NITROGEN SUPERSATURATION PROBLEM

Presentation to

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LEGISLATIVE INTERIM COMMITTEE

ON

FISH, GAME AND GAME FISH

AT

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North Pacific Division
CORPS OF ENGINEERS
Portland, Oregon

Introductory Remarks
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North Pacific Division, Corps of Engineers

Chairman Peterson, Members of the Committee and ladies and gentlemen. The Corps of Engineers appreciate the opportunity to participate in this meeting to keep you and the public informed of our plans and progress on means and methods proposed to alleviate the problem of nitrogen supersaturation in the Columbia and Snake Rivers. It is a problem of great concern to us as it is to you and its solution is of highest priority. General Kelley, our Division Engineer, extends his regrets at not being able to attend due to a prior commitment in Wenatchee. I am Gordon Fernald, Chief of the Engineering Division of the North Pacific Division.

It is most unfortunate that none of us were aware of the nature and magnitude of this problem early enough to avoid it. Testimony this afternoon has clearly explained the causes and effects as we now know them. The need for corrective action is acknowledged by the Corps of Engineers and the other project owners and operators on the river. The best talents of the Corps of Engineers are being devoted to finding a solution and we are grateful for the advice and assistance we are receiving from the fisheries agencies and from others concerned. Progress in the last year makes me optimistic that solutions are available. Unfortunately it takes time and money, both of which are in short supply.

We have prepared a rather complete brochure on the subject to present for your information. I have with me three very knowledgeable people from our office to make oral presentations and to assist me in answering any questions you may have. In the interest of time and to avoid duplication of previous testimony our oral presentations will be brief.

With me are Mr. Edward M. Mains, our fisheries biologist, formerly with the State of Washington who has prepared the material describing the problem. Next is Mr. Morris Larson of our Reservoir Control Center who will describe the operational problems and measures which were taken this year and which will be extended in the future. Lastly, Mr. Hugh Smith, our hydraulic engineer will discuss structural measures being developed and applied which gives us the feeling of optimism that a solution can and will be found.

With us also, representing the large body of district people working on the problem is Mr. Carl Richardson from the Walla Walla District. I may call on him to assist in answering questions.

Nitrogen Problems on the Columbia and Snake Rivers

Nitrogen Causes and Remedies

The supersaturation of gases in water can occur naturally or artificially so long as a situation exists where air can be entrained with water and placed under pressure. The gases of entrained air (nitrogen, 78%; oxygen, 20%, and other gases, 2%), when placed under pressure, becomes dissolved in the water in greater concentration than would be possible under normal atmospheric pressure. In the dissolved rather than the gaseous form, nitrogen and other dissolved gasses may be taken into the tissues and circulatory system of fish inhabiting the supersaturated water.

Air can be entrained and pressurized naturally in waterfalls and ground water aquifers if proper conditions exist. As an example, Willamette Falls in Oregon increases gas concentrations to about 115 percent of saturation. Almost all falling water will entrain air, and plunge pool or aquifer depth frequently provides sufficient increases in pressure to cause supersaturation. The same process can be created artificially either by "sucking" in air with water in a pumping process and placing it under pumped pressure higher than atmospheric or by creating manmade waterfalls and plunge pools such as spillways or regulating outlet chutes and stilling basins at dams where air is entrained and pressurized.

Degasification occurs naturally in stream situations primarily as a result of shallow water conditions and turbulence which permit a high ratio of water-atmosphere interface and thus a high opportunity for dissolved gases in the water to equilibrate with the atmosphere or reach 100 percent saturation.

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Ground water aquifers or springs are often unable to release their supersaturated gases until they emerge from beneath the ground. Supersaturation of spring water with nitrogen has long been a problem at some fish hatcheries where this type of water source is utilized. In the relatively small amounts of water involved in these situations, it is possible to degasify the water by passing it over baffles, or through screens or sprays, and permitting it to equilibrate with the atmosphere. Artificial degasification of enormous quantities of water equivalent to that spilled at Snake and Columbia River dams in April, May, and June of each year has not been attempted and is probably not practical. Where one reservoir spills into another reservoir there is little opportunity for natural degasification since only a small fraction of the water has opportunity to equilibrate at the water-air interface of the pool. The Corps believes the most practical method for resolving the problem is to pass the excess water that would otherwise be spilled through or around the project in a manner that will not entrain air and thus cause a supersaturated condition.

Nitrogen Effects on Fish

Fish in their normal respiratory process extract dissolved gases from the water in the gill structures. These dissolved gases remain in this form in the blood which is supplied to all the body tissues through the circulatory system so long as the fish remains under similar pressure or temperature conditions. If fish in such a condition move to an area of lesser pressure (shallower) or greater temperature(surface water tends to be warmer and holds less dissolved gas in summer months), the dissolved gases in the blood and tissues tend to equilibrate to new conditions of pressure and/or temperature, and some of the gases return from a dissolved form to a gaseous state. Gas bubbles in the circulatory system or tissue may kill or damage the fish.

It should be stressed that a great deal is yet to be learned about the capability of different forms of fish to accommodate some supersaturation levels, and recover from severe exposure, and time-dosage relationships. However, surface tests of fish to date indicate extreme danger to fish in the upper six or seven feet of water when concentrations exceed 120 percent. Because juvenile salmonids generally migrate in the top 15 to 20 feet of water, it is probable that a substantial portion of their population may be exposed to dangerous conditions. Adult salmonids generally swim at deeper levels but must pass the dams in relatively shallow fishways where they may be exposed for up to several days to dangerous conditions.

Nitrogen History in the Columbia and Snake Rivers.

"Gas Bubble" disease caused by supersaturated nitrogen has been a well recognized problem for many years at fish hatcheries utilizing spring water supplies that are often supersaturated with nitrogen. It has only been in the past few years, however, that nitrogen supersaturation has been recognized as a problem in the Columbia and Snake Rivers. Canadians H. H. Harvey and A. C. Cooper in 1962 reported on the origin and treatment of supersaturated river water in a special situation in British Columbia. Richard Westgard of the Washington Department of Fisheries in 1964 reported on the cause and results of gas supersaturation in the McNary Dam Experimental Spawning Channel. In retrospect, these were isolated manifestations of the major problem that faces us today; however, at the time they were only recognized as small scale local problems that could be corrected.

Observations in the spring of 1965 by the Washington State Department of Fisheries and the Bureau of Commercial Fisheries showed that saturation of dissolved nitrogen at some sites in the Columbia River was as high as 125 percent. Because levels of this magnitude had produced gas bubble disease in adult and juvenile salmon in the studies mentioned above and others, additional surveys were made in 1966-67 to attempt to determine how this supersaturation occurred and whether high levels of dissolved nitrogen might be responsible for losses of adult and juvenile salmonids. The mortality studies in these years, while not conclusive, did strongly indicate a potential problem to fish and did demonstrate that the supersaturated conditions were related to heavy spill periods at the dams.

In 1968, concentrations of dissolved nitrogen gas were measured in the Columbia River from April to September to determine the effect of newly constructed John Day Dam on nitrogen saturation downstream. Observations were also made of symptoms of gas bubble disease and mortality in juvenile and adult salmon. Heavy spillway discharge at the dam caused abnormally high (123-143%) supersaturation downstream, and mortalities of juvenile and adult salmon and steelhead trout appeared to be substantial. While it was obvious that a problem existed at John Day Dam because of the heavy spill and few operating turbines, there was still uncertainty whether the situation would persist as more turbines came into operation or whether a serious nitrogen supersaturation mortality problem truly existed at other dams.

In 1969 and since that time the National Marine Fisheries Service, the Washington Department of Fisheries, the Oregon Fish Commission, and the Corps of Engineers have cooperated in the funding and conduct of nitrogen sampling on the Columbia and lower Snake Rivers. At a minimum, samples are taken every other week during the April, May, and June period. These samples show nitrogen levels increasing with amounts of spill throughout the river and generally staying high until flood waters abate and spill is reduced. The Corps has also had a mathematical model developed by Water Resources Engineers, Inc. to enable us to better understand the relationships of flow and design features with nitrogen saturation levels. We are in the process of doing a great deal of detailed sampling at individual projects to develop input material for the model. While this matter is complex, the WRE study has greatly assisted us in understanding the problem.

Nitrogen Fish Losses

Laboratory tests of fish have demonstrated conclusively that fish exposed to high nitrogen supersaturation levels for sufficient amounts of time in surface waters will be killed. At 125 percent saturation, about a week of exposure is required for migratory size juvenile salmon. At the higher concentrations of 135-140 percent, much less time exposure is required. The real difficulty has been determining what truly occurs in the field. Even though an occasional dead adult salmonid and from a few to several hundred dead juvenile and resident fish have been observed at times, no statistically sound estimates of mortality or valid conclusions can be made from information so gathered.

The most significant information to date concerning the impact of nitrogen supersaturation has come from National Marine Fisheries Service studies that have been primarily concentrated in the lower Snake River. These studies have been scientifically oriented and have been conducted in an atmosphere free from emotionalism and prejudice. It has been the results of the National Marine Fisheries Service studies in 1969 and 1970 that have at the same time triggered what might be considered hysteria in some quarters and a strong program of remedial action by the Corps of Engineers. The conclusions of these National Marine Fisheries Service studies from their report entitled "A Summary of the 1969 and 1970 Outmigration of Juvenile Chinook Salmon and Steelhead Trout from the Snake River" are quoted below:

"The recently completed Little Goose and Lower Monumental Dams on the Snake River have seriously impaired the 1970 outmigration of juvenile chinook salmon and steelhead trout as indicated:

"1. Prior to impoundment of water at Lower Monumental and Little Goose Dams chinook smolts took 14-16 days to travel from the Salmon River to Ice Harbor Dam in 1966 and 1967. After impounding in 1970, chinook required 22 to 28 days to travel the same stretch of river; an apparent delay of about 10 days.

"2. The measured delay was reflected in the timing of chinook passing Ice Harbor Dam; in previous years the chinook peak ranged from April 25 to May 9, but in 1970 the peak occurred on May 15.

"3. Steelhead trout experienced delay as evidenced by their peak on May 25th about 10 days after the chinook salmon as has occurred nearly every year.

"4. The magnitude of the naturally-reared chinook outmigration between 1964 and 1968 varied between 2.5 and 3.8 million; in 1969, the magnitude dropped to 1.6 million and in 1970 to 1.2 million. The decline in 1970 was especially significant since 4.0 million smolts were estimated to have entered the Snake River in the spring of 1970. This means 70% percent did not survive to Ice Harbor Dam.

"5. The steelhead outmigration was estimated at 4.2 million in 1970, and 2.0 million in 1969. The increase in 1970 was mostly due to the first year's release from Dworshak Hatchery.

"6. Survival of chinook smolts sharply declined in 1970. Prior to the new dams, survival from the Salmon River to Ice Harbor Dam, based on marked fish released in the Salmon River and recovered at Ice Harbor Dam, was essentially 100%. In 1970, with two new dams completed, the survival dropped to 30%.

"7. A logical explanation for low survival of chinook salmon in 1970 is the prolonged exposure of fish to high levels of supersaturated nitrogen in the Snake River.

"8. Steelhead survival to Ice Harbor Dam varied from a high of 85% for release from Dworshak Hatchery to 50% - Salmon River, and 20% - Grande Ronde River. Average steelhead survival based on the population estimates was 75%. By contrast, survival of the Grande Ronde release in 1969 was nearly 100%.

"9. Total loss of steelhead from the Snake River based on McNary Dam recovery data may be as high as the 70% chinook loss. Between 30 and 40% of the steelhead collected at Ice Harbor showed gas bubble symptoms but simply had not been in the river long enough for significant mortalities to have taken place by that time. Data from recovery of fish at McNary Dam indicates a substantial mortality of steelhead occurred between Ice Harbor and McNary Dam."

From other studies of marked fish released at Little Goose Dam, the National Marine Fisheries Service reported: "In 1970, approximately 90% of the juvenile migrants died between Little Goose Dam and the estuary largely because of supersaturated nitrogen in the river. This condition will not be alleviated until all dams contain their full complement of turbines, at least 3 or 4 years hence. Four years of 90% mortalities would nearly destroy the Snake River anadromous fish runs which are valued at about 2.6 million annually to commercial and sport fishermen." The National Marine Fisheries Service indicates that data collected in 1971 have not yet been evaluated.

Since the Corps does not field large biological staffs and thus relies on the work of its sister federal agencies for fisheries information, it has no basis for refuting the results cited above. Accordingly, the Corps has taken the position that the situation is serious and is proceeding with an action program to minimize nitrogen supersaturation to the maximum entent possible. At the same time, for the sake of the fisherics, we sincerely hope the above estimates based on extrapolations from releases and sample recoveries of test lots of fish that were handled, marked, and reexamined in surface water are in error. Returning adult runs in the next few years will, of course, confirm or deny these test results. In no way do we intend to reflect unfavorably on the quality of work by the National Marine Fisheries Service. They have excellent scientists that have done everything humanly possible to secure an accurate measurement of loss under extremely difficult field conditions. The fact must be accepted, however, that this type of evaluation has inherent, if unavoidable, weaknesses.

Status of Runs

In examining the status of runs, one must clearly understand that many factors affect their size. At the present time, much attention is focused on nitrogen supersaturation as it is an apparent serious problem. Do not, however, lose sight of the fact that there have always been substantial fluctuations in fish stocks from year to year caused by hydrological and meterological conditions in spawning areas, effects of dams other than nitrogen, variable ocean survival conditions, pollution, and the effect of the fisheries themselves, to name but a few.

In considering the impact of N_2 supersaturation on seaward migrants on runs, one must relate the year of major seaward migration with the major year of return. The following table provides this relationship:

Returning Adults	Four-Year Fish Year of Downstream Migration*				
	1971	1970	1969	1968	1967
Spring Chinook	1969	1968	1967	1966	1965
Summer Chinook	1969	1968	1967	1966	1965
Steelhead	1970	1969	1968	1967	1966

*Majority of fish return as 4 year olds. Some smaller portion return as 3's and 5's.

This means, then, that the adult chinook runs of 1969 and prior years were unaffected as downstream migrants by the new dams, John Day, Lower Monumental, and Little Goose, as were the steelhead adult returns of 1968 and prior years. Returning adult steelhead of 1969 were exposed as juveniles to new N_2 conditions caused by John Day. The 1970 adult steelhead run was exposed as juveniles to new N_2 conditions of John Day and Lower Monumental, and the 1971 adult steelhead run will have been exposed to the new N_2 conditions at John Day, Lower Monumental, and Little Goose. Not until 1972 and after will we see returning steelhead runs whose parents and juvenile phases both were affected by the added condition at John Day, Lower Monumental, and Little Goose.

Adult spring and summer chinook runs of 1970 were exposed to N_2 conditions at John Day as juveniles in 1968 and the 1971 runs were exposed to N_2 conditions at John Day and Lower Monumental in 1969 and 1970. As with steelhead, we will not see returning adult chinook runs whose parents and juvenile phases both were affected by added conditions at John Day, Lower Monumental, and Little Goose until 1972 and after.

With reference to the above information on juvenile fish exposure to new conditions, let's examine the adult returns for these groups of fish:

Adult Fish Counts

	Bonneville	The Dalles	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose
1969							
Spring Chinook	173,562	100,482	81,724	70,079	52,090	48,637	Not in Operation
Summer Chinook	102,153	61,978	64,732	63,953	30,917	30,445	
Steelhead	140,782	112,529	86,348	76,681	63,889	71,434	
1970							
Spring Chinook	110,225	83,522	72,555	64,026	47,925	45,579	43,246
Summer Chinook	64,222	48,326	43,444	43,166	23,171	22,379	19,450
Steelhead	113,437	94,742	75,893	70,032	50,620	60,113	57,667
1971							
Spring Chinook	125,383	73,655	56,625	42,601	32,638	30,739	28,432
Summer Chinook (Thru 22 June)	22,223	11,660	12,890	11,288	6,825	7,529	6,635
Steelhead	-	-	-	-	-	-	-
Average Run	(32 yr ave)	(13 yr ave)	(3 yr ave)	(16 yr ave)	(8 yr ave)	Use Ice Harbor Average For Snake River Comparisons	
Spring Chinook	87,287	73,396	77,253	55,508	34,151		
Summer Chinook	63,180	66,811	61,223	66,209	24,832		
Steelhead	141,326	131,829	94,449	101,030	71,043		
Spring Run Ends	31 May	3 June	5 June	8 June	11 June	13 June	15 June
Summer Run Ends	31 July	3 Aug	5 Aug	8 Aug	11 Aug	13 Aug	15 Aug

It can be seen that the steelhead returns since 1968, when the first juvenile outmigrants were exposed to the presence of John Day Dam, are below average and appear to be declining. The next few years' returns that will reflect impact of the new dams on both upstream parent migrations as well as juvenile seaward migrations should clearly indicate how critical the problem really is. Some of the indicated decline is probably due to adult migration problems at an increased number of dams that are intensified by the high flow period. For all species the large number of missing fish between dams indicates a serious problem that has existed for some years and is one which we have been investigating to determine causes.

For spring chinook, the 1970 adult return, whose juveniles were exposed to John Day conditions, was above average. The 1971 run, exposed as juveniles to conditions at John Day and Lower Monumental, appears to be well above average at Bonneville, but possibly somewhat below at upstream projects. Because spring fish delayed by unusually high water are still moving in significant numbers after the official termination dates at upstream projects, an average escapement into the Snake appears assured. Early high flows this season have impeded the adult migration and probably will cause a higher interdam loss than usual. Again we have yet to see returns whose parent and juvenile migrations both were affected by the three new dams. This year's above average return to the river is encouraging in that the seaward migrants for this group were exposed to the full measure of N_2 supersaturation except for that created by Little Goose.

Summer Chinook - The 1970 adult run, whose juveniles were exposed to new conditions at John Day, was slightly below average. The 1971 run is just beginning to evidence itself at Bonneville. The summer run has been barely maintaining itself since 1965 and there has been little or no river fishery permitted since that time. While there is no information on the effect of ocean fisheries on this run, it would appear that upstream migration problems at dams coincident with the usual high flow period are at least part of the problem. Summer run chinook reached peak production in the Columbia River in 1957 and have been on a general decline since. Completion of McNary in 1954 and The Dalles in 1957 may have influenced this decline. Mid-Columbia dams, Rocky Reach, 1961; Priest Rapids, 1962; and Wanapum, 1963, had further impact on summer chinook by inundating their spawning grounds in that area.

Limited information is available on spawning success of spring and summer chinook in the Snake watershed. Index nest or redd counts have been made by Idaho Fish and Game Department in the Salmon River system since 1965 and are listed below. These numbers in themselves mean little except that over a period of years they reflect increases or decreases in spawning success. In the Snake, their trend can be compared with Ice Harbor counts.

Spring Chinook

	1965	1966	1967	1968	1969	1970
Spawning Index Nest Counts	2,508	4,362	4,662	4,479	2,317	3,003
Ice Harbor Passage	12,178	43,881	35,593	44,773	52,090	47,925

Summer Chinook

	1965	1966	1967	1968	1969	1970
Spawning Index Nest Counts	1,544	2,120	2,148	1,389	1,475	1,100
Ice Harbor Passage	14,701	16,983	30,315	29,531	30,917	23,171

For spring chinook it is apparent that in spite of substantial adult passage rates during 1969 and 1970, the spawning index counts dropped markedly. This could indicate that the addition of Lower Monumental and Little Goose and their N_2 saturation problems affected adult fish passing them so that survival to spawning was reduced.

For summer chinook the picture is not quite so clear. There has been a reduction in spawning success from 1968 and that could indicate an impact on adult passage from John Day, Lower Monumental, and Little Goose.

Spring and summer chinook and steelhead runs in the Snake may well be reduced for the next few years as a result of N_2 impact on juveniles, missing adult fish between dams, and reduced spawning efficiency. Severe N_2 exposure to seaward migrants at John Day and Lower Monumental in 1969 still permitted a fair return of springs this year. Corps plans to reduce or eliminate the N_2 problem in the Snake next year should greatly improve the lot of the seaward migrant from that watershed. Added storage in the upper Columbia, additional power units at John Day and The Dalles, and remodeled fish facilities at Bonneville by 1973 will reduce spill and N_2 problems in the lower river and hopefully will reduce interdam adult fish losses to "long run fish." Steelhead and summer chinook that pass through the river as adults during the high flow period should be particularly aided by reduced spilling at lower Columbia dams and the consequential reduction in N_2 concentrations and improved fish collection conditions. Fall and spring chinook, coho, and steelhead adults produced in the lower river and its tributaries are not exposed to nitrogen supersaturation. Their juvenile forms that migrate in the spring are so exposed; however, they obviously have been for many years (34 years of spilling at Bonneville and 15 years of spilling at The Dalles) and have survived. There is no evidence to indicate that nitrogen values below Bonneville are any higher now than they probably have been since The Dalles project was placed in operation. Thus, while the elimination of nitrogen supersaturation in the lower Columbia River may be expected to improve conditions for fish, the problem there does not appear to be as critical as it is in the upriver areas where "long run" fish are involved.

Results of 1971 Nitrogen Reduction Studies

For 1971 the only possible way that even limited nitrogen supersaturation control could be achieved was by a modified reservoir system operation and to some extent individual project operational revisions. Through close coordination with the fisheries agencies, a plan of water storage, selected turbine loading, and power transfers was executed in the Pacific Northwest and western Canada to curtail spill for one week at lower Columbia River projects. During this period, all state and federal salmon and steelhead hatcheries on the lower Columbia made their annual releases of some 40 million young fish into waters relatively low in nitrogen content. Testing indicated that these fish migrated into the estuary of the river before it was necessary to resume heavy spilling once more.

A great amount of effort is being expended on studies of structural changes to reduce or eliminate nitrogen. Hydraulic and mathematical model studies are being conducted to determine possible solutions through modifications to spillways or development of water bypass systems. One of the most promising results of this work is a structural modification that permits the passage of substantial amounts of water through skeleton bays constructed for future power units at many of our projects. A submerged orifice gate has been devised to dissipate energy and avoid air entrainment in the skeleton bay and is now installed and being tested at Little Goose Dam on the Snake River. Initial results look very promising. Volumes of water at least equal to those passed through a turbine are being carried in this test unit with no increase in nitrogen saturation levels. We are proceeding with a plan to install such devices in all nine skeleton units at the three lower Snake River dams (the major problem area) prior to next season's runoff and, thus, reduce the amount of spill and nitrogen supersaturation to minimal levels. We are also continuing to investigate other possibilities as well.

The program of trapping and hauling seaward migrants around dams has been under study for many years by the National Marine Fisheries Service (formerly U.S. Bureau of Commercial Fisheries). The studies have concentrated on methods of effectively deflecting juvenile fish from the turbine intakes and on the effect of transporting fish around long segments of river on the homing instinct of returning adult fish. The application of such a program, if successful, was intended primarily to mitigate known losses through turbines (about 11 percent) and unknown predation losses in the reservoirs. Obviously, fish so transported have reduced exposure to water supersaturated with nitrogen, and such a system offers a possible contingency method for protecting a portion of the fish runs while ways of eliminating nitrogen supersaturation are devised and implemented.

In 1971, the National Marine Fisheries Service, under a $544,000 contract with the Corps of Engineers, is testing a prototype deflection, trapping, and transport system at Little Goose Dam on the Snake River. The large, complex, traveling deflection screens are installed in only one of the three turbine intakes to determine the efficiency of such a system in deflecting fish and to test the structural and operational capability of the equipment design. NMFS is also marking the fish trapped at Little Goose so that they may compare the return survival of fish hauled with that of control groups released below the dam and allowed to migrate to sea in the normal manner. As with most any new equipment, they have had some mechanical difficulties and are going through a debugging process. These problems are readily solvable, and NMFS is diligently working toward this end. Despite the problems, the deflector screens have been operable much of the time this season and the system offers much promise for accomplishing its originally intended purpose. Tests have shown that when the screens are operating, about 90 percent of the fish entering a turbine can be trapped and safely handled. Such a system, when installed in the full complement of turbine units at a project, would in effect be capable of collecting 90 percent of the migrating population. It is our intent to continue support of these experiments for future application as necessary to maintain the anadromous fish runs in the Columbia basin. In the meantime, so far this year some 331,000 juvenile salmon and steelhead have been trapped, transported or otherwise handled as a part of this endeavor.

OPERATIONAL MODIFICATIONS TO REDUCE NITROGEN SUPERSATURATION PROBLEM

The projects of principal concern today are those on the lower Columbia and Snake Rivers. These are Bonneville, The Dalles, John Day and McNary dams on the lower Columbia, and Ice Harbor, Lower Monumental and Little Goose dams on the lower Snake River. These projects, being the most downstream projects on the Columbia and Snake Rivers, have the bulk of the nitrogen problem since they are located in the principal path of the anadromous fish runs.

Of secondary concern are the mid-Columbia River projects -- that is, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids. Although a nitrogen problem also exists on the mid-Columbia reach, fewer anadromous fish pass these projects and the nitrogen supersaturation contribution of these projects to the lower Columbia River tends to be dissipated in the open river reach below Priest Rapids. The location of all of these projects is shown on the attached Figure 1.

These are so-called run-of-river projects. That is, their storage capacity is small compared to the flow of the river. Generally speaking, the total storage of each of these projects is less than one day's flow. Unfortunately, considering the nitrogen supersaturation problem, they do not have enough storage capacity or pondage to control the river to prevent spill.

The flow of the Columbia River is regulated by upstream storage reservoirs located principally in headwaters areas. At present there is about 30-million

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acre-feet of active storage. This will soon be increased to nearly 50-million acre-feet when reservoirs now under construction are completed. However, not all of this storage is usable for flood regulation. But even with this future storage the Columbia River will be only partially controlled. Unlike the Missouri or Colorado Rivers, whose reservoir storage capacities far exceed their annual runoff, the reservoir storage capacity of the Columbia is but a fraction of its annual runoff. For example, the Missouri River's reservoir capacity is about four times its annual runoff while the Columbia River's annual runoff is about four times its reservoir capacity.

The flow of the Columbia River varies widely with the season of the year (see Figure 2). The lowest flows occur during the winter months and the highest during the spring snowmelt period. The available reservoir storage tends to level out this seasonal variation in flow, augmenting flows during the low-flow season, principally for power generation, and reducing flows during the spring freshet for flood control. But, in most years, the existing degree of flood control is insufficient to prevent spill at our run-of-river projects. Water passes over the spillways and results in nitrogen supersaturation.

It has been suggested that a solution to the nitrogen supersaturation problem would be to install more generating units at our hydroelectric projects. Then during the spring freshet the high river flows could be passed through the turbines of these units, which does not cause nitrogen supersaturation, rather than over the spillways of the dams.

In the long run this is a practical solution. But it takes time to build and install generating units. Also it is a fact that at present the water that can be passed through the turbines is limited by the electrical load on the generators and the installation of additional generating units in advance of load growth would not decrease the total amount of spill at the hydroelectric projects. The Corps is currently investigating means whereby it may be possible to discharge water through the turbines of generating units with little or no resulting generation. Mr. Hugh Smith will discuss this further.

The time of heaviest electrical power demand in the Pacific Northwest occurs during the winter months (see Figure 3). In June, when the Columbia River normally reaches its maximum annual flow, the power demand is at its annual minimum. Generating capacity, installed to serve peak winter power demands, cannot all be used during the spring high-water season, either now or in the future. The problem of keeping generating units loaded is further compounded by daily variation in system power demand. During the night and early morning hours power demands are much lower than during the daytime hours. If means can be devised to pass water through turbines without generating appreciable power it will be most helpful in solving the nitrogen supersaturation problem.

With regard to this year's operational modifications to reduce the nitrogen supersaturation problem, the principal efforts were directed toward avoiding excessive spill at times and places of hatchery fish releases. A Task Force was formed to guide the operation. On this Task Force are representatives of the Fisheries agencies, the Environmental Protection Agency, the Bonneville Power Administration, the Bureau of Reclamation, the mid-Columbia Public Utility Districts, and the Corps of Engineers. The Task Force met frequently during the period of major concern.

This year's spring flood had an exceptionally large volume of runoff. The April through August runoff at The Dalles is estimated to be 120-million acre-feet which is 121 percent of normal. As a result of our reservoir regulation and the relatively cool weather this spring, the peak observed flow at The Dalles was limited to some 550-thousand cubic feet per second. This was excellent flood regulation for a flood of this magnitude. But it was inadequate for prevention of nitrogen supersaturation this year. High rates of spill occurred and nitrogen supersaturation was extremely high. Beginning next year, with the addition of Dworshak and Libby reservoirs to the system, it is estimated a flood of the magnitude of the one that occurred this year could be controlled to less than 500-thousand cubic feet per second.

The principal regulation effort for nitrogen reduction was concentrated on the week of 26-30 April when some 40-million hatchery-raised juvenile fish were released in the lower Columbia River. During this period the flow of the lower Columbia River was reduced to 180-200 thousand cubic feet per second. This regulation was accomplished by storing water in eight reservoirs as shown in the following tabulation:

Project	Owner	1000 Acre-Feet Stored
Arrow	B.C. Hydro & Power Authority	240
Grand Coulee	Bureau of Reclamation	570
Brownlee	Idaho Power Company	90
Little Goose	Corps of Engineers	35
Lower Monumental	Corps of Engineers	10
Ice Harbor	Corps of Engineers	20
McNary	Corps of Engineers	35
John Day	Corps of Engineers	200
TOTAL		1,300

In addition to the foregoing regulation, the lower Columbia and Snake river generating stations were kept fully loaded to pass as much water as possible through the turbines and thereby avoid spill to the maximum extent possible. No spill occurred at McNary, John Day or The Dalles during the period and spill was minimized at Bonneville and the lower Snake River projects. This was done by transferring load to these projects from other projects. During the period 26-30 April, a little over 12 million kilowatt-hours of energy was delivered to utilities under a special "in-lieu" arrangement. In addition, a little over 4.5 million kilowatt-hours was delivered to utilities for immediate spill. Some 250 thousand kilowatt-hours was delivered to B.C. Hydro for storage in Lake Williston on Peace River. The total energy transferred under these special arrangements was about 17 million kilowatt-hours.

As a result of this special regulation, nitrogen levels were reduced to tolerable amounts. Nitrogen supersaturation ranged from 103 to 112 percent in the Bonneville forebay and from 107 to 114 percent at Warrendale, Oregon, immediately below Bonneville Dam during this period.

Shortly after the low-flow period of 26-30 April, the lower Columbia River rose rapidly. The rise was caused in part by the termination of storing in the upstream reservoirs, but of even greater importance was the effect of warmer temperatures which produced a sharp rise of snowmelt runoff. The flow of Columbia River at Bonneville Dam increased 160 percent from 202 to 524 thousand cubic feet per second in the seven-day period, 30 April to 7 May. Had the warm weather occurred a few days earlier, it would not have been possible to maintain the low river flows for the five days.

The downstream movement of the hatchery-raised fish cannot be accurately determined. Observations of downstream fish passage during and following the period of special regulation were made by Oregon Fish Commission and Washington Department of Fisheries at the downstream migrant bypass trap at Bonneville Dam. Similar observations were made by National Marine Fisheries Service by means of seining operations at Prescott, Oregon, and at Wauna, Oregon, near the estuary. From those observations there is reason to believe that the bulk of the hatchery-raised fish moved downstream before high nitrogen levels were experienced on the lower Columbia River.

The outlook for the next few years, insofar as the nitrogen problem is concerned, is more optimistic. Generally speaking, nitrogen supersaturation will become less of a problem with the passage of time. As additional upstream storage is completed, as additional generating units are added at our run-of-river projects to serve growing power demands, and as other means of nitrogen reduction now being planned are implemented, there will be less spill and hence less nitrogen supersaturation.

By the spring of 1972, two additional large storage projects will be completed. These are Dworshak Dam on the Clearwater River in Idaho and

Libby Dam on the Kootenai River in Montana. In addition, Mica Dam on the Columbia River in British Columbia will be completed by the Spring of 1973 (see Figure 1). Together these three projects will add 19-million acre-feet of active storage to the Columbia River system. This will do much to further reduce spill and nitrogen supersaturation. In a median flood year they will reduce the flood peak of The Dalles by about 100 thousand cubic feet per second.

Added power units at Corps of Engineers' and other generating stations will also reduce spill (see Figure 4). The most immediate additions now scheduled for the lower river are at John Day and The Dalles projects. Additional units are also scheduled to be installed at Ice Harbor in 1975 and at Little Goose in 1978. And within the decade additional units will probably be added at Bonneville Dam. By the year 1980 the hydraulic capacities of the lower Columbia River projects will average some 300-thousand cubic feet per second and those of the Snake River projects about 130-thousand cfs. With the increased electrical power loads anticipated at that time, river flows of this magnitude will result in no harmful spill at most of these projects. If the plans for installing slotted gates in skeleton bays and in the intakes of some of our existing units are successfully carried out, this time-table may be accelerated.

Thus the outlook for reduction of the nitrogen supersaturation problem is optimistic. The additional reservoir storage capacity and turbine capacity that will be available, along with other measures to be taken will result in virtually no nitrogen-producing spill from a flood of median size. Even a flood of this year's magnitude will have markedly reduced levels of nitrogen supersaturation. And the chances of having a flood as large as this year's flood in any given year are about one in ten.

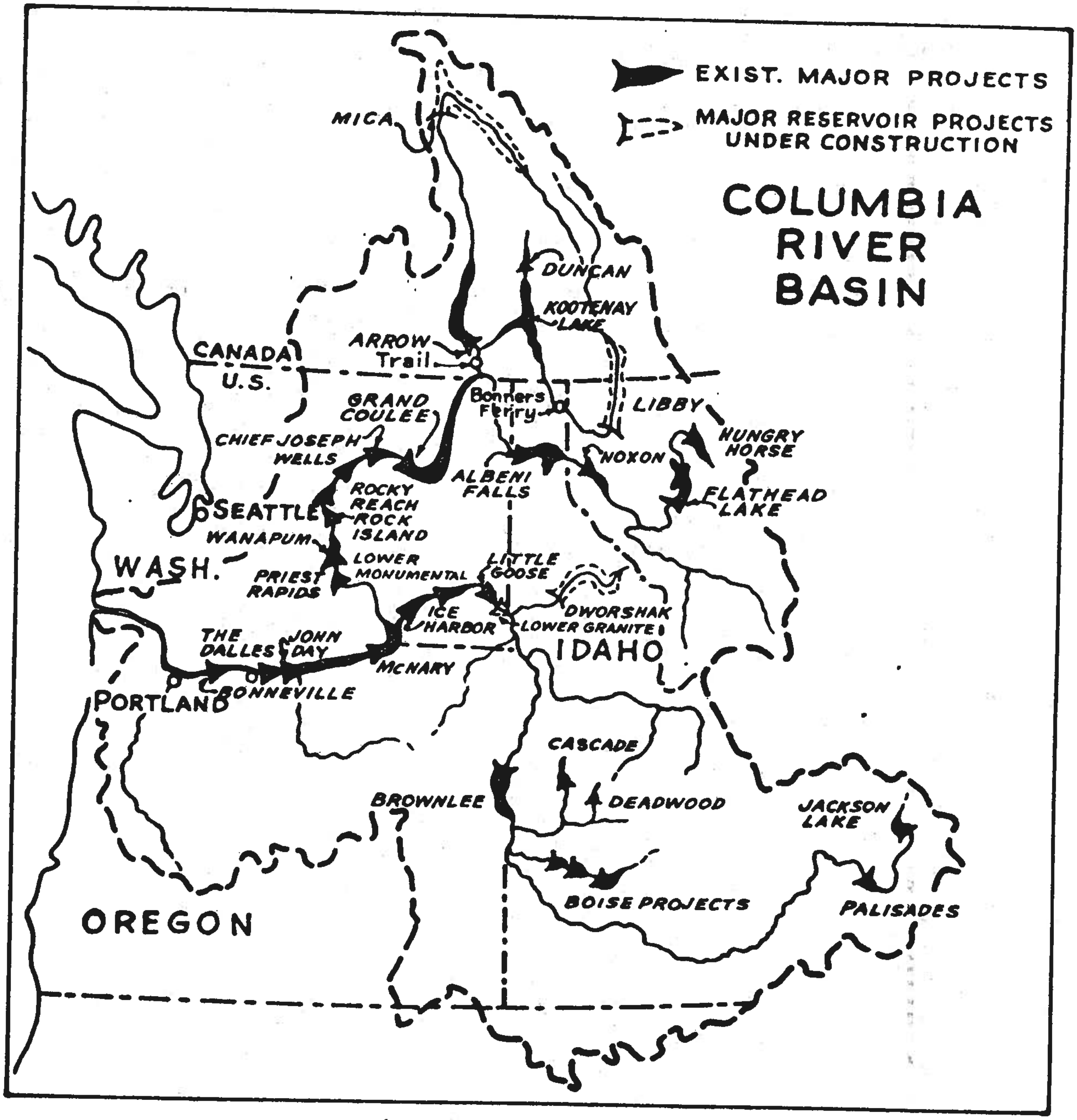

EXIST. MAJOR PROJECTS
MAJOR RESERVOIR PROJECTS UNDER CONSTRUCTION
COLUMBIA RIVER BASIN
MICA
DUNCAN
KOOTENAY LAKE
ARROW
Trail
CANADA
U.S.
GRAND COULEE
Bonners Ferry
LIBBY
HUNGRY HORSE
CHIEF JOSEPH
WELLS
NOXON
ALBENI FALLS
FLATHEAD LAKE
ROCKY REACH
ROCK ISLAND
SEATTLE
WANAPUM
LOWER MONUMENTAL
LITTLE GOOSE
WASH.
PRIEST RAPIDS
DWORSHAK
ICE HARBOR
LOWER GRANITE
THE DALLES
JOHN DAY
IDAHO
McNARY
BONNEVILLE
PORTLAND
CASCADE
DEADWOOD
BROWNLEE
JACKSON LAKE
BOISE PROJECTS
PALISADES
OREGON

FIG. 1

SUMMARY HYDROGRAPH

COLUMBIA RIVER NEAR THE DALLES, OREGON
DRAINAGE AREA = 237,000 SQ. MI.

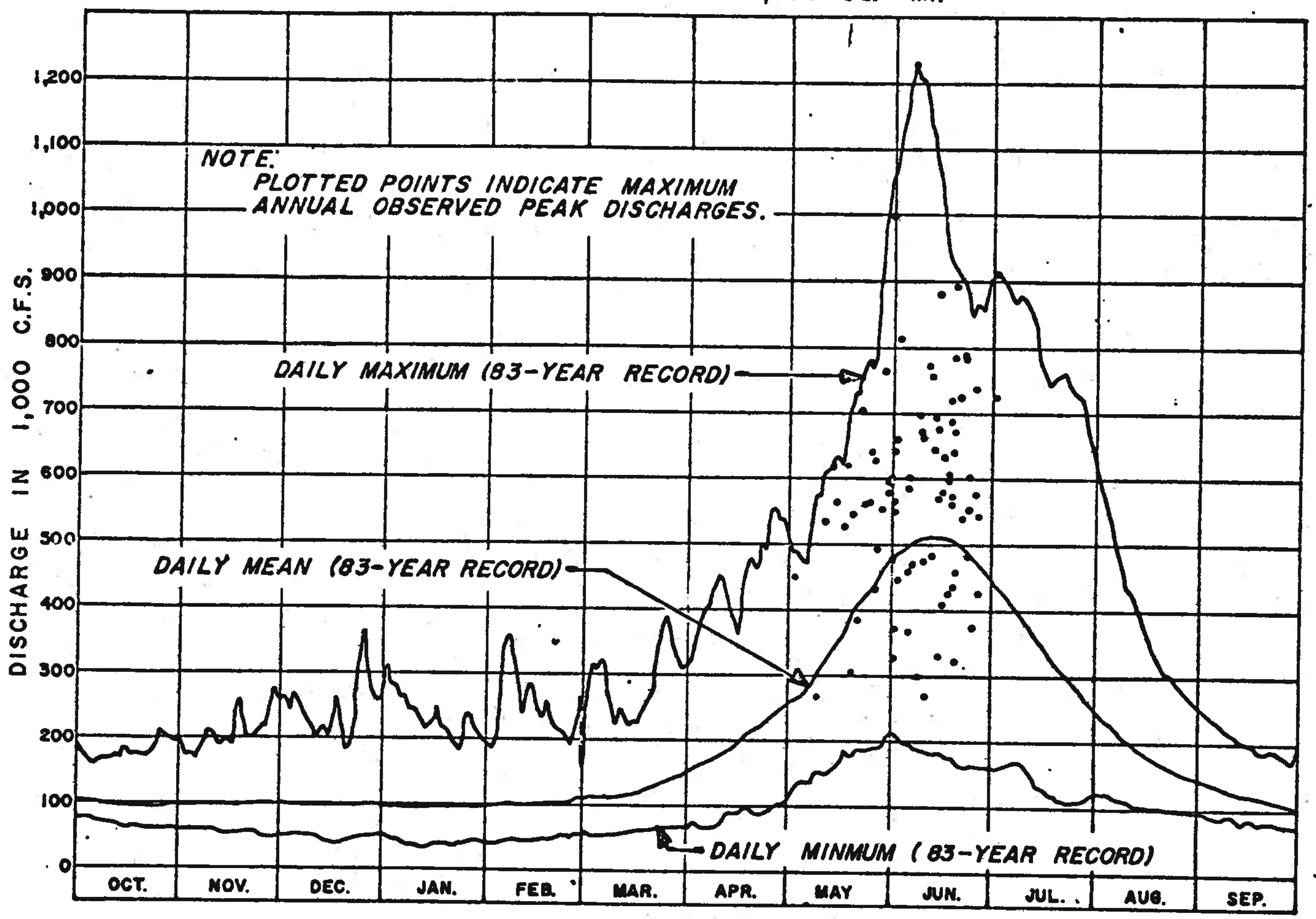
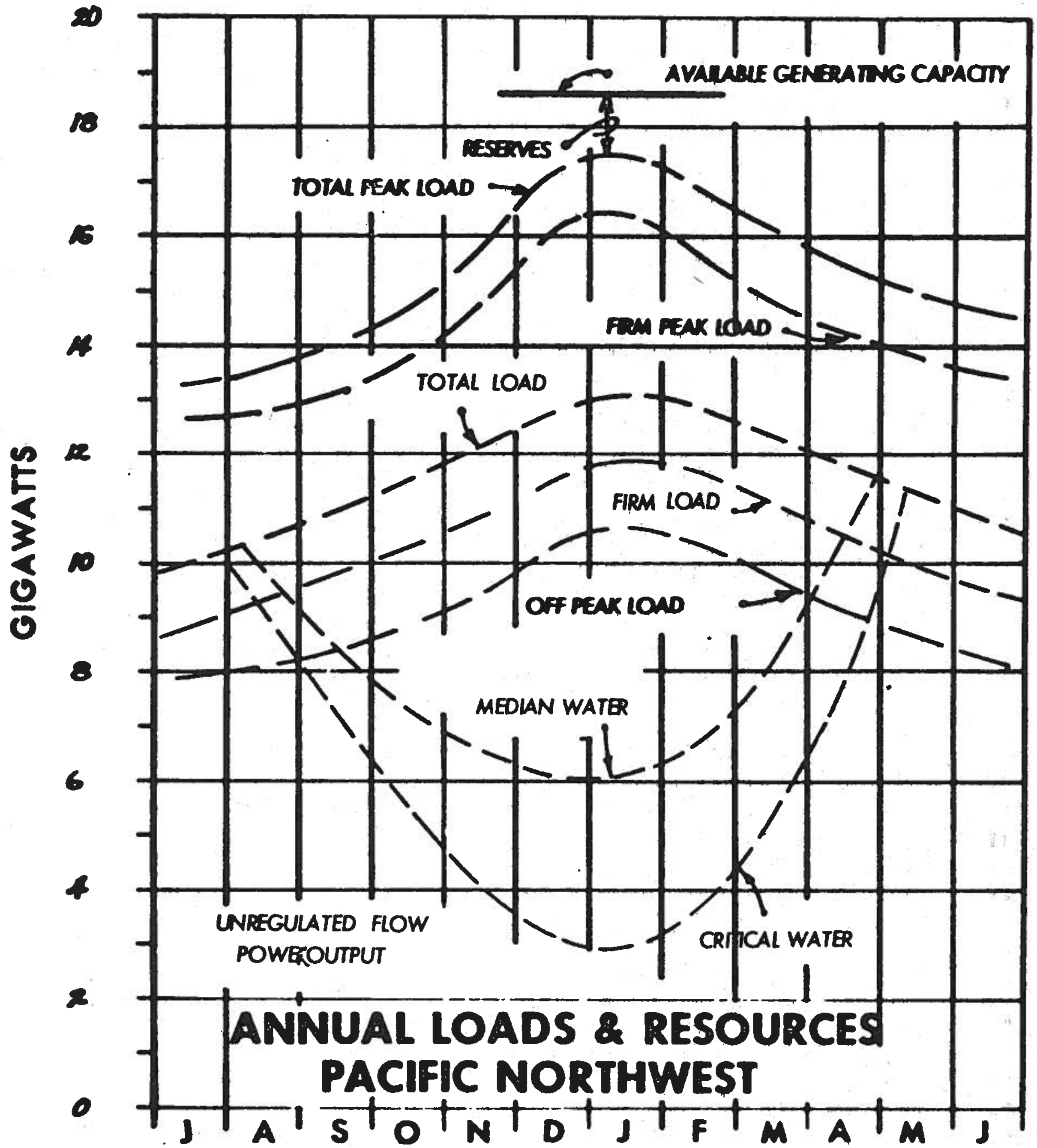


FIG. 2



AVAILABLE GENERATING CAPACITY
RESERVES
TOTAL PEAK LOAD
FIRM PEAK LOAD
TOTAL LOAD
FIRM LOAD
OFF PEAK LOAD
MEDIAN WATER
UNREGULATED FLOW
POWER OUTPUT
CRITICAL WATER
ANNUAL LOADS & RESOURCES
PACIFIC NORTHWEST
GIGAWATTS
20
18
16
14
12
10
8
6
4
2
0
J
A
S
O
N
D
J
F
M
A
M
J

FIG. 3

COLUMBIA RIVER PROJECT CAPACITIES

HYDRAULIC CAPACITY-NUMBER OF UNITS

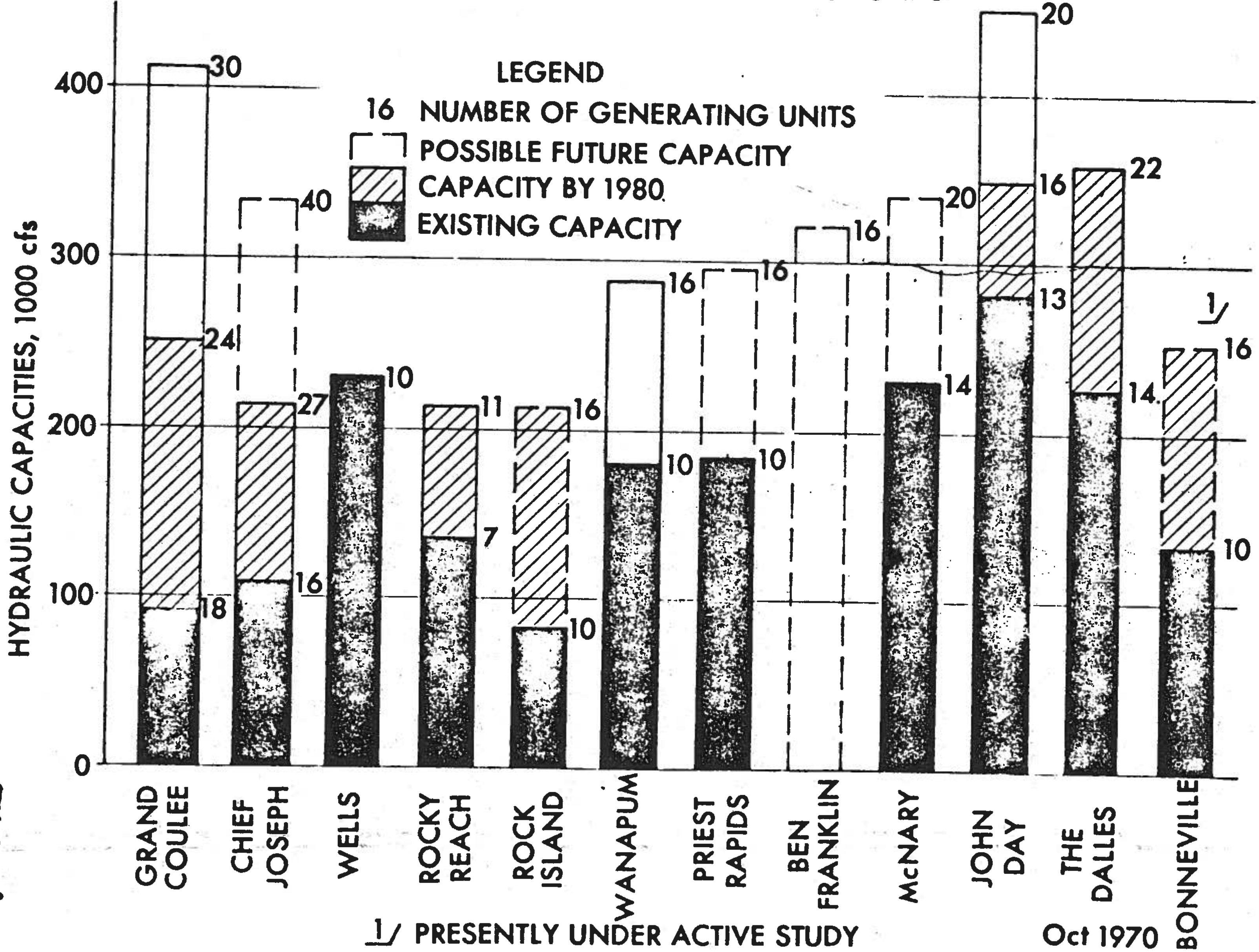


FIG. 4

24 June 1971

Structural Modifications to Reduce

Nitrogen Supersaturation Problem

Earlier meetings with environmental and fishery agencies in March and April of this year were more or less oriented towards what could be done in the immediate future to minimize the nitrogen problem in the Snake River -- corrective action before the freshet seasons of May and June of 1971 and 1972. In addition, however, the talents of the Corps of Engineers and of all other concerned agencies were put to work to come up with ideas for more complete solutions. As you know, no agency was quite prepared, either scientifically or monetarily, for the requirements to mitigate and/or eliminate the critical problem of nitrogen that has developed in the waters below the projects of the Columbia-Snake River dam system.

In addition to operating adjustments to reduce spill as much as possible, a method was devised to permit passage of water thru the skeleton powerhouse bays. Following successful model tests, the slotted bulkheads were procured and installed in Bay 6 at Little Goose for a prototype test. It has been found that not only is the concept structurally sound but that the flow passed, equivalent in quantity to that which can be passed thru one of the turbine generator units, does not increase the nitrogen supersaturation of the inflow. See Figures 1 and 2. This was measured several times by the National Marine Fisheries Service to confirm the model indications. Thus, with the full installation of three turbine-generator units at Little Goose project plus the diversion capacity of three skeleton bay units thru the now proven slotted bulkheads, we will be able to pass all but 30,000 cfs of a future average year's peak flow of 160,000 cfs without materially increasing the N_2 saturation downstream. Table I reflects estimates of the effect of the slotted bulkhead installation on the

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Prepared by: Hugh Smith, Hyd Engineer, North Pacific Division, CofE
Gordon H. Fernald, Jr. Chief, Engr Division, North Pac Div, CofE

generation of nitrogen supersaturation at Little Goose. Comparable results are expected at Lower Monumental and Ice Harbor with installation of slotted bulkheads and equal or better effects will be built into the Lower Granite project now under construction. We consider this the first, and probably a most important forward step, towards a complete solution of the nitrogen problem now evident on the entire river system.

Now, at this time, we have two further ideas which may also prove to be as important, if not more so, than the skeleton bay diversion concept. One new idea appears very favorable as has already been indicated in a small scale model at our laboratory at Bonneville Dam. In essence, this is a lip or baffle, located on the downstream face of the spillway structure, which directs small to moderate concentrations of spillway flow along the surface of the tailwater in lieu of plunging to the bottom of the stilling basin. See Figure #3. Since most scientists and engineers now consider the actual increase in nitrogen saturation to be dependent on the depth --(or the pressure) to which air-water mixture is subjected, the concept of surface flow should reduce the absorption of nitrogen in the downstream area when compared to the existing condition where the flow plunges 50 to 75 ft in the stilling basins. We have now installed this proposed modification to the spillway in a larger scale model (1:40±) and are expediting the tests and evaluation of this plan as a further means to reduce the nitrogen problem. The interesting aspect of this proposal is that we consider the idea as generally applicable as a remedial measure for most of the projects in the Snake-Columbia River system. However, it will be necessary, even after apparently successful hydraulic model studies, that we install the proposed design in a prototype structure to assure its efficiency insofar as improvement in nitrogen levels downstream are concerned and to assure no major adverse effects on other river uses. If the model testing appears successful, we would propose the prototype test possibly next winter before funds are sought for general application.

The second concept is possibly a little more nebulous, since we have not yet conducted any tests on models. In essence, it is the use of the slotted bulkheads, or modification thereto, in the operating turbine-generator bays of a project. Our normal design criteria are to provide water passageways to minimize the hydraulic losses, and thereby maximize the power output from the turbine installation. During the normal months of May and June we would wish to do just the opposite -- to increase the hydraulic losses or decrease the efficiency of the turbine. It is visualized that use of the slotted bulkheads above the installed units to increase the headloss and produce a corresponding reduction in efficiency of power output would make it possible to pass nearly full powerhouse flow with insignificant power output. This could permit nearly full powerhouse flow when loads are not available for full generation with a corresponding decrease in spillway flows. We are now planning to conduct these prototype tests at Little Goose project in the month of July this year. When you consider the imbalance of installed generating capacity compared to electrical demand in the months of May and June, this concept of "inefficient" operation could be as important as the skeleton bay diversion scheme.

In summary, our proposed plans to rectify or eliminate our common problem consist of the following at this time:

a. Skeleton Bay Diversion

b. Spillway Modifications

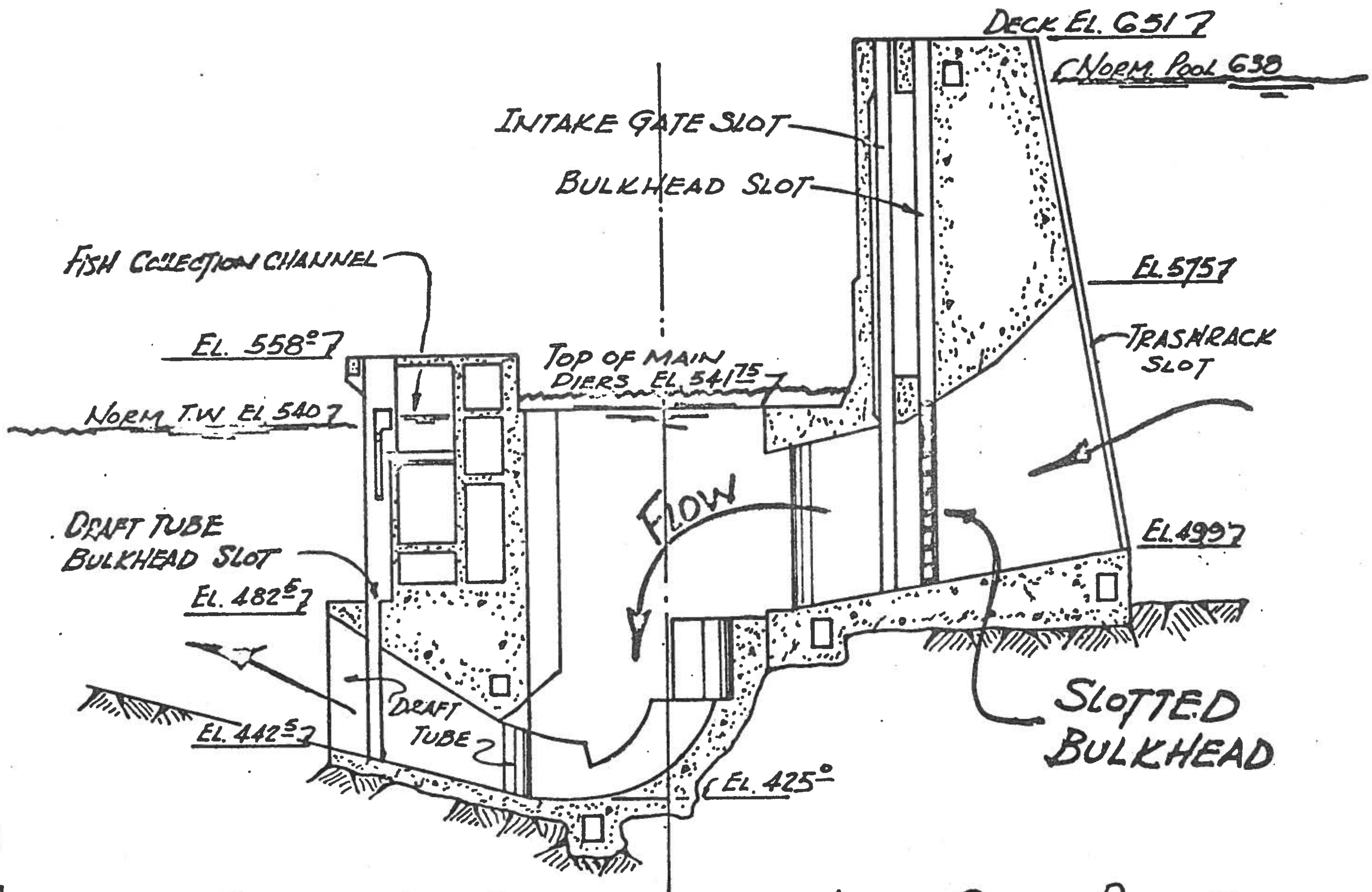
c. Inefficient Powerhouse Operation

Since only one of the above structural plans can at this time be considered a "proven" plan -- the skeleton bay diversion thru the slotted bulkheads -- only the schedule for installation of this modification for the Snake River projects can be considered firm at this time and only dependent on availability of funds. Any suggestion of schedule for completion of the other possible remedial construction must be considered tentative and dependent on successful completion of both model and prototype tests to be accomplished this summer and fall as well as dependent on availability of funds. We are optimistic that the funds required to complete the skeleton bay diversions at Little Goose, Lower Monumental and Ice Harbor, $12,175,000 will be available in July. A tentative schedule is shown on Table II.

Table III attempts to provide an indication of the relative seriousness of the nitrogen supersaturation problem at each of the Corps projects after completion of the above discussed possible modifications and construction work currently underway. The estimated spillway discharge at that time is based on the average annual freshet discharge, both with and without the upstream storage to be available for use after for freshets after 1972. Larger but less frequent Spring freshet or flood runoff flows will result in increased spillway discharges. It appears probable that with the spillway modifications under study that the discharges indicated, with storage, will be passed in an average or less runoff year with no or very little generation of additional nitrogen supersaturation with the exception of Bonneville and possibly McNary. Studies are nearing completion with regard to construction of a second powerhoue at Bonneville. With a second powerhouse by the Spring of 1978, Bonneville spillway discharges during an average freshet period should be reduceable to tolerable limits. Further consideration of McNary may result in additional corrective action.

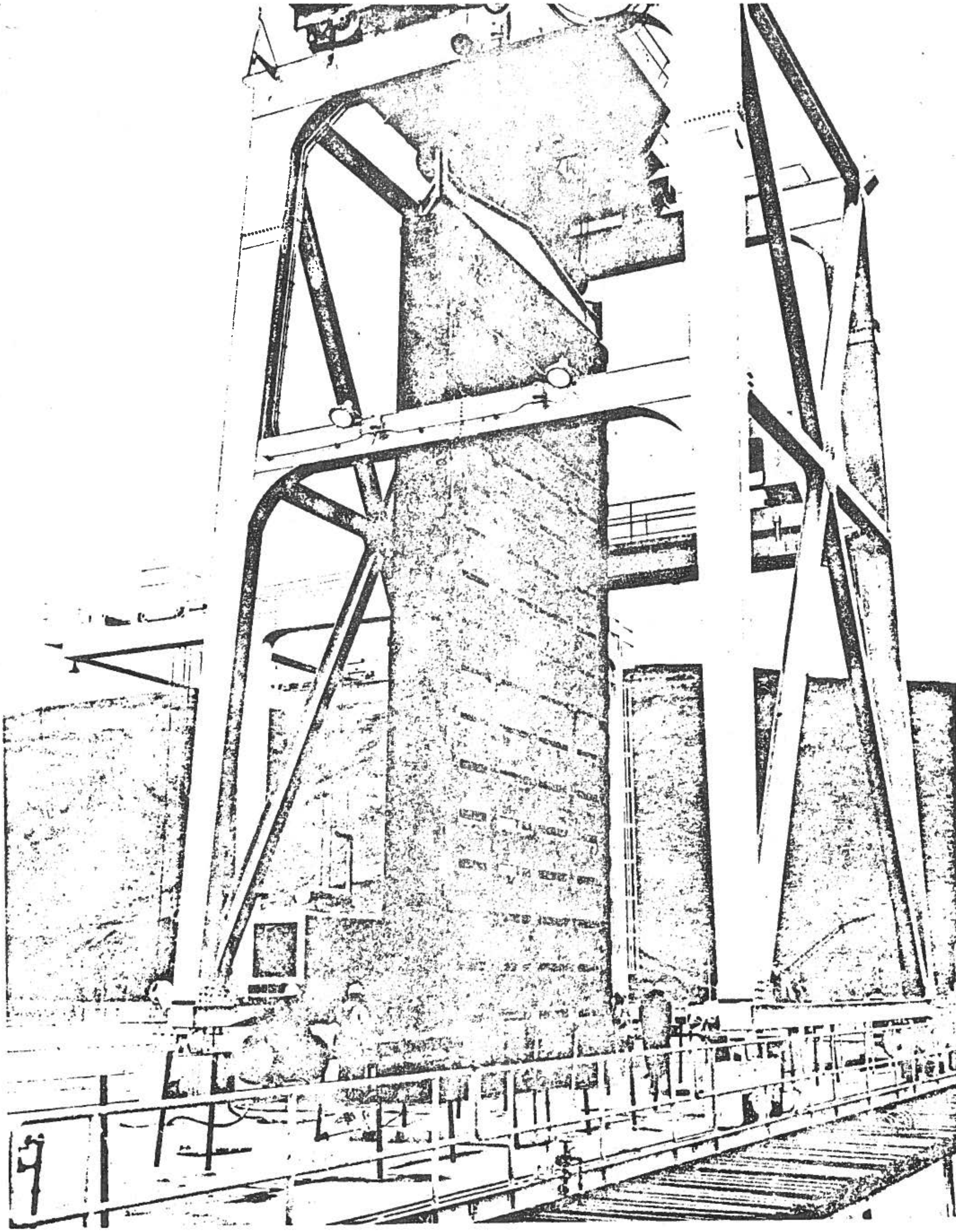
The above evaluations are based on an average Spring discharge, a two-year flood on a frequency basis. We cannot hope to provide adequate safe hydraulic capacity to pass major floods which could exceed a million cubic ft per second on the lower Columbia River on rare occasions and more than 400,000 cfs on the Snake River. However, it appears that a reasonable goal might be set to design or modify each project so as to produce little or no increase in the nitrogen saturation level for flows with an average recurrence level of 10 years. This criterion may be impossible of achievement at all projects without additional upstream storage control but it would appear to be a reasonable goal for all project operators to strive for.

I can certainly reassure you that we do not plan to terminate our efforts at this time, but plan to continue the effort until nitrogen supersaturation at Corps projects is no longer a hazard to the fishery resources of the Pacific Northwest. Rapid progress has been made this year and we have every reason to believe that this accomplishment is only the first step to attain our goal.

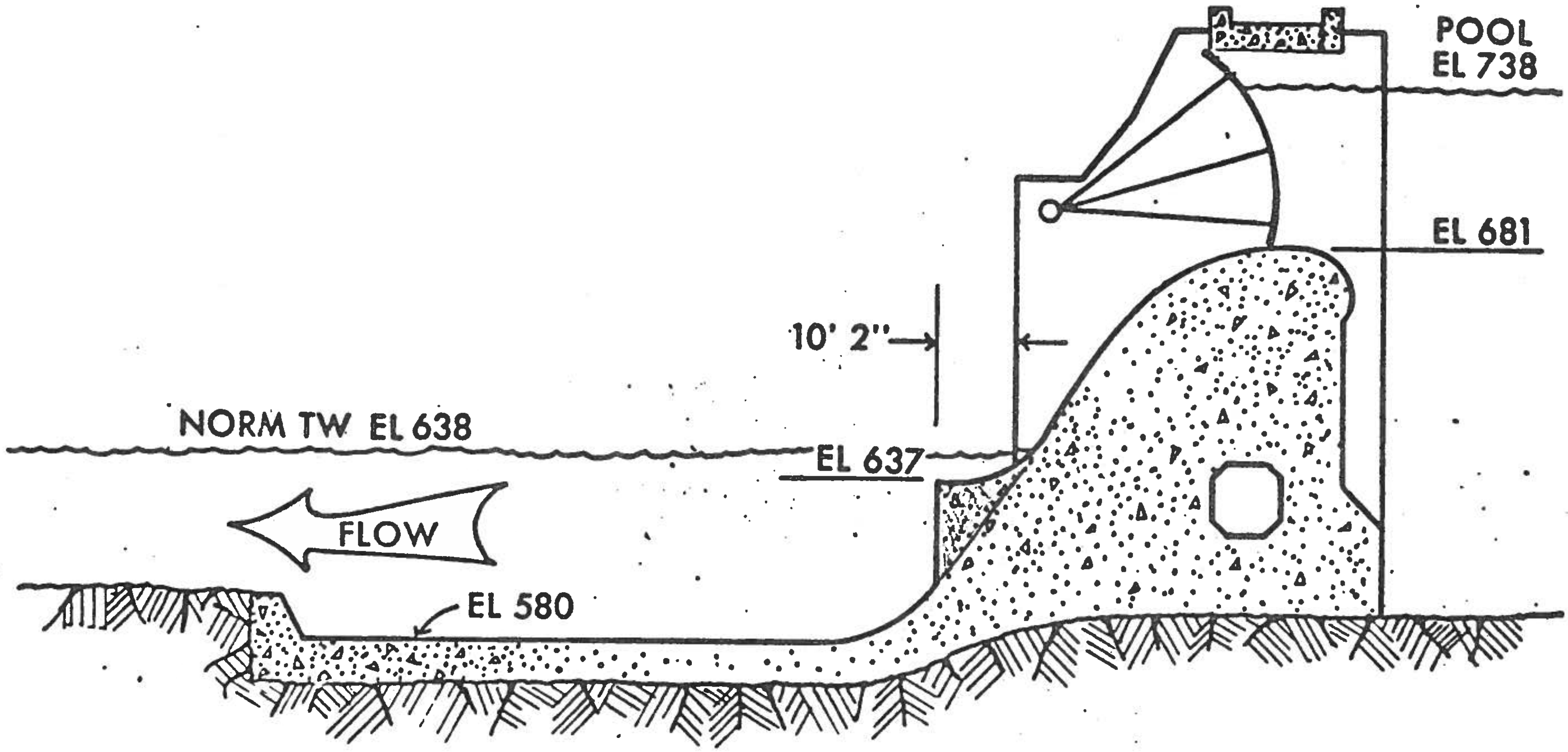


SECTION THRU SKELETON BAY LITTLE GOOSE PROJECT

Fig #1



PROTOTYPE SLOTTED BULKHEAD Fig. #2



SPILLWAY DEFLECTOR
LOWER GRANITE SPILLWAY

Fig. #3

June 1971

TABLE I

Little Goose Project

	Total 2/ River Flow in cfs	Powerhouse + 3/ Skeleton Bay Flow in cfs	Spillway 3/ Flow cfs	Computed Nitrogen 5/ Saturation Level Below Little Goose
Condition (existing without Dworshak regulation)				
3 phse units	200,000 (2-year flood)	66,000	134,000	127%
3 phse units + 1 skeleton bay 1/	200,000 (2-year flood)	87,000	113,000	123%
Future (1972 and beyond with the effect of Dworshak regulation)				
3 phse units + 3 skeleton bays	200,000 (4-year flood)	130,000	70,000	114%
	160,000 (2-year flood) or median peak	130,000	30,000 4/	104%

1/ Existing project operation (June 1971)

2/ Project inflow assumed to have 100% N_2 saturation

3/ Spill Q assumed to produce 140% N_2 saturation while powerhouse and skeleton bay assumed to produce no change in inflow N_2 saturation

4/ Reduced spill Q assumed to produce 120% N_2 saturation

5/ The absolute values of saturation not established at this time, therefore, this table only shows relative change due to powerhouse diversion

TABLE II

Schedule for Construction - Nitrogen Alleviation 1/

Project	Skeleton Bay Diversion: Model Tests	Skeleton Bay Diversion: Construction Complete by	Skeleton Bay Diversion: Approx. Cost
Little Goose	Yes	Spring 1972	
Lower Monumental	Yes	Spring 1972	$12 200.000
Ice Harbor	To be accomp Summer 1971	Spring 1972	
John Day	To be accomp. Winter 1971	Spring 1973	$8,000,000 2/ (4 bays)
McNary			No skeleton bays available
Bonneville			No skeleton bays available
The Dalles			Complete phse. installation now under construction
Chief Joseph			No skeleton bays available

Project	Spillway Modification: Model Tests	Spillway Modification: Construction Complete by	Spillway Modification: Approx. Cost
All projects	To be accomp. Summer 1971 with prototype test Fall 1971 at Lower Monumental	Earliest date for completion at any project would be Spring 1974	$300,000 per spillway bay

Project	Slotted Bulkheads in Operating Bays: Model Tests	Prototype Tests	Construction Complete by		Approx. Cost
All projects	Not required	July 1971 at Little Goose	Earliest date possible for any project Spring 1974		$400,000 per unit

Studies will be required to determine how many bulkheads can be installed and still meet the system needs for power in May and June. This to be accomplished after the prototype test.

Notes:

1. This schedule assumes that Lower Granite will be provided with remedial construction prior to pool raising now scheduled in Spring 1975.

2 Status of this plan may be altered by results of tests using slotted bulkheads in the operating bays.

TABLE III

Nitrogen Problem Alleviation at Corps of Engineers Projects - Columbia and Snake River Systems

Project	Existing Condition	Powerhouse Capability	Skeleton Bay Capability	Average Annual Freshet Q/cfs	Max. Q that must be spilled (cfs) in average year	No. of Spillway Bays	Spillway Q in cfs/bay 5/
Lower Columbia River							
Bonneville	10 phse units	140 000 cfs	None at this time	500,000 cfs 6/ (360,000 cfs) 7/	360,000 cfs (220,000)	18	20,000 (12,200)
The Dalles	14 phse units plus 8 under constr	376,000 cfs 1/	None at this time	500,000 cfs 6/ (360,000 cfs) 7/	125,000 cfs (0)	23	5,400 (0)
John Day	16 phse units plus 4 semi-skeleton phse units	352,000 cfs 2/	See Note #3/	500,000 cfs 6/ (360,000 cfs) 7/	148,000 cfs (8,000)	20	7,400 (200)
McNary	14 phse units	230,000 cfs	None at this time	500,000 cfs 6/ (360,000 cfs) 7/	270,000 cfs (130,000)	~~20~~ 22	~~13,500~~ 12,300 ~~(6,500)~~ (5,900)
Lower Snake River							
Ice Harbor	3 phse units	45,000 cfs	64,000 cfs 4/	160,000 cfs 7/	51,000 cfs	10	5,100
Lower Monumental	3 phse units	66,000 cfs	64,000 cfs 4/	160,000 cfs 7/	30,000 cfs	8	3,700
Little Goose	3 phse units	66,000 cfs	64,000 cfs 4/	160,000 cfs 7/	30,000 cfs	8	3,700
Lower Granite	3 phse units	66,000 cfs	64,000 cfs 4/	160,000 cfs 7/	30,000 cfs	8	3,700
Mid-Columbia							
Chief Joseph	16 phse units	100,000 cfs	None at this time	300,000 cfs 6/ (210,000) 7/	200,000 cfs (110,000)	19	10,500 cfs (5,500)

Notes:

1. The additional 8 phse units at The Dalles are now under construction. Present plans indicate this capability will be available by spring 1974.
2. The 16th phse unit should be available fall 1971. (under construction at this time)
3. The last four skeleton bays at John Day not the same as Little Goose, etc. Concrete now in place in these units could possibly reduce the ultimate diversion capability to an extent we do not know at this time when compared to Little Goose.
4. The additional powerhouse or diversion capability in cfs assumes the same quantity flo as obtained at the skeleton bay operation (slotted bulkhead test) at Little Goose.
5. Assume uniform Q/spillway bay as an index of the nitrogen problem at the project.
6. Median peak of freshet with existing storage.
7. Median peak of freshet with Dworshak, Libby, Mica (1973 and later). Effect of this storage shown above in brackets ( ).

STATE OF MONTANA
DEPARTMENT OF FISH AND GAME
HELENA, MONTANA

Office Memorandum

TO : File

DATE: April 18, 1972

FROM : Art Whitney

SUBJECT: Report on out-of-state meeting - NITROGEN SUPERSATURATION

On April 11, 1972, I attended a meeting of a group called The Nitrogen Task Force in Portland. A copy of the agenda for this meeting is attached and my notes refer to these agenda items.

Item 1. Gordon Fernald is Chief of Engineering for the North Pacific Division, Corps of Engineers, thus the highest ranking civilian in the Division. He stated the Corps is deeply concerned with fishery problems, but would not want to spend a lot of money to solve this one fisheries problem and at the same time hurt some other interest. I interpreted his remarks to mean, if the only workable solutions this group could come up with would be extremely expensive and would be detrimental to power or navigation, then we better start teaching our fish how to live in supersaturated water.

Item 2. This was really a review of several previous meetings. This Task Force, which has been going on for well over a year, was originally set up to make recommendations for the timing of flows in the lower Columbia to give low dissolved nitrogen concentrations at points and at times when many fish were passing. Conversely, they would then try to do their spilling and cause the higher nitrogen concentrations at times when fish were not passing. The Governors of Idaho, Washington and Oregon got together at the fall Governors' meeting in 1971 and reoriented the Task Force to be more concerned with research into methods of reducing the problem rather than merely timing to try to avoid most of the runs. They also greatly increased the size of the Task Force.

Item 3. The Oregon Department of Environmental Quality in March of this year set a dissolved nitrogen standard of 105 percent of saturation maximum. The Washington Department of Ecology has been conducting hearings to receive comments on their proposed standard of 110 percent of saturation. The only opposition they have had to it has been from a group called the Tri-State Steelheaders who would rather see 105 percent set because they have information that 109 percent has caused mortalities at Dworshak. Their representative believed Washington would soon adopt the 110 percent of saturation standard. Idaho is not quite as far along at setting standards as the other two states but their representative believes they will also set 110 percent. EPA doesn't really care whether it is 105 or 110 but wishes all three states would set the same thing.

It seemed to be the consensus of most people in the Task Force that setting standards at this time is getting into a numbers game that will accomplish little.

They felt that until practical, effective methods for reducing dissolved nitrogen concentrations are developed, setting maximum allowable concentrations of dissolved nitrogen is about as practical as setting some maximum take limit on an open ocean fishery where most of the nations engaged in it are under no obligation to provide their catch statistics.

Item 4. EPA is setting up a standard data collection program for the Columbia. All cooperating agencies are reporting similarly arranged data on standard forms to EPA so that it can be rapidly entered in their storet system. Much of the discussion under Item 4 was on techniques of sampling and data analysis which meant little to me at that time. The following morning we had a seminar on the use of the gas saturometer at Oregon Fish Commission's Clackamas Lab. I'll get back to data collection techniques when I get into the report of that seminar.

Item 5. Project Modifications. By way of introduction to this section, remember that nitrogen supersaturation occurs when air is entrained with falling water and plunges deeply so that the increased pressure at depth drives a large portion of the air into solution, thus supersaturation occurs primarily at times of spills, either over the spillway or through permanent spilling sluiceways. It does not usually occur with water run through generators. Water run through the penstocks to generators does not entrain large volumes of air and it is usually expelled horizontally so it does not plunge deeply into the stilling basin. Thus, methods under test and examination to reduce supersaturation include modifications to the spillway to prevent the water-air mixture from plunging deeply when it hits, (the common term for this seems to be a "flip lip") and methods of design and operation to put more water through the penstocks. Apparently a number of dams on the Columbia have penstocks with no generators in them. You cannot simply turn water through these open tubes or it will tear the structures apart. They have developed something called slotted bulkheads which when put at the head end of the penstocks dissipate enough energy so that water can be run through them. Also, the capacity of generators in the Columbia is considerably greater than the power demand at times of the day and of the year. So far generators have only been turned on or off; there is no way of running them at a slower speed (that is, inefficiently) so they are producing less power when less power is needed. Obviously, when generators are shut off during periods of high runoff, the water has to go somewhere and it is usually run over the spillway.

Item 5-a. Lower Snake. At Little Goose and Lower Monumental Dams, the power units can pass 72,000 cfs. They have added 9 slotted bulkheads to penstocks which have no generators in them and those 9 slotted bulkheads can now pass 63,000 cfs. This gives them a total capacity of 135,000 cfs and there is no spill at the present time. At Ice Harbor, power units can handle 45,000 cfs. Nine slotted bulkheads have been added to penstocks with no generators for a capacity of 54,000 cfs, so Ice Harbor can pass 99,000 cfs. John McKern of the Walla Walla District Corps of Engineers added that slotted bulkheads work only at full gate opening. Anything less than this they vibrate and vibration in penstocks seems to be something that dam owners want to avoid. Thus, if the amount of water to be wasted is less than a full penstock flow, they still have to spill.

Item 5-b. One power unit at Little Goose was used for a test of "inefficient" operation of a power unit. I couldn't fully understand the engineering problems involved here, but apparently vibrations were set up which caused some 90-ton gate to drop when it shouldn't and it was obvious that the engineers engaged in this project felt further pursuit of this method of investigation would be extremely dangerous.

Item 5-c & d. Flip lips have been installed on several of the Bonneville and Lower Monumental spillways. This directs the water either back up in the air or more horizontal so it doesn't plunge deep into the stilling basin. At Bonneville nitrogen was 103 percent in the forebay just before it went over the dam. Without a deflector, saturation was 125 percent, with the deflector it was 112 percent. Apparently eight of these deflectors have been installed in Lower Monumental which is the last downstream dam on the Snake. They are good for only certain flows but that is pretty high; 20,000 cfs was the maximum tested but this gives a capacity of 160,000 cfs spill which along with 135,000 cfs, which can be run through the power units and the slotted bulkheads, means 295,000 cfs maximum flow can be run out of the Snake without increasing nitrogen saturation to lethal levels.

Item 5-e. Wes Ebel of the National Marine Fisheries Service reported on the effect of putting screens in front of the penstock gatewells to slow their velocity. Apparently these penstock gatewells have higher velocity than the transport tubes which they want the fish to go down. They shut penstock units down during periods of the day and then kept track of the number of fish going through the transport tube. Numbers of fish through the tube increased several hundred percent at times when one or more penstock units were shut down. The obvious question to this report was, "Doesn't the shutting down of the penstocks cause more spill and thus more nitrogen?" The answer was, " Yes, by a small amount, but getting the fish down safely seems to be more important."

Item 6. Research. Again Wes Ebel of NMFS reported. The following table summarizes his report.

% of Saturation	LD_{50}	Remarks
130	13 hrs.	Swimming ability of survivors badly impaired.
125	14.1 hrs.	
120	27.6 hrs.	
115	Not over 10% mortality in 30 days. Looked terrible. Eyeballs hanging out and lots of bubbles but fed normally and swimming ability not impaired.	
110	No change in appearance or swimming ability	
105		

These data are for spring chinook. Times to death for steelhead are almost the same.

John McKern stated they had found about 70 percent mortalities with concentrations of 120 to 135 percent in the river. He asked if the dams could hold it down to 115 percent in the same area should this reduce mortalities to 5 to 10 percent. Ebel felt 115 percent in the river should reduce mortalities to zero if these test data are valid. This is because fish in deeper water are less affected. Obviously, a fish at the same depth the water plunged when it became supersaturated would not be affected at all since it is not supersaturated for that depth and pressure. It is only when the water saturated at a depth rises and pressure is released that it is supersaturated.

Item 6-b. EPA is requesting funds for study on adults. (The previous data were for juveniles.) They expect to get their equipment by late summer and be set up to run next year.

Item 6-c. Rucker has found no mortalities of eggs and fry of fall chinook at 112 percent saturation. He has also found (for what reason I can't imagine) that he can induce gas bubble disease by holding either end of a fish in a supersaturated solution and letting the other end of the fish remain in the normal solution. At this point someone asked if carbon dioxide levels were important and Ebel reported that they could detect no change in carbon dioxide saturation by plunging water. He said it was actually less than saturation after the plunge.

Item 6-d. This was bypassed because nobody from the Washington Department of Fisheries was there.

Item 6-e. The Corps of Engineers may fund some other agency's studies. Apparently National Marine Fisheries Service already has a contract to prove to the Corps for bioassay work. Morris Larson reported that the Corps has a construction model of John Day Dam and is testing the relative merits of slotted bulkheads versus flip lips but they have come to no conclusion yet as to which is best. Personally, it would seem to me they ought to do both.

Item 7. Runoff volume and flow forecast sheets were passed out. I noted that no flow was estimated on the Kootenai and asked why. The answer was that they are uncertain of the effect of Libby Dam. I took this to mean they don't really know how much water they can run out of their permanent sluiceways until they try.

Item 8. Included a very confusing list of dams in decending order of importance in keeping at full load, but it was unclear to me how this was germane to the problem of reducing spills to reduce nitrogen saturation levels. Since the meeting was running behind time and adjustment of spills for runs of anadromous fish is not germane to our problem at Libby, I didn't ask.

The sum total of the discussion was that they can't really run the dams to save fish this year anyway because runoff is too great. Therefore, they decided to run the dams to give the best tests. An example of this was given as Dworshak just closed off last fall and this year in March the flow was three times the maximum flow of record. They also mentioned in this discussion that they were going to draw Hungry Horse Reservoir down 125 feet. This gives them flood control storage up there that they then don't have to hold down below. It allows them to spill water at Hungry Horse where they don't create nitrogen problems instead of some downstream dam where they do. Also, under Item 8, they asked me to give a report on our problems at Libby. Most of the people in the group seemed amazed at the magnitude of our problem at Libby with only 2,000 cfs being spilled. They apparently don't have trouble in the lower river until they get up into the hundreds of thousands of cfs being spilled. Idaho did, however, ask when they reviewed the Corps' Environmental Impact Statement on Libby whether they expected supersaturation problems at high flows and the Corps replied that they did not. Thus, we were not alone in not being able to predict this problem.

Item 9. Concerned plans for a low flow release at Bonneville on April 23, both to benefit upstream migrants as well as juveniles released from hatcheries. Major discussion was concerned with how long they could do this. If river flows are extremely high, as expected, they might not be able to hold over one or two days and the Corps wondered if this was of any value. They were told that with the juveniles being released from hatcheries, one or two days was much better than nothing because they might go all the way downstream in that time. However, they expected little benefit to the adults from one or two days of reducing nitrogen. It was somewhat humorous to see the reservoir regulation people from the Corps trying to consider all the pressures on them for different releases and levels. They have a lower limit in the reservoirs set by navigation, an upper limit set by goose nesting, releases set by power demands, and now they must do their best to reduce spills in order to cut down fish mortalities. It is obvious that it is not easy to play the role of God.

Another item of interest I picked up from one of the maps they were using has nothing to do with this meeting, but may well concern us in the future. On this map of the Columbia Drainage, dated June 1, 1969, were (in addition to the reservoirs already built) some "recommended for construction." These included Ninemile Prairie and the Blackfoot-Knowles on the Flathead and Long Meadows on the Yaak for Montana; Pennycliffs on the Middle Fork of the Clearwater, High Mountain Sheep, Asotin, and China Gardens on the Snake and Enaville on the Coeur d' Alene all for Idaho.

On the morning of April 12, I attended a seminar at the Oregon Fish Commission's Clackamas Lab on the operation of the gas saturometer. This instrument, recently devised by Dr. Ray Weiss of Scripps Institute, is far more simple in principal and operation than any previous method. It consists roughly of about 150 feet of dimethyl silicon rubber surgical tubing of extremely small diameter supported by being wrapped around the corners of a metal frame and connected by impermeable nylon tubing to a gauge which reads pressure in millimeters of mercury. With the permeable tubing immersed in the water to be tested and agitated slightly, gas pressure from the water transfers to the interior of the tube into the gauge. If the water is below saturation the gauge will register negative pressures; if its above they will be positive. If you also have an aneroid barometer you read that at the same time; if you don't you take the standard pressure for the elevation you are at, add your reading from the gauge on your instrument to the actual pressure and divide that figure by the actual pressure. This gives percent saturation of total dissolved gases. You then take a Winkler D.O. converted by a couple of formulae to partial pressure of oxygen, subtract that from your reading, look up in the tables from the handbook of chemistry and physics the pressure of water vapor for your temperature and altitude, subtract that from your reading, ignore carbon dioxide because that doesn't saturate, and your remainder is nitrogen and argon with argon being insignificant. That compared to your standard pressure, multiplied by the portion of the air that is nitrogen gives you percent saturation of nitrogen.

At this point in the discussion I asked if it was only nitrogen that caused the problems or if it was total dissolved gas. I was told that everything to date points to the fact that it is total dissolved gas that causes the problem. I then asked why go to all the effort to get nitrogen and the only reason I could get was that it was what everybody has always done. EPA is now asking for both total dissolved gases and nitrogen on their new reporting forms.

Enclosed is a copy of a report on the nitrogen supersaturation problem. The first two or three pages of the main body of the report (not of Fernald's introduction) give a good description of how the water gets supersaturated and what then happens to the fish.

AGENDA

NITROGEN TASK FORCE MEETING
Room 309 Custom House
Portland, Oregon
0900 Hours, 11 April 1972

1. Introduction (Fernald)

2. Review of Notes of 9 March Meeting

3. Dissolved Nitrogen Standards
   a. Oregon Department of Environmental Quality
   b. Washington Department of Ecology
   c. Idaho Department of Health
   d. Environmental Protection Agency

4. Data Collection Program
   a. EPA (Rulifson)
   b. NMFS (Ebel)
   c. CE (Boyer)
   d. BR (Bushnell)
   e. PUDs
   f. Others

5. Project Modifications
   a. Lower Snake Project Slotted Bulkheads (Larson)
   b. Little Goose Power Unit Test (Larson)
   c. Bonneville Spillway Deflector (Boyer)
   d. Lower Monumental Spillway Deflector (Boyer)
   e. Little Goose Special Fish Facilities and Studies (Ebel)

6. Research
   a. NMFS
   b. EPA
   c. BSF&W
   d. WDF
   e. CE
   f. Others

7. Runoff Volume and Peak Flow Forecasts (Larson)

8. System Power Generation
   a. Priorities of spill and powerplant loading (George)
   b. Power exports and related matters (Bissell)
   c. Status of major reservoirs (Larson)

9. Special Regulation for Low Flow at Bonneville Dam
   a. Target discharge and starting date (Larson)
   b. Tentative plan of reservoir regulation (Larson)
   c. Power considerations (Bissell, PUDs)

10. Other Business
11. Next Task Force Meeting

NPDEN-WC
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