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Appraisal of watershed management program in Wind River basin, Wyoming

By

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WIND RIVER BASIN, WYOMING

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INTRODUCTION

At a Wind River basin meeting October 13, 1967, in Room 5031, Federal Building, Billings, Montana, and in a confirming memorandum to the Regional Hydrologist, U.S. Geological Survey, WRD, Denver, Colorado, dated October 17, 1967, Mr. H. F. Mosbaugh, Regional Coordinator, U.S. Department of the Interior, Missouri Basin Field Committee, Billings, Montana, requested that the Geological Survey submit an appraisal of the value of the watershed management program in the upper Wind River basin. The appraisal was to assess the value of the program to date, with an estimate of the value over the next 50 years. Mr. Mosbaugh also requested that a statement be included regarding current instrumentation in the Wind River basin and plans for future instrumentation.

The latter request presents no problem, but frankly, the Geological Survey is hard pressed for several reasons to assign a realistic value present or future, to the overall watershed management program in the upper Wind River basin. First, our field studies and data collection programs to date have been almost wholly aimed at determining runoff and sediment yields, channel stability, etc., in relation to various watershed characteristics and climatologic factors. Hence, Survey

personnel are generally unqualified, and thus hesitant, to place a value, especially a monetary value, on inferred benefits involving other disciplines such as changes in forage production, water for livestock, improved wildlife habitat, recreation, etc. Further, studies by the Geological Survey Soil and Moisture Program, aimed at appraising the results of watershed management programs in the Wind River basin were necessarily restricted by budget and personnel limitations to selected representative subbasins in the Muskrat Creek and upper Fivemile Creek watersheds. No attempt was made to determine the scope, magnitude, or past effectiveness of watershed management programs in Bighorn Draw, Muddy Creek, Dry (Pasup) Creek, Cottonwood Creek, Beaver Creek, Kirby Draw, and Badwater Creek watersheds. Extrapolation of results obtained from study basins in the Muskrat and upper Fivemile Creek areas to these other watersheds, therefore, is exceedingly tenuous at best. Despite these uncertainties, however, the writer will attempt to comply with Mr. Mosbaugh's request.

APPRAISAL OF THE VALUE OF THE PROGRAM TO DATE

The 1965 Appraisal Report prepared by the Missouri Basin Field Committee states that primary impetus for a coordinated watershed management program in the Wind River basin was furnished by the need to reduce the high sediment content of streams in the area and thereby increase the useful life of Boysen Reservoir. Thus, the writer believes that an appraisal of the value of the program to date should dwell largely on the effectiveness of watershed management programs in keeping sediment out of Boysen Reservoir.

Computation of volume of sediment kept out of Boysen Reservoir as a direct consequence of treatment

A determination of the effectiveness of sediment control programs in the upper Wind River basin would be greatly simplified if it could be assumed that an acre-foot of sediment retained in control structures in the upper reaches of treated watersheds were approximately equivalent to an acre-foot of sediment kept out of Boysen Reservoir. Unfortunately, this is not the case. For example, data from river basins in semiarid regions, such as the Wind River basin, characteristically show that unit rates of runoff and sediment yield generally decrease with increasing size of drainage basin. In other words, unit rates of runoff and sediment yield measured in the course of our studies in comparatively small upland basins might normally be expected to be somewhat higher than corresponding unit rates of runoff and sediment yield for the larger watersheds in which they are located. Another complication is introduced by the fact that floodwaters controlled and then released from a detention or diversion type structure in a headwater area after having dropped the bulk of their sediment load above the structure may again replenish their load by scouring the channel bed and banks as the flow moves downstream. A third complication is that reservoirs in noneroding areas may show very low sedimentation rates, yet they may detain flood flows and significantly reduce peak discharges in unstable alluvial channels downstream. The result may be a far greater reduction of sediment movement into Boysen Reservoir than volumes of sediment retained in headwater structures might indicate. Thus, measurements of sediment

retained in small upland reservoirs are not necessarily indicative of the effectiveness of those structures in keeping sediment out of Boysen Reservoir.

A direct computation of unit rates of runoff and sediment yield from records collected at gaging stations on streams draining the basin floor is also subject to considerable uncertainty. These stations were installed during the period 1947-49 just prior to initiation of watershed management programs by the Bureau of Land Management and the Bureau of Indian Affairs. The bulk of the records collected at these stations, therefore, reflect the effects of treatment programs within the respective watersheds. Calibration periods prior to initiation of treatment programs are not adequate to establish average unit rates of sediment yield from the watersheds in question.

In the absence of direct measurements, an indirect method has been used to approximate unit rates of sediment yield from watersheds prior to treatment by the Bureau of Land Management and the Bureau of Indian Affairs. Logic and procedure are described as follows:

> Muskrat Creek watershed at the gaging station near Shoshoni has a total drainage area of 733 square miles. The Bureau of Land Management structures in Logan, Mahoney, and Fraser Draws reduce the size of the contributory area to 600 square miles. Observations show that no outflow of water or sediment has occurred from any of these treated subbasins since closure of Boysen Reservoir in 1952.

Records collected at the Muskrat Creek station during the period October 1951 to September 1958, and October 1959 to September 1965 show a total suspended sediment load of 2,246,600 tons passing the station. Approximately 75 percent of this amount was measured during the period February 10-15, 1962, when snowmelt caused extreme basin-wide flooding.

Data furnished by T. F. Hanly1/ (written communication) show that the unmeasured (bed) load in Muskrat Creek is about 12 percent of the measured (suspended) load. Bureau of Reclamation data (1960, table 1) show that unit weight of sediment derived from Muskrat Creek watershed and deposited in Boysen Reservoir is 1,209 tons per acre-foot after 7 years compaction.

By computation from the foregoing data

$$\text{Volume of sediment deposited in Boysen Reservoir from Muskrat Creek Watershed, in acre-feet} = \frac{\text{suspended load in tons + bed load in tons (12\% of suspended load}}{\text{Unit weight of sediment in tons/acre-foot}}$$

$$= \frac{2{,}246{,}600 + 269{,}600}{1{,}209}$$

$$= 2{,}080 \text{ acre-feet}$$

This volume prorated over a period of 13 years (no record was collected during 1959) and a contributory area of 600 square miles is equivalent to 0.27 acre-foot per square mile per year.

1/ District Engineer, U.S. Geological Survey, WRD Subdistrict Office, Worland, Wyoming.

A similar computation for the Badwater Creek watershed, using appropriate data furnished by T. F. Hanly for bed-load (14% of suspended load) and Bureau of Reclamation data for unit weight of sediment after compaction in Boysen Reservoir (1,346 tons per acre-foot), but with no adjustment for the effects of the Bureau of Land Management treatment program, shows a unit sediment yield from the watershed over the period 1948-65 of 0.26 acre-foot per square mile per year. This figure would be only slightly higher, coinciding very closely with that computed for the Muskrat Creek watershed, if appropriate downward adjustments could be made in the size of the contributory area as a result of the Bureau of Land Management treatments. Rough estimates indicate that the Bureau of Land Management treatments in Badwater Creek watershed have controlled about one-eighth of the total area.

A general familiarity with virtually all ephemeral streams draining the basin floor enables the conclusion that a unit sediment yield of 0.27 acre-foot per square mile per year can be applied with considerable confidence to streams draining the south and eastern parts of the Wind River basin. Treated areas are generally typical of the larger watersheds in which they are located. A yield of 0.27 acre-foot per square mile per year, however, is much too low for those

severely eroding streams heading on the Wind River Indian Reservation in the northwestern part of the basin. Measurements on small reservoirs in the upper reaches of Fivemile Creek, for example, show unit rates of sediment yield that are two to five times as great as for comparable size subbasins in the eastern part of the Wind River basin. Sediment records collected at Fivemile Creek station above Wyoming Canal (see fig. 1) begin to show pronounced effects of treatment after 1950. Thus, only the first two years of record (1949-50) afford a measure of sediment yield from the watershed prior to treatment. A computation similar to that used for Muskrat Creek and Badwater Creek watersheds shows a unit sediment yield of 0.79 acre-foot per square mile per year for this two-year period. Just how representative this figure might be of the long-term average, had no treatment been applied, is not known, but it checks very well with comparisons of data from small reservoirs (Missouri Basin Field Committee Appraisal Report, 1965, table 18). It may be tentatively assumed, therefore, that watersheds in the more severely eroding northwestern part of the Wind River basin have a unit sediment yield of approximately 0.8 acre-foot per square mile per year.

Computed volumes of sediment presumably withheld from Boysen Reservoir as a result of Bureau of Land Management and Bureau of Indian Affairs watershed management programs are shown in table 1. Studied opinion of the results of these computations is that the annual volume

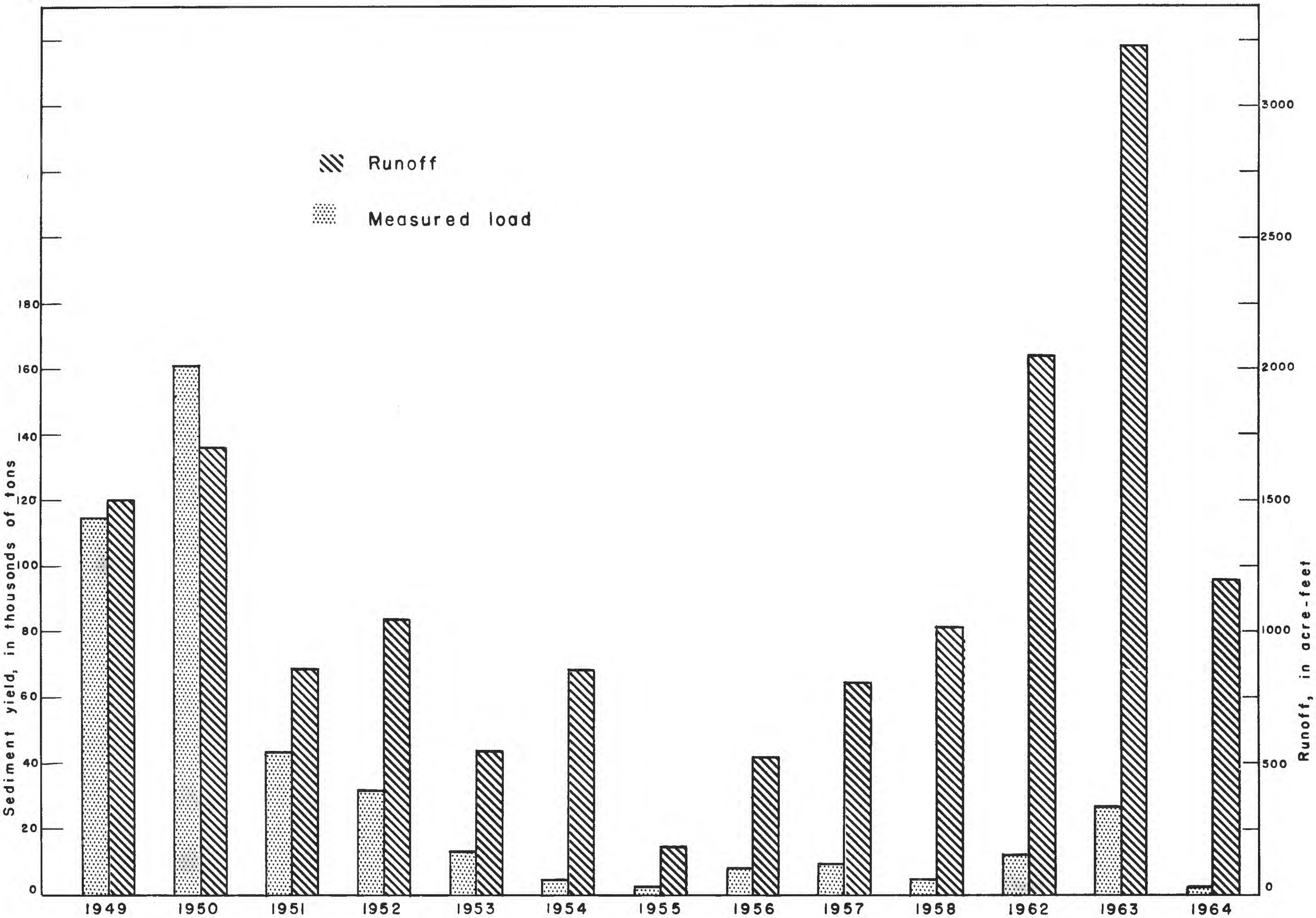

Figure 1.--Comparison of annual load to runoff, Fivemile Creek above Wyoming Canal near Pavillion.

Table 1.--Sediment kept out of Boysen Reservoir as a result of watershed management programs

Watershed	Area controlled by treatment (sq mi)	Effectiveness of structures in stopping sediment (percent)	Period of[1/] effective control of sediment movement (years)	Unit sediment yield (acre ft per sq mi per year)	Volume of sediment kept out of Boysen Reservoir: Annually (acre-ft)	Volume of sediment kept out of Boysen Reservoir: Total 1952-67 (acre ft)	Remarks
Bureau of Land Management							
Muskrat Creek	133	100	16	0.27	36	580	Reservoir records very good.
All other watersheds in eastern part of Wind River basin	342[2/]	80[3/]	10[3/]	0.27	74	740	Approximate only.
Bureau of Indian Affairs							
Fivemile Creek above Wyoming Canal	118	90[4/]	15	0.8	85	1,270	Reservoir records fair to good.
Big Muddy Creek above Wyoming Canal	260[5/]	90	10[3/]	0.8	187	1,870	Watershed and controls very similar to Fivemile Creek. Effectiveness of structures in stopping sediment assumed to be same.
Cottonwood Creek	150[5/]	50[3/]	10[3/]	0.8	60	600	Structures damaged by floods with loss of effectiveness after 1960.
Kirby and Beaver Creeks	130[5/]	35[3/]	10[3/]	0.27	12	120	Approximate only.
Plains Area	100[5/]	50[3/]	14[3/]	0.27	14	200	Do
					468	5,380	

1/ Many structures were not completed at time of closure of Boysen Reservoir. Effective life of control systems, therefore, may be less than period since closure of Boysen Reservoir.

2/ Data furnished by Bureau of Land Management, Lander District, Wyoming.

3/ Estimated from general knowledge of area and data furnished by Bureau of Land Management and Bureau of Indian Affairs.

4/ Computed from ratio of sediment passing station 1952-65 to computed amount from watershed for same period in absence of treatment program.

5/ Data from Misouri Basin Field Committee Appraisal Report (1965, table 1).

of sediment kept out of Boysen Reservoir as shown in table 1 is probably slightly on the high side, if anything, but no more than by a factor of 1.5. The total volume of sediment kept out of Boysen Reservoir to date (1952-67) as shown in table 1 is also probably on the high side, but the margin for error is somewhat higher than for annual volumes because of the uncertainties involved in estimating the average length of time that control systems have effectively withheld sediment from Boysen Reservoir. In Fivemile Creek watershed, for example, construction began in 1946, but present control of water and sediment was not achieved until 1954.

Volume of sediment kept out of Boysen Reservoir
as an indirect consequence of treatment

It is a matter of record that the great bulk of the sediment being deposited in Boysen Reservoir immediately following its closure was derived from erosion of the banks of Fivemile and Muddy Creeks by wastewater from the Riverton Project. Channel controls installed by the Bureau of Reclamation have reduced present sediment loads of these streams to about 10 percent of the load they carried in 1952. Elimination of flood flows from the upper basins on both Fivemile and Muddy Creeks undoubtedly facilitated stabilization of these channels in their lower reaches. The Bureau of Reclamation estimates that the savings in flood damage as a direct result of upstream controls is about $5,000 annually. The writer cannot flatly state that upstream flood control is essential to continued stability of Fivemile and Muddy Creek channels on the Project area, some hydrologists believe not, but it is unreasonable to

discount success--and the present combination of upstream flood control with downstream bank protection has been eminently successful. Although quantitative estimates are not possible, the writer is inclined to attribute a part of the reduction in bank erosion on the Project area and, thus, a reduction in part of the sediment load to Boysen Reservoir, to upstream flood control on Indian lands.

Changes in channel morphology resulting in aggradation have occurred downstream from controlled subbasins in the Muskrat Creek watershed, and presumably in other watersheds in the basin not included in our appraisal studies. Initially, it appeared that accumulation of sediment in main channels, such as that observed on Conant Creek in the Muskrat Creek watershed (Missouri Basin Field Committee Appraisal Report, 1965, p. 96) might be important in reducing movement of sediment into Boysen Reservoir. Scour during the 1962 flood, however, apparently flushed out large quantities of sediment that had accumulated in the main channel of Muskrat Creek and initiated headcuts on tributaries that threaten to remove deposits like the one in Conant Creek. It appears, therefore, that volumes of sediment kept out of Boysen Reservoir as an indirect consequence of treatment have been small except in the Fivemile and Muddy Creek watersheds.

Other benefits

The land-management agencies list an impressive number of benefits other than flood control and sediment abatement as a direct consequence of watershed management programs. Among these are reduced damages to roads and bridges; improved forage utilization because of fencing and

an almost fourfold increase in water sources; improved wildlife habitat, which has greatly enhanced recreational hunting; and locally increased forage production, especially along Fivemile Creek and Muddy Creek channels, which have been largely converted from raw eroding gullies to well-vegetated, stable channels. Efforts to increase forage production through construction of waterspreaders have been generally disappointing because of deficient runoff. The writer readily acknowledges the worth of the benefits listed above, but as previously stated, he is unable to even approximate their value.

Significant intangible benefits have also accrued to the Geological Survey as a consequence of the watershed management programs initiated in the Wind River basin. At the outset of those programs Survey hydrologists knew very little about the hydrology of upland areas in dry climates. Processes of headcutting, gully formation, and channel erosion were only superficially understood. Virtually nothing was known about the relative merits of various treatment practices or the consequences of treatment, onsite and offsite. Today, much remains to be learned, but the science of conservation on arid and semiarid lands has come a long way. Successes and failures have demonstrated the advantages of some practices over others. In their attempts to evaluate treatment programs, Survey hydrologists have acquired both method and efficiency and gained some understanding of natural processes operating in ephemeral stream channels. Only the future will reveal the true value of these intangible benefits when know-how gleaned from studies in the Wind River basin is applied to similar watershed management programs on eroding lands elsewhere in the Western United States.

ESTIMATE OF THE VALUE OF THE PROGRAM OVER THE NEXT 50 YEARS

Observations on treated areas in the Muskrat Creek and upper Fivemile Creek watersheds show that these systems have functioned very well to date. Structures in the Muskrat Creek watershed completely controlled all runoff from their respective contributory watersheds during the 1962 flood with no apparent damage. A flood frequency plot using maximum 5-day discharges (see fig. 2) indicates that the 1962 flood may have a recurrence interval of more than 200 years. It can be assumed, therefore, that structures in Muskrat Creek watershed have been adequately tested by a major flood. Structures in upper Fivemile Creek watershed have not been subjected to a comparable test, but there is no reason to believe that they are less durable than their counterpart in Muskrat Creek watershed.

Probably the greatest threat to the continued effectiveness of structures in both Muskrat Creek and upper Fivemile Creek watersheds--and presumably to structures in the other watersheds treated by the Bureau of Land Management and the Bureau of Indian Affairs--is the gradual loss of capacity as sediment accumulates in reservoir basins. Measurements show that present rates of sediment yield to structures in the eastern part of the Wind River basin, if projected over the next 50 years, offer no serious threat to their continued effectiveness. Very probably the life expectancy of most structures could be extended considerably beyond 50 years by installing sediment barriers at the upper end of reservoir basins. The same cannot be said for structures in the northwestern part of the Wind River basin where unit rates of sediment yield are comparatively high. Control systems as a whole remain effective with the exception of the Cottonwood Creek watershed.

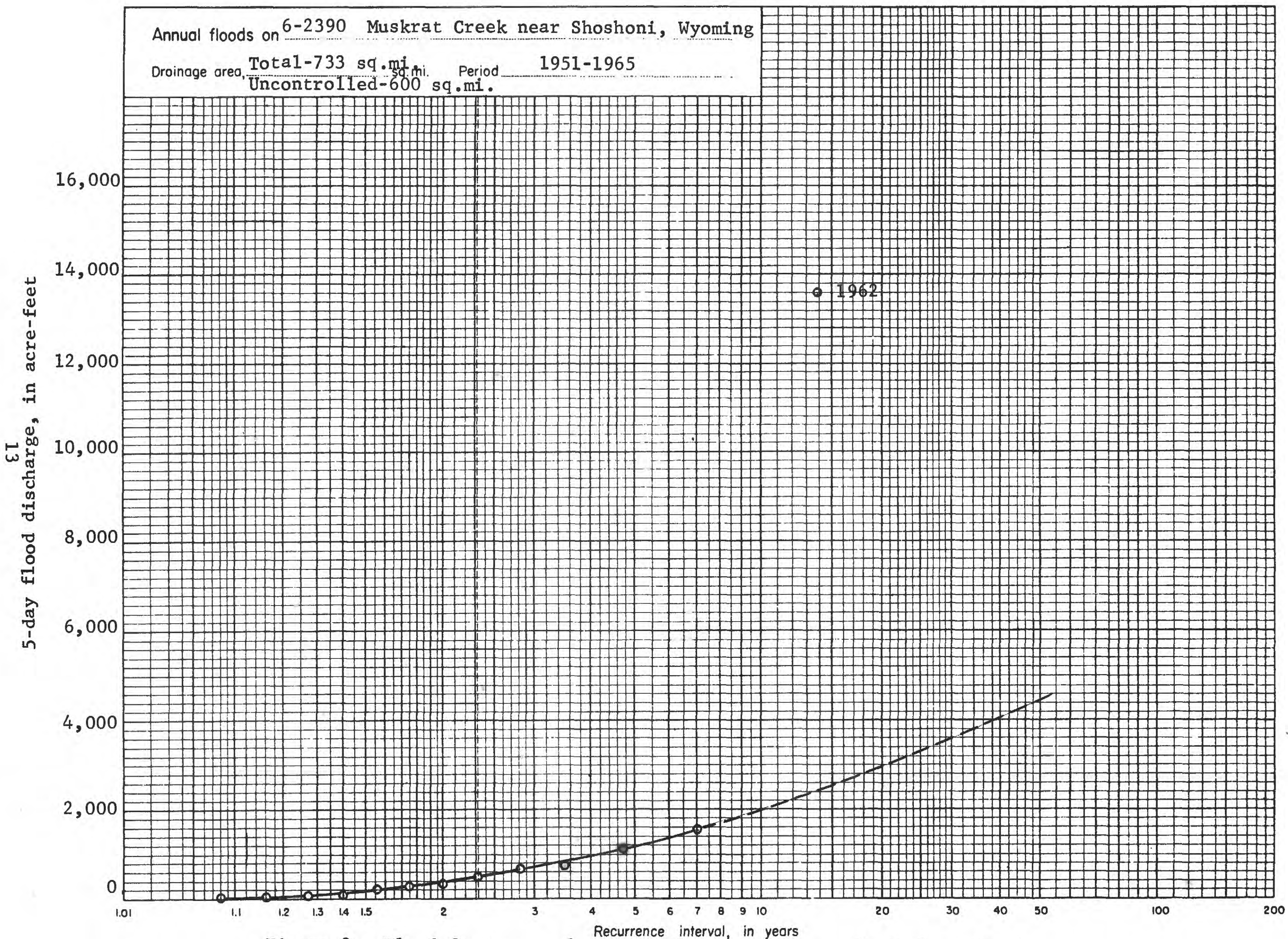

Figure 2.--Flood frequency plot using 5-day discharges in Muskrat Creek.

Performance of individual structures, however, depends on their location in the drainage net with respect to actively eroding hillslopes or gullied channels. For example, in Blue Draw a headwater tributary of Fivemile Creek, 7 out of 9 reservoirs have been completely filled with sediment and one of the filled reservoirs has breached in a period of less than 15 years. As a result of this entrapment of sediment upstream, downstream reservoirs have received comparatively little sediment. Fivemile Creek Reservoir, the lowermost structure on upper Fivemile Creek, shows a sediment yield of only 0.10 acre-foot per square mile per year for the period 1956-67. Assuming that upstream structures were repaired and that sediment barriers were installed above existing reservoirs, the life of the system could probably be extended another 50 years. Much depends on what happens in the channel of Fivemile Creek upstream from Fivemile Creek Reservoir. Continued stability and aggradation throughout this reach of the stream could greatly prolong the life of Fivemile Creek Reservoir and, thus, the effectiveness of downstream flood control. Conversely, any upset in the present channel stability would have the opposite effect.

Assuming continued maintenance of structures with no overall loss in the effectiveness of watershed systems for controlling runoff and sediment movement, the volume of sediment kept out of Boysen Reservoir over the next 50 years could be as much as 23,800 acre-feet. More likely, the amount would be somewhat less than that owing to a gradual loss in effectiveness of control systems despite maintenance.

The value of other benefits projected over the next 50 years is difficult to assess. Forage production and wildlife habitat along stream channels, especially along Fivemile and Muddy Creeks, should increase in value with time. Also, waterspreaders may become more productive as reservoirs fill with sediment and overflow more frequently. On the other hand, siltation of reservoirs will reduce their effectiveness as flood-control structures and as sources of water for livestock and wildlife.

It is possible that watershed management programs may induce downstream changes in channel regimen resulting in aggradation and the healing of old gullies. Future evaluation studies in the Muskrat and Fivemile Creek watersheds will be broadened to cover this aspect of treatment.

CURRENT INSTRUMENTATION OPERATED BY THE GEOLOGICAL SURVEY IN THE WIND RIVER BASIN AND PLANS FOR FUTURE INSTRUMENTATION

Soil and Moisture Conservation Program

The Geological Survey, through the Soil and Moisture Program, is currently collecting data through instrumentation at 13 sites. This program is financed wholly by direct appropriation of Soil and Moisture funds. Types of data collected and location of gages are shown in table 2. Tentative plans are to enlarge the scope of activities in the upper Fivemile Creek watershed beginning in April 1968. Two additional recording precipitation gages and about 3 nonrecording (storage type) precipitation gages will be installed. A number of monumented channel cross-sections will be established on Fivemile Creek upstream from Fivemile Creek Reservoir. Resurveys will be made annually to determine sediment yield to Fivemile Creek Reservoir.

Table 2.--Instrumentation operated by the Geological Survey, Soil and Moisture Conservation Program, in the Wind River basin, Wyoming

Location	Precipitation		Continuous Water-stage recorder
	Recording	Nonrecording (Storage)	
Logan Draw	3	1	1
Fraser Draw	2	--	1
Graham Draw	1	2	--
Fivemile Creek	1	--	1
	7	3	3

Wyoming District Program

The Geological Survey, through the Wyoming District office, is presently collecting data at 80 sites. According to R. C. Williams[1/] (written communication) this program, as in the past, is financed by the Missouri River Basin program and by Federal and State agencies. The only Geological Survey funds used in the collection of these data are federal-state matching funds. The types of data collected and the sponsors are given in table 3. Because the program is entirely dependent on funds from sponsoring agencies, definite plans cannot be made for future instrumentation.

1/ Supervisory Hydrologist, U.S. Geological Survey, Basic Data Section, WRD District Office, Cheyenne, Wyoming.

Table 3.--Instrumentation operated by the Geological Survey, District Program, in the Wind River basin, Wyoming

Types of data	Number of Sites							Total Number of Sites
	State Sponsors				Federal Sponsors			
	WSE	WDA	Wyo. Hwy.	NRB	USBR	BLM	MRB	
Streamflow	6			1	2	1	12	22
Stage-Rainfall			9					9
Crest-Stage			22					22
Chemical Quality		7					1	8
Sediment					2	1	6	9
Observation Wells	10							10
	16	7	31	1	4	2	19	80

WSE = Wyoming State Engineer

WDA = Wyoming Department of Agriculture

Wyo. Hwy. = Wyoming Highway Department

NRB = Natural Resources Board

USBR = Bureau of Reclamation

BLM = Bureau of Land Management

MRB = Missouri River Basin program

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