STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
704 Lewis Building
Portland, Oregon
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Placer Mining on the Rogue River, Oregon, in Its Relation to the Fish and Fishing in that Stream

By

Dr. HENRY BALDWIN WARD, Consultant

An Ecological Study Made for the
Oregon State Department of Geology and Mineral Industries
September, 1937 – May, 1938

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FOREWORD

Any matter which seriously affects the status, or which might conceivably cause the stoppage, of mining in a considerable portion of a state, must be of interest to other mining communities and of concern in the area affected as well as to the state agency formed to foster mining and mineral industries.

A controversy during 1937 between fishing and recreational interests, and mine operators in the Rogue River drainage, caused the former to bring injunction proceedings—later terminated by compromise—which would have gone far to kill both placer and quartz gold mining in southwest Oregon. One of the principal objections of the complainants, the fishermen-recreationists, was the alleged harmful effect on fish and fish life of the discharging into streams muddy water from placer mining.

For no other reason than to determine the true facts as to this phase of the controversy—the effect of muddy, mine water on fish and fish life—the State Department of Geology and Mineral Industries caused a strictly scientific study of the situation to be made. This report by Dr. Ward is the result of the investigation. The impeccable record of the author and his standing as a biologist among American men of science must be sufficient guaranty for all that his observations are accurate and his interpretations sound.

The essence of Dr. Ward's findings is that the placing of muddy water from placer operations in the Rogue River drainage is not inimical to fish and fish life.

Conservationists and fishermen should note particularly Dr. Ward's observation that the future of our famed coastal fishing streams—whether the fish population will be slowly decimated or whether it will be increased and maintained for the pleasure of all—will be determined by whether or not we demand real, honest-to-goodness, scientific biological control of our streams and fish problems.

EARL K. NIXON, Director.

September 1, 1938.
Portland, Oregon.

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INTRODUCTION

In August, 1937, I was consulted by Mr. Earl K. Nixon, director of the Oregon Department of Geology and Mineral Industries. He stated that the governing board of that department desired to arrange for a study of the effects of placer mine washings on the runs of valuable fish in the Rogue River. Mr. Nixon assured me that the Board had no desire to confirm fixed views but sought to ascertain the actual facts in the case and would welcome the most careful and complete study of the river whatever might be the results of such a study.

Shortly after this conference I received an invitation from the Board to undertake the work in accordance with the general understanding reached in my interview with Mr. Nixon. The month of September was spent partly in Portland conferring with various persons officially interested in the work on the Rogue River, and in part on the river. This was the low water period of the year. Further studies were made on the river at high water stage in March and early April, 1938; following that, the results of my work were discussed in Portland with the director and others.

A preliminary report was submitted last October. At that time as a basis for final conclusions I recommended the periodic collection of water samples at different places on the Rogue and the determination of turbidity and of erosion load throughout the year at points above the entrance of placer mine run-off and also below that. It was agreed that such tests be carried out at Grants Pass and at Agness.

During September I had been granted the assistance in the field of Mr. A. M. Swartley of the department. His intimate knowledge of the area and broad professional experience in geology proved of great service in the study of the river conditions and their probable origin. At the conclusion of our work together, Mr. Swartley wrote an extended report on the physiographic features of the region. From this valuable record I present herewith a part of Mr. Swartley's manuscript having a particularly intimate relation to the biological studies and conclusions reached in my own report. Mr. Swartley's section appears as Appendix A.

I also recommended that experiments be made to measure the effects on young salmon and trout kept for some time in water heavily loaded with mud from placer mining projects. Accordingly Mr. Nixon arranged with Dr. L. E. Griffin to carry out such experiments in his laboratory at Reed College. A summary of Dr. Griffin's important experiments is given with his permission in Appendix B. It is important here to emphasize one conclusion of Dr. Griffin: namely, that these few preliminary experiments should be carried further. The general results secured cannot be questioned, but their unique character and their importance both practically and scientifically call for their repetition in the light of experience gained in order to determine the limits, if any, within which the conclusions are to be accepted. I am indebted to Mr. Swartley and to Dr. Griffin for the privilege of including sections of their reports in my own.

Before I started on a study of the river the complaint filed with the court by citizens of Curry county was placed in my hands. Careful and repeated study of this document familiarized me with the views of the complainants regarding the condition of the river, the state of the fisheries and the alleged cause of the conditions which were described in detail in the document. This presentation of the case was kept constantly in mind; the region was studied with care and no trouble was spared in my efforts to determine the accuracy of the report and the justification for the opinions advanced. The various items included in that complaint are discussed later in my report in connection with the analysis of the situation as I found it.

My problem was to determine how far and in what way the fish of the Rogue River and its tributaries were affected by the placer mine run-off. No other region was to be considered; no other type of mining was to be taken into account. I was free to ascertain the facts in the situation and to make known all the facts which might be discovered in my study without suppressing or modifying any of them to meet the views of any of the apparently conflicting interests involved. I have tried to justify the responsibility laid upon me and hope that I have succeeded in some measure in discharging that responsibility.

THE ROGUE RIVER

The Rogue River rises in the Cascades of southern Oregon; its headwaters drain the entire western slopes of the ridges which encircle Crater Lake. For about 250 miles among mountains and hills it pursues a circuitous course trending southwest before it empties into the Pacific Ocean at Gold Beach. The region has long been known for the beauty of its scenery, the fertility of its orchard-filled valleys, the abundance and quality of its fish. First of all in the record of history was the fame of its gold-bearing sands and gravels which were extensively exploited by early settlers and have continued with varying activity to yield of their riches to those engaged in placer mining. No records have been found giving accurate data concerning the condition of the water in those early days. We may be sure that workings so extensive as were operated then discharged into the river considerable volumes of the same material that characterizes the run-off today. Indeed, it is reported by early navigators along this coast that the outlet of the river could be detected by the volume of reddish yellow water which it poured out and which could be followed for a considerable distance into the sea before it mingled indistinguishably with the ocean waters.

Only one published record has been found of previous analyses made of water from the Rogue River. This was printed in Water Supply Paper 363 (U. S. Geol. Survey, 1914). The table given there covers a period from September 10, 1911, to August 14, 1912, and the samples were taken near Tolo (now Goldray). It represents conditions in the stream far above placer mining operations, hence due entirely to natural erosion. The suspended matter varied from 3.6 to 1,360 tons per day and the dissolved matter from 239 to 2,328 tons per day. The turbidity varied from a trace to 350 scale units and the curve of variation in turbidity departed somewhat widely from that of the amount of suspended matter present. Thus the maximum turbidity recorded was observed in the period July 16–25, whereas the maximum of suspended and dissolved materials was obtained on January 8–17. The volume of the river fluctuated also widely, as shown by variations in the mean discharge from 1,141 to 14,134 second feet. Though this record covers a single year only, it shows wide and also rapidly fluctuating conditions to which the fish in it have been and still are subjected by nature.

The geography, geology, climate, water supply and floods in the Rogue River valley are succinctly discussed in the introduction to Water Supply Paper 638-B (U. S. Geol. Survey, 1932) on the Water Power Resources of the Rogue River Drainage Basin, Oregon. No further discussion of these features is needed here. The data given in this bulletin are of value in determining the significance of the additions to the normal stream flow as the results of placer mining operations.

ROGUE RIVER FISH AND FISHING

The Rogue River has long been held in high esteem as a salmon stream. It has been visited annually by many fishermen from Oregon and from other states and records of their sport, printed in various magazines devoted to travel and outdoor life, have given it truly an international reputation. Some years ago I met on the Rogue the treasurer of the International Olympic Games Committee who had come from England to test his skill on the far-famed salmon and steelhead of that stream. In 1930 I myself published in *Outdoor America* an article in which I dwelt on the beauty of the stream, the abundance and fine quality of its fish and its high value as a recreational center for Oregon and its visitors. Many other similar articles might be cited.

Only three species of anadromous fish contribute in significant numbers to the fame of the river: the chinook salmon (*Oncorhynchus tschawytscha*), also known as king, Columbia River, or quinnat salmon; the silversides (*Oncorhynchus kisutch*), also called coho, or silver salmon; and the steelhead (*Salmo gairdnerii*), commonly classed as salmon trout and regarded by ichthyologists as the sea-run form of the rainbow trout (*Salmo irideus*). Of interest to the fisherman are the various trout of the Rogue system. These do not run to the sea and are not further considered in this report.

It has been customary to speak of separate runs of spring and fall chinooks and of summer and winter steelheads. These are not always clearly separable and their spawning periods are either identical or closely continuous. Structurally the varieties cannot be separated and differences in movement and other activities vary with exact climatic conditions. They are not known to be affected differently by factors discussed in this report.

No one knows when salmon or trout first came to the Rogue River, but it seems probable that the salmon spawned at the foot of the retreating glaciers of the Ice Age and followed up the cool run off of the disappearing ice masses until their spawning grounds became as today: "These species of anadromous fish ascend the river to the highest point attainable before making their spawning beds, seeking the waters that are purest and coldest." (Wharton—*The Rogue River*)

The first settlers found the stream teeming with the same fish that are present today in lesser numbers. Testimony of the former abundance of salmon is given by many brief references in early records which though apparently extreme in phraseology are nevertheless proof that the fish in their annual migrations appeared in enormous numbers. That these numbers have been greatly reduced in the last 75 years is unquestionably true. But the same is true in every region and probably in every stream from California to Alaska. Increase in population and consequent modifications in natural conditions, multiplication in number of fishermen and "improvements" in means of capturing the fish, better means of transportation and economic pressure are among the factors which have multiplied many times the hazards facing the fish. As one scans the long list of perils that confront the fish in fresh water and in the sea, from the start of life to its finish, should we not rather marvel that despite all so many survive to multiply and maintain the race?

The river was once the seat of an extensive commercial fishery. From the records of the Oregon State Fish Commission it appears that the commercial catch in the years 1929-1933 inclusive was 185,775; 194,269; 267,766; 528,384; and 346,962 chinook salmon alone. In 1934 the catch was 174,006, and the river was closed to commercial fishing June 13, 1935. During all this period the steelhead was rated as a game fish and was not legally taken except on hook and line. Large meshed nets employed in commercial fishing insured a nearly total escapement of the steelheads and also of all save the largest silver salmon, although in the years 1929–1933 from one to 42,000 silversides were taken annually, or on the average in that period nearly 15,000 a year. Since the time when the Rogue was closed to commercial fishing in 1935, all the fish captured have been taken legally only by sport fishermen limited in season and to the use of hook and line alone. But no record of the catch is required and no figures can be given to measure the present size of the run. Estimates are subject to individual prejudice and are of limited value. In considering the present supply one must bear in mind furthermore that the time intervening has not been long enough to demonstrate the results of this remedial measure. It is well known that the curve of destruction descends sharply, but the curve of recovery rises very slowly at the start.

MUDDY WATER

The Rogue has always carried loads of silt. The extent of its drainage, the depth of its valleys, the amount of water-worn material in its area, and the drop of several thousand feet in its course of 250 miles to the sea, as well as the consistent testimony of explorers and settlers during the last century, give evidence of marked fluctuations in volume of stream flow and in clearness and turbidity of its waters.

All the evidence that has been obtained justifies the conclusion that no present-day contributions of materials produced by bank erosion differ in character or exceed in amount those added periodically by purely natural processes in past times. Splendid runs of salmon and steelhead were established and maintained under truly natural conditions which certainly were on occasion more extreme and violent before man ever came into the picture than they are today. Furthermore, there is good reason to believe that placer mining run-off was larger in amount and more continuous in the early years of that industry when for a time at least greater areas were being mined, more men were at work and cruder, more violent methods were followed than are employed today.

Somewhat later the best deposits seemed to have been exhausted, new discoveries of gold elsewhere drew attention away from this region. More recently social and economic changes have led to new interest in this resource and to renewed activity in Rogue River valley placer mining. Even at that the industry has not apparently assumed the proportions of that first period. This is important in our discussion as indicating that conditions today do not exceed and probably do not equal those which the fish met naturally before our nationals invaded this valley and also during that earlier period of pioneer mining activity.

CHANGES IN THE RIVER AFFECTING FISH LIFE

The river is modified and the life and habits of the fish in its waters are affected by such changes as are produced by human agencies. To be sure no one can think rightly of the stream itself as a constant environment. On the contrary it is undergoing continual change. The amount and location of winter's snowfall, the volume and time of seasonal rains, the duration and precise period of regional droughts, and other climatic variations produce variations in water level, in bank erosion, in growth of grasses, underbrush and trees in the drainage basin; thus sudden and often extreme changes in contours of the banks and surrounding country add sediments of different types to its waters and modify the conditions under which the fish it harbors are forced to live.

Similar changes which are not so easily seen take place in the bed of the river. Each flood cuts deep holes at some places and fills up such holes elsewhere; materials picked up at one point are sorted as the current varies and deposited at many different points. No region is spared, for even solid rocks are deeply grooved or broken and moved about as time passes. During my study of the river in March a tremendous slide at one point poured tons of material into the stream and blocked its course for days. In the past history of the valley such occurrences have often recurred and interfere violently with the gradual though slow disintegration of rocks and soil which are constantly adding to the environmental materials on which weather and water may work in tearing down and upbuilding the different areas in the valley.

Coming from the spring-fed slopes of high mountains, its waters were cold and pure. Its rapid descent and its rocky banks with frequent rapids in its course loaded the water with a rich supply of oxygen. The heavy forest cover of its shores in primitive days served to maintain the low temperature and high oxygen supply of its waters.

Thus the Rogue River furnished originally unsurpassed conditions for the development and perpetuation of large and fine races of the anadromous fishes. The coming of man has wrought many changes in the environment which have been clearly unfavorable to the fish. These changes have been (1) the construction of dams; (2) the building of diversion ditches; (3) the development of agricultural interests, such as farms, orchards, forests, nurseries; (4) the organization of towns and cities; (5) the establishment of factories and industrial enterprises. Probably in point of time before any of these, came placer mining with its violent overturnings of natural soil.

All of these enter into relations with the river which necessarily modify its original character. The changes are usually made without consideration of their effect on the stream as the home of the fish and in most instances affect unfavorably the welfare of those and other forms of aquatic life. It is important to consider in detail the precise relations involved and the results of the changes made.

Dams interfere with the upstream migration of the adult fish. Under natural conditions the fish penetrate into the smaller tributaries and upper reaches before depositing eggs and milt. To avoid interference with the migration of the fish, dams are provided with fish ladders, the construction and condition of which are all important factors. The dams in the Rogue, at Savage Rapids and Goldray, are equipped with ladders, but at the time of my visit they were not operating well. More extended study would be required to determine whether this was only a temporary condition and how far it affects the welfare of the fish. The same conditions were reported by Ledgerwood who studied the river in August, 1936 (see below). No special devices were found to aid the young fish in their journey down stream. It looked as if the migrating young would be drawn into the turbines and destroyed. No study was made of this problem.

Dams also modify the natural temperature of the river water. This factor was studied in August, 1936, by Edgar Ledgerwood, from whose report to the Oregon Fish Commission the following data has been taken. Above the obstructions the temperature of the river water rose on the average 1° F in 6 miles. At Goldray dam it mounted to 3.5° F in one mile, and at the Savage Rapids dam, while average daily temperatures remained about equal, the minimum was raised about 2° F, and the water in the fishways reached 72° F, a level distinctly unfavorable to salmonoid fishes.

When cooler water from lower levels behind the dam is drawn into turbines and discharged through a tailrace, this stream of lower temperature proves a strong attraction to adult fish ascending the river in search of spawning grounds. The fish attracted to the tailrace fight, of course in vain, to find access thus to upper levels and many attempts have been made to bar them from this stream. Similar deceptive streams start from leaks at lower levels in dams and draw the fish away from ladders that have been constructed to furnish them access to the water above the dam. As ladders are naturally fed by surface water from the basin behind the dam, they carry a stream warmer than the flow from the tailrace and from leaks near the base of the dam. Under these circumstances the adults are at least delayed, if not injured, on the trip to the spawning grounds, but as yet studies have not been made to determine the loss due thereto.

The plans proposed by the Reclamation Service (Bull. U. S. Geol. Survey 638-B) for transforming the stream into a power-producing element by constructing 34 possible dams, or even part of the maximum efficient number, would undoubtedly entirely destroy the runs of salmonoid fishes and close the career of the Rogue as a rendezvous for fishermen.

Diversion ditches have also modified natural conditions in the Rogue River. The wide open entrance of such a ditch with its inflowing current invites the entrance of aquatic animals, and particularly those living near the surface or feeding along the shore. This includes especially young fish, either fry or fingerlings, seeking to descend the stream and escape into the ocean. Even older fish such as spawned-out steelheads, moved by the same impulse for the sea, will at times enter such ditches. That such is the case abundant testimony can be furnished. Young fish have been watched often entering such ditches, moving freely down the current, accumulating in deeper holes when the water was shut off, or found dead in irrigated fields. They are seen in miners' settling basins or power-plant reservoirs, are torn to sheds in turbines or ejected with water from the nozzle of a giant. It is immaterial whether the diversion ditch serves a power plant, an irrigation project, a mining enterprise or some other purpose, the fish, young and old, which enter it are condemned to destruction. While the number tempted to enter at any particular moment may be small, it must be remembered that such ditches work day and night until shut off and the total count of fish destroyed is unquestionably large. Most of these conditions I have observed personally on the Rogue and these observations have been confirmed by testimony of others.

Recognizing this serious loss, Oregon has provided by law that the intake of diversion ditches must be screened so as to prevent the entrance of fish. At the Savage Rapids dam an expensive screen has been installed to prevent fish from entering the ditch which takes a large volume of water out of the river. No study whatever was made of the efficiency of this installation, but even casual observation of other ditches showed some to be entirely without protection as well as others in which the screen as placed was worthless. These conditions are responsible for a large and preventable loss in the fish supply of the Rogue River.

Changes in the valley due to human occupation and necessary modifications are significant and in part not usually recognized. The cultivation of farms, orchards, nurseries, and all other agricultural activities, save forestry alone, break up the sod, destroy the underbrush, dry out the soil, drain marsh areas large and small, reduce the capacity of the land to serve as a holding ground for water, hasten the run-off of rain and melting snow, heighten erosion; and all of these influences react unfavorably on the stream as the home of the fish. These conditions are too well known and too often discussed to call for further notice here.

One other feature is less widely recognized and deserves mention because of its intimate relation to the welfare of salmonoid fishes. The diversion of river water through ditches, its disperson over fields, and slow return to the river by seepage channels results in raising the average daily temperature of the river during the dry summer season. This is certainly significant in the case of a stream like the Rogue where the water temperature at this season is near the upper limit of tolerance for salmonoids. One can hardly doubt that the water of the river is on the average warmer in summer now than it was 100 years ago before the cutting of the forests, the mining of the soils and the creation of farms began. These changes are inevitable, but no one would wish it otherwise. Some modifications of natural conditions must be accepted if the land is ever to be made useful for human homes and the prosperous existence of man. Temperature conditions in the Rogue River have not yet changed sufficiently to make the river unsatisfactory for fish life, but the destruction of forests around its sources and on the mountainous areas of its lower reaches will certainly threaten its supremacy as a famous fishing ground and should be controlled with the utmost care.

The influx of population into the valley of the Rogue led as elsewhere to the organization of towns and cities, and also to the establishment of industrial plants, such as canneries, factories, packing plants, and other establishments which yield considerable amounts of waste that as usual are discharged into the streams. These materials are often distinguished as domestic sewage and industrial wastes, but are actually not separate types. Under present day conditions both are ordinarily mixed and discharged through collecting systems, i. e., municipal sewers. These wastes contain organic materials in process of disintegration or chemical substances which are by-products of industrial plants. The latter are often toxic in character and the former take up oxygen with such avidity that the water of the stream is deprived of this essential element. Either condition is serious and in the extreme case fatal to the fish. Young fish are most sensitive to these as to other unfavorable conditions.

The establishment of sewage treatment plants by the larger communities in the Rogue valley has been adequate to meet present dangers. The stream is now free from toxic chemicals and the oxygen content is adequate at all points tested. But the growth of other communities, the establishment of isolated canneries or manufacturing plants and the use of industrial processes involving chemicals of a toxic nature may discharge into the river at any time untreated wastes which will seriously threaten the welfare of the fish. Such occurrences in other regions have resulted in the sudden destruction of large numbers of fish. It would be deplorable if ever such a misfortune befell the Rogue.

PRESENT CONDITION OF ROGUE RIVER SYSTEM

MY SURVEY AT LOW WATER

The relations of any organism to the environment are complex and the relative importance of any single factor difficult to determine definitely. Superficial conditions are always most apparent but often of minor significance if any in the solution of a given problem. The first step is necessarily the precise determination of the facts at issue. Only after those have been precisely determined can the causal relations be profitably discussed. At the outset of my study I was forcibly impressed by the mass of wild statements current regarding the condition of the river and the fish. Even among those who lived near the river, fished at all seasons in its waters, knew the pools and the habits of the fish and were not influenced by relations that might warp their judgment of actual conditions, there was wide difference of opinion regarding the condition of the river and the number of fish as well as the cause of changes which all agreed had taken place.

It was of primary importance to settle if possible some of the facts in dispute and my attention was first directed to the river. Since the most serious complaints came from the part of the stream which was below the points at which placer mine run-off reached the main river, it was decided to begin the study near the mouth and work up stream. The work started the first of September and at that time the river water stood at or near the lowest level reached in the course of the year. Placer mining in the district had stopped some weeks earlier; stored up water supplies had been drained and no rain had intervened to complicate the situation. In consequence the river water was remarkably clear and free from products of erosion, the current ran slowly, pools were drained down so that the flowing water rippled lazily over gravel bars. One could see with clearness the records of earlier water levels on the banks and bars and read from a boat the actual condition of the bottom in all save the deepest spots in the pools. No period could have been more favorable for determining the real condition of the stream and the deposits made at various levels.

A trip was made on September 6 in a fishing boat from Gold Beach to Agness. I was accompanied by Mr. Nixon and Mr. Swartley. Evidences of stream activity at various periods were sought for with great care. Floating materials stranded high on the banks marked the extreme limits of high water; more abundant deposits were found in back waters, on shelving beaches above the existing water level and reaching down to the margin of the water; even on the stones in the pools one could find evidence of stream deposits of recent date. From point to point we landed on the shore, studied the features noted, measured the thickness of the deposits, determined roughly the materials of which the deposits were composed, scraped samples from the surface of the larger stones in protected corners where the covering was thickest and discussed together the amount and origin of these deposits. I made extended field notes on the color, thickness, consistency and physical character of these deposits as well as of the areas involved and their relations to rocks, promontories and direction of stream flow. Since these deposits had occupied a prominent place in statements both written and oral regarding the condition of the Rogue, extreme care was devoted to recording every detail of the situation that could be found.

The area covered by these deposits was conspicuous. As the river channel shifts from bank to bank the deeper water forms a series of crescentic areas reversed in direction and joined at the tips (Fig. 1). The crescents vary in proportions but are essentially uniform in type. The shore which faces the concave side of the crescent has usually a longer, gentler slope (Fig. 2) and these beaches which showed clearly the deposit were from one to several times the area of the low-water river itself. They formed thus conspicuous features of the landscape. On some of them were prominent longitudinal bars of coarse gravel sharply set off from the stream (Figs. 3, 4). In other places the slope of the beach was longer and gentler. Sometimes rocky headlands (Fig. 5) or strings of smaller rock masses along the shore broke up the formal pattern to some extent (Fig. 6). In sheltered spots behind such rock masses one could find deposits of almost pure sand, varying in depth from half an inch to a foot or more, but in number and total volume such deposits were small in comparison with the length of the stream and the area within the high-water marks on the banks.

FIGURE 1—*View of riffle where one crescent of river connects with the reversed crescent next below.*

FIGURE 2—*Wide, gently sloping beach between high and low water levels on Rogue River near the mouth of the Illinois.*

The area within which rocks and stones were covered by the material deposited from the river water was not only considerable in extent but it was conspicuous by virtue of the color of the deposit. That was of a pale reddish yellow hue varying somewhat in intensity or density of coloring but still of a characteristic shade in sharp contrast with the clear greenish water and the darker green of the vegetation or the dull colors of the rocks. In fact, as we rode up stream in the motor boat such areas came out with striking distinctness at every bend when we passed from one pool to the next and the sloping beach with its painted stones was shifted from side to side. No one observing the situation could fail to be impressed with this as the most conspicuous feature of the landscape. Apparently the deposit stopped just at the water's edge, but closer observation showed that stones under water were covered with a similar deposit that needed only to be dried out to attain the appearance of that on the stones of the bank above the water level. At one extreme, stones that were not coated at all or only faintly were located at or near the upper limits of the high water, showing that the material was not present in equal amount or the conditions for its deposit were not favorable at maximum high-water level. But by contrast over the lower half, more or less, of the interval between high water and lower water limits all the stones on the sloping beaches and even the rocky promontories and steep rock faces, which in a few places margined the stream, were colored similarly by this conspicuous deposit.

The amount and character of the deposit was also carefully studied. We landed often and examined at close hand the stones of the beaches, sought to measure the thickness of the deposit on stones at varying levels and in different areas along the course of the river. It varied more in amount than in color; at some points it was so thin that only with difficulty could a sample be scraped off the stone even with the aid of a knife. On rough, broken, nearly vertical rock surfaces the color was distinct, but the material too scanty to get any sort of a sample. Under unusually favorable conditions flat stones lying fairly level carried a layer of the deposit estimated to be 1/16 of an inch thick. In one place, namely in a backwater behind a large rock where there was a considerable deposit of sand, I found a crust about 1/8 of an inch thick. It was so friable or "crumbly" that portions could hardly be removed without breaking up into powder even under careful manipulation. The surface of the crust was like that on the stones, but it graded without visible boundaries into the sand below, and as the crust was lifted grains of sand fell off leaving some still loosely connected to the upper part in which also some sand grains could be seen. At the first attempt to follow up the structure of the crust, it collapsed into a mass of loose sand grains with a small quantity of a fine powder. When still undisturbed on the surface of the sand or on stones where it was much thicker and devoid of larger sand grains, the surface of the crust was traversed by a multitude of small furrows running in every direction and reaching down into the crust. These furrows divided the crust into small, irregular blocks measuring ½ inch or less in maximum diameter. They resembled in miniature the broken surface of dried-out mud. The crust has thus scanty volume, imperfect continuity, and little or no adhesion or cohesion.

Samples of this material were obtained at different times from points on the Applegate River, from both forks of the Illinois River, from various creeks tributary to these or the Rogue, and at numerous places on the Rogue River itself. In gross appearance the samples were alike and manifested similar physical characteristics when handled. At most one could note only slight differences in the color of the dry sample.

When samples of this crust were added to water, thoroughly agitated and left to settle, the sediment settled out in 24 hours, but the water was still colored and held in suspension a small quantity of very fine material. After standing 44 hours the water was perfectly clear. When tested this water showed a very small amount of colloid material which could not be measured in any such rough determination. It probably agreed substantially in amounts with the exact measures given in the Lazell determination (see later). All of these tests show that the amount of colloidal material in the water of the Rogue River and its tributaries below the point at which the run-off of placer mine workings has been added to the stream is too small to produce on the bottom a "blanket" which might affect adversely young fish, eggs in nests if present, or the fish food in the water.

I have discussed this deposit at length so that its character may be clear even if its source is uncertain. It may be derived from natural erosion and it may come from placer mining as artificial erosion. It is more likely to come in part from each of those sources. However that may be it is not entitled to be called a "blanket" or to be charged with injurious or destructive influences on the fish life of the river. Certain fresh water formations are designated "blankets" because they cover the bed of the streams or lakes so thickly or imperviously that they smother the aquatic life there and prevent its multiplication as well as its growth. Thick cohesive mud layers, deposits of petroleum refining wastes or of some other chemical industries, sludge from domestic wastes and similar substances form continuous, resistant, impermeable layers which rightly are designated as "blankets". Their physical, chemical, and ecological differences from the deposit I have just described in detail are too evident to call for further analysis.

During the month of September our study was extended to cover the Rogue River and its tributaries. The work was carried to points well above all traces of placer mining and of all influences of human interference. Throughout this period conditions were uniform; minimum water level, sluggish current, lack of suspended materials and consequent clear water in the river at all points made it possible to investigate deposits, food supply, and general conditions for fish life thoroughly and reach some definite conclusions. Sewage treatment plants visited at Grants Pass and Medford were being operated well and no evidence was found that domestic or industrial wastes had been released without proper treatment. No extensive or dangerous deposits of any sort were seen at any point. Even below the points at which tributaries entered from areas in which placer mining had gone on at earlier months in the year, no changes from normal conditions were observed. The pools sheltered migrating fish; they were also seen in the stream below the dams, and a normal supply of fish food was found at various points visited. While the fishermen reported scanty catches, or none at all, this condition was apparently due to inactivity on the part of the fish, and that might well be attributed to the plentiful food and lack of stimulating weather.

The data just given summarizes results of the work done in the field last September. That was the period of low water, little or no precipitation and no placer mining. It was deemed important to study the river at the time of high water when the mines were in full operation. The preliminary report submitted at this time was regarded as subject to modification on the basis of later studies.

ROGUE RIVER SYSTEM AT HIGH WATER

Conditions found on the second visit, during March and April, contrasted strongly with those just described during September, 1937. The water in the river was very high and remained at a high level during my entire stay. Consequently observations on fish and their activities were limited. It was impossible to secure any data on spawning grounds below Grants Pass. However, at that stage of water the fish were hardly likely to stop for spawning in areas where the depth and strong current made conditions so unfavorable. The placer mines were operating actively and the run-off was a conspicuous feature in smaller tributaries and at points on the main river also.

The water supply of the placer miners was about at its maximum and consequently the run-off and its burden of soil materials washed out by the operations were also at a high level. Accompanied by Director Nixon and in some cases by Dr. Griffin also, I visited some of the largest and most active of the operations. Samples of the run-off were taken at points where the stream was first turned out from workings into a watercourse and then at points farther down the creek in order to determine how rapidly the original concentration was diluted. The results of these studies are discussed in a later section of this report. In general it was evident that the amount of material in suspension was reduced more rapidly than the appearance of the water changed. The color of the run-off coming from those workings being carried on in brilliant red deposits was particularly persistent while the amount of material in suspension (ppm) fell off rapidly.

An examination of the Rogue and its tributaries made at a period intermediate between high and low water would disclose, no doubt, some features of the situation not determined at the time of either visit I made to the region. Indeed it would be valuable to continue a study of the stream throughout the entire year. Such an investigation would furnish a solid foundation on which to build regulations for preserving and developing rightly all of the resources of the region. Without such a complete record of the changes from one period to another and of the varying relations between different influences the exact effect of the work done on a single resource can only be roughly determined. The proper solution of all the complex factors involved can only be found by securing

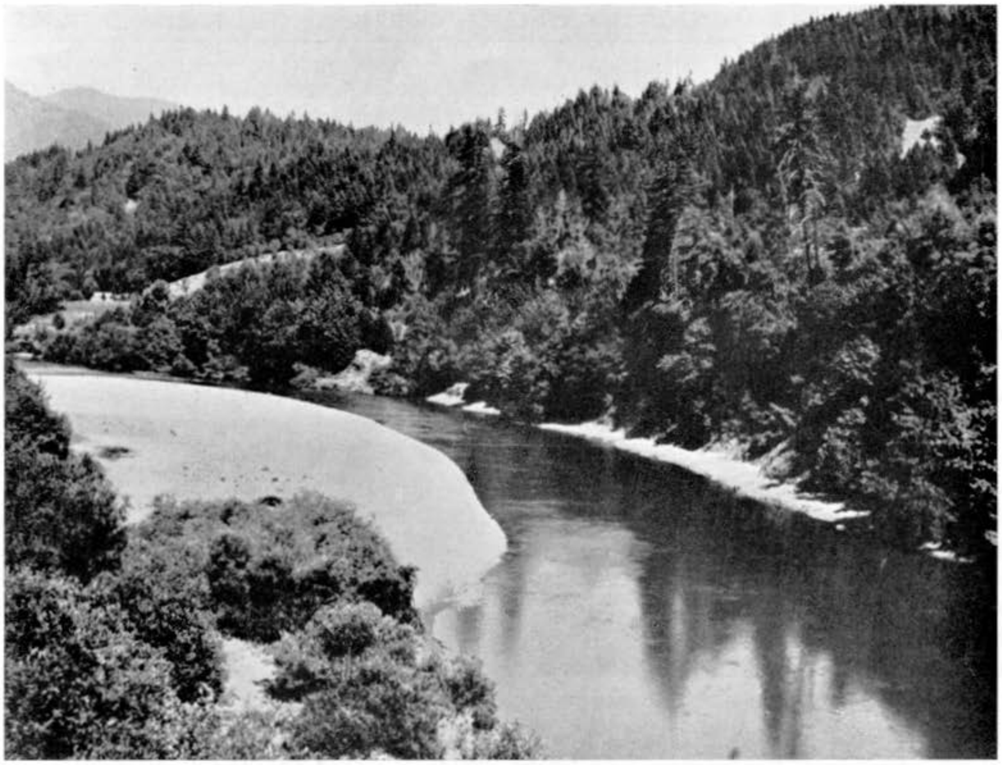

FIGURE 3—*Crescent of river above bridge at Agness showing beach with sharper bank at low-water level*

FIGURE 4—*Crescent with longitudinal bar of coarse gravel on outside of curve and higher rocky bank with vegetation inside curve. Taken at junction of Rogue and Illinois rivers.*

much larger knowledge and more perfect coordination of all interests involved.

In connection with this section giving the record of the survey made on the Rogue River it is appropriate to call special attention to the value of the assistance given me in different parts of the work. It would not have been possible to start the study and carry it out so promptly without the personal attention afforded me by Director Nixon. Frequent discussions with him enabled me to follow up details I wished to study without loss of time. His frankness in recognizing the dangers in the situation and his constant efforts to find a fair solution of the problem made his assistance inspiring as well as constructive.

The supplementary report of Mr. A. M. Swartley, who aided me in the part of the survey made in September, 1937, is of value in giving the views of a careful and experienced geologist. He confirmed fully statements I had reached in my preliminary report as to the physical conditions found in the Rogue River drainage, and especially the small amount of clay and other fine material on shores and stream bottoms, in backwaters and otherwise in our examination of the river and its tributaries. He discussed fully the methods of rock disintegration and decomposition and the transportation and ultimate character of the materials produced. He emphasized the fact that mining debris "is chemically inert, makes no oxygen demand on the stream and therefore takes away from the flowing water nothing which the fish require. This is equally true of this material whether placed in transit by nature or by man since [the products] are alike in nature, come from the same sources and are only being accelerated by man in their journey to the sea." Further he stated: "All these materials entering the streams, whether by natural or human activity, whether coarse or fine, whether traveling on the bottom, in suspension or solution, are almost altogether inert, suffer little change on their way to the sea, and having reached the end point of chemical change * * * do not rob the water of oxygen which the fish demand, or add to the water toxic agents injurious to fish" [fish food or other forms of life]. The portion of this report printed as Appendix A includes only a few of the items of special importance in connection with features I am discussing in this my own report.

The appended summary in Appendix B of experiments by Dr. L. E. Griffin on young fish in water carrying a heavy load of natural soil materials gives strong support to the conclusions from stream study. The mud came from the placer mining region in the Illinois River drainage basin; the fish were of species found in the Rogue River basin.

These experiments are unique. To be sure adult fish have been kept in water loaded with sawdust and with pulp or paper mill waste, so that much has been ascertained concerning the effects of certain types of material on adult fish. Also a long series of valuable experiments has been conducted by Shelford and his students on the effects of particular chemicals on adult fish. Further in Oregon, Finley and his associates have tested the results of placing young salmon in diluted municipal wastes and found the fatal effects of such an environment to be almost immediate.

In contrast with all these the experiments of Dr. Griffin have shown that young fish live well up to 30 days in good water mixed with an amount of natural soil materials from two to three times as large as the extreme load of the materials contributed to the Rogue River by maximum conditions produced by placer mining. These findings are discussed later in greater detail.

PLACER MINING AND WELFARE OF FISH

It is essential now to consider with exactitude the process of placer mining, the character of its by-products or materials discharged into the streams in the Rogue valley and the effects on the fish of the river at all periods in their life history and under the varying conditions in the stream at different seasons. In this consideration we are concerned only with those features designated properly as biological that have some influence direct or indirect on the life of fish. Problems involved in the construction and maintenance of dams and diversion ditches have been given adequate mention in the earlier portions of this report.

Placer mining is pursued in the Rogue River district by dredging and by sluicing or hydraulicking. The dredges are employed in only a few places and on extensive level areas where settling basins are provided. Under these conditions the final run-off as discharged into the Rogue or some tributary is free from silt and consequently may be left out of further consideration here.

Placers which are mined by hydraulicking and sluices are located in rough territory, very often in narrow gulches where settling basins are mechanically impossible so that the run-off passes into the Rogue River directly or into a tributary from which it ultimately reaches the main stream. The water used is usually obtained by a diversion ditch which taps some tributary at a higher level and is thus in itself of fine quality. Accordingly the character of the run-off is determined by the materials in the soil which is broken up by the action of the water employed. The water carries a heavy burden of soil materials regularly designated as waste. In a large part of this region the run-off is highly colored and criticism has been particularly violently directed at the conspicuous and persistent color contributed to the stream. All of the materials involved deserve further consideration.

Attention must first be directed to the various meanings attached to the word waste or wastes. In mining, waste is "superfluous or rejected material not valuable for a given purpose". In physical geography, waste is defined as "material derived by mechanical and/or chemical erosion from the land, carried by streams to the sea." Wastes may thus consist of or include materials unchanged in nature or those which have been chemically altered, i. e., natural constituents of the soil or new substances produced by chemical action. The placer mine run-off is waste in the sense that it is superfluous and unserviceable material, but it is not material that has been modified by processes of manufacturing or chemical treatment. The placer mine run-off is composed of good water and normal unaltered soil; it carries no materials that can rightly be called *deleterious substances.* This distinction is fundamental and should be emphasized.

To designate placer mine run-off as pollution is a confusion of terms. Neither in dictionary definition nor in scientific analysis can the use of this term be justified. To pollute is to defile; to contaminate with wastes of man or animals; this is done by introducing domestic or community wastes, or such as are produced in manufacturing and industrial processes. Chemically these include toxic materials or unstable compounds which have a high affinity for oxygen and withdraw promptly so much oxygen from the water that they threaten the life of organisms in it. Trout and salmon prefer waters which are surcharged with dissolved oxygen and they are sensitive to any diminution in the oxygen supply. They are also sensitive to domestic and industrial wastes, i. e., foreign substances. But the substances carried in the water coming from placer mines are those common to the soil of the region. They are stable compounds and make no draft on the oxygen content of the waters. Washings from placer mining have been poured into the Rogue River in quantities since 1850 and even when the stream was crowded with the immense runs of salmon, which characterized it in earlier days, the fish found these waters favorable for their existence; they maintained their runs.

Evidence of the character and effect of erosion materials is given in an important publication on the Detection and Measurement of Stream Pollution (Bulletin U. S. Bureau of Fisheries, No. 22; 1937) by Dr. M. M. Ellis, in charge Interior Fisheries Investigations. On page 432 Dr. Ellis points out that erosion silt has no effect on streams (a) in decreasing dissolved oxygen, (b) in increasing acidity, (c) in increasing alkalinity, (d) in increasing specific conductance, (e) in increasing ammonia, or (f) in specific toxic action on fishes. In his tabulation of effects under the headings of bottom pollution blanket and increase in turbidity, he indicates that erosion silt and other suspensoids have a critical limit which is discussed in detail at another point in his paper (p. 394). The dangers which he sets forth there are not one of them present in the Rogue River, as I shall proceed to show in detail.

In the Rogue River I have already noted the absence of any continuous layer of erosion materials which could possibly be designated as a *blanket*, or cover fish foods, nests or spawning ground with an impermeable layer. Cole (1935) has demonstrated experimentally that fish move uninjured through very muddy waters. Swartley in his supplementary report gives a table of the amount of suspensoids recorded in a group of streams, some of which are good salmon rivers; these carry from 137 to 395 ppm of solid materials and have turbidities varying from 27 to 245. In his experiments Griffin maintained for some weeks young salmon in good condition in water containing more than 1000 ppm of mud from placer mine areas in the Rogue River valley, whereas the maximum amount actually found in water taken from the river at Agness was 440 ppm (See Table II, p. 21).

Placer mining does not burden the stream with foreign materials or with substances that are toxic or inimical to fish life. Its processes contribute to the normal burden of the stream the same materials which are brought down from the hillsides of this area and no substance is involved which is

FIGURE 5—*Bold rocky promontory. Rock marked by color of thin layer of deposit below high-water level.*

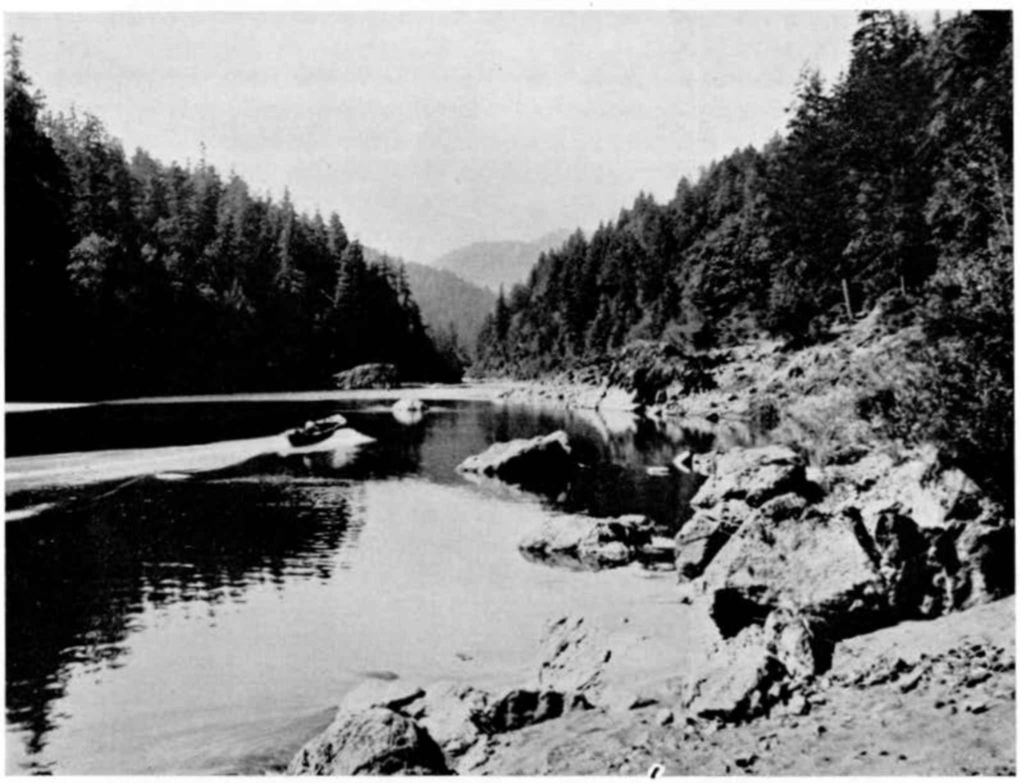

FIGURE 6—*Scattered rocks along shore with bed of sand in right foreground.*

foreign to the materials the stream has carried for centuries. Not one of the particular materials listed or discussed by Ellis in his paper as constituting stream pollution hazards is found in the placer mine run-off of the Rogue.

An analysis was made of the dried soil from placer mines used in making the muddy water experiments carried on by Dr. L. E. Griffin (see Appendix B). The analysis was furnished by Dr. E. W. Lazell of Portland Chemical Laboratories. The protocol of this test follows:

Laboratory No. 39058.

Alumina 15.24%

Total Sulphur .002% equals .005 sulphuric anhydride.

Settling Test

Time	*Percent in Suspension*	*Particle Size Microns*
2 hours	0.15	40
6 "	0.048	22
24 "	0.027	9
48 "	0.25	5

The particles remaining in suspension 48 hours are amorphous, having no action on polarized light.

Assuming 5 microns as the maximum size of a mineral colloid, the maximum amount would be .025%.

The material of which this analysis was made was taken directly from banks on which placer miners were working or had been working. The placer mine run-off secures its load of suspensoids from the same banks that furnished this material and has no other source of the material it carries.

Actually the process of placer mining adds no new material to the water of the river and produces no change in the aquatic environment except in quantity of soil materials found in the river at a given time. Now the exact amount of such material in the river has changed often radically and rapidly during each year in the past history of the river. Natural variations in climate make natural erosion work variable and with rapid and unpredictable as well as violent changes at unexpected intervals as well as from season to season. So long as materials remain of the normal type found in local soils the quality of the water is unimpaired and neither old nor young fish suffer. We can find no way to distinguish between the effects of placer mining (*artificial erosion*) and those of rain and flood (*natural erosion*). They differ at most only in degree and intergrade at different stream levels. Both comparative data from other streams and experimental evidence with placer mud from the Rogue River area seem to indicate clearly that the limit of tolerance has not yet been reached here. As the stream flow in the river tapers off seasonally, the drop in miner's water reduces somewhat similarly the run-off from the placer mines, so that the concentration is not likely to exceed the amount employed experimentally without harm to the fish.

The run-off from placer mines in the Rogue River area is characterized by its deep red color which is strikingly persistent as well as conspicuous. This is a finely divided iron compound, probably iron rust, a stable compound, and contrary to common opinion in the region, not in the least injurious to the fish. It may contribute to the opacity of the water and perhaps also makes it difficult for the fish to see the fly, although Dr. Griffin found that young fish readily saw and promptly captured food thrown into the tanks in his experiment. However, if the fish cannot see or are not attracted by the caster's lures, the condition of the water may reasonably be said to protect the fish, even though it disappoints the fisherman!

TURBIDITY OF ROGUE RIVER WATER

The turbidity of the Rogue has been measured regularly by Mr. Edward N. McKinstry, engineer of the waterworks at Grants Pass. I am indebted to him for the following data which cover the hydrogen ion concentration (pH) as well as the turbidity of the stream during the period October, 1937, to May, 1938, inclusive. These data are recorded daily at that station and give a very good picture of the condition of the river above the region in which it receives the run-off from placer mining operations. The determinations of turbidity are recorded there by visual comparison with standard solutions made from water and fuller's earth in accordance with specifications of the La Motte Chemical Company. This method is recognized as standard for such analyses, and is widely used. At the same time I wish to call especial attention to the fact observed by several of us independently: the color of the sample affects the result, indicating a higher apparent turbidity than actually exists. (See Table I)

Turbidity samples were taken from the Rogue River at Agness from January to April inclusive and are given in the following table. These represent the condition of the river water after all contributions of placer mine run-off have reached it. These samples were delivered to the Department in Portland and the determinations were made by Dr. L. E. Griffin. (See Table II)

In March Dr. Griffin accompanied Director Nixon and myself in a survey of the chief points in the Rogue River valley at which placer mines were operating at that time. Samples of the run-off were taken at the seat of operations and in the small streams at places between the workings and the Rogue River. The determinations of turbidities in these samples were made by Dr. Griffin later. In all determinations he used a photo-electric cell apparatus constructed by Professor Day of Reed College on the general principle of that described by Ellis in *Science*. These determinations, though accurate for practical purposes, were found to be influenced by the color of the sample. (See Table III)

Comparison of these records with those of the river at Grants Pass shows that only two (Nos. 10 and 12) taken on small streams close to workings were in excess of the concentrations recorded this year for Grants Pass where no placer mine contributions were involved. Sample No. 13 from Coyote creek equals the Grants Pass maximum for the past winter as recorded on February 6; the next largest sample we took (No. 6) came from the middle of Fry creek near O'Brien with 630 ppm; it only barely exceeds the second Grants Pass record this winter, viz, 600 ppm on March 23, while at No. 7 only one-eighth of a mile down stream from the point of No. 6 sampling this concentration had fallen from 630 ppm to 165 ppm and 450 feet further down stream it had dropped to 105 ppm, much below concentrations observed on various dates at Grants Pass during this winter. (Compare Table I with Table III)

The extremes of concentration of placer mine run-off which we could find were represented by

TABLE I

DETERMINATIONS OF ROGUE RIVER WATER AT GRANTS PASS

Date	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May	
	pH	Turb.	pH	Turb.	pH	Turb.	pH	Turb.	pH	Turb.	pH	Turb.	pH	Turb.	pH	Turb.
1	7.3	8	7.3	15	7.1	15	7.2	20	7.1	50	7.3	30	7.1	20	7.1	25
2	7.3	8	7.1	12	7.1	15	7.2	15	7.1	45	7.1	30	7.1	20	7.1	35
3	7.1	8	7.1	10	7.1	15	7.1	30	7.1	150	7.1	30	7.1	20	7.1	30
4	7.1	8	7.3	10	7.1	12	7.3	15	7.1	60	7.1	30	7.1	20	7.1	28
5	7.1	8	7.3	10	7.1	10	7.2	15	7.3	30	7.1	30	7.1	20	7.1	28
6	7.3	10	7.3	10	7.1	10	7.1	15	7.1	700	7.1	15	7.1	15	7.1	20
7	7.1	12	7.4	10	7.1	10	7.1	10	6.9	500	7.3	15	7.1	10	7.1	20
8	7.3	12	7.3	10	7.1	10	7.1	10	7.1	325	7.3	15	7.1	10	7.1	20
9	7.7	10	7.3	10	7.0	7	7.1	25	7.1	100	7.3	10	7.1	10	7.1	15
10	......	......	7.3	10	7.1	30	7.1	10	7.1	85	7.1	10	7.2	10	7.1	15
11	7.5	10	7.1	50	6.9	350	7.1	10	7.1	85	7.1	10	7.1	10	7.1	14
12	7.3	10	7.1	75	7.0	225	7.1	10	7.7	50	7.3	10	7.1	10	7.2	12
13	......	......	7.1	30	6.9	60	7.1	12	7.1	60	7.3	15	7.1	10	7.1	10
14	7.1	8	7.1	30	6.9	40	7.1	20	7.1	270	7.1	15	7.1	10	7.1	10
15	7.1	8	7.1	50	7.1	30	7.1	80	7.1	80	7.1	15	7.1	10	7.1	20
16	7.1	8	7.1	25	6.9	25	7.1	35	7.1	40	7.1	160	7.1	10	7.1	15
17	7.4	8	7.1	20	7.1	20	7.1	40	7.1	35	7.1	60	7.1	15	7.1	15
18	7.1	12	7.1	70	7.1	18	7.1	225	7.1	35	7.1	45	7.1	15	7.1	15
19	7.1	12	7.1	200	7.1	15	7.1	80	7.1	35	7.1	200	7.1	35	7.1	15
20	7.1	12	7.1	400	7.1	15	7.1	35	7.1	35	7.1	80	7.1	35	7.1	13
21	7.1	12	7.1	90	7.1	15	7.1	30	7.1	35	7.1	35	7.1	35	7.1	12
22	7.1	12	7.1	25	7.1	12	7.1	100	7.3	25	7.1	50	7.1	20	7.3	12
23	7.5	12	7.1	40	7.1	10	7.1	80	7.1	25	7.1	600	7.1	20	7.3	12
24	7.3	12	7.1	25	7.1	20	7.0	35	7.1	60	7.1	225	7.1	20	......	......
25	7.5	12	7.1	20	7.0	10	7.0	20	7.1	50	7.1	150	7.1	18	......	......
26	7.3	12	7.1	15	7.1	10	7.0	15	7.1	45	7.1	50	7.1	18	......	......
27	7.3	12	7.1	15	7.1	15	7.1	10	7.1	40	7.1	40	7.2	18	......	......
28	7.3	11	7.1	15	7.1	12	7.1	10	7.1	40	7.1	40	7.1	15	......	......
29	7.3	11	7.1	15	7.1	90	7.1	12	......	......	7.1	35	7.1	12	......	......
30	7.5	11	7.1	15	6.9	30	7.1	10	......	......	7.1	30	7.1	20	......	......
31	7.1	10	......	......	......	......	7.1	10	......	......	7.1	25	......	......	......	......

* From E. N. McKinstry, Grants Pass.

sample No. 10, just below the sluice of the Fry pit, with 7,840 ppm and No. 12, at the escape of a working on Coyote creek, with 38,000 ppm. In both cases the concentration was greatly reduced on the small stream a short distance below the point of actual discharge. Fish were seen in Coyote creek above the point of entrance where the sample was taken; they probably had ascended the creek and had passed through the water, although the discharge may not have been as heavy at the time when they went up that section of the creek as it was at the time that sample No. 12 was taken.

EFFECTS OF SILT ON FISH

Popular opinion cherishes an old and widespread belief that sawdust, silt, and similar solid particles carried by flowing waters clog the gills of fish and kill them by suffocation. This opinion is apparently sustained by frequent discovery on streams or banks of dead fish in which the gills are crowded full of fibers and masses of floating materials identified as sand, paper, and pulp-mill waste, etc. Since these materials came apparently from mines and industrial plants, the responsibility for the destruction of the fish was at once charged to the specific industries. The discussion has long waged violently around the lumber, paper, and pulp mills. It is now clearly recognized that those wastes are dangerous because of the toxic substances discharged with the mill wastes or the decay set up in accumulated masses of such wastes, and not in any degree because of any damage due

TABLE II

TURBIDITY DETERMINATION OF WATER TAKEN AT AGNESS

(Made with photo-electric cell by L. E. Griffin)

Date	Turbidity			
	January	February	March	April
1	......	130	65	73
2	......	120	103	65
3	......	210	106	68
4	......	150	120	77
5	......	108	76	65
6	......	250	95	......
7	......	267	75	......
8	......	440	60	......
9	......	153	57	......
10	......	157	70	......
11	......	152	65	......
12	......	156	76	......
13	......	168	75	......
14	......	175	67	55
15	......	87	128	57
16	62	*	285	54
17	70	*	220	74
18	55	*	165	68
19	100	135	215	123
20	125	90	180	107
21	127	89	136	76
22	155	88	*	65
23	103	106	*	54
24	135	122	*	56
25	112	125	*	......
26	102	103	142	......
27	175	75	134	......
28	50	70	100	......
29	60	......	100	......
30	103	......	65	......
31	55	......	54	......

* No sample submitted.

Determinations of pH also were made of 10 samples, all of which were 7.0.

TABLE III

REPORT ON SEDIMENT CONTENT OF SAMPLES TAKEN MARCH 26, 1938

		pts per million
1.	From stream at first bridge beyond Ruch, 2.8 miles below summit of hill west of Jacksonville	475
2.	East fork of Illinois River at first bridge on Highway 199, south of Caves Junction	25
3.	West Fork of Illinois River. Taken on west bank 50 feet above bridge. First West Fork bridge on Highway 199, south of Caves Junction	30
4.	From bank of West Fork of Illinois River, opposite entrance of Fry Creek, 200 feet above steel bridge east of O'Brien	10
5.	Taken in West Fork of Illinois River, 2 feet above bridge (same as 4) on east bank of river, below entrance of Fry Creek into Illinois River	600
6.	From middle of Fry Creek, 75 feet above its entrance into Illinois River	630
7.	From east side of Illinois River, ⅛ mile below Fry Creek. Taken from small side channel of river. Water here heavily colored by Fry Creek discharge; other side of river clear	165
8.	From west bank of Illinois River, about 450 feet below 7	105
9.	From west bank of Illinois River, 1,550 feet below bridge. (Same as 4.)	97
	Numbers 5-9 form a series showing how rapidly the discharge of Fry Creek becomes diluted in the Illinois River. At point 9 the discharge of Fry Creek seems to be evenly distributed in the river. Above this point it was heavier on the east side of the river.	
	March 28, 1938	
10.	Sample taken from pool just below sluice of the Fry pit, 1.9 miles above steel bridge and Illinois River. Mine in operation with water flowing through sluice	7,840
11.	Taken from stream at bridge 54, at Bridgeview. Althouse Creek	30
12.	From end of flume at pit working on Coyote Creek, on left of road, operated by Cleveland. Fine bright red soil. Very fine material, much colloidal stuff apparently	38,000
13.	At Coyote Creek bridge on Highway 99. 2.5 miles below point where sample 12 was taken	700

to floating particles. Some of the evidence for this may be given.

In 1899 Professor Prince, fish commissioner of the Dominion of Canada, a scientist of high standing at home and abroad, wrote as the conclusion of years of travel and observations on lakes and streams in different parts of Canada, "so far as our present knowledge goes, sawdust pollution, if it does not affect the upper waters, the shallow spawning grounds, appears to do little harm to the adult fish in their passage up from the sea. * * * There is no case on record of salmon or shad, or any other healthy adult fish being found choked with sawdust, or in any way fatally injured by the floating particles". This pronouncement was amply sustained by the researches of Dr. A. P. Knight of Queens University. He began investigations in 1900 and in his first preliminary experiments reported in 1901 found that trout, though badly injured when placed in a mixture of sawdust in water as thick as gruel were healthy and active after two weeks in it. Post mortem examinations showed no trace of damage from sawdust. In a final report published in 1907, he presented at length the results of other observations and experiments on the problem. While his work dealt only with sawdust, the conclusions reached are so significant that I quote some of them *verbatim*: "1. Strong sawdust solutions poison adult fish and fish fry through the agency of compounds dissolved out of the wood cells. 2. The overlying water in an aquarium containing sawdust does not at first kill fish. After about a week it does kill, but solely through suffocation, the dissolved oxygen having all been used up."

In other words floating particles do not damage the fish; but products of decaying organic matter and toxic materials are destructive.

More recently the problem has been studied by Cole (1935) with reference to pulp and paper mill waste. He kept fish three weeks in a gruel-like mixture of pulp. On the basis of his work he states (p. 301), "as long as the fish remained healthy and active their gills were kept clean. * * * It was only when fish were dying that the fibers clogged their gills."

I have myself often observed dead fish with the mouth and gills filled with masses of floating debris which were taken in with the last feeble respiration movements when energy was not sufficient to force the material out through the gill slits. To avoid error and confusion in the mind of the reader, it must be emphasized that sawdust accumulating in streams does serious damage to fish life, but only by the production of toxic materials that are absorbed in the water and by the exhaustion of free oxygen through decay. Similar effects follow the discharge of pulp and paper mill wastes. However, as floating particles in water neither the rough granular masses of sawdust nor the fibrous elements of wood pulp damage the gills or are accumulated on the gills of healthy fish.

It has also been stated that harsh materials such as sand or grit will injure the surface of the gills or accumulate and clog the passage ways. On careful consideration of conditions this appears most unlikely. The abrasive action of such gritty substances is exerted only when they are forced down on surfaces by pressure from behind. Bathers are familiar with the fact that sharp sand and gravel, although carried by a strong current, do not injure or even irritate the soft skin of the human body. Even in a mixture of a density equal to more than 1,000 ppm, the amount of rough solids is so small that the cushioning power of the volume of water is adequate and mechanical injuries are fully prevented.

Fish live and thrive in rivers carrying large loads of silt. One could make a long list of such streams in the central West and on the slopes of the mountains between that region and the Pacific coast. To be sure, all of these do not have salmon runs, but they do carry trout and up to recent times those affording suitable conditions were the home of the grayling, which is clearly more sensitive to adverse conditions than salmon.

Between California and Alaska are many streams which are seasonally, and some of them constantly, loaded heavily with silt that comes from glacial run-off and from bank erosion. Such streams include those which under undisturbed conditions—i. e., before human interference affected the numbers and environment of the salmon —carried large numbers of these fish every year. It has been impossible to secure from the reports of explorers, surveyors, engineers, or government bureaus which have studied these streams and have recorded the heavy loads of materials in suspension which they carry, any precise mathematical data to compare with those obtained for the Rogue River. Nevertheless the descriptions given show reasonably clearly that the amounts of silt in some of these rivers at least were larger than that found in the Rogue at any time. Engineers and other experienced men have in personal discussion borne positive testimony to this view, both as to the relative amount of silt and as to the presence of vigorous and healthy fish.

I have myself seen and studied numbers of such rivers in the United States and in Alaska which rank among the well-known salmon streams of the west coast and which are heavily loaded with sediments. I shall confine myself to more precise statements of one region. The Copper river in Alaska has been one of the famous salmon streams of that territory. It has a large number of tributaries which come out of mountain ranges east, north and west of the Copper River valley. Some years ago I had opportunity to visit the upper reaches of some of these rivers where the salmon spawn under what at that time were undisturbed natural conditions. Some of these streams were clear, but others were heavily loaded with glacial detritus. I have seen among these Alaska rivers in which salmon run and spawn some so heavily loaded with mud that one could not trace the body of an adult salmon ascending the river even when the dorsal fin cut the surface of the water. Yet the fish examined on the spawning grounds just before and just after death showed that the gills had suffered no injuries on the way though the body had met with conspicuous external damage through violent contact with sharp rocks at rapids or falls or along the shore. The examination was made in connection with the study on the cause of death after spawning and all organs were closely inspected. The gills were reported as apparently in perfect condition. Although the object of the investigation was not to determine the effect on the gills of silt-loaded waters, still, if any evident injury had been present, it would have been noted. The journey from the sea up the Copper and its tributary was long and strenuous; the chance for damage to the salmon from muddy water was certainly large if any damage could be wrought by such conditions, and yet none was observed. Many other similar cases could be cited from printed as well as personal records.

The long period of past time in which the salmon of the Rogue had been subject to the influence of heavily silted waters in that stream and the persistence of a run large in numbers and unsurpassed in quality serves to confirm the views expressed above on the basis of other evidence. The adult fish are not injuriously affected by upstream migration through water as heavily loaded with silt as is the Rogue River.

Strong as this argument is, it must take second place to the results of the experiments on young fish which I suggested and which have been carried out so well by Professor Griffin. His results are fully stated in Appendix B. In further comment I desire to call attention first to the fact that these experiments were performed with young fish. Despite their far greater sensitiveness to changes in environment and susceptibility to injury, the young salmon lived heartily in a concentration of sediment which was at its minimum (760 ppm) twice as much as the maximum recorded at Agness (see Table II). Indeed the average amount of turbidity in Griffin's experiments was ten times the average recorded at Agness. Those who think that normal erosion products will prove injurious to such fish should examine carefully the records in these tables.

EFFECT ON SPAWNING GROUNDS

Erosion silt in some streams has been found to cover nests and spawning grounds with a blanket such that the bottom fauna was killed and eggs also were suffocated in nests. In these ways such a deposit does great damage to the fish population in a stream. Unquestionably this is serious in some places and under some circumstances, and it is important to examine the situation carefully in the Rogue River. This was one of the first items to which I devoted my attention in making the study of the Rogue at low-water level.

In the stretch from Gold Beach to Agness I found no evidence of spawning having taken place in the river. Nowhere could I find any of the characteristic nesting areas in the water or on the beaches between the high-water mark and the then present water level. To be sure the time of my visit did not coincide with the spawning period of any species which occurs in the Rogue so that the absence of freshly formed nests was normal, but in spawning areas one can usually see distinctly traces of nests built a year or even more before the date of the inspection. If any spawning had taken place in this stretch of the river, then the intervening floods had been heavy enough to wipe out all the evidence. Equally clearly the spawning had been of no value since the nests had either been scoured out or covered so deeply that the eggs were killed. I have already called attention to the film deposited on the bottom and on beaches between high and low water marks and have shown that it is thin, granular and broken. It is in no sense a blanket and would not interfere with the respiration of developing eggs if there were any in this region. Normally the fish cover the eggs by a layer of sand or fine gravel; the fresh water carrying oxygen easily penetrates this cover and the young wriggle out after the eggs hatch. A thin, broken layer such as I have already described would not interfere with the permeation of fresh water with oxygen and the development of such eggs as might be present. But I am clear that this is not a true spawning area. As Mr. Joseph Wharton said in an admirable paper on the salmon of the Rogue River, "It is the ambition of all these species of anadromous fish to ascend the river to the highest point attainable before making their spawning beds, seeking the waters that are purest and coldest." This statement is absolutely correct; in difficult streams or when held behind man-made barriers, these fish struggle to the end to make their way upstream and will sacrifice life rather than accept spawning areas in the lower reaches of the river. The urge which drives them on is the basis for the safety of the race. For the straggler or the weakling who may find the achievement of headwaters impossible, an enforced spawning in the lower river is of no significance; the river level varies too widely and its current at full flood is too fierce. Eggs deposited at high water will be exposed and die when the water falls; or if the spawning occurs at a lower water level, the next flood waters will bury the eggs or sweep them away. The suddenness, the violence and the irregularity of the changes in water level of the Rogue are conspicuous in the records of every year.

The spawning grounds lie chiefly at least above the region in which placer mining run-off is poured into the stream so that whatever the effect of this added burden it is not exerted in the spawning period or on the early stages of life of the new generation. Even though natural erosion contributed to the stream burden more material in time long past, and less abundantly and frequently in more recent years, still the fish, young and old, in the higher reaches of the stream held their own and maintained the run under natural conditions. Only when man introduced new barriers, devised new traps in diversion ditches which led away from safety, or discharged waste materials of unknown and destructive type have the fish been unable to cope with the changes of the environment.

QUANTITY OF FISH FOOD PRESENT

My attention was early drawn to the question of the supply of fish food in the Rogue. The low-water season was naturally favorable for the study of this factor as the slow movement of the stream, its numerous shallows and the transparency of the water made it easy to observe the numbers and kinds of aquatic organisms present. I was impressed by the abundance and variety of the aquatic population. Both in the lower river and as far up as Rogue Elk I studied the forms which could be seen in different parts of the stream and recorded in my field notes the frequence with which organisms known to be fish food were met with on the trip. No attempt was made to secure a complete list or to determine precisely the species which were encountered. Such an undertaking would have demanded far more time than had been agreed upon for the study. Speaking generally and in a broad way, I am confident that the food supply of the fish is abundant and well distributed and also adequate to sustain a large run of fish.

One word of caution must be expressed here. No factor is more variable or spotty in my experience than the quantity of food to be seen in traveling along a stream. Conditions vary with every pool. At one moment on a good stream the student may see a veritable crowd of crayfish, insect larvae and smaller organisms and only a few yards away miss entirely some types abundant before, or even look long without seeing much of anything. The conditions of a stream cannot be determined by random sampling at a few places or on a single day. Fisherman's luck affects the student of river conditions also and fish food is as erratic apparently in habits and distribution as are the fish themselves.

Early in October I saw fish in pools where local fishermen were unable to attract them by flies or bait. The temperature of the water was a little higher than usual and the current slower so that the warmer, less oxygenated water may have made the fish logy. It seems possible that the abundant food was so easily caught that bait and lure were less attractive. Certain it is that neither natural nor artificial erosion up to date has exerted any demonstrable change in the fish food supply in the Rogue.

This discussion would not be complete if I omitted to mention certain ecological relations which indicate that the placer mine run-off may be of advantage to the fish. One of these is protection afforded by the turbidity of the water and the other is the suggested increase in the primitive food supply.

That adult fish are screened by the turbid waters is well known and often made the subject of comment by fishermen. In fact, they attribute the difficulty in catching fish to the amount of "waste" discharged by placer mines. I have already discussed the quantity of this discharge and called attention to the rapidity with which it settles. In Table III are given the muddiest water we could find; half the tests were 105 ppm or less, and four were only 30 ppm or less. Yet anyone standing on the bridge at the points where these samples were taken would say the water was too muddy for fishing; and it *was* too dense to see fish in the stream, but really contained very little sediment. This does not deter the fish from getting their own food.

Most significant is a possible relation of fine silt to the food of young fish. It has been shown that the presence of finely divided suspensoids of natural origin may be of advantage to the microbiota which constitutes the foundation element in the food supply of water. Studies on aquatic biology conducted by the Wisconsin Survey demonstrated that colloidal organic particles collect on carbon and sand grains to build a culture medium for aquatic bacteria. The finest suspensoids and colloidal particles in the placer mine run-off would evidently function in this way and increase the supply of aquatic bacteria and other associated micro-organisms. Thus would be multiplied the food supply of protozoa and other types of aquatic life which subsist primarily on bacteria. Among such are young stages or larvae of small crustaceans and insects which form such an important part of the food of young fish at the start of life. It is even possible that colloidal particles encased by bacterial cultures may form an element in the direct food supply of young fish.

I have on many occasions dissected under the microscope very young fish from muddy waters and found to my surprise that the alimentary canal was filled to repletion with what was apparently only mud, even though the fish were healthy and vigorous. Instead of being merely inert material taken in by chance with small organisms floating in the muddy water, this mass may represent particles coated with a layer of zoogloea, or bacterial jelly, that is in itself of nutritive value. But whether under circumstances the fine material may have any positive worth for the growth or nourishment of the fish, I am clear that evidence thus far obtained from many streams, and at many times, shows that such material does not under conditions already outlined do damage to the gills or to the digestive system even of the young fish at the most susceptible period of life.

APPENDIX A

EXTRACTS FROM REPORT ON ROGUE RIVER TURBIDITY

By ARTHUR M. SWARTLEY

Transportation methods. Material is moved by transportation, in suspension and as dissolved matter.

Traction is the method by which the particles, too coarse to be carried in suspension, are moved forward upon the bottom of the stream by sliding, rolling, or in short jumps.

Suspension is that method of stream transportation wherein the small particles are lifted above the bottom for considerable time and distance. The larger particles in suspension are largely dependent upon velocity, the smaller particles are somewhat independent, while colloidal material is almost independent of it.

With lowering of velocity the larger particles in suspension drop to the bottom and become a part of the tractional movement. If the currents proceeded in straightforward movement as in a flume, the suspended particles might soon go to the bottom except those of colloidal size.

Solution material is independent of velocity in its forward movement.

Material in solution and suspension is mostly carried out to sea at once or within a short time, once it reaches the larger tributaries. A minor part of this fine material may be left behind where streams pass through occasional valleys and remain there indefinitely. The bulk of these valley deposits are of the larger particles such as coarse sand, gravel and boulders. The lateral migration of streams and the deepening of their channels may leave benches of gravel well above the flood-water level to remain for ages to be affected only by the slower agencies of erosion, like rain, to transport it to a nearby stream.

These stream beds, benches and valley deposits are of necessity no different than the material that is continually migrating to sea from the narrow canyons and their more rapid flowing streams. The material is derived from the same places but was stopped because the channel widened out and the grade lessened so that the stream was not competent to carry the load. If the erosion is from a mountainous area containing gold, platinum and the other heavy metals, these will be deposited in the valley along with the boulders, gravel and sand, but at best these are only incidental. Their presence there is of interest to the placer miner, but to others it is only of academic interest until such time as placer mining begins and mining debris is being dumped into the stream. It there enters into the problem here being discussed and a more particular description of its nature is pertinent, whether in transit or sidetracked for a time in the valley or on beaches to await removal by the agencies of nature or of man, and the material transported along the bed of the stream whether gravel or sand is essentially no different than the solid rock from which it came. Water flowing over it is as clear as though it were flowing over solid rock. In flood periods it is in slow motion, the deeps being deepened and the shallows being filled and broadened. When the flood recedes the deeps are slowly filling from the shallows. Each flood makes its contribution to its downstream movement. That it does not shallow the pools as the years go by is well known to all observers of the habit of streams. It is composed of small rock fragments and contributes practically nothing to the composition of the water, either chemically or in turbidity. It is chemically inert and has no oxygen demand and therefore takes away from the flowing stream nothing which the fish require. This is equally true of this material whether placed in transit by nature or by man, since they are alike in nature, come from the same places, and are only being accelerated by man in their journey to the sea.

The material carried in suspension varies from fine sand to particles almost infinitely small. Speaking in sizes, the fine sand, which is about the very coarsest material carried in suspension, ranges from a maximum of 1/100 of an inch in diameter down to 1/200 inch; very fine sand 1/200 inch to 1/400 inch; silt 1/400 inch to 1/6400 inch; and clay 1/6400 inch and finer. The coarse sizes of fine sand are now in suspension, now in traction, dependent mainly upon the velocity of the stream under flood conditions.

Along with the above described materials which are merely minerals in a fine state of subdivision, are the colloids. Colloids are the more finely divided particles altered physically and chemically, usually combined with water, and frequently jelly-like. Material in solution is fully dissolved matter; it is composed of various substances and varies in the different streams, dependent upon the rock found in each watershed, and it contains practically all the elements found in the suspended material, such as silicon, iron, calcium, magnesium, sodium, and potassium combined with oxygen or as carbonates, sulphates, nitrates, and chlorides, plus the decomposition products of vegetation.

It is to be noted that all the materials entering the streams, whether placed there by nature or by man, whether coarse or fine, whether travelling upon the bottom, in suspension or in solution, are almost altogether inert, suffer little change on their way to the sea, and having reached the end point of chemical change have no further need of oxygen, therefore not robbing the water of its oxygen which the fish demand, or adding to the water toxic agents injurious to fish or fish life.

From various sources data on the Rogue River and other streams, not subjected to influence of mining projects, show a range of parts per million and an average turbidity as follows:

	Parts per million	*Average turbidity*
Rogue River at Copper Canyon (estimated)	321	....
Snake River at Weiser, Idaho	324	80
Owyhee River at Owyhee, Oregon	395	167
Klamath River at Klamath Falls, Oregon	146	....
Umatilla River at Umatilla, Oregon	247	79
John Day River at McDonald, Oregon	324	245
Columbia River at Cascade Locks, Oregon	137	27
Colorado River (flood conditions)	21,500	....
Rio Grande	14,840	....

APPENDIX B

EXPERIMENTS ON TOLERANCE OF YOUNG TROUT AND SALMON FOR SUSPENDED SEDIMENT IN WATER

By Dr. L. E. GRIFFIN, Reed College

The experiments which are described in the following account were undertaken to obtain definite information as to the direct effect of large amounts of soil sediment in water upon the fish inhabiting such water. The Department of Geology and Mineral Industries of the state of Oregon arranged with me for experimental studies on this question. I have been ably assisted in carrying on the studies by Mr. Harry Beckwith of Reed College.

The experiments covered two periods: One of three weeks, the other of four weeks. In the first period the fish tested were cutthroat fingerlings; in the second, young chinook salmon. The fish were kept in troughs, similar to those used in fish hatcheries, in which a depth of five inches of water was maintained. The water was kept flowing by circulation through a centrifugal pump, and aeration was secured by ejection of the water into the troughs in a heavy spray. The pumps used were small, limiting the flow of water to a rate of about one-half mile an hour. The slow streamlike movement of the water along the troughs was sufficient to keep a much heavier load of fine sediment in suspension than is ordinarily found even in muddy streams, but was not rapid enough to keep in suspension all the sediment which was put into the troughs, or to maintain a turbidity of more than 750 parts per million for 24 hours.

The material used for the sediment consisted of soil and alluvial material taken from ten spots around the Esterly mine, near O'Brien, Josephine county, Oregon, which were representative of the alluvial soils of that region. The samples were thoroughly mixed; when material was needed for the tests, the dirt was mixed with water and the portion which settled quickly was rejected. When the remaining fine sediment was placed in the fish troughs it was found that a considerable portion settled out at a regular rate during the first six hours after it was put in, but that after that period the amount of suspended silt remained nearly constant. As the sediment which settled in the troughs was stirred and strained daily, and occasionally fresh soil was added, the water of the experimental trough carried a heavy load of sediment for a few hours of each day and a lighter but constant load for the remainder of the day.

After several preliminary experiments in which apparatus and methods were tested, the first trial run was begun. Two troughs were arranged parallel to each other in a dimly lighted, unheated building. The water with which the troughs were filled came from a spring-fed stream on the Reed College campus, in which trout are living and breeding. One trough contained the sediment-laden water, the other clear water. Aside from the processes needed to keep the sediment in suspension, both troughs and the fish placed in them were treated in the same manner.

December 11, 1937, 90 cutthroat trout fingerlings, 2 to 2½ inches in length, were secured from the federal hatchery at Clackamas, Oregon. Fifty of these were placed in the sediment-containing trough, 40 in the clear-water trough. The experiment continued until December 30. At the time of the daily stirring (at which time fresh sediment was occasionally added) the load of sediment varied from 2,300 to 3,500 parts per million by weight. This was enough to make the water a dark brown color, and so opaque that a hand held an inch under the surface was invisible. The load of sediment fell rapidly during the first hour, and then more slowly, until after the sixth hour an almost constant load was carried for the remainder of a 24-hour period. This constant load varied from day to day from 360 ppm to 600 ppm, being 500 or more ppm on all but six of the 19 days during which the test lasted.

The fish were fed with the same food used in the hatchery from which they came. Those in the clear water usually did not feed until the operator had backed away from the trough. In the muddy water the fish were not seen to feed for the first two days, but after that they rose to the surface and fed actively as soon as particles of food began to fall on the surface of the water. The trout in the clear water remained nervous throughout the experimental period, while those in the muddy water became bold enough to peck at the operator's hand when it was placed in the water. Because of the necessity of scraping the bottom of the trough, stirring up the silt, and adding fresh soil, fish in the sediment trough were disturbed much more than those in the clear water.

When the test was ended on December 30, it was found that a much larger proportion of the fish in the sediment-containing trough had survived (56%) than in the clear-water trough (10%). There was no noticeable difference in the color of the surviving fish in the two troughs, and the fish which had lived in the muddy water were as large as the survivors from the clear-water trough.

On January 12, 1938, a second experiment was begun in which 150 chinook salmon fingerlings, 1¾ to 2 inches long, were divided equally between the two troughs. This time the sediment was placed in the trough which had contained clear water in the previous experiment, and the other trough was used for clear water. Care was taken to reduce all movements near the troughs to those absolutely necessary to conduct the test. During the period of this test, which lasted 28 days, until February 9, the load of sediment was greater than in the first test. The maximum load at the time of stirring was from 3,100 to 6,500 ppm on most days. The constant load after the sixth hour was from 300 to 480 ppm from January 12 to January 25; and from 650 to 750 ppm from January 26 to February 9, except on two days when the load fell to 380 and 410 ppm.

The salmon fingerlings in the clear water at first showed the same nervousness as the trout, but after a week those which survived were not easily disturbed and fed avidly. The young salmon were not seen to feed in the muddy water quite so quickly as the young trout, and when they were seen they took food more deliberately than the trout. After the fish became accustomed to the new conditions of their lives and to the movements of the operator, those in both troughs fed satisfactorily.

Most of the salmon fingerlings in the muddy water were considerably lighter in color than the controls at the close of the test, though a few had not changed color. The fish of the muddy water were also irregular in growth, some having grown as much as the controls, while some were noticeably smaller.

At the close of the 28-day experimental period, 88% of the fish kept in the muddy water were alive, while 36% of the controls lived. Most of the controls which died did so during the first three days of the test; after which time there is no significant difference in the death rate of the two lots of fish.

On examining the day-by-day record one is struck by the heavy mortality which occurred on the third day of both experiments among the fish kept in the clear-water trough. This was not due to special conditions in one of the troughs, because the troughs were reversed for the two experiments. It could not be determined whether the fish kept in clear water were more active than those in the muddy water trough because the latter were invisible most of the time. The fact that more of the fish in clear water jumped over the ends of their trough indicates that they were more nervous. It was evident also that the fish in clear water were more disturbed by movements of the observers, changes of light intensity, etc., than the other fish.

In the second experiment the electric lights in the dimly illuminated aquarium room were not turned on, so that disturbance was avoided; but it was necessary to scrape the bottoms of the troughs, adjust screens and strainers, and perform other necessary actions daily. All these disturbed the fish in clear water much more than those in the muddy water. When excited, the fish frequently darted against the sides of their trough with considerable force. On several occasions startled fish were seen to strike the side of the trough with sufficient speed to stun themselves. It seems possible that the high mortality of the fish in clear water during the first week of both experiments was due to the injuries they inflicted upon themselves when excited. After a few days the fish became accustomed to their living conditions and to the movements of the operator in and around their trough, and then were excited much less easily.

After the first week the mortality among the young trout of the first experiment was almost the same in both troughs; 13 in the muddy water, 11 in the clear water. As the cutthroat trout fed well and grew normally in the muddy water, the conditions there do not seem to have been unfavorable for these fish.

After the first week of the second experiment, with young salmon for subjects, 9 died in the muddy water trough and 2 in the clear water. But after the heavy loss discussed above only 29 remained alive in clear water and 74 in muddy water, so that the difference in mortality is relatively about the same.

The results of the experiments indicate that young trout and salmon are not directly injured by living for considerable periods of time in water which carries so much soil sediment that it is made extremely muddy and opaque. They also indicate that cutthroat trout and salmon fingerlings can feed and grow apparently well in very muddy water.

The sediment load of the water in these experiments was continuously much greater than it is in the ordinary muddy stream. Water taken from the Willamette River at flood stage after three days of heavy winter rains, and when the river water appeared to be extremely turbid, contained only 42 ppm of sediments.

While the results of these experiments throw some light on the problems which were under consideration, it seems desirable that more extensive tests should be undertaken, in order to secure a larger accumulation of data, and to investigate factors which could not be studied in the limited time or with the apparatus available for these experiments.

EXPERIMENT I

Cutthroat Fingerlings

Date	Water Temperature	Sediment Stirred	Sample Taken	Parts per Million	Tank 1 with Sediment		Tank 2 with Clear Water	
					Dead	Living	Dead	Living
Dec.	*F.*							
11	62.6	5:00 pm	6:00 pm	840	0	50	0	40
12	62.6	9:00 am	10:00 am	760	0	50	0	40
13	62.6	9:00 am	9:30 am	1190	1	49	12	28
			4:00 pm	520	0	49	0	28
14	62.6	....	....	....	2	47	3	25
15	62.6	9:00 am	9:30 am	1140	0	47	0	25
			4:00 pm	690	3	44	8	17
16	62.6	9:00 am	9:30 am	1130	0	44	0	17
			4:00 pm	390	3	41	2	15
17		No	record		0	41	0	15
18	62.6	9:00 am	9:30 am	990	0	41	0	15
			4:00 pm	480	5	36	* 5	10
19	62.6	9:00 am	9:30 am	1040	1	35	1	9
20	62.6	9:00 am	9:30 am	990	0	35	0	9
			4:00 pm	500	0	35	† 1	8
21	60.8	9:00 am	9:30 am	750	1	34	0	8
22	60.8	9:00 am	4:00 pm	560	‡ 4	30	0	8
23	58.0	....	....	....	0	30	0	8
24	57.2	....	....	....	1	29	1	7
25	58.0	....	....	....	1	28	0	7
26	58.0	....	....	....	0	28	2	5
27	58.0	....	....	....	0	28	0	5
28	58.0	....	....	....	0	28	1	4
29	58.0	....	....	....	0	28	0	4
30	58.0	....	....	....	0	28	0	4
				Totals	22	28	36	4

Circumstances made weighing impossible from December 23 to December 30; conditions of the troughs were kept the same as they had been.

* Two of these jumped over the end screen and were carried through the pump.

† Killed by the pump.

‡ One killed by the pump.

EXPERIMENT II

Chinook Salmon Fingerlings

Date	Water Temperature	Sediment Stirred	Sample Taken	Parts per Million	Tank 1 with Sediment		Tank 2 with Clear Water	
					Dead	Living	Dead	Living
Jan.	*F.*							
12	58.0	†	....	....	0	75	0	75
13	58.0	....	....	....	0	75	1	74
14	58.0	....	....	....	0	75	* 40	34
15	58.0	....	....	....	1	74	5	29
16	58.0	....	....	....	0	74	0	29
17	58.0	9:00 am	9:30 am	820	0	74	0	29
18	58.0	9:00 am	9:30 am	950	0	74	0	29
19	58.0	....	....	....	0	74	0	29
20	58.0	9:00 am	9:30 am	960	0	74	0	29
21	58.0	9:00 am	9:30 am	1100	0	74	0	29
22	58.0	9:00 am	9:30 am	1350	0	74	0	29
23	58.0	3:00 pm	3:30 pm	1240	0	74	0	29
24	58.0	3:00 pm	3:30 pm	1600	1	73	1	28
25	57.2	....	....	....	1	72	0	28
26	57.2	3:00 pm	3:30 pm	2130	1	71	0	28
27	55.4	11:30 am	4:00 pm	930	0	71	0	28
28	55.4	9:00 am	9:30 am	2050	0	71	0	28
29	55.4	9:00 am	9:30 am	1670	0	71	0	28
30	53.6	9:00 am	9:30 am	1520	0	71	0	28
31	53.6	9:00 am	9:30 am	2120	0	71	0	28
Feb.								
1	53.6	11:30 am	4:00 pm	850	2	69	0	28
2	53.6	9:00 am	9:30 am	1480	0	69	0	28
3	53.6	9:00 am	9:30 am	1060	1	68	0	28
4	55.4	....	....	....	0	68	0	28
5	60.8	6:00 am	6:30 am	2317	3	65	0	28
			12:30 pm	841	0	65	0	28
			8:00 pm	770	0	65	0	28
6	60.8	....	....	....	0	65	1	27
7	60.8	6:00 am	6:30 am	2150	0	65	0	27
			12:30 pm	780	0	65	0	27
			8:00 pm	760	0	65	0	27
8	60.8	....	....	....	0	65	0	27
9	60.8	4:00 pm	4:01 pm	5960	0	65	0	27
				Totals	10	65	48	27

From January 12 to 16 silt was added to the sediment trough daily in order to build up the load of suspended matter to a maximum. The load of suspended material was somewhat greater than during the first experiment.

* Four of these jumped over the screen at the outlet and were killed in the pump; six leaped over the side at the inlet end, which was not covered by mosquito netting as was the rest of the trough.

† Fish put in trough.

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