INSTREAM FLOW REGIMENS
FOR
FISH, WILDLIFE, RECREATION
AND
RELATED ENVIRONMENTAL RESOURCES

BY

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ABSTRACT

Describes the "Montana Method," a quick, easy methodology for determining flows to protect the aquatic resources in both warmwater and coldwater streams based on their average flow. With this method, biologists do their analysis with the aid of hydrological data provided by the U.S. Geological Survey. Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974, testing the "Montana Method." This work involved physical, chemical, and biological analyses of 38 different flows at 58 cross-sections on 196 stream-miles, affecting both coldwater and warmwater fisheries. Reports or publications on 6 study streams are available. Numerous black and white photos and 35 mm. slides were taken of all the flow stages studied at each cross-section. The studies were all planned, conducted, and analyzed with the help of state fisheries biologists. Results reveal that the condition of the aquatic habitat is remarkably similar on most of the streams carrying the same portion of the average flow. Similar analyses of hundreds of additional flow regimens near U.S.G.S. gages in 21 different states during the past 17 years substantiated this correlation on a wide variety of streams. Running waters studied ranged from small precipitous brooks high in the Rocky Mountains to large, low-gradient rivers and streams out on the prairies of mid-America or along the coastal plains. Results are consistent from stream to stream or state to state, and it is impossible to get a zero flow recommendation using this method. Ten percent (10%) of the average flow is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Thirty percent (30%) of the average flow is recommended as a base flow to sustain good survival habitat for most aquatic life forms. Sixty percent (60%) of the average flow is recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. Thirty pages illustrated with tables, graphs, and photos.

George: A special thanks to you and many of your boys for all the streamflow data you have provided me over the years.

ACKNOWLEDGEMENT

Dedicated to all the scientists who helped develop the "Montana Method" for prescribing instream flows to protect our natural, free-flowing aquatic environment.

May this work serve them and their colleagues well in future efforts to preserve and enhance this vital resource.

D. L. Tennant

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INTRODUCTION

Natural, free-flowing streams are one of the world's most beautiful and valuable resources. Before the coming of Christ, the Roman Emperor Justinian said: "By the law of nature certain things are common property; for example, the air, running water, and the sea." America's late Senator Norris said: "The streams that are flowing downhill were given us by a creator. They do not belong to any special interest or to any individual. They belong to the people and ought to be utilized for the benefit of all of them."

Few streams in the United States have escaped degradation from altered flows by some kind of man-made, "water development" project. Some recognition is finally being given to instream flow regimens to protect the natural environment. Scientists from many disciplines are seeking reliable, practical methods for determining streamflow requirements to protect fishes, waterfowl, furbearers, reptiles, amphibians, mollusks, aquatic invertebrates, and related life forms from all the various people competing for our Nation's water.

With the help of several hydrologists and many state and federal biologists, I have developed a quick, easy method for determining flows to protect the aquatic resources, in both warmwater and cold-water streams. This methodology evolved over the past 17 years from my work on hundreds of streams in the states north of the Mason-Dixon Line between the Atlantic Ocean and the Rocky Mountains. My work has been cited in a score of publications and is best known as the "Montana Method."

METHOD

The Montana Method is so brief it can be typed on a 3" x 5" card. It can be applied rapidly to many segments of thousands of streams by referring to Table 1 of this paper and surface water records of the U.S. Geological Survey (U.S.G.S.). 1/

The following intensive use of this method will produce a factual, conclusive, streamflow study on any stream. First, determine the average annual flow of the stream at the location(s) of interest (listed as AVERAGE DISCHARGE by U.S.G.S. and hereinafter called average flow). If the average flow isn't published by the U.S.G.S., they can quickly calculate it for you. Visit the stream and observe, photograph, sample, and study flow regimens approximating 10%, 30%, and 60% of the average flow. Other flows can be studied, but these three regimens will cover a flow range from about the minimum to near the maximum that can normally be justified and recommended to protect the natural environment on most streams (fig. 1).

If the flow is not controlled, study U.S.G.S. records for flow patterns, then go to the field and check their gage(s) until you can view and study natural flows approximating 10%, 30%, and 60% of the average flow.

If flows are controlled, begin by having the highest flow you wish to study released first, then regulate so that each succeeding lower flow will begin the following midnight. Photos taken early the next morning

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1/ Water Resources Data for (name of state), Part 1. Surface Water Records, United States Department of the Interior, Geological Survey.

Table 1

Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources

Narrative Description of Flows[1]	Fisheries Classification[2]	Recommended Base Flow Regimens	
		Oct.-Mar. :	Apr.-Sept.
Flushing or Maximum	--	200% of the average flow[3]	
Optimum Range	--	60%-100% of the average flow[4]	
Outstanding	I	40%	60%
Excellent	II	30%	50%
Good	III	20%	40%
Fair or Degrading	IV	10%	30%
Poor or Minimum	--	10%	10%
Severe Degradation	--	10% of average flow to zero flow	

[1] Most appropriate description of the general condition of the streamflow for all the parameters listed in the title of this paper.

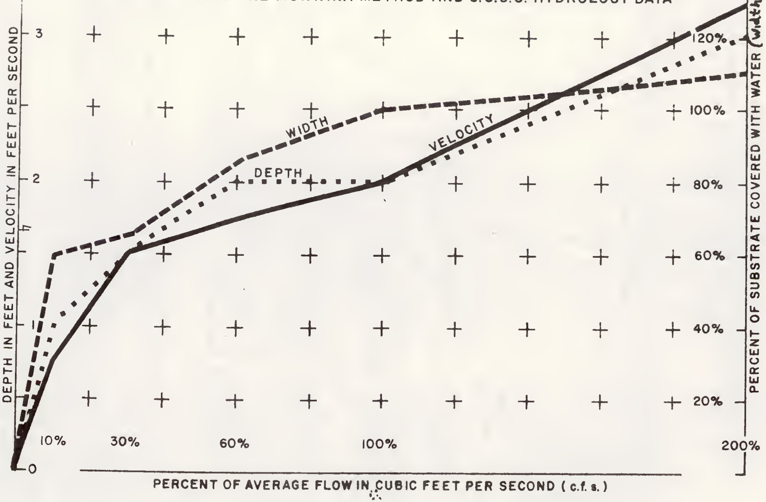
[2] Roman numeral ratings for Fisheries Classification Systems like those developed for the States of Idaho, Montana, West Virginia, Wyoming, and the Delaware River Basin Comprehensive Study by the U.S. Fish and Wildlife Service.[5, 11, 14, 19, 26] The base flow regimens outlined above in columns 3 and 4 to maintain the respective designated classes, are judged to be as reliable and valid as the classification systems themselves. These recommended flows generally apply very well to both cold and warm water streams. Regimens should be reversed or altered to fit different hydrologic cycles, like the Salmonid streams on the West Coast, or to favor species like the fall spawning brown trout. Flows may be refined further by specifically matching them to vital periods of the life cycle of fishes, like migration, spawning, incubation, growth, etc. Use of the Montana Method on spring creeks or streams that have a very uniform flow year-around may provide unprecendented low-flow regimens at the minimum or base flow levels.

[3] The average flow will usually fill the active stream channel approximately 1/3 full or to the line of permanent terrestrial vegetation, while 3 times the average flow will often fill the active channel approximately to the point of spilling out on the first bench of the flood plain.[15] Twice the average flow will produce effective depths and velocities within the stream channel for moving silt, sediment and other bed load material without doing extensive damage to the banks and riparian vegetation. Twice the average flow is a good maximum flow recommendation as well as a good flushing flow (Fig. 1).

[4] Optimum is a nebulous term; however, this flow range covers that definition best for all the parameters of this paper collectively.

FIG. I

AVERAGE WIDTH, DEPTH AND VELOCITY FROM TEN FIELD TESTS OF INSTREAM FLOW REGIMENS USING THE MONTANA METHOD AND U.S.G.S. HYDROLOGY DATA



will reveal the difference in exposed substrate or wetted perimeter (fig. 2). This is photographic "regression analysis." An 8 - 10 hour interval will normally be sufficient to negate any appreciable differences in flow levels due to bank storage.

Pictures may be the best data you will collect for selling your recommendations to the general public, administrators of construction agencies managing water development projects, and judges or juries adjudicating water laws. Black and white photographs and 35 mm. slides of key habitat types (e.g., riffles, runs, pools, islands and bars) from elevated vantage points like bridges and high stream banks will give results superior to ground level shots or photos from aircraft high above the stream. Record appropriate, vital information on all photographs and slides as soon as they are received.

U.S.G.S. monthly measurements cover a variety of flows at most of their stream gage or cable crossings. Obtain cross-sectional data on width, depth, and velocity measurements from the local U.S.G.S. field office for flow regimens under study. Use this information to plot and compare water widths, depths, and velocities to known requirements for aquatic resources. U.S.G.S. will make specific cross-sectional measurements of width, depth, and velocity at any point on a stream for a reasonable fee. With the proper experience, equipment, and plenty of time, others can make the necessary cross-sectional measurements. Study both the average daily streamflow regimen tables and previous historic low-flow data published by U.S.G.S. to learn the base flow patterns of the climatic year and help determine and justify your final recommendations.

Fig. 2

Missouri River below Holter Dam, Montana, showing differences between flows of 3,000 cfs (55% of the average flow) and 2,000 cfs (37% of the average flow). The vertical drop was 7 inches. Flows reduced about midnight will clearly reveal differences in wetted substrate when photographed the next morning (photographic "regression analysis").

MRBS Photo #9000
by Don Tennant 6/10/70

Recommend the most appropriate and reasonable flow(s) that can be justified to provide protection and habitat for all aquatic resources.

RESULTS

Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974 testing the Montana Method (Table 2). This work involved physical, chemical, and biological analyses of 38 different flows at 58 cross-sections on 196 stream miles, affecting both coldwater and warmwater fisheries. Reports or publications on 6 study streams are available as indicated in Table 2. Numerous black and white photos and 35 mm. slides were taken of all the flow stages studied at each cross-section. The studies were all planned, conducted, and analyzed with the help of state fisheries biologists. These studies reveal that the condition of the aquatic habitat is remarkably similar on most streams carrying the same portion of the average flow.

Width, depth, and velocity are physical instream flow parameters vital to the well-being of aquatic organisms and their habitat. Sixteen-hundred measurements of these parameters for 48 different flows on 10 of the streams cited in Table 2 show that they all increase with flow and that changes are much greater at the lower levels of flow (fig.1). Width, depth, and velocity all changed more rapidly from no flow to a flow of 10% of the average, than at any point thereafter. Ten percent (10%) of the average flow covered 60% of the substrates, depths averaged 1 foot, and velocities averaged 3/4 foot per second. Studies show that these are critical points or the lower limits for

Table 2

DETAILED STUDIES OF INSTREAM FLOW REGIMENS USING THE MONTANA METHOD

Name of Stream	State	Date	Miles Studied	Number of Stations	Different Flows	Parameters Studied (1)	Type of Fishery (2)	Reference
Republican R.	Nebraska	1964	40	3	4	W,D,V,S,B,C,T,F	WW	25
Wind-Bighorn R.	Wyoming	1968	50	10	3	W,D,S,B,C,T,F	CW & WW	24
Marias R.	Montana	1968	67	9	3	W,D,V,S,B,C,T,F	CW & WW	
Missouri R.	Montana	1970	15	8	4	W,D,V,S,B,C,I,F	CW & WW	
Blacks Fork R.	Wyoming	1971	16	4	3	W,D,V,S,C,I	CW	31
Shoshone Creek	Wyoming	1971	1	2	9	W,D,V,S,B,C,F	CW	
Ruby R.	Montana	1971	1	4	3	W,D,V,S,B,C,F	CW	
W. Fk. Bitterroot	Montana	1971	1	5	3	W,D,V,S,B,C,F	CW	10
W. Rosebud R.	Montana	1971	3	3	4	W,D,V,S,B,C,F	CW	10
N. Platte R.	Wyoming	1974	2	10	2	W,D,V,S,B,C,F	CW & WW	10
Totals			196	58	38			

(1) Parameters Studied -- W=Width, D=Depth, V=Velocity, S=Substrate & Sidechannels, B=Bars & Islands, C=Cover M=Migration, T=Temperature, I=Invertebrates, F=Fishing & Floating, E=Esthetics & Natural Beauty

(2) Type Fishery -- WW=Warmwater, CW=Coldwater

the well-being of many aquatic organisms, particularly fishes. This substantiates the conclusion that this is the area of most severe degradation or that 10% is a minimum short-term survival flow at best. Flows from 30% to 100% of average result in a gain of 40% for wetted substrate, average depth increases from 1½ to 2 feet, and average velocities rise from 1½ to 2 feet per second. These are within good to optimum ranges for aquatic organisms, however, it requires 3 to 10 times the amount of water needed for a short-term minimum or good base flow, and gains or benefit-cost ratios may become questionable. Increasing flow from 100% of average to 200% of average (doubled) only increases average wetted substrate by 10%, average depth increases from 2 to 3 feet, and average velocity rises from 2 to 3½ feet per second. Velocities averaging 3½ feet per second are probably too high for the general well-being of most aquatic organisms but good for moving sediment, bedload, and white water boating. In all 11 field tests of the Montana Method, water depth appeared adequate for aquatic organisms whenever velocities were satisfactory.

Analyses of hundreds of additional flow regimens near U.S.G.S. gages in 21 different states during the past 17 years substantiate these correlations between similar flows on a wide variety of streams. Running waters studied ranged from small precipitous brooks high in the Rocky Mountains, to large, low-gradient rivers out on the prairies of mid-America and streams along the coastal plains. This phenomenon of nature is documented with hundreds of black and white photographs and 35 mm. slides that are registered and filed with the U.S. Fish and Wildlife Service (FWS) in Billings, Montana; Grand Island, Nebraska; and Denver, Colorado.

The average flow of a stream (or any given portion or percent of the average flow) is a composite manifestation of the size of the drainage area, geomorphology, climate, vegetation, and land use. These relationships have also been evaluated and reported by other biologists and hydrologists.[8, 13, 15, 16, 18, 29, 31]

Use of the Montana Method has produced over 100 separate streamflow recommendations to protect fish, wildlife, and environmental resources in more than 70 reports issued by the FWS.[20] The recommendations were made with the aid of district fishery biologists from 11 different states, endorsed by both the Directors of their state Fish and Game Departments and the Director of the FWS and generally accepted by various construction agencies. This work occurred on at least 30 warmwater streams and 70 coldwater streams.

Many of our recommendations were not adopted, since providing streamflow for fish, wildlife, and environmental preservation or enhancement is not a legal beneficial use of water in most of the country, especially the 17 western states.[9] Administrators managing water development projects have generally been willing to regulate flow regimens for instream flow studies and provide minimum flows necessary to protect these resources when there is plenty of water. However, these resources are the first to suffer when water is short.[6, 9, 24, 25, 27]

In 1970, the project managers of the U.S. Bureau of Reclamation, U.S. Corps of Engineers, and the Montana Power Company were requested to identify the minimum flows that they recognized solely for the protection of fish, wildlife, and the aquatic environment, downstream from dams under their jurisdiction.[21] These agencies control the operation of 23 major dams in Montana and Wyoming. Table 3 compares their replies to previous FWS recommendations and mean and minimum flows of record.

The agencies reported minimum flows for fish, wildlife, and environmental protection which ranged from zero (four instances) to 38% of the average flow. The 38% flow was the result of fish and wildlife interests getting 500 cubic feet per second (cfs) released below Kortes Dam on the North Platte River in Wyoming. Congress reauthorized the operation of that project, which took about 10 years and is the only known accomplishment of its kind in the U.S.A.

Twelve of the 21 flows accepted by the agencies were less than 10% of the average flow of record, which is inadequate to sustain the normal life cycles of either warmwater or salmonid fishes.

Federal and state biologists analyzed flows and made flow recommendations on 12 of the streams involved. However, flows accepted by the agencies agreed with these recommendations in only 3 instances.

In 10 of 20 cases, the minimum natural inflow of record to the regulating reservoir exceeded their recognized release for the conservation of fish, wildlife, and the aquatic environment downstream below the dams. All flow recommendations should stipulate that outflow from dams should at least equal inflow when managing agencies cannot release the flow regimens requested to protect the environment. Project

Table 3
Minimum Instantaneous Flows for Fish, Wildlife, and Aquatic Environment Below Dams in the Missouri River Basin in Montana and Wyoming - 1970

Dam & Agency	Minimum Flow for Fish Recognized by Construction Agency	% of Mean Flow	Mean Flow of Record	FWS Recommended Min. Flow	% of Mean Flow	Minimum Reservoir Inflow or Natural Flow of Record
Seminoe[1] (BR)	---		1279 cfs			70 cfs
Kortes (BR)	500 cfs	38%	1300 cfs	500 cfs	38%	70 cfs
Pathfinder (BR)	0 cfs	0%	1423 cfs			70 cfs
Alcova[2] (BR)	---		1500 cfs			70 cfs
Gray Reef (BR)	330 cfs	22%	1500 cfs	330 cfs	22%	70 cfs
Glendo (BR)	0 cfs	0%	1680 cfs			170 cfs
Guernsey (BR)	0 cfs	0%	1710 cfs			170 cfs
Boysen (BR)	100 cfs	7%	1350 cfs	250-400 cfs	19-30%	42 cfs
Buffalo Bill (BR)	15 cfs	1%	1256 cfs	350 cfs	28%	41 cfs
Heart Mountain (BR)	200 cfs	16%	1256 cfs	350 cfs	28%	41 cfs
Yellowtail (BR)	1000 cfs	29%	3500 cfs	1000 cfs	29%	179 cfs
Clark Canyon (BR)	25 cfs	8%	324 cfs	250 cfs	77%	69 cfs
Barretts Div. (BR)	25 cfs	6%	405 cfs	200 cfs	29%	69 cfs
Hebgen (MP)	50 cfs	5%	969 cfs	400 cfs	41%	200 cfs
Ennis (MP)	200 cfs	12%	1675 cfs			275 cfs
Holter (MP)	1000 Cfs	19%	5289 cfs	2000 cfs	38%	747 cfs
Moroney (MP)	1500 cfs	20%	7362 cfs			1760 cfs
Ft. Peck (CE)	3000 cfs	32%	9292 cfs			1120 cfs
Gibson (BR)	50 cfs	6%	850 cfs	270 cfs	32%	60 cfs
Sun River Div. (BR)	100 cfs	12%	852 cfs	270 cfs	32%	47 cfs
Sherburne (BR)	0 cfs	0%	200 cfs			0 cfs
St. Mary's Div.[3] (BR)	25 cfs	3%	790 cfs			16 cfs
Fresno (BR)	25 cfs	6%	430 cfs			0 cfs
Tiber (BR)	100 cfs	11%	880 cfs	250 cfs	28%	10 cfs

[1] Outflow directly into Kortes

[2] Outflow directly into Gray Reef

[3] A Canal to Milk River - Canada

managers often reminded us that there were no legal requirements for providing any water specifically for the conservation or enhancement of fish, wildlife, and environmental resources. Water agencies "sell" their projects by declaring that their operation will moderate the extreme high and low flows that occur naturally. Just the opposite was true on ½ of these projects. Our analysis did not include scores of existing, smaller projects under the programs of the U.S. Forest Service and the U.S. Soil Conservation Service, most of which did not recognize or provide any minimum flows for fish, wildlife, or the environment.

The Montana Method has been used by the FWS while conducting major comprehensive type studies that required quick, consistent streamflow recommendations for fish, wildlife, and the aquatic environment on numerous streams, covering extensive geographic areas.[1, 2, 3, 4, 28] It has also been very useful for prescribing streamflows on large rivers where data are difficult to obtain using other procedures.

The Montana Method has virtues other than being quick and easy to use. It assures consistency from stream to stream or state to state. You always know the portion of the total streamflow requested and will never get a zero flow recommendation like some other methods produce (e.g., use of 7-day or 3-day minimum or historic minimum flow criteria). In 1970, I evaluated 7-day minimum flow criteria input for the Upper Missouri, Yellowstone, Kansas, and Platte-Niobrara Sub-Basins of the Missouri River Basin Comprehensive Study. I found that these criteria resulted in zero flow in 86 of 305 instances, or about 28% of the time.[22]

In 236 of 305 cases (77%), the 7-day minimum flow was less than 10% of the average flow, which I consider in the range of severe degradation for most elements of the aquatic environment. Criteria for 3-day minimum flows would be worse yet, and recommending the meager, alltime, historic minimum flow would be unthinkable. That would be like prescribing a person's alltime worst health condition as a recommended level for a portion of his future well-being.

Avoid recommending vacillating flow regimens specifically for fishes, coincidental with monthly (m.a.f.) or daily (d.a.f.) average flows because there are too many unknown, degrading effects on the life cycles of many other organisms in the aquatic environment and other uses of water to justify frequent ebb and flow changes in most streams. Quarterly variations in flow regimens might approximate climatic hydrology and be appropriate. The Montana Method can easily be modified to suit the individual convictions of any biologist or the monthly or daily hydrological variations of any given stream. I usually recommend variation in flow regimens for 6-month periods (e.g., columns 3 and 4 of Table 1) that mimic nature and coincide most naturally with the so-called climatic year used by the U.S.G.S. and the U.S. National Weather Service. This offers the following distinct advantages:[12] a) Stages of ground water are more nearly uniform on October 1 in most inland sections of the United States than on any other date, leading in general to fairly reliable comparisons of annual rainfall-runoff relations because of the relatively small errors due to annual differences in the ground-water table on that date; b) In the arid and semi-arid parts of the country, September 30 usually marks the end of the irrigation season and in humid regions it approximates the end of the growing season; c) There is a minimum probable error due to the effect of ice in the records of winter flow if the discharge for the winter period (November to April) is computed together at one time; d) The winter or base flow period coincides with reduced metabolic functions and decreased demands for vital life elements by most aquatic organisms (e.g., oxygen, food, removal of waste products, and increased tolerance to pollution); e) A low flow winter period matches the downstream migration habits of many fishes (warmwater and coldwater), when they travel to deeper more permanent water to spend the winter. This is also the spawning and incubation season for most salmonids, when they naturally seek less water by moving into headwater or tributary streams and onto redds in shoal or shallow riffle areas; and f) Higher summer flow regimens provided by this method coincide with the frost-free, recreation season and the major growth period for most aquatic plants and animals, when their requirements for dissolved gases, space, food, and removal of septic waste products are naturally higher (the attendant increased width, depth, and velocities in the stream all serve to enhance the availability of elements vital to these recreation uses and critical life functions). These phenomena may be seasonally reversed for anadramous fishes using the coastal streams of Alaska, the Canadian Provinces, and our west coast states and flow regimens should be adjusted accordingly.

Using the Montana Method, it is easy to adjust to above or below normal water years and maintain stream flows that are appropriate portions of monthly, quarterly, or annual instream supplies of water. This helps fish, wildlife, and aquatic resources share surpluses and shortages of water equitably with other users.

With the Montana Method, U.S.G.S measures the hydraulic characteristics of the stream and biologists interpret the biological responses. This saves considerable precious time that biologists can use on a more complete ecological analysis of streamflow needs. U.S.G.S. is recognized nationwide for its expertise in making reliable streamflow measurements, and their results are less apt to be questioned by water resource development agencies and more likely to withstand the scrutinty of adversaries in a court of law.[12] This method is applicable to hundreds of thousands of streamflow records that have been published by U.S.G.S. since 1888 on most of the perennial streams in America. In 1972 alone, there were nearly 24,000 active, surfacewater gaging stations in the United States.[17] U.S.G.S. employes more than 2,000 professional hydrologists, working out of 220 different locations to measure streamflow parameters on our Nation's lotic waters.[12] These scientists maintain and use several million dollars worth of specialized supplies and equipment specifically for this purpose.[7]

There is significant hydrological and biological evidence that the Montana Method can also be used successfully on streams throughout the world. [6, 8, 10, 13, 15, 16, 18, 23, 24, 25, 27, 29, 30, 31]

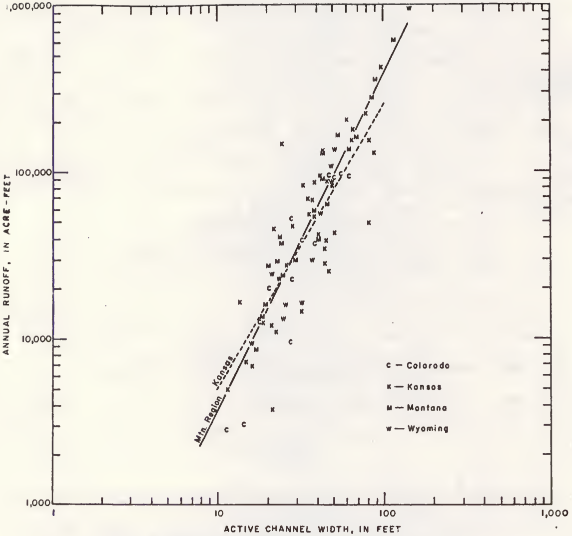
U.S.G.S. is considering the revision of streamflow data programs for most of the states.[23] The majority of existing gages may be discontinued under its future program. Techniques like measuring channel geometry, interpolation from a known flow to an unknown flow, and correlations with adjacent streams will be used to provide streamflow information at any point on any stream. Simple channel geometry measurements have produced average flow data as accurate at 10 years of continuous gage records.[13] The standard errors were lowest for mountain regions and in competition with 5 to 10 years of gaged records for the plains region. There is very little variation when results are compared between channel width and average flow (fig.3). Mean annual discharge is one of the few criteria that will be routinely provided by this future program. Therefore, the Montana Method can still be used with this new program, since it is based primarily on knowledge of the mean annual discharge or average flow. The ability to provide the average flow at any point on any stream would actually facilitate the use of the Montana Method in the future.

Adopting the metric system would not require conversion tables or other problems since this method is based on percentages of the average flow however it is expressed.

CONCLUSIONS

The following conclusions on flows are the result of frequent observations and detailed analyses of flows from a wide variety of streams over a large geographical area of the United States

Fig. 3



Correlation between average flow and channel width for streams in the mountain and plains regions of Colorado, Kansas, Montana and Wyoming

Ten percent (10%) of the average flow (fig. 4): This is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Channel widths, depths, and velocities will all be significantly reduced and the aquatic habitat degraded (fig. 1). The stream substrate or wetted perimeter may be about ½ exposed, except in wide, shallow riffle or shoal areas where exposure could be higher. Most side channels will be severely or totally dewatered. Most gravel bars will be substantially dewatered, and islands will usually no longer function as wildlife nesting, denning, nursery, and refuge habitat. Streambank cover for fish and fur animal denning habitat will be severely diminished. Many wetted areas will be so shallow they no longer will serve as cover, and fish will generally be crowded into the deepest pools. Riparian vegetation may suffer from lack of water. Large fish may have difficulty migrating upstream over many riffle areas. Water temperature may become a limiting factor, especially in the lower reaches of the stream in July and August. Invertebrate life will be severely reduced. Fishing will often be very good in the deeper pools and runs since fish will be concentrated. Many fishermen prefer this level of flow! However, fish may be vulnerable to overharvest. Floating is usually difficult even in a canoe or rubber raft (stream with an average flow of more than 100 cfs). Natural beauty and stream esthetics are badly degraded. Most streams carry less than 10% of the average flow at times, so even this low level of flow will occasionally provide some enhancement over a natural flow regimen.

Fig. 4

Republican River below Hardy Bridge, Nebraska, showing a flow of 42 cfs (10% of the average flow). Water depths were adequate to provide some fish cover, living space, movement and for fishing. Temperatures were within tolerable limits. This is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms.

MRBS Photo #7159
by Don Tennant 7/10/64

Thirty percent (30%) of the average flow (fig. 5): This is a base flow recommended to sustain good survival habitat for most aquatic life forms. Widths, depths, and velocities will generally be satisfactory (fig. 1). The majority of the substrate will be covered with water, except for very wide, shallow riffle or shoal areas. Most side channels will carry some water. Most gravel bars will be partially covered with water and many islands will provide wildlife nesting, denning, nursery, and refuge habitat. Streambanks will provide cover for fish and wildlife denning habitat in many reaches. Many runs and most pools will be deep enough to serve as cover for fishes. Riparian vegetation should not suffer from lack of water. Large fish should have no trouble moving over most riffle areas. Water temperatures are not expected to become limiting in most stream segments. Invertebrate life is reduced but not expected to become a limiting factor in fish production. Water quality and quantity should be good for fishing, floating, and general recreation, especially with canoes, rubber rafts, and smaller shallow draft boats (streams with an average flow of more than 100 cfs). Stream esthetics and natural beauty will generally be satisfactory.

Fig. 5

Bighorn River below Boysen Dam, Wyoming, showing a flow of 400 cfs (30% of the average flow). Water depth was adequate for trout movement, spawning, incubation and winter survival in most run and pool areas for a distance of 45 car miles downstream. This is a base flow recommended to sustain <u>good</u> survival habitat for most aquatic life forms.

MRBS Photo #8542-B
by Don Tennant 10/2/68

Sixty percent (60%) of the average flow (fig. 6): This is a base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. Channel widths, depths, and velocities will provide excellent aquatic habitat (fig. 1). Most of the normal channel substrate will be covered with water, including many shallow riffle and shoal areas. Side channels that normally carry water will have adequate flows. Few gravel bars will be exposed, and the majority of islands will serve as wildlife nesting, denning, nursery, and refuge habitat. The majority of streambanks will provide cover for fish and safe denning areas for wildlife. Most pools, runs, and riffles will be adequately covered with water and provide excellent feeding and nursery habitat for fishes. Riparian vegetation will have plenty of water. Fish migration is no problem in any riffle areas. Water temperatures are not expected to become limiting in any reach of the stream. Invertebrate life forms should be varied and abundant. Water quality and quantity should be excellent for fishing and floating canoes, rafts, and larger boats, and general recreation (stream with an average flow in excess of 100 cfs). Stream esthetics and natural beauty will be excellent to outstanding.

Fig. 6

North Fork Shoshone River near Wapiti, Wyoming, showing a flow of 456 cfs (approximately 60% of the average flow). Water widths, depths and velocities very good for fish and fishing in all riffles, runs and pools. This is a base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses.

FWS Photo #6-1-68
by Don Tennant 9/29/72

A flow of 2 to 3 times the average flow is often best for kayaks and whitewater canoeing. A flow of this magnitude is also preferable for larger boats with inboard or outboard motors, like those many people use on the annual Missouri and Yellowstone River floats held in June and July in Montana.

RECOMMENDATIONS

1. Request "instantaneous flows" to prevent flow releases from dams and diversion structures that are averaged over a day, month, or year, which permits erratic releases or even no flow at times.

2. Recommend that dual or multiple outlets to all dams be designed and constructed so that minimum flows of an appropriate temperature and quality to protect the aquatic environment can be by-passed at all times, including drawdowns for safety inspections and emergency repairs.

3. Insist that costs for providing of instream flows to protect the aquatic environment downstream below dams be project costs, including costs for unforeseen emergency repairs and routine maintenance over the life of the project.

4. Justify only that portion of a stream flow required to fulfill specific instream needs. If fish need a flow of 100 cfs in a segment of stream where there are already legal requirements of 25 cfs for municipal water, 15 cfs for irrigation water transport, and 10 cfs for a U.S. Environmental Protection Agency water quality requirement, you logically and legally should only have to justify a flow of 50 cfs

(the additional increment necessary to provide 100 cfs). Planners of water development projects may ask you to justify and apply cost/benefit ratios for fish to the 100 cfs flow because this makes their "project purpose" look more favorable on a comparable cost/benefit basis.

5. Stipulate that the downstream flow will not be less than the inflow to impoundments, whenever operators of water development projects cannot provide specific flow requirements. Make this an integral part of every flow regimen recommendation, preferably part of the same sentence.

6. Reduced releases to a stream should not exceed a vertical drop of 6 inches in 6 hours (equal to 2 feet in 24 hours). Fluctuations greater than this may significantly degrade aquatic resources.

7. Request that maximum flows released from dams not exceed twice the average flow. Prolonged releases of clear water greater than this will cause severe bank erosion and degrade the downstream aquatic environment.

8. Use "undepleted" U.S.G.S. hydrology data for flow recommendations that relate to the stream in its pristine conditions (e.g., before dams, diversions, pumps, etc.). Otherwise, recommendations from the Montana Method may relate to depleted stream conditions and result in less than ideal flows.

9. Avoid recommending minimum instantaneous stream flow regimens less than 10% of the average flow since they will result in catastrophic degradation to fish and wildlife resources and harm both the aquatic

and riparian environments (fig. 1). Encourage lawmakers to pass legislation that would prevent diversions or regulation at dams, whenever it would reduce streamflow below this level. If water development projects cannot make it on 90% of the water carried by a stream, use of the remaining 10% probably won't justify their projects. Philosophically, it is a crime against nature to rob a stream of that last portion of water so vital to the life forms of the aquatic environment that developed there over eons of time.

REFERENCES

1. Anonymous. 1967. Black Hills Area Resources Study, A Resources Study Prepared by the Departments of Agriculture and Interior, 225 pp.

2. Anonymous. 1971. Fish and Wildlife Tentative Needs and Problems Upper Missouri River Tributaries Sub-basin. The Missouri River Basin Comprehensive Framework Study. Missouri Basin Inter-Agency Committee, 94 pp.

3. Anonymous. 1971. Fish and Wildlife Tentative Needs and Problems Yellowstone River Basin. The Missouri River Basin Comprehensive Framework Study. Missouri Basin Inter-Agency Committee, 99 pp.

4. Anonymous. 1973. Western United States Water Plan. Reports of the State Study Teams for Montana and Wyoming.

5. Bailey, Randy E., O.E. Maughan and R.A. Whaley. 1974. Stream Classification System for West Virginia., Symposium on Trout Habitat Research and Management in the Southern Appalachians. Cullowhee, North Carolina, 10 pp.

6. Banks, Roger R.L. and J.W. Mullan, Bureau of Sport Fisheries and Wildlife and R.W. Wiley and D.J. Dufek, Wyoming Game and Fish Department. 1974. The Fontenelle Green River Trout Fisheries Considerations in Its Enhancement and Perpetuation, Including Test Flow Studies of 1973. United States Department of the Interior, Fish and Wildlife Service, 125 South State Street, Salt Lake City, Utah, 37 pp.

7. Barnes, Harry H. 1975. Information on United States Geological Survey Streamflow Measurements. Letter of personal correspondence, 3 pp.

8. Baxter, G. 1961. River Utilization and the Preservation of Migratory Fish Life. Proc. Inst. of Civ. Eng., 18:225-44.

9. Dewsnup, Richard L. 1971. Legal Protection of Instream Water Values. National Water Commission, Arlington, Virginia, 58 pp.

10. Elser, A.A. 1972. A partial evaluation and application of the "Montana Method" of determining streamflow requirements. In proceedings, Instream Flow Requirement Workshop, Pacific Northwest River Basins Commission, Portland, Oregon, pp. 3-8.

11. Fish Division, Wyoming Game and Fish Commission. 1971. Wyoming Stream Fishery Classification.

12. Grover, C.N. and A.R. Harrison. 1966. Streamflow Measurements, Records and Their Uses. Dover Publications, Inc., New York, 363 pp.

REFERENCES
(continued)

13. Hedman, E.R. and W.M. Kastner. 1974. Progress Report on Streamflow, Characteristics as Related to Channel Geometry of Streams in the Missouri River Basin. Open-File Report, U.S. Geological Survey, 24 pp. and personal letter.

14. Idaho Fish and Game Department. 1968. Idaho Stream Classification.

15. Leopold, Luna B., J.P. Miller and M.G. Wolman. 1974. Fluvial Processes in Geomorphology. W.H. Freeman and Company, San Francisco, pp. 198-332.

16. Leopold, Luna B. and T. Maddock, Jr. 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. U.S. Geological Survey Professional Paper 252, 19 pp.

17. Pauszek, F.H. 1973. Digest of the 1972 Catalog of Information on Water Data. U.S. Geological Survey Water Resource Invesigations 63-73, 83 pp.

18. Rantz, S.E. 1964. Stream Hydrology Related to the Optimum Discharge for King Salmon Spawning in the Northern California Coast Ranges. U.S. Geological Survey, Water Supply Paper (1779-AA), 16 pp.

19. Stream Classification Committee. Revised 1965. A Classification of Montana Fishing Streams.

20. Tennant, Donald L. 1957-1975. Ecological Service Studies and Reports - Major Fish and/or Wildlife Input. Unpublished list of RBS and ES reports, 3 pp.

21. Tennant, Donald L. 1970. Minimum Instantaneous Streamflow to Protect Fish, Wildlife and the Aquatic Environment. Unpublished memorandum in the Area Office files of the U.S. Fish and Wildlife Service, Billings, Montana, 3 pp.

22. Tennant, Donald L. 1970. Minimum Stream Flows - National Environmental Policy Act of 1969 (P.L. 90-190) and Executive Order 11514. Unpublished memorandum in the Area Office files of the U.S. Fish and Wildlife Service, Billings, Montana, 2 pp.

23. United States Department of the Interior, Geological Survey. A Proposed Streamflow Data Program for <u>(state)</u>.

24. U.S. Fish and Wildlife Service. 1961. Initial Follow-up Report, Boysen Unit, Wyoming, 21 pp. Illus.

25. U.S. Fish and Wildlife Service. 1966. Kansas River Basin - Republican River, Nebraska - Fishery Study of Experimental Flows, 28 pp. Illus.

REFERENCES
(continued)

26. U.S. Fish and Wildlife Service. 1959. Report on the Comprehensive Survey of the Water Resources of the Delaware River Basin - Appendix J.

27. United States Department of the Interior, Fish and Wildlife Service. 1966. Fishery Study of Experimental Flows Between Kortes Dam and Pathfinder Reservoir, 25 pp. Illus.

28. Water Resources Council, Washington, D.C. 1975. National Assessment of Water and Related Land, Phase I - Nationwide Analysis (In Press).

29. Wesche, Thomas A. 1973. Parametric Determination of Minimum Stream Flow for Trout. Water Resources Institute, University of Wyoming, 102 pp.

30. Whelan, Donald E. and R.K. Wood. 1962. Low-Flow Regulations as a Means of Improving Stream Fishing. Proceedings of the Sixteenth Annual Conference, Southeastern Association of Game and Fish Commissioners, Charleston, South Carolina, pp. 375-386.

31. Wiley, R.W. 1972. Blacks Fork River Volume Flow Observations. Wyoming Game and Fish Commission Administrative Report #0472-08-6602, pp. 1-17.