ICING AFFECTS FALL DISCHARGE CHARACTERISTICS OF A RANGELAND STREAM

By
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INTRODUCTION

The influence of ice formation on river discharge has been the subject of numerous investigations. Similar studies have not extended to small streams where ice effects, in relation to stream discharge, may have an even greater hydrologic impact. This paper describes how increasing distance from a spring in combination with ice formation in the fall and early winter, altered short-term discharge characteristics of a small stream originating on sagebrush rangeland.

STUDY SITE

Data were collected from the Loco Creek (668 ha) and Sane Creek (238 ha) watersheds located on the Stratton Sagebrush Hydrology Study area (2300-m elevation) in south-central Wyoming. The Sane Creek streamgage is located 45 m below a spring. Water flows 4.6 km from the Loco Creek spring before reaching the stream gage. Discharge is continuously measured through 120° V-notch weirs.

Spring discharge is stable, but flow gradually diminishes through the winter. Average discharge of Loco and Sane Creek in late fall is 0.006 and 0.002 m^3/sec, respectively, and the streams are about 0.6 m wide. Both springs discharge water at approximately 4°C in the fall. Water remains above freezing at the Sane Creek streamgage through the winter. In the fall, ice forms on Loco Creek downstream from the spring in response to subfreezing air temperatures, but melts once snow covers the channel.

PROCEDURES

The variability in daily flow volume during the 154-day interval from September 15 to February 15, was examined using a modular coefficient, K. The coefficient was derived by dividing each day's discharge by average discharge for the 15 days before and after the day in question. Twenty-one years of record extending from September 15, 1968 to February 15, 1989 were used in the analysis. A frequency distribution was constructed from daily modular coefficients. The distribution of K was tested for normality with the Cramér-von Mises statistic, modified for the case of a known mean (1.00 for data transformed to modular coefficients), and an unknown variance (Stephens 1974). Separate analyses were performed for each creek for each year of record, and for data ensembles.

RESULTS

The daily flow regime of Sane Creek was extremely stable. There were no days in the 21-year record period when discharge at the streamgage was reduced as much as 10%. In contrast, daily discharge at the Loco Creek streamgage was more than 25% below average on 55 days and more than 50% below average on 16 days. The earliest date of flow reduction was October 11, and the last date was January 24. Flow was more than 25% below average on 14, 13, 15, and 13 days in October, November, December, and January, respectively.

Testing of Modular Coefficients for Normality

The dispersion of Sane Creek's modular coefficients about the mean value of 1.00 was much less than the dispersion in Loco Creek data (Fig. 1), reflecting the uniformity of daily discharge at Sane Creek. The data ensembles for Sane Creek and for Loco Creek were not normally distributed (0.05 probability level). Seasonal data for Sane Creek data from 18 of the 21 intervals were normally distributed, but seasonal data for Loco Creek were normally distributed in only 4 of the 21 intervals.

Presented at 58th Western Snow Conference, April 17-19, 1990; Sacramento, CA.

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"Reprinted Western Snow Conference 1990"

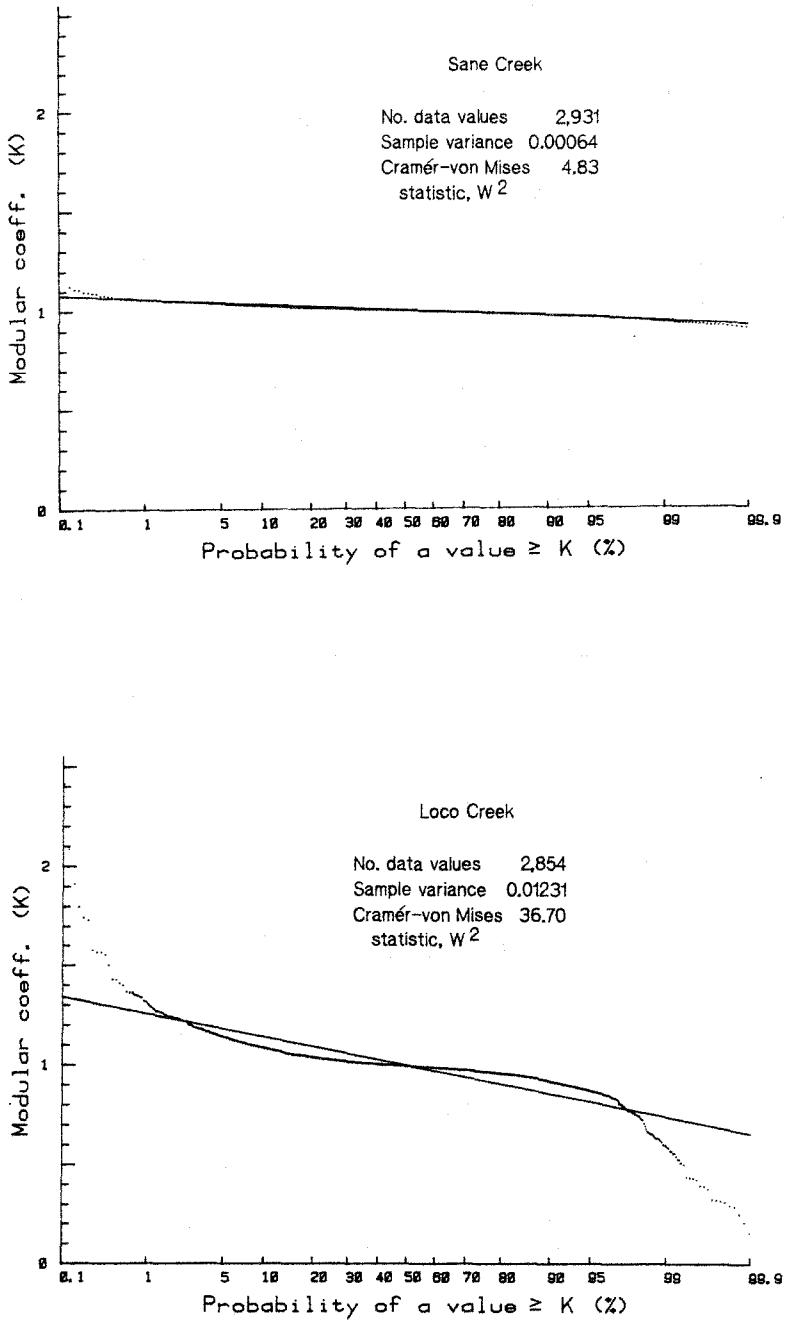

Figure 1. Frequency distribution of modular coefficients for data ensembles from Sane Creek (top) and Loco Creek (bottom). Plotting positions along the normal probability scale are 100 m/(n+1), where m is rank in order of increasing magnitude, and n is the number of observations (Gumbel 1954). The solid line is fitted to data values.

Intraday Discharge Rates

Freeze-thaw periods had a strong effect on intraday discharge rates of Loco Creek in most years, but did not influence Sane Creek. Ice formation on Loco Creek during October and November (Fig. 2), acted to temporarily withhold water from the creek, causing the flow rate at the streamgage to decrease substantially below the average discharge rate for the day. Drifted snow covered the channel in December, insulating the creek from the atmosphere and causing the large variation in intraday discharge rates to disappear. Minimum instantaneous discharge was substantially below that of Sane Creek on several days even though Loco Creek's flow is normally three times larger than Sane Creek's flow. Subsequent melting of ice, or breaching of ice dams, commonly elevated maximum instantaneous discharge four or more times above the average discharge rate for the day. The duration of erratic flow on Loco Creek was highly variable from one year to another.

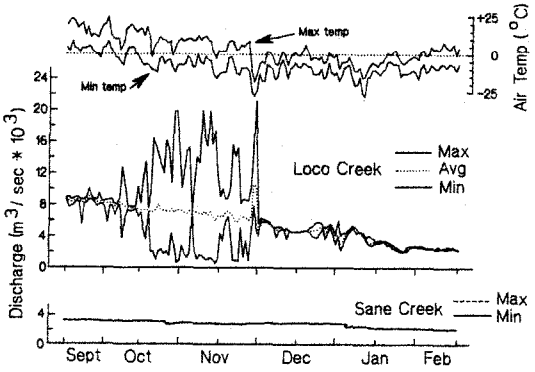

Figure 2. Daily maximum and minimum discharge on Loco and Sane Creek, and maximum and minimum daily air temperatures for the period, September 15, 1976 to February 15, 1977. The effects of icing on Loco Creek discharge were unusually pronounced in October and November of 1976. Maximum and minimum daily discharge values on Sane Creek were identical on most days.

DISCUSSION AND SUMMARY

The data ensembles for Loco and Sane Creek data did not show a normal distribution in contrast to findings by Markovic (1965) and Tabler (1982) who worked with annual streamflow, precipitation, or snow course data. They utilized modular coefficients calculated by dividing the yearly observed data value by the long-term station mean. Daily modular coefficients in this study were not independent of one another because of the correlation in discharge between consecutive days, and the use of a running average to determine mean discharge. The use of modular coefficients, however, was effective in demonstrating the effects of icing on discharge characteristics.

The short-term effects of icing on a small stream such as Loco Creek are negligible if flow characteristics are expressed over a monthly or yearly time span, but such effects may be biologically significant. The temporary reduction in discharge could reduce fish abundance in streams of marginal habitat, and algae and macroinvertebrate populations may also be affected. Frost action along dewatered banks and rapid changes in water depth and water velocity can loosen sediment, which then becomes available for transport once flow increases during snowmelt.

Differences in flow characteristics measured at the Loco and Sane Creek streamgages in fall and early winter were attributable to the combined effects of icing and the length of stream exposed to the atmosphere. Daily flow on Loco Creek was more than 25% below average on 55 days over a 21-year record period; flow at the Sane Creek streamgage was stable because water remained above freezing. Intraday discharge characteristics were also strongly affected by icing, but the wide fluctuation in daily flow rates dissipated once a snow cover insulated the creek from the atmosphere.

ACKNOWLEDGMENT

The author is most appreciative of the help provided by Dr. Ronald D. Tabler (President of Tabler and Associates, Consultants in Snow and Wind Engineering) to calculate and statistically analyze discharge probability functions presented in this paper.

Portions of the research reported here were conducted in cooperation with the Bureau of Land Management, U.S. Dept. of Interior.

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