout as the most preferred game fish. Because of introductions of other fishes and competition with or predation by some nongame fishes, special management of certain trout waters is often needed to restore the trout fishery to a satisfactory level. Similarly, introduction of nongame fish or reduction of predator species and overpopulation and stunting of prey species may throw a warmwater fishery out of "balance." If management objectives for a body of water listed in the Five-Year Fisheries Management Plan are not being met, then the fishery manager should assess the situation and give consideration to alternative management schemes to attain the desired goal. Use of rotenone is one of those alternatives.

A biological survey to assess the fish population composition is needed before proposing a renovation to the public and a determination to renovate can be made. At a minimum, gill nets, trap nets, and electrofishing should be used to sample a variety of species and respective age groups and to determine the presence of the most resistant species. Mountain lakes and other coldwater salmonid-only waters may be sampled by gilinetting alone. Spot creel survey information will be obtained as a relative measure of angler success and use, and of course written or oral comments from the angling public provide information about general satisfaction with a fishery.

Once the need to renovate has been determined, the rest of the process can proceed. The checklist and time line in Appendix J. is provided so the fishery manager can track the renovation project progress. The manual details the steps, but the checklist should be used to ensure a vital step is not omitted.

B. Determination of Public Involvement

Waters being considered for treatment will be posted with appropriate signage giving notice of public meeting(s) time and location. Newspaper articles, paid news releases, radio announcements, informational meetings with outdoor and environmental groups, and regional wildlife councils will precede the formal public meeting. At the public meeting and through the other media, results of the fish population assessments, anticipated benefits, extent of kill above and below the reservoir or lake, future management options, and information about rotenone and related activities will be presented.

Public and private landowners in the vicinity of the waters to be treated and downstream through the likely exposure zone will be contacted about the renovation proposal. Any potable water supply users identified in the planning process will also be notified.

The regional fishery manager will submit to the Fisheries Bureau a synopsis of public and landowner input with a recommendation for or against the treatment.

C. Administrative Functions

1. Interdepartmental

Based on samples of the lake's fish populations, creel survey, and other public input, the regional supervisor will notify the Fisheries Bureau in writing by April 1 of the lake(s) being contemplated for treatment, the time of treatment, and the approximate quantities of rotenone and potassium permanganate which will be needed. This lead time is needed for ordering necessary chemicals and prioritizing projects statewide if budgets are limiting. There is adequate flexibility to do smaller projects with materials and equipment on hand if a need is determined after the cut-off date.

Sometime after the Fisheries Bureau has been notified of intent to renovate, an internal (one-page) environmental assessment should be done which lists pertinent information about the project (ie., size at full pool, fish species present, potential treatment date, risks/ benefits of treatment, prior treatment information, management plans). This formalizes the process and will provide some information for requesting approval from the Federal Aid Coordinator, endangered species clearance, Division of Environmental Quality (DEQ) permit application, and public meetings.

The Bureau will notify the Commission at the May meeting of intent to renovate. This will be included in the Director's written report.

2. Division of Environmental Quality

An application for "short term activity exemption" will be prepared (see Appendix B for form) and submitted through the Fisheries Bureau to DEQ, Department of Health and Welfare. The application shall include the name of the responsible contact person and information regarding the project, including the name, size, and location of the water body, bioassay studies, limnologic and hydrologic information, dosing/neutralization rates, and extent and nature of anticipated fish loss in the outlet. All fish eradication projects shall be conducted in accordance with this Procedures Manual.

3. U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (Service), Boise field office, will be notified by the State Fishery Manager of intent to renovate, and will be requested to provide a list of any threatened or endangered species that might be adversely affected by the project. The State Fishery Manager will submit documentation of endangered species consultation and a request for approval from the Federal Aid Coordinator to expend federal aid funds for renovating lakes larger than 100 acres which have never been previously renovated.

4. Public Land Administrators and Reservoir Ownership

If the lake or reservoir to be treated is on land administered by the U.S. Forest Service, Bureau of Land Management, or Idaho Department of Lands, the regional fishery manager will pursue necessary permits or written permission to do the project. This request should be initiated one year in advance because some district rangers require a one year lead-in for an EA before a special use permit can be issued. A project will not be undertaken on a reservoir without written approval from the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, or private owners of a dam or the water in the reservoir.

D. Pre-treatment Survey

1. Determine Time of the Treatment

In most instances, the Department desires to treat waters that are isothermic, but yet as warm as possible. Rotenone kills faster and detoxifies faster in warmer water. Marking and Bills (1976) found the toxicity decreased more rapidly at 17 C than at 12 C (the half-lives were 13 and 22 days, respectively). In other studies, Dawson and Gilderhus (1986), and Gilderhus et al. (1986) documented rotenone half-lives of 10.3 days in cold water (0-6 C) and 0.94 days in warm water (23-31 C). In irrigation reservoirs, late summer or fall is often the best time because they are usually isothermic, water volumes are lowest, and outlets have no or reduced flow. It also allows anglers the summer to remove desirable fish before the treatment.

2. Prepare Detailed Operational Plan

a. Personnel Needs

This Procedures Manual is designed for the more complex projects. Small closed systems may be treated by two persons in just a few hours. A large project, or one in a sensitive area, may take months of planning and preparation. The regional supervisor will obtain assistance from other regional personnel and from other regions if needed. Personnel needs and assignment of responsibilities will be determined early in the process.

The regional supervisor will assign one person to be the renovation supervisor for each project. He or she may delegate responsibilities, depending on the magnitude of the project. Crew leaders may be assigned to oversee and supervise specific tasks. For instance: pre-treatment, public relations, logistics, rotenone application to primary water body, rotenone application to tributaries, rotenone application to special attention areas (shoreline, aquatic vegetation zones, freshwater seeps, etc.), detoxification, post-treatment activities. It should be understood by all that the renovation supervisor is in charge.

b. Equipment Needs

An equipment list will be developed. It will include items that need to be purchased, rented, or borrowed. Many items will come from other regions when the biologists arrive for the treatment. Equipment must be in good working order. Make sure that borrowed equipment is operational before it arrives. Arrangements should be made to have spare parts arrive with pumps and sprayers. The list will be project specific, but may include: boats, motors, rotenone, potassium permanganate, live cars, pumps, deep water hose and nozzle, venturis, backpack sprayers, chemical dispensers, generators, protective clothing, goggles or safety glasses, masks, and footwear, first-aid needs, communication equipment, maps, thermistor, water chemistry kit, ropes, buoys, flagging, Kemmerer bottle, hose and nozzle for shoreline spraying, and back-up items for each of the mechanical devices. Remember equipment should be cleaned after each.

Some of these items will be available from the Fisheries Bureau to avoid unnecessary costs for each region. They include: live cars, the larger potassium permanganate dispenser, some venturis and backpack sprayers, gas-powered pump, and the deep water hose and nozzle.

Rotenone is an excellent solvent of things made of rubber (latex in particular), so use roller bearing pumps with teflon gaskets when pumping rotenone mixtures. Inform aerial application contractors that some rotenone formulations may dissolve the plastic in bubbles of aircraft. Some pilots have been known to become disagreeable when streaks are etched into their aircraft windows.

c. Water Volume

Use of available bathymetric maps is advised. However, it is imperative to verify maps for accuracy. If no map is available, soundings must be taken and the map adequately detailed (including contours) so lake volume can be calculated and percentages of lake volume by sectors can be determined (see Appendix C for procedures). Calculations should be double checked by another person. Volume/water level relationships provided by irrigation reservoir managers may be used. A staff gage should be conveniently placed to check lake level. A range of volumes and related rotenone application rates should be precalculated, referencing the staff gage readings, for quick reference on the day of treatment. The day before treatment begins, the water will be marked with shoreline markers and buoys to define sectors.

d. Lake and Stream Surveys

The outlet and all inlets need to be located and mapped. Also, seeps, springs, and aquatic vegetation zones need to be located and mapped. The reaches of tributaries and the outlet to be treated will be identified, as well as passage barriers, diversions, and gradient on these streams. Sampling should be done to determine upstream range of target species. Rotenone drip station sites must be selected and stream discharge determined. A temporary staff gage should be placed to assure discharge is known when treatment begins. Refer to tables in Appendix H for treatment rate.

The outlet stream will be surveyed for beneficial species and need for detoxification. Discharges will be determined and dilution factors from other streams will be required for detoxification assessments. All managers have flow meters on their inventories and should use those to determine discharges.

e. Determine Water Characteristics and Temperature Profiles

Toxicity of rotenone varies greatly with the fish species. Toxicity is not greatly influenced by temperatures from 7 to 22 C, by water hardness of 10 to 300 mg/l of $CaCO_3$ or by pHs from 6.5 to 9.5 in laboratory tests (Marking and Bills 1976). With pHs of 7 or 8, the 2.5% synergized formulation can be used at the same concentration as 5% rotenone. However, a temperature profile is needed to determine whether or not a themocline exists, and if so, its depth for application of toxicant below it, or if only the epilimnion is to be treated. Water hardness and pH information is needed to determine if the lake is outside the bounds listed above. In general terms, rotenone works more rapidly at higher temperatures (Almquist 1959, Ball 1948, Hooper 1955), more acidic waters (Leonard 1939, Foye 1964) and in softer water (Foye 1964).

3. Final Bioassay and Survey (within 72 hours of treatment)

Immediately before the treatment begins, the regional fishery manager must check the staff gage to verify that the lake or reservoir volume has not changed. The temperature profile will be repeated. Bioassays on target fish will be performed on site to determine rotenone concentrations needed for treatment (see Appendix D for procedures). If a detoxicant is used, application rate will be determined at this time. Do not rely on flow measurements taken a week or a month earlier. A temporary staff gage in the stream is recommended. A sufficient number of fish of all species present may be collected, marked, and released to be able to estimate total biomass based on marked fish in post-renovation counts. If few fish are present, an appropriate number of marked hatchery fish may be stocked.

There will be some small projects with closed outlets where bioassays are not required. In these cases the difference in quantity (cost) of rotenone used will be insignificant, compared to the cost of the bioassay.

E. Renovation

1. Operational Meeting - Renovation Briefing

A meeting of all personnel who will be participating will be held prior to the treatment. The meeting will be conducted by the renovation supervisor. On large or complex projects, each crew leader may conduct a meeting with their workers. All workers will receive instructions on their assigned duties. This meeting will establish a command center with which everyone is familiar. Location should be convenient and practical, and communications should be continuous until the project is complete or a stable point has been reached. Information will be provided on first aid. In particular, the dangers of materials being handled and procedures for first aid will be discussed during this meeting.

2. Safety Considerations

Although there is little chance of any serious injury resulting from exposure to rotenone when proper handling procedures and labeling instructions are followed, some irritations have been noted by those mixing chemicals and those operating the application mechanisms. In Washington, fisheries biologists handling rotenone powder have noted one or more of the following symptoms: "numbing sensations of the mouth and lips; a mild sore throat; mild headache; eye irritation and a runny nose" (Bradbury 1986). For these reasons, personnel working with the chemicals, either mixing them or operating application mechanisms, will utilize face masks, goggles, and protective clothing, such as rain suits and rubber gloves. Necessary precautions should be taken to avoid chemical spills during off-loading and on-loading operations.

For larger projects involving numerous personnel and added risk of accidental injuries, the renovation supervisor may want to contact local Emergency Medical Technicians ahead of time. Contacts should be made well in advance of the project, and information about rotenone and $KMnO_4$ should be provided so they can prepare for such emergencies. The local conservation officer should be able to direct the renovation supervisor to the appropriate personnel.

Safety precautions for rotenone and $KMnO_4$ handling are provided on the labels by the supplier. Proper safety equipment will be utilized whenever chemicals are handled. Large or heavy containers should be moved with appropriate means of mechanical assistance to avoid physical injury and to reduce the potential for exposure and spills. Whenever opening containers, dispensing or mixing liquid, or applying a water-rotenone mixture, protective goggles or safety glasses, masks, footwear and raingear will be worn. After handling, thorough clean up with soap and water is recommended. Contaminated clothing should be washed before reuse. Personal safety equipment used in rotenone applications should be kept clean and stored separate from rotenone stocks to avoid contamination.

Rotenone should be stored on wooden pallets and, if outside, covered. It should be stored only in original containers with visible and secure labels. Stock should be rotated. The first products opened should be used first. Open containers should be used before unopened containers. Regular inspections for leaks, corrosion, loose caps, or bulges should be made. Corrective action will be taken if irregularities are found.

The question will be asked by the public, "Is it safe to eat fish killed with rotenone?" Calculations that address a worst case situation indicate that a 132 pound person would have to consume 535 pounds of raw fish containing 100 ppb rotenone to acquire a toxic dose. Cooking destroys rotenone, so there would be a further loss of any residues during cooking. However, because no tolerance (acceptable residue level permitted in fish flesh) has been set by EPA, the consumption of rotenone-killed fish cannot be recommended (Sousa et at. no date). The Department policy is to discourage salvage of rotenone-killed fish.

3. Application of Rotenone

a. Lake With Outlet

The lake will be sectioned off with shoreline markers and buoys. No sector will constitute more than 10% of the total lake volume. Read the label instructions found on containers for application information.

During the operational meeting, each sector of the lake will be assigned to a Department employee. Depending on the size of the lake, several sectors may be assigned to one person. Each employee should become familiar with his/her sector and its markings in a test run prior to the application. Different colored/shaped flags and buoys should be used for specific grids. Rotenone may be applied to the propeller wash of the outboard motor by use of a venturi pump mixing lake water and the rotenone emulsion. This should be done in a grid pattern to maximize distribution and effect of the rotenone. Application rates by this method are 1.0 to 1.5 gallons per minute at boat speeds of approximately 4 to 5 miles per hour. Shoreline and marshy areas may be sprayed from a boat, or from shore with backpack sprayers. Aerial applications may be made where appropriate. Because of difficulty in uniform application in shoreline, weedy, or marshy areas, the rotenone emulsion should be diluted for better dispersal. However, the application rate will remain the same.

It is advised to treat lakes when they are isothermic. However, if treatment takes place under stratified conditions, volume of the hypolimnion shall be calculated separately, and rotenone pumped below the thermocline using a weighted hose.

b. Lake Without Outlet or Outlet Closed

The lake will be sectioned off with shoreline markers and buoys. No sector will constitute more than 20% of the total lake volume. Rotenone will be applied as described for lakes with outlets.

c. Tributaries to the Lake

Prior surveys of the lake, outlets and inlets, will have allowed determination of fish species, passage barriers, and appropriate drip station locations for tributaries. Equipment will be placed on site shortly before treatment (security and logistics will dictate when). Drip stations should be calibrated on site to assure accurate delivery of rotenone concentration desired. Backpack sprayers will be used where appropriate. The Progressive Fish Culturist (July 1957, page 107) describes a constant siphon for barrels, which has been used on many projects.

III. DETOXIFICATION PROCEDURES

A. General Considerations

Potassium permanganate ($KMnO_4$) will effectively detoxify rotenone. Other oxidizing agents have been used (chlorine, sodium thiosulfate) but $KMnO_4$ has been most widely used and accepted, and does not kill fish at proper concentration.

A detoxification process is required as a part of all projects where the chemically-treated water cannot be stored in a non-discharging lake or reservoir until the rotenone oxidizes to a condition harmless to fish and other aquatic life. Detoxification is also required if the receiving stream contains significant populations of desirable species. It should be assumed that all reservoir outlet structures leak unless there is good documentation otherwise.

Detoxification with $KMnO_4$ is not immediate, so there will always be a detoxification zone below the application point. The length of this zone at given rotenone and $KMnO_4$ concentrations can be predicted accurately. In Colorado (Colorado DNR 1989) and Utah (Leo Lentsch, Personal Communication) 20 minutes is used as the standard contact time for $KMnO_4$ to neutralize rotenone. Therefore, potential fish mortalities are anticipated in a detoxification zone the distance of 20 minute stream flow time downstream from the detoxification station. An efficient method for determination of travel time is to use fluorescent dye tracers, which are visible in clear water at 1 ppm. The dye is available in solid or liquid form, from the Fisheries Bureau, and is biodegradable and nontoxic.

Because a reasonably fast reaction requires a large excess of permanganate ions over rotenone molecules, residual $KMnO_4$ will usually be present at the downstream end of the detoxification zone. The amount of $KMnO_4$ "used up" in the reaction with rotenone is essentially negligible, but $KMnO_4$ reacts with most other organic substances. Dissolved or suspended organic matter exerts a "permanganate demand" which must be considered in setting the $KMnO_4$ application rate. A fairly high demand will make treatment easier, since there need be less concern about high residual concentrations downstream, though a higher initial concentration will be needed.

At minimum, the detoxification process is to consist of two dispensers with $KMnO_4$, two live cages, and three fish for each cage. If we need to detoxify, then a two-phase process is required. The detoxification process will be initiated one-half hour before time of flow studies indicate the rotenone will reach the detoxification station. At least one person will be assigned to each detoxification station at all times throughout the project duration. These people will always have communication with the command center. The person at the first station will be an experienced Idaho Department of Fish and Game permanent employee.

A live cage with fish will be placed downstream of the detoxification zone or below the outlet of a non-discharging lake or reservoir (assuming water is present), to verify that no toxicant is released downstream. The most sensitive species present in the water being treated, or hatchery trout, will be placed in the live cage. The cage will be kept in place and monitored for the duration of the treatment and/or detoxification process. Another detoxification unit will be employed downstream from the primary detoxification zone and live cage. It will be operated simultaneously starting about 20 minutes after the primary station is initiated. The application rate for the second unit will depend on the sensitivity of non-target species below the renovation zone. The likelihood is that this unit will be operated at an application rate much lower than the primary station. In very sensitive areas, a third unit should be placed downstream and put into operation if an emergency happens. A live cage will be maintained above this unit also.

Potassium permanganate can be toxic to fish. Toxicity of $KMnO_4$ increases with increased water hardness and alkalinity. Engstrom-Heg (1972) presented tables and graphs showing contact time and amount of $KMnO_4$ required to detoxify varying amounts of Noxfish. He said trout will tolerate long-term exposure to $KMnO_4$ at about 3 ppm in soft water and 1.5 ppm in hard water. Brief exposures (up to a few hours) to concentrations up to 10 ppm are usually not lethal. However, his recommended levels of $KMnO_4$ are in conflict with the $KMnO_4$ toxicity levels found by Davies (1983). Davies, in testing the toxicity of $KMnO_4$ to trout in soft, medium hard, and hard waters found that levels of $KMnO_4$ above 2.0, 1.0, and 0.7 ppm, respectively, were toxic to trout. One ppm (1.0 ppm) $KMnO_4$ will neutralize 1 ppm of 2.5% synergized or 5% rotenone (Colorado DNR 1989). These conflicting findings are presented to warn the project manager to use caution and determine specific concentrations if circumstances so dictate.

In general, $KMnO_4$ should be applied at a rate that will detoxify the rotenone before it reaches the first habitat for fish of concern, and that will not result in a toxic residual concentration. In many situations this can be accomplished with a "standard" application of 2.0 ppm plus half the permanganate demand. This is in conformity with the approved EPA use pattern of 2.0 ppm with incremental additions to compensate for demand. For hard water situations, the application rate should not exceed 1.5 ppm plus the full permanganate demand measured over the travel time to the foot of the detoxification zone. The standard 2.0 ppm application results in a 16-28 minute detoxification, depending on the rotenone concentration and the species of fish to be protected (Engstrom-Heg 1990 draft, per telephone conversation with Engstrom-Heg on March 6, 1997, this is still a draft).

If a shorter detoxification zone is required, or if tributary dilution is involved, or we have sterile Idaho water, an application rate other than the standard one may be appropriate. In any case, the application rate should not be less than 1.0 ppm (to provide a margin of safety) and should not be high enough to result in a final residual concentration greater than 2.0 ppm in soft water (to meet EPA standards) or 1.5 ppm in hard water.

Detoxification is most effective against rotenone concentrations up to about 1 ppm of 5% formulation. This, however, refers to the lake-wide average concentration, once the chemical has dispersed. It should be obvious that higher temporary local concentrations will occur during a treatment. "Hot spots" are particularly common in situations where weedy shoreline areas are sprayed with hand pumps. Any milkiness is an indication that colloidal rotenone is present and that the local concentration is greater than 3.2 ppm of formulation. Detoxification at these high concentrations is much more difficult, and in some cases may be a practical impossibility (Engstrom-Heg 1990 draft).

The area immediately adjacent to the lake outlet should be buoyed off to prevent intensive shoreline spraying. If this area is weedy or otherwise in need of treatment at a rate above the pond-wide average, rotenone should be applied volumetrically at a rate no greater than 1.0 ppm of formulation. If a 2.5% synergized rotenone formulation is used, it should be applied at the same rate as would be used for a 5% standard formulation (Engstrom-Heg 1990 draft).

Technical grade $KMnO_4$ can be purchased in 110 lb (50 kg) containers in fine-crystalline or free-flowing form. Several devices have been tested for applying $KMnO_4$ to streams at a constant rate. Probably none work better than the unit stored at the Department's Garden City warehouse. However, smaller more portable automatic units may be desirable for small projects. For most purposes, one found most satisfactory by New York fishery biologists is a modification of a clockwork-driven Zeigler fish feeder (Zeigler Brothers, Inc., P.O. Box 95, Gardners, PA 17324, Telephone number 717-677-6181), which operates well with either of the two available grades of the chemical, and which can apply $KMnO_4$ at a constant rate to anything from a measured seepage to the equivalent of a 3 cfs stream at 3 ppm. Larger flows would require multiple units. Currently available units require resetting at 12-hour or 24-hour intervals (Engstrom-Heg 1990 draft).

B. Determination of Potassium Permanganate Demand (from Pfeifer 1985)

Potassium permanganate is a strong oxidizing agent and, as such, is readily reduced by many naturally occurring compounds. For example, suspended organic matter, either as silt-sized particles or as colloidal humic (tea-colored) materials, can measurably "use up" introduced KMnO4, with it being reduced to tetravalent manganese compounds. Controlled detoxification of piscicides such as rotenone requires an accurate determination of this $KMnO_4$ demand. Since equal concentrations of $KMnO_4$ and chlorine have very nearly the same oxidizing capacity (Jackson 1957), and since there are established methods for measuring chlorine demand of natural water, chlorine demand has often been used to approximate $KMnO_4$ demand.

Chlorine and $KMnO_4$ probably do not react with all reducing agents in the same manner, therefore Engstrom-Heg (1971) measured $KMnO_4$'s demand directly through use of an orthotolidine procedure where the manganous ions produce a yellow color which can be measured using a color comparator. He noted that $KMnO_4$ demands and residual concentrations can be determined in the field with fair precision, using a color comparator calibrated for residual chlorine readings in the 0.1 to 1.0 ppm range. He also gives a blow-by-blow description of field procedures (Appendix E). In general, slow-moving mud-bottomed streams will be more likely candidates for high $KMnO_4$ demands than swift, rock-bottomed ones (Engstrom-Heg 1976).

If the presence of a significant demand is likely and detoxification is critical, determination of the demand would be prudent. However, since the chemical procedures and calculations are cumbersome, another approach would be to increase the level of $KMnO_4$ applied to assure complete detoxification of the rotenone. Such an approach would almost certainly then mandate use of a reducing agent to detoxify the permanganate. Also, in such cases, the long-term economics (cost of your time, chemicals, etc.) should be considered. Under certain circumstances it would be possible for the $KMnO_4$ demand to be as high as 2-3 ppm.

If the outlet to be treated is likely to have a substantial permanganate demand, and if the level of rotenone residual is substantial, and if time and materials are at a premium, it may be prudent to hire a chemist to perform the permanganate demand determination. The manager would then be certain that the rotenone residual will be detoxified, while at the same time being as economical with available resources as possible.

C. Salvage of Desirable Sport Fish

Rotenone's toxic effects are reversible for some warm water species, depending on the quantity absorbed by the fish. No reports from the literature suggest cold water species are able to reverse the toxic effects once they have lost equilibrium. On some projects it may be feasible to salvage desirable fish for reintroduction. Use of fresh (untreated) water, $KMnO_4$, or methylene blue has been shown to counteract some of the intracellular effects of rotenone (Lindahl and Oberg 1961; Fletcher 1976; Hepworth and Mitchum 1966; Bouck and Ball 1965). Michigan Department of Natural Resources (1990 draft) reports dipping fish in $KMnO_4$ for 20 seconds, then placing in fresh water is more effective than fresh water alone. Bouck and Ball (1965) reported that all rock bass which had lost equilibrium in 0.5 ppm rotenone were revived in water with 5.0 ppm methylene blue during a three-hour treatment. All rainbow trout in the same experiment died and all other fish not treated with methylene blue died within 24 hours. Methylene blue and $KMnO_4$ dips left fish more vulnerable to bacterial infection.

III. POST-TREATMENT PROCEDURES

A. Bioassays

Rotenone degrades naturally over time. Schnick (1974) provides a detailed review of rotenone literature which includes this topic. At intervals following treatment, the project biologist may need to perform bioassays to determine the lake's toxicity. Special consideration must be taken on lakes with a detoxification station on the outlet. The toxicity level must be known before the detoxification can be terminated. The pre-treatment bioassays had to be conducted in a controlled environment, in the post treatment phase, hatchery trout need to simply be suspended in live cars at depth intervals to determine how long the lake remains toxic. A Kemmerer bottle may be used to bring water into the boat from a specified depth. Placing fish and water in tubs in the boat can facilitate several assays at one time. Engstrom-Heg (1990 draft) suggests that trout not losing equilibrium in 2.5 hours at 65 F or 5 hours at 47 F will survive. Washington biologists consider the water is non-toxic when trout survive in a live car for one to six days (Bradbury 1986).

B. Biomass Estimate

If fish were marked during the final survey (see Section II.D.3.), then the shoreline will be sampled for marked fish to make an estimate of biomass. It only takes a small amount of additional effort to gather this management information for the files. During this sampling, fish species will be noted for comparison to pre-treatment inventory.

C. Sampling Treated Waters

No sooner than 72 hours after the rotenone treatment, standard sinking and floating experimental gill nets and standard trap nets will be set overnight to assess completeness of the treatment.

D. Clean-up

1. Disposal of Fish

It has been suggested that the decay of dead fish might produce nuisance algal blooms in some lakes (Funk and Moore 1984). Where recreational uses may be impacted, large concentrations of floating dead fish should be removed from the waterway and disposed of properly. But for the most part, the nutrient recycling will be a benefit to systems in Idaho. Our policy is to leave dead fish.

2. Disposal of Barrels and Contaminated Equipment

All empty containers will be triple rinsed in the treated water after the treatment. The Fisheries Bureau will pursue the possibility of recycling containers with the rotenone and $KMnO_4$ suppliers. It is not a viable option now, but may be so in the near future. Local recyclers also refuse to take empty barrels, because of potential hazard from residues. If they are not recycled, barrels should be cut in half and disposed of at municipal landfills. Clothing that cannot be adequately decontaminated, and unusable equipment should also be disposed of properly at municipal landfills. Disposal of containers should be arranged before the treatment begins.

3. Equipment

Equipment should be rinsed and dried (boats and pumps completely drained) on site before final clean-up with soap and clean water at a safe site. Boats should be taken to a car wash and sprayed with a pressure hose. Do not return borrowed or rented equipment without a thorough cleaning first. Common sense should dictate thorough clean-up after a treatment project.

E. Debriefing Meeting

To obtain information for the final report, a debriefing meeting will be held following the treatment, with as many participants as possible in attendance. This can be a very important meeting, so the renovation supervisor should assure maximum attendance. Discussion of what happened, what went right, what went wrong, and suggestions for future projects, should occur while the smell of rotenone is still in the air.

V. FINAL REPORT

Within 60 days of the project completion, a brief report of project activities will be prepared and sent from the regional supervisor to the Chief, Fisheries Bureau. The Bureau will send a copy to DEQ. The purpose of the report will be to record key information and file it for future reference. It should include:

- What was done, with what product, and at what application rate.
- What fish species were killed and an estimate of the biomass (if applicable).
- The conditions at the time of the project, both atmospheric and in the lake.
- What were the results of the renovation.
- An explanation of problems encountered.
- Recommendations for future renovations.
- Other observations noted by the participants.

ACKNOWLEDGMENTS

In an attempt to avoid "reinventing the wheel," I contacted fisheries workers in many states to find out if they had developed procedures manuals for chemical renovation of lakes. The responses were as varied as the states; however, most had some written documentation they gladly shared with me. I borrowed freely from many authors to piece together a manual usable for the Idaho Department of Fish and Game. Much of this manual is unique to Idaho, but on the other hand, historical information, bioassay techniques, and determination of permanganate demand are adequately covered in the literature and are taken nearly verbatim from other authors. In particular, Bradbury, Engstrom-Heg, Lennon et al., Pfeifer, Schnick, and anonymous authors from California, Colorado, and Michigan departments unknowing provided direct input to this manual.

Al Van Vooren and Steve Huffaker reviewed the manuscript and added valuable criticism. Their help and encouragement is appreciated. Sherri Moedl and Margaret Whipple compiled the manuscript.

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Appendix A. General information, recent history, toxicity, and safety related to rotenone [from Lennon et al. (1971) and California Department of Fish and Game (1985)].

The rotenone-bearing roots of many plants of the family Leguminosae have been used for many centuries to stun and kill fish by primitive peoples in different parts of the world (Leonard 1939). In recent times, rotenone resin formulations have been manufactured from various species of *Denis* and *Lonchocarpus* genera, but cube' root *Lonchocarpus nicon is* the only commercial source of rotenone presently available for piscicide production (Farm Chemicals Handbook 1981).

The first recorded use of rotenone in the United States was in 1934 in the State of Michigan (Ball 1948). Two small ponds were treated to remove populations of carp. In that same year, Eschmeyer (1937) treated South Twin Lake, Michigan to remove a population of stunted yellow perch. He poured the toxicant (powdered derris root containing 5% rotenone) on the surface of the water in the wake of an outboard motor. In an attempt to get the toxicant thoroughly mixed into the lake, 100 sticks of 40-percent dynamite were discharged in deep water. This method of toxicant dispersal was unsuccessful, however, as not all perch were killed.

Canadian workers, taking a lead from Eschmeyer, applied rotenone to obtain a disease free water source for a new hatchery (M'Gonigle and Smith 1938). The use of rotenone in several formulations then spread rapidly throughout the United States and Canada (Krumholz 1948; Solman 1950; Smith 1950; Prevost 1960; and Stroud and Martin 1968). Rotenone apparently was introduced in Europe as a fish management tool by Swedish workers in the 1950s. In the late 1950s and early 1960s, use of rotenone spread to Denmark, Finland, and Ireland. A change in the law of the United Kingdom in 1965 makes it legal to use rotenone as a fish toxicant there.

South American countries also have used rotenone for fish control. Fontenele (1963) records the prodigious effort made in Brazil to control piranhas. In the northeastern state of Ceara alone, over 965 km (600 mi) of the Acarau River were treated with 4.5 metric tons of timbo powder. The cost of this program was more than compensated for by increased income from fishing licenses generated by the absence of piranhas. In addition, there was reduced danger of physical injury to fishermen as well as an increased yield of fish.

Most recently (1990), Utah treated Strawberry Reservoir with a massive project that tied up much of the worlds supply of rotenone for 3 years. They used approximately 880,000 lbs of powdered rotenone and 4,000 gallons of liquid rotenone for this renovation (personal communication, Leo Lentsch).

Different uses, different techniques for application, and new formulations evolved. Davis (1940) and Greenbank (1941) demonstrated that warmwater fish could be controlled by treating the epilimnion of trout lakes with little harm to the trout. Wales (1942) controlled carp by poisoning coves in a lake where they were spawning. Surber (1948) found that emulsified rotenone is superior to the powdered form. Beginning in the 1940s, wettable rotenone paste and emulsifiable concentrates were manufactured because these formulations were easier to handle, faster acting, and can be dispensed more readily. By 1949, 34 states and several Canadian provinces were using rotenone routinely in reclamation projects (Solman 1950). The annual global consumption of rotenone as a pesticide and fish toxicant ranged from 10,000 to 20,000 tons (Biotech Research 1981). In recent years, the harvest of cube' root and manufacture of rotenone has been reduced because the value of cocaine as a cash crop in South America has taken some of the work force.

When the use of rotenone in fishery management was initiated, a concentration of about 0.5 mg/l (ppm) was advocated, and under ideal conditions it was adequate. However, failures often occurred under conditions that were less than ideal, with the result that application rates gradually were increased to whatever levels experience dictated. In general, there has been a tendency to calculate the amount needed, and to add a certain excess to provide a margin of safety. Depending upon the amount of water to be treated and other conditions involved, the excess might amount to as much as two or three times the "normal" dose.

Appendix A. Cont.

Instability of product and inconsistency of results were early problems with rotenone. Moorman and Ruhr (1951) pointed out that deterioration in strength of stored rotenone could contribute to failure of reclamations. Almquist (1959) noted that the toxicity of rotenone is decreased by exposure to light, heat, oxygen, alkalinity, and turbidity. Pintler and Johnson (1958) found that the rotenone content of cube' powder ranged from 2 to 5%. Powders used by Washington from 1977 to 1984 have ranged from 6.6% to 8.1% rotenone (Bradbury 1986). Manufactured formulations that have guaranteed content of rotenone, however, became available in the 1950s.

The mode of action of rotenone in fish has been studied by a number of investigators. Hamilton (1941) reported that rotenone is a respiratory poison in fish and acts by vasoconstriction of the gill capillaries. Oberg (1967) found that rotenone is a powerful inhibitor of the respiratory chain in fish with the site of action located in the flavoprotein region of the chain. The specialized structure of gills favors entrance of rotenone into the blood for transport to vital organs for inhibition of respiration. Oberg (1964) also found that Hamilton observed affects on the gills that were secondary changes due to a very advanced stage of poisoning.

Specifically, it blocks the transfer of oxygen at the cellular level by inhibiting the mitochondria) oxidative phosphorylation-electron system. It is alternatively known as Nox-fish, Pro-Noxfish, Chem-fish Regular, Chem-fish Special, Fishtox, Derris, Cube', Derrin, Nicouline, Tubatoxin, and Timbo Powder. Rotenone has the molecular formula of C,H_VO_6 and a molecular weight of 394. It is extremely toxic to fish, moderately toxic to mammals, and slightly toxic to birds.

The effects of rotenone on aquatic invertebrates were reviewed by Taube, Fukano, and Hooper (1954), Almquist (1959), Wollitz (1962), and Binns (1967). Toxicity varies by species. Mallards and pheasants have oral LD50s in excess of 1,000 mg/kg (Tucker and Crabtree 1970), whereas the oral LD50s for certain mammals are 60mg/kg for guinea pigs, 1,500 mg/kg for rabbits, and 3,000 mg/kg for dogs (Cohen et al. 1960). Tilemans and Dormal (1952) reported that the oral LD50 of rotenone for man is 2,850 mg/kg.

Rotenone formulations continued to evolve, and Shannon (1969) tested nine, commercially available formulations for toxicity and detoxification. They included one wettable powder and eight emulsions. Some of the latter formulations contain 5% or more of rotenone; others contain 2.5% of rotenone plus synergists; and some are homogenized for enhanced performance in special situations. These toxicants are effective against fresh-water and marine fishes. The liquid formulations, however, are malodorous because of solvents or carriers, and they obviously repel fish. Great care must be taken, therefore, to deny target fishes any avenue of escape during reclamations.

Inhalation of powder causes headache, sore throat, and other cold symptoms, and sores on mucous membranes; contact causes irritation of eyes and rash on skin. Protective clothing is required when using powdered root. Use of wettable powder or liquid formulations reduces risks to safety and health.

The emulsifiers and solvents used in the rotenone formulations contain a mixture of surfactants (alkylaryl polyether alcohols and organic sulfonate), xylene, methanol, aromatic hydrocarbons (trimethyl and alkyl benzenes and napthalene), and benzoic acid which constitute slight to moderate health hazards to applicators. Ingestion of the emulsifiers in concentrated form can cause blindness and death, and direct liquid contact with eyes will cause moderate irritation and possibly permanent injury. Skin exposure can lead to dermatitis. Inhalation of the emulsifiers can cause irritation to eyes and throat, headache, dizziness, nausea, weakness, necrosis, and visual disturbances. Prolonged or repeated topical exposure to acetone may cause erythema and dryness and inhalation may produce headache, fatigue, and bronchial irritation. Benzoic acid is a mild irritant to skin, eyes, and mucous membranes (Merck 1968). The synergist piperonyl butoxide is irritating to mucous membranes and large doses can cause vomiting and diarrhea. The material is, however, not considered to be highly toxic (Merck 1968).

Safety considerations and risk analysis are discussed earlier in this manual. Despite the previous two paragraphs, the literature suggests that rotenone is relatively free of hazards in normal use if applied properly (manufacturers's suggestions followed) and appropriate clothing is used.

Appendix B.

APPLICATION FOR SHORT-TERM ACTIVITY EXEMPTION

Applicant: Idaho Department of Fish & Game (IDFG) and Payette National Forest (PNF)

Contact Person(s): Don Anderson, 634-8137; John Lund, 634-1333

Body of Water: Grass Mountain Lake #1 and Grass Mountain Lake #2 and outlet stream downstream to Corral Creek (see map)

Tributary To: Hard Creek - Hazard Creek - Little Salmon River

Objective: To chemically eradicate stunted brook trout using rotenone and replace with golden trout or cutthroat trout (see attachments)

Date: September 5, 1990

Evidence of protection or promotion of public interest:

Beginning in 1983 the IDFG heard from the public and PNF that the brook trout in the Grass Mountain lakes (aka Grassy Twins) were stunted and not of interest to anglers. In 1984 the IDFG obtained baseline data on the population and introduced fall chinook salmon to act as a predatory control on the population. We also stocked fall chinook salmon in 1986. By 1988 the fall chinook were absent in the lakes and the brook trout population was unchanged. The fall chinook apparently could not compete with the overpopulation of brook trout and did not grow to predatory size.

The IDFG using a PNF furnished helicopter has recently planted catchable-size brown trout in seven other alpine lakes with stunted brook trout in an attempt to control the brook trout through predation. These attempts are still under evaluation, but preliminary results show some promise for success. We cannot use brown trout in the Salmon River drainage by IDFG policy decision.

In 1989, the IDFG and PNF decided to attempt chemical control in the Grass Mountain lakes. The PNF completed NEPA documentation of the proposed activity including publishing a description of the proposed eradication. They requested public input. The IDFG presented the proposal to the McCall Chapter of Trout Unlimited and solicited input from the general public, anglers at the trail head to the Grass Mountain lakes, and known alpine lakes anglers. Of about 25 personal contacts and telephone comments, 5 have been opposed to the project and 20 in favor.

About 40 alpine lakes in the McCall area are considered to have stunted brook trout populations. Most anglers would prefer larger, more healthy fish. If this method of control proves successful we could improve the fishing in some of these identified lakes. Some brook trout lakes will be managed for over-populations and that specific type of fishing experience.

Prevention of long-term injury of beneficial use:

We plan to stock either golden trout or cutthroat trout into Grass Mountain lakes as soon as the zooplankton population re-establishes. We expect the lake to be toxic 3-5 weeks and zooplankton established 4 weeks later.

We will treat at 0.25 ppm. Our serial bioassays conducted *in situ* at 0.5, 0.4, 0.3, 0.2, and 0.1 ppm of Roussel Biocorp Nu-Syn Noxfish, a 2.5% synergized formulation showed 0.1 ppm caused brook trout to lose equilibrium in 3 hours and 30 minutes. Treating at the higher concentration should guarantee an 0.1 ppm concentration of rotenone in the lake during application.

Natural decomposition of the chemical will be enhanced by the increased exposure to atmospheric oxygen in the extremely steep outflowing stream characterized by cascades and numerous 10-25 foot bridal veil-type falls; and by its course through a high-organic meadow area. However, we fully anticipate killing fish in the stream below the lakes.

The 0.25 ppm concentration leaving Grass Mountain Lake #2 at an estimated 0.5 cfs flow will be diluted by 0.5 cfs from an unnamed tributary, then by 0.5 cfs from Hard Creek, then 2.0 cfs from Hidden Lake Creek, then 0.5 cfs from Frog Lake Creek, then 0.5 cfs from Corral Creek. Therefore the treated outflow will be diluted by 8 times or to a concentration of 0.03 ppm.

A live box containing trout will be maintained near the mouth of Frog Lake Creek. If lethal concentrations of rotenone are detected at this location, then a pre-positioned potassium permanganate drip station at Corral Creek will be activated at 1 ppm to neutralize the rotenone. Additional live boxes will be maintained immediately above the detoxification station and below the mixing zone to determine if lethal concentrations reach the detoxification station and if the $KMnO_4$ protected fish below the mixing zone.

On June 26, 1990, Kellie Whitton, Fisheries Technician and Peggy Conway, USFS Bio Aide conducted lake surveys on the Grass Mountain lakes. To determine lake volumes, depth soundings were taken. Six transects were done per lake with 2-5 depth measurements per transect (an appendix was included with the application that contained maps, volume calculations, and copies of pertinent reports). Peggy Conway used this data to draw bathymetric maps showing depth contour lines and she used topographic maps to ensure maps were drawn to scale. Kellie then calculated surface areas using **a** grid system (i.e., graph paper) where each square had a known area. The number of squares were counted and then multiplied by area/square. The calculated acreage for Grass Mountain Lake #1 was 11.6 acres and for Grass Mountain Lake #2 was 11.5 acres. This contradicted the following values found in historical files for the respective lakes:

-USFS GAWS inventory (1965) 26/24 acres
-USFS map (1947) 24 acres each
-IDFG report (1973) 26/24 acres

To verify the scale on the topographic maps, forest service personnel drove a stretch of road visible on Grass Mountain lakes aerial photos. In addition, USFS also measured the surface area using a planimeter. Values found for Grass Mountain Lake #2 (11.5) was very similar to calculated value, but values found for Grass Mountain Lake #1 were slightly higher (12.5) then calculated area.

To determine the volume, Kellie calculated surface area of each depth contour and used the following equation to determine volume between each contour level (from Orth 1983).

$$V_s = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$

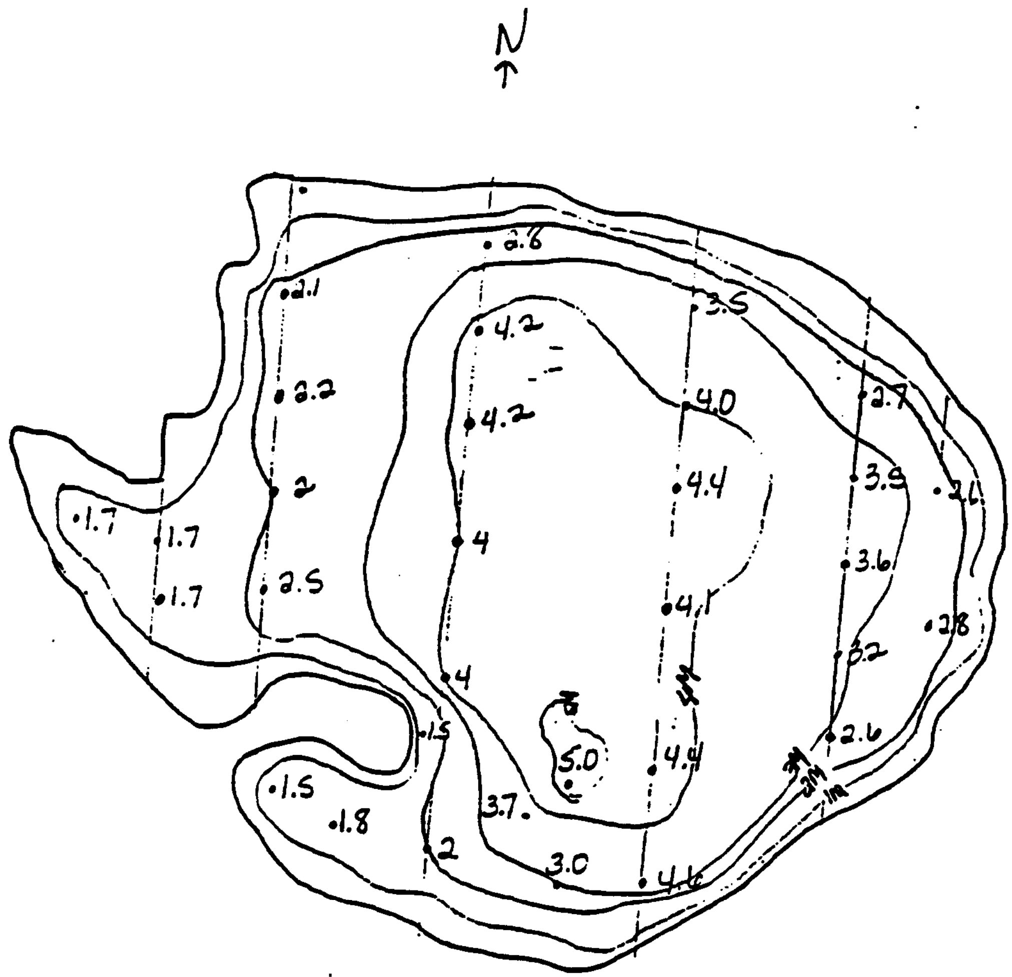
h = height or stratum
A, = area of upper surface
A_2 = area of lower surface

We determined volumes to be:

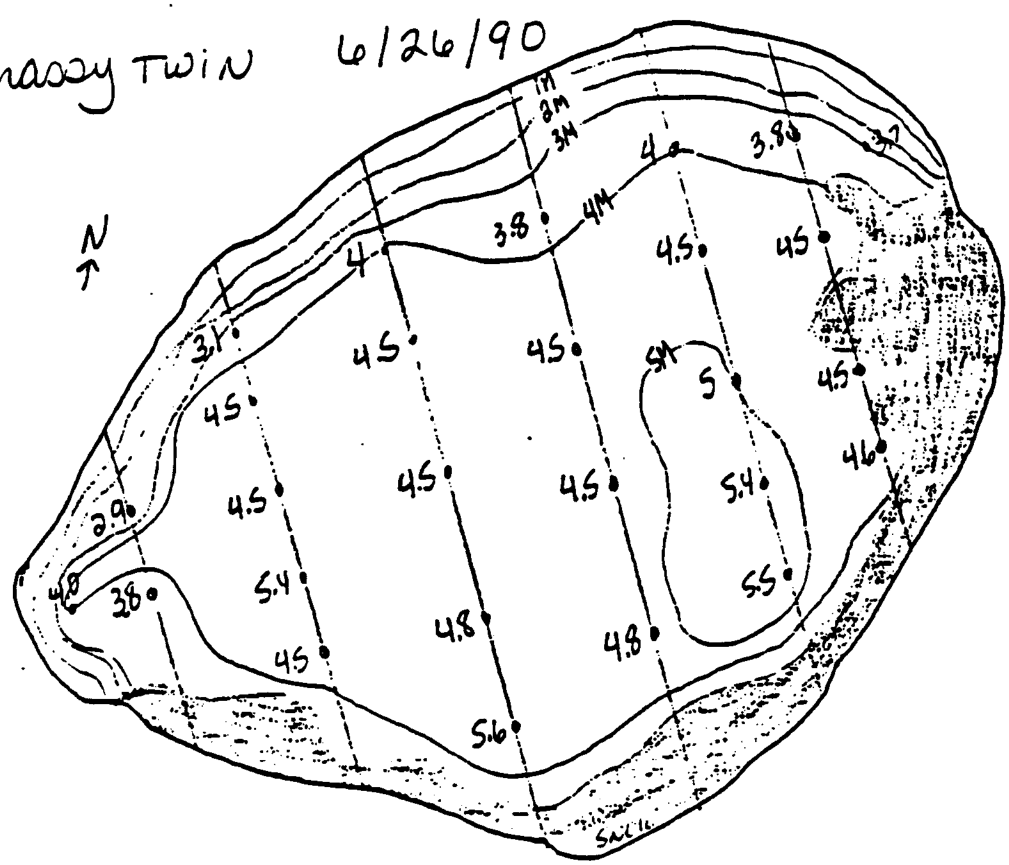
Grass Mountain Lake #1: 137.94 acre-feet
Grass Mountain Lake #2: 99.9 acre-feet

Rotenone necessary at 0.25 ppm = 1 gal/12 acre-feet
Grass Mountain Lake #1: 138 AF = 11.5 gallons
Grass Mountain Lake #2: 100 AF = 8.33 gallons

LOWER grassy TWIN 6/26/90



upper grassy TWIN 6/26/90



Appendix C. Procedures for mapping lake or reservoir, and determining volume.

Useful information and equations.

Volume - Usually figured in acre-feet

One acre-foot = 43,560 cubic feet
= 326,000 gallons
One cubic foot = 7.48 gallons

Volume Total = $\frac{\text{surface area x maximum depth}}{3}$ (rough estimate)

Volume Total = surface area x average depth (rough estimate)

Volume each contour $= \frac{h}{3} (A_1 + A_2 + \sqrt{A_1 A_2})$

h	=	height of stratum
A,	=	area of upper surface (in acres)
A_2	=	area of lower surface (in acres)

1. Check file for maps completed by previous fishery workers.

2. Obtain USGS topographic maps, USFS/BLM maps, and aerial photographs.

3. Develop a bathymetric map of the lake showing depth contours. This is done by dividing the lake into transects and doing depth soundings or depth profiles. The number of transects is determined in part by the size and shape of the lake and the regularity of the lake bottom. Transects should be done in more than one direction, and a sufficient number of soundings will be done to develop accurate contours. It is the regional fishery manager's responsibility to develop an accurate map. Accuracy is critical if the lake has an outlet and non-target species are present.

4. Surface area can be calculated using a planimeter, but should be verified by calculating from measurements taken during the survey. One method is to plot them to scale on graph paper, count the number of squares within the shore line; then multiply the number of squares by the area determined per square.
5. Volume for each contour is calculated, using the formulae given above, total volume is additive.

Example: Grass Mountain Lake #1 (from Don Anderson)

Surface area = 12.5 acres, maximum depth 5.5 meters

Appendix C: Cont.

Contours:

5m	= 57,967.0 ft^2	= 1.33 acres
4m	= 302,256.5 ft^2	= 6.90 acres
3m	= 364,364.0 ft^2	= 8.36 acres
2m	= 414,050.0 ft^2	= 9.50 acres
1 m	= 469,946.75 ft^2	=10.79 acres
0m	= 505,141.0 ft^2	=11.60 acres

V_1 (of 5.5 to 5m) $= \frac{3.23 \text{ ft}}{3} (1.33 + 0 + \sqrt{(1.33)(0)})$

= 1.093 (1.33 + 0)

= 1.45 acre-ft

V_2 (of 5 to 4m) $= \frac{1.093 \text{ ft}}{3} (6.9 + 1.33 + \sqrt{(6.9)(1.33)})$

= 1.093 (8.23 + 3.03

= 12.31 acre-ft

V_3 (of 4 to 3m) $= 1.093 (8.36 + 6.9 + \sqrt{(8.36)(6.9)})$

= 1.093 (15.26 + 7.59)

= 24.98 acre-ft

V_4 (of 3 to 2m) $= 1.093 (8.36 + 9.5 + \sqrt{(8.36)(6.9)})$

= 1.093 (17.86 + 8.91)

= 29.26 acre-ft

V_5 (of 2 to 1m) $= 1.093 (9.5 + 10.79 + \sqrt{(9.5)(10.79)})$

= 1.093 (20.29 + 10.12)

= 33.24 acre-ft

V_6 (of 1 to 0m) $= 1.093 (10.79 + 11.60 + \sqrt{(10.79)(11.60)})$

= 1.093 (22.39 + 11.19)

= 36.7 acre-ft

V_{total} = 137.94 acre-ft

Appendix D. Estimating Rotenone Concentration by Trout Bioassay

Rotenone concentrations can be estimated quickly and with fair precision by placing trout in the treated water and measuring the time to loss of equilibrium (Loeb and Engstrom-Heg 1971). Figure 1 is from that paper.

Tests will be run on water taken from the lake, placed in plastic bags and rotenone added to it. Target concentrations and volume to attain those concentrations will be predetermined. Bioassay is as follows (citing unknown). Target fish will be collected from the lake, three will be placed in plastic bags containing each target concentration. A control using just lake water will also be monitored. The plastic bags used will be 33 gallon Mobiltuff LLD Liners, 1.35 mil thickness. These bags are gas permeable and will pass oxygen from surrounding water into the bags, therefore eliminating the need for aeration. The bags are suspended in the water from a rope or wire just above the water surface.

Concentrations are measured in ppm of 5% (or 2.5% synergized) rotenone stock solution. Remember, all concentrations are a percentage of product, not the active ingredients. This requires laboratory equipment (micro pipettes, test tubes, graduated cylinders) to premix solutions to be carried to the lake for testing. Testing will be done on the stock of rotenone to be used in the treatment, do not use just any rotenone available.

The curves in Figure 1 are based on bioassays done on brown trout, but are appropriate for hatchery rainbow trout. Loeb and Engstrom-Heg used trout in the 6 to 9 inch range and placed three in each cage to record the times to loss of equilibrium. (This is considered to have occurred when the mid-dorsal line comes in contact with the bottom of the container and the fish does not right itself and begin swimming normally again.) If this occurs in less than 15 minutes (65 F) or 30 minutes (47 F), rotenone concentration is fairly high (above 0.3 ppm of formulation). You will get more accurate results by repeating the assay using a diluted sample, prepared by mixing two liters of treated water with eight liters of untreated water. Concentration of rotenone formulation can be estimated by finding the time to loss of equilibrium on the X axis, connecting this with the test temperature with a straight edge, then reading the estimated concentration of rotenone formulation on the Y axis. If the test was run on a 4:1 diluted sample, this value should be multiplied by 5.

Example: (From Engstrom-Heg 1990 draft)

A pond is treated at 0.7 ppm of 5% rotenone formulation. Treated water is bioassayed at 65 F with brown trout. Times to loss of equilibrium for each fish are:

10 minutes
9.5 minutes
11 minutes
mean time, T = 10.17 minutes

At 0.7 ppm, T should be 10.17 minutes, which is close. A 4:1 diluted sample gives the following turnover times:

21 minutes
22 minutes
23 minutes
mean time, T = 22.0 minutes

The estimated concentration from Figure 1 is 0.14 ppm of formulation. 0.14 x 5 = 0.70 ppm, which is identical with the application rate. Even if the rotenone concentration is extremely high, to the point of causing milkiness, it will still take about seven minutes for the trout to keel over. If you get a turnover time of less than about ten minutes, it is vital to run a diluted sample.

If trout survive without loss of equilibrium for 2.5 hours at 65 F or 5 hours at 47 F, it can be concluded that there has been detoxification to the lethality threshold for trout. Mortality beyond this point is rare.

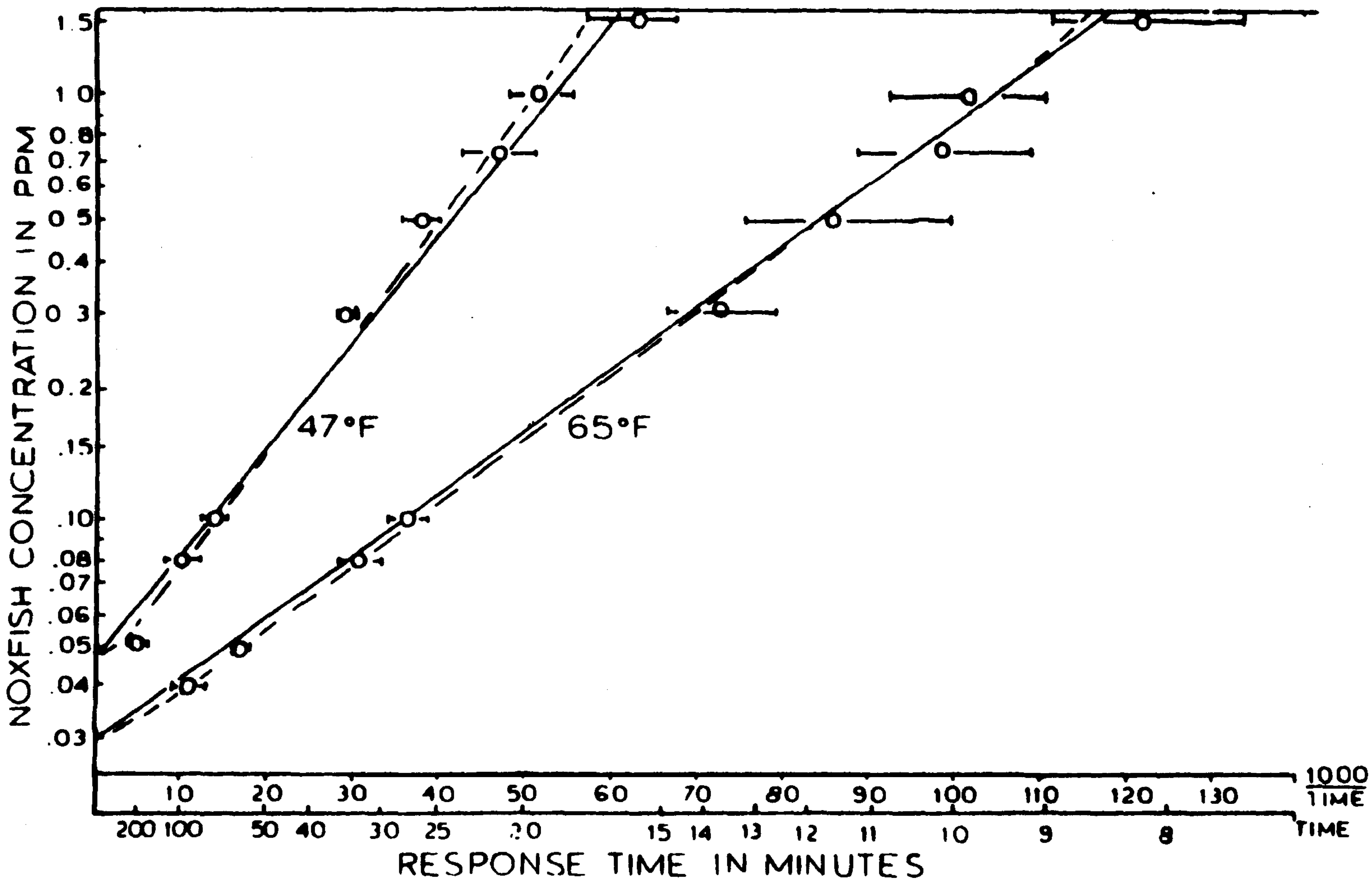


Figure 1. **Concentration-response curves for brown trout in Noxfish dispersions. Solid lines represent semilogarithmic, dashed lines logarithmic, regressions. Each point represents mean time to loss of equilibrium ± standard deviation.** From Loeb and Engstrom-Heg (1971).

Appendix E. Determination of In-Stream Potassium Permanganate Demand (from Engstrom-Heg 1971 and 1976).

Where rotenone detoxification is planned for a stream outlet having a largely organic bottom, it is recommended that *in situ* measurement of total potassium permanganate demand be made, in addition to the permanganate demand of the water itself. This can be done in the following manner.

Determine the potassium permanganate demand of the water to be treated:

A. Reagents

1. Stock potassium permanganate solution. Dissolve 5.0 grams of potassium permanganate in distilled water, and make up to a value of 500 milliliters.

2. Orthotolidine solution, 0.1% in hydrochloric acid (15% by volume). Available at most drug stores in prepared form.

3. Distilled water.

B. Standardization

1. Collect 10 liters of distilled water.

2. Add 1.1 milliliters of stock potassium permanganate solution to the 10 liters of water for a 1.1 ppm solution of permanganate.

3. Add 0.5 milliliters of orthotolidine to 100 ml of the 1.1 permanganate solution in a beaker.

4. Place a sample from the beaker in a color comparator calibrated for residual chlorine in the 0.1 to 1.0 ppm range. (Available in 0-1.0 ppm and 0-3.0 ppm ranges from Hach Chemical Company -- Models CN-46 and CN-46A, Catalog 11-B, 1978. Hand-held colorimeters available more recently.) The reading should be 1.0.

C. Potassium permanganate demand determination

1. Collect a 10-liter sample of the water to be tested. Stabilize the temperature at a value near that of the source body of water. If the water contains coarse suspended material, it should be kept in motion by stirring.

2. Add stock potassium permanganate solution to obtain a known initial concentration.

   a. For clear water, add 1.1 milliliters of the stock solution to the 10-liter sample for a 1.1 ppm permanganate concentration.

   b. For slightly turbid or stained water, add 5.5 ml of stock solution to the 10-liter sample for 5.5 ppm.

   c. For water carrying a heavy organic load, add 11.0 ml of stock solution to the 10-liter sample for 11 ppm.

3. At desired time or times (e.g. 20 minutes for a 20-minute contact time), place an aliquot of solution in a 100-milliliter or larger beaker and add 5.0 milliliters of orthotolidine.

   a. For 1.1 ppm, use 100 ml aliquot and do not dilute.

b. For 5.5 ppm, use 20 ml aliquot and dilute with 80 ml of distilled water.

c. For 11.0 ppm, use 10 ml aliquot and dilute with 90 ml of distilled water.

4. Place a sample from the beaker in the comparator and read the residual chlorine (permanganate) value. Compute potassium permanganate demand by equation (1), where D = permanganate demand in ppm, Co = the original permanganate concentration in ppm, and A = the residual chlorine (permanganate) reading at the end of the time period. The table gives some representative values (from Engstrom-Heg 1971).

(1)

$$D = \frac{Co\ (1-A)}{0.573}$$

Table. Approximate measurement of potassium permanganate demand with a chlorine comparator.

Residual chlorine reading (ppm)	Potassium Permanganate 1.1 ppm no dilution Residual	Demand	5.5 ppm 20-80 dilution Residual	Demand	11 ppm 10-90 dilution Residual	Demand
1.0	1.1	0.0	5.5	0.0	11.0	0.0
0.9	0.9	0.2	4.5	1.0	9.0	2.0
0.8	0.7	0.4	3.5	2.0	7.0	4.0
0.7	0.5	0.6	2.5	3.0	5.0	6.0
0.6	0.3	0.8	1.5	4.0	3.0	8.0
0.5	0.1	1.0	0.5	5.0	1.0	10.0
0.4	0.0	1.1	0.0	5.5	0.0	11.0

II. Determine the total potassium permanganate demand of the water to be treated:

1. Set up the potassium permanganate drip station and measure the stream discharge using a weir or other method(s). Calculate the permanganate demand of the water itself (Section I, above). Then begin introducing permanganate solution at concentration approximately equal to that needed to detoxify the rotenone in the desired time plus half the permanganate demand of the water. If salt is introduced so as to allow tracing the passage of a bolt of treated water between two points, it should be introduced at a rate equal to 102 grams per part per million for each cubic foot per second of stream discharge.

2. Time the passage of the leading edge of the potassium permanganate to the projected detoxification point. Allow the permanganate to run into the stream at a constant rate until three times this time interval has elapsed. If there is no permanganate demand, this will assure a steady-state concentration equal to the concentration at the point of introduction.

3. Determine the residual potassium permanganate at the projected detoxification point as follows:

   a. Collect a 20 ml sample from the stream and dilute it to 100 ml with distilled water.

   b. Add 0.5 ml of orthotolidine to the sample. This should always be done in a shaded location, as the color will fade rapidly in direct sunlight

   c. Place an aliquot of the prepared sample in a residual chlorine color comparator and read the residual chlorine (permanganate) value.

   d. Compute the residual potassium permanganate concentration according to the equation $C = 9.5A - 0.74Co$

   Where C = residual potassium permanganate concentration
   Co = initial potassium permanganate concentration
   A = residual chlorine value of the sample

4. Compute the <u>total</u> potassium permanganate demand by $D = Co\text{-}C$.

If the total potassium permanganate demand is substantially greater than that of the water only, then half of the former, rather than half of the latter figure should be added to the potassium permanganate concentration needed to detoxify the rotenone.

Appendix F. Useful Conversions

1 acre = 43,560 square feet

1 acre-foot (ac-ft) = 43,560 cubic feet

1 cubic foot = 7.481 gallons

1 cubic foot per second (cfs) = 448.831 gallons per minute 1

gallon water = 8.3453 pounds

1 pound = 0.4536 kilograms

102 grams of any pure chemical per cfs = 1 part per million (ppm) 1

milligram per liter = 1 ppm

0.164 gallons of rotenone emulsive per ac-ft = 0.5 ppm by volume

0.328 gallons of rotenone emulsive per ac-ft = 1.0 ppm by volume

0.656 gallons of rotenone emulsive per ac-ft = 2.0 ppm by volume

0.984 gallons of rotenone emulsive per ac-ft = 3.0 ppm by volume

Approximately 1 gallon (.984) will treat 6 ac-ft at 0.5 ppm

0.85 ml/min/cfs = 0.5 ppm by volume

1.7 ml/min/cfs = 1.0 ppm by volume

3.4 ml/min/cfs = 2.0 ppm by volume

5.1 ml/min/cfs = 3.0 ppm by volume

Appendix G. Idaho waters treated with fish toxicants.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1948	Sublett Reservoir	Cassia	85	Rainbow		
1949	Solomon Lake	Boundary	9	Squawfish, chub, shiner	Cutthroat	Fish-Tox[h]
	Antelope Lake	Bonner	15	Stunted largemouth bass	Cutthroat	Fish-Tox
	24-Mile Reservoir	Caribou	24	Chub	Rainbow	
	Glendale Reservoir	Franklin	12	Chub	Rainbow	
	Lamont Reservoir	Franklin	24	Chub	Rainbow	Fish-Tox
	Jewel Lake	Bonner	29	Squawfish, stunted bass	Cutthroat	
1950	Stone Reservoir	Oneida	60	Carp, sucker, chub, shiner	Largemouth bass, crappie	
	Brush Lake	Boundary	29	Sucker, shiner	Rainbow, Kamloops, kokanee	Fish-Tox
	Smith Lake	Boundary	29	Stunted bass	Cutthroat ('51), rainbow since	Fish-Tox
	Elk Creek Reservoir	Clearwater	46	Bullhead, shiner	Brook, rainbow	
	Oakley Reservoir	Cassia	10-12	Chub, sucker	Rainbow	
	Chesterfield Reservoir	Caribou	18	Chub	Rainbow	
	Solomon Lake	Boundary	9	Squawfish	Cutthroat	Fish-Tox
	Julia Davis Lagoon	Ada	9	Carp, sucker	Warmwater species	
	Parkinson Pond	Ada	3	Carp		
	Musser Slough	Canyon	3	Carp, squawfish		
	Hardin Slough	Gem	5	Carp, sucker		
	Arrowrock Reservoir[a]					
1952	Buttermilk Slough	Washington	80	Carp	Warmwater species	
	Weston Reservoir	Oneida	80		Rainbow	
	Paul Pond	Minidoka	20	Carp	Perch	
	Twin Lakes Reservoir	Franklin	330	Carp	Rainbow & cutthroat	
	Robinson Lake	Boundary				

Appendix G. Cont..

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1953	Caldwell Ponds	Canyon	15		Bass, perch, crappie catfish	
	Mirror Lake	Bonner	98	Stunted perch, sunfish, bullheads	Kamloops	Fish-Tox
	Roseworth Reservoir	Twin Falls	1,200	Chub	Rainbow	Fish-Tox
	Smith Lake	Boundary				
1954	Hump (Buffalo) Lake	Idaho	13	Brook trout	Rainbow	
	Stone Reservoir	Oneida	200		Rainbow	
	Dennick Lake	Bonner	8		Cutthroat	Fish-Tox
	Sand Lake	Bonner		Yellow perch, black crappie	Grayling	Fish-Tox
	Blue Lake	Bonner	90	Stunted spiny rays	Rainbow & brook	Fish-Tox
	Granite Lake	Bonner	21	Stunted spiny rays	Rainbow	Fish-Tox
	Kelso Lake	Bonner	70	Stunted spiny rays	Rainbow	Fish-Tox
	Beaver Lake	Bonner	23	Stunted spiny rays	(not stocked)	
	Lambertson Lake	Bonner	17	Stunted spiny rays	Rainbow	Fish-Tox
	Mud Lake	Jefferson	2,000	Stunted perch	Rainbow & cutthroat	Rotenone
	Stanley Lake	Custer	180		Rainbow, kokanee	
1955	Waha Lake	Nez Perce	90	Squawfish, carp, sucker	Rainbow	
	Blue Lake	Nez Perce	6		Rainbow	
	Chesterfield Reservoir	Caribou	1,320	Utah chub	Rainbow	
	24-Mile Reservoir	Caribou	40	Utah chub	Rainbow	
	Perkins Lake	Boundary	60	Sucker	Brook	Rotenone
	Bonner Lake	Boundary	23	Perch, bass	Rainbow	Rotenone
	Dodge Creek	Boundary	2	Long-nosed sucker	None	Rotenone
	Reeder Creek	Bonner		Sucker	Cutthroat	Rotenone
	Westmond Creek	Bonner	0.25	Peamouth	None	Rotenone

Appendix G. Cont..

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1956	Glendale Reservoir	Franklin	260	Utah chub	Rainbow	
	Crowther Reservoir	Oneida	50	Utah chub, carp	Rainbow	
	Dodge Creek	Boundary	2	Longnosed sucker	None	Rotenone
	Westmond Creek	Bonner	0.25	Peamouth	None	Rotenone
	Hayden Lake	Kootenai				
	Hauser Lake Outlet	Kootenai				
1957	Cocolalla Lake	Bonner	800	Minnow, sucker, spiny-ray species	Cutthroat	Rotenone
	Round (Little Cocolalla) Lake	Bonner	58	Minnow, sucker, spiny-ray species	Cutthroat	Rotenone
	Algoma Lake	Bonner	1	Minnow, sucker, spiny-ray species	Cutthroat, rainbow	Rotenone
	Westmond Creek Lake	Bonner	12	Minnow, sucker, spiny-ray species	Cutthroat	Rotenone
	St. Joe River Rotenone	Benewah/Shoshone		sculpins	Squawfish, sucker,	
	Fry Creek	Bonner	3	Peanose, sucker	None	Rotenone
	Jewel Creek	Bonner	0.25	Peanose, sucker	None	Rotenone
	Soldier Creek	Bonner		Brook trout, sucker	Cutthroat	Rotenone
	Reeder Creek	Bonner		Brook trout, sucker	Cutthroat	Rotenone
	Rock Creek	Twin Falls		Sucker, shiner, chiselmouth		Rotenone
	Cocolalla Creek Drainage System	Bonner		Sucker, minnow inc squawfish		Rotenone
1958	Spruce Lake	Boundary	5	Shiner, sucker	Trout	
	Sinclair Lake	Boundary	3	Pumpkinseed sunfish	Trout	
	Little Wood River Reservoir (includes tributaries)	Blaine		Sucker	Rainbow	
	Island Park Reservoir	Fremont	7,794	Utah chub, shiner, dace sucker, sculpin, whitefish	Rainbow	Rotenone
	North Fork Snake River	Fremont		Whitefish, Utah chub dace, sculpin, brook trout	Rainbow	Rotenone Rotenone

Appendix G. Cont..

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1958	Fry Creek	Bonner	3	Peanose, sucker	None	Rotenone
(Cont.)	Jewel Creek	Bonner	0.25	Peanose, sucker	None	Rotenone
	Soldier Creek	Bonner		Brook trout, sucker	Cutthroat	Rotenone
	Reeder Creek	Bonner		Brook trout, sucker	Cutthroat	Rotenone
	Lake Lowell	Canyon	43	Carp		Rotenone
	North Fork Payette River	Valley	17-18	Squawfish		Rotenone
	Oakley Reservoir	Cassia				Toxaphene
	Goose Creek					Toxaphene
1959	Little Camas Creek	Elmore	**4**	Perch, sucker	Rainbow	
	Little Wood River	Blaine/Lincoln	48	Sucker, minnow	Rainbow	
	Fry Creek	Bonner	3	Peamouth, sucker		Rotenone
	Reeder Creek	Bonner		Brook trout, sucker, sculpin	Cutthroat	Rotenone
	Bear Creek	Bonner		Brook trout, peamouth, shiner	Cutthroat	Rotenone
	Moose Creek Reservoir	Latah	52	Minnow, sucker	Rainbow	Rotenone
	St. Johns Reservoir	Oneida		Utah chub	Rainbow	Rotenone
	Lost Valley Reservoir	Adams	1,140	Spiny-ray	Rainbow	Rotenone
	Little Camas Reservoir	Elmore	220	Perch, sucker	Rainbow	Rotenone
1960	Fry Creek	Bonner	3	Peamouth, sucker		Rotenone
	Kalispell Creek	Bonner		Brook trout, sculpin sucker	Cutthroat	Rotenone
	Willow Creek	Bonneville/ Bingham	95	Sucker, minnow		
	Salmon Falls Creek	Twin Falls	28	Sucker, minnow		
	Camas Creek	Elmore/Camas/ Blaine	55	Sucker, minnow, perch		
	Big Wood River	Blaine	4	Perch, sucker		
	Goose Creek	Cassia	24	Sucker, shiner		
	Pettit Lake	Blaine	395	Squawfish, sucker, shiner		Toxaphene
	Magic Reservoir	Blaine		Perch, sucker, minnow	Rainbow	Rotenone

Appendix G. Cont..

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1960 (Cont.)	Mormon Reservoir	Camas		Perch, sucker, minnow	Rainbow	Toxaphene
	Oakley Reservoir	Cassia		Perch, sucker, minnow	Rainbow	Toxaphene
	Sagehen Reservoir	Gem	230	Largemouth bass	Rainbow	Rotenone
	C. Ben Ross Reservoir	Adams	380	Spiny-ray, sucker, squawfish	Rainbow	Rotenone
	Black Lake	Kootenai	400	Spiny-ray	Rainbow	Toxaphene
	Bond Lake	Boundary	6.2	Pumpkinseed	Rainbow	Rotenone
	Lee's Bay (Hayden Lake)	Kootenai	16	Spiny-ray, perch, tench, black crappie, bullhead, largemouth bass		Rotenone
1961	Blackfoot Reservoir	Caribou	18,900	Chub	Rainbow	Toxaphene
	Chesterfield Reservoir	Caribou		Utah chub	Rainbow	Rotenone
	Hidden Lake	Boundary	50	Stunted brook	Cutthroat	Toxaphene
	Mormon Reservoir	Camas		Perch, sucker		Toxaphenel Rotenone
	Roseworth Reservoir[b]	Twin Falls		Shiner, sucker		Rotenone
	Soldier's Meadow Reservoir	Nez Perce	114	Dace	Rainbow	
	Blackfoot River (Blackfoot Reservoir Upstream)	Caribou	24	Sucker, carp	Rainbow, cutthroat	
	Little Blackfoot River	Caribou	1	Chub	Rainbow	
	Meadow Creek	Caribou	20	Chub, sucker	Cutthroat	
	Yellowbelly Lake	Custer	186	Sucker, brook trout		Toxaphene
	Orofino Creek	Clearwater	75			
1962	Bull Run Lake	Kootenai	100	Bullheads, perch, tench	Largemouth bass black crappie, rainbow	Rotenone or Toxaphene
	Little Camas Reservoir[s]	Elmore		Perch, sucker, dace shiner		Toxaphene/ Rotenone
	Orofino Creek	Clearwater	75	Dace, shiner, sucker	Rainbow	
	North Fork Payette River	Valley	12	Squawfish	Rainbow	Rotenone
	Glendale Reservoir	Franklin	3	Utah chub, sucker	Rainbow	Rotenone
	Lamont Reservoir	Franklin	48	Utah chub	Rainbow	Rotenone
	Rose Lake	Kootenai				

Appendix G. Cont.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1963	Milton Branch Ponds	Washington	10	Bullhead, catfish	Largemouth bass	Rotenone
	Springfield Lake	Bingham	66	Utah chub, sucker	Rainbow	Rotenone
	Cow Creek	Owyhee	7	Sucker, squawfish	Rainbow	Rotenone
1964	C. Ben Ross Reservoir[d]	Adams	30	Bullhead	Rainbow	Rotenone
	Caldwell Ponds	Canyon	9	Bluegill, carp, bullhead	Rainbow, brown trout	Rotenone
	Lost Valley Reservoir°	Adams	200	Perch, bullhead	Rainbow	Rotenone
	Stone Reservoir	Oneida	5	Carp	Bass, crappie, rainbow	Rotenone
1965	Anderson Ranch Reservoir'	Elmore		Squawfish	Rainbow, kokanee	Rotenone
	Parker Lake	Boundary	3	Brook trout	Cutthroat	Rotenone
	Upper Willow Creek & Tributaries	Bonneville/ Bingham	79	Utah chub, dace, sucker shiner	Rainbow, brown, brook, cutthroat trout	Rotenone Rotenone
	Winchester Lake	Lewis	1			
1966	Grays Lake Outlet & Tributaries	Bonneville/ Bingham	70	Utah chub, dace, sucker shiner, sculpins	Rainbow, brown, brook, cutthroat trout	Rotenone
	Willow Creek Drainage	Bonneville/ Bingham	150	Utah chub, sucker, shiner sculpin, dace	Cutthroat, brown, rainbow trout	Rotenone
	Manns Creek	Washington	6	Mountain sucker, dace	Rainbow	Rotenone
	Island Park Tributaries	Fremont	34	Chub, sucker, shiner	Rainbow, eastern brook	Rotenone
	Moose Creek Reservoir	Latah	30	Bullhead, shiner	Rainbow	Rotenone
	Soldiers Meadow Reservoir	Nez Perce	5	Dace	Rainbow	Rotenone
	Mountain Home Reservoir	Elmore	2	Perch	Rainbow	Rotenone
	Island Park Reservoir	Fremont	500	Chub, shiner, sucker	Rainbow, coho, kokanee cutthroat	Rotenone
	Trudes Reservoir	Fremont	45	Chub	Rainbow, eastern brook	Rotenone
	Sheridan Reservoir	Fremont	45	Chub, shiner	Rainbow, eastern brook	Rotenone
	Deep Creek Reservoir	Oneida	1	Sucker	Rainbow, cutthroat	Rotenone
	24-Mile Reservoir	Caribou	3	Chub, shiner	Rainbow	Rotenone
	Glendale Reservoir	Franklin	6	Sucker, chub, shiner	Rainbow	Rotenone
	Foster Reservoir	Franklin	45	Chub, shiner, sucker	Rainbow	Rotenone
	Windor Reservoir	Franklin	5	Carp, green sunfish	Rainbow	Rotenone
	Gravel Pond	Minidoka	12	Carp, bullhead, sucker,	Rainbow	Rotenone
	Anderson Ranch Reservoir°	Elmore		Squawfish	Rainbow, kokanee	Rotenone
	Perkins Lake	Blaine		Squawfish		
	Round Lake	Benewah				

Appendix G. Cont.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1967	Lower Malad River	Oneida	5	Utah chub	None	Rotenone
	Willow Creek Drainage	Bonneville/ Bingham	180	Utah chub, sucker, dace, shiner, sculpin	Cutthroat, brown, brook, rainbow	Rotenone
	Silver Lake (Railroad Ranch)	Fremont	170	Utah chub	Rainbow	Rotenone
	Winchester Lake	Lewis	75	Goldfish, bullhead, perch, crappie, sunfish	Rainbow, cutthroat	Rotenone
1968	St. Joe River	Shoshone/ Benewah	22	Squawfish	None	Squoxin
	Kelso Lake	Bonner	61.2	Bullhead, perch, tench, pumpkinseed, bluegills	Rainbow	Rotenone
	Round Lake (Little Kelso)	Bonner	9.4	Bullhead, perch, tench, pumpkinseed, bluegill	Rainbow	Rotenone
	Granite Lake	Bonner	20.9	Bullhead, perch, tench, pumpkinseed, bluegill	Cutthroat	Rotenone
	Perkins Lake	Boundary	60	Bullhead; sucker, shiner pumpkinseed, bluegill	Brook	Rotenone
	Solomon Lake	Boundary	9	Shiner	Cutthroat	Rotenone
	Bass Lake	Boundary	5.2	Sucker, perch, squawfish, pumpkinseed	Brook	Rotenone
	Anderson Ranch Reservoir°	Elmore				
1969	Cove Arm Lake	Owyhee	76	Carp, sucker, shiner	Rainbow, coho	Fintrol
	Anderson Ranch Reservoir°	Elmore	240	Squawfish	Rainbow, coho, kokanee	Rotenone
	Pleasantview Reservoir	Oneida	channel	Utah chub, sucker	Rainbow	Rotenone
	St. Males River	Benewah	25	Squawfish	None	Squoxin
	North Fork Payette River	Valley	18	Squawfish	None	Squoxin
	Lake Fork	Valley	18	Squawfish	None	Squoxin
	Gold Fork	Valley	4	Squawfish	None	Squoxin
	Camas Creek	Clark	40	Shiner, dace, sucker, chub	Cutthroat, brown rainbow	Rotenone
	Little Blackfoot River	Caribou	100 yds	Carp, sucker	None	Fintrol

Appendix G. Cont.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1970	Campbell's Pond	Clearwater	10	Stunted largemouth bass, bullhead	Brook, rainbow	Rotenone
	Bonner Lake	Boundary	23	Pumpkinseed	Rainbow	Fintrol
	Upper Payette Lake	Valley	300	Squawfish, sucker, shiner	Rainbow	Fintrol
	Windor Reservoir	Franklin	10	Sunfish	Rainbow	Rotenone
	St. Joe River Benewah	Shoshone/	22	Squawfish	None	Squoxin
	North Fork Payette River	Valley	18	Squawfish	None	Squoxin
	Lake Fork	Valley	18	Squawfish	None	Squoxin
	Gold Fork	Valley	4	Squawfish	None	Squoxin
	Anderson Ranch Reservoir°	Elmore	–	Squawfish	None	Rotenone
	Little Malad River	Oneida				
1971	Hell Roaring Lake	Custer	59	Sucker, shiner, dace	Grayling, kokanee	Fintrol
	Little Payette Lake	Valley	400	Sucker, shiner, dace	Rainbow	Fintrol
	St. Joe River	Shoshone/ Benewah	22	Squawfish	None	Squoxin
	North Fork Payette River	Valley	18	Squawfish	None	Squoxin
	Lake Fork	Valley	18	Squawfish	None	Squoxin
	Gold Fork	Valley	4	Squawfish	None	Squoxin
	North Fork Clearwater River	Clearwater	110	Squawfish	None	Squoxin
	C. Ben Ross Reservoir	Adams				
	Dog Creek Reservoir	Gooding	0.5			Fintrol
	Blackfoot Reservoir	Caribou	18,900			Fintrol
1972	Lost Valley Reservoir	Valley	600	Perch	Rainbow	Fintrol
	North Fork Payette River	Valley	18	Squawfish	None	Squoxin
	Gold Fork	Valley	4	Squawfish	None	Squoxin
	St. Maries River	Benewah	25	Squawfish	None	Squoxin
	St. Joe River	Benewah/ Shoshone	30	Squawfish	None	Squoxin
	Salmon Falls Creek and Tributaries	Twin Falls	100			Fintrol

Appendix G. Cont.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1973	Mud Lake	Jefferson	7,000	Chub, sucker	Perch, walleye	Fintrol
	Kelso Lake	Bonner	60	Sunfish, bullhead	Rainbow, cutthroat	Fintrol
	Granite Lake	Bonner	20	Sunfish, bullhead	Cutthroat	Fintrol
	Beaver Lake	Bonner	23	Sunfish, bullhead	Cutthroat	Fintrol
	Lambertson Lake	Bonner	17	Sunfish, bullhead	Cutthroat	Fintrol
	Mountain Home Reservoir	Elmore	50	Carp	Rainbow	Fintrol
	Deadwood Reservoir	Valley	3,000	Kokanee	Cutthroat	Rotenone
	Deadwood River & Tribs	Valley	15	Kokanee	Cutthroat	Rotenone
	North Fork Payette River	Valley	18	Squawfish	None	Squoxin
	St. Maries River	Benewah	25	Squawfish	None	Squoxin
	St. Joe River	Benewah/ Shoshone	30	Squawfish	None	Squoxin
1974	North Fork Payette River	Valley	18	Squawfish		Squoxin
	24-Mile Reservoir	Caribou	26			Fintrol
	Foster Reservoir	Franklin	8			Fintrol
	Glendale Reservoir	Franklin	10			Fintrol
1975	Ririe Reservoir	Bonneville	1,500	Utah chub cutthroat	Coho, rainbow,	Rotenone
	Willow Creek	Bonneville	50	Utah chub cutthroat	Brown, rainbow	Fintrol
	Lost Valley Reservoir	Adams	1,140			Fintrol
1977	McArthur Lake	Boundary		Yellow perch	Brook trout	Rotenone
	Little Camas Reservoir	Elmore		Perch, shiner	Rainbow	Fintrol
	Crane Falls Lake	Owyhee	100			
	East Springs Impoundments					
	Soldier's Meadow Reservoir	Nez Perce				Rotenone
	Chesterfield Reservoir	Caribou	1,600			Fintrol, Rotenone
1978	Lewiston Levee Ponds	Nez Perce	100			Rotenone
	Crane Falls Lake	Owyhee	100			
1979	Island Park Reservoir	Fremont	600	Sucker, chub		Rotenone
	Sheridan Reservoir	Fremont	45	Sucker, chub		Rotenone
	Sheridan Creek	Fremont		Sucker, chub		Rotenone

Appendix G. Cont.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1979	Icehouse Creek	Fremont	2	Sucker, chub		Rotenone
(Cont.)	Bishop Springs Reservoir	Fremont	10	Sucker, chub		Rotenone
	Henrys Fork at McCrea Bridge	Fremont		Sucker, chub		Rotenone
	Grizzly Springs	Fremont		Sucker, chub		Rotenone
	Trudes Reservoir	Fremont	45	Sucker, chub		Rotenone
	Hotel Creek Reservoir	Fremont	30	Sucker, chub		Rotenone
1980	Weiser Bass Pond	Washington	1	Carp	Largemouth bass	Rotenone
	Moose Creek Reservoir	Latah	100			Rotenone
1983	Horsethief Reservoir	Valley		Perch	Rainbow	Rotenone
	Brownlee Reservoir	Washington				
1985	Lost Valley Reservoir	Adams	300	Perch	Rainbow	Rotenone
1986	Mountain Home Reservoir	Elmore	50	Carp	Rainbow, Lm Bass	Rotenone
	Rattlesnake Creek		5	Carp		Rotenone
1987	Salmon Falls Creek Reservoir[s]	Twin Falls				
	Little Payette Lake	Valley	450	Squawfish, sucker	Rainbow	Rotenone
1988	Salmon Falls Creek Reservoir[s]	Twin Falls				
	Daniels Reservoir	Oneida				
	Treasureton Reservoir	Franklin	60	Carp	Rainbow	Rotenone
1989	Herrick Reservoir	Valley	10	Bullhead	Rainbow	Rotenone
	Pitkin Reservoir	Valley	2	Bullhead	Rainbow	Rotenone
	Jewel Lake	Bonner	29	Perch	Rainbow	Rotenone
	Sinclair Lake	Boundary	3	Perch	Cutthroat, Rb/Ct hybrids, kokanee	Rotenone
	Marsing Pond	Owyhee	5			Rotenone
	Star Lane Ponds	Gem	4			Rotenone
1990	Yellowbelly Lake	Custer	186	Sucker, dace, brook, shiner	Westslope cutthroat	Rotenone

Appendix G. Cont.

Year	Name	County	Surface acres or miles treated	Target species	Species stocked	Toxicant
1991	Disappointment Lake	Idaho	14	Brook trout	Bull trout	Rotenone
	Lost Valley Reservoir	Adams	180	Yellow perch	Rainbow	Rotenone
	Mirror Lake	Bonner	98	Black crappie	Cutthroat, brook, kokanee	Rotenone
1992	Star Lane Ponds	Gem	4	Carp		Rotenone
	Indian Creek Reservoir	Ada	11	Crappie	Catfish, bass, bluegill	Rotenone
	Roseworth Reservoir	Twin Falls	60	--	Rainbow	Rotenone
	McTucker Ponds (8)	Bingham	22	Carp		Rotenone
	Montpelier Reservoir	Bear Lake	30	Brook trout		Rotenone
	Chesterfield Reservoir	Caribou	2	Carp	Rainbow	Rotenone
	Island Park Reservoir	Fremont	75		Rainbow, Rb/Ct	Rotenone
	Sheridan Reservoir	Fremont				Rotenone
	Trudes Reservoir	Fremont				Rotenone
1993	None					
1994	Little Valley Reservoir	Bear Lake	18	Perch	Rainbow, cutthroat	Rotenone
	Rose Pond	Bingham	2	Carp, perch, sucker	Bass, bluegill, rainbow	Rotenone
	McTucker Pond (1)	Bingham	15	Carp, perch, sucker	Bass, bluegill, rainbow	Rotenone
	Twin Lakes Reservoir	Franklin	60	Carp	Bass, bluegill, rainbow	Rotenone
	Lost Valley Reservoir	Adams	5	Yellow perch	Rainbow	Rotenone
	Little Camas Reservoir	Elmore	15	Black crappie	Rainbow	Rotenone
1995	Horsethief Reservoir	Valley	3	Yellow perch	Rainbow	Rotenone
1996	Roberts Gravel Pond	Jefferson	50	Yellow perch, sunfish, Bullhead	Rainbow	Rotenone
	Bruneau Dunes East Pond	Owyhee	28	Carp	Bass, bluegill	Rotenone

[a]Some eradication work was carried on after the reservoir was drained to kill undesirable fish.
[b]Drainage treatment included 2 % miles on Cedar Creek and 11 miles on House Creek.
`Includes about 5 miles of stream treated above the reservoir.
°includes 3 miles of tributaries treated above the reservoir.

Appendix G. Cont.
[e]Includes 2 % miles of tributaries treated above the reservoir.
`Twenty miles of shoreline treated for newly-hatched fry.
[9]Shoreline spawning areas treated only.
[h]Paul Jeppson (1952-1982) said Fish-Tox was sold as Rotenone, but main active ingredient was toxaphene.
NOTE: This table was assembled from Bi-ennial reports, regional reports and fliers, and collective memories of fish managers, past and present. Many blanks occur. Estimates of acres or miles treated may be incorrect, i.e., treating the full pools of a reservoir is unlikely, but that is what the documentation provided.

Appendix H. Coefficients for application of fish toxicants.

Powdered Rotenone

Parts per million	Pounds per acre-foot
0.25	0.67
0.50	1.35
0.75	2.02
1.00	2.70
1.25	3.37
1.50	4.05
1.75	4.72
2.00	5.40

Parts per million	Pounds per cfs for 1 hour
0.25	0.058
0.50	0.116
0.75	0.174
1.00	0.233
1.25	0.291
1.50	0.349
1.75	0.407
2.00	0.466

Appendix H. Continued.

Emulsifiable Rotenone

Parts per million	Gallons per acre-foot
0.25	0.084
0.50	0.167
0.75	0.251
1.00	0.334
1.25	0.418
1.50	0.501
1.75	0.585
2.00	0.668

Parts per million	Gallons per cfs for 1 hour
0.25	0.007
0.50	0.014
0.75	0.021
1.00	0.028
1.25	0.035
1.50	0.042
1.75	0.049
2.00	0.055

Appendix I. Checklist for lake renovation projects.

1. Region notifies Bureau of intent to renovate	April 1
2. Internal EA to Bureau	May I
3. Bureau notifies Commission of intent to renovate	May
4. Public involvement	June-July
5. Application for appropriate permits	
a. Short term activity exemption - DEQ	June
b. T&E check with USFWS (by Bureau)	June
c. Approval from Federal Aid (by Bureau)	June
d. Land owner permission	June
e. Special use permit (may need one year lead time if EA is required)	
6. Synopsis of public and land owner input, with final recommendation to Bureau	July
7. Develop equipment and materials list and coordinate procurement	2 mo. before treatment
8. Pretreatment activity	
a. Recalculate water volume	in the few
b. Lake and stream surveys	weeks before
c. Limnological survey	treatment
d. Final bioassay	
e. Biomass estimate	
f. Arrange for disposal of chemical barrels	
g. Coordinate logistical support	
9. Renovation activity	
a. Pretreatment conference/briefing	the day before
b. Treatment	
10. Post treatment activities	
a. Bioassay for rotenone persistence	as needed as
b. Biomass estimate	needed after 72
c. Set nets for samples	hours as needed
d. Clean up	as needed
e. Disposal of waste	within 24 hours
f. Post-treatment debriefing	
11. Final report	within 60 days

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