DETERMINING STREAM FLOWS FOR

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Prior to 1955 the administration of Oregon's water resources was seriously impaired by the authority vested in a large number of public agencies and single-purpose policies to regulate and control water use. This resulted in friction and duplication of activities and a resulting state of confusion as to what was primary and what was secondary beneficial use of the water. Most efforts made to control water for its maximum beneficial uses were foredoomed to failure.

The 1955 Oregon Legislature enacted a water code which significantly modified the administration of this resource. Foremost, the State Water Resources Board was established and directed to develop beneficial water use programs for the several drainage basins of the state. Pertinent sections of law relating to this code read as follows:

> The Board shall proceed as rapidly as possible to study... existing and contemplated needs and uses of water for domestic, municipal, irrigation, power development, industrial, mining, recreation, wildlife, and fishlife uses and for pollution abatement, all of which are declared to be beneficial uses...

and

> The maintenance of minimum perennial stream flows sufficient to support aquatic life and to minimize pollution shall be fostered and encouraged if existing rights and priorities under existing laws will permit.

It is this last section which made the stream flow requirement determinations necessary.

Our first approach to determining minimum stream flows for fish was by what we now label as the "Crystal Ball" technique. Without extra time, men, or money our area biologists accepted the chore—recommend the flow where minimum desirable fish populations and aquatic environment could be maintained during the low flow season.

It soon became obvious that this approach not only lacked continuity, but setting a single minimum flow for the entire year was folly. Even if the flow recommended were adequate in late summer, it would result in disaster during the late fall and spring spawning periods when water requirements of fish are substantially greater.

In 1961 the Oregon State Game Commission set out to determine by field study the specific stream flow requirements of fish life by season of the year. With an objective in mind and reasonable assurance that no one had developed methodology or even generalized "yardsticks" which could be used for our purpose, we launched a program that has taken us through the 18 drainage basins of Oregon, a half million dollars, and provided the state with recommended minimum and optimum flows by month in several hundred of its most important streams for game fish.

With this experience behind us, we can reflect on a variety of criteria and methodology and those which have been most useful.

Techniques for determining stream flow recommendations which we have tested might be classified into four basic categories: those which apply field measurements; techniques which employ a variety of conversion factors; techniques which involve field observation and the application of judgment: and those methods based on various formulas. For those who appreciate the jargon, they are more simply the "Gurley," the "Slide Rule," the "Eye-Ball," and the "Crystal Ball" techniques. I once overheard a biologist comment, "There are two fundamental differences in these techniques—those employed behind a desk are easy; those in the field are reliable." Undeniably, those requiring field examinations give the biologist first-hand knowledge of the relation between the discharge in a stream and the depth and velocity characteristics of that flow. In short, they give him results which he can more forcefully defend. On the other hand, a comprehensive minimum flow program based on conversion factors or various equations can be designed almost overnight and with very little expense.

These techniques, as we have used them, have two common denominators. Each is based on criteria which reflect flow depth and velocity requirements of fish and each technique expresses flow requirements in terms of one or more of four biological activities: passage, spawning, incubation, and rearing.

Even though we have had the opportunity to explore, test, and even inspire several methods for determining stream flow recommendations for fish life, certain techniques have demonstrated the best balance between cost and reliability.

With a favorable priority, adequate state and federal funding, and 10 years to accomplish our objective, we selected field measurement and observation techniques as those to rely upon most. I will attempt to summarize the criteria and methodology Oregon Game Commission have emphasized in their flow requirement surveys.

The following criteria and guidelines provide the basic tools for translating flow conditions required for the four basic activities of salmonids into the discharge needed to create those conditions (Figs. 1-3).

To determine the flow to recommend for passage in a given stream, the shallow bars most critical to passage of adult fish are located and a linear transect marked which follows the shallowest course from bank to bank. At each of several flows, the total width and longest continuous portion of the transect meeting minimum depth and maximum velocity criteria are measured (Fig. 4). For each transect, the flow is selected which meets the criteria on at least 25 percent of the total transect width and a continuous portion equaling at least 10 percent of its total width (Fig. 5). The results averaged from all transects is the minimum flow we have recommended for passage. I might caution that the relationship between flow conditions on the transect and the relative ability of fish to pass has not been evaluated.

Spawning flow recommendations can be formulated by a similar analysis. Three gravel bars are selected which represent the typical dimensions of those occurring in the study stream. On each gravel bar is marked a transect which coincides with the area where spawning is most likely to occur. At each of several flows, the total portion of the transect is measured where flow conditions meet depth and velocity criteria (Figs. 6-7). The mean relationship discharge has with gravel area usable for spawning is then assessed from all transect measurements (Fig. 8). An optimum spawning flow is that which provides suitable flow depth and velocity conditions over the most gravel. The discharge which created suitable flow conditions over 80 percent of the gravel available at an optimum spawning flow we have recommended for minimum spawning. This generally coincides with the flow most efficient for creating flow conditions suitable for spawning over the most gravel. In other words, the flow which makes available the most gravel per unit of flow. Not only does this explanation omit several essential ingredients of the procedure, but fails to mention observation techniques which normally are employed to reinforce the conclusions of the measurement technique. We are prepared to elaborate on these omissions during tomorrow's discussions. Once again, to our knowledge no one has attempted to evaluate the relation flow conditions have with spawning success for any species.

Because the relationship which surface flows have with the intra-gravel environment varies with each stream and realizing the time-consuming nature of determining these relationships, we have resorted to combining judgment

Fig. 1

SALMONID PASSAGE CRITERIA

Species	Minimum Depth	Maximum Velocity
Chinook	0.8'	8.0 fps
Coho, chum, steelhead, and large trout	0.6'	8.0 fps
Trout	0.4'	4.0 fps

Fig. 2

SALMONID SPAWNING CRITERIA

	ChF	ChS	Co	CS	St	Br	K	Other trout
Water Velocity (fps)	1.0 to 3.0	1.0 to 3.0	1.0 to 3.0	1.5 to 3.2	1.0 to 3.0	0.7 to 2.1	0.8 to 2.1	1.0 to 3.0
Water Depth (ft)	0.8	0.8	0.6	0.6	0.6	0.8	0.4 or 0.6	0.4 or 0.6
Sample	440	158	251	177	363	115	106	

Fig. 3

GUIDELINES FOR RECOMMENDING REARING FLOWS

1. Adequate depth over riffles

2. Riffle–pool ratio near 50:50

3. Approximately 60% of riffle area covered by flow

4. Riffle velocities 1.0 to 1.5 fps

5. Pool velocities 0.3 to 0.8 fps

6 Most stream cover available as shelter for fish

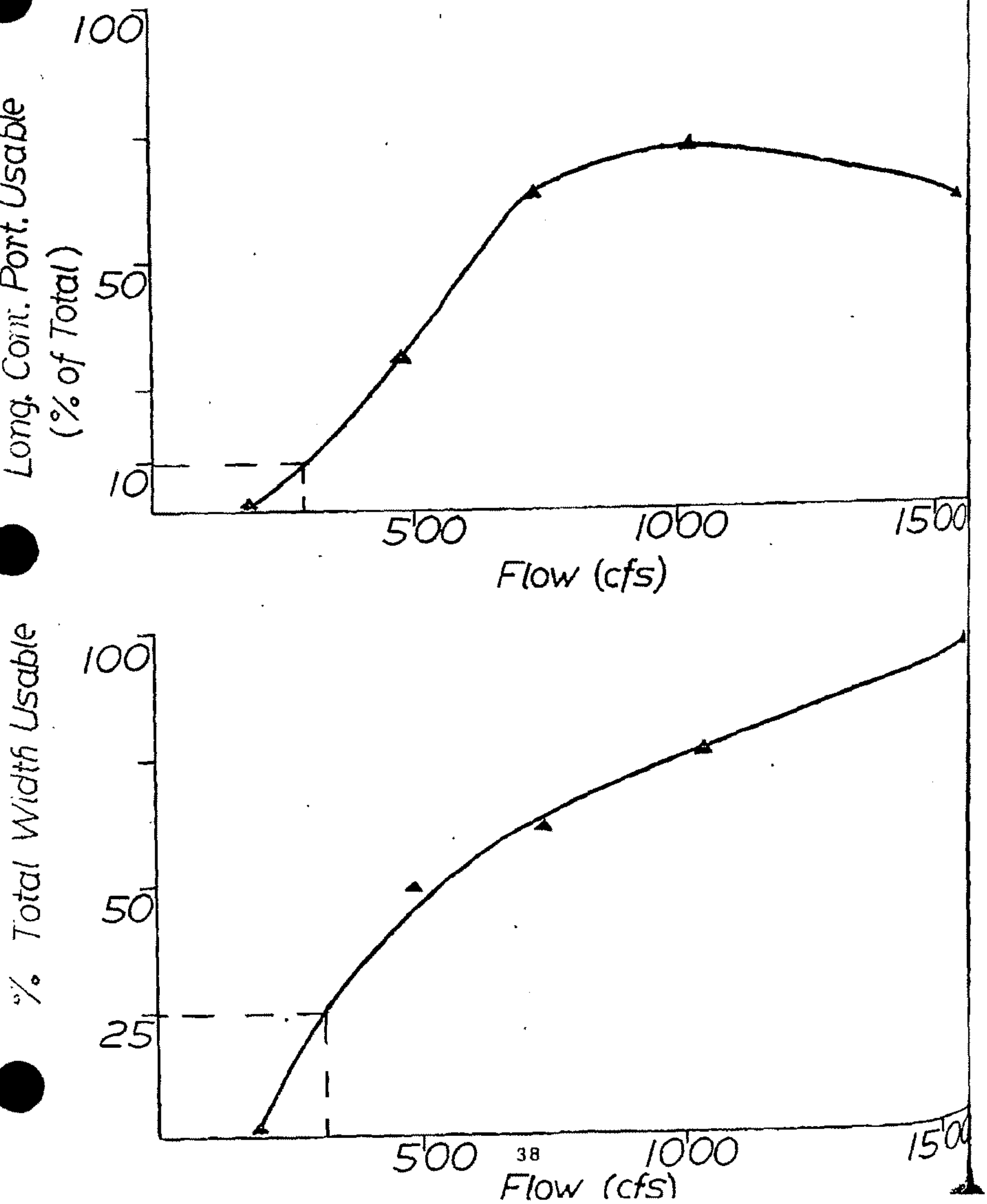
PASSAGE CROSS-SECTION DATA

6 Most stream cov available as shelter for fis

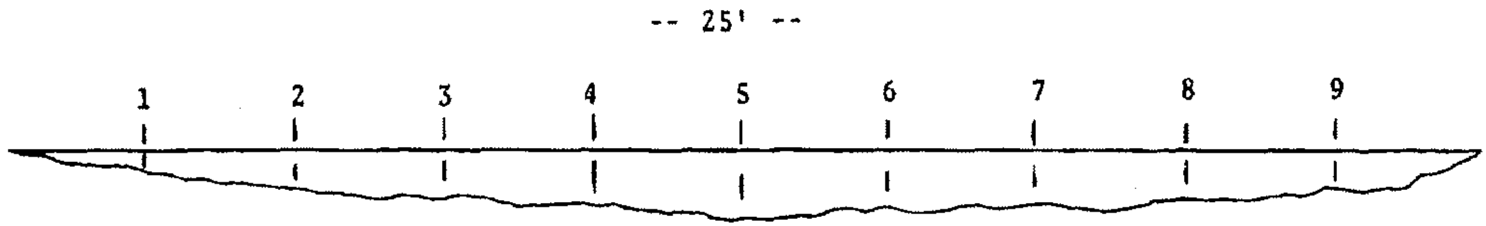
PASSAGE CROSS-SECTION DATA

Flow	Date	Total width	Width wetted	Width usable		Long. cont. port. usable %	
				feet	%		
190	9-24-71	1000'	460'	22	2	11'	1
1035	9-28-71	1000'	820'	754	75	722'	72
1570	9-29-71	1000'	1000'	950	95	620'	62
739	10-13-71	1000'	940'	627	62	627'	63
479	10-14-71	1000'	810'	490	49	304'	30

Fig. 5



Long. Cont. Port. Usable
(% of Total)
100
50
10
500
1000
1500
Flow (cfs)
% Total Width Usable
100
50
25
500
1000
1500
Flow (cfs)



SPAWNING BAR CROSS SECTION

Station	Depth (ft)	Velocity (frs)
1	0.4	1.4
2	0.6	1.6
3	0.7	1.9
4	0.9	2.3
5	1.1	3.1
6	1.0	2.6
7	0.8	2.0
8	0.7	1.4
9	0.6	0.9

<u>Spawning Flow Criteria</u>

Minimum depth - o.6'

Velocity - less than 3.0 but greater than 1.0 f.p.s.

<u>Flow=Width x m Depth x m Velocity</u>

Flow=25'=o.75=1.93 fps

=36 CFS

<u>Stream Width Usable for Spawning</u>

$$\text{Usable width} = \frac{\text{stream width}}{10} \times \#\ \text{usable stations}$$

$$= \frac{25'}{10} \times 6$$

$$= 15.0'$$

FLOW (cfs)	USABLE WIDTH (ft)
7	2
10	6
15	9
22	12
36	15
45	22.5
61	18

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Usable width cross-section measurements

Location	Date	X-section stations (lt. to rt. bank)										Total width	Mean depth	Mean vel.	Usable width	Flow (cfs)
			1	2	3	4	5	6	7	8	9					
		D														
		V														
		D														
		V														
		D														
		V														
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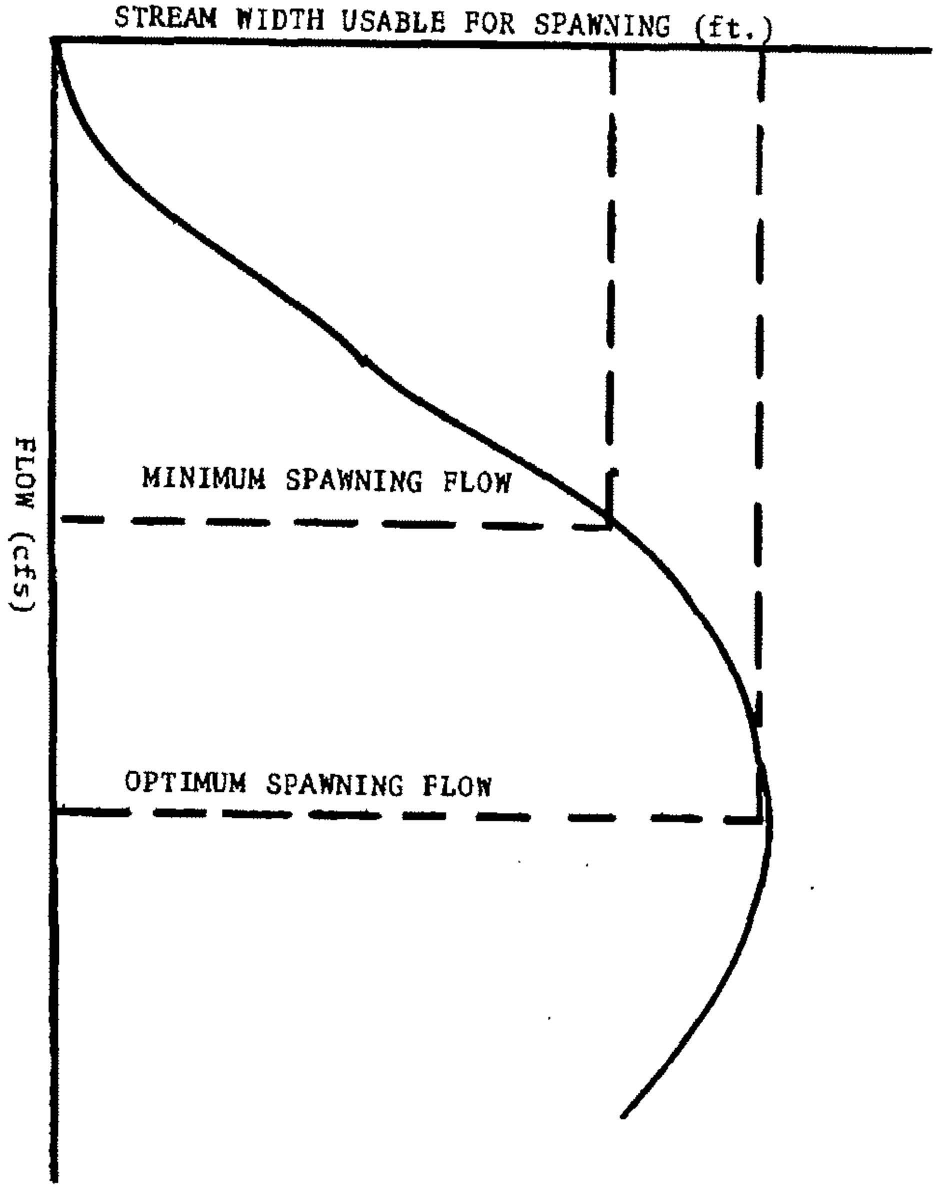
Stream Temperatures and Flows

Stream	Date	Time	Temp. °F. Water	Air	Flow Cfs	Location	Remarks


STREAM WIDTH USABLE FOR SPAWNING (ft.)
FLOW (cfs)
MINIMUM SPAWNING FLOW
OPTIMUM SPAWNING FLOW

with field observations to derive incubation flow recommendations. At each of several flows, an estimate is made of the flow required to cover gravel areas used for spawning and to create an intra-gravel environment conducive to successful egg incubation and fry emergence. The flow recommended is that which the various observed estimates seem to indicate. This generally is equivalent to about two-thirds the flow required for spawning.

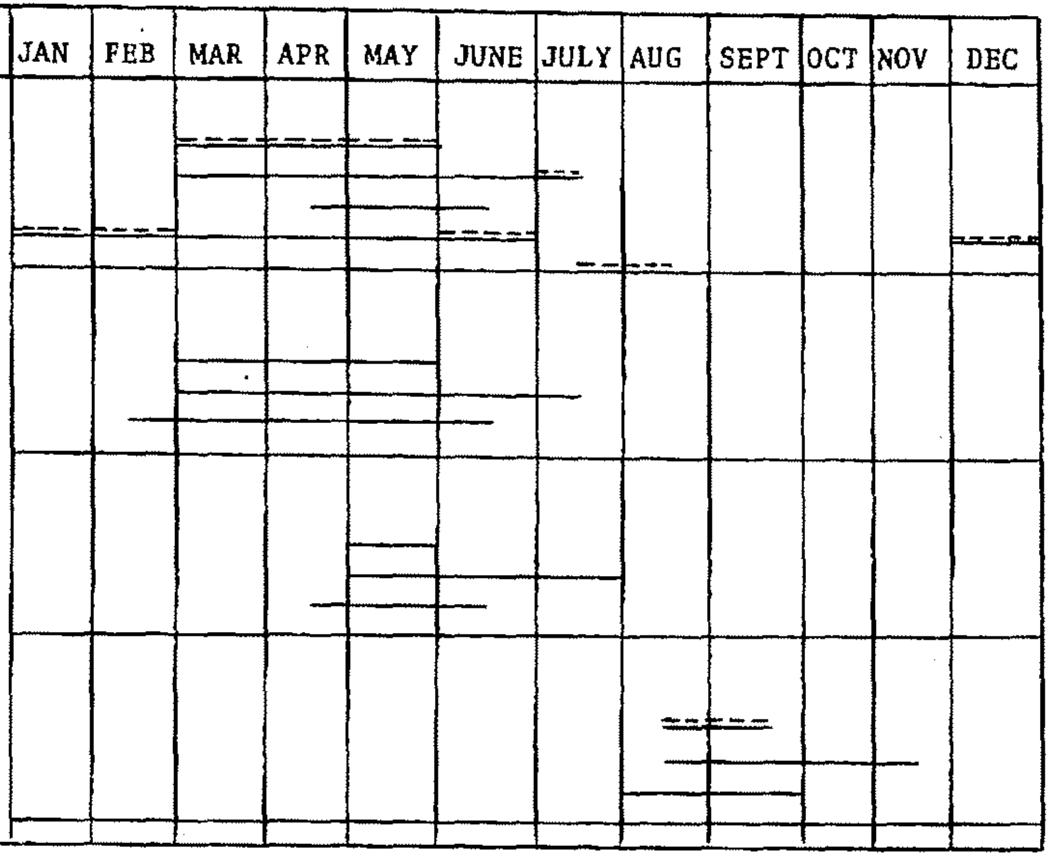
The period of the year when fish are not migrating, spawning, or when eggs or fry are not in the gravel, we have loosely defined as the rearing period. Because this period encompasses many activities whose relationships with stream flow are highly complex, we have, by necessity, rested on our laurels of good judgment to almost a dangerous degree. It is for this period that literature knows so much, yet so little about its relation with flow. It is for rearing that we know least about flow requirements and unfortunately the period in the life of a salmonid that probably is most critical to its survival. A combination of measurements, observations, and judgments have been employed to determine recommended rearing flows. At each of several different flows, an estimate is made of the flow required to create a suitable stream environment for rearing. These conditions are enumerated in Fig. 3 as a list of guidelines. The flow we would recommend for rearing, which generally is less than for any other biological activity, would be the flow which the various estimates seemed to indicate.

Perhaps because the issue of rearing is so hazy or maybe the intrigue of its vast interrelated ecological systems—whatever, rearing seems to be the focus of considerable research. We have spent a great deal of time during the past 3 years characterizing the environmental niches of stream rearing juvenile salmon and trout with the hope of a more reliable tool for recommending rearing flows. The Game Commission's research staff initiated an extensive literature search last fall as a prelude to a quarter million dollar study of stream flow—juvenile fish production relationships. By this summer, we expect to know whether such a study is actually feasible.

With a flow recommendation for each of the four biological activities for each important species in the study stream, the chore of determining the stream flow regimen required becomes relatively simple. A chart depicting the life history periodicities is prepared for each study stream or stream section (Fig. 9). The flows required for passage, spawning, incubation, and rearing for each species are assigned to their respective periods illustrated on the chart. The flow selected for any month or 2-week period is the highest flow required to accommodate any biological activity during that period. The highest flows required by month for 12 consecutive months is the regimen we have customarily selected. There are at least two inviolable ground rules which have evolved in our methodology. Regardless of how tempting and how realistic it might be, flow recommendations are based on the biological requirements of fish and are not adjusted for seasonally natural flow deficiencies. Second,

LIFE HISTORY PERIODICITY and MINIMUM FLOW
REGIMEN for EXISTING SALMONID POPULATIONS
in REYNOLDS CREEK, JOHN DAY BASIN

Species Life History Phase and Minimum Flow	
STEELHEAD	
Spawning	18 cfs
Incubation	12 cfs
Smolt Migration	12 cfs
Adult Migration	15 cfs
Rearing	5 cfs
RAINBOW	
Spawning	12 cfs
Incubation	5 cfs
Adult Migration	5 cfs
Rearing	5 cfs
CUTTHROAT	
Spawning	12 cfs
Incubation	5 cfs
Adult Migration	5 cfs
Rearing	5 cfs
DOLLY VARDEN	
Spawning	12 cfs
Incubation	5 cfs
Adult Migration	5 cfs
Rearing	5 cfs



Recommended Minimum Flow Regimen	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
	15	15	18	18	18	15	12/5	5/12	12/5	5	5	15

we do not recommend flows for relatively unimportant species if the flow would be harmfully excessive to an important species.

Much of our time has been devoted to writing reports which convey our recommendations and which lend perspective to fishery resource values. Even though the format has changed, they generally include the following: stream flow recommendations for fish life by stream and month; fish species distribution and abundance; a description of the biological requirements of salmonids; limiting factors to fish in the study area; fish resource values; stream flow and temperature measurements; and a variety of photographs.

With an efficient crew, at least 8 months, and about $100 per study stream, these field examination techniques could be employed almost anywhere to determine stream flows required for fish life.

With the $100, however, you have not purchased stream flow protection. Shelves are filled with reports of studies and recommendations to investigations to be studied. But, until the recommendations are made law, our objective has not been met nor stream flow protection for fish resources engendered. I believe we should endeavor to provide data whose quality is commensurate with the value of the resource at stake and, in a professional manner, promote its cause long after the report has collected dust on the shelf.

OPEN DISCUSSION
Paper No. 5

<u>Question:</u> How do you make flow recommendations when more than one species of fish are present?

<u>Answer:</u> Well, for instance, in some of the streams in the John Day system you may have a very important population of steelhead, rainbow, maybe some brook trout and a smattering of Dolly Varden. Perhaps the spawning period for the Dolly Varden, in this particular case a very minor population, where the flow required to provide the spawning might be excessive, we would not recommend the higher flow for the Dolly Varden. Based on numbers of fish in the stream and how important the species is to the sport or, in some cases, commercial fishery, however the fish resource is being utilized.

<u>Question:</u> Do you incorporate flows to enhance fishibility, or in other words, to allow for harvest?

<u>Answer:</u> Yes, we do. We've gotten in to this area and we've been pretty much pushed into it. It's an area I think we should address ourselves to, but we don't have much of a handle on it. The best we've done is to confer with our area biologists, ask them what level the rivers are when they get the best fishing and then we go to USGS records and interpolate the flow at that particular level as we have in the north coast and in other areas along the coast, recommending flows for angling. But insofar as implementation is concerned, I don't think our laws have any authority to consider flows for angling, so our main push is for minimum flows for fish life.

<u>Question:</u> Do you actually recommend a spawning flow and then recommend dropping the flow a third for the incubation end which takes less water?

<u>Answer:</u> Do we recommend dropping the flow after the spawning period? Yes, we do, from the standpoint that we can't justify asking for any more. According to the guidelines we have, we base the flows entirely on these parameters and we try to stay away from individual judgment the best we can, but we haven't anything in writing with which to justify recommending more than approximately the two-thirds level, but it isn't always the situation; it depends on the stream.

<u>Question:</u> You feel certain enough that you don't mind dropping it a third?

Answer: We've recommended it.

Question: In discussing maximum flows, is what you mean actually the maximum-minimum flow?

Answer: Right. In this case, where we're operating--where we're recommending minimum flows for fish life, that would be the maximum-minimum flow occurring during that period. We have recommended optimum flows which would be the maximum optimum flow.

Question: Does water temperature enter into the report?

Answer: We have found that temperature relationships with flow requirements are very complex and time-consuming to assess. Where we're operating with a three-man crew and covering the whole state, some times we plug in to very limited extent some subjective judgments, but we haven't had the time to go into a heat budget study, etc., and plug this thing.

Question: Is this methodology appropriate for large rivers?

Answer: I think the largest rivers we've dealt with would be the Willamette River's major tributaries or major coastal rivers--that's probably the largest. No, it is not really practical for rivers larger than that because their minimum flows do not get down to the point where the flow characteristics are within the limitations of our criteria. In other words, velocities over gravel at the minimum flow at many times in the larger rivers are many times over the 3 feet per second. Then you would have to extrapolate what flow is required and it would involve guesswork. In order to implement these measurement techniques, you have to have a stream where the flow can either be regulated or naturally falls within these parameters.

Question: Also, don't most of the salmonids try to move out of these bigger streams into the tributaries or do a lot of them try to spawn in the large streams?

Answer: We have some mainstem rivers where we get spawning, yes, but...

Question: Don't they tend to move into the tributaries?

Answer: I'm not real qualified to answer that, but from our limited experience this does occur in some situations.

Question: Since the Oregon law relates to determining flows for aquatic life, do you direct your work to any aquatic life other than fish life?

Answer: No, we don't. We've been real busy just trying to determine those for fish life. I think it's a good question. It might well be considered.

Question: Well, haven't you pretty well limited your studies to salmonids?

Answer: Yes. We've limited our studies to salmonids. We have no criteria for warm water species.

Question: You mentioned that your method is not to be applied to large rivers, but you have been involved in a literature review and can you, at this point in time, make any comment about what other methods or modifications of your methods might be suitable for use in large rivers?

Answer: No. The closest thing we have is a prediction method where we look at drainage area and mean annual precipitation and expand from the relationship we found between this and our previous recommended flows, we could make some wild guess as to what would be required with this formula we use. But it wouldn't really be a reliable indication of the biological requirements; in other words, creating the flow conditions for fish in the river. Keith spent about a day and a half with us here about 2 months ago, going over our method, and I think at that time we did caution you that working on these streams in Idaho with rather substantial minimum flows, that you're going to run into trouble and you're going to have to do quite a bit of extrapolating. Nevertheless, by getting out there in the stream and taking the measurements I think you'll have a better handle on what flow it's going to take to create the stream condition.

Question: Do you recommend flows at more than one place on a stream?

Answer: On small streams we make one recommendation at the mouth. On larger rivers we'll divide it into study sections, maybe have two, three or four different recommendation points up the river, to take into account this very thing.

Question: Do you include slope as part of your prime factors in determining the velocity?

Answer: We get out in the stream and measure what the actual velocities are at different flows, so we don't have to make adjustments for slope.

Question: How many cross sections do you make per recommendation? How many spawning transects would you make per study section?

Answer: For spawning, we just arbitrarily pick three cross sections per study section. We just don't have time to do more.