Reprint
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CONFERENCE PROCEEDINGS

NITROGEN STUDIES MEETING
CORPS OF ENGINEERS WITH NORTHWEST FISHERY AGENCIES
AND ENVIRONMENTAL PROTECTION AGENCY

17 FEBRUARY 1971

Stenographer's Note: Due to the size of the group, as well as the room, it was difficult to hear and identify all speakers. Also, there was much discussion that was indistinguishable on the tape. My apologies for any errors either of commission, omission or identification of the speakers.

June W. Frostad
Secretary to Chief, Engineering Division, CE

ENGINEERING RESEARCH AND DEVELOPMENT
BY PETER B. BOYER
CHIEF, WATER QUALITY SECTION

INTRODUCTION

Previous speakers have informed you of our efforts to alleviate the nitrogen problem in the Columbia and Snake Rivers. The remedial measures reported on were:

a. Nitrogen supersaturation reduction through structural and regulation modifications and

b. Collecting and transporting a portion of the downstream migrating fingerlings which is essentially being done as a controlled experiment this year.

We would be overlooking an important long-range nitrogen control measure if we did not study the causes and effects of the problem in depth along with our structural and regulation studies. Mr. Rockwood and Mr. Hildebrand indicated that to serve all interests as equitably as possible, we must have a balanced reservoir operation. A regulation schedule based on runoff forecast and power demand alone is no longer entirely satisfactory in Columbia - Snake River reservoir system. A third factor, the dissolved nitrogen concentration and the duration of supersaturation levels must enter the regulation scheduling activity. We are doing this now by concentrating spills at dams where the nitrogen contribution is small. We hope to do better in 1972 when our nitrogen computer model becomes operational.

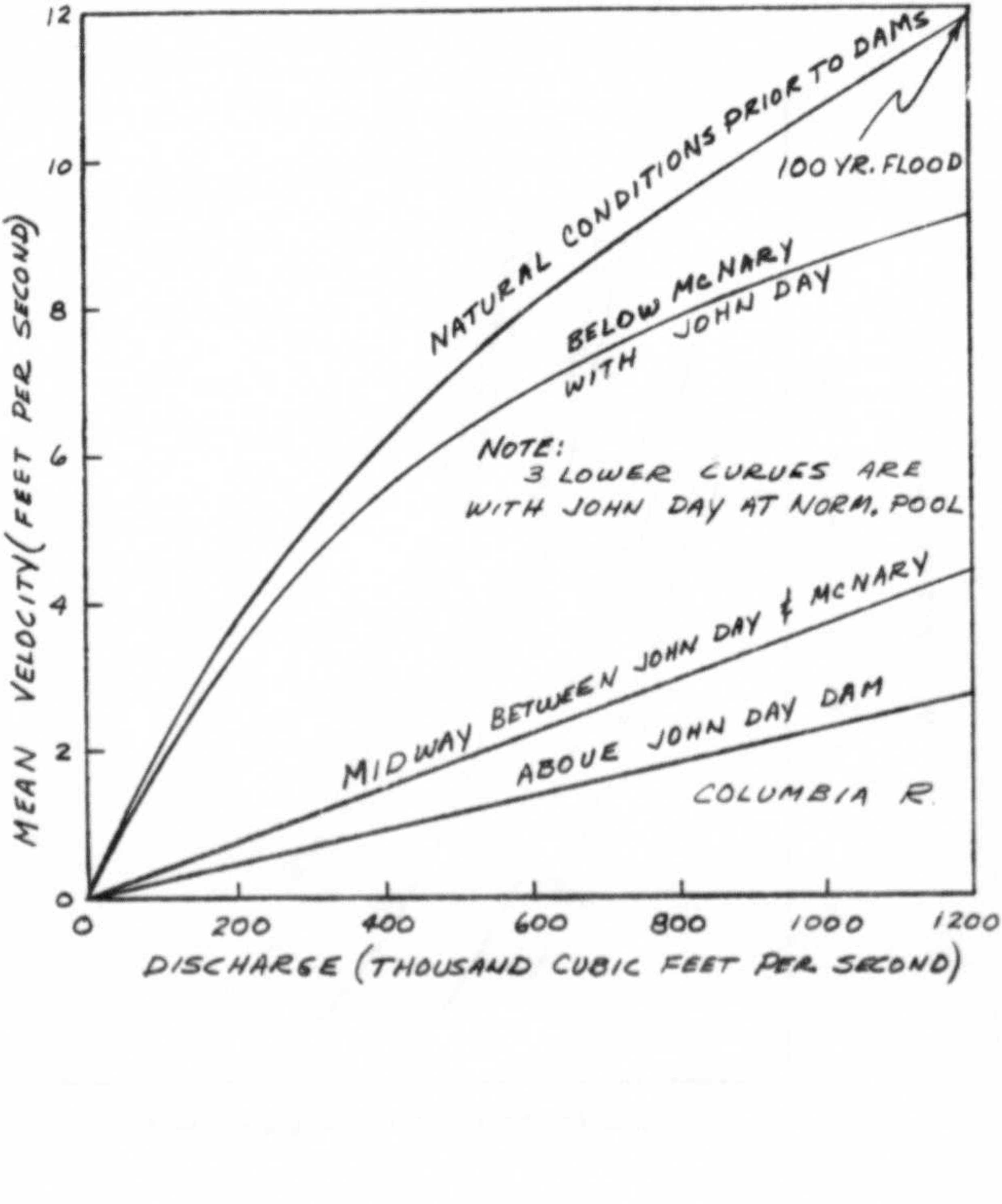
PROBLEM STATEMENT

Before reporting on our nitrogen-related engineering research activities let's state the problem. What do we know about nitrogen supersaturation? Why and under what conditions does it occur in Lower Columbia and Snake?

The gradual development of the Lower Columbia and Snake Rivers has culminated in a series of dams with slack waters between them. While this development produces many benefits, it has had unanticipated adverse effects on fish.

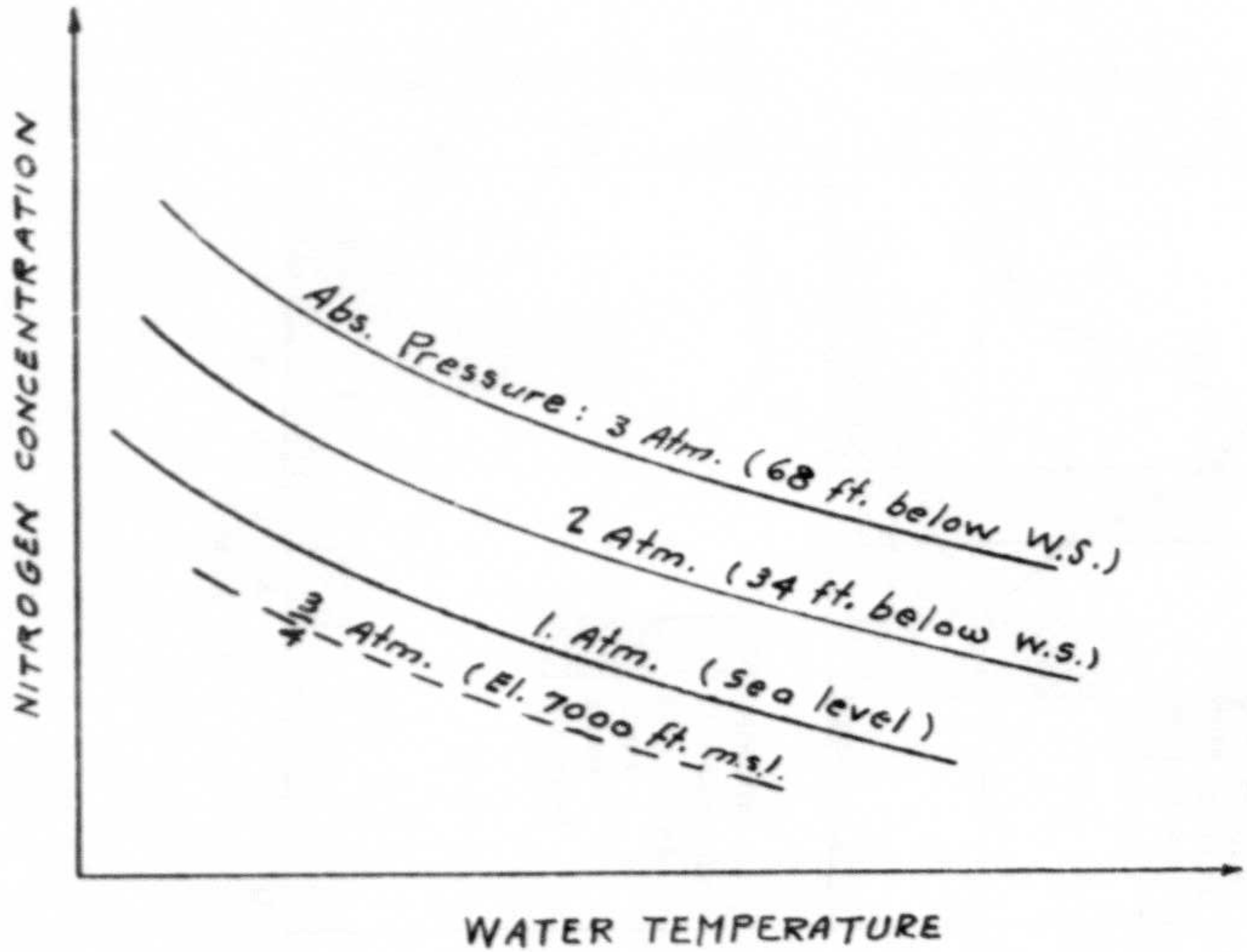
The modification of the river channel has produced hydraulic conditions conducive to trapping nitrogen at the dams and retaining it for a period longer than we had expected. We knew that air would be entrained; nitrogen and oxygen would go into solution in the stilling basin in concentrations in excess of the saturation values. But, no one suspected that the circulation in the modified channel would not be sufficient to purge a run-of-the-river reservoir of this excess nitrogen within a relatively short distance. I was completely surprised when I saw fishery agencies' reports, revealing persistence of nitrogen supersaturation even below Bonneville, in the 145-mile dam-free channel all the way to the Pacific Ocean.

The dissolution of gases is temperature and pressure dependent. See fig. 2. Under favorable conditions, high concentrations of dissolved nitrogen gas can and do occur at any project anywhere when its spillway must pass



NATURAL CONDITIONS PRIOR TO DAMS
100 YR. FLOOD
BELOW McNARY WITH JOHN DAY
NOTE:
3 LOWER CURVES ARE WITH JOHN DAY AT NORM. POOL
MIDWAY BETWEEN JOHN DAY & McNARY
ABOVE JOHN DAY DAM
COLUMBIA R.
MEAN VELOCITY (FEET PER SECOND)
DISCHARGE (THOUSAND CUBIC FEET PER SECOND)
0
2
4
6
8
10
12
0
200
400
600
800
1000
1200

FIGURE 1



N_2 SOLUBILITY

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FIGURE 2

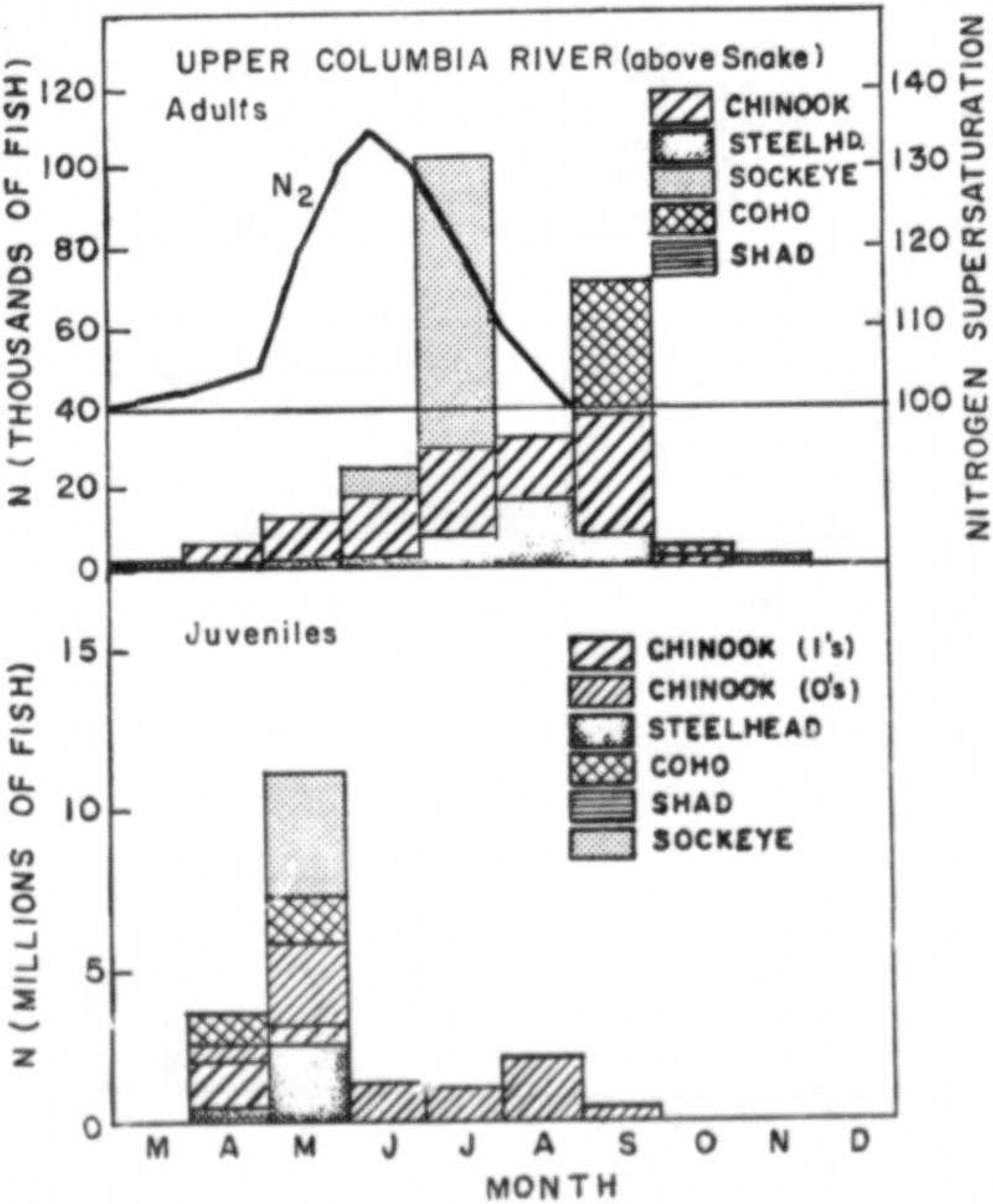

UPPER COLUMBIA RIVER (above Snake)
Adults
N₂
CHINOOK
STEELHD.
SOCKEYE
COHO
SHAD
N (THOUSANDS OF FISH)
NITROGEN SUPERSATURATION
Juveniles
CHINOOK (1's)
CHINOOK (0's)
STEELHEAD
COHO
SHAD
SOCKEYE
N (MILLIONS OF FISH)
M A M J J A S O N D
MONTH

FIGURE 3

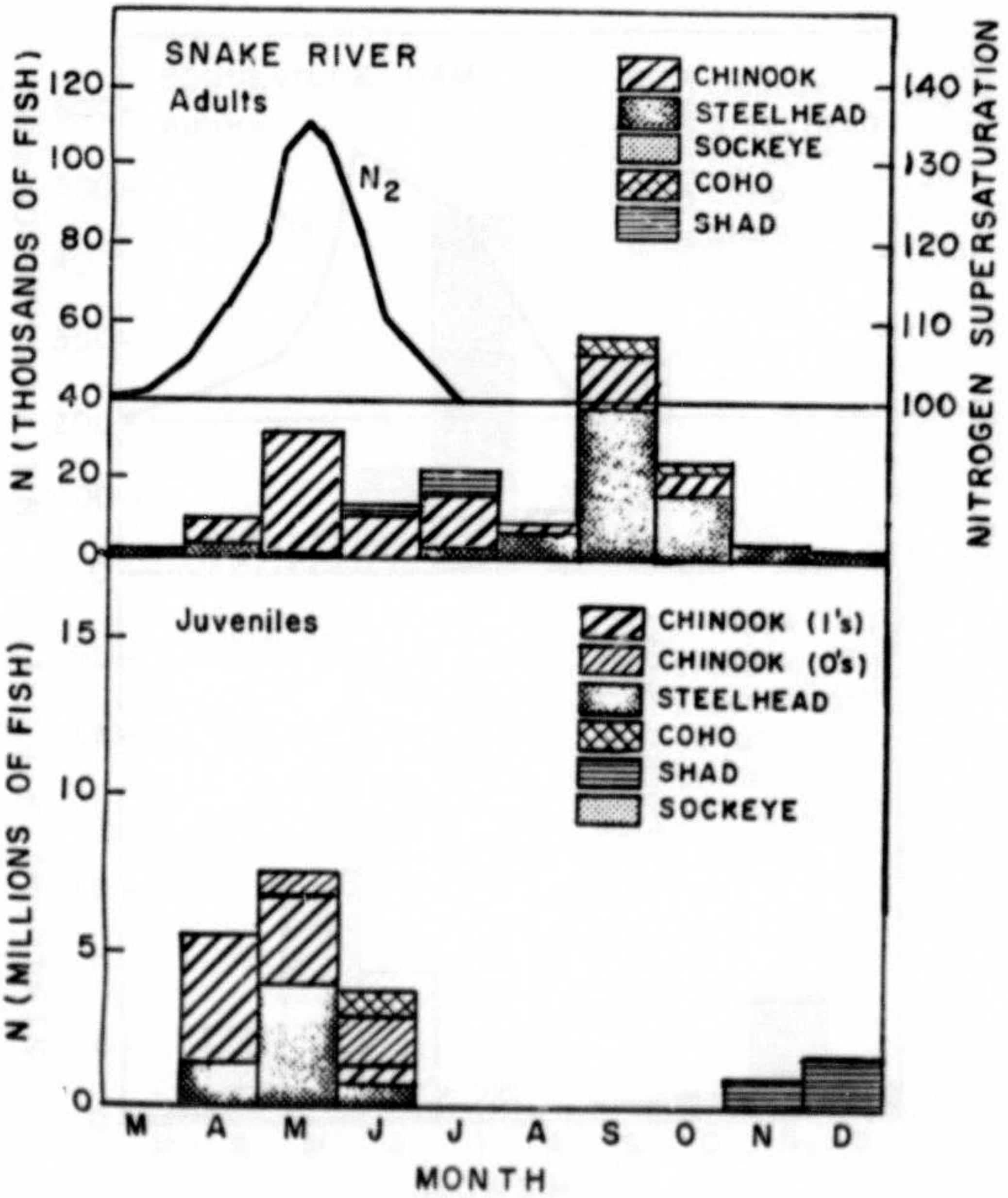
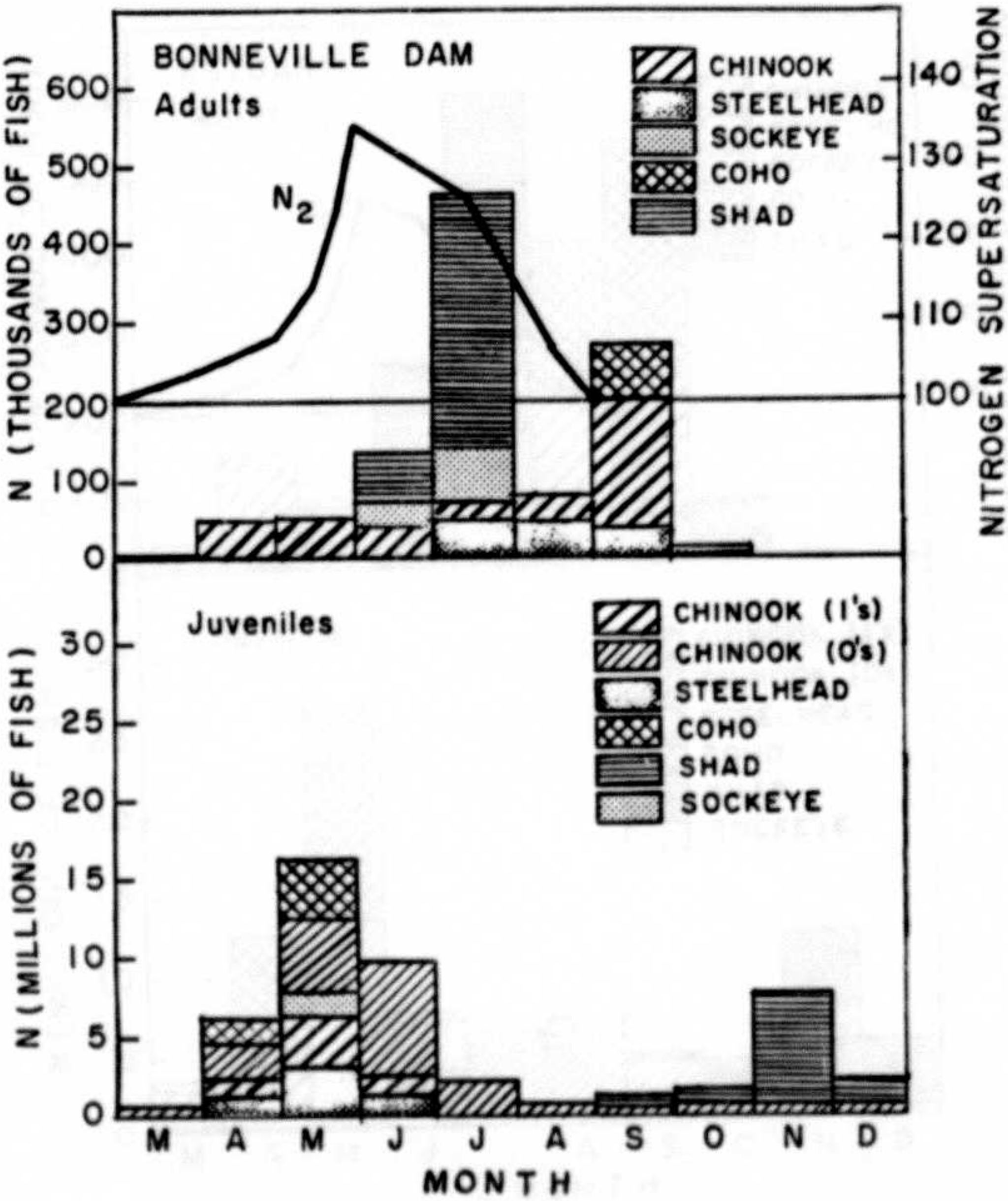

SNAKE RIVER
Adults
N (THOUSANDS OF FISH)
120
100
80
60
40
20
0
N_2
CHINOOK
STEELHEAD
SOCKEYE
COHO
SHAD
140
130
120
110
100
NITROGEN SUPERSATURATION
Juveniles
N (MILLIONS OF FISH)
15
10
5
0
CHINOOK (1's)
CHINOOK (0's)
STEELHEAD
COHO
SHAD
SOCKEYE
M
A
M
J
J
A
S
O
N
D
MONTH

FIGURE 4



BONNEVILLE DAM
Adults
N₂
CHINOOK
STEELHEAD
SOCKEYE
COHO
SHAD
N (THOUSANDS OF FISH)
NITROGEN SUPERSATURATION
600
500
400
300
200
100
0
140
130
120
110
100
Juveniles
CHINOOK (1's)
CHINOOK (0's)
STEELHEAD
COHO
SHAD
SOCKEYE
N (MILLIONS OF FISH)
30
25
20
15
10
5
0
M A M J J A S O N D
MONTH

FIGURE 5

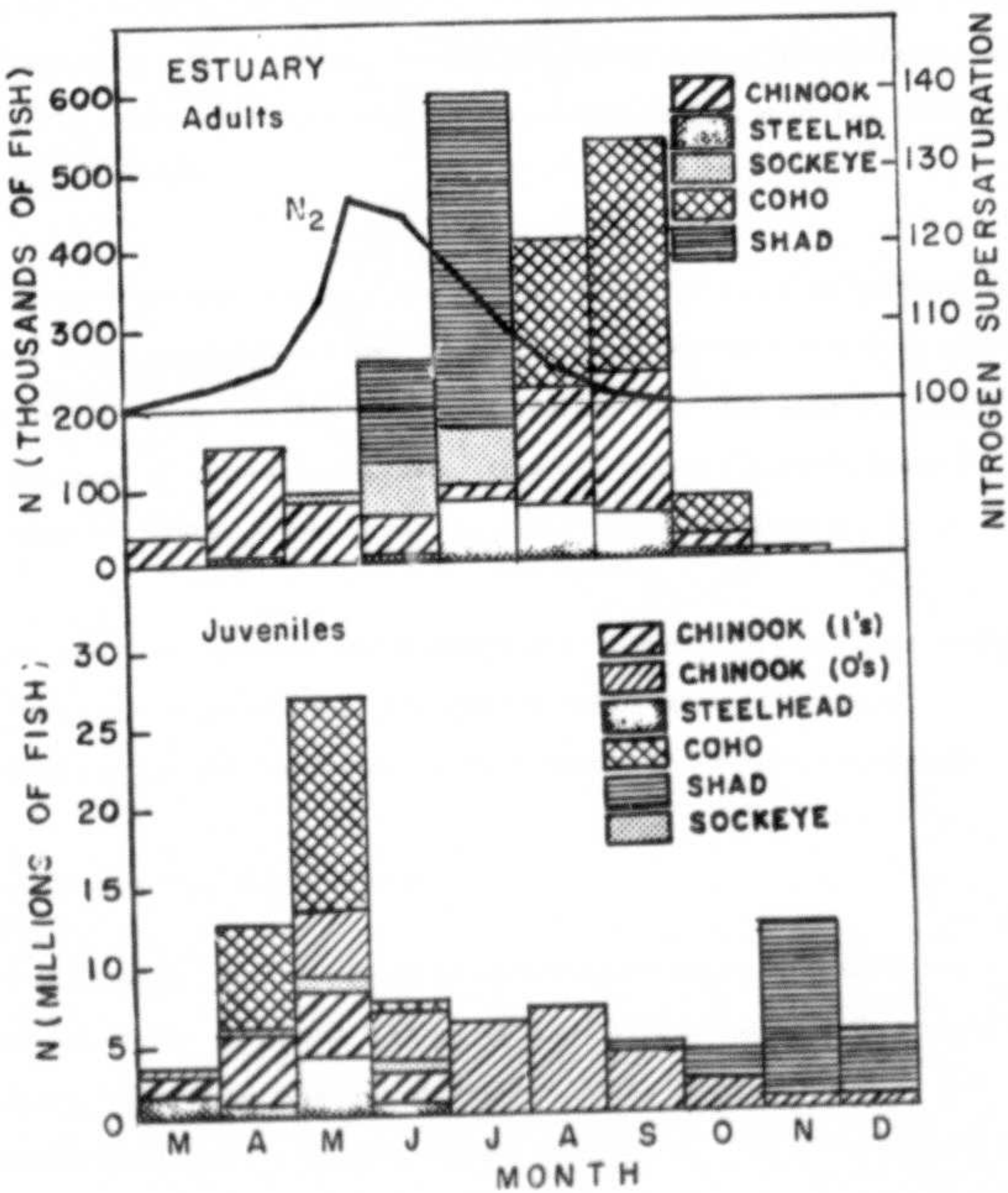

ESTUARY
Adults
N (THOUSANDS OF FISH)
NITROGEN SUPERSATURATION
CHINOOK
STEELHD.
SOCKEYE
COHO
SHAD
N_2
Juveniles
N (MILLIONS OF FISH)
CHINOOK (I's)
CHINOOK (O's)
STEELHEAD
COHO
SHAD
SOCKEYE
M A M J J A S O N D
MONTH

FIGURE 6

excess water and its stilling basin must dissipate the kinetic energy of that water quickly and efficiently. In Columbia and Snake, the nitrogen supersaturation is a problem, because the spills are of long-duration and the spill season coincides with the downstream migration of the figerlings. See figures 3-6.[1/]

So, we now know why, where, when, and how dissolved nitrogen supersaturation occurs and is sustained to some degree. Thanks to the information made available to us by the fishery scientists, we know, not only the levels and duration of nitrogen supersaturation at various points in Lower Columbia and Snake, but also the tolerance levels considered safe for fish.

It was not mere curiosity which prompted us to learn all this, we needed the knowledge to relate the nitrogen supersaturation to hydraulic characteristics and regulation of the Columbia River reservoir system.

RESEARCH OBJECTIVE & ACTIVITIES

We mentioned the need for advanced dissolved nitrogen information as a third factor for preparing a balanced regulation schedule. This need sets our engineering research objective. It is simply to predict the nitrogen profile under varying release conditions. The predetermined nitrogen levels are not only useful to the engineer preparing an advanced regulation schedule, but also to the engineer who designs the release facilities with an eye on the nitrogen potentials of his "creation".

[1/] Source: National Marine Fisheries Services, N.W. Region

Our research effort, therefore, is directed toward establishing cause-and-effect relationships between dissolved nitrogen and the associated parameters of physical and operational nature. Our ultimate aim is to develop design and operational criteria for nitrogen supersaturation control. To achieve this goal, we are engaged in the following activities:

a. Maintain close coordination and working relationship with the fishery agency nitrogen experts. This we have done to a satisfactory degree with the scientists from the National Marine Fisheries Service and the Oregon State Fish Commission. We have been consulting and conferring with them and exchanging ideas and information quite frequently. Our Walla Walla and Seattle Districts have been receiving aid from Washington and Idaho fishery biologists.

b. No researcher is satisfied with the available data. We are no exception. Our second important research activity is to conduct or support field surveys. We have no expertise in this area. We have been supporting NMFS and OFC in collecting dissolved nitrogen data for our research needs. We will continue this arrangement, subject to funding limitations. Our nitrogen monitoring programs this year include biweekly surveys in Lower Columbia and Snake, and special surveys for assessing dissolved nitrogen potentials at projects under construction. The Projects where these special surveys will be made and results applied are shown below:

Existing Projects where Surveys are Made	Projects under construction where Survey Results are Applied
Grand Coulee	Dworshak
Ice Harbor	Lower Granite
Cougar & Fall Creek	Lost Creek
John Day-Bonneville Reach 1/	N_2 Simulation Model

The principal reasons for collecting nitrogen data this year, as it was last year, are.

a. Documentation of the current nitrogen levels.

b. For use as guide in conducting nitrogen control studies by structural and regulation modifications.

c. For determining empirical entrainment coefficients, unique to each spillway-stilling basin.

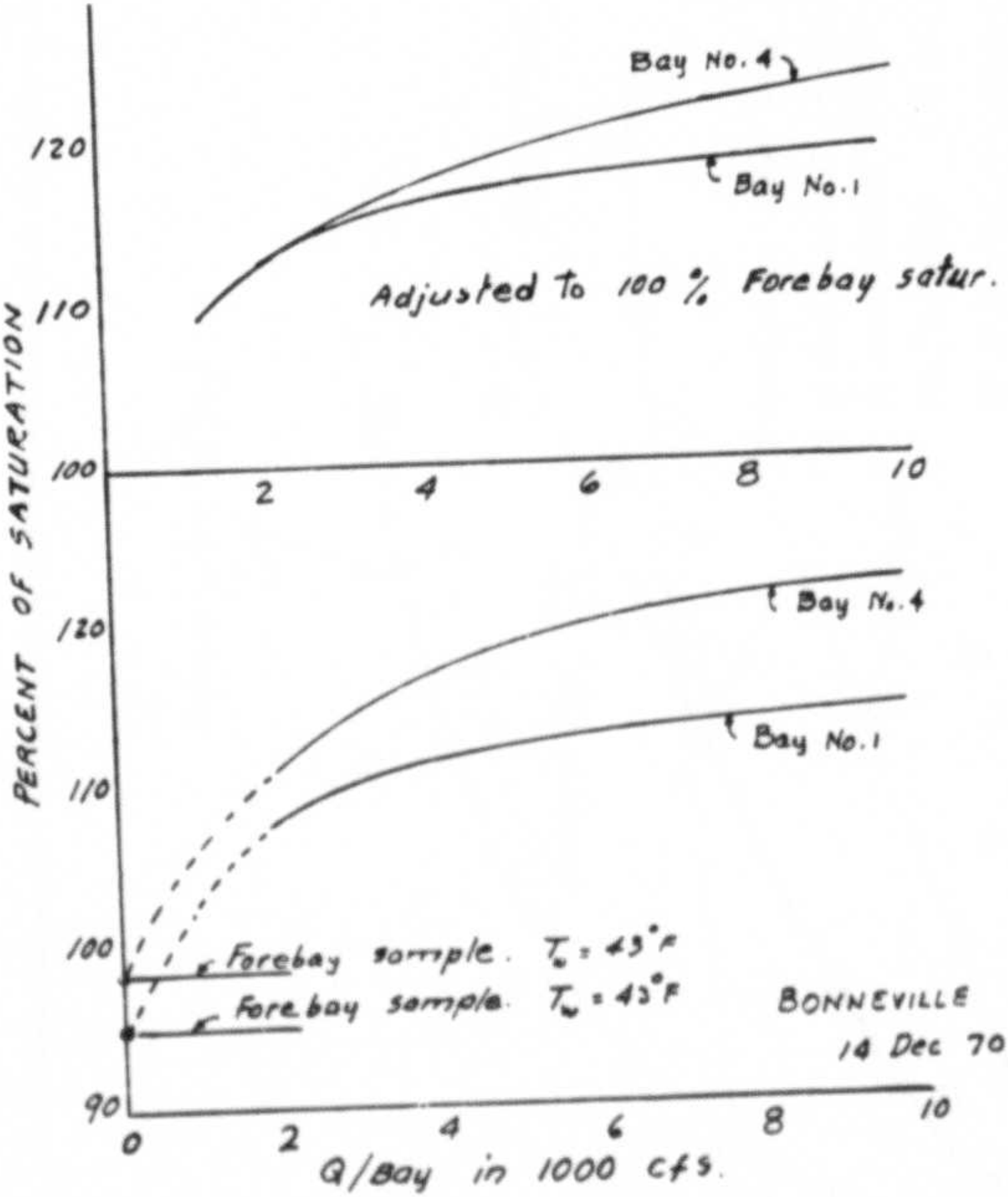
Instrument Development. The present method of sampling and testing river waters for nitrogen is cumbersome, slow, and expensive. We are examining the possibility of assemblying a portable unit which will automatically sample at specified intervals, analyze and record the results, and be relatively simple to operate and maintain. We have made inquiries and received proposals for the development of such a unit. A preliminary

1/ More extensive and intensive than others; designed to test the reliability of a recently completed nitrogen prediction computer program. Prospect of making this survey this year is not good.

cost estimate for developing the first unit, with accuracy acceptable to fishery scientists and chemists, is at $20,000 by Kramer, Chin and Mayo of Seattle and $35,000 by Stanford Research Institute. We also plan to consult the universities, EPA Laboratory in Corvallis, and fishery personnel who have expertise in instrumentation, sampling, and testing for dissolved nitrogen.

Another research activity we are conducting is the assembling of nitrogen and associated hydrologic and hydraulic data available in various offices. This is nearly complete. Nearing completion also is the entry of the field survey results on cards for computer processing in any desired tabular and/or chart form. As data are processed, they will be appraised for reliability and adequacy. Appraisal of data is also accomplished by simple graphical correlations of related factors or time variations of nitrogen supersaturation with spill as a parameter. See figures 7-9.

Since release facilities at a project play an important role in the entrainment of nitrogen, we are making sketches of powerhouse discharge facilities and the spillway-stilling basin configuration for each project, with auxiliary information, such as, the number of units, discharge capacity of each, normal elevations of the forebay pool and the stilling basin. All of these are factors affecting the magnitude of the supersaturation increment at each project when the spillway is operating.



Bay No. 4
120
Bay No. 1
Adjusted to 100 % Forebay satur.
110
PERCENT OF SATURATION
100
2
4
6
8
10
120
Bay No. 4
Bay No. 1
110
100
Forebay sample. T_w = 43°F
Forebay sample. T_w = 43°F
BONNEVILLE
14 Dec 70
90
0
2
4
6
8
10
Q/Bay in 1000 cfs.

FIGURE 7

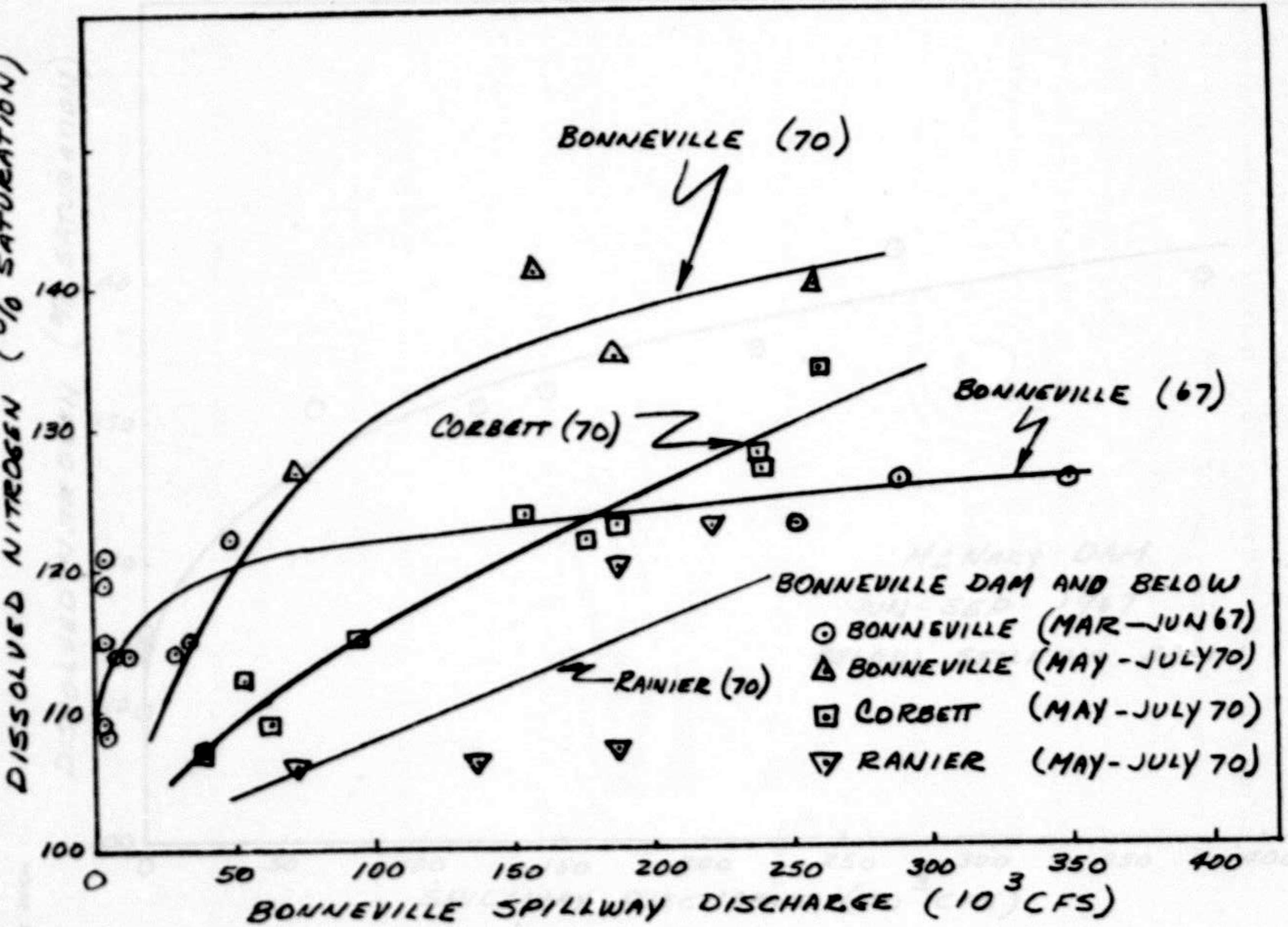

BONNEVILLE (70)
CORBETT (70)
BONNEVILLE (67)
RAINIER (70)
BONNEVILLE DAM AND BELOW
BONNEVILLE (MAR—JUN 67)
BONNEVILLE (MAY-JULY 70)
CORBETT (MAY-JULY 70)
RANIER (MAY-JULY 70)
DISSOLVED NITROGEN (% SATURATION)
100
110
120
130
140
0
50
100
150
200
250
300
350
400
BONNEVILLE SPILLWAY DISCHARGE (10³ CFS)

FIGURE 8

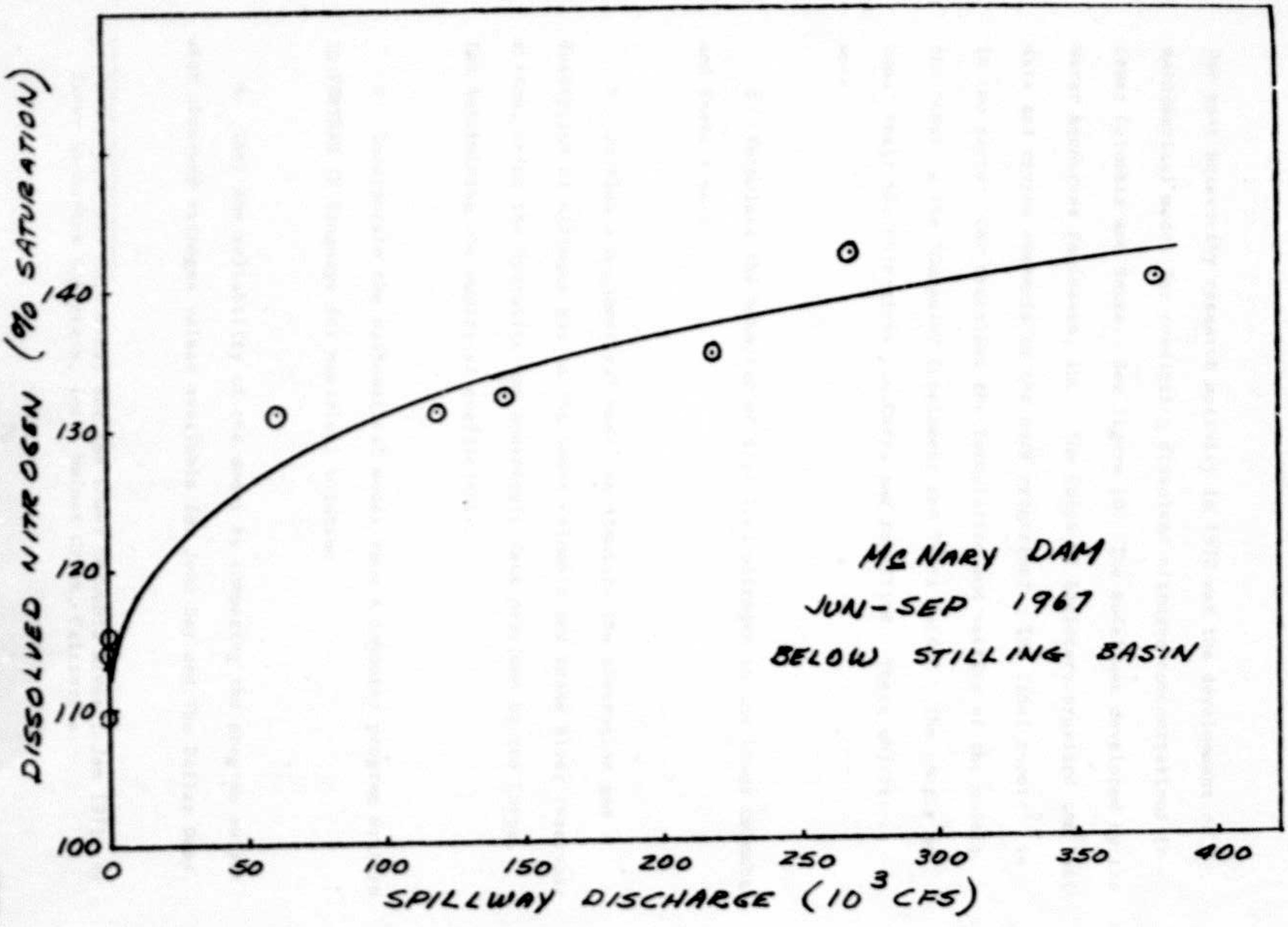

McNARY DAM
JUN-SEP 1967
BELOW STILLING BASIN
DISSOLVED NITROGEN (% SATURATION)
SPILLWAY DISCHARGE (10^3 CFS)
100
110
120
130
140
0
50
100
150
200
250
300
350
400

FIGURE 9

Our most noteworthy research activity in 1970 was the development of a mathematical model for predicting dissolved nitrogen concentrations in Lower Columbia and Snake. See figure 10. The model was developed by the Water Resources Engineers, Inc. The Corps of Engineers provided the basic data and review comments as the work progressed. The final report[2/] is in two parts: One describes the formulation and testing of the model; the other is the "Computer Supplement and Users Guide". The completed model meets the objectives the Corps had specified. These objectives were:

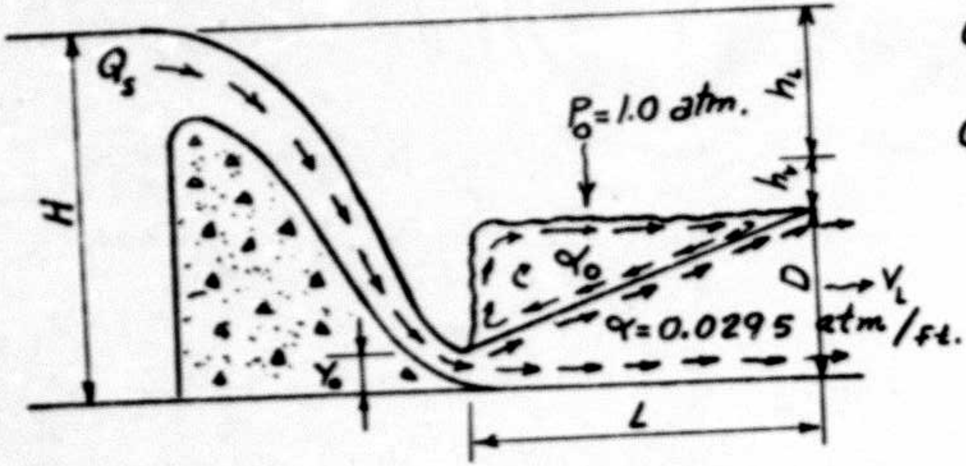
a. Formulate the behavior of dissolved nitrogen in the Lower Columbia and Snake Rivers.

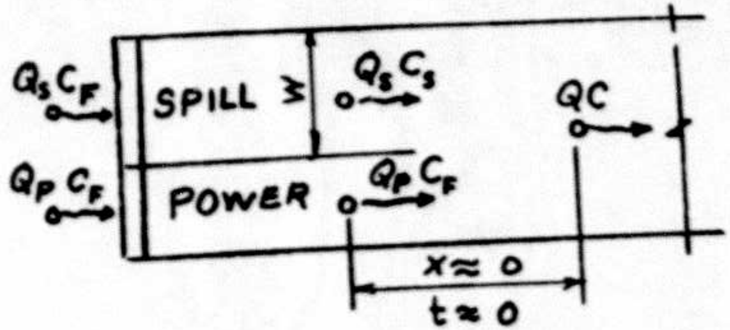
b. Develop a mathematical model to simulate the absorption and desorption of nitrogen gas in the Lower Columbia and Snake River reservoir system, using the hydraulic and hydrologic data provided by the Corps, for determining the empirical coefficients.

c. Incorporate the mathematical model into a computer program written in FORTRAN IV language for numerical solution.

d. Test the reliability of the model by comparing the program output with observed nitrogen values available for John Day and The Dalles Dams.

2/ "A Nitrogen Gas (N_2) Model for the Lower Columbia River", Jan 1971, by Water Resources Engineers, Inc., Walnut Creek, California.





$$Q_s C_s - Q_s C_F = Q_c - C_F (Q_s + Q_P)$$

$$C_s = \frac{Q}{Q_s}(C - C_F) + C_F$$

$$C = \frac{Q_s}{Q}(C - C_F) + C_F$$

RESIDENCE TIME: $t_R \approx WDL/Q_s \approx L/V_L$

ENERGY LOSS RATE: $E = h_L/t_R$

$$\bar{P} = P_0 + \frac{\alpha_0}{2}(D - Y_0) + \frac{\alpha}{4}(D + Y_0)$$

$$\overline{\Delta P}^{1/3} = \left[\bar{P} + \frac{\alpha}{4}(D + Y_0)\right]^{1/3} - \left[\bar{P} - \frac{\alpha}{4}(D + Y_0)\right]^{1/3}$$

$$C_s = \bar{P}C^* - (\bar{P}C^* - C_F)\, exp\left(-\frac{K}{q} L \overline{\Delta P}^{1/3}\right)$$

$$K = \frac{3}{\alpha}\left(\frac{6\sqrt{\pi}\, R}{28.9}\right)^{2/3}\left[T^{2/3} K_L M_A \int_0^1 n_b^{-1/3} dB\right]$$

$$= a E^b (1.028)^{(T-20)} = \text{ENTRAINMENT COEF.}$$

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N_2 MODEL

FIGURE 10