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DETERMINING STREAM FLOW FOR FISH LIFE

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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 section 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 baneful 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 measurements 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 overhead 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 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 dimension 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 most of the 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 most of the 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 (feet)	Maximum Velocity (feet/sec)
Chinook Salmon	0.8	8.0
Coho, chum salmon Steelhead Trout Large Trout	0.6	8.0
Trout	0.4	4.0

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. Approx. 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

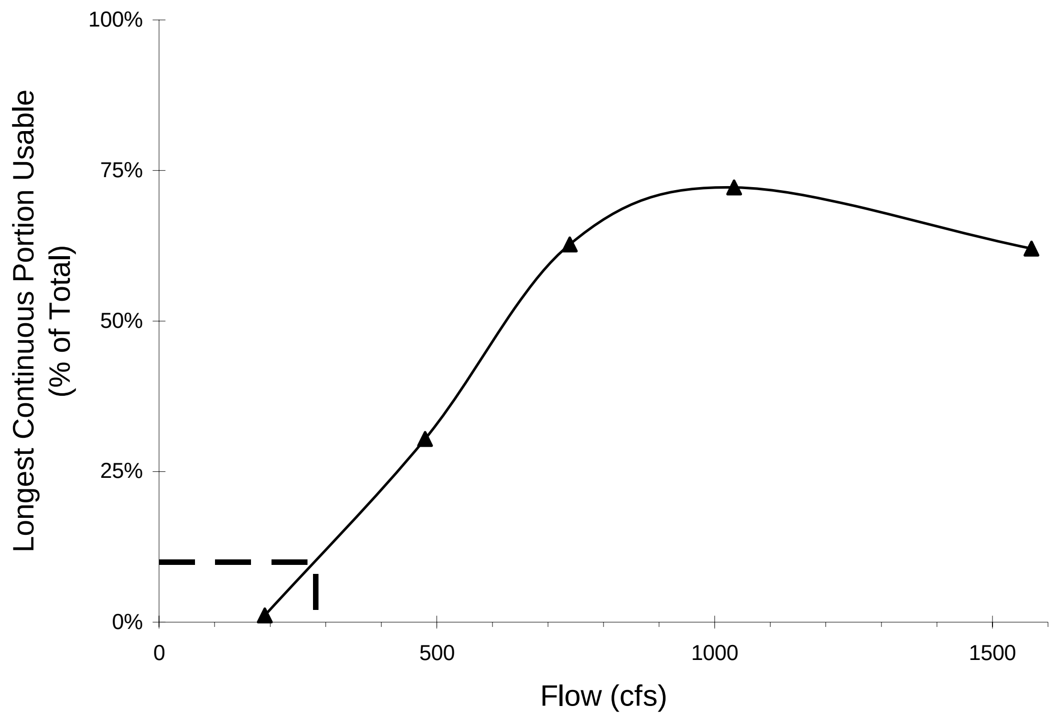
6. Most stream cover available as shelter for fish

Fig. 4

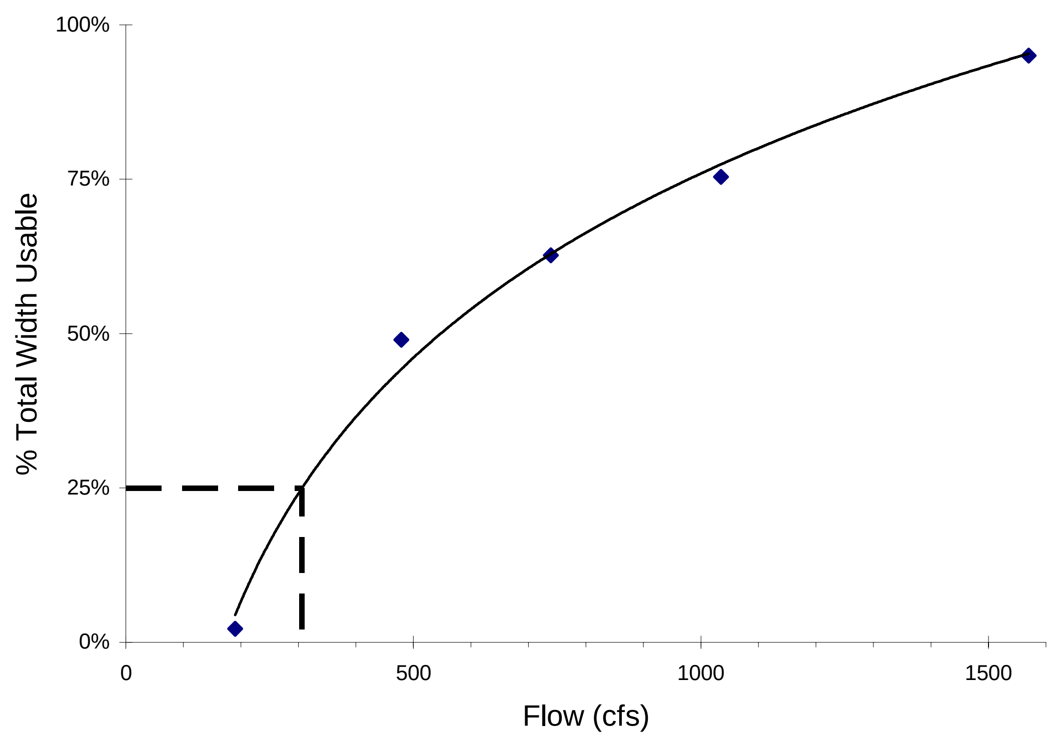
PASSAGE CROSS-SECTION DATA

Flow	Date	Total width	Width wetted	Width usable		Longest Continuous Portion 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

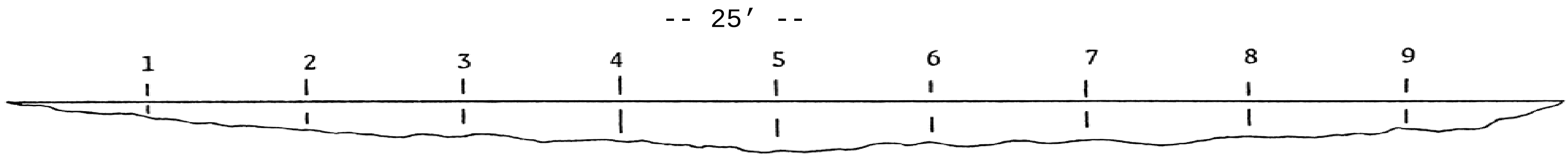


100%
75%
50%
25%
0%
Longest Continuous Portion Usable
(% of Total)
0
500
1000
1500
Flow (cfs)



100%
75%
50%
25%
0%
% Total Width Usable
0
500
1000
1500
Flow (cfs)

Fig. 6



SPAWNING BAR CROSS SECTION

Station	Depth (ft)	Velocity (fps)
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 - 0.6'

Velocity – less than 3.0 but greater Than 1.0 f.p.s.

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

Flow = 25' = 0.75 = 1.93 fps

= 36 CFS

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

Usable width = $\frac{\text{Stream width}}{10}$ x # usable stations

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

= 15.0'

Fig. 7

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

Fig. 8

OREGON STATE GAME COMMISSION
Usable width cross-section measurements

Stream Location	Date	X-section stations (lt to rt. Bank)										Total width	Mean depth	Mean velocity	Usable width	Flow (cfs)
			1	2	3	4	5	6	7	8	9					
		D														
		V														
		D														
		V														
		D														
		V														
		D														
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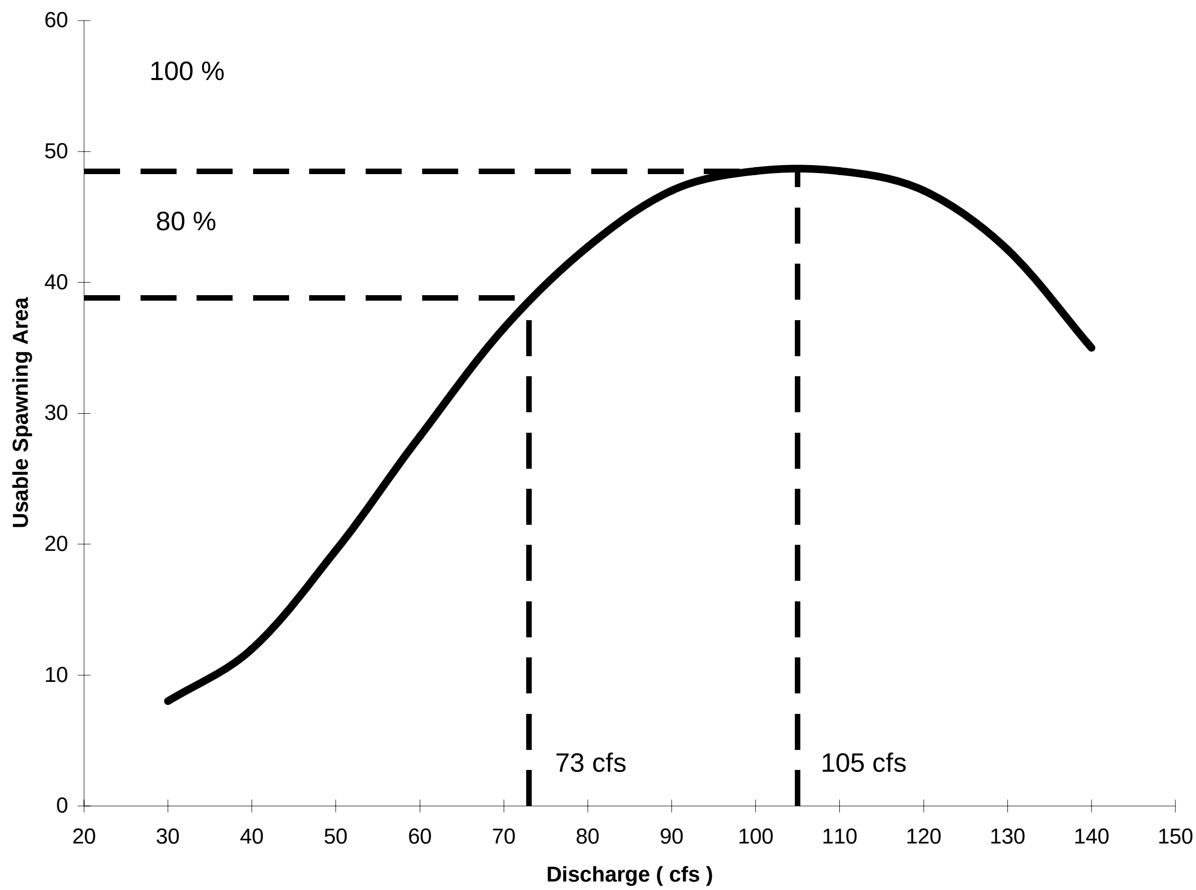
OREGON STATE GAME COMMISSION

Stream Temperatures and Flows

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



60
50
40
30
20
10
0
100 %
80 %
Usable Spawning Area
73 cfs
105 cfs
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Discharge (cfs)

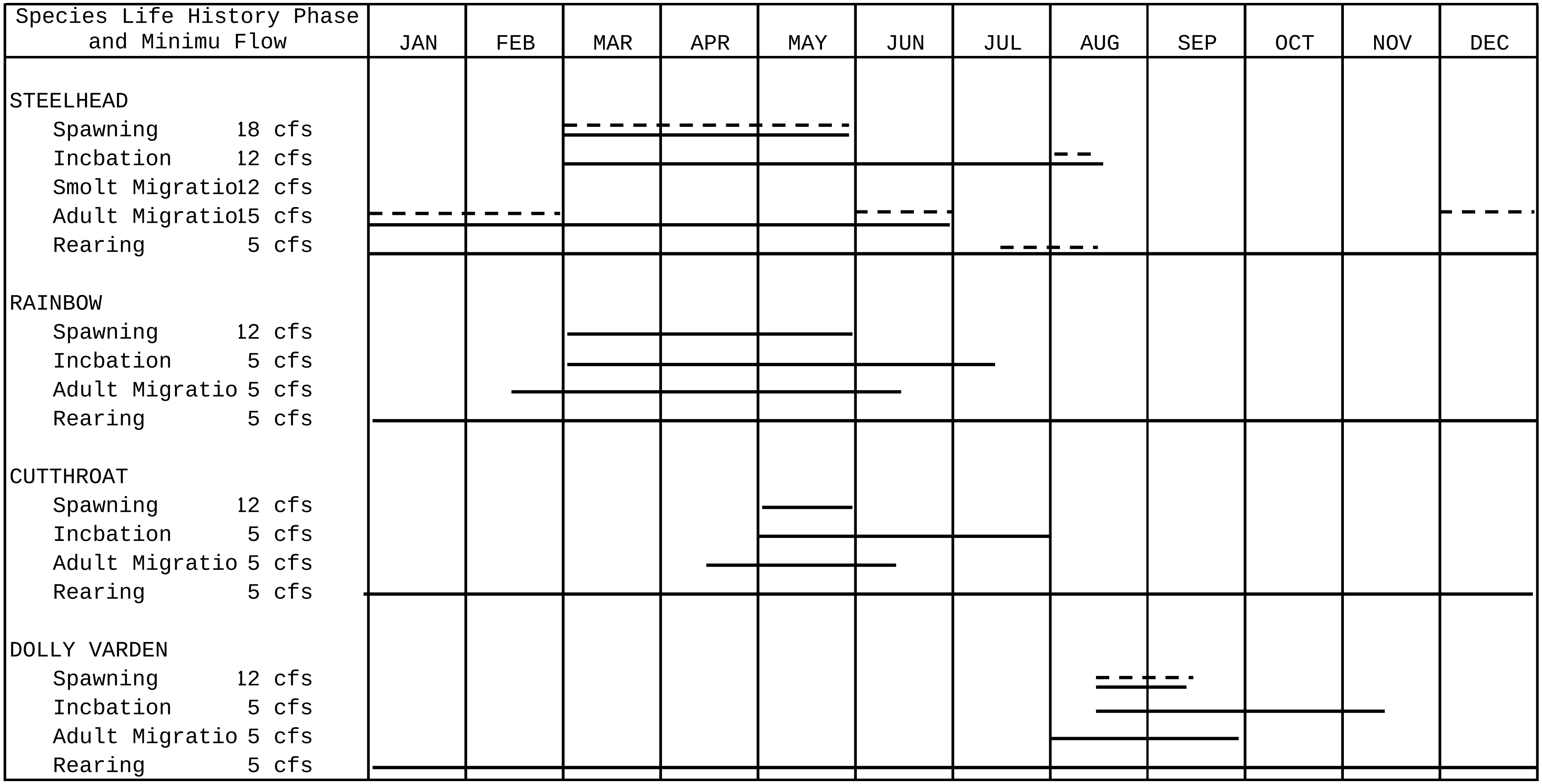
with field observations to derive incubation flow recommendations. At each of several flows, an estimate is made of the flow required to cover gravel areas used for spawning and to create an intra-gravel environment conducive to successful egg incubation and fry emergence. The flow recommended is that 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, as estimate is made of the flow required to create suitable stream environment for rearing. 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 flow deficiencies. Second,

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



Recommended Minimum Flow Regimen	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	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 a bout $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 resources 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

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

Answer: 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.

Question: Do you incorporated flow to enhance fishability, or in other words, to allow for harvest?

Answer: 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 go to USGS records and interpolate the flow at that particular level as we have in the north coast an 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 flow for angling, so our main push is for minimum flows for fish life.

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

Answer: Do we recommend dropping the water 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.

Question: 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 river?

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 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 larger streams?

Answer: We have some mainstem rivers where we get spawning, wes, 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 forms other than fish?

<u>Answer:</u> 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.

<u>Question:</u> Well, haven’t you pretty well limited your studies to salmonids?

<u>Answer:</u> Yes. We’ve limited our studies to salmonids. We have no criteria for warm water species.

<u>Question:</u> You mentioned that your method is not to be applied to large rivers, but you have been involved in a literature review and you can, 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?

<u>Answer:</u> No. The closest thing we have is a prediction method where we look at drainage area and the 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.

<u>Question:</u> Do you recommend flows at more than one place in a stream?

<u>Answer:</u> 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.

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

<u>Answer:</u> 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.

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

<u>Answer:</u> For spawning we just arbitrarily pick three cross sections per study section. We just don’t have time to do more.

DETERMINING STREAMFLOWS FOR FISH LIFE
Environmental Management Section
Oregon State Game Commission
March 15-16-1972

B. Planning
1. Set study goals and objectives (broad)
2. Recognize financing and deadlines
3. Select types of flow recommendations needed
   a. Biological requirements of fish life (minimum or optimum)
   b. Others (minimum or optimum)
      (1) Wildlife water requirements
      (2) Angling considerations (bank and boat)
      (3) Recreational boating
      (4) Esthetics
      (5) Water quality
4. Determine existing flow protection and recommendations
5. Gather basic study data
   a. Obtain maps showing stream systems and access
   b. Obtain USGS stream discharge annuals, rating tables and telephone gages
   c. Interview local biologists
      (1) Formulate stream priority list by considering
         (a) Importance for fish production
         (b) Recreational use and potential
         (c) Potential for water developments
         (d) Access
      (2) Determine road access and routes
      (3) Inventory, abundance and distribution of fish and wildlife resources
      (4) Identify limiting factors
      (5) Determine fish life-history periodicities by species and stream or stream system
6. Determine appropriate study procedures
7. Determine number of stream or points of recommendation that time and financial limitations will permit
   a. 60-80 points of recommendation per man
      (1) If crew station close to study area
      (2) Prolonged work schedule
      (3) Limited travel between study stations
   b. 40-60 points of recommendation
      (1) Commuting to survey
      (2) Short work season
      (3) Considerable travel between study stations

8. Obtain equipment
9. Determine miscellaneous study activities
a. Photographs
b. Temperature studies
   c. Water quality analysis
   d. Others
10. Appointing assisting personnel
11. Chart stream run-off patterns to predict activity schedule
12. Assign appropriate criteria to individual stream and stream reaches

C. Equipment
1. Current meter (Gurley #622)
2. Steel tape
3. Tape recorder (Norelco)
4. Camera
5. Thermometers (Normal and max.-min.)
6. Data tabulation forms
   a. Flow-temperature-remarks
   b. Cross-section
7. Maps
   a. SWRB (Oregon)
   b. U.S. Forest Service
   c. Bureau of Land Management
   d. U.S. Geological Survey
8. Gage records (USGS)
9. Calculator
10. Direct reading Gurley meter
11. Recording thermometers

D. Stream flow measurement procedures
1. Site selection
   a. Flow characteristics
      (1) Uniform depth (05.-20')
      (2) Uniform velocity (0.5-3.5 fps)
      (3) Pool tail-riffle head area generally best
2. Procedure--where precision is required
   a. Measurement units (cubic feet per second)
      (1) Width (ft.)
      (2) Depth (ft.)
      (3) Velocity (ft/sec.)
   b. Width measurement
      (1) Tag line
      (2) Edge of current to edge of current
      (3) Perpendicular to flow or angular compensations
   c. Depth measurements

(1) Taken along the imaginary transect of the width measurement
(2) At least ten measurements each to represent no more than 10 percent of the total flow
(3) Measured in feet and tenths of feet to simplify computations

d. Velocity measurements
(1) Taken along transect established by width measurement
(2) Measurement taken at points along transect to represent mean velocity in each section created by depth measurements
(3) Velocities taken at 0.2 and 0.8 of total depth if total depth is over 1.5 feet. Velocities measured at 0.6 of the total depth from the flow surface if total depth is 05.-1.5 feet. Velocities measured at 0.5 of total depth if total depth is less than 0.5 feet.

3. OSGC Procedure (+ or - 10 percent error)
a. Independent of flow requirement cross-sections
(1) Site selection as described above (D,1)
(2) Width measurement perpendicular to flow
(3) Transect not segmented for depth and velocity measurements
(4) Number of depth and velocity measurements variable, depending on stream size
(5) Depth measurements evenly spaced
(6) Velocity measurements spaced along transect to represent equal parts of total flow
(7) Velocity measured at 0.6 of the total depth from the flow surface

b. Discharge measured on cross-sections used to determine flow requirements of fish
(1) Site normally similar to ideal flow measurement site
(2) Only cross-sections perpendicular to flow are used as flow measurement sites
(3) Nine evenly spaced depth measurements are averaged
(4) Variable number of velocities measured, depending on stream size; but measurement points coincide with cross-section points
(5) Discharge = product of width X mean depth X mean velocity

E. Criteria
1. Purposes
a. Determine stream discharge required to create flow characteristics needed for various biological activities of fish life
b. Lend continuity to recommended stream flow regime

   c. Enhance the justification for flows recommended
2. Adult passage criteria (OSGC)
3. Spawning criteria (OSGC)
4. Incubation criteria
   a. 0.8 mg/l intragravel dissolved oxygen before hatching
   b. 0.5 mg/l intragravel dissolved oxygen from hatching to fry emergence
   c. No relationship to stream flow velocity established
   d. Criteria not used in OSGC conventional stream flow requirements study here described
   e. General guidelines for recommending incubation flows
      (1) Enough water to cover gravel made available by recommended spawning flow
      (2) Approximately equivalent to 2/3 the spawning flow recommendation
5. Rearing criteria
   a. General guidelines for recommending minimum rearing flows
      (1) Adequate depth over riffles
      (2) Riffle-pool ratio near 50:50
      (3) Approximately 60 percent of riffle area covered by flow
      (4) Riffle velocities 0.3-1.05 fps
      (5) Pool velocities 0.3-.08 fps
      (6) Most stream cover available as shelter for fish

   b. Tentative criteria -- Not used to date in OSGC stream flow requirements studies

Species	Preferred zone	Prefer. Stream depth ft.	Prefer. Velocity fps
Chinook	Mid pool and pool head	1.0- 4.0	0.2- 0.8
Coho	Mid pool and pool head	1.0- 4.0	0.2- 0.8
Steelhead	All zones	0.6- 2.2	0.2- 1.6
Rainbow			
Cutthroat	Riffle tail and pool head	1.3- 4.0	0.2- 1.6

F. Stream flow requirement measurement procedures
1. Advantages (The use of criteria and standard procedures)
   a. Enhances the justification for flows recommended
   b. Lends continuity to recommended stream flow regime
   c. Avoids bias inherent in individual judgment decisions
   d. Procedures may be more easily explained to a nontechnician; hence, more likely to gain the confidence of those affected by the recommended flows
2. Disadvantages
   a. Not applicable to streams without uniform (symmetrical) cross-section sites

b. Not applicable to even-flowing spring-fed streams or rivers with substantial minimum flows
c. Most time consuming and expensive procedures
d. Relationship recommended flows have with fish production levels is no more clearly understood nor demonstrated than flows recommended by other less sophisticated procedures
e. Not applicable to fish species or biological activities where criteria have not been identified

3. Adult fish passage
   a. Purpose
      (1) Provide adequate water for physical movement through most critical reaches to spawning areas
      (2) Not to provide flows generally believed necessary to induce migration
      (3) Most important in streams used by anadromous fish
   b. Select the point on the stream or stream sections where extreme width creates shallow flows most critical to passage of adult fish
   c. Measurements
      (1) Discharge
      (2) Transect length
         (a) Measured from edges of flow following the shallowest course
         (b) Measured once during a flow that covers all or most of the transect
      (3) Depth measurements
         (a) Evenly spaced along transect which follows shallowest course
         (b) Every 2 feet on small streams
         (c) Every 4 feet on medium sized streams
         (d) Every 8 feet on large streams and rivers
      (4) Velocity measurements
         (a) 0.6 of the total depth from the flow surface
         (b) Only to verify that velocities are not excessive at any given point along the transect
      (5) Frequency and number of measurements
         (a) Six sets of depth measurements on each transect (six different flow levels)
         (b) Measured often enough to insure data on six evenly spaced flow levels
   d. Data analyses
      (1) Analysis of depth and velocity data at each flow
         (a) Percent of total width meeting depth and velocity criteria
         (b) Longest continuous segment of transect meeting depth and velocity criteria expressed as percent of total transect width

(2) Analysis of the usable width for passage-discharge relationships
(a) Prepare line graph of percent total width meeting depth and velocity criteria vs. discharge. Determine the flow which yields 25 percent of the total original width measurement passage
(b) Prepare line graph of longest continuous segment of transect meeting depth and velocity criteria vs. discharge. Determine the flow which yields a continuous portion of the transect, equaling 10 percent of the total original width measurement, passable.
(3) Derivation of the recommended flow
(a) Select the flow required to make passable at least 25 percent of the total width and a continuous portion of the transect of at least 10 percent of the total width
(b) If more than one transect is measured to determine the recommended minimum flow, select from the transects the highest flow requirement indicated.
(c) Make certain that other obstructions to fish passage, such as falls and cascades do not require more flow to pass fish

4. Spawning
a. Purpose
(1) Provide adequate water for adult salmonids to spawn in their preferred stream areas
(2) Flow requirement determined for all important species of salmonids inhabiting the study stream or stream section
b. Transect locations
(1) For most species, establish the transect on a symmetrical gravel bar in the prime spawning area at the head of the riffle
(2) Select three transects for each flow recommendation to be developed
(3) Select gravel bars which approximate the size of those typically found in the study stream or stream section
(4) Straight line transect
(5) Not necessarily perpendicular to the flow
c. Measurements
(1) Discharge (if transect measurements not applicable)
(2) Transect length (stream width)
(a) Measured from edges of flow
(b) Measure each time depths and velocities are measured
(3) Depth measurements
(a) Nine evenly spaced measurements along transect, the first and last measurements being 1/10 of the transect length from the stream edge

(b) Spaced to divide the transect into 10 equal parts
(c) One section on each end of the transect, each equivalent to 1/20 of the total transect length, theoretically never meets spawning criteria and is automatically disregarded

(4) Velocity measurements
(a) Measured 0.4 foot from stream bottom
(b) Measured at same points on transect where depths are measured (nine measurements)
(c) Except where obtaining measurements to compute discharge, the velocities at each of nine stations need only be identified as they relate to parameters of velocity criteria

(5) Frequency and number of measurements
(a) Measurements at enough different flow levels to reliably identify the "discharge-usable width for spawning" relationship (approximately six different flow levels)
(b) The most intensive study period should coincide with the season of declining flows

d. Data analysis

(1) Compute and graph stream width usable for spawning
(a) At each flow
(b) On each transect

(2) Summarize the relationship "stream width usable for spawning have with discharge" for the transects in each study stream or stream section:
(a) Determine the average stream width usable for spawning on the transects at each of six different flow levels
(b) Regraph the relationship of "discharge with mean stream widths usable for spawning" for each study stream or stream section
(1-1) Maximum gravel = optimum spawning
(2-2) 80 percent of maximum gravel = optimum spawning

5. Spawning (usable-area procedure - see OSGC manual)

G. Stream flow requirements observation procedures

1. Advantages
   a. Applicable to all types of streams
   b. Less time consuming and less expensive than measurement procedures
2. Disadvantages
   a. Results subject to bias of individual observers
   b. Justification of results not as strong as for the measurement procedure; hence, less likely to gain the confidence of those affected by the recommended flows

c. Less inherent continuity in the results than the measurement procedure

3. Adult fish passage
   a. Purpose
      (1) Provide adequate water for physical movement through the most critical reaches to spawn areas
      (2) Not to provide flows generally believed necessary to induce migration
      (3) Most important in streams used by anadromous fish
   b. Select the point on the stream or stream section where extreme width creates shallow flows most critical to passage of adult fish
   c. Observations
      (1) The estimated flow which would yield approximately 25 percent of the total width and a continuous section of the bar equaling approximately 10 percent of its total width passable according to the parameters of passage criteria are estimated at several different flow levels
      (2) Incidental observations of fish passing suspected critical spots and the flow at which they pass
   d. Discharge measurement during each observation
   e. Derivation of the recommended flow
      (1) Select the flow the various observed recommendations seem to indicate
      (2) Make certain that other obstructions to fish passage, such as fall, cascades, or cataracts, do not require more flow to pass fish
4. Spawning
   a. Purpose
      (1) Provide adequate water for adult salmonids to spawn in their preferred stream areas
      (2) Insure recommended flows which will accommodate all important species of salmonids inhabiting the study stream or stream section
   b. Observation locations
      (1) For most species, observations are made on the portions of gravel bars where spawning is most likely to occur (the head of the riffle)
      (2) Select about three symmetrical gravel bars which approximate the size of those typically found in the study stream or stream section
   c. Discharge measurement during each observation
   d. Observations
      (1) At each of several flow levels, an estimate is made of the approximate flow required to provide a spawning flow (see criteria)

(a) Optimum spawning flow is that which coves the maximum amount of gravel with flow depths and velocities specified by spawning flow criteria (excessive velocities will be limiting factor)

(b) Minimum spawning flow is that which covers 80 percent of the gravel available at an optimum spawning flow

(2) The measurements taken to determine discharge are useful in estimating spawning flow requirements

e. Derivation of the recommended flow
   (1) Select the flow the various observed estimates seem to indicate
   (2) Repeat the same procedure where different species have different spawning flow requirements

5. Incubation
   a. Purpose
      (1) Provide adequate water to insure successful egg incubation and fry emergence
      (2) Insure recommended flows which will accommodate all important species of salmonids inhabiting the study stream or stream section
   b. Observation locations
      (1) Spawning areas (for most salmonids, on gravel bars at the head of the riffle)
      (2) Same sites where the spawning flow observations are made is most convenient
      (3) On gravel bars which approximate the size of those typically found in the study stream or stream section
   c. Discharge measurement during each observation
   d. Observations
      (1) At each of two or three flow levels near that required for spawning, an estimate is made of the approximate flow required for incubation
      (2) Measurements taken to determine discharge are useful in estimating incubation flow requirements
   e. Derivation of the flow recommended flow
      (1) Select the flow the various observed estimates seem to indicate
      (2) Repeat the same procedure where different species have different spawning flow requirements
6. Rearing
   a. Purpose
      (1) Provide adequate stream flow conditions for salmonids when flows for passage, spawning, or incubation are not required
      (2) Insure recommended flows which will accommodate all species of salmonids, both juvenile and adult, which inhabit the study stream or stream section

- b. Observation locations
  - (1) Most conveniently those areas where other observate recommendations are made
  - (2) On both riffles and pools which approximate the size of those typically found in the study stream or stream section
  - (3) In some areas with stream-side shade cover
- c. Discharge measurement during each observation
- d. Observations
  - (1) At each of several flow levels near that required for rearing (relatively low flows), an estimate is made of the approximate flow required for rearing (see rearing criteria and guidelines)
  - (2) Measurements taken to determine discharge are useful to estimate flows required for rearing
- e. Derivation of the recommended flow
  - (1) Select the flow the various observed estimates seem to indicate
  - (2) Repeat the same procedure if different species have different rearing flow requirements

H. Stream flow requirement prediction technique

1. Advantages
   - a. Least time consuming and least expensive technique
   - b. Results not subject to biases of personnel using the technique
   - c. Applicable to streams where the lack of symmetrical cross-sections preclude other techniques
   - d. Results display high level of continuity
2. Disadvantages
   - a. Least inherent justification for results of all techniques; hence, least likely to gain confidence of those affected by the recommended flows
   - b. Not applicable to spring-fed streams
3. Spawning and rearing
   - a. Equipment
     - (1) Maps
       - (a) Isohyetal with streams prominent
       - (b) Sectional with streams prominent
     - (2) Spawning and rearing constants
   - b. Derivation of flow recommendations
     - (1) Determine drainage area above point where flow is to be recommended
     - (2) Determine mean annual precipitation in drainage above point where flow is to be recommended
     - (3) Multiply drainage area (mi^2) by mean annual precipitation (in.)

(4) Select the appropriate constant value
(5) The recommended flow is equivalent to the product of the (mi^2) X (in.) X (constant value)
c. Adult passage and incubation
(1) Constants not available
(2) Use OSGC conversion factors

I. Stream flow requirement conversion factors
1. Advantages
a. Enables the derivation of flow recommendations not obtainable by any other procedure
(1) Angling flow recommendations
(2) Esthetic flow requirements
(3) Boating flow requirements
b. Enables the derivation of flow recommendations not obtainable by measurement of observation procedures during the field survey
(1) Adult fish passage (minimum and optimum)
(2) Spawning “ ” ”
(3) Incubation “ ” ”
(4) Rearing “ ” ”
c. One of the least time consuming and least expensive procedures
d. Results not subject to biases of personnel using the techniques
e. Flow recommendations proportional to flow recommendations upon which they are based, thus lending continuity to recommended flow regimen for any given location
2. Disadvantages
a. Little direct justification for flow recommendations; hence, it may be difficult to gain the confidence of those affected by the recommended flows
b. Existing flow recommendations required to which the conversion factors are applied
3. Conversion factors
a. Adult passage
(1) Optimum passage = minimum spawning
(2) Minimum passage = 0.67 X minimum spawning
b. Spawning
(1) Optimum spawning = 1.67 X minimum spawning
(2) Minimum spawning with 0.8' flow depth criteria = 1.2 X minimum spawning with 0.6' criteria
(3) Minimum spawning with 0.6' criteria = width of typical gravel bar (feet) X 1.0 (under 20 feet)
(4) Minimum spawning with 0.8' criteria = width of typical gravel bar (feet) X
1.5 (under 50 feet)

2.0 (over 50 feet)
2.5 (over 100 feet)

c. Incubation
   (1) Optimum incubation = minimum spawning
   (2) Minim incubation = 0.67 X minim spawning
d. Rearing
   (1) Optimum rearing = 0.67 minimum spawning
   (2) Minimum rearing = 0.2 X minimum spawning
e. Bank angling = 0.5 X optimum spawning
f. Boat angling
   (1) 2.0 X optimum spawning in eastern Oregon
   (2) 4.0 X optimum spawning in western Oregon

J. Preparing recommended flow regimen
1. Information required
   a. Recommended flows for
      (1) Adult passage
      (2) Spawning
      (3) Incubation
      (4) Rearing
   b. Fish species distribution by stream
   c. Life history periodicity
      (1) Biological activity
      (2) Fish species
2. Procedure
   a. Assign recommended flows
      (1) By month or 2-week periods
      (2) By stream or stream section
      (3) By species
      (4) By biological activity
         (a) Passage
         (b) Spawning
         (c) Incubation
         (d) Rearing
   b. Select highest flow required for any given period for each stream or stream section
   c. Precautions
      (1) Recommended flows are not adjusted to accommodated seasonally natural flow deficiencies or water right appropriations
      (2) Flows should not be recommended for a relatively insignificant species if the flow would be harmful excessive for an important species
      (3) A flow recommendation derived by measurement procedures which is not similar to the flow recommended for the same location by the observation technique should be carefully evaluated for errors

K. OSGC stream flow requirement survey reports--contents

1. Stream flow recommendations
   a. Minimums
   b. Optimums
   c. Other
2. Fish species, abundance, and distribution
3. Biological requirements of salmonids
4. Limiting factors of fish life
5. Fish resource values
6. Stream flow and temperature measurements
7. Photographs
   a. Stream flow comparisons
   b. Limiting factors
   c. Sport and commercial fisheries
   d. Study procedures

Appendix No. 1

OREGON STATE GAME COMMISSION
Usable width cross-section measurements

Stream Location	Date	X-section stations (lt to rt. Bank)										Total width	Mean depth	Mean velocity	Usable width	Flow (cfs)
			1	2	3	4	5	6	7	8	9					
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