THE PLANNING, OPERATION, AND ANALYSIS OF THE GREEN RIVER FISH CONTROL PROJECT

A JOINT REPORT
OF THE

UTAH STATE DEPARTMENT
OF FISH AND GAME

Harold S. Crane, Director

WYOMING GAME AND FISH
DEPARTMENT

S. J. Jiacoletti, Commissioner

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by

Alan Binns - Wyoming Game and Fish Department
Fred Eiserman - Wyoming Game and Fish Department
F.W. Jackson - Wyoming Game and Fish Department
Albert F. Regenthal - Utah State Department of Fish and Game
Roderick Stone - Utah State Department of Fish and Game

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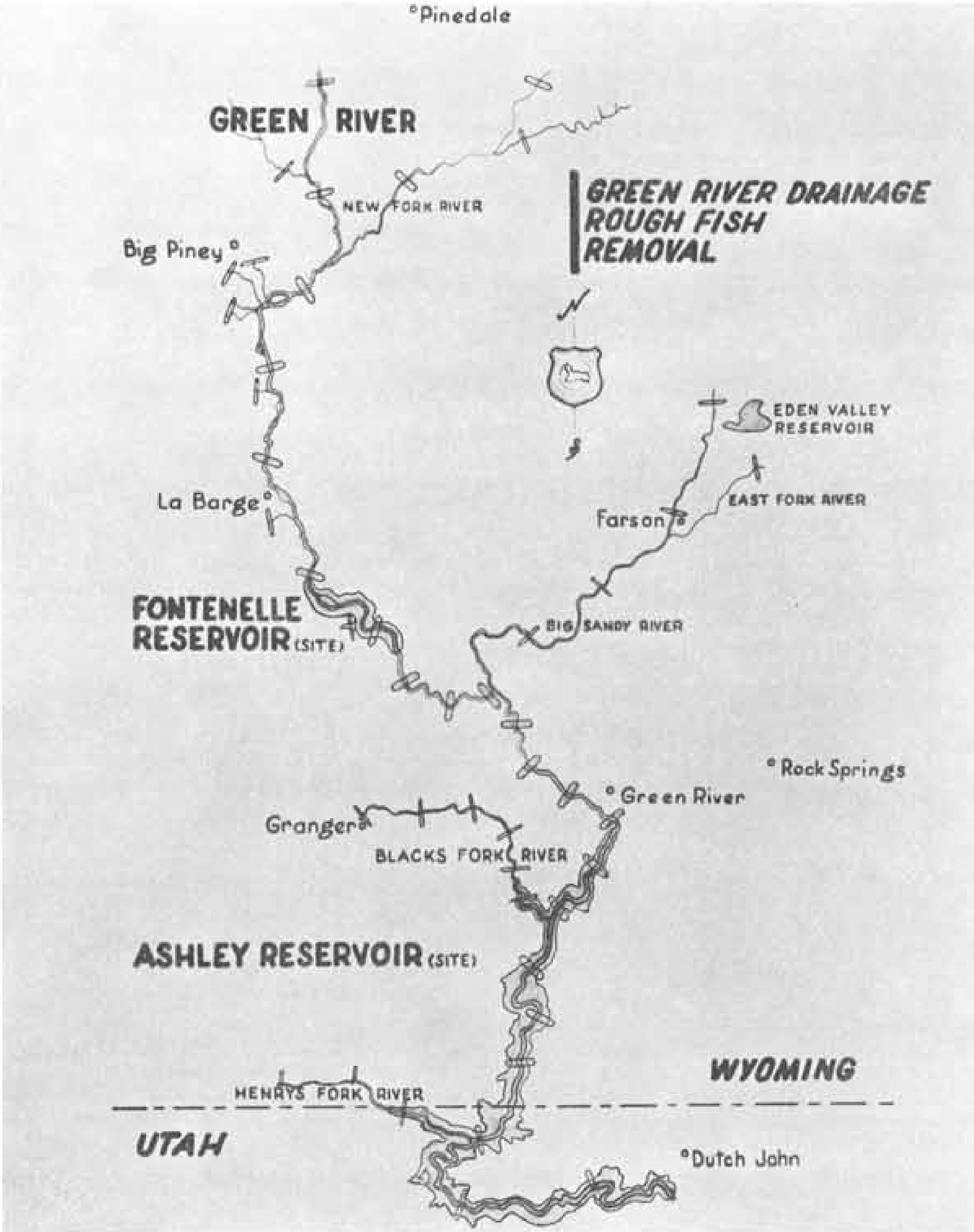

Figure 1. Portion of the Green River included in the chemical treatment. The approximate locations of toxicant drip stations are shown.

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INTRODUCTION

In November of 1962 Flaming Gorge Dam, a unit of the Colorado River Storage Project in Northeastern Utah, began impounding waters of the Green River from approximately 15,000 square miles of drainage area. The dam, 495 feet high, will impound 3,930,000 acre feet of water and form a reservoir some 42,000 surface acres when full. This publication describes and analyzes the five years of planning and field work which eventually terminated in the treatment of 445 miles of the river and its tributaries above the dam. The project had one principal objective---to manipulate non-desirable fish populations in favor of more desirable game fish species.

The Green River, upstream from the Big Piney Area, has long been regarded as one of the finest trout streams in the State of Wyoming. Unfortunately, this reputation does not prevail throughout the lower reaches of the river in Wyoming and Utah. The lower section of the Green River courses through over 100 miles of the Green River, Bridger and Wasatch formations. These formations are composed of gravel, sandstone and shale, and are overlain with highly erosive soils. The precipitation in this drainage varies from 13 inches annually in the headwaters to 8 inches along the lower section. Near Flaming Gorge, river flows vary from approximately 12,000 cfs during spring runoff to average lows of approximately 450 cfs. Within the project area air temperatures range generally from -50° F. extreme in winter to about 100° F. and water temperatures from 32° to 75° F.

A rehabilitation program was informally discussed as a possible step in the management of the proposed Flaming Gorge Reservoir as early as 1957. At that time, both the Seedskadee and LaBarge projects were being considered as participating projects in the Colorado River development, but definite information was lacking. Wyoming was considering treatment above the proposed Fontenelle Dam of the Seedskadee Project located on the Green River some 150 miles above Flaming Gorge Dam, and both agencies were interested in cooperative efforts of management between the dams. Subsequently, action on the LaBarge Project was terminated and closure of the Fontenelle Dam, which it had been hoped would closely coincide with that of the Flaming Gorge Dam, was set for 1963. Since then it has been delayed still further. This sequence of events made it necessary to consider the management of the river and reservoirs as a unit rather than as separate segments.

Specific recommendations for treatment were based on fisheries surveys conducted upstream from the Flaming Gorge Dam during the years 1958, 1959, and 1960. The surveys measured and evaluated physical, chemical, and biological features of the habitat and established a check list of fish present and the range and the relative abundance of each species recorded. Similar check lists were established for other forms of aquatic life. These investigations are described in two reports, (Bosley, 1960)(McDonald and Dotson, 1960).

Generally, good trout habitat was found to extend from the upper reaches of the project area downstream to the town of Green River. Below the town the river courses through highly erosive country, and game fish habitat is limited by the effects of siltation and adverse water temperatures.

Non-game fish species, including suckers, chubs, and carp, comprised the bulk of the fish populations found in the study area.

The advent of the Flaming Gorge Reservoir and the Fontenelle Reservoir (8,000 surface acres) with the resultant changes in the aquatic environment would produce game fish habitat where none previously existed as well as provide excellent opportunity for the rapid expansion of the existant non-game species.

It has been well established that the drastic environmental changes resulting from the construction of a new reservoir usually results in population explosions of the fish present. If such an explosion potential involves undesirable fish species drastic reduction of these species must be effected prior to development of a successful sport fishery.

In some instances this explosion has produced an upstream emigration of management significance. In the aquatic habitat resulting from Boysen Dam, on Wyoming's Wind River, carp populations have become so excessive that this species dominates not only a good portion of the lentic water of the reservoir, but also much of the lotic water many miles upstream.

This dominance and spread of carp into habitat normally suitable for trout has seriously reduced the game fish producing potential of these waters. It should be mentioned that a good trout fishery did exist in Boysen Reservoir for a two-year period prior to the population explosion of less desirable species. In this case no effort was made to control these less desirable species prior to impoundment.

In the North Platte River, in Wyoming, two rotenone treatment programs have been completed with encouraging results. A stream treatment project (Peterson, 1958), completed just prior to the closure of Glendo Dam; has resulted in five years of good trout fishing in the reservoir proper. Stream habitat, above the reservoir, is producing a limited trout fishery and gives every indication of becoming a more important fishery.

A second treatment project on the North Platte River was associated with Pathfinder Reservoir. Prior to 1957, carp and longnose and common white suckers were abundant in the reservoir. Despite repeated trout stocking programs and limited non-game fish control programs, the trout fishery remained poor.

In 1958, installation of electrical generating facilities necessitated evacuation of most of the reservoir's water. Chemical treatment was carried out in reservoir pot-holes and tributary streams. Test-net results, as of this writing, indicate no carp, and the reservoir is producing an exceptional trout fishery.

The manipulation of fish populations by chemical treatment is one of the most generally accepted techniques at the disposal of fisheries biologists. Properly administered rotenone toxicants have relatively short range effects on aquatic flora and fauna, are not cumulative, do not endanger homoiothermal species, and can be contained within specific habitat.

Fish and Game Agencies in Utah and Wyoming are charged with the responsibility of providing a sport fishery where possible. This is particularly important in the semi-arid intermountain region. It is anticipated that fishing pressure on Flaming Gorge Reservoir will reach a magnitude never before encountered on waters in either state. The control of nongame species is an important initial step in the development and management of this large reservoir sport fishery. Initial estimates, based on conservative figures, anticipate that between 120,000 and 150,000 annual fishermen days will be spent on the waters of the Flaming Gorge Reservoir. By 1975, this use is expected to reach 185,000 to 228,000 fishermen days. These figures do not include fishermen use of the upper Green River proper and the Fontenelle Reservoir, both within the area covered by the project.

During the years between approval of the fish control project by the Federal Government and its consumation, a few individuals and groups mounted a campaign to block treatment of the river. This opposition contended that the chemical treatment constituted a threat to the survival of a few fish species indigenous to the Colorado River drainage. These species are the Colorado River squawfish, Ptychocheilus lucius, the humpback sucker, Xyrauchen texanus, a form of chub closely associated with the roundtail and bonytail and sometimes identified as Gila cypha, the humpback chub. All of these species have been described as being specially adapted to swift water environments. It seemed probable to expect that the environmental changes resulting from impoundment would be responsible for any drastic reductions in swift water species. On this premise the use of rotenone would be largely academic.

Long before treatment commenced investigations conducted by fisheries biologists of the Wyoming, Utah and Colorado Fish and Game Departments verified the existence of these fish in well established numbers on the mainstem of the river and several major tributaries outside the treatment area.

Originally the treatment was to be coordinated with the closure of Flaming Gorge Dam in September, 1962 so as to confine toxicant to the impoundment area. Late in the year of 1961 it became evident that construction of the dam would not be completed until sometime in November, 1962. Since rotenone would be less effective in the colder temperature prevalent during that time of year, the treatment had to take place earlier. A request was made of the Bureau of Reclamation to close the diversion tunnel at the time of the treatment and hold water behind the coffer dam for one or two days. This would provide time for rotenone to dissipate. The Bureau indicated that structural aspects of the diversion tunnel and coffer dam were such that this plan might cause damage and jeopardize the completion of the entire project.

A detoxification program designed to neutralize the toxic chemical somewhere below Flaming Gorge damsite was initiated by the participating agencies in January of 1962. The detoxification effort would attempt to insure perpetuation of native fish species within Dinosaur National Monument. Again, the Bureau of Reclamation was asked if any method could be employed to partially close the diversion tunnel or otherwise reduce flows passing the dam so that detoxification operations could be simplified. The Bureau felt that even partial closure might endanger the structure. Therefore, detoxification had to proceed upon the full flow of the river.

The project was financed by the Section 8 program of the Colorado River Storage Project Act at a total cost of $106,000. The Bureau of Sport Fisheries and Wildlife of the U. S. Fish and Wildlife Service supported the program and acted as the coordinating agency in the administration of Federal funds designated for the project. To facilitate the handling of these funds, all expenditures were initially financed from the Wyoming Game and Fish Fund and reimbursed through the Bureau of Sport Fisheries and Wildlife upon completion of the project. Other participating agencies included the U.S. Public Health Service and the Colorado Game and Fish Department.

In order to evaluate the effect of the rotenone treatment on stream fauna, a D.J. study (F-25-R-2) was initiated on June 1, 1962 and will continue through December, 1963. The objectives of the study include an appraisal of the aquatic invertebrate population of these waters treated prior to and for at least a one-year period following treatment, and to study the recovery made by fish populations within the limits of the project.

By anticipating and critically evaluating a fishery potential of a proportion never before encountered in Utah and Wyoming, and by taking positive action to guide that potential into desirable channels, initial responsibilities have been met. In progress are programs formulated long before the treatment to insure that the sport fishery of the Flaming Gorge Reservoir and the Green River will have every opportunity to realize its full potential.

TREATMENT TECHNIQUES

Project Economics

The justification of any stream or lake fish management program is largely dependent on the probable recreational utilization to be served. Because a project of the scope of that on the Green River requires very sizable expenditures of time and money, such estimates should be made as accurately as possible. In 1959 a recreational use projection was made for the Flaming Gorge Reservoir, based on the 1955 National Survey of Fishing and Hunting,[1] the 1950 Government census, and all available state fishing-use data. In this projection a figure of 120,000 annual fisherman days was estimated for the reservoir and tailwater initial use. Applying a National average fisherman-day expenditure of $5.36 to the Flaming Gorge fishery, the total initial annual fishing expenditure would be in excess of $643,200. After the 1960 Government census figures were available, it became obvious that the original population and fishermen estimates were too low.

According to the figures in the 1960 National Survey, [2] freshwater fishermen numbers increased by about 18 per cent from 1955 to 1960. If this increase should continue at the same rate from 1960 to 1975, it is reasonable to surmise that fisherman use will be at least proportional. By 1975, the annual use on the Flaming Gorge Reservoir would be a minimum of 185,000 fisherman days with a total annual expenditure of at least $991,600. Most available data indicate that Intermountain Area fishing use and expenditures exceed the National averages.

Preliminary River Mapping and Flow Estimation

A determination of the extent of the stream areas to be treated involved location of the upper limits of carp populations detrimental to trout fishery development. While the goal of the entire project was the reduction of all nondesirable fish in the river proper, the upper area treatment was specifically aimed at the carp and its potential population explosion from the proposed Seedskadee Reservoir near LaBarge. This was effected over two summers and included an intensive inventory of fish populations by various electro-fishing and netting techniques. Representative sections of the Green, New Fork, and East Fork Rivers, as well as the lower reaches of all nonintermittent tributaries, were checked, and the upstream limits of all carp waters were carefully established. Next the upstream treatment station sites were located sufficiently far above carp population limits for a reasonable assurance of the complete inclusion

1. U.S. Fish and Wildlife Service, 1955. National Survey of Fishing and Hunting, Circular 44, 50 pp.

2. U.S. Fish and Wildlife Service, 1960. National Survey of Fishing and Hunting, Circular 120, 73 pp.

of that species. The general location of these sites may be found on the accompanying map (Figure 1).

With the upstream limits as starting points, a total mileage estimate of all the project waters downstream to the Flaming Gorge Damsite near Dutch John, Utah was made by direct scaling from aerial photographs. [3] From past river-treatment programs, experience indicated that maximum treatment coverage and operational efficiency was obtained from rotenone introductions made at approximate ten-mile intervals. With the use of the aerial photographs, all major stream waters were arbitrarily divided into ten-mile sections, starting from the upstream limits.

The U.S. Geological Survey maintains a system of water gauging stations on the Green River proper and many of its tributaries. From these stations the survey has compiled many years of daily flow data which are published annually in the Surface Water Supply papers for the Colorado Basin. [4] For this project records of flows for these stations were analyzed and volume of flow and velocity of the river was correlated with gauge height readings. A table was compiled indicating the average flow and velocity at all normal gauge heights. This made it possible for field personnel to have uncorrected river flow data immediately available.

In order to carry out a treatment program with the greatest facility and economy, stream flows should be at the lowest level possible without involving other complicating factors. On the upper Green River drainage, the month of September was ascertained to be the time of lowest water flow concurrent with satisfactory water temperature and climatic conditions. Average September water flow estimates were calculated for all stations.

Past river treatment experience indicated the necessity of making rotenone introductions at a 5 ppm concentration in order to maintain an adequate toxic level for carp throughout each ten-mile stream segment. Furthermore, it was considered that, for maximum lethal effectiveness, rotenone introduction should be continued for at least six hours from every station. Total rotenone requirements for average September flows were calculated with these criteria. To provide for the contingency that, at the actual time of treatment, water conditions might be above normal, rotenone requirements were also calculated for 1.36 and 1.6 times the average flow.

Initial Testing of Rotenone Introduction Methods

For its previous river treatment operations, the Wyoming Game and Fish Department had worked out a rotenone flow control system using automobile carburetors attached directly to the 55-gallon rotenone barrels (Peterson 1958). The system was very successful for stream flows under 100 cfs, but the Green River Project, with flows ranging from 200 cfs to a potential maximum of 1400 cfs, would require considerably greater rotenone releases than possible with the carburetor controls. In an effort to

3. U.S. Department of Agriculture - Contact Prints, 10"x10", Scale 1"=1667 ft.
4. U.S. Geological Survey Annual Surface Water Supply of the United States, Part 9, Colorado River Basin. Yearbooks for 1947 through 1961.

duplicate, on a larger scale, the constant-flow effect of the carburetor float-chamber, experiments were run with a 3/4 inch float valve in a three gallon bucket. With this system it was possible to maintain a relatively constant rate of flow regardless of any static pressure changes resulting from the liquid level changes in the rotenone barrels. The next problem was the development of a satisfactory system for maximum rotenone dispersal across the stream channels. The major channels, included in the Green River Project, range from 200 to 300 feet in width. In general, water depths are sufficiently great to eliminate any possibility of locating drip barrels in the channels proper. The best alternative appeared to be a plan to mount barrels on the highest available river banks and attach them to a hose line stretched across the stream. Numerous experiments were made with such systems under "laboratory" conditions, to determine the most efficient arrangement. By using 50-foot sections of 3/4 inch, plastic garden hose, it was possible to construct an extremely versatile dispersal line. Valves were coupled between hose sections so as to release liquid at two or three points along the line (Figure 2). Rotenone flow was controlled at the barrels, by a main valve. No attempt was made to control flow measurement from the comparatively inaccessible dispersal valves coupled into the hose line. These were simply adjusted so that all emitted approximately equal flows at intervals along the hose line span.

All preliminary testing of dispersal equipment was done with water, which, having a lower viscosity than emulsifiable rotenone, flows much more rapidly. In order to determine the actual efficiency of the proposed dispersal system as well as rotenone flow rates, rates of rotenone decay, stream current effects, dispersion rates and station spacing, it was felt that a field test with rotenone was necessary. For this purpose it was decided to set up a pilot study section on the Green River proper, about twenty miles below Green River, Wyoming. (Eiserman, 1961)(Stone, 1961). The sites selected were representative of the most difficult river sections from the standpoints of both access and stream conditions. The trial was planned for late August, 1961, when river flow was in excess of 700 cfs. At each station, a wire was sloped from the maximum height of the barrel location to the water's edge at the opposite bank. The wire was stretched taut and supported, at intervals, by steel fenceposts driven into the river bottom. The hose and valve dispersal line was then hung from the wire and bound at close intervals so as to prevent excessive sagging, (Figure 2). The upper treatment station was placed in operation and it soon became apparent that at 700 cfs flow the dispersal system could not apply rotenone at a rate faster than that which would provide a maximum concentration of 3.5 ppm. In order to gain the other information desired from the pilot study the dispersal time was increased to nine hours. The lower station, approximately fourteen miles downstream, was activated six hours after the upper station. In order to check treatment efficiency, live cages containing various sized carp were distributed throughout the 24 miles of the test area. These were placed in locations where it was felt that rotenone might have difficulty reaching. Careful observations were made on these and the general fish kill relative to thoroughness of rotenone dispersion and velocity of rotenone movements. In general, the dispersal systems worked very satisfactorily and produced relatively rapid chemical diffusion. A thorough check of the entire test area including the test fish indicated that the fish kill was nearly complete. This initial indication of success was later substantiated by investigations during the second week of September. The pilot study demonstrated that a practical treatment technique was possible.

In the fall of 1961, it was decided to make comparative tests, under field conditions, of the efficiency of several emulsifiable rotenone products. One of the questions to be answered was the degree to which fairly high water alkalinity might reduce rotenone's distance-length of effectiveness. For this purpose, several test stations, with interspersed cages of live carp, were set up on the Big Sandy River, one of the most alkaline waters to be included in the major project. At that time the stream had a pH of 8.1 to 8.2, total alkalinity of 170 to 240 ppm, and a temperature range of 44 to 56 degrees Fahrenheit. The tests demonstrated that the various chemicals showed no appreciable variations and relatively little loss of efficiency due to alkaline conditions.

For additional information it was decided to repeat some of the tests in the spring of 1962. This was done during the week of May 7, prior to the runoff, with three rotenone treatment stations. To simulate the main project's plan, the stations were set ten miles apart, placed in operation at three-hour intervals, and maintained for six hours duration. Observations made during both series of tests on fish-kill time requirements, indicated that it would be advisable to extend all rotenone introduction periods from six to seven hours.

The Refined Rotenone Introduction System

From the numerous preliminary chemical treatment tests evolved certain basic facts. For a rotenone concentration of 5 ppm, the float-valve system of flow control and the 3/4 inch dispersal line were satisfactory only when river flows were under 500 cfs. As it was felt that the Green River treatment techniques should be capable of handling flow volumes up to 1400 cfs, some refinements of the original dispersal system were necessary. It was suggested that, with the large water volumes, the overall aspects of rotenone introduction were so gross, that extreme exactitude of low measurement was unwarranted.

A series of checks were made of rotenone flow rates from 55-gallon barrels. It was indicated that the variation from initial flow to final flow was insufficiently great to justify the complexities and expense of the float-valve control. It was also determined that replacement of the 3/4 inch hose with a one-inch system made it possible to obtain sufficient rotenone dispersion for the maximum workable stream of 1400 cfs. While there was a good probability that some of the upper river stations would not have stream flows of a volume requiring the one-inch capacity equipment, for the sake of uniformity and interchangeability, the one-inch system was selected for a standard. Basically, the specifications for a typical treatment station required two 55-gallon rotenone barrels to which was coupled a one-inch capacity yoke. The yoke was composed of three valves, a gate valve on each of the two barrel connections, and a gas valve on the main stem (Figure 3). Because the gas valve was adjustable from full open to full close in a quarter turn of its handle, it was ideally suited for fairly exact control of rotenone flow rates. From the yoke, the rotenone was transported across the stream channel by one-inch industrial hose. The hose was purchased in 50-foot lengths with standard pipe couplings attached. A sufficient number of hose sections were coupled together to accommodate each specific stream situation, and two or three 3/4 inch valves were located between sections so as to allow maximum stream coverage. In general, except for increased weight, the hose-line system and installation was basically similar to that previously described. However, two minor modifications were necessitated by the planned use of airboats which do not lend themselves to ready portage. Either the hose line at the station end was sufficiently high to clear an airboat engine or the terminal end was anchored into the stream bed so as to allow a clear channel near the far bank. Secondly, each line was draped with brightly colored markers so that airboat operators could spot them from considerable distances (Figure 4).

General Treatment Plan

With information supplied by U.S. Geological Survey, it was determined that the velocities of all major streams, in September, would be between 1-1/½ miles per hour, even with unseasonable water volumes. This rate estimate was verified by field observations made during the 1961 pilot study. With reasonable assurance that stream velocities would not fall below this range, it was decided, for simplicity, to plan all schedules on the basis of one mile per hour.

If all stations had been placed in operation at consecutive ten-hour time intervals, the entire project treatment time would have exceeded nine days and greatly increased many budgetary, personnel and logistic requirements. By starting stations at consecutive three-hour intervals, total time was reduced to three days, with a minimum possibility of either excessive rotenone overlap or incomplete coverage. Based on a ten-mile space interval, a three-hour starting interval, and a stream velocity of one mile per hour, a complete operational schedule was calculated for the Green River proper. From this it was possible to estimate the approximate locations of rotenone bearing waters at any given time and to coordinate the treatment of tributaries so as to provide a margin of rotenone overlap at all mainstream confluences. All mainstream dispensing stations were located and installed to conform to this schedule.

The installation of station cable lines was started about one month prior to the proposed treatment date. A cable crew of four men could, with extreme effort, sometimes rig three units during daylight hours. Some sites presented special problems that greatly increased time requirements, and many hours were consumed in transporting equipment and personnel.

Aerial reconnaissance and photographs indicated the presence of numerous backwaters and side channels along the entire length of the river proper. Many such areas could receive little or no rotenone from the mainstream. To assure adequate treatment of these, three airboats, (Figure 5), were scheduled to coordinate their activities with the general treatment operations. Because of their shallow draft and high speed, airboats can easily navigate river shoals and bars. Prior to the Green River treatment, airboat personnel made familiarization trips along all mainstream waters. They verified that two-man airboat crews, equipped with supplies of rotenone and back-pack pumping units would have relatively easy access for treatment of all backwater areas on the Green and New Fork Rivers, (Figure 6).

Many sloughs were located adjacent to the mainstream waters - some at considerable distances from the channel. Most have stream flows only during periods of high water and form highly productive brood ponds for carp and other nondesirable fish. It was decided that the most complete and efficient coverage of these sloughs could be made with a helicopter. The Blacks Fork River, some seventy miles of which were scheduled for treatment, often drops from a spring flood of over 1000 cfs to less that 10 cfs. Sometimes these drastic flow-pattern shifts take place within a few hours, leaving great pockets full of nongame fish. Because of the stream's unpredictable fluctuations and lengthy inaccessible reaches, helicopter application seemed to present the best method for obtaining complete treatment coverage (Figure 7).

In order to expedite the operations of both airboat and helicopter units, special crews and vehicles were assigned to service them with gasoline and rotenone.

All past experience indicated that each major station should have a two-man crew on duty during its operation. On the larger stations, the rotenone requirements were sufficiently great to demand almost continuous handling of stockpile barrels. Furthermore, the possibilities of flow stoppages or variations required constant vigilance. A sizeable number of engine-driven and hand-operated pumps were available to assist with rotenone transfer. Each operating station was equipped with a tool kit, first aid kit, snake-bite kit, lantern, rubber gloves and rotenone measuring devices.

Public Relations

Early in the general planning it was agreed that maximum public cooperation would be essential for successful project completion. To advertise the purpose of the project, a series of lectures was given to service clubs, chambers of commerce, and other interested groups. Numerous press releases were prepared by the information divisions of both states, and the Utah Department produced descriptive television material which was channeled in both Utah and Wyoming. Besides innumerable person-to-person contacts with sportsmen and ranchers in general, a special effort was made to obtain the complete cooperation of all landowners on whose property treatment stations were to be located. While much of the land within the project's general scope is in Federal or state ownership, sizeable acreages of private property were also included. To have made personal contact with all the owners would have been almost impossible. However, the names and addresses of all corporate and individual landowners, with stream-adjacent properties, were obtained from the three Wyoming counties involved, and each owner was mailed a brief descriptive notification of the project (Figure 8). All ranchers in Utah and Colorado normally concerned with the bridge across the Green River at the detoxification site were personally contacted and appraised of the project and the necessity for closing the bridge for several days during the operation. There was no dissent encountered.

It seems probable that this sizeable public relations and information program was worth the effort. Despite the fact that dozens of men and vehicles worked night and day on private lands, landowners were helpful and cooperative in the extreme and no unsatisfactory public contacts are known to have occurred.

The Mapping and Final Location of Station Sites

As previously described, all the main streams of the project were arbitrarily divided into ten-mile sections by map and photograph measurement. During the summer of 1962, all thirty-eight station sites on the New Fork, East Fork, Green, Big Sandy, Blacks Fork, and Henry's Fork Rivers were exactly located in the field. Fortunately, access throughout the project area was sufficiently good to allow the stations to be placed very close to the planned ten-mile map points. Several of the station locations were in very rough, remote country, requiring four-wheel drive truck equipment and many hours of travel time. To provide a comprehensive picture of transportation problems, all distances to station sites were measured, timed, and checked for vehicle-type requirements. A list of the highway distances between station access roads was provided to project personnel.

Because much of the project's operation would be at night and most of the participating personnel were totally unfamiliar with the Green River drainage, it was necessary for efficiency and safety, that each individual in supervisory capacity be relatively familiar with the station sites for which he would be responsible. All supervisory personnel were conducted over their assigned areas and familiarized with roads and identifying land marks. As additional guidance aids, large marker arrows were placed at all main turn-off points and questionable junctions. These arrows were painted a bright, fluorescent orange and each had a reflective point to facilitate night work. Each arrow also showed a large, black number corresponding to the number of the station to which it pointed. Further assistance was provided by a field map showing the general location, access, and number for each station. Copies of this map were distributed to all personnel other than the two-man station crews (Figure 9).

Personnel Organization and Servicing Arrangements

On a project of this size, it seemed advisable to organize all personnel on a semi-military plan (Figure 10). Careful timing and coordination were essential in order to have "the assigned people doing the right jobs in the proper places at the scheduled times." The Green River proper was divided into four sections determined largely by general accessibility. Section One included stations 1 through 5 and tributaries; Section Two, stations 6 through 10; Section Three, stations 11 through 16; and Section Four, stations 17 through 22. The stations in each section were placed under the direction of two experienced fisheries biologists assigned as day and night section foremen. Their responsibilities included placement of the two-man station crews on site, initiation of station flows, and maintenance of planned time schedules.

Four assistant field chiefs, two for day and two for night shifts, were assigned over the section foremen in total responsibility. These were experienced fisheries biologists intimately familiar with the entire project area. They were equipped with mobile two-way radio units and their duties related to project coordination, assistance and advice to operating field units, and liaison between field chiefs and all operational activities.

Two field chiefs were in charge of the coordination of project operations. Both men were fisheries biologists with considerable knowledge and experience in stream treatment work and related problems. Their schedule, throughout the project, was divided into 12-hour shifts, during which time each maintained radio contact with the general progress of the treatment program. The field chiefs were prepared to provide trouble-shooting or emergency assistance for any field unit at any time.

The coordination and direction was handled by two operational chiefs, the fisheries management supervisors for the states of Utah and Wyoming. One of these men was to make continual daytime reconnaissance flights over the areas of activity while the other was to maintain surveillance of field activities from an airboat. Their observations were to provide constant checks on treatment progress and effectiveness, as well as an efficient lookout for field problems and trouble spots. Because of the superiority of line of sight, air-to-ground radio communication, the airplane could serve as a mobile relay for ground-to-ground information. The lack of dependability of ground radio communication because of the long distances and rough terrain made this an important consideration.

While many of the vehicles from Utah and Wyoming were equipped with two-way radios, the radio frequencies of the two states are different. For expediency, several Utah radio units were changed to the Wyoming frequency. All supervisory personnel were radio equipped. A portable two-way unit installed in the Wyoming Department airboat, was to provide direct contact with boat and station operations. Several more portable units were to be distributed to the vehicles involved in airboat and helicopter servicing. Commissary trailer units were also equipped with radios to provide centralized communications posts.

Once the scheduled details of the entire operation were formulated, it was possible to prepare manpower rosters and make specific assignments for every job. A descriptive, chronological outline was prepared for all project activities, (Appendix A). Supplementing this were schematic charts of the hour-to-hour responsibilities of all supervisory and supporting personnel, (Appendix B); and a lodging roster covering all personnel assignments, (Appendix C). In addition to these general directions, specific work sheets were prepared for each section chief and each station crew, (Appendix D and E). The sheets described, on an hour-to-hour basis, each individual's duties for the entire project and listed immediate supervisors, special equipment requirements and billeting.

Lodging and eating arrangements were prearranged so that all personnel would be assured of these facilities. As the communities along the Green River are many miles apart, it was necessary to arrange an auxiliary feeding system for men on duty. Two small house trailers were equipped to serve as field commissary units. These, stocked with a variety of soft drinks, coffee, sandwiches and snack material, were assigned parking and travel schedules to keep them continually near the fields of major activity (Appendix F). Each individual was supplied with a copy of the commissary schedule, lodging roster, schematic treatment outline and his individual work schedule.

As there seemed little doubt that many trout would be killed throughout the upper sixty miles of the treatment area, two crews were assigned to salvage these fish. Each crew was to be equipped with a truck supplied with a sizeable quantity of dry ice and scheduled to generally follow the center of activity and retrieve as many fish as possible. Once loaded to icing capacity, salvage units were to transport their fish to refrigeration facilities at the state fish rearing station at Boulder for storage until distribution to public and charitable agencies could be effected. For general public relations purposes and maximum fish utilization, all creel limits in the treatment area were lifted prior to the treatment program.

There are several communities of varying size along the treated reaches of the Green River. As there seemed to be some possibility of dead-fish nuisance problem at these points, one crew of men was assigned the responsibility of dead-fish removal if the circumstances dictated.

The Wyoming communities of Fontenelle, Green River and Rock Springs and the Utah community of Dutch John all obtain their municipal water supplies from within the treatment area of the Green River. For this reason, it was mandatory to obtain project clearance from the Wyoming Department of Environmental Health, the Utah State Department of Public Health and the U.S. Public Health Service. These agencies not only provided the necessary clearance but also valuable assistance in directing coordinated water supply manipulations and auxiliary treatments for taste and odor control. The U.S. Public Health Service personnel were to maintain water quality checks on municipal water supplies during periods of maximum rotenone concentrations past supply intakes. A brief summary of the U.S. Public Health Service activities as part of this project is included as Addendum 1.

The Final Details

As previously described, a general estimate of rotenone requirements was made for every station of the project. Throughout the summer of 1962 checks at U.S. Geological Survey gauging stations provided current information on stream-flow developments, and, by the latter part of August it was possible to make a reasonably exact estimate of the maximum rotenone gallonage for every station. Based on this information, the total rotenone requirement for each station was calculated in 30 and 55 gallon barrel combinations. Because of possible vandalism, station stockpiles were not set out until the week prior to the treatment, during which time they were under continual surveillance.

Immediately prior to the start of treatment on September 2 and 3, a final series of water-flow checks were made at all Government gauging stations. Where no permanent gauging equipment was available, last minute recordings were made with a portable flow meter. Based on these data, final rotenone flow figures were calculated for every toxicant dispensing station on the project and distributed to respective personnel (Appendix G and H).

Review Of Operation

At 0800 on September 4, 1962, the number one stations on the New Fork and Green Rivers were placed in operation. Thereafter, chemical treatment continued uninterrupted until its completion on the morning of September 7.

On September 9, because observations indicated some live fish were still present, particularly in off-channel slough areas, the uppermost ten miles of the New Fork River treatment area were retreated. No unforeseen or unmanageable problems developed relative to operational techniques; and personnel and equipment functioned more efficiently that anticipated.

During treatment, the Utah Department was prepared to carry out a detoxification program to protect native fish species in the river reaches below the Flaming Gorge Dam. While the detoxification, per se, was effective, the available supply of rotenone neutralizer was insufficient to meet total neutralizing requirements. As the problem related directly to upstream rotenone concentrations, probable causative factors should be reviewed.

It has been pointed out that final water-flow readings were taken just prior to the start of treatment. These readings were made directly from the U.S. Geological Survey gauges. At almost all these stations there is a percentage of error between the gauge reading and the actual measured flow as periodically determined by Survey personnel. This error may vary considerably according to water conditions and may be either plus or minus. When the final flows were read for the Green River Project an estimated error, based on past data, was applied to the gauge readings. Subsequent comparison, however, has revealed that these estimated final flows were still greater than the actual river volume (Table 1).

In addition, the mainstream volumes dropped considerably during the treatment period with the result that stream flows on the third day, September 6, were actually 19 to 24 percent lower than originally calculated. Both of these variations were complementary and the increased rotenone concentrations complicated detoxification. It is suggested that where a detoxification program is planned, relatively exact flow figures must be calculated during each day of rotenone treatment.

One additional suggestion for better rotenone control would be a maximum refinement of aerial application systems. With the helicopter employed on the Green River Project, rotenone release control was inadequate resulting in excessive concentrations for such waters as the Blacks Fork River and an additional possible source of complication for detoxification facilities.

A total of 21,495 gallons of Chem Fish Regular was used on the project. This material was purchased from the Chemical Insecticide Corporation, Metuchen, New Jersey, at a total cost of $76,307.25.

Table 1 Green River Flows Estimated From Gauge Readings Compared With Actual Stream Flows Occurring During Treatment, and the Effect on Concentrations of Rotenone Introduced

Treatment Station	Stream-Flow Estimates Prior To Treatment (cfs)	Actual Stream Flows Occuring During Treatment (approx. cfs)	Planned Rotenone Concentrations (ppm)	Rotenone Concentrations Based On Corrected Stream-Flow Data And Actual Rotenone Gallonage Introduced (ppm)
NF #1	300	176	5	9.4
NF #2	350	224	5	7.8
GR #1	450	352	5	6.4
GR #2	475	377	5	6.3
GR #3	825	601	5	7.1
GR #4	899	644	5	7.3
GR #5	899	644	5	7.0
GR #6	899	700	5	7.1
GR #7	944	717	5	7.3
GR #8	944	718	5	7.3
GR #9	944	718	5	6.8
GR #10	944	718	5	6.8
GR #11	977	763	5	7.2
GR #12	977	763	5	7.5
GR #13	977	774	5	6.7
GR #14	977	774	5	6.3
GR #15	977	774	5	6.7
GR #16	977	774	5	6.7
GR #17	999	810	4.5	6.0
GR #18	999	810	4	4.8
GR #19	999	800	4	5.3
GR #20	1038	790	4	5.4
GR #21	1038	790	4	5.8
GR #22	1038	790	2	2.5

EVALUATION OF TREATMENT EFFICIENCY

The rotenone treatment project planned for the Green River was of such a scope as to present many unknowns relative to treatment effectiveness, post treatment re-entry of fish species, and decimation and recovery of invertebrate populations. The size of the treatment area, and the wide variety of stream conditions involved, indicated that post-treatment developments on other projects might be different from those on the Green River. Accordingly, under authorization of the Federal Aid to Fisheries Act (DJ F-25-R-2), the Wyoming Department initiated, in June of 1962, a detailed program of stream fauna investigations. From June until the start of the rehabilitation in September, numerous invertebrate and fish collections were made throughout the upstream 130 miles of the Green River treatment area and the entire treatment area of the New Fork River. The data from these initial collections are providing a set of comparative standards for continuing month to month investigations of post-treatment developments. During the operation, information was gathered on chronology of treatment, water chemistry, water temperatures, rotenone concentrations developed in the river, completeness of the fish kill, and species of fish killed.

To aid in establishing the chronology of toxication, live cages containing fingerling carp were placed in the Green and New Fork Rivers two to three days prior to the introduction of rotenone on September 4. Each station, with the exceptions of numbers 12 and 15 where no cages were placed, had at least two such cages located on its upstream side. One cage was set in the shallows and the second as far out in the river as depth and current would permit. In some cases current deflectors were constructed of flat rocks. The live cages were checked prior to treatment to assure the survival of their contents and rechecked, during treatment, as often as possible. Additional data relating to rotenone movement was based on direct observation.

The rotenone concentrations of the river water were measured by a colorimetric rotenone test (Post, 1955) and by field and laboratory bio-assay. The water samples designated for laboratory bio-assay were packed in ice and taken to Green River, Wyoming, where the U.S. Public Health Service made the analysis.

Field bio-assay work was carried out using a method similar to that described in the 11th edition of Standard Methods for the Examination of Water and Waste Water, 1960. The procedures and experimental conditions, as described, were followed as closely as was possible under field conditions. A shortage of test fish limited the field bio-assay work to one series of determinations made at a point three-fourths of a mile downstream from Green River Station 1, on September 4, 1962. Test fish used were fingerling carp which had been acclimated to the river water for 24 hours prior to use. The uncontaminated water used in the bio-assay work was taken from the river immediately prior to treatment and stored in milk cans. The test containers were four-quart polyethylene buckets, each containing five fish and placed in the river to minimize temperature fluctuations in the water being tested. The time required for all five fish in a test container to lose equilibrium was used as a measure of toxicity. One test container was set up as a control and no mortality was noted. The graphical curve from which estimates of the rotenone concentration in the river were made, was determined from data obtained simultaneously with the checks on the contaminated river water.

The field water chemistry checks were made according to standard methods. The measurements recorded included pH, methyl orange alkalinity, and temperature. The temperature was recorded with a pocket thermometer to the nearest degree Fahrenheit.

The effectiveness of the river treatment on eliminating fish populations was checked by spot rotenone application, gill netting, dynamiting, and direct observation. Rotenone was used only in the sloughs and backwaters to avoid any possible influence on the invertebrate sampling stations. The gill nets were set overnight or floated through deep areas in the river.

Follow-up checks on the effects of the toxicant on invertebrate populations were made by weekly sampling at nine permanent sample stations. Sampling stations were located on the river between treatment stations 1 and 14 (Figure 9). Samples were collected with a Surber square-foot bottom sampler and a square-foot drift net.

The results of rotenone concentration checks by field bio-assay, three-fourths of a mile below Green River Station 1, are shown in Table 2. The data show that the concentration of rotenone in the river at the bio-assay station varied throughout the day. This conclusion was substantiated by observation of the color of the river water which varied from milky white to light green, depending on the rotenone concentration. The higher readings were obtained from water with a milky color. A visual check of the river, immediately above the bio-assay station, revealed that the water near the west bank was a strong milky color, indicating that most of the chemical was moving downstream in a mass near this bank. However, a sufficient amount of rotenone was present along the east bank at the same time to produce a concentration of 5.5 ppm.

The predicted arrival time of rotenone at each station (Table 3) was calculated from an estimated stream velocity of 1 mph and river mileages obtained from aerial photograph and topographical map measurements. The data show that above Station 9 the rotenone was usually on schedule, indicating a fairly uniform stream velocity above this point. Below Station 9 the rate of rotenone movement was more rapid and irregular ranging up to three and three-fourths hours ahead of schedule.

The rotenone front on the New Fork River appeared to move downstream more slowly. It was observed to be about four miles above New Fork Station 2 at 1900 hours and the predicted time of arrival at this station was 1800 hours. Because the rotenone did not arrive at New Fork Station 2 until late on September 4th or early on September 5th , and because the rotenone flow from Station 2 was shut off at 1800 hours, there may have been a zone of untreated water moving down the New Fork River. Immediately prior to and for a short time following passage of the rotenone front at any given point, large schools of fish, especially suckers and carp, could be seen moving downstream ahead of the rotenone. The front of the rotenone was characterized by a few, then many, fish thrashing about and struggling for air on the surface of the river with whitefish usually being the first to show signs of distress.

Table 2. Rotenone Concentrations Three-Fourths of a Mile Below Green River Station #1 as Determined By Field Bio-Assay on September 4, 1962.

SAMPLE	CHANNEL	TIME TAKEN	CONCENTRATION P.P.M. (Formulation)
1	west	1035	3.9
2	west	1100	4.4
3	west	1215	6.8
4	east	1245	5.5
5	east	1328	6.5
6	west	1328	7.3
7	west	1426	4.5
8	east	1435	6.5

Table 3. Predicted and Observed Times of Arrival of Rotenone at Various Points, and Results of Live Car Checks Made Soon After Toxicant Arrival.

Green River Station	Date	Predicted Arrival Time Of Rotenone Based On Constant Flow of 1 MPH	Observed Arrival Time Of Rotenone	Time Of Live Car Check	Observations Made
3	Sept.4	2100	2015	2115	Test Fish in good shape
3	Sept.5			1145	All test fish dead
7	Sept.5	0900	0930		
8	Sept.5	1200		1100	Test fish in distress
9	Sept.5	1500	1530	1700	Test fish dead
10	Sept.5	1800	1415	1500	Test fish still alive
11	Sept.5	2100	1730	2030	Test fish show distress
13	Sept.6	0300	0130	0300	All test fish dead or in distress
16	Sept.6	1200	1000	1100	Test fish dead or dying
17	Sept.6	1500	1330	1200	Test fish still alive
18	Sept.6	1800	1600	1700	Test fish very weak, river fish dying
19	Sept.6	2100		2000	Test fish alive but beginning to show signs of toxicant
20	Sept.6	2400	2125	2230	Test fish near death
Detox. Station	Sept.8	0630	0615		

The survival time of the small carp in the live cages varied from one to four hours after initial rotenone contact. These differences may have been due to variations in the strength of rotenone fronts moving from station to station. In other words, fish at one location may have been exposed to an initial contact of relatively high concentration while fish at another location may not have been exposed to an equivalent concentration until sometime after initial contact was made. Differences in resistability of test fish might also account for some of the variations in mortality-time requirements. All test fish, except the control fish above Green River Station 1, were dead when the live cages were removed from the river after the treatment.

The chemistry of the river changed as the river water flowed downstream through strata with different chemical and physical characteristics, and most of the maximums for the various measurements were recorded from the lower river. Except for the water temperatures recorded during the treatment, no water chemistry data was obtained below Station 14. Minimum-maximum water temperatures recorded during the treatment were 52° and 64° Fahrenheit, respectively. Daytime water temperatures in the lower river section ranged from 65° to 67° Fahrenheit. Temperatures taken one week before treatment ranged from 50° to 61° Fahrenheit while the range of temperatures taken one week after treatment was from 52° to 61° Fahrenheit. Methyl orange alkalinity, measured as ppm $CaCO_3$, showed a gradual increase with time and progression downstream. Over the three-week period, minimum readings went from 91 ppm to 100 ppm while the maximum readings changed from 135 ppm to 142 ppm.

The pH of the river varied from 7.8 to 8.6 during the three-week period. Minor increases in pH with the time were noted at several different points on the river, but much of the variation was due to the location of the checking point on the river. There was no evidence to indicate that the water chemistry was affected by the treatment.

A tentative checklist of fishes killed during the treatment is presented in Table 4. Mountain whitefish, Coregonius williamsoni and flannelmouth suckers, Catostomus latipinnis, were the predominant species of fish in the river. The whitefish were most abundant in the upper sections of the river, especially in the New Fork River, while the suckers were predominant below Green River City.

In addition, a two-man crew traveled down the river from drip stations 19 and 21 with the toxicant front. Other areas searched included Hideout Canyon, the damsite, Little Hole, and the upper portions of Brown's Park. Trout were found to be extremely infrequent in the Green River above the dam and totally lacking below. The few observed above the dam are thought to be recruitment from treatment of tributary streams and from natural movement of the fish down the tributaries into the Green River. Five squawfish were taken during the work. No squawfish were found above the dam diversion tunnel. The bonytail or Colorado chub, Gila robusta, was numerous but no humpback chub, Gila cypha, were collected.

In order to obtain an estimate of the number and weight of fish killed per unit of stream, a crew of four men was assigned to make spot counts and measurements of dead fish as the rotenone moved downstream. This plan was abandoned during the first day when the salvage activities of the multitude of onlookers made it impossible to get unbiased samples, and no estimate of fish production in the river was obtained. A large number of fish

Table 4 Checklist of Fishes Killed During The Treatment of the Green River, September, 1962, in Order of Apparent Abundance.

SPECIES

Flannelmouth sucker - *Catostomus latipinnis*

Mountain Whitefish - *Prosopium williamsoni*

Bonytail chub - *Gila robusta*

Redside shiner - *Richardsonius balteatus*

Speckled dace - *Rhinichthys osculus*

Mottled sculpin - *Cottus bairdi*

Bluehead sucker - *Pantosteus delphinus*

Carp - *Cyprinus carpio*

Brown trout - *Salmo trutta*

Rainbow trout - *Salmo gairdneri*

Cutthroat trout - *Salmo clarki*

Hybrid trout - *Salmo clarki* x *Salmo gairdneri*

Fathead minnow - *Pimephales promelas*

Utah sucker - *Catostomus ardens*

Channel catfish - *Ictalurus punctatus*

Colorado squawfish - *Ptychocheilus lucius*

Humpback sucker - *Xyrauchen texanus*

of all species and sizes were salvaged along the entire river by the public for use as bait or food. At no time did a buildup of fish produce a nuisance problem.

Post-Treatment Investigations

In the six months following treatment, an attempt was made to determine the exact extent of fish reduction. Fish population checks were made with gill nets and rotenone as long as weather and ice conditions permitted. Subsequent winter investigations were made with dynamite. Overnight gill net sets were made in the numerous locations yielding fish prior to treatment. After treatment no fish were taken in the sets below Big Piney, and whitefish were the only species caught above that point. The whitefish were probably downstream migrants from untreated waters. In October small unidentified fish, probably cyprinids, were seen approximately six miles below Green River Station 1. In November, additional unidentified fish were seen in the New Fork River between Stations 1 and 2, and two redside shiners were captured with a handnet in a backwater below Station 2. In addition, rotenone spot checks in the upper treatment area revealed the presence of numerous suckers and cyprinid fry and fingerling in some of the small backwaters.

In October rotenone spot checks were made on the disconnected sloughs and backwaters along the New Fork drainage where small carp were found prior to treatment. Numerous fish, including trout and carp, were still present in some of the sloughs sampled. A single brown trout and a few dozen sucker fry were found in a small, side-channel dam about ten miles below New Fork Station 1. The fry were probably newly hatched and the larger fish may well have been downstream migrants. Water temperatures in the sloughs were in the low forties when the fish were discovered and retreatment at that time was deferred until the spring of 1963.

Sampling by underwater dynamite detonation was initiated in late November when ice conditions precluded the effective use of gill nets. As of April 1, 1963 a comprehensive dynamite sampling program on all main stream waters has produced only a few whitefish in the upper treated area. From September 20, 1962 to November 28, 1962 Petroleum Geophysical Company of Denver, Colorado carried on intensive seismographic survey operations on the Green River. From the town of Green River, Wyoming to a point about three miles downstream from the Utah-Wyoming state line, 275 underwater detonations at one-fourth mile intervals, using high velocity 40-60 percent nitroglycerine explosive, were made. All "shots" were made in the Green River proper at water depths of from two to six feet. During the period of these seismographic operations, the river water was clear and visibility was excellent. Petroleum Geophysical Corporation reported that no fish were observed in this section of the river.

Comparative observations, before and after treatment, indicate almost total destruction of the aquatic invertebrate fauna present in the river prior to treatment. The pretreatment aquatic invertebrate fauna included the following forms: Hydracarina, Gastropoda, Annelida, Nematoda, Diptera, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Hemiptera, Odonata, and Lepidoptera. Representatives of all of these groups, except Lepidoptera, have been found in invertebrate collections made since the treatment, but as of March 1 none of the forms had regained their former distribution in the river. It is planned to continue fish and invertebrate population studies in order to establish the rate and degree of recovery of river fauna.

Figure 2. Rotenone hose line as constructed for pilot treatment, August, 1961. Note gate valves placed in line dispensing the chemical.

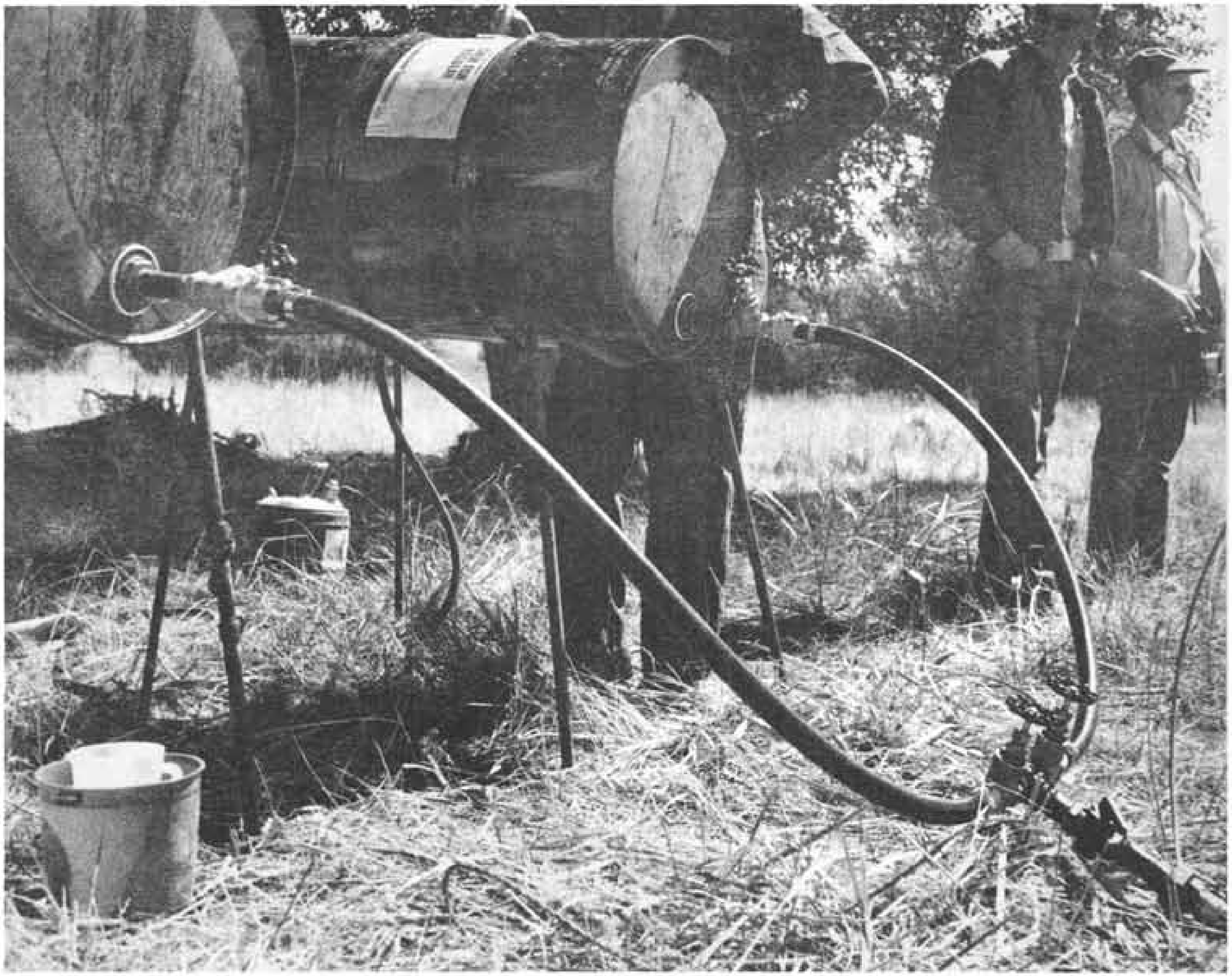


Figure 3. Refined plumbing system used to carry chemical from the barrels to hose extending across the river. Gate valves control flow of toxicant from the barrels while the gas valve controls amount sent to the river.

Figure 4. View of a drip station located on the upper reaches of the Green River. Notice hose line across river is flagged for easy visibility. Boats can pass under hose on the near side.

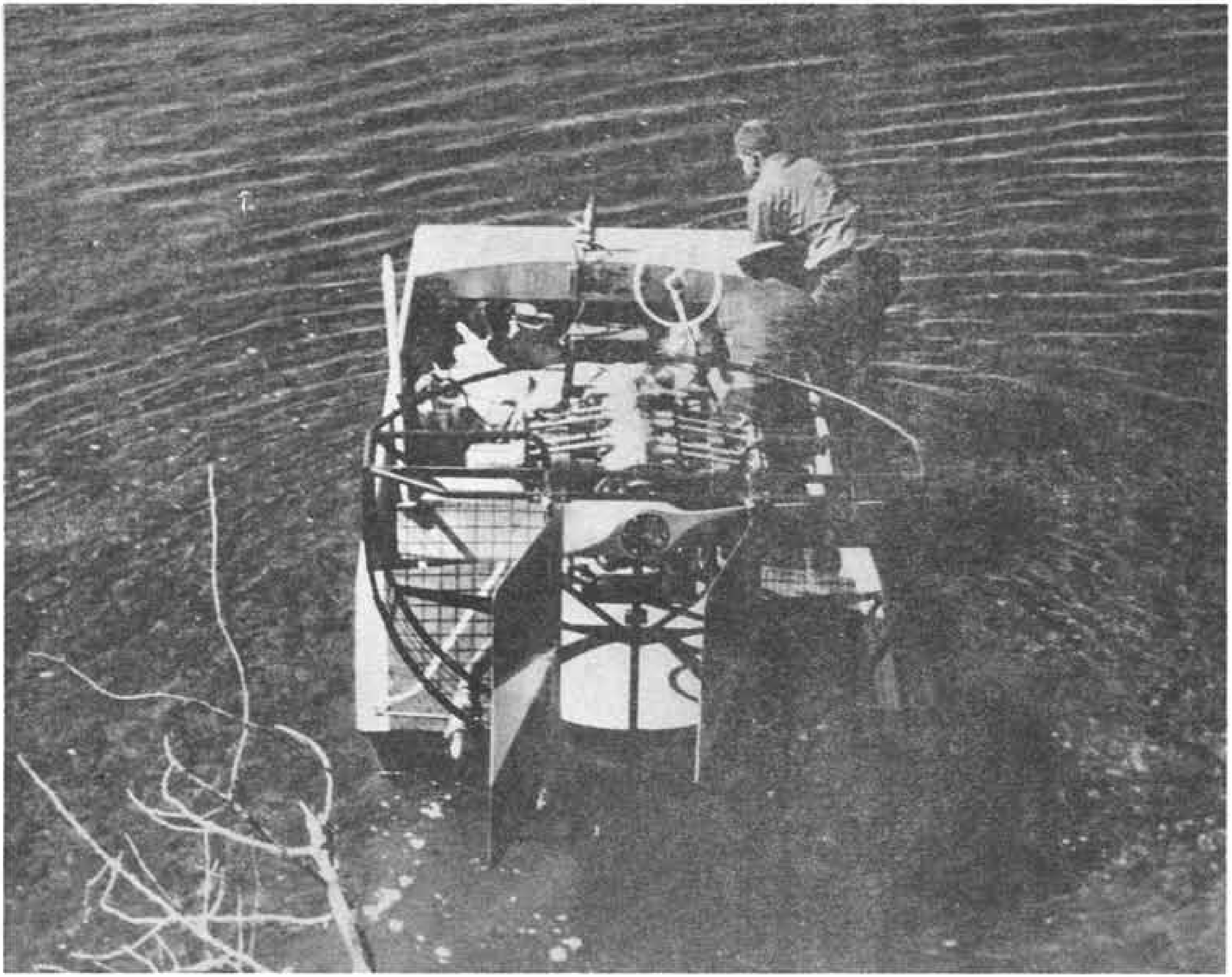


Figure 5. An air-thrust boat used on the project. The motor is a light aircraft engine mounted above the boat's stern.

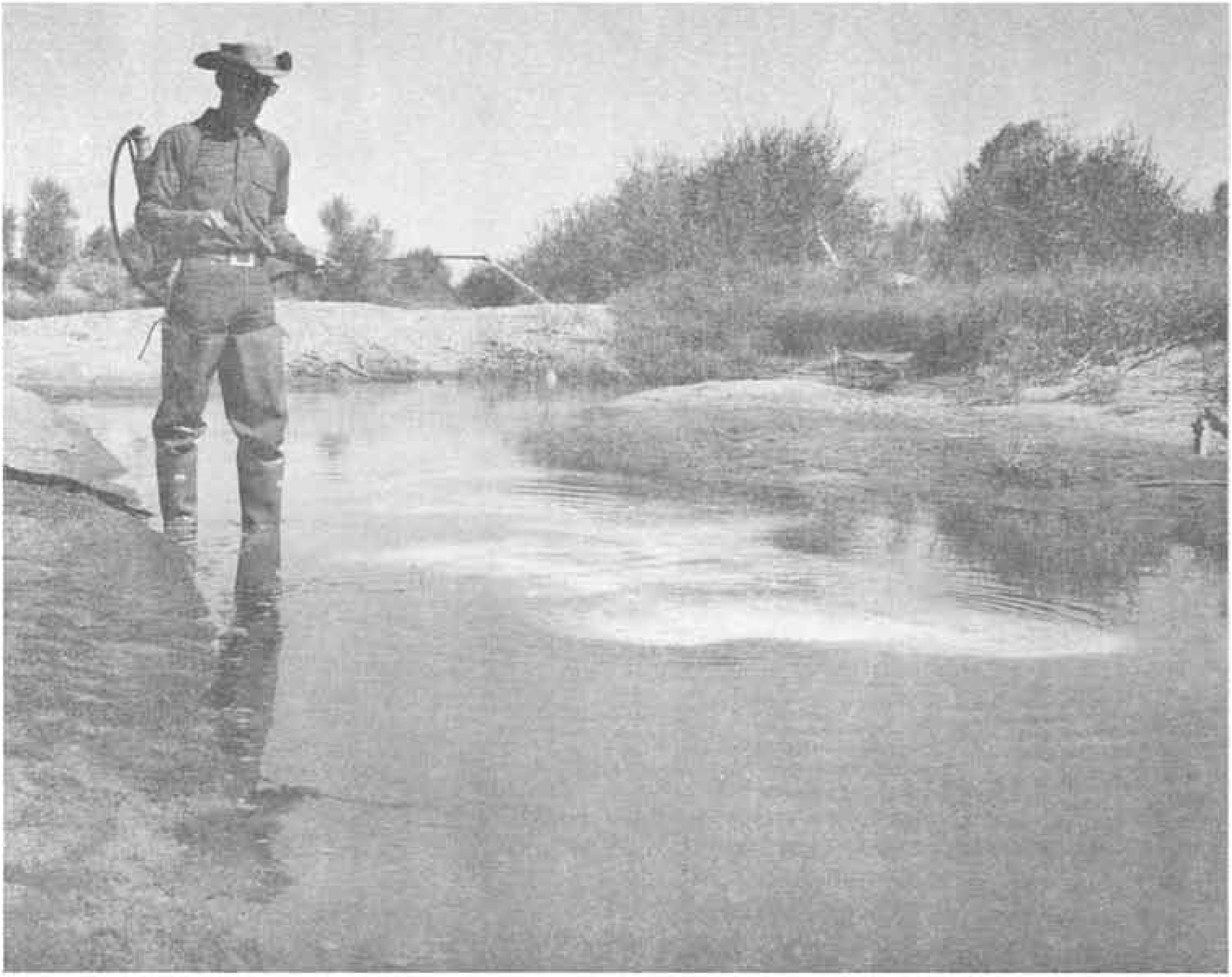


Figure 6. Hand back pumps were used by airboat personnel to treat long bays and side channels.

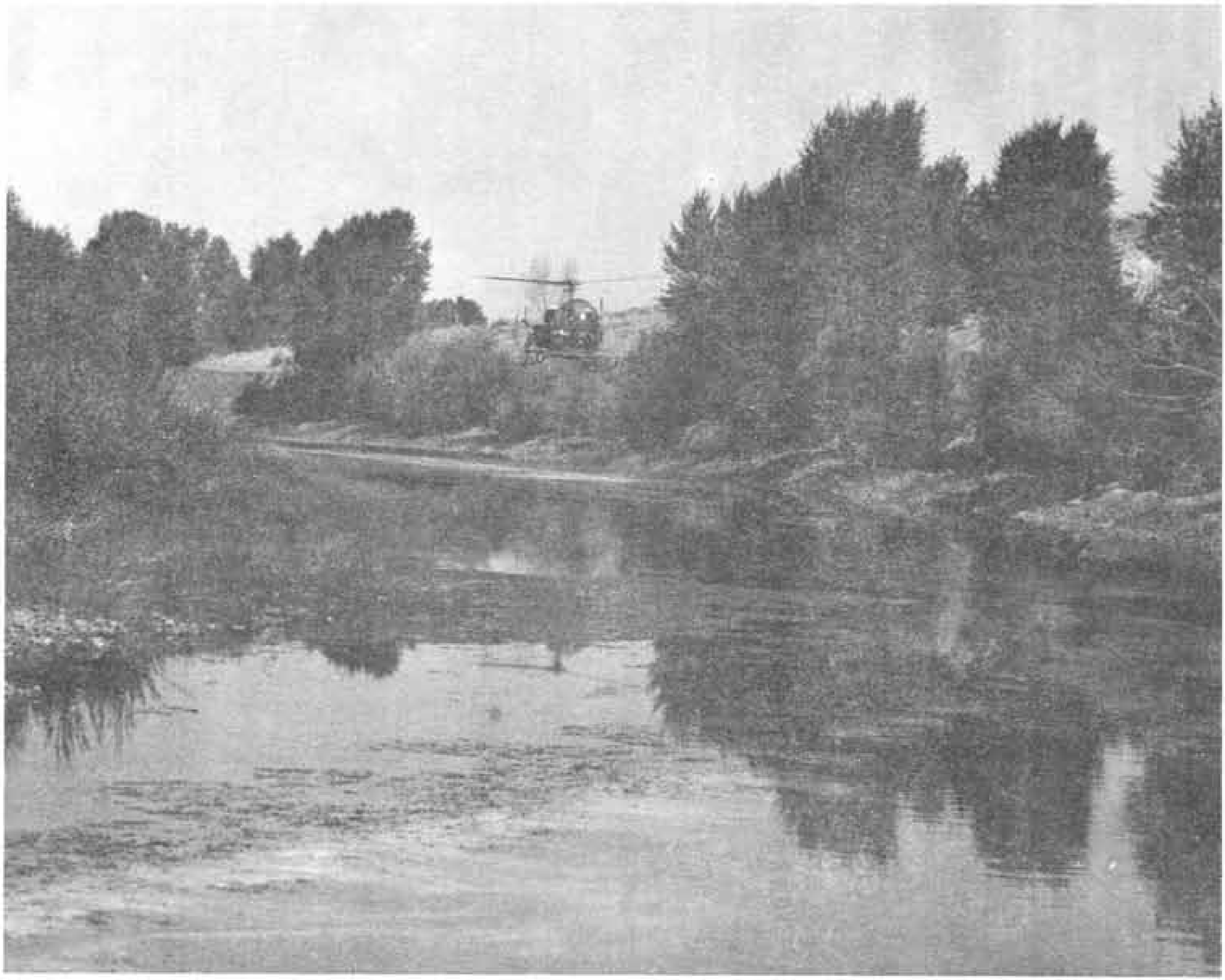


Figure 7. Helicopter spraying a river oxbow which is isolated from the main channel.

DR. O. R. DOCEKAL, Sheridan
GARL RIGGAN, Jackson
J. E. ACKERMAN, Upton
LEO D. RHODES, Tensleep
CYRIL D. CRANNEY, Afton

State of Wyoming

JAS. B. WHITE
Game Warden
FRED R. BEAL
Fish Warden
PHIL F. LESLIE
Chief Clerk
CHARLES R. RODERMEL
Chief I. & E.
CHESTER C. ANDERSON
Chief Technical
Service Division

JACK R. GAGE, Acting Governor
R. W. SPRATT, Pres., Lost Cabin JAMES F. POWERS, Vice Pres., Cheyenne
S. J. JIACOLETTI, State Game and Fish Commissioner

GAME AND FISH COMMISSION
CHEYENNE

June 20, 1962

TO WHOM IT MAY CONCERN:

The presence of the Fontenelle (Seedskadee) and Ashley (Flaming Gorge) reservoirs on the Green River will greatly increase the breeding and habitat areas suitable for undesirable species of fish such as carp and suckers. In order to preserve existing trout fishing waters above the Ashley Reservoir, the Game and Fish Departments of the states of Wyoming and Utah plan to chemically treat the Green River drainage from Sommers Bridge, near Pinedale, downstream to the Ashley dam site in Utah. The project will also include large parts of the lower sections of the New Fork, Big Sandy, Black's Fork, and Henry's Fork rivers, as well as the lower mile or two of each of the other main tributaries entering the river below the initial starting point.

The chemical to be used is rotenone which suffocates fish but is harmless to humans and all non-gillbreathing animals. The rotenone, in liquid form, will be introduced into the waters to be treated at ten-mile intervals. According to the present time schedule the treatment program will be carried out in September of this year.

As county records indicate that certain of the waters to be treated may come in contact with lands under your ownership or management, the Game and Fish Department wishes to notify you of the project so that you may have ample time to contact Department personnel concerning any questions you may have. Information may be obtained by writing or calling either the State Fish Warden or Fisheries Management Crew No. 4. The addresses and telephone numbers are as follows:

Fred R. Beal, State Fish Warden, Box 378, Cheyenne, Wyoming. Phone 634-2711, Ext. 254.

Fisheries Management Crew No. 4, Box 457, Pinedale, Wyoming. Phone 367-4612 or 367-2254.

Sincerely,

S. J. Jiacoletti
S. J Jiacoletti
State Game & Fish Commissioner

SJJ/FWJ/pw

Figure 8. Letter of notification of the project which was sent to all landholders along the treatment route.

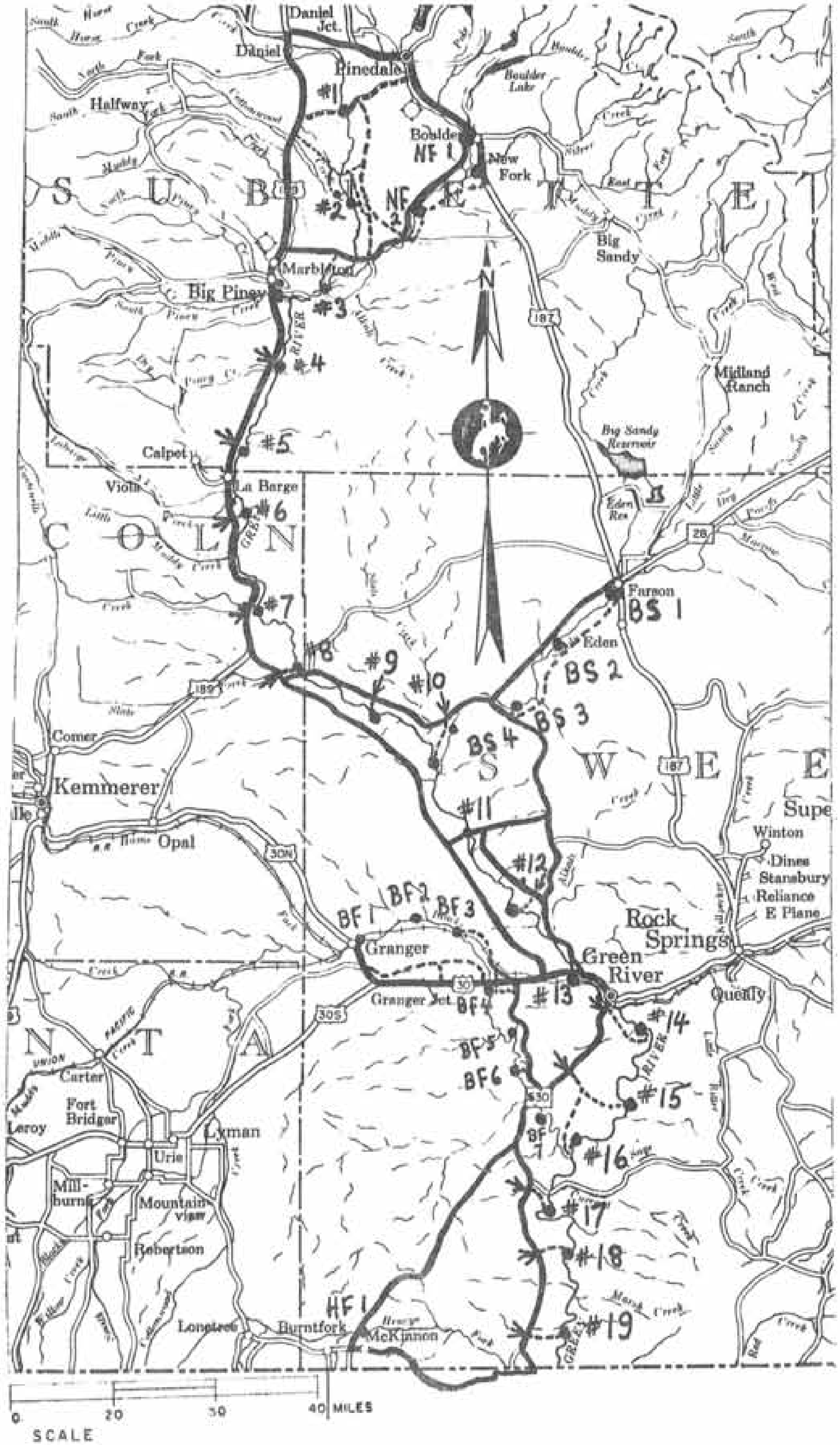
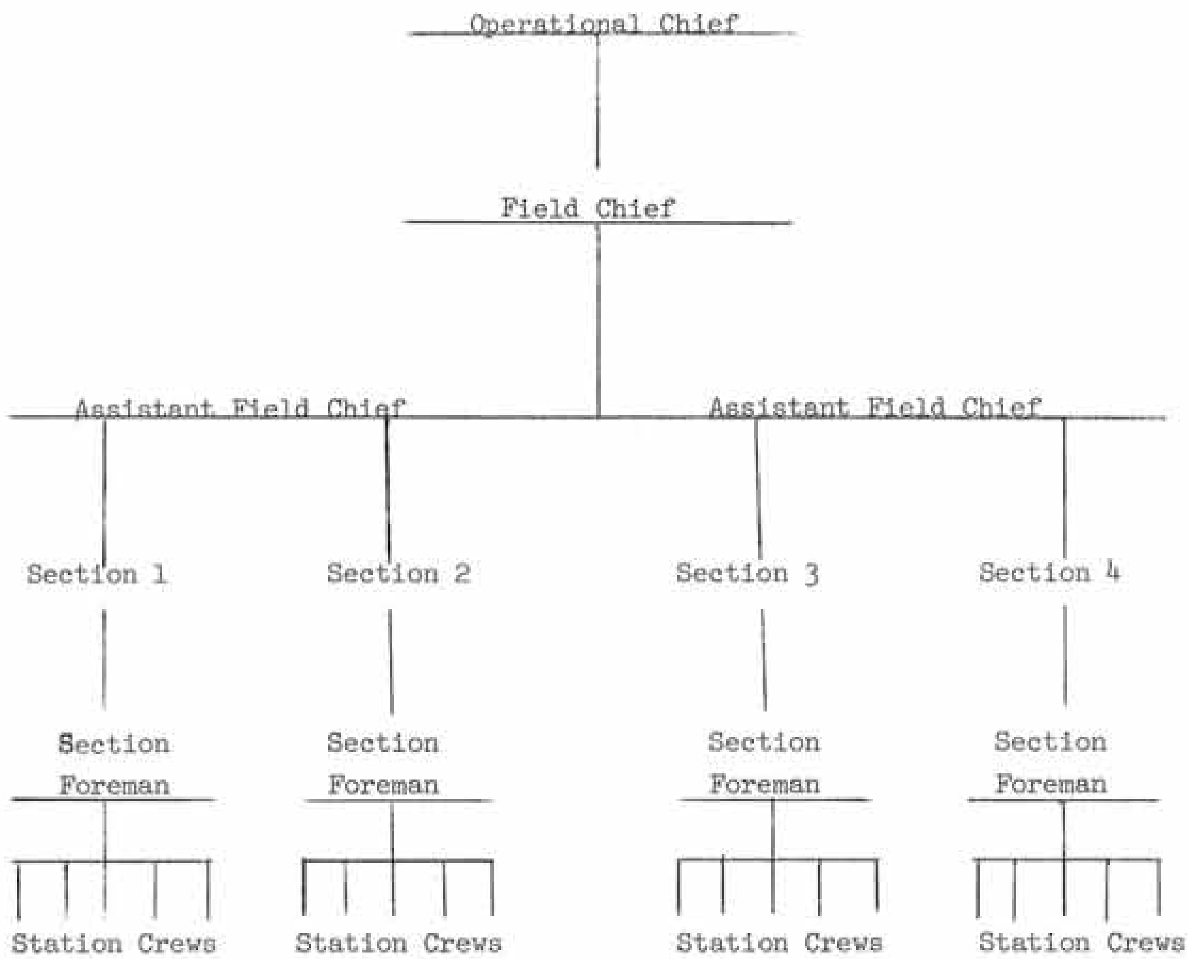


Figure 9. Map given to all station crews showing the drip station locations, and main (________) and side (----------) roads or trails.

FIGURE 10. LINE OF RESPONSIBILITY FOR RIVER TREATMENT OPERATIONS



DETOXIFICATION

Preliminary Considerations

It was known that rotenone detoxification, at least on a small scale, was possible. Jackson (19--) found that rotenone could be neutralized by introducing strong oxidizing chemicals to the water. The technique was successful when either potassium permanganate ($KMnO_4$) or active chlorine were added in amounts equal to the rotenone formulation plus the chlorine demand of the water. Post (1958) experimented with $KMnO_4$ in water possessing chemical properties similar to those of the Green. He found that in both the laboratory and small creeks [1] permanganate would detoxify rotenone if applied at roughly twice the amount of the toxicant formulation. At a temperature of 50° F., the reaction time necessary for this change was about 30 minutes. Potassium permanganate in quantities less than 3.5-4 ppm was not toxic to trout in these waters.

It was apparent that before a large-scale detoxification could be attempted several questions had to be answered. Investigations to provide answers began soon after the decision to detoxify was made.

Natural Breakdown of Rotenone

Literature gives few accounts of the natural dissipation time of rotenone under known conditions. However, some data has been accumulated which can be used as a guide for western waters. Post (1956) performed tests at different temperatures and pH values in natural waters similar to the Green. One part per million of rotenone broke down as follows: 78.5 F. - 42 hours; 64° F. - 3 days; 44.5° F. - 20 days. [2] Laboratory work could not be directly extrapolated to a river environment. Therefore, the major information used to determine an expected decay rate was drawn from the Green River pilot treatment of August, 1961. The 3.5 ppm introduced in this operation produced some fish kill for a distance of almost fifty miles. The rate of breakdown over the complete course was, then, very near 16 river miles for one part per million of rotenone formulation.

Location of Detoxification Site

The Green River below the damsite generally takes the form of a turbid, moderately fast river with large areas of sandy, moving bottom. Turbidity is usually so great that wading in more than one or two feet of water is possible only by feel. Water velocity is about two feet per second. In most places the river bed is over 300 feet in width. It was anticipated that at the time of treatment, flows of 1800 cfs were likely to occur in the detoxification area. The constantly moving bottom would preclude building catwalks or other extensive structures into the river. The long distance from bank to bank would make difficult the suspension of overhead cables. In addition, such an operation demanded that the station be accessible to loaded trucks and other heavy equipment. These restrictions meant that only a limited number of points on the river could be seriously considered for construction of the necessary apparatus. Figure 11 shows the general areas that were considered for location of the station.

1. Personal Communication
2. Values are for the commercial formulation used on the project.

A major consideration in the placement of the neutralization station was the amount and duration of rotenone that would be present at any location below the dam. Ideally, the detoxification station should be situated as close upstream as possible to the area to be spared. This would accomplish both protection of the area and allow for maximum natural breakdown of the toxicant. When a natural rotenone breakdown rate was established, the quantities of neutralizer needed at all the accessible sites were computed. The amount of neutralizer needed and the probable hours of application are shown in Table 5.

Table 5. Amounts of Potassium Permanganate Needed To Detoxify The Green River At Several Potential Detoxification Sites. Amounts Calculated at 1:2.3 ratio And A Natural Decay Rate of 1 ppm Rotenone per Sixteen River Miles.

Site	Pounds of $KMnO_4$ Required	Hours of Operation
Little Hole	49,390	45
Taylor Flat	31,960	31
Sears Creek	22,080	28
Brown's Park Bridge	14,060	21

Brown's Park Bridge, finally chosen for the detoxification site, is located 31 river miles below the dam and some 16 miles above Dinosaur National Monument. The distance below the dam insured that much of the toxicant introduced would have decayed. Since cold, well aerated water released from the dam would make the river below the reservoir optimum trout habitat, chemical treatment of this portion was desirable. After passing under the bridge, water would not enter the Monument for about 16 hours providing ample contact time between toxicant and neutralizer. The bridge made a convenient platform from which to work. A wooden suspension bridge, it had no superstructure below to interfere with application of the chemical. The river narrowed to a width of about 245 feet and coursed between vertical rock walls from which the bridge extended. The bridge was approximately 35 feet above the water and river depth was between three and six feet. There were several additional access sites immediately above and below the bridge which presented adequate space for detoxification evaluation and monitoring procedures.

Two alternative sites were considered at Taylor Flat and Sears Creek; 14 miles and 8 miles, respectively, above Brown's Park Bridge. This short distance made considerable difference in the amount of neutralizer that would have to be handled. Neither site was located far enough upriver to significantly reduce fish loss below the dam. A third alternate, Little Hole, was considered early in the study because it had the shortest access route and was situated only seven miles below the dam. However, it was rejected when the excessive amounts of chemical necessary for detoxification were known.

Selection Of The Neutralizing Chemical

Chlorine releasing products such as calcium hypochloride or lime; chlorine itself; or an oxidizing agent (potassium permanganate) have been recommended for field neutralization of rotenone products. The decision to use $KMnO_4$ resulted from investigation of the physical characteristics of each chemical and consideration of each in reference to application methods. Several characteristics of $KMnO_4$ indicated that it was best suited for use on the Green River.

Potassium permanganate was available in U.S.P. or technical grades as 99 per cent active ingredient. Three crystal size classifications were offered. The largest crystal was specified as staying on a 30 mesh and passing through a 4 mesh screen. This product had by far the most variation in crystal size. The medium crystal was of technical grade and appeared to have little size variation. The fine crystal all passed through 30 mesh.

The best chlorine source was calcium hypochloride. This product is used in most culinary water treatment facilities, and available in tablet or granular form. According to prices quoted by the various chemical companies, calcium hypochloride was less expensive per unit weight. However, active chlorine constituted only 70% of the hypochloride. A cost analysis showed the hypochloride to be more expensive in actual field use than potassium permanganate.

It has been fairly well established at what concentrations $KMnO_4$ itself is toxic. No mention was found in water quality literature dealing with toxicology of the materials formed by oxidation of $KMnO_4$ in the amounts that would be used in this project as being harmful to aquatic life. Experience with chlorine in culinary water treatment and from knowledge obtained in the literature led us to believe that its toxicity and residual powers were significantly more powerful than that of potassium permanganate. Since we expected occasions when the amounts of rotenone to be detoxified would reach or slightly exceed 1 ppm; a danger existed to fish, aquatic organisms, and even to personnel if the hypochloride was used.

In the available literature, lime as a source of chlorine is recommended for large field detoxification operations because it can be applied dry whereas $KMnO_4$ has been introduced in solution. Using $KMnO_4$ in this fashion involves an additional step of dissolving the chemical. A saturated solution of permanganate at normal room temperature is about 15% by weight. For this project, then, large amounts of equipment and manpower would be needed to handle the water necessary to put permanganate crystals into solution. Plans to store the solution any length of time before introduction would be impractical as it is unstable. The most efficient application of the chemical would be in a dry form, at a rate equaling the amount necessary to neutralize the rotenone present. This method postulates fast dissolution of the neutralizing chemical. The three potassium permanganate crystal sizes gave much more latitude for the formulation of a final introduction technique than the tablet or single granular form of calcium hypochloride.

Experiments were performed to investigate the amount of crystalline $KMnO_4$ necessary to produce a known and constant amount of solution, and to determine how different crystal sizes would affect this relationship. The experimental work was performed in an adjustable flume located in the hydraulic laboratory, Utah State University. The flume was manipulated until water velocity corresponded to that expected in the area of the detoxification station during treatment.

In the first test, a muslin bag containing 186 grams (wet weight) of the coarse size permanganate was exposed to a flow of two feet per second. The bag occupied an area of 4 x 4 inches. At the end of two minutes the bag was taken from the flume and again weighed. It had lost 111 grams of material This would place a maximum dissolution rate, under these circumstances at approximately 140 ppm.

In subsequent tests permanganate was introduced directly into the water at a constant rate of 4 ppm for ten minutes. A water sampling station was set up 60 feet below the point of introduction. Two minutes were allowed for the flume system to stabilize. Water samples were then taken at the station every 30 seconds for the duration of the test run and for two minutes afterwards.

The experiment was first performed using the coarsest crystals. Permanganate color appeared in the water at the sampling site less than one minute after application upstream. Within 30 seconds, the concentration rose to 3 ppm and remained at this level for the duration of the test.

The identical procedure was followed using medium-size crystals. Within four minutes after the start of introduction upstream, the permanganate concentration was fluctuating between 3 and 4 ppm. A weighted average of these water sample readings gave a mean concentration of 3.6 ppm. This particular crystal size formed "clods" which made a constant rate of application difficult and concentration erratic. The smaller size crystal was so difficult to handle in all respects that it was no longer considered for use.

From the results of these tests it became apparent that the crystals would readily dissolve in sufficient quantity to treat any amount of rotenone expected at the detoxification site. The ease with which the coarse material was handled more than offset any benefits of slightly more rapid dissolution by the other crystal types.

From this experience in handling the chemical and observing the effects of its density in a current similar to that at the detoxification site, it also appeared that neutralization could be adequately handled by broadcasting the coarse crystals over the entire river surface. It could be expected that many crystals would sink through all water strata and help insure neutralizer throughout the vertical plane of the river.

Development Of A Detoxification Technique

Several types of machines are available which introduce dry chemical materials into culinary waters, and which are designed for varying the rates of application. In all probability, $KMnO_4$ could have been used in the machines. However, most units were machined to such fine tolerances that their cost for field use was prohibitive. In addition, none of the devices investigated had a mechanism for spreading dry chemical over a large area. Regardless of the neutralizer used, any of these dispensing units would have had to be thus modified. It was decided that it would be no more difficult to modify a less expensive machine.

Interest finally centered on a machine manufactured by the Neilson Metal Industries, Salem, Oregon. It was designed to be used in trout hatcheries and deliver a measured amount of pellet type feed over the surface of ponds or raceways (Figure 12).

Essentially, the unit consisted of a hopper with an adjustable, sliding gate at the bottom. Flow from the hopper was controlled by presetting the gate mechanism, and distribution was accomplished by a circular plate with attached ribs located below the gate. A solenoid switch, manually or remotely controlled, lifted the hopper gate to the preset position, and started the small electric motor which turned the spreading disc. Several slight modifications in gate and spreader design were made on a single machine, tested, and incorporated into the additional machines necessary for the project.

Planned Detoxification Operations

The substantially above-average snowfall of the previous winter, a late runoff, and a continuing high flow through the summer months led us to expect that the river in the treatment area would be near maximum treatable flows at the time of poisoning. Such an occurence would result in flows of 1600 to 1800 cfs at the detoxification site.

The amount of rotenone arriving at the detoxification station would be dependent upon concentrations introduced at various drip stations above the dam. By calculating the natural decay rate of several upstream combinations of rotenone introduction, a dispensing program was formulated that would be most advantageous to detoxify, yet still insure the objective of the project. This plan called for a reduction in the amount of rotenone introduced from drip stations within 60 miles of the dam (beginning at Station 17). Table 6 illustrates the rate of toxicant injection at each of these drip stations and the anticipated effect upon neutralization.

If treatment operations upriver progressed as scheduled, and temperatures and flows approximated those normally occurring, it was estimated that: operations would continue without interruption for about 24-28 hours; rotenone would arrive in three more-or-less distinct concentrations of approximately 0.6, 1.0, and 0.4 ppm with perhaps differing amounts between each level due to the overlap of water from adjacent drip stations; and 2.3 parts of permanganate would more than insure neutralization of 1 part rotenone.

Since it was expected that the rotenone would arrive at the bridge in more or less distinct levels, determinations of amounts above the bridge were to be performed only near the beginning of work as a check to see if concentrations flowing downriver were near the calculated figures; and to indicate the magnitude of any overlap of drip stations. The spreaders were calibrated to dispense $KMnO_4$ at a 1:2.3 ratio for the three amounts which should arrive, however, intermediate settings had been provided in the event other toxicant concentrations occurred. Upon report from the above-bridge monitoring, the machines would be set to dispense correct amounts of neutralizer. If further tests indicated that the rotenone was running as anticipated, and overlap concentrations were not dangerous; the machines would be automatically changed to conform to the schedule shown in Table 6. Detoxification would proceed on this basis until toxicant had ceased to flow past the bridge. Checks on the effectiveness of the neutralization would be run as treated water appeared at below-bridge monitoring sites. The reactions of test fish or data on water quality would determine corrections necessary in the rotenone to $KMnO_4$ ratio, placement of spreading machines, and other factors pertinent to permanganate introduction.

Rotenone concentrations arriving at the bridge and the effectiveness of the neutralization were to be measured by three different methods. First, bio-assay analyses for the concentration of rotenone were to be made at several sites above and below the bridge. Field bio-assay would be conducted by Fish and Game personnel and laboratory tests by the U.S. Public Health Service. The second method for determination of rotenone concentration was a chemical colormetric test (Post, 1955). The third method was used primarily for a final evaluation of the effectiveness of detoxification, and entailed the placement of fish in live cages in the river below the neutralization station.

Two water sampling sites were located above the bridge. The uppermost, Site A, was about three miles and the lower, Site B, several hundred yards above the bridge. Below the detoxification station Sites C and D were located 1.5 and 3.25 miles, respectively. The effects of any treatment procedure used at the bridge would be observed after intervals of about 1.5 and 3.0 hours.

Colormetric tests were to be conducted to determine the existence and concentration of rotenone before and after detoxification. Those monitoring sites below the bridge were to be sampled at least once every four hours. Above the bridge these tests were to be utilized only at the beginning of the operation, and when specifically needed thereafter.

As a further check on the concentration undergoing detoxification and the effectiveness of neutralization, bio-assay procedures were to be conducted independently by two separate parties. Mr. Crosswell Henderson of the Colorado River Basin Laboratory, United States Public Health Service, consented to perform tests in conjunction with those being run by his agency at the culinary water treatment plant, Dutch John, Utah. Samples for these analyses were to be taken from Stations B, C, and D, and shipped via vehicle to Dutch John. Since Public Health Service operations were not to run on

Toxicant Station	Miles Above Detox.	Amount Toxicant Dispensed	Station #17	Station #18	Station #19	Station #20	Station #21	Station #22	Detoxification Station
17	88	4.5	4.5	3.9	3.3	2.7	2.1	1.5	-
18	78	4.0		4.0	3.4	2.8	2.2	1.6	-
19	68	4.0			4.0	3.4	2.8	2.2	-
20	58	4.0				4.0	3.4	2.8	0.4
21	48	4.0					4.0	3.4	1.0
22	38	3.0						3.0	0.6

Potassium Permanganate Necessary For Neutralization with Ratio of Neutralizer to Rotenone 2.3 : 1.
Anticipated Maximum Flow 1600 c.f.s.

Rotenone Concentration (ppm)	Hours	$KMnO_4$ Rate (lbs/hr)	Dispensing Rate Per Machine With Four Machines (gm/min)	Total Amount $KMnO_4$ (lbs.)
0.6	8	496.1	939.8	3969.0
1.0	9	826.9	1566.3	7442.0
0.4	8	330.8	626.5	2646.0
				14,057.0

Table 6. Amounts of Rotenone in ppm Calculated to Reach the Detoxification Station Using A Rate of Decay of 1 ppm Per 16 River Miles.

a twenty-four hour basis, it was decided to collect water for Mr. Henderson twice daily at such times that the water could be transported to Dutch John before six hours elapsed and to arrive when the Health Service work was in progress. At the same time water samples were to be taken for field bio-assay as a check against the colormetric tests. Standard curves of toxicant concentration, water temperature, and fish reactions used for the state bio-assay were prepared by the Public Health Service.

Live fish were held in cages to indicate if harmful amounts of rotenone were continuing below the station. At the monitoring sites above the bridge the cages were to indicate the first appearance of toxicant and periodically to determine whether or not the river was clear of toxic quantities of rotenone. The live cages at sites C and D were to be closely observed during operations, and reports of condition of the fish radioed to the bridge each half hour.

Actual Operation of Detoxification Station

A total of 13,860 pounds of potassium permanganate was ordered in 110 pound steel kegs. At the time the shipment arrived sample kegs were opened to inspect the product. Almost every keg examined contained crystals smaller than had been specified. Tests made at the delivery site indicated that 20% of the crystals passed through a 30 mesh screen. Many of the kegs contained hard "clods" composed primarily of these small crystals. As the company had no other immediate source of the chemical, the shipment was reluctantly accepted. Prior to construction of the detoxification facilities, all permanganate was sifted through a wire screen and collected on a drop cloth. After it had thoroughly dried on the cloths, a dry lubricant was mixed with the material and it was repackaged. Following this treatment, the permanganate was able to flow more freely and did not form new clods.

Detoxification equipment was installed on the bridge September 7. Sections of the wooden flooring were removed and four remodeled pellet feeders were mounted so that the gate and spreading disc extended below the lower-most portions of the bridge. The top of the hoppers remained about two feet above the floor (Figure 13). Units were mounted about sixty feet apart, with the machines on each end of the bridge about thirty feet from the river bank. This arrangement produced adequate coverage. A fifth space was prepared near the center of the bridge for an emergency dispenser. Electrical power was supplied by means of a 3000 watt, 60 cycle, A.C. generator. This power plant simultaneously ran all five dispensers and the 100 watt light bulbs placed above each dispenser for night operation. As a precautionary measure, two smaller generators with a total capacity of 2500 watts were held in reserve.

Live cages were located at sites A, C, and D, and were secured by pegs placed to serve as partial barriers to the river current. Fish species used included rainbow trout, green sunfish, and goldfish; except that rainbow trout were the sole species used at site A. All trout were under five inches total length, and the other fishes ranged from two to three inches. Sunfish had been seined from Utah rivers while the goldfish were taken from the stock used by the Utah Department for laboratory experimentation.

The lengthy confinement of these fish in holding tanks and pens for the duration of the operation accounted for some loss of fish. However, fish which appeared distressed were not used for either live cage or bio-assay work. Generally, fish were replaced in the cages each twenty-four hours or within an hour after any mortality.

Two hours after toxicant Station 13, immediately above the town of Green River, Wyoming had been put into operation the U.S. Public Health Service began bio-assay determinations of rotenone content at the municipal raw water intake. Readings obtained during the course of this work made it apparent that toxicant was persisting far longer than had been anticipated. It was realized then, that the operation to forcibly break down the toxicant at Brown's Park would probably extend beyond the original plan. With this complication, conservation of the potassium permanganate became very important. The amount of rotenone from drip Station 22 was curtailed to reduce permanganate needed to neutralize that toxicant. About 3,200 additional pounds of permanganate was immediately obtained, depleting all known local supplies. Even this extra quantity, however, did not eliminate concern over premature exhaustion of the chemical.

Plans were formulated to substantially change the method of operation of the station. The primary concern was to cut down on any waste inherent in treating 1 part rotenone with 2.3 parts potassium permanganate. Detoxification was to begin at a ratio of approximately 1:2.3. If the monitoring sites downriver indicated that treatment at this rate was satisfactory, the ratio would be gradually reduced until the first signs of disturbance. The $KMnO_4$ application would then be maintained slightly above this minimum level. Any subsequent changes in the rate of application would be controlled by monitor reports of rotenone concentrations above the bridge or by reaction of test fish in cages below.

Rotenone was first detected at Site A at 0410 hours on September 8th. The detoxification station was started at 0615 hours, and rainbow trout in a live cage at Site B were affected at 0630 hours. Operations then continued uninterrupted for over 83 hours. Including some 3,200 pounds delivered to the bridge during operations, a total of 17,160 pounds of crystal $KMnO_4$ was expended A cold front entered the area at the beginning of detoxification and the accompanying winds made working conditions most unfavorable. Daytime temperatures dropped to 50° F. and night temperatures were well below freezing. This did affect a decrease in river flow, but for the greater part of the operation about 900 cubic feet per second was treated.

Monitoring work proceeded as planned except that the live cages below the bridge were kept under continued observation and colorimetric and bio-assay tests at the above-bridge sites were conducted once each hour during the last two days. Normally, each water test consumed from one and one-half to two hours before final determination of rotenone could be made. Several determinations for rotenone presence below the station were made by Public Health Service bio-assay in Dutch John. The samples sent to Dutch John conformed in all ways to samples gathered for state analysis. Caution was maintained that water to be trucked to Dutch John contained no $KMnO_4$. All samples were packed in ice.

A concise description of the detoxification is presented in Table 7. This table records the changes in rotenone concentrations above the bridge, the

Table 7. Synopsis of the Detoxification Operation At Brown's Park-Green River Chemical Treatment Project - September, 1962

Time at Bridge Date	Hour	Rotenone Conc. At Bridge (ppm)	$KMnO_4$ Intro. Rate (gm/min)	Ratio: Rotenone to $KMnO_4$	Condition of Test Fish	Rotenone Conc. at Site C(ppm)
9-8	0615	0.5	1715	1:2.2	O.K.	0.0 0.0 1/
9-8	0800	0.8	1715	1:1.4	O.K.	0.2
9-8	1030				Trout dead at C&D	0.2 0.5 1/
9-8	1200	0.8	2187	1:1.8	Trout dead at C	0.4 0.1 1/
9-8	1230				O.K.	
9-8	1400	1.0+	4340	1:2.8	O.K.	0.0
9-8	1530	1.2+	1981	1:1.2	O.K.	0.2-0.3
9-8	1700				O.K.	0.0
9-8	2300	0.7	1960	1:1.9	O.K.	0.0
9-9	0130	0.6	1960	1:2.0	O.K.	
9-9	0800				O.K.	0.0
9-9	0900	0.5	1093	1:1.4	Trout, Sunfish dead at C; all sick at D	
9-9	1230	0.7	1640	1:1.6	O.K.	0.0
9-9	1530	0.5	1640	1:2.0	O.K.	
9-9	2330	0.6	1640	1:1.8	O.K.	
9-10	0200	0.7	1640	1:1.5	O.K.	
9-10	0500	0.8	1640	1:1.4	O.K.	
9-10	0800	0.5	1640	1:2.0	O.K.	
9-10	0900	0.5	1640	1:2.0	Trout dead at C&D	0.3
9-10	1000	0.5	1640	1:2.0	O.K.	0.0
9-10	1300	0.4	1640	1:2.0	O.K.	0.0
9-10	1900	0.4	848	1:1.5	O.K.	
9-10	2100	0.35	848	1:1.6	O.K.	
9-10	2230	0.2	848	1:2.5	O.K.	
9-11	0100	0.6	848	1:1.0	Sunfish dead at C&D	
9-11	0430	0.2	848	1:2.5	O.K.	
9-11	1100				O.K.-Live cages out	
9-11	1430	0.4	848	1:1.5	-	

1/ Sample taken from Site D.

changes in neutralizer introductions, and the change in condition of test animals or of other rotenone detection measures below the bridge. Each entry shows that a segment of water passed the bridge at a particular time and was treated. This same segment then flowed through the various test areas, affected the fish, and was subjected to physical tests as recorded on the same line in the table. Changes in the operation of the dispensing machines and other procedures were based upon the information obtained from live cages and water test procedures. The results of rotenone tests made by the Public Health Service were not immediately available in the field, and were intended only as an additional check upon circumstances at the bridge. The tests performed by this agency did confirm that detoxification was successful (Table 8).

The initial concentration of rotenone arriving at the bridge was determined as 0.5 ppm and was treated at a rotenone-permanganate ratio of 1:2.2. Reports from Site C indicated that this ratio was wasting potassium permanganate. The amount of permanganate was then reduced to a ratio of about 1:1.5. Rotenone concentration in the river later rose and because of the time required to complete testing allowed some rotenone to pass downstream incompletely neutralized. The amount of rotenone flowing beyond the detoxification was sufficient to kill rainbow at points C and D. No distress was noticed among the green sunfish or goldfish. When this condition was detected at the live cages, the ratio was increased to 1:1.8 in accordance with the latest information of toxicant concentrations above the bridge. As rotenone concentrations continued to increase during the day, more adjustments were made on the dispensing rate but the toxicant increased so rapidly that some rotenone persisted downstream until mid-afternoon.

Detoxification continued without any rotenone escaping neutralization or further disturbance to the test fish from mid-afternoon on September 8 until the morning of September 9. At this time the rate of permanganate application was again gradually reduced. When the rotenone-$KMnO_4$ ratio was lowered to 1:1.4 fish at both live cage sites became distressed. The trout and green sunfish at Site C finally succumbed but no mortalities occurred at Site D. Introduction of $KMnO_4$ was immediately increased and the short-term disturbance eliminated. Water samples sent to Dutch John show that no rotenone traveled below the detoxification station after introduction rates had been increased.

Operations continued until all potassium permanganate had been consumed with only two other disturbances of about one hour each. These occasions were probably caused by a rotenone overlap which went past the upriver monitoring sites undetected.

After the morning of September 9 the remaining trout were excluded from use in the live cages as they were too important for bio-assay purposes. Green sunfish and goldfish continued to act as test fish. Also, on the afternoon of the 10th, the original supply of $KMnO_4$ was exhausted, and the emergency material put to use. These spreader machines could not dispense the new crystals properly. Much of the new order was of a finer crystal size, and none had been screened or mixed with lubricant. The combination of moisture content and crystal size made it necessary to open the machine gates wide to let the chemical flow. This resulted in waste of permanganate. The method used to alleviate the situation was to punch small holes into the metal kegs of permanganate. The kegs were spaced across the river so that the chemical dissolved at a rate of about 112 pounds per hour. This method eliminated much of the flexibility in responding to changes in amount of toxicant coming to the bridge.

Table 8. Results of Bio-Assay Water Analysis Conducted By The U.S. Public Health Service From Samples Taken Above and Below The Detoxification Station

Date	Time Collected	PPM Toxicant Formulation
River Above Detox. Station		
9/8	7:40 a.m.	0.14
	11:30 a.m.	1.3
	2:00 p.m.	1.1
	6:00 p.m.	1.2
	10:30 p.m.	1.8
9/9	1:30 a.m.	1.7
	11:30 a.m.	1.6
	3:30 p.m.	1.2
	8:30 p.m.	1.0
	11:30 p.m.	0.7
9/10	1:00 p.m.	1.2
Below Detox. Station (Sta. C)		
9/8	12:45 p.m.	0.4
	6:00 p.m.	0.0
	10:00 p.m.	0.0
9/9	1:00 a.m.	0.0
	10:00 a.m.	0.0
	3:45 p.m.	0.0
9/10	1:15 p.m.	0.0
Below Detox. Station (Sta. D)		
9/8	9:30 a.m.	0.0
	2:30 p.m.	0.09

During the night hours of September 10-11, toxicant concentrations above the bridge were 0.2 - 0.3 and decreasing. Hourly bio-assay readings were taken at Site A to determine when the rotenone column would cease. By daybreak of September 11, rotenone readings were about 0.15 to 0.2 ppm. Indications from Station A confirmed a long-term downward trend. In response to requests by local residents, the bridge was cleared of equipment and opened to traffic at 1000 hours. By about 1200 hours all permanganate had been placed across the river. Potassium continued to dissolve from the kegs at previous rates until 1430 hours. After this time, kegs began to empty and the supply to the river dwindled until about 1700 hours.

DISCUSSION OF FACTORS RELATING TO DETOXIFICATION

Operations

Despite screening and lubrication of the permanganate crystals, some annoying difficulties were encountered with the dispensers. There was a tendency for stoppages to occur at the gate of the hopper. To avoid these stoppages it was necessary that the machines be attended constantly. It appears that a combination of factors was responsible. Not containing a dessicant, and being held next to a river, the chemical acquired some moisture. Thus, the considerable number of small crystals present caused clod formation which was exactly the condition we had been trying to avoid by specifying larger crystals. The paramount problem, however, was with the dispensing mechanism itself. It appears that gravity flow through a small orifice is not adequate when small amounts of potassium permanganate are needed. The problem could have been eliminated had the dispensers been equipped with a worm-gear or other controlled feed arrangement. The spreading mechanism did a very satisfactory job of distributing permanganate across the river surface.

The potassium permanganate crystals were uniformly dissolved through the river within one mile of the bridge. It was anticipated that most, if not all, of the $KMnO_4$ would be destroyed by the time it had traveled the 1.5 miles to Site C. However, the first arrival of neutralized water at this site showed a very dark red. Colorimetric standards for potassium permanganate solution indicated that the concentration remaining at this point was slightly under 1.0 ppm. As soon as water which had been treated with lower amounts of $KMnO_4$ arrived at the monitoring site, the normal green color of the river returned.

Throughout the operation water color at Site C vacillated from the normal green to a dark red. Water color approaching the norm almost always occurred somewhere near the time of a fish disturbance. The necessary contact time for permanganate and rotenone must be greater when a crystal form is used than the 30 to 45 minutes required when a $KMnO_4$ solution is introduced.

For the majority of the operation the river between the bridge and Site D was colored a light brown. This was caused by the deterioration of the $KMnO_4$ into an oxide of manganese and subsequent combination with organic matter in the river, a normal situation. There is no reason to conclude that either rotenone or $KMnO_4$ is present in this situation. However, because of the disagreeable properties of manganese in culinary water this condition may require some attention on other detoxification projects.

Almost every aspect of the detoxification procedures affirmed the inadequacies of present methods of rotenone determinations. Using either the colorimetric or bio-assay procedures, information could not be obtained at times when most needed. The chemical test often took one and one-half hours to complete. The bio-assay in these cool waters took almost as long. No tests for the determination of rotenone were able to establish the exact amount in solution. By relying upon the tests we were vulnerable to discrepencies between actual and indicated rotenone levels. On some occasions, $KMnO_4$ application rates that had been completely satisfactory were only partially successful at another time. This must be explained by inadequacies of the tests. Because a detoxification project patterned to the concentrations actually arriving is no better than the method used to determine these concentrations, one major recommendation of this project is that new impetus be given to improvement of methods for rotenone determination. Something must be done to develop a faster, more accurate test. Until that time arrives, bio-assay with all its necessary calibrations, aquaria, fish holding pens, etc. is probably superior to the colorimetric method.

Mention has been made of the rapid decline in flow of the Green during treatment and detoxification (Table 1). Rotenone drip stations set one or two days before treatment to deliver amounts of toxicant equal to 5 ppm thus contributed a greater concentration. The discrepency was compounded in some instances by the error between estimated water flow read from gauge stations and actual volumes. This situation increased the chances for a more effective kill, but it significantly changed the plans for detoxification.

Another influence disruptive to detoxification was the increased time necessary for rotenone in the river to break down. Evidence has been gathered, which indicates that factors other than daylight and temperature have a pronounced influence on the natural decay rate of rotenone in a lotic environment. As has been previously mentioned, the U.S. Public Health Service conducted determinations of rotenone content of river water at two primary locations: Green River, Wyoming and Dutch John, Utah. By making use of the known river speed over various segments of the treatment area, each sample taken by the Health Service could be identified with specific drip station or combination of stations. Differences between amounts introduced at the drip station and that found by the later analysis gives a fairly accurate picture of the mean rate of natural breakdown. Water suspected of containing rotenone from more than one drip station was eliminated from these calculations because of our inability to determine the exact rotenone concentrations produced when overlap occurred. Table 9 shows the results of this procedure.

It is apparent that natural decay was not constant. The greater distance a given "batch" or rotenone traveled, the slower was its overall rate of decay. For example, the toxicant from one drip station (#10) was found to have broken down at a mean rate of 7.2 miles for each part per million for the first 37 miles of river, but at a mean rate of 28 miles for each part per million after 164 miles of flow. Figure 14 illustrates these results. The rotenone apparently undergoes very rapid detoxification for a short time after introduction. If quantities of rotenone remain after this rapid breakdown period, they are eliminated at increasingly slower rates. When the water is analyzed at a point downstream, the average speed of breakdown is a combination of the fast and slow rates. The rate at which toxicant was decaying as it reached the sampling station must be slower than this average. The minimum average rate shown on Figure 14 is approximately 24-28 miles for each part per million. Limited data for instantaneous decay rates of the last remaining rotenone is near 40 miles for one part per million to breakdown. Whether a minimum decay rate had been realized by the time water from the drip stations reached the points of analysis is not known. The curvalinear decay described may be, to some extent, an artifact of the bio-assay methods. However, the departure of these data from a steady rate of decay is too pronounced and abundant to be entirely the result of the testing procedure.

Problems which occurred with the test fish below the bridge on the days of September 8 and 9 (first two days of the detoxification) were the result of purposeful experimentation with the $KMnO_4$ to establish minimum treatment levels. Identical rotenone-permanganate ratios produced these kills - exactly the result

Table 9. Mean rates of natural toxicant decay calculated from Public Health Service bio-assay and field rotenone concentration results.

Toxicant Dispensing Station	Miles of Flow From Drip Station To Analysis	Amount of Toxicant Introduced (ppm)	Total Amount of Breakdown (ppm)	Amount of Breakdown in Mi/ppm.
GR 3	107.0	7.1	5.9	18.77
GR 5	87.5	7.0	5.7	15.91
GR 6	78.5	7.1	5.6	14.54
GR 7	68.0	7.3	5.5	12.36
GR 8	185.0	7.3	7.1	26.06
GR 9	175.0	6.8	6.5	26.92
GR 10	37.5	6.8	5.2	7.21
GR 10	163.5	6.8	5.9	28.01
GR 11	27.0	7.2	5.6	4.91
GR 11	28.0	7.2	4.2	6.67
GR 11	121.5	7.2	5.3	22.92
GR 11	153.0	7.2	6.8	22.36
GR 11	153.0	7.2	6.0	26.00
GR 12	17.0	7.5	5.1	3.40
GR 12	143.0	7.5	7.0	20.43
GR 13	99.0	6.7	5.3	19.13
GR 13	131.0	6.7	6.0	21.83
GR 14	119.5	6.3	5.9	20.25
GR 15	107.5	6.7	5.5	19.55
GR 15	107.5	6.7	6.2	17.34
GR 16	66.0	6.7	4.8	13.78
GR 16	97.5	6.7	6.1	15.27
GR 18	28.0	4.8	3.5	8.29
GR 18	79.0	4.8	4.2	18.81
GR 19	69.5	5.3	4.1	16.95
GR 19	69.5	5.3	4.7	14.79

to indicate a danger level of application. Obviously these occasions when toxicant progressed downriver cannot be considered failure of the detoxification process. Little, if any, difficulty would have been encountered had not circumstances dictated that the detoxification operate to conserve as much permanganate as possible. Records of the operation confirm that when detoxification proceeded at near the 1:2.3 ratio originally decided upon no harm occurred to test fish nor was rotenone detected below the bridge. The only times when rotenone escaped was when rotenone-permanganate ratios were dropped substantially below the 1:2 level.

Public Health Service tests found no rotenone present in any waters below the neutralization station following the afternoon of the first day. Other chemical tests also produced no evidence of rotenone below the bridge except during one short-term disturbance. It is significant that rotenone was never detected chemically when test fish were behaving normally. When these tests were performed during periods of fish distress they always indicated the presence of rotenone. If rotenone was present below the detoxification, it evidently was confined to periods when test fish became distressed.

Every effort was made to detoxify the rotenone and to extend neutralization until the threat to fish downstream had passed. Crews on the bridge worked for a total of 83 hours, and only secured the station when $KMnO_4$ supplies were exhausted. Though some rotenone remained in the river when work was terminated, a great deal more would have passed below the bridge had not the original plans for a constant 1:2.3 ratio been abandoned. A supply of 13,800 or 17,200 pounds of permanganate would have lasted only about 45 or 57 hours, respectively, at the 1:2.3 ratio. Rotenone concentrations ranging from 0.8 to 0.5 ppm would have passed downstream untreated for the remaining 24 or 36 hours. At the time the operation was terminated, toxicity of rotenone arriving at the bridge was below levels lethal to most fish. Levels of rotenone known to be lethal were satisfactorily inactivated at the detoxification station so that no major problems occurred with live test fish placed in the river below. Tests run by an interested, but unaffiliated, agency; in addition to checks performed by crews concerned with the work bear out the fact that rotenone concentrations were eliminated for over 95% of the operation and that during the remaining time very reduced amounts were passed. The incompletely neutralized material was below normal lethal levels and escaped for only short periods of time. There is nothing in our information to suggest that detoxification, even on this large scale, is not possible or that it cannot be repeated in the future.

Post Detoxification Developments

National Park Service rangers patrolling the Green River from the upper boundary of Dinosaur National Monument to its exit observed fish in distress at several points on September 13-15. The probable arrival of the causative agent was established at two locations within the monument: Echo Park near the confluence of the Yampa River, and at Split Mountain Campground near the Monument headquarters (Figure 11). Toxicant arrived at Echo Park shortly before 0600 hours, September 13; and at Split Mountain Campground sometime in the early evening of September 14. The large majority of affected fish were channel catfish. No evidence of a fish kill was observed below Split Mountain. 1/

1/ Oral communication with Chief Ranger and Park Naturalist at Dinosaur National Monument

A party of Utah and Bureau of Sport Fisheries and Wildlife personnel arrived at Split Mountain on the morning of September 15 where the "kill" had been observed the previous evening. They noted in the area many large and small cyprinid fishes apparently unaffected. A bio-assay run at that time was negative for rotenone. It is possible that the fish seen the previous night were drift from upriver. At the detoxification site fish had been noticed passing under the bridge both alive and dead as the front of the toxicant arrived. It is possible that aggregations of dead fish observed for some distance below the bridge resulted in whole, or in part, from this type of situation.

The river in the Monument courses through a series of canyons, the gradients of which are steeper than, or equal to, that of the canyon which Flaming Gorge Dam has inundated. The U.S. Geological Survey gauging station in the now flooded canyon gave the mean velocity of the Green River as 2.60 mph on 16 August, 1962. A careful measurement of the U.S. Geological Survey maps of Dinosaur National Monument shows the following river distances separate the locations mentioned.

Brown's Park Bridge to Upper Monument boundary	16.0 miles
Upper bouncary to Echo Park	18.5 miles
Echo Park to Split Mountain Campground	25.0 miles

Therefore, from the detoxification bridge to Echo and Split Mountain Camp is 34.5 and 59.5 miles, respectively. Mean river speed over the 16 mile interval between the detoxification bridge and the Monument boundary is known to have been very near 1.0 mph at the time of the treatment. Sixteen hours would elapse before water which passed under the bridge could arrive at the Monument boundary. From there it would move downstream 18 miles in 7 hours at an average rate of about 2.6 miles per hour. It would have taken another 10 hours to reach the additional 25 miles to Split Mountain. To have produced the fish kills noted on September 13 and 14, the causative agent would have had to pass the detoxification site anywhere from 12 to 36 hours after operations there had terminated. If the kill had been the result of incomplete detoxification, the toxicant would have had to have moved through the canyons at the very unlikely speeds of less than 0.7 to 0.9 mph.

On September 24 through 27, personnel from the fisheries division of the Utah and Wyoming Fish and Game Departments conducted an investigation of disturbances at Island Park and Echo Park within the Monument. Biologists from the Bureau of Sport Fisheries and Wildlife also performed a survey of the river from Split Mountain Canyon to Echo Park in the weeks following the treatment project (Azevedo, 1962). Unfortunately, heavy rains occurred over the Upper Green River drainage immediately preceding the state sampling operations. The river at the time was swollen and turbid. High water made working with nets extremely difficult, and filled them with debris almost as soon as set. For this reason only these two locations could be sampled with any degree of validity.

Fish were secured without undue effort once collecting methods which were not affected by the turbid conditions were used. A list of the fish species taken is presented in Table 10. Small fish were found in abundance. All species except sunfish and shiner were represented by individuals from 6-16 inches in length. At Echo Park again, both juvenile and mature individuals were taken except for the roundtail chub, Gila robusta and the dace, of which only immature specimens

Table 10. Fish Collections Made by State Agencies in Dinosaur National Monument After Chemical Treatment Project

	September 1962		April 1963	
Species	Island Park	Echo Park	Island Park	Split Mountain
Flannelmouth sucker	X	X	X	X
Bluehead sucker		X	X	X
Bonytail chub	X	X	X	X
Speckled dace		X	X	X
Carp	X	X	X	X
Colorado squawfish	X		X	
Redside shiner	X		X	X
Green sunfish	X			
Humpback sucker			X	X
Black bullhead			X	
Channel catfish			X	X

were obtained. During the sampling procedures many live aquatic organisms were caught and identified. Represetnatives of the principal orders were found, including Trichoptera, Odonata, Ephemeroptera and Diptera, and they were well represented in all environments.

A second fish survey was conducted by members of the Utah and Wyoming Fish and Game Departments in Dinosaur National Monument, April, 1963. The primary purpose of this effort was to gain additional knowledge of species composition and relative abundance of fishes in the area. The locations sampled were Island Park and the vicinity of Split Mountain Campground. Results were much the same as before. Fish of all sizes were secured in greater numbers without difficulty, and some species which had not been obtained during the September trip were captured. Table 10 also shows the species taken at each location.

A comparison of the fish collected after the disturbance in Dinosaur National Monument with data from surveys made before the treatment project is presented in Table 11. Of the native species which were of concern to opponents of the treatment program, all have been found adequately represented by these surveys. The only fish which may have been slightly reduced in numbers by the disturbance appears to be the Colorado or bonytail chub, *Gila robusta*, and possibly the bluehead sucker, *Pantosteus delphinus*. Present numbers of these species in the Green River and of course its tributaries, should return it to its former status if the environment produced by Flaming Gorge Dam allows.

Table 11. Evaluation of fish species found in the Green River within Dinosaur National Monument after the treatment project; and a comparison with the estimated composition from surveys performed before the fish control project. 1/

	Collected Before September 1962		Collected After September 1962	
Species	Presence	Approx.% Of Total Sampled	Presence	Approx.% Of Total Sampled
Flannelmouth Sucker-*Catostomus latipinnis*	X	15.9	X	54.7
Carp-*Cyprinus Carpio*	X	1.3	X	0.9
Bluehead Sucker-*Pantosteus delphinus*	X	4.4	X	0.6
Bonytail Chub-*Gila robusta robusta* and *Gila robusta elegans*	X	7.6	X	4.6
Channel Catfish-*Ictalurus punctatus*	X	0.9	X	1.7
Squawfish-*Ptychocheilus lucuis*	X	0.1	X	0.3
Humpback Chub-*Gila cypha* 2/	X	0.1	X	0.1
Humpback Sucker-*Xyrauchen texanus*	X	0.1	X	0.2
Black Bullhead-*Ictalurus melas*	O	-	X	-
Redside Shiner-*Richardsonius balteatus*	X	50.1	X	13.8
Speckled Dace-*Rhinichthys osculus*	X	19.5	X	23.1

1/ Data preceding treatment project from collections made by the Utah Fish and Game Department in the vicinity of Red Canyon 1959-1960, and augmented by records of the collections within Dinosaur National Monument made by the Bureau of Sport Fisheries and Wildlife Service (Azevedo, 1962).

2/ Specimens obtained by Bureau of Sport Fisheries and Wildlife personnel.

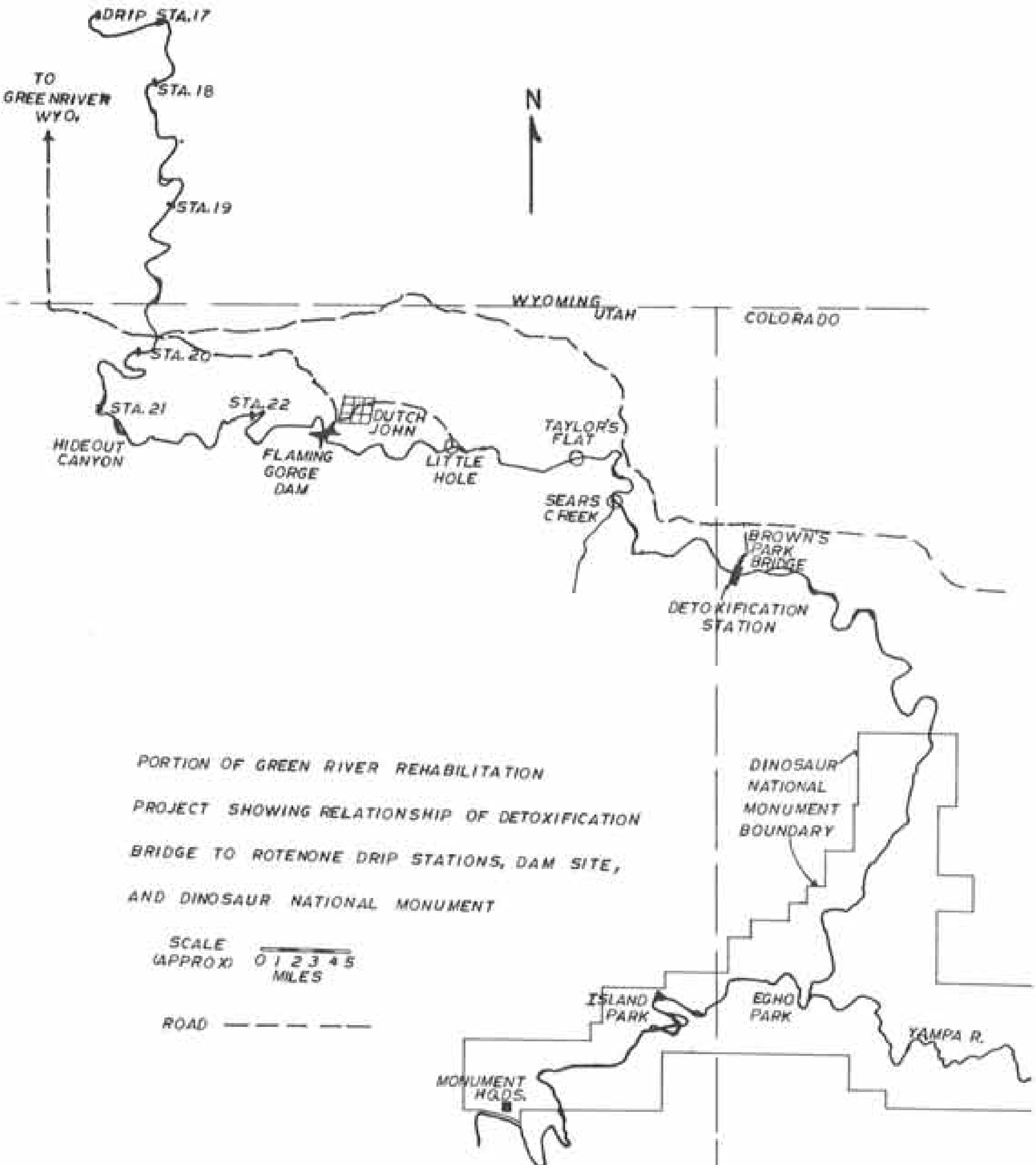


Figure 11. Location of the detoxification station below Flaming Gorge Dam.

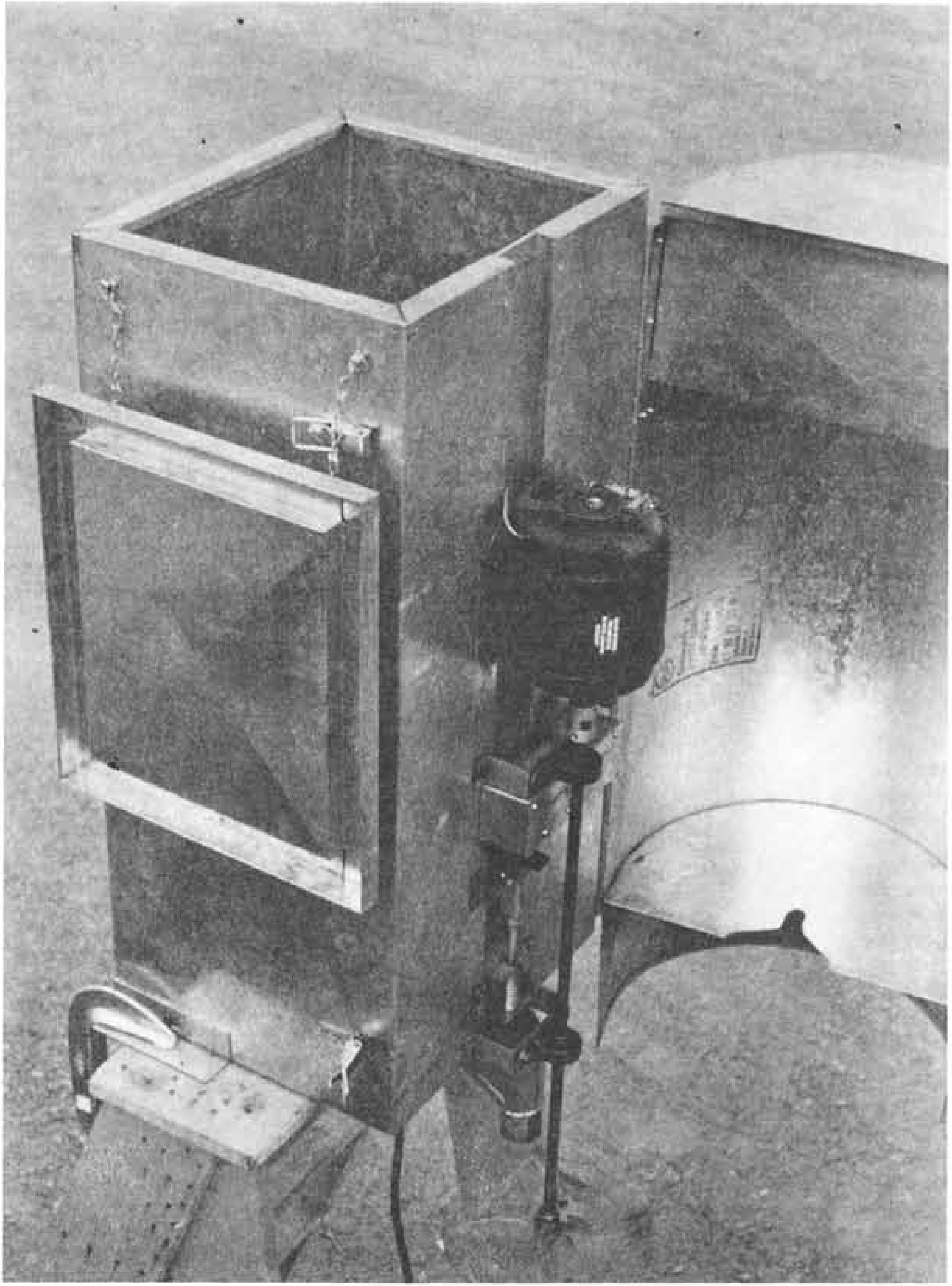


Figure 12. Pellet-type fish food dispensor which was used to distribute crystalline potassium permanganate.

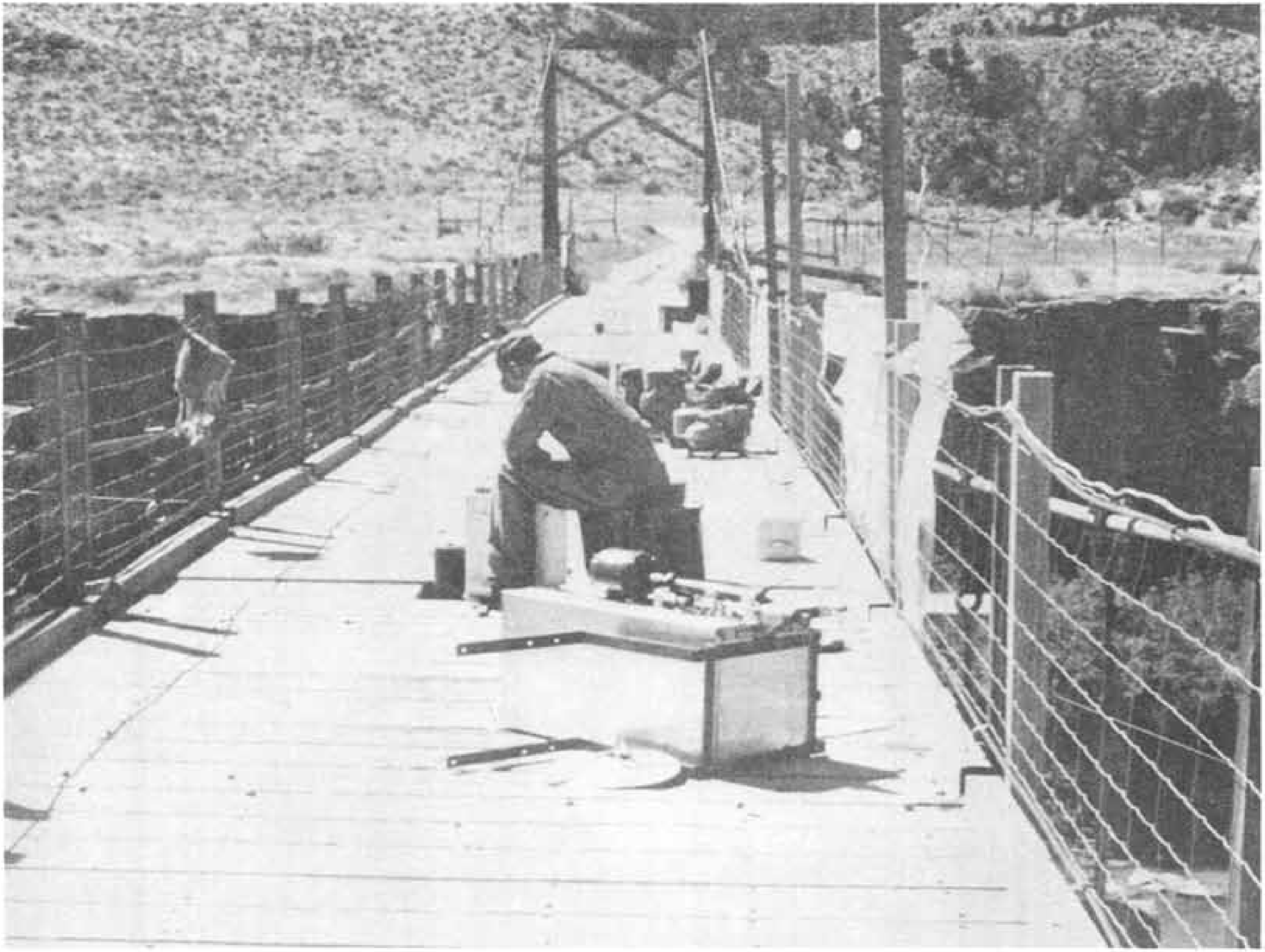


Figure 13. Method of placement of permanganate dispensors through bridge floor. Note iron straps on machine in foreground.

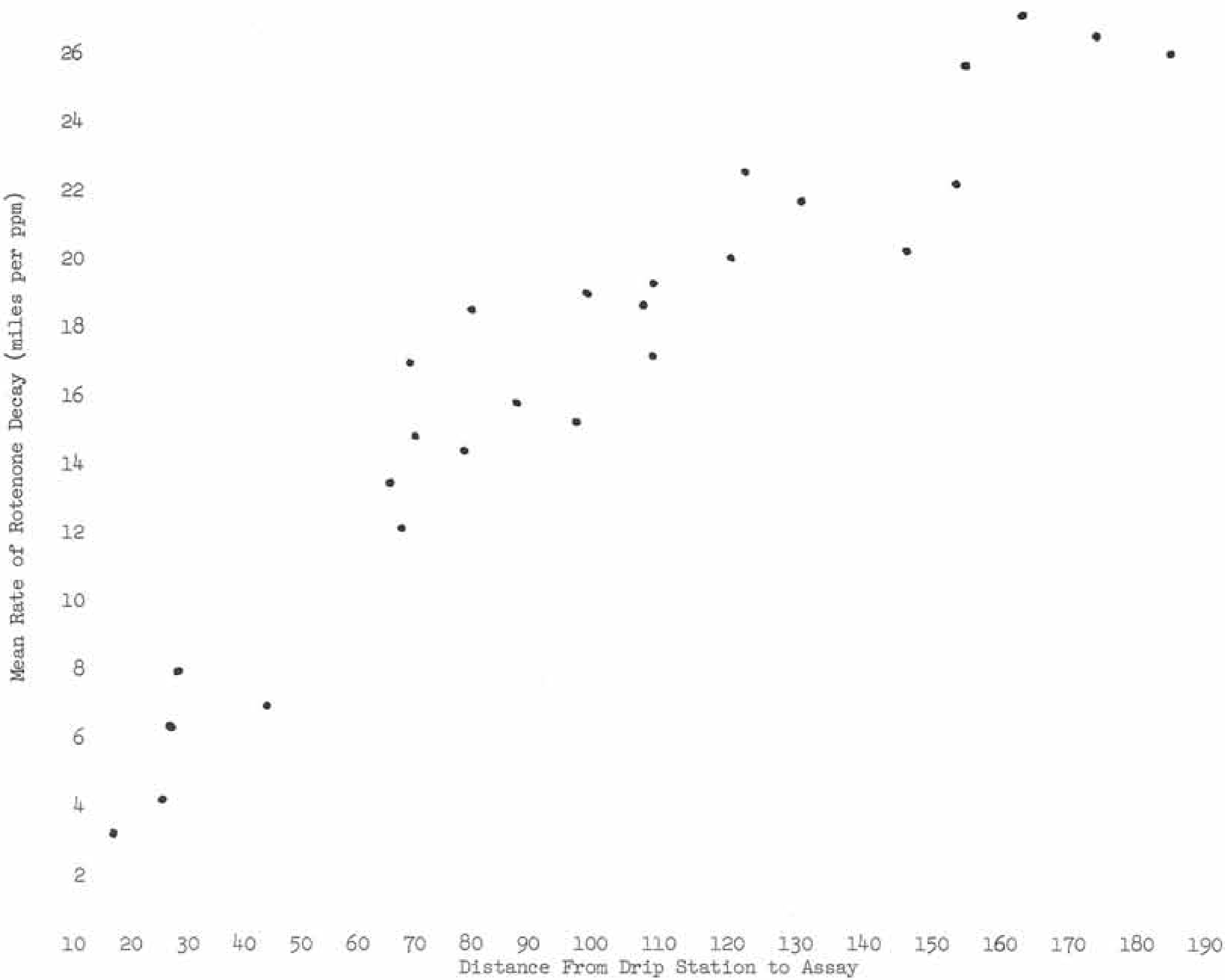


Figure 14. Average Speed of Rotenone Breakdown in Relation to Distance Traveled.

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Appendix A.

Green River Treatment Work Schedule

Utah-Wyoming Segments

Treatment Date - Week of September 3 or week of September 17.

PRE-TREATMENT PHASE

Period between July 10 & August 1 - Five days to unload trucks into warehouse in Green River or Rock Springs. Utah stake truck and pickup - two men to store toxicant for stations 20, 21, & 22, and Henry's Fork Drainage at Manila.

August 13 (If T-Day Sept. 4) - Allen Binns, Helms, two Wyoming summer helpers and two Utah men start setting up stations. Utah men move dry rotenone to Pinedale.

August 16, 17 & 18 - Airboat operators run exploratory trip on entire drainage - meet at Big Piney. Jackson, Peterson and Erickson - Wyoming; Dietz and Smith - Utah; Azevedo, Fish and Wildlife Service.

- Two men from crew #2 and two Utah men start putting toxicant into stations # 22, 20, & 15; three four-wheel drive vehicles rigged with gin boom or pickup box boom plus steel mats.

August 20, 21, 22, 23, & 24 Coordination Meeting - Court House at Green River, Wyoming

Operational Chiefs	- Regenthal (Utah Eiserman (Wyoming)
Field Chiefs	- Peterson (day-Wyo.) Jackson (night-Wyo.)
Asst. Field Chiefs	- Bosley (Wyoming) Garbutt (Wyoming) Helms (Wyoming) Stone (Utah)
Section Foremen	- Rollefson Viox Millis Mueller Kanaly Williams Rockett Hales Livesay
Helicopter Pilot	- J. Burr
Ground Assistant	- Pete Lange

Appendix A (cont'd)

<u>PRE-TREATMENT PHASE</u>	Fish & Wildlife Serv. Coordinator	- Bob Azevedo
August 23, 24 Coordination Meeting - Court House at Green River, Wyoming.	- Chief of Fisheries	- Andriano (Utah) Beal (Wyoming)
	- Transportation and Communication Staff	- Arnoldi Ray Arzy W. McNeel
	- Commissary Chief	- Jack Conley
	- I & E Personnel	- Kaminski Ruskanen Rawley Reynolds
	- Inter-Agency Coordinator	- Earl Thomas
August 27 (If T-Day Sept.4)	- Helms and Stone in charge. Start distribution of toxicant out of Green River City	
To distribute to 8 field stock piles located at Blacks Fork Dr. (1), south of Green River City (2), between Green River and Sommers Bridge (4) & Big Sandy Dr. (1). One stock pile set up at Manila at the time toxicant delivery in July. Toxicant for Station #8 to be stored at Bur. of Rec. camp at Fontenelle damsite. Toxicant for Station #13 to be stored at Jack Wilsons.	- Fork Lift Three large flat-bed trucks One stake body truck	- Rich Basye Adams - Raper
Location for distribution by pickups. Helicopter distribution during operation as needs demand and for Blacks Fork Dr.	- Twelve pickup trucks (3 with gin booms & 5 with pickup box booms)	1 - Kent* 2 - Kozas 3 - Hulse* 4 - Livesay* 5 - Miller* 6 - Mueller# 7 - Millis# 8 - Hudelson 9 - Leo Rogers 10 - J. Wilson 11 - P. Lange 12 - C. Viox
	- Two fork lifts for loading at warehouse and a good number of old tires to facilitate unloading.	

* Rigged with pickup box boom
\# Winch trucks with booms

Appendix A (cont'd)

PRE-TREATMENT PHASE

August 27 (If T-Day Sept. 17)	- Start setting up stations - crews as indicated for August 13.
September 1	- Pinedale field crew make final readings on all flow gaging stations and set up all Big Sandy Creek stations. Utah set up Henry's Fork, Birch Creek and all tributary stations on Green River in Utah.

TREATMENT PHASE

September 3	- At Big Piney - Initial Headquarters - 8 A.M. final meeting for distribution of flow data, tools and last minute instructions. Operational Chiefs, Field Chiefs, Asst. Field Chiefs, Section Foremen, Transportation Communication Staff and all Green River and New Fork Crew members. All treatment personnel at designated lodging sites.
September 3	- At Big Piney - 1 P.M. Final meeting of Operational Chiefs and Field Chiefs with airboat units and supply crew, Commissary Chief, helicopter pilot, ground assistants and all supporting personnel.
September 3	- Assistant Field Chiefs and Section Foreman supervising the "setting" of toxicant stations for proper flow*. Work obligated as follows:

Green River crews 1 through 7 set up Green River stations 1 through 7 respectively and familiarize personnel with area.

Green River crew #2 - set up Cottonwood station afternoon prior to treatment.

Green River crew #3 - set up Muddy Cr. (if flowing) and North Piney Creek stations.

Green River crew #4 - set up Middle Piney Creek and South Piney Creek.

Green River crew #6 - set up LaBarge Creek station.

Green River crew #7 - set up Fontenelle Creek.

New Fork crews 1 and 2 - set up New Fork stations 1 and 2.

New Fork crew #1 also set up East Fork station.

Big Sandy crews #1 through 4 - arrive at lodging - Farson, evening of T minus 2.

Sectional Chief at Farson to distribute flow data and assist Big Sandy crews at stations on T Day. Section Chief stay at Farson until Big Sandy job is complete.

* Setting stations means installing valves and making initial flow checks - when stations to be "set up" stands & barrels will have to be put in place.

Appendix A (Cont'd)

TREATMENT PHASE

September 3 (cont'd)

Helms, Dotson, Rollefson, Kanaly, Mueller, Williams responsible for setting these stations as indicated on individual job responsibility sheets.

Those assistant field chiefs and section foremen not obligated on this date spend day going over sections they are responsible for.

Date	Time	Job Scheduled	Responsibility
			Asst.Field Chiefs and Foremen
Sept. 4 (1st day)		Start treatment - all main river stations run seven hours. (Blacks Fork, Henry's Fork, and minor tributaries will run six hours.)	Peterson-Field Chief on Duty
		All crews should be on station no later than ½ hour prior to treatment time to "set" stations and to check toxicant flow. At the end of treatment period crews will take all barrel valves and couplings.	
	8 a.m.	Green River Crew #1 start Green River Station #1	(Helms) Stone (1)
	8 a.m.	New Fork Crew #1 start New Fork Station #1	(Helms) Kanaly
	11 a.m.	Green River Crew #2 start Green River Station #2	(Helms) Stone (1)
	11 a.m.	New Fork Crew #2 start New Fork Station #2	(Helms) Kanaly
	P.M.	Utah Special Crews arrive at Manila lodging sites.	Livesay
	1 p.m.	New Fork Crew #1 (1 man) start East Fork Station	(Helms) Kanaly
	2 p.m.	Green River Crew #3 start Green River Station #3	(Helms) Rollefson
	3 p.m.	Green River Crew #8 move barrels to Station #8 from Bur. of Rec. camp - set station in morning (Sept.5) need truck with boom.	Mueller
	4 p.m.	Millis start Cottonwood Cr. Station. Relieved by Green River Crew #1 at 5:30 p.m.	Garbutt Rollefson Millis (assist)

(1) Acts as section foreman for start of operation.

Appendix A(Cont'd)

TREATMENT PHASE

Date	Time	Job Scheduled	Responsibility
Sept.4	5 p.m.	Green River Crew #4 start Green River Station #4. Helms - at the end of this day move to Black's Fork Drainage, if flowing, and take charge at toxicant stock pile location Sept. 5 at 6 a.m.	(Helms) Rollefson
	6 p.m.	Green River Crew #4 start South Piney Cr., Middle Piney Cr., North Piney Cr. One man from this crew starts stations assisted by Section Foreman (Rollefson). After stations are started, this one man makes continuous rounds of all tributary stations - other crew member remains at Green River Station #4. At 8 p.m. the crew member tending the Piney tributary will also start the Dry Piney and Muddy Creek station, if flowing.	(Garbutt) Rollefson Millis (Assist) and Stone Jackson-Field Chief on Duty
	8 p.m.	Green River Crew #5 start Green River Station #5.	(Garbutt) Rollefson
	8 p.m.	Green River Crew #4 start Dry Piney and Muddy Creek if flowing (see 6 p.m. obligations).	(Garbutt) Rollefson, Mueller re-lieve Rollefson of foreman responsibility after station is started
	9 p.m.	Big Sandy Crew #1 start Big Sandy Station #1 at confluence of Big and Little Sandy Creeks.	Bosley Williams
	11 p.m.	Green River Crew #6 start Green River Station #6.	(Garbutt) Mueller
Sept.5 (2nd day)	12:00 midnight	Big Sandy Crew #2 start Big Sandy Station #2	Williams
	2 a.m.	Green River Crew #7 start Green River Station #7	Garbutt Mueller
	3 a.m.	Big Sandy Crew #3 start Big Sandy Station #3	Williams
	3 a.m.	Green River Crew #7 start LaBarge Creek Station. One man from Crew #7 and Section Foreman start station. Run for six hours.	(Garbutt) Mueller Peterson-Field Chief on Duty
	5 a.m.	Green River Crew #8 start Green River Station #8.	(Garbutt) Mueller

Appendix A (Cont'd)

TREATMENT PHASE

Date	Time	Job Scheduled	Responsibility
	6 a.m.	Big Sandy Crew #4 start Big Sandy Station #4. Rollefson relieve Williams by 8 a.m. (Through at 1 p.m.)	(Garbutt) Williams Rollefson
Sept.5	6 a.m.	If Black's Fork is flowing helicopter and support crew start putting out barrels on stations 2,3,4,5, & 6 on Black's Fork Station 1 distribute by pickup.	Helms Stone (Asst.)
	A.M.	Utah Special Crews start back-pump treatment of Manila area irrigation complex.	Livesay
	8 a.m.	Green River Crew #1 start Green River Sta.#9. Kanaly relieve Mueller at this time.	(Helms)[1] Mueller, Kanaly
	10 a.m.	Green River Crew #1 start Fontenelle Sta. One man from crew #1 and Section Foreman start station.	(Helms) Kanaly
	11 a.m.	Green RiverCrew #2 start Green River Sta. #10. After Green River Station #10 is running, if Black's Fork is flowing, Helms to move to this area of responsibility.	(Helms) Kanaly
	2 p.m.	Green River Crew #3 start Green River Sta. #11 (if Black's Fork not flowing, Helms assist Dotson).	Stone Viox
	2 p.m.	Green River Crew #5 and Rockett and Williams (with boom truck) move toxicant from Wilson's yard to Green River Station #13.	Rockett
	3 p.m.	New Fork Crew #1 start Black's Fork Station #1 (if flowing).	Helms[2] (Millis assist)
	5 p.m.	Green River Crew #4 start Green River Sta. #12.	Stone Viox
		Stone -Bosley-Jackson make sure valves are available for Henry's Fork, Birch Cr., Carter Cr., Sheep Cr. and Spring Cr. Operation scheduled for a.m. on the following day	Jackson-Field Chief on Duty
	6 p.m.	New Fork Crew #2 start Blacks Fork #2 (if flowing).	Helms (Millis & Williams assist)
	8 p.m.	Green River Crew #5 start Green River Sta.#13	(Stone) Viox

[1]If Black's Fork is flowing, Helms will be in charge of treatment in that drainage and Field Chief to take Asst. Field Chief duties on Stations 9 & 10 and Fontenelle Creek.

[2]Act as stream section foreman for this phase of operation.

Appendix A (Cont'd)

TREATMENT PHASE

Date	Time	Job Scheduled	Responsibility
Sept.5	9 p.m.	Big Sandy Crew #1 start Blacks Fork Station #3 (if flowing).	(Garbutt) Helms[1]
	11 p.m.	Green River Crew #6 start Green River Sta.#14.	(Bosley) Viox
Sept.6 (3rd day)	12:00 midnight	Big Sandy Crew #2 start Blacks Fork Station #4	Garbutt[1]
	2 a.m.	Green River Crew #7 start Green River Station #15. This station is hard to get into - Rocket should take crew in with a four-wheel vehicle.	(Bosley) Rockett
	3 a.m.	Big Sandy Crew #3 start Blacks Fork Sta. #5.	Garbutt[1]
	5 a.m.	Green River Crew #8 start Green River St. #16. Bosley take over Section Foreman duties and make sure crew is located on station. Stone relieves Bosley by 7:30 a.m.	(Bosley) Rockett
	6 a.m.	Set up Blacks Fork block.	Peterson-Field Chief on Duty
	6 a.m.	Big Sandy Crew #4 start Blacks Fork Sta. #6.	Garbutt[1]
	6 a.m.	If Blacks Fork is now flowing, helicopter start treating this drainage. Use Big Sandy Crew #1 and helicopter support crew to assist.	Helms - Garbutt in coordinate operation
	8 a.m.	Green River Crew #1 start Green River Sta. #17	Hales (Stone)
	8 a.m.	(Utah Special Crew #1) Henry's Fork Crew #1 (Utah) start Henry's Fork #1	Livesay (Stone)
	8 a.m.	Utah Special Crew #1 start Birch Creek Sta.#1	Stone (Livesay)
	9 a.m.	Kent and Utah man start Blacks Fork Sta. #7 if Blacks Fork is flowing, if not flowing, continue to help helicopter.	Hales
	11 a.m.	Kanaly and Millis start Henry's Fork Sta. #2	Stone (Livesay)
	11 a.m.	Green River Crew #2 start Green River Sta. #18 at 4 ppm.	Hales

[1]Act as stream section foreman for this phase of operation.

Appendix A (Cont'd)

TREATMENT PHASE

Date	Time	Job Scheduled	Responsibility
Sept.6	11 a.m.	Utah Special Crew #1 start Birch Cr. Sta.#2.	Livesay (Stone)
	12 noon	Utah detoxification personnel report to Clay Basin Lodging - Colorado personnel report to quarters.	Regenthal Post
	2 p.m.	Green River Crew #3 start Green River Sta.#19	Hales
	2 p.m.	New Fork Crew #1 start Henry's Fork Sta.#3. (Start Spring Cr. Sta. at 6 p.m. 1 man).	Viox (Stone)
			Jackson - Field Chief on Duty
P.M.		Utah man into Eagle Creek Station	Livesay (Stone)
	4 p.m.	(Utah Special Crew #3) Sheep Creek Crew start Sheep Creek Station	Williams and Hales (Bosley)
	5 p.m.	Green River Crew #4 start Green River Sta.#20 (at 4 ppm) Four wheel drive recommended.	Williams and Hales (Bosley)
	6 p.m.	New Fork Crew #1 start Spring Creek Station Run for three hours.	(Bosley) Viox
	7 p.m.	Sheep Creek Crew start booster Sta. #2	Livesay
	8 p.m.	Green River Crew #5 start Green River Sta. #21 (at 4 ppm.)	Williams (Bosley)
	9 p.m.	(Carter Creek Crew) Utah Special Crew #2. start Carter Creek Station.	Livesay (Stone)
	11 p.m.	Utah man start Eagle Creek Station (in p.m. 3rd day, out a.m. of 4th day.)	(Stone)
	11 p.m.	Green River Crew #6 start Green River Sta.#22 (at 3 ppm). Know this station-tough to get into. Take crew in with four-wheel drive vehicle.	Mueller (Bosley)
Sept.7 4th day	6 a.m.	Henry's Fork Crew #1 start Cart Creek Station	Hales (Stone)
			Regenthal take over Field Chief Duty
A.M.		Detoxification personnel set up station and material.	Post
	7 a.m.	Utah man start Skull Creek Station (in a.m. 4th day - out after 4 p.m. 4th day).	Hales (Stone)

Appendix A (Cont'd)

TREATMENT PHASE

Date	Time	Job Scheduled	Responsibility
Sept.7 4th day	8 a.m.	Utah man start Trail Cr. Station (in a.m. 4th day - out after 4 p.m. 4th day).	Hales (Stone)
	8 a.m.	Utah man start Allen Creek Station (in a.m. 4th day - out after 4 p.m. 4th day).	Hales (Stone)
	10 a.m.	Henry's Fork Crew #1 (Utah) walk in and operate Dutch John Draw Station.	Hales (Stone)
			Jackson to assist if necessary
Sept.8 5th day	8 a.m.	All Utah Crews working above dam and Colorado personnel report at detoxification site to assist in set-up.	Post - Regenthal Stone
		Start primary detoxification station; run until detoxification of rotenone complete as indicated by live cage tests (approx. 24 hours).	

SUPPORTING OPERATION

	Airboat Crews		Responsibility
Sept. 3	1 p.m.	Big Piney - meeting, pick up flow data and equipment. Final briefing with all support groups.	Operational Chiefs (Regenthal-Eiserman)
		Familiarization with Upper Green River and North Fork area. Supporting personnel pick up toxicant emulsified and dry rotenone.	
Sept.4	11 a.m. to 7 p.m.	Airboat #1 (Wyoming) start patrol and treatment of Green River. Treat backwaters with emulsified rotenone and spring & seepage areas by "staking in" dry rotenone sacks.	
	11 a.m. to 7 p.m.	Airboat #2 (Utah) start patrol and treatment of New Fork areas. Treatment by airboats will have to be coordinated and operated based on flow schedules. Airboat crews will have to operate as observations and judgement indicates. Each airboat will have a supporting pickup truck for supply and pick up of crews. These supporting personnel will be Wyoming Game Wardens familiar with the drainage. No airboats to operate after dark. A third airboat is also expected to be operating for observation and emergency assistance.	

Appendix A (Cont'd)

TREATMENT PHASE

SUPPORTING OPERATIONS

Airboat Crews

Date	Time	Job Scheduled	Responsibility
Sept.5 2nd day	6 a.m. to 7 p.m.	Airboats #1 and #2 will coordinate their efforts on treating the Green River. It is expected that the day will be divided to allow for relief of crews.	Operation Chiefs Regenthal-Eiserman
Sept.6 3rd day	6 a.m. to 7 p.m.	Airboats #1 and #2 will coordinate their efforts on treating the Green River. It is expected that the day will be divided to allow for relief of crews. Finish operation upstream from canyon rapids (Disaster Falls). Utah airboats assist in transportation of equipment to Eagle and Carter Creeks.	
Sept.7		Utah airboats to transport personnel and equipment in and out of gorge area.	

Helicopter Group

Date	Time	Job Scheduled	Responsibility
Sept.3	8 a.m.	Meet at Big Piney airport for coordination and familiarization of work plans.	(Regenthal-Eiserman) Ground Asst. P.Lange
	1 p.m.	Meet with all Support Groups at Big Piney.	
Sept.4 1st day	8 a.m.	Start on New Fork, East Fork and Green River sections. Treat all isolated water adjacent to river. Continue downstream independent of river treatment - work with a 3-man ground crew (2 pickups and utility trailer) to supply toxicant, gas and food, one pickup will be rigged with transfer pump and spray unit.	
Sept.5 2nd day	8 a.m.	If Black's Fork is flowing, move toxicant to set up stations on this drainage for drip flow treatment. If Black's Fork is not flowing, continue treatment of isolated waters off Green River.	Helms
Sept. 6 3rd day	6 a.m.	If Blacks Fork is not flowing, start treatment of this drainage.	Helms
	3 p.m.	Transport material to Eagle Creek and Carter Creek.	Regenthal
Sept.7	7 a.m.	Transport material and men in canyon areas.	Regenthal

Appendix A (Cont'd)

TREATMENT PHASE

SUPPORTING OPERATIONS

Commissary Use Game Div. Trailers #1 (15 ft.) and #2 (35 ft.)

Date	Time	Job Scheduled	Responsibility
Sept.3	8 a.m.	Conley meet at Big Piney with Operation Group Move commissary trailers into place - one (trailer #1) parked at the junction, Farson-Blue Ridge Rd. (Big Sandy Opr.) and one parked at a "to-be-designated spot" south of LaBarge. This unit to work wouth with Green River crews on the LaBarge-Green River cut-off road (trailer #2). Use commissary trailer #2 as field headquarters.	Conley
Sept.4 1st day		Have commissary trailers equipped with portable radio, sandwiches, coffee, pop and water by noon this date. Also trucks towing trailers should have (1) 55-gallon drum of gas for emergency use.	
Sept. 5 2nd day		At 9 a.m. this date secure Big Sandy Opr. trailer #1 and move to a "to be designated spot" near station #15 and 16 by 3 p.m. this date. LaBarge-Green River commissary trailer #2 continue to move south with operation. This trailer, at about noon on this date, should be in the vicinity of Green River Station #10 and by 9 p.m. should be near Green River Station #12 and #13.	
Sept.6 3rd day		At about 1 a.m. this date, have commissary trailer #1 operating near Green River Station #15. At about 5 p.m. this date, commissary trailer #1 should be operating near the junction of Manila-Dutch John Road to service personnel on Stations #20, #21, #22 and to check in tools and equipment at the termination of operations.	
Sept.6 3rd day		At about 10 a.m. this date have commissary trailer #2 operating at a "to-be-designated" spot south of the junction Manila-Henry's Fork road to service Henry's Fk. Stations and Stations 18 and 19 and to check in tools.	Conley
Sept.7 4th day		Secure all commissary trailers at noon this date. Park trailers at J. Wilson's place-Green River. A roster of designated sleeping areas for personnel will be kept at each commissary trailer. In addition, coordination personnel will consider commissary trailers as mobile headquarter units and portable radios will be on hand. At the end of the treatment phase, tools will be checked in to commissary trailers #1 or #2.	

Appendix A (Cont'd)

TREATMENT PHASE

SUPPORTING OPERATIONS

Date	General Time	Job Scheduled	Responsibility
Sept.3	8 a.m.	Those Administrative and I & E personnel desiring to meet on final briefing meeting to be in Big Piney on this date. All I & E and Administrative personnel sleep at Pinedale this night.	
		Communications personnel meet at Big Piney for final briefing.	J. Arnoldi
Sept.3		I & E personnel arrange for coordination of visiting dignitaries.	
		Note: All I & E personnel and Administrative personnel will have lodging only if arranged for in advance. In no case should this group take over Game and Fish lodging if not previously arranged.	
		Special studies and post-treatment crews to operate independently of operation - lab trailer to be used for lodging for this three-man team.	
Sept. 3, 4, 5th		Trout salvage. Two crews designated for these duties shall follow the operation downstream on the New Fork and Green River during the daylight hours of Sept. 4 and Sept. 5 to at least Station #8 at the Fontenelle Bur. of Rec. Camp. These crews shall come equipped with icing facilities to transport trout to the freezer at the Boulder Rearing Station for later distribution to State institutions at Lander, Evanston and Rawlins. Suggest that a fish distribution truck and tank from Daniel and Boulder be used for this job. Meet at 1 p.m. on Sept. 3 for final briefing.	Huggins
		Clean-up personnel will be on standby for Sept. 4,5, and 6 - will act as liaison units and general assistance if not needed for clean up. To work out of commissary trailer setup. Will also assist Huggins in trout salvage.	
		All tools and operational equipment in possession of personnel at the end of their obligation period should be checked in at the commissary trailers.	

Appendix A (Cont'd)

POST TREATMENT

Date	Time	Job Scheduled
Sept.7	8 a.m.	Personnel as designated below for station dismantling and barrel pick-up meet at Game Warden station in Green River (Jack Wilson), Peterson and Helms in charge. Wyoming crews to pick up all stations to Green River #19 and Black's Fork; Utah crews to pick up below this station, Henry's Fork and tributaries. Wyoming to stock pile barrels, hose and posts at the Boulder Rearing Station. Operation should be completed by the evening of September 10.
		Equipment needed - two large flat bed trucks, one dump truck, one pickup rigged with a boom, one pickup rigged with a box hoist.

Larry Peterson	Rodzinak	Bill Helms
Dean Rich	R. Kent	Jim Pritchard
J. Hulse	R. Wiley	E. Basey
		Jim Mediate

Appendix B. Diagrammatic Outline Of The Treatment Schedule Which Was Supplied To All Field Personnel.

Section I
Op.C. Regenthal - Eiserman
Field C. Peterson (Jackson 6 P.M.)

Asst.F. Chief	Section Foremen	River Crews
Helms	Stone	GR #1 (crew) G.R. Crew #1 (start) 8 A.M.-T (Lodge) Big Piney T-2 Pinedale T-1
Helms	Kanaly	(Next) Relieve Millis Cottonwood 5:30
Garbutt	Rollefson	Cottonwood Cr. Millis(G.R.Crew #1)
Helms	Kanaly	(s) 4 P.M.-T (N) G.R. #9
Helms	Stone	GR # 2 G.R. Crew #2 (s) 11 a.m. -T
Helms	Kanaly	(L)Big Piney T-2,T-1 (n) G.R. # 10
Helms	Rollefson	GR #3 G.R. Crew # 3 (s) 2 P.M.-T (L) Big Piney T-2,T-1 (N)G.R. #11
Garbutt	Rollefson Millis + Stone Asst.	N.Mid.S.Piney G.R. Crew #4 (s) 6 P.M.-T
Helms	Rollefson	GR # 4 G.R. Crew #4 (s) 5 P.M.-T (L) Big Piney T-2,T-1 (N) G.R. #12
Garbutt	Rollefson Millis + Stone Asst.	Dry Piney-Muddy G.R. Crew #4 (s) 8 P.M.-T
Garbutt	Rollefson	GR #5 G.R. Crew # 5 (s) 8 P.M.-T (L) Pinedale T-2 Big Piney T-1,T (N) GR # 13

New Fork #1
New Fk.Crew #1
(s) 8 A.M.-T
(L) Pinedale T-2
Pinedale T-1
(N) Blacks F.#1

East Fork
New Fk.Crew #1
(1 man)
(s) 1 P.M.-T

New Fork # 2
New Fk. Crew #2
(s) 11 A.M.-T
(L) Pinedale T-2
Pinedale T-1
Farson-T
(N) Blacks F.#2

Support

Airboats

Airboat # 1 Wyo.
G.R. to Sta. #9
(L) Big Piney T-2,T-1
(N)G.R. #9 thru #17
Airboat # 2 Utah
New Fk. and G.R.
to Sta.# 9
(L)Big Piney T-2,T-1
(N)G.R.#9 thru #17

Helicopter
T-G.R.far as possible
(L)Big Piney T-2,T-1
(N) Supply Blacks Fk.
if flowing or
treat G.R.

Commissary
Trailer #1
T-1,T Junc.Farson
Blueridge Rd.
(N)move to near
GR #15
Trailer #2
A.M. T-1 south of
Labarge
(N) move with OP.

Appendix B (continued)

Section 2
Field C. Jackson (Peterson 5 a.m.)

Asst.F. Chief	Section Foremen	
Garbutt	Mueller	Labarge Cr. GR Crew #7 (s) 3 a.m. T + 1
Garbutt	Mueller	G.R. #6 G.R. Crew #6 (s) 11 p.m.-T (l) Pinedale T-2 Big Piney T-1,T (N) G.R. #14
Garbutt	Mueller	G.R. #7 G.R. Crew #7 (s) 2 a.m. T+1 (L) Pinedale T-2 Big Piney T-1,T (N) G.R.#15
Bosley	William	Big Sandy #1 B.S. Crew #1 (s) 9 p.m. T (L) Farson -T (N) Blacks Fk. #3
Garbutt	Mueller	G.R.#8 G.R. Crew #8 (s) 5 a.m. T + 1 (L) Pinedale T-2 Big Piney T-1,T (N) G.R. # 16
	Williams	Big Sandy #2 B.S. Crew #2 (s) 12 M.-T (L) Farson -T (N) Blacks Fk.#4
Helms	Kanaly	G.R. #9 G.R. Crew #1 (s) 8 a.m. T + 1 (L) Big Piney-T (N) G.R. #17
	Williams	Big Sandy #3 B.S. Crew #3 (s) 3 a.m. T + 1 (L) Farson -T (N) Blacks Fk. #5
Helms	Kanaly	Fontenelle Cr. G.R. Crew #1 (s) 10 a.m. T + 1
Garbutt	Williams + Rollefson	Big Sandy #4 B.S. Crew #4 (s) 6 a.m. T + 1 (L) Farson -T (N) Blacks Fk. #6
Helms	Kanaly	G.R. #10 G.R. Crew #2 (s) 11 a.m. T + 1 (L) Big Piney - T (N) G.R. #18

Support

Airboats #1,#2
G.R. Sta.#9-#17,T+1
(L) Big Piney - T
(N) G.R.#17-Rapids

Helicopter
T+1 Supply Blks.F.
if flowing or treat
G.R.
(L) Big Piney - T
(N) Spray Black SF.,if
nec.,-Trans.Mat./men
in-out Gorge-Spray
Remainder G.R.

Commissary
Trailer #1
a.m. T+1 move to
G.R.-Linwood RD.
near GR #15
Trailer #2
Move with OP. to
G.R. Wyo. by 9 p.m.
T + 1

Appendix B (continued)

Section 3
Field C. Peterson (Jackson 5 p.m.) Peterson 5 a.m. + 2

Asst.F. Chief	Section Foremen		
Stone	Viox Helms Millis (asst.)	Blacks Fork # 1 New Fork Crew #1 (s) 3 p.m. T + 1 (L) Farson T (N) Henry's F. #3	G.R. # 11 G.R. # 3 (s) 2 p.m. T + 1 (L) Big Piney T (N) G.R. # 19
Stone	Viox Helms Millis + Williams Asst.	Blacks Fork #2 New Fork Crew # 2 (s) 6 p.m. T + 1 (L) G.R. T + 1 (N) off	G.R. # 12 G.R. Crew # 4 (s) 5 p.m. T + 1 (L) Big Piney T (N) G.R. # 20
Stone Garbutt	Viox Helms	Blacks Fork # 3 Big Sandy Crew # 1 (s) 9 p.m. T + 1 (L) G.R. T + 1 (N) off	G.R. # 13 G.R. Crew # 5 (s) 8 p.m. T + 1 (L) G.R. T + 1 (N) G.R. # 21
Bosley	Viox Garbutt	Blacks Fork # 4 Big Sandy Crew # 2 (s) 12 M. T + 1 (L) G.R. T + 2 (N) off	G.R. # 14 G.R. Crew # 6 (s) 11 p.m. T + 1 (L) G.R. T + 1 (N) G.R. # 22
	Garbutt	Blacks Fork # 5 Big Sandy Crew # 3 (s) 3 a.m. T + 2 (L) G.R. T + 1 (N) off	
Bosley	Rockett		G.R. # 15 G.R. Crew #7 (s) 2 a.m. T + 2 (L) G.R. T + 1, T + 2 (L) Big Piney T+1 (day) (N) off
	Garbutt	Blacks Fork #6 Big Sandy Crew #4 (s) 6 a.m. T + 2 (L) G.R. T + 1 Manila T + 2 (N) Standby T + 3	
Bosley Stone	Rockett Hales	Blacks Fork #7 Kent and Fields (s) 9 a.m. T + 2 (N) Fields-Standby T+3	G.R. #16 G.R. Crew #8 (s) 5 a.m. T + 2 (L) Big Piney T+1 (day) (L) G.R. T + 1 (N) off

Support

Helicopter

T+2 Treat Blk's Fork
if nec.-Trans. men + mat. to Gorge Area + out again
Spray remaining G.R.
(L) G.R. T + 1
(N) Trans. Gorge area

Commissary

Trailer # 1
Follow Oper. to Linwood Bridge by 5 p.m. T + 2

Trailer #2
Follow oper. to Manila, utah by 10 a.m. T+2

Section 4
Field C. Peterson (Jackson 4 p.m.) Regenthal 6 a.m.

Asst.F. Chief	Section Foremen	Tributary	Green River	Support
Stone Stone	Hales Livesay	Henry's Fork #1 Henry's Fk. Crew #1 (s) 8 a.m. T + 2 (L) Manila T+1, T+2 (N) Cart Cr.	G.R. #17 G.R. Crew # 1 (s) 8 a.m. T + 2 (L) G.R. T + 1 (N) off	Airboat #1,#2 T+2 Treat G.R. #17 to rapids - Trans. men/mat. to Gorge (L) G.R. T+1, T+2 (N) Standby
Stone Stone	Livesay Hales	Henry's Fk. #2 Kanaly-Millis (s) 11 a.m. T + 2 (L) G.R. T + 2 (N) off	G.R. #18 G.R. Crew #2 (s) 11 a.m. T + 2 (L) G.R. T + 1 (N) off	Helicopter T+3 Trans. Gorge area, Clean up (L) G.R. T + 2 (N) off
Stone Bosley	Viox Hales	Henry's Fk. #3 New Fk. Crew #1 (s) 2 p.m. T + 2 (L) G.R. T+1, T+2 (N) off	G.R. # 19 G.R. Crew #3 (s) 2 p.m. T+2 (L) G.R. T+1,T+2 (N) off	Commissary Trailer #1 Secure p.m. T + 3 Trailer #2 Secure PM T+3
Stone	Livesay	Sheep Cr. #1 McQuivey (s) 6 p.m. T+2 (L) Manila T+1,T+2 (N) Fish col.		
Stone Bosley	Livesay Hales + Williams	Sheep Cr. #2 Berg (s) 9 p.m. T+2 (L) Manila T+1, T+2 (N) Fish Col.	G.R. #20 G.R. Crew #4 (s) 5 p.m. T+2 (L) G.R. T+1,T+2 (N) off	
	Stone	Carter Cr. Carter Cr. Crew (s) 9 p.m. T+2 (L) Manila T+1,T+2 (N) Detox.		
	Stone Williams	Eagle Cr. Arnold (s) 11 p.m. T+2 (L) Manila T+1,T+2 (N) Detox.	G.R. # 21 G.R. Crew #5 (s) 8 p.m. T+2 (L) G.R. T+2 (N) off	
Stone	Hales	Skull Cr. Fields (s) 7 a.m. T+3 (L) Manila T+2 (N) Detox.		
Stone	Hales	Trail Cr. Miller (s) 8 a.m. T+3 (L) Manila T+2 (N) Detox.		
Stone Bosley	Hales Mueller	Allen Creek Stevens (s) 8 a.m. T+3 (L) Manila T+2 (N) Detox.	G.R. # 22 G.R. Crew #6 (s) 11 p.m. T+2 (L) G.R. T+2 (N) off	
Stone	Hales	Cart + Dutch John Henry's Fk. Crew #1 (s) 6 a.m. T+3 (L) Clay Basin T+3 (N) Detox.		

Appendix C A Sample Page of the Sleeping Roster Given To All Personnel

Sept. 3 - Special Study Group (Binns, Mediate, Mitchum) sleep and eat in field trailer through entire project.

Sept. 4 - Big Piney:

Piney Motel - Peterson, Millis, Stone, Conley, Fike, Parks, Rogers, Burnap.

Frontier Hotel - Eiserman, Azevedo, Regenthal, Helms, Green River Crews 1,2,3, & 4 (8 men) airboat and support (6 men).

LaBarge:

Red Cliff Motel - Mueller (day, Garbutt (day), Rollefson, Green River Crews 5, 6, 7, & 8 (8 men), Arzy & McNeel (1 day and 1 night), Jackson (day), Helms.

Pinedale - Helicopter group (7 men), Beal, Andriano, Garlic (& 2 men), Crane, Jiacoletti, I & E and coordinator personnel (8 men), fish salvage (3 men) and Huggins.

<u>I & E, Observation and Administration Personnel make arrangements for their own lodging after this date.</u>

Farson:

Sitzman Motel - Williams, Bosley, New Fork Crews 1 and 2 (4 men), Big Sandy Crews 1, 2, 3, and 4 (7 men).

Green River City - Viox (at home).

Star Motel - Rockett, Stone and Hales.

<u>Commissary Personnel - sleep with trailers to Sept. 6.</u>

Sept. 5 - LaBarge:

Red Cliff Motel - daytime only - Green River Crews 7 & 8 (4 men), fish salvage (3 men) and Huggins.

Sept. 5 - Green River City:

Star Motel - Jackson, Peterson, Regenthal, Azevedo, Kanaly, Fike, Eiserman, Williams, Bosley, Stone, Rockett, Mueller, Millis, Conley, W. McNeel, Arzy, airboat units and support (7 men), helicopter group (7 men), Big Sandy Crews 1, 2, 3, & 4 (6 men).

Desmond Motel - Green River Crews 1,2,3,4,5,6,7,& 8 (16 men), New Fork Crews 1 & 2 (4 men).

At home - Wilson, Long, Viox, Arnoldi and June.

Sept. 6 - Green River City (Viox at home):

Star Motel - Jackson, Peterson, Regenthal, Williams, Azevedo, Kanaly, Millis

Appendix D Example of Individual Work Schedule For A Section Foreman

Work Schedule-MUELLER

Equipment needed - pickup, sleeping bag

August 20 to 24 - Attend coordination meeting at Green River.

September 3 - 8:00 A.M. Big Piney final briefing.

September 3 - Set up and put in order Green River Stations #6 & #7, and LaBarge Creek Station.

September 4 & 5 - A.M. - sleep late, you are on duty all night September 4 and 5.

3:00 P.M. - move toxicant from Bureau of Reclamation Camp at Fontenelle to station location.

11:00 P.M. - start and operate Green River Station #6 followed by Green River Stations #7, #8 and # 9 and LaBarge Creek. Relieve Rollefson at 8:00 P.M. on Green River Station #5. You are relieved by Kanaly after starting Green River Station #9 at 8:00 A.M. on September 5.

September 6 - Pick up four wheel drive vehicle from Rockett. Allow plenty of time to get into Green River Station #22. Take crew in with you.

At 11:00 P.M. start to operate Green River Station #22 using Green River Crew #6.

September 7 - 6:00 A.M. - Secure Station #22 and return to Green River for sleep. Pick up first aid kit, tools and valves from crew.

You will work with Green River Crews #1, #6, #7, and #8 - Rollefson, Kanaly, Garbutt, Helms, Stone and Bosley.

You will sleep at LaBarge September 2 and 3rd; sleeping bag September 4 (if possible).

September 5 - Green River (daytime);

September 6 - Sleeping bag (if possible);

September 7 - Green River (daytime) if desired.

Terminate obligations September 7 after 8:00 A.M.

Appendix E Example Of An Individual Work Schedule For A Station Crew Member.

GREEN RIVER CREW WORK SCHEDULE

Green River Crew #1 J. Einerson

Equipment needed - 1 pickup

September 2 - Sleep at Big Piney

September 3 - 8:00 a.m. - Big Piney final briefing

September 3 - Set Green River Station #1 to familiarize yourself with equipment, work plan and area of obligation. Sleep at Big Piney.

September 4 - Be at Green River Station #1 by 7:30 a.m. Start station at 8:00 a.m. at flow indicated on flow data sheet. Station terminates at 3:00 p.m. Take barrel valves and fittings. Go to Cottonwood Creek Station and relieve Millis by 5:30 p.m. Terminate station at 10:00 p.m. Stay at lodging at LaBarge. (Dotson is Section Foreman; Helms is Assistant Field Chief)

September 5 - Be at Green River Station #9 by 7:15 a.m. Rig valves and set flow. Start station at 8:00 a.m. at flows indicated on flow data sheet. Station terminates at 3:00 p.m. Take barrel valves and fittings.

10:00 a.m. - One man and Section Foreman Kanaly start Fontenelle Station. Terminate station at 5:00 p.m.

Stay at lodging at Green River City. (Kanaly is Section Foreman; Helms is Assistant Field Chief)

September 6 - Be at Green River Station #17 by 7:15 a.m. Rig valves and set flow. Start station at 8:00 a.m. at flows indicated on flow data sheet. Station terminates at 3:00 p.m. Take barrel valves and fittings. (Hales is Section Foreman; Stone is Assistant Field Chief)

Turn in tools, first-aid kits, valves and fittings to commissary trailer and terminate obligations.

Appendix F Commissary Trailer Parking and Travel Schedule

Sandwiches, coffee, milk and soft drinks will be available to all personnel assigned to Green River Rehabilitation Project at the Game and Fish commissary trailers. Commissary trailers will be manned on a round-the-clock basis from noon on September 4 to noon on September 7. The location of these units is as indicated below. Prior to 12:00 noon on September 4 sandwiches will be distributed to the Green River Crew #1 and #2 and New Fork Crew #2 at the New Fork bridge and Green River bridge on the Boulder-Big Piney cutoff road. New Fork Crew #1 will have sandwiches distributed to them on station.

Trailer #1 - Small trailer - responsibility - Bill Kozas and Ray Arzy.

September 4 - Park at LaBarge check station from noon to daylight (6:00 a.m.). September 5 move to Big Island Bridge.

September 5 - Park at Big Island Bridge until 5:00 p.m. - move to junction LaBarge-Green River road and U.S. 30 - park rest of night.

September 6 - At 6:00 a.m. move to Game Warden Station Manila, Utah. Secure station at noon the 7th - check in equipment from crews. P.M. on this date park trailer at Jack Wilson's, store equipment in trailer.

September 7 - Secure commissary at noon this date.

Trailer #2 - large trailer - responsibility Chuck Raper and Mike McIntosh.

September 4 - Park at bridge over Big Sandy Creek-Blue River road crossing. Be here at 5:00 p.m. and remain until 10:00 a.m. September 5.

September 5 - Park at turn-off to Station #15 and #16 on State Highway 530, 8.4 miles from Green River City. Be here at 5:00 p.m. and remain until 12:00 noon September 6th and move to Linwood Bridge on Green River.

September 6 - Park just east of Linwood Bridge across Green River and off road away from heavy truck movement. Check in equipment from crews.

September 7 - Secure commissary at noon this date - move trailer to Boulder Rearing Station and store equipment in trailer.

Appendix G   Table Of Stream Flows In C.F.S. With Corresponding Amounts of Toxicant In Liquid Ounces Per Minute and C.C. (or ml.) Per Minute For Rates Of 1 and 5 Parts Per Million

C.F.S.	Liquid Ounces Per Minute 1 ppm.	Liquid Ounces Per Minute 5 ppm.	C.C. or ML. Per Minute 1 ppm.	C.C. or ML. Per Minute 5 ppm.
1	.06	.29	1.7	8.5
2	.11	.57	3.4	17.0
3	.17	.86	5.1	25.5
4	.23	1.15	6.8	34.0
5	.29	1.44	8.5	42.5
6	.34	1.72	10.2	51.0
7	.40	2.01	11.9	59.5
8	.46	2.30	13.6	68.0
9	.52	2.59	15.3	76.5
10	.57	2.87	17.0	85.0
20	1.15	5.75	34.0	170.0
30	1.72	8.62	51.0	255.0
40	2.30	11.49	68.0	340.0
50	2.87	14.36	85.0	425.0
60	3.45	17.24	102.0	510.0
70	4.02	20.11	119.0	595.0
80	4.60	23.00	136.0	680.0
90	5.17	25.85	153.0	765.0
100	5.75	28.73	170.0	849.0
200	11.49	57.45	340.0	1,699.0
300	17.24	86.18	510.0	2,548.0
400	23.00	115.00	680.0	3,398.0
500	28.73	143.63	849.0	4,247.0
600	34.47	172.35	1,019.0	5,097.0
700	40.22	201.08	1,189.0	5.946.0
800	45.96	229.80	1,359.0	6,796.0
900	51.71	258.53	1,529.0	7,645.0
1,000	57.45	287.25	1,699.0	8,475.0
1,100	63.20	315.98	1,869.0	9,344.0
1,200	68.94	344.70	2,039.0	10,194.0
1,300	74.69	373.43	2,209.0	11,043.0
1,400	80.43	402.15	2,379.0	11,893.0
1,500	86.18	430.88	2,548.0	12,742.0

Prepared By:

Bill Helms
Fisheries Biologist
Pinedale, Wyoming

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CONVERSION TABLE

1 C.F.S. = 448.83 gal./min.
1 C.F.S. = 57,450.24 liq. oz./min.
1 C.F.S. = 1,698.96 liters/min.
1 C.F.S. = 1,698,960 c.c. or ml./min.

Appendix H

Table of River Flows and Toxicant Dispensing Information Which Was Supplied to all Personnel

Flow Data Sheet

Station No.	Stream Flow at station: Est.	Stream Flow at station: Actual*	Toxicant to be added per unit of time: Liquid oz. per min.	Toxicant to be added per unit of time: ½ Barrel Time	Total toxicant in stream for seven-hour period. Six or three hours for trib. as designated: Gals.	Total toxicant in stream for seven-hour period. Six or three hours for trib. as designated: Barrels & Gals.
New Fork #1	300	176	87	40 min.	275	5
New Fork #2	350	224	101	36 min.	320	5 plus 45
Green River #1	450	352	130	28 min.	410	7 plus 25
Green River #2	475	377	137	27 min.	430	7 plus 45
Green River #3	825	601	238	16 min.	750	3 plus 35
Green River #4	899	644	259	14 min.	825	15 plus 5
Green River #5	899	644	259	14 min.	825	15 plus 5
Green River #6	899	700	259	14 min.	825	15
Green River #7	944	717	272	13.6 min.	850	15 plus 5
Green River #8	944	718	272	13.6 min.	850	15 plus 5
Green River #9	944	718	272	13.6 min.	850	15 plus 5
Green River #10	944	718	272	13.6 min.	850	15 plus 5
Green River #11	977	763	281	13.2 min.	875	16 plus 5
Green River #12	977	763	281	13.2 min.	875	16 plus 5
Green River #13	977	774	281	13.2 min.	875	16 plus 5
Green River #14	977	774	281	13.2 min.	875	16 plus 5
Green River #15	977	774	281	13.2 min.	875	16 plus 5
Green River #16	977	774	281	13.2 min.	875	16 plus 5
Green River #17	999	810	259	14.1 min.	819	15 plus 6
Green River #18	999	810	230	15.9 min.	728	13 plus 19
Green River #19	999	800	230	15.9 min.	728	13 plus 19
Green River #20	1038	790	239	15.3 min.	756	14 plus 11
Green River #21	1038	790	239	15.3 min.	756	14 plus 11
Green River #22	1038	790	179	20.4 min.	567	10 plus 13
Big Sandy #1		27	8		25	
Big Sandy #2		27	8		25	
Big Sandy #3		45	13		40	
Big Sandy #4		45	13		40	
Black's Fork #1		10	-		-	
Black's Fork #2		10				
Black's Fork #3		10				
Black's Fork #4		10				
Black's Fork #5		10				
Black's Fork #6 & 7		10	3		10	
East Fork		50	15		45	
Cottonwood Creek		25	7.2		22	
Muddy Creek		2.5	0.72			
Dry Piney		Dry				
LaBarge Creek		25	7.2		22	
N. Piney-Middle Piney Cr.		25	7.2		22	
South Piney		15	4.3		14	
Fontenelle Cr.		1.5	4.3 & 0.5		14	
Henry's Fork #1		25			20	
Henry's Fork #2		25			20	
Henry's Fork #3		25			20	
Birch Creek						
Sheep Creek #1		23	7		20	
Sheep Creek #2		23	7		20	
Spring Creek		Dry				

* Not obtained until after treatment completed.

Addendum 1 Report Presented by Croswell Henderson, Colorado River Basin Project Laboratory, at the Technical Sessions of the Colorado River Basin Water Quality Control Conference, Santa Fe, New Mexico, February 14, 1963

U. S. PUBLIC HEALTH SERVICE
PROTECTION OF WATER SUPPLIES AND STUDIES OF POLLUTIONAL PARAMETERS DURING THE GREEN RIVER FISH TREATMENT PROJECT

THE TOXICANT OPERATION:

During September 1962, a large-scale fish rehabilitation project was initiated on the Upper Green River by the Wyoming and Utah Fish and Game Departments and the U. S. Fish and Wildlife Service. The purpose of the project was to eliminate, insofar as possible, the undesirable rough fish population in the Green River prior to the closing of Flaming Gorge Dam. The area would later be restocked with desirable game species such as trout which would have a much better opportunity for survival and growth in the new reservoir.

Approximately 450 miles of streams were treated with a fish toxicant during the operation. The reach of the Green River treated extended from above Big Piney, Wyoming, through Wyoming and Utah to the Utah-Colorado border, about 30 miles below Flaming Gorge Dam. The remainder of the mileage consisted of tributaries entering the Green River within this reach.

The toxicant used was an emulsifiable rotenone formulation, Chem-Fish Regular, containing 5 per cent rotenone, a methylated naphthalene solvent and an emulsifier. Toxicant application stations were set up at 10-mile intervals throughout the reach of the river. The toxicant was applied through precalibrated valves on hoses stretched across the river at each station. Enough of the formulations was added to maintain a concentration of 5 ppm (formulation) in the river water. Toxicant was applied at each station for a period of seven hours. Application from each downstream station started three hours after the one above had been placed into operation. Thus, a lethal concentration of toxicant was maintained over a long stretch of the river for a considerable period of time. The overlap would prevent the possible escape of any fish from the area. Over a period of three days, 21,495 gallons of toxicant were applied. Over 100 men took part in the operation. Flows in the Green River ranged from about 200 - 900 cfs during the operation. It was believed that dead fish would be scattered sufficiently so as not to create nuisance conditions, however, provisions were made to eliminate problems of this nature had they materialized. In addition, the whole area was opened to the general public and they were allowed to collect any number of edible fish desired.

The last toxicant application station was approximately seven miles above Flaming Gorge Dam. It was expected, however, that a lethal concentration of toxicant would travel much further downstream. In order to prevent destruction of fish in the Dinosaur National Monument, a detoxification station was established near the Colorado-Utah border about sixteen miles above the upstream park boundary. At this station, a strong oxidizing agent, potassium permanganate, was used to nullify the effects of the rotenone. This crystalline material was added through spreaders located on a bridge over the river. Over the three and one-half day period, 17,160 pounds of permanganate were added.

Apparently, the whole operation was successful. The kill of fish at all up-river stations was considered essentially complete. Relatively few fish were killed below the detoxification station.

PROBLEMS OF POSSIBLE CONCERN

Some concern was manifested over the possible effects of the toxicant application on other water uses, especially domestic water supplies. The methylated naphthalene solvent was highly odorous and 5 ppm would impart a strong "kerosene" taste and odor to water and thus render it unpalatable. Also, it was expected that large quantities of dead and decaying fish would be present in the river for at least several weeks following the toxicant application.

Five domestic water plants obtained water from the Green River in the reach to which the toxicant was applied. As no alternative water supplies and a minimum of storage capacity were available, it would be necessary to use water from the river during most of the toxicant operation. The water plants concerned were: Fontenelle Camp, Wyoming, operated by the U. S. Bureau of Reclamation, with a population of about 400; Stauffer and Inter-Mountain Chemical Companies each with about 400 to 500 employees and additional use of considerable water for industrial uses; Green River, Wyoming, which also furnished water to Rock Springs, Wyoming, total population of about 15,000, operated by the Pacific Power and Light Company; Dutch John, Utah, operated by the Arch Dam Construction Company for the U. S. Bureau of Reclamation, with a population of about 1,200. With the exception of Fontenelle Camp, all of these plants had complete treatment facilities. Fontenelle had provision for chlorination only and about two days' storage.

Two water users downstream from the area of toxicant application could have been affected. These were the California Oil Company which obtained water at Red Wash, Utah, and the town of Green River, Utah, with a population of 1,000, located over 200 miles further downstream. Both of these plants had complete treatment facilities.

The Public Health Service had recently conducted research and field studies on a similar toxicant operation. These studies showed that toxicity, tastes, and odors could successfully be removed from water with activated carbon.

Colorado River Project personnel were requested to participate in the toxicant operation and to assist water plant operators in producing a palatable water. It was also felt that this was an opportune time to study the effects of the fish toxicant application on certain pollution parameters. No knowledge was available as to what effects may be produced either from the toxicant or from the large tonnage of decaying fish on such parameters as coliform count or B.O.D. Also, little was known concerning the effect of the toxicant on bottom macroinvertebrates which are often used as a measure of pollution.

PROTECTION OF WATER SUPPLIES

Field laboratories were set up in Green River, Wyoming, and Dutch John, Utah, water plants. Their major purpose was to determine the toxicant concentration in the raw waters, to estimate the amounts of carbon needed to remove toxicity, tastes and odor, and to check the finished water for palatability. Other determinations would be made as time permitted. The State Health departments assisted in collecting samples from other water plants and in conducting some of the analyses.

As no satisfactory chemical method of analysis for rotenone was available, analyses were made by a bio-assay technique using fingerling trout furnished by State Fish and Game departments. Ten trout were subjected to a series of concentrations of the rotenone formulation in Green River water. A standard curve was plotted on logarithmic paper, relating time of fish reaction (loss of equilibrium or mortality) to concentration. By timing fish reaction in unknown samples and using this curve, the toxicant concentration of any sample could be estimated. It was, however, necessary to conduct all tests at the same temperature (16°C.) or to prepare known curves for different temperatures to produce valid results.

Laboratory tests were conducted to determine the amount of carbon needed to remove toxicity, taste, and odor from water containing specific concentrations of the rotenone formulation. Varying amounts of carbon (Aqua-nuclear, powdered) were added to waters containing a fixed amount of formulation. It was found that 150 ppm of carbon would remove 5 ppm of toxicant formulation. Likewise, 60 ppm of carbon would remove 2 ppm of formulation. By using a straight-line arithmetic plot, the amount of carbon needed to remove any quantity of formulation could be estimated. Threshold odor determinations indicated that tastes and odors were also removed by this amount of carbon.

Raw water samples from the water plants were analyzed for toxicant concentration. Based on the analyses, the amounts of carbon needed were estimated from the prepared curve. The necessary amounts of carbon were added at fixed intervals to the water supply, usually through one of the chemical feeders. Samples of finished water were assayed for toxicity and threshold odor to determine the effectiveness of the carbon treatment.

The above procedure was carried out on raw and finished water samples for a four or five day period until the toxicant had naturally dissipated. The operations were successful in that few consumer complaints were received. Expected odors from dead fish did not materialize. Apparently, the dead fish were well scattered throughout the treatment area with no accumulation sufficient to produce an odor in the water.

EFFECT ON POLLUTION PARAMETERS

MF coliform determinations were made during the toxicant operation at the laboratory in the Green River, Wyoming water plant. No effect on coliform counts were observed that could be attributed to the toxicant operation.

The Utah Health Department conducted coliform, B.O.D., manganese and other water quality determinations on river samples from Dutch John, Jensen, and Red Wash, Utah. Four sets of samples were collected, the first before the operation and the remainder at weekly intervals following the toxicant application. Little, if any, definite effect on pollution parameters was apparent. However, a few coliform counts and some manganese concentrations were higher following the toxicant operation.

Coliform, threshold odor, B.O.D., and manganese and other water quality determinations were made on river samples collected at Green River, Utah, several hundred miles downstream from the treated area. These determinations were made several times daily for a week following the estimated arrival time of waters from the area in which the toxicant was applied. No effects on these parameters were indicated. A heavy rainstorm in the area was believed to be the cause of some increase in coliform counts and manganese concentrations towards the latter part of the survey period.

Bottom animal samples were collected at five river stations before and after the toxicant application. Although good populations of clean-water animals were found before the operation, the bottom animal population was almost completely destroyed by the toxicant. Follow-up studies are needed to determine the extent and time of recovery of these populations.