WYOMING GAME AND FISH DEPARTMENT

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE: Snake River Instream Flow Studies

PROJECT: IF-1088-09-8701

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INTRODUCTION

Instream flow studies on the Snake River were initiated by the Wyoming Game and Fish Department (WGFD) in the fall of 1987. These studies were designed to address the impacts of various reservoir release rates on physical habitat for trout during the winter (Annear 1987). These preliminary instream flow studies were further limited in scope to address impacts only in the 4.3 mile long segment of the river between Jackson Lake Dam (JLD) and Pacific Creek. Impacts to this segment were regarded as potentially more severe than downstream segments since no other tributaries enter this segment of the river which might help sustain the fishery during periods of extremely low reservoir releases. Subsequent consideration and input from interested groups suggested that fishery impacts in more downstream segments of the river are also important. To address these concerns, additional studies were designed and implemented in 1988 to evaluate stream flow/fish habitat dynamics in other segments of the river.

Studies were designed to 1) evaluate incremental changes in physical habitat with change in stream flow for adult Snake River cutthroat trout, 2) determine the stream flow that will maintain hydraulic criteria which are important for trout passage and aquatic insect survival in the main channel of the river, and 3) identify the stream flow that will maintain hydraulic criteria in side channels of the Snake River. The results and recommendations of all studies were applied to the time period between October 1 and March 31 only.

METHODS

Study Area

The morphological characteristics and trout habitat in the river below the dam change markedly at Pacific Creek. The river between the dam and Pacific Creek consists of a relatively narrow, well-defined channel with a series of long deep runs. Below this tributary, trout habitat includes numerous side channels and gravel bars in addition to main channel habitat. Bank habitat assumes greater importance

for adult trout and side channels are important nursery areas for fry and juvenile trout in the lower segment of the river. As a consequence, results from those two study areas provide information on different habitat components in the river.

Studies in 1988 were designed to evaluate instream flow relationships in the segment of the river between Pacific Creek and Moose. This is a distance of about 21.4 stream miles. Data were collected at four different study sites within this river segment (Figure 1). The legal description of each site is contained in Table 1. Dates when data were collected and corresponding discharges are listed in Table 2. Because of the proximity of SNR1, 2 and 3 to each other and the absence of tributaries between them, stream flows were assumed to be equivalent at all three sites.

Table 1. Location of study sites used for instream flow studies in 1987 and 1988 on the Snake River.

Study Site	Legal Description
SNPC (1987)	R114W, T45N, S22, SE1/4
SNR1 (1988)	R114W, T44N, S 6, SE1/4
SNR2 (1988)	R114W, T44N, S 7
SNR3 (1988)	R114W, T44N, S18, NW1/4

Table 2. Dates when instream flow data were collected at three study sites in 1988, the measured discharge (cfs), the corresponding recorded discharge of water released from Jackson Lake Dam on those dates and the percent of water at the study site originating from the dam.

Date	Measured Discharge	Released Discharge	Percent
June 21	4450	1980	45
September 7	1640	1436	88
October 3	400	201	50

Data were collected at the SNPC site concurrently with other instream flow studies in 1987. Results of these analyses were not included in the previous report as that study addressed only the river segment upstream from Pacific Creek. These two river segments provide distinctly different habitats for trout. The study site at SNPC consisted of one transect placed across a riffle. Information collected from this site was intended to provide an analysis of the potential impact of different stream flows on fish passage and aquatic insect survival.

The SNR1 study site was chosen to describe physical habitat conditions that are representative of physical habitat found throughout the Pacific Creek to Moose segment of the river. This study site contained deep pool, deep run and riffle habitat.

The SNR2 study site consisted of a single well-defined riffle. This site was chosen to assess the potential impact of different stream flows on fish passage and aquatic insect survival.

The SNR3 study site was located at the head of a long side channel. A well-defined riffle was located in the main channel of the river as well as at the

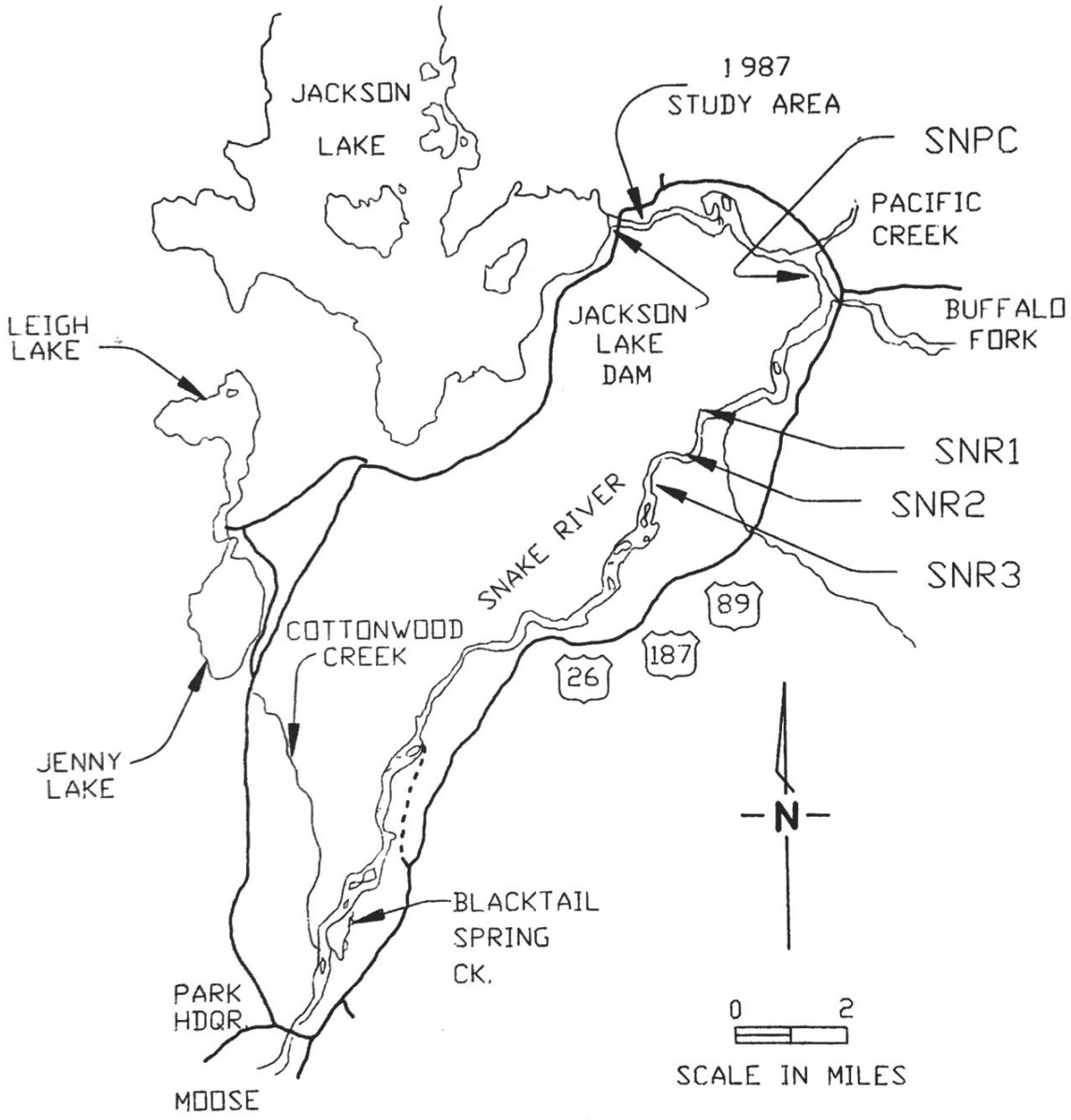

Figure 1. Location of 1988 study sites on Snake River.

Table 3.

head of the side channel. Transects were placed across both the main channel and side channel at the point on each riffle where the water surface elevations were the same. This site was chosen to identify the stream flow that would maintain certain hydraulic criteria in this side channel. Though not directly linked to other side channels, it was assumed that stream flow characteristics at this study site were representative of other side channels within the defined segment of the river.

Methodologies

A physical habitat simulation (PHABSIM) model developed by the U.S. Fish and Wildlife Service (Bovee and Milhous 1978) was used to incrementally simulate hydraulic characteristics within the SNR1 study site over a range of stream flows. Data used for this model were collected from five transects placed across all habitat types within a 1,130 foot section of the river. Velocities and depths were measured at 5 to 10 foot intervals across each transect when the discharge was 1,640 cfs. Water surface elevations for all five transects were measured at each of the flow events shown in Table 2. These data permitted simulation of physical habitat at a range of flows between 160 and 9,000 cfs.

The PHABSIM model provides information only on the suitability of the study site for the target species and life stage in terms of depth, velocity and substrate. These habitat components are normally the primary ones affecting fish distribution during the non-irrigation season. Although the model provides an accurate assessment of habitat suitability in the main channel of the river, it may provide an incomplete analysis especially for rivers like the Snake. For example, in large rivers the model tends to overlook the importance of some microhabitat components such as bank cover. In the Snake, bank cover comprises a relatively small percent of the total area of the channel yet provides important escape and resting cover for trout. The model also was not applied to any side channels in the river. Potential fishery impacts to these areas are addressed by other methods in this study.

Several different calibration techniques were used to obtain the best hydraulic simulation for this model (Milhous 1984). Suitability indices developed specifically for adult Snake River cutthroat trout winter habitat preferences were used to calculate weighted usable area (physical habitat) over the specified range of flows (Johnson et al. 1987).

A Habitat Retention method (Nehring 1979, Annear and Conder 1984) was used to identify maintenance flows at all riffle transects at the three study sites. A maintenance flow is defined as a continuous flow that is needed to maintain minimum hydraulic criteria at riffle areas in a stream segment. These criteria are important for providing passage for all life stages of trout between different habitat types and maintaining adequate survival of aquatic insects. The maintenance flow is identified as the discharge at which two of the three criteria in Table 3 are met.

Table 3. Hydraulic criteria used to obtain an instream flow recommendation for the Habitat Retention method.

Category	Criteria
Average Depth (ft)	Top width[1] X 0.01
Average Velocity (ft per sec)	1.00
Wetted Perimeter (percent)[2]	70

1 - At average daily flow
2 - Compared to wetted perimeter at bank full conditions

Hydrologic Analysis

Several major tributaries enter the Snake River between Jackson Lake Dam and SNR1. As a consequence, the instream flow recommendations which result from the 1988 studies must take these contributions into account. To address these inputs, a hydrologic analysis was conducted to determine the amount and percent of water at SNR1 that originates from the dam.

Data from stream flow gaging stations located on Pacific Creek and Buffalo Fork were used to provide a portion of this information. However, substantial amounts of water are also derived from Buffalo Fork below the gaging station, Lava Creek and Spread Creek. To estimate the amount of water originating in these drainages, a hydrograph simulation technique was used (Tom Wesche, Wyoming Water Research Center, Personal Communication).

This technique involved determining the discharge/area ratio for gaged streams in the upper Snake River drainage. This ratio was then averaged for all drainages by month. The area in ungaged drainages was then determined and multiplied by the average discharge/area ratio for each month. Additional studies may be needed to provide a more refined analysis.

RESULTS

Results of the hydrologic analysis revealed that reservoir releases comprise between 47 and 89% of the water at the 1988 study sites depending on season (Table 4). The highest ratio of water originating from the dam was during late summer when flows in tributaries decreased and irrigation releases from the dam were high. Between October 1 and March 31, releases from the dam comprise approximately 70% of the water at the study sites.

Comparison of measured flows at the study sites with releases from the dam were consistent with percentages shown in Table 4. For example, the average historic percent of water at the study sites in June, September and October that originate from JLD are 47, 89 and 64% respectively. Reservoir releases (Table 2) were 45, 88 and 50% of the water measured at the sites in 1988. Additional studies may provide better estimates of yield from the various sources shown in Table 4.

Table 4. Average monthly stream flows and estimates based on hydrograph simulation (cfs) for all drainages that contribute flow to the 1988 study sites on the Snake River. Percents of the total flow at these study sites for each drainage are shown in parentheses.

	JACKSON LAKE*	PACIFIC CREEK*	BUFFALO FK ABOVE GAGE*	BUFFALO FK BELOW GAGE**	LAVA CREEK**	SPREAD CREEK**	TOTAL
AREA (Sq Mi)	807	169	323	21	30	102	
OCT	748(64)	75(7)	249(21)	13(1)	18(2)	62(5)	1165
NOV	712(67)	70(7)	189(18)	12(1)	18(2)	60(6)	1061
DEC	670(71)	59(6)	151(6)	9(1)	12(1)	41(4)	942
JAN	631(74)	50(6)	126(15)	7(1)	10(1)	35(4)	859
FEB	524(69)	50(7)	132(17)	7(1)	11(1)	36(5)	759
MAR	798(75)	59(6)	141(13)	8(1)	12(1)	40(4)	1058
APR	423(71)	192(20)	258(13)	20(1)	29(1)	97(5)	2019
MAY	699(52)	851(17)	1003(19)	85(2)	122(2)	413(8)	5173
JUN	867(47)	1236(15)	2156(26)	134(2)	193(2)	650(8)	8236
JUL	3462(66)	283(5)	1134(22)	54(1)	78(2)	263(5)	5274
AUG	2247(78)	97(3)	390(14)	19(1)	27(1)	90(3)	2869
SEP	3429(89)	66(2)	252(7)	12(1)	18(1)	59(2)	3836
AVG	1459	270	564	31	46	154	2462

* - Historic average flow from gage data
** - Estimated from hydrograph simulation

Results from the Habitat Retention method employed at SNPC revealed that a stream flow of 1,301 cfs is the minimum flow that will maintain the identified hydraulic criteria at this site. This value is significantly greater than the maintenance flow recommendation derived using this method at the 1987 study site near the dam. The marked increase reflects the drastic change in river channel morphology that occurs in the Snake River at Pacific Creek.

Results from the Habitat Retention method at SNR1 and SNR2 also reflected the need for significantly more water to maintain the specified hydraulic criteria. The maintenance flow recommendations for these sites were 1,718 and 844 cfs respectively.

The Habitat Retention method was also used to determine the stream flow necessary for maintaining hydraulic criteria in side channel riffles between Pacific Creek and Moose. The recommendation was determined by identifying a maintenance flow for the side channel at SNR3 and subsequently identifying the flow in the main channel that produced this side channel flow.

Results from this method showed that the maintenance flow recommendation for the side channel at this study site is 202 cfs. The same water surface elevation in the main channel results in a flow of 1,635 cfs. The resultant total flow in the river is 1,837 cfs.

Results from the PHABSIM analysis at SNR1 indicated that usable area for adult Snake River cutthroat trout is maximized at 400 cfs (Figure 2). The percent of maximum usable area (MUA) decreases rapidly at flows less than 400 cfs. Percent MUA also decreases rapidly at flows above this flow level up to about 1,000 cfs. The model indicates relatively little change in suitability at stream flows between 1,000 and 9,000 cfs. The hydrologic analysis indicates that a release of approximately 280 cfs would be required from the dam to realize a 400 cfs flow at the study site.

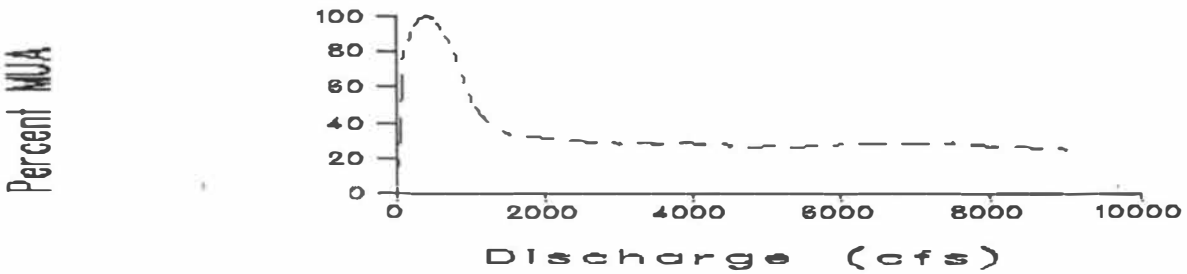

Figure 2. Changes in percent of maximum usable area for Snake River cutthroat trout with change in stream flow at SNR1 during the winter.

As noted earlier, the PHABSIM model provides information on only one component of habitat used by trout in the river. Specifically, it does not reflect the importance of bank cover for trout. Most of the escape and hiding cover in the river is found in overhanging vegetation, sloughing banks and snags associated with the banks. The main channel of the river away from the banks contains very little structure that is capable of providing this type of habitat. Although depths and velocities at lower flows improve for adult trout, other important habitat components are degraded which limit the overall suitability of the river for adult trout. Figure 3 illustrates how bank cover is completely covered and usable by trout at a flow of 4,500 cfs. Figures 4 and 5 show that bank cover is totally exposed at 400 cfs. At this flow level, trout are forced to reside exclusively in the main channel of the river where little cover is found. Table 5 summarizes the results from each study site and method.

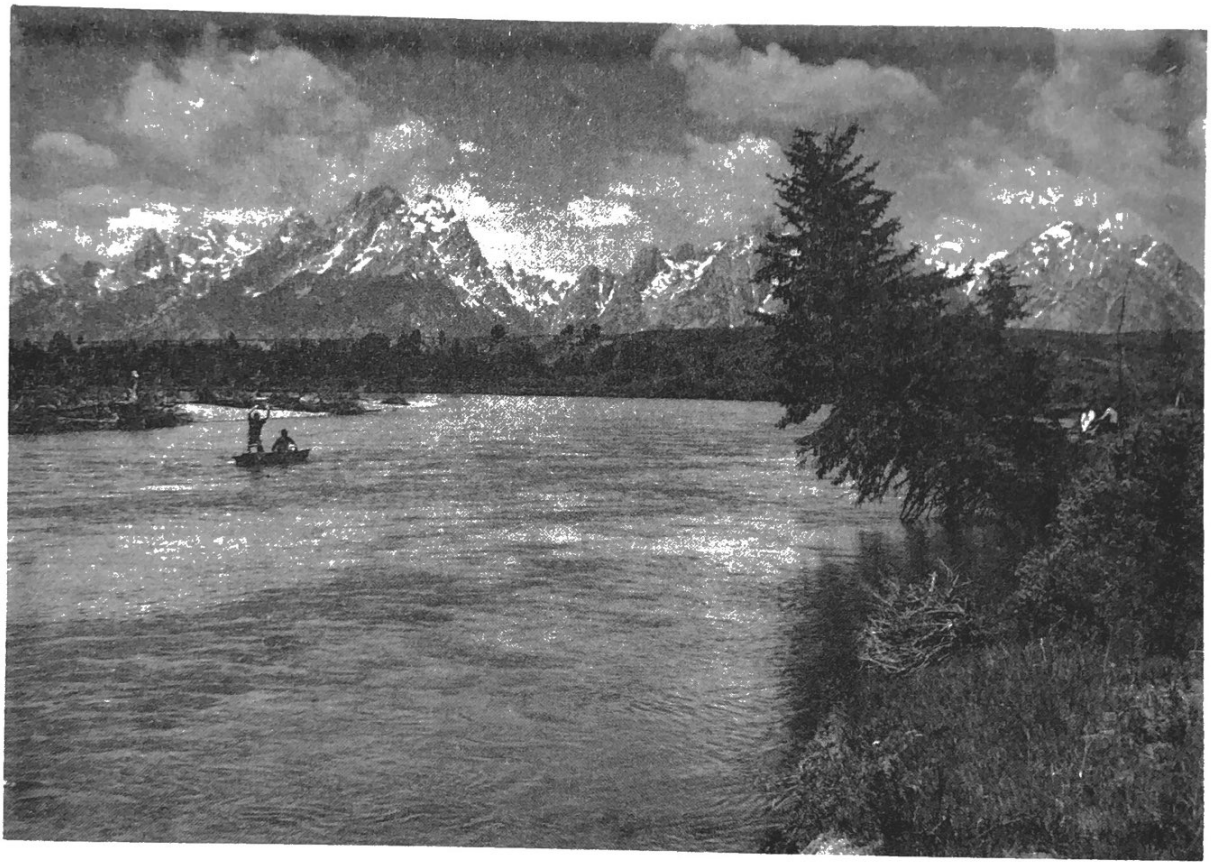

Figure 3. Snake River at SNR1 when main channel flow is 4,500 cfs. Bank cover is completely accessible to trout.

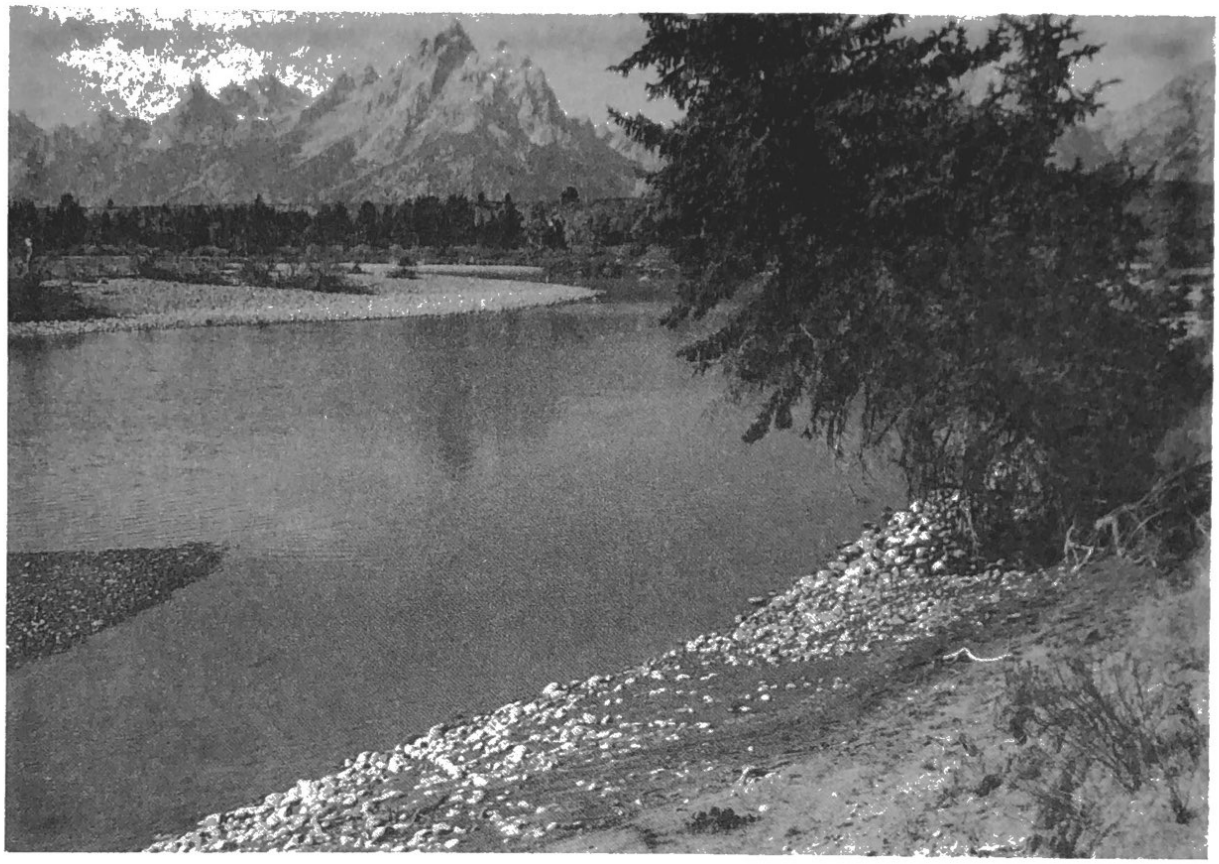

Figure 4. Snake River at SNR1 when main channel flow is 400 cfs.

Figure 5. Snake River at SNR1 when main channel flow is 400 cfs. Bank cover is exposed.

Table 5. Instream flow recommendations (cfs) from each method and study site on the Snake River in 1988.

SITE	METHOD	RECOMMENDATION	EQUIVALENT JLD RELEASE
SNPC	Habitat Retention	1301	911
SNR1	PHABSIM	400	280
SNR1	Habitat Retention	1718	1203
SNR2	Habitat Retention	844	591
SNR3	Habitat Retention	1837*	1286

* - Based on 202 cfs maintenance flow recommendation for side channel

DISCUSSION

Although resolution of instream flow conditions in the Snake River below Jackson Lake Dam is a high priority, this issue represents only a portion of a complex management problem. As illustrated by the two instream flow studies, different quantities of water may be needed to adequately manage the fishery in different segments of the river. In addition, releases from the dam may directly affect reproductive success of lake trout in Jackson Lake. If releases exceed inflows by too much for too long a period, some trout redds could be exposed, reducing recruitment to the important lake trout fishery in the lake. Instream flow releases could also affect storage of water for downstream water users.

Each of the methods used in this study provides information that addresses slightly different components of instream flow needs in the river below Jackson Lake Dam. Results from the Habitat Retention method in 1987 showed that a flow of 280 cfs is needed to maintain trout passage and aquatic insect survival in the segment of the river between the dam and Pacific Creek. This same method indicates that a maintenance flow of 1,718 cfs is needed to maintain trout passage and aquatic insect survival in the section of the river between Pacific Creek and Moose.

In order to maintain side channel habitat in the river segment between Pacific Creek and Moose, a stream flow of 1,837 cfs is needed. The PHABSIM analysis indicates that a stream flow of 400 cfs maximizes physical habitat for adult trout. Several trends and conclusions can be drawn from these results.

The sharp contrast in maintenance flow recommendations between the 1987 and 1988 study sites illustrates that the morphological characteristics of riffle habitats change significantly between these river segments. This situation indicates that flow reductions have much more serious fishery consequences for the river below Pacific Creek than above it. For example when releases equal 280 cfs (400 cfs at SNR1) maintenance flow criteria are met near the dam but are less than 25% of the flow needed to meet these criteria at SNR1. Actual field measurements showed that when the main channel flow at the 1988 study site equals 400 cfs, only 12 cfs flows down the side channel at SNR3. This low flow almost completely eliminates side channel habitat (Figure 6).

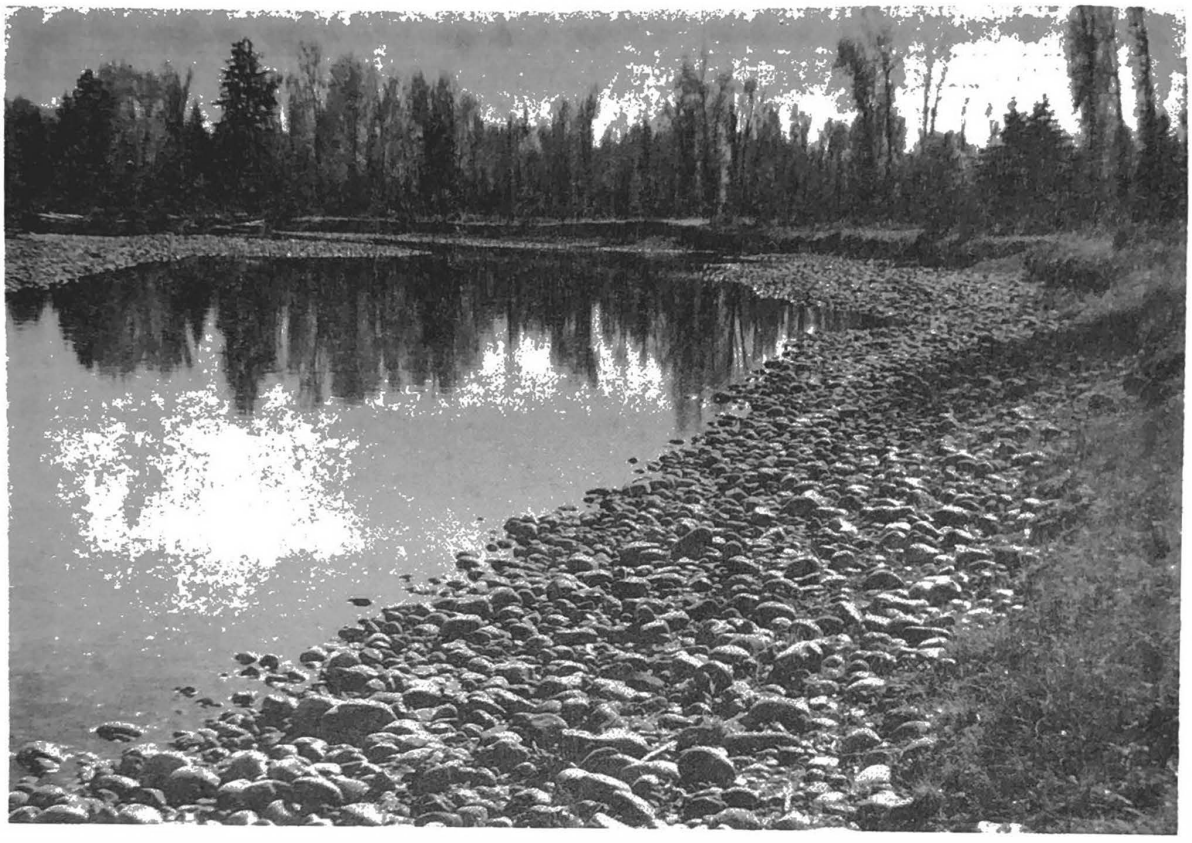

Figure 6. Side channel at SNR3 when discharge is 400 cfs in the main channel. Discharge in side channel is 12 cfs.

Since records have been kept, average releases from JLD have ranged between 524 and 798 cfs (759 and 1,058 cfs at SNR1) between October 1 and March 31 approximating natural inflows to the reservoir. These flows are as little as 44% of what the Habitat Retention method indicates is necessary to maintain adequate fish passage and survival. This is as little as 41% of the instream flow needed for maintenance of hydraulic criteria in side channels. Unlike most streams in Wyoming, natural winter flows in the Snake River are considerably less than the recommendations derived from the Habitat Retention model. This disparity provides a strong indication that, even under natural flow conditions, hydraulic attributes important for maintaining the fishery are extremely limiting. During periods when releases have fallen significantly below natural winter flow levels, fishery impacts have likely been even more severe. This finding does not indicate that such a shortfall precludes development and maintenance of a sport fishery in the Snake. Rather, it illustrates

how the fishery is limited by natural winter flows and places an emphasis on the importance of ensuring that winter flows in the river do not fall below natural or average winter flow levels.

The results from 1988 instream flow studies provide an indication that significantly greater releases of water from the dam than occur naturally are desirable for maintaining winter survival conditions. However, such a scenario is unlikely as the amount of water needed in excess of natural winter inflow is not readily available from Jackson Lake Dam. Providing these quantities could seriously impair other resource values such as lake trout spawning success, recreational uses and downstream water users.

In light of these findings, management strategies should focus on maintaining a base flow during the winter equal to historic average monthly flows or the natural instantaneous winter inflow to the reservoir, whichever is less. As shown by the data in Table 4, this operational strategy would result in a reservoir release approximating 700 cfs between October 1 and March 31 under average conditions. Based on the preliminary hydrologic analysis, this would result in a flow of 1,000 cfs at the 1988 study area.

Although these releases would fall short of providing recommended maintenance flows, they would accomplish several important objectives within the complex framework of managing the Snake River. Releasing instream flows according to the above criteria would allow storage of winter flows in excess of historic average flows for use by downstream water users. Flexibility to provide water for other recreational uses would be maintained. This management approach would also protect the lake trout fishery in Jackson Lake by maintaining relatively stable lake levels. In addition, this strategy would maintain the population of Snake River cutthroat trout in the river below the dam at historic levels.

SUMMARY

1. Instream flow studies have been conducted on the Snake River below Jackson Lake Dam in 1987 and 1988. These separate studies identified stream flow/fish habitat relationships for two distinctly different river segments.

2. Results from 1987 studies addressed only the portion of the river between the dam and the mouth of Pacific Creek. This 4.3 mile long segment of the river contains a relatively narrow, well-defined channel with a series of long deep runs. The fishery maintenance flow recommendation for this segment was 280 cfs.

3. Results from 1988 studies addressed the portion of the river between Pacific Creek and Moose. The habitat in this segment is significantly different from the river above Pacific Creek and consists of extensive side channels, wide riffles, deep pools and deep runs. Several different models and approaches were used to evaluate instream flow needs in this study area.

4. Results of a hydrologic analysis showed that approximately 70% of the water passing the 1988 study area between October 1 and March 31 originates from Jackson Lake Dam. The approximate release from Jackson Lake Dam needed to realize the various instream flow recommendations in the following summary items is shown in parentheses.

5. The fisheries maintenance flow recommendation for main channel portions of the river segment below Pacific Creek is 1,718 cfs (1,203 cfs).

6. Studies designed specifically to address maintenance of hydraulic criteria in side channels of the river segment below Pacific Creek provided a recommended flow of 1,837 cfs (1,286 cfs).

7. Results from a physical habitat simulation analysis showed that usable area for adult Snake River cutthroat trout in the main channel of the river below Pacific Creek is maximized at 400 cfs (280 cfs). Results from this method did not address maintenance of side channel habitat or the relative importance of bank cover for trout.

8. Under normal operating conditions, average releases from Jackson Lake Dam (which approximate total inflows) range between 524 and 798 cfs (759 and 1,058). These flow levels are as little as 41% of preferred instream flows in the river segment below Pacific Creek.

9. These findings indicate that the river fishery is more limited by natural winter flow conditions than most other Wyoming streams.

10. Although studies indicate that significantly greater flows are needed than are available naturally, several constraints exist which limit the feasibility of improving the existing situation. Providing these flows entirely from Jackson Lake Dam could seriously impact lake trout spawning success and also limit deliveries of water to downstream water users.

11. Management objectives should emphasize establishment of historic average releases or natural instantaneous inflows to the reservoir, whichever is less, as a base flow in the river. This operation strategy would provide storage waters for downstream water users, provide flexibility for recreational uses, maintain stable lake elevations which would protect lake trout spawning areas in the lake and maintain the Snake River cutthroat trout fishery at historic levels.

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