WATER LOSSES AND GAINS ACROSS THE PAHASAPA LIMESTONE, BOX ELDER CREEK, BLACK HILLS, SOUTH DAKOTA

Thomas J. Crooks
Department of Geology and Geological Engineering
South Dakota School of Mines and Technology
Rapid City, South Dakota

ABSTRACT

Box Elder Creek, which originates in the central Black Hills, has a drainage area of approximately 100 square miles above the point where the stream starts across the outcrop of the cavernous Pahasapa (Madison) Limestone. The stream length across the outcrop is 5.8 miles, although the true down-dip width is only about 2 miles. Varying volumes of water alternately disappear into sinkholes along the stream and reappear downstream as springs from caverns or apparently from the gravel stream bed.

As shown by monthly discharge profiles compiled from measurements made at selected points along the creek, the net water loss across the Pahasapa outcrop ranges from the entire flow when initially less than 15 cubic feet per second up to a maximum of 43 cubic feet per second when the initial flow is in excess of the latter figure. (Additional losses appear to be dependent upon the stream's access to loss areas lying above the normal water level.)

Variation in temperature of the surface flows and the springs and the relationship between the volumes of water starting across the limestone outcrop, the distribution of losses to sinkholes, and the discharge of the springs indicates very close connections between the sinks and springs.

INTRODUCTION

A proposal to investigate water losses and gains along the principal streams on the eastern slope of the Black Hills was approved and financed by the United States Department of the Interior's Water Resources Research Office in the spring of 1966.

The investigation was confined to gaging of stream flows, location of sink areas, and determining the relationship of sinks to springs in the Mississippian limestone outcrop belt. The subject of this paper is Box Elder Creek, one of the eight streams under investigation (Figure 1).

Cooperation and assistance was received from many individuals and agencies too numerous to mention in this brief paper.

GEOLOGY

General geology. The Black Hills of South Dakota and Wyoming form a northwest trending roughly elliptical uplift about 120 miles long by 60 miles wide (Figure 1). The formations pertinent to the following discussion are, from youngest to oldest:

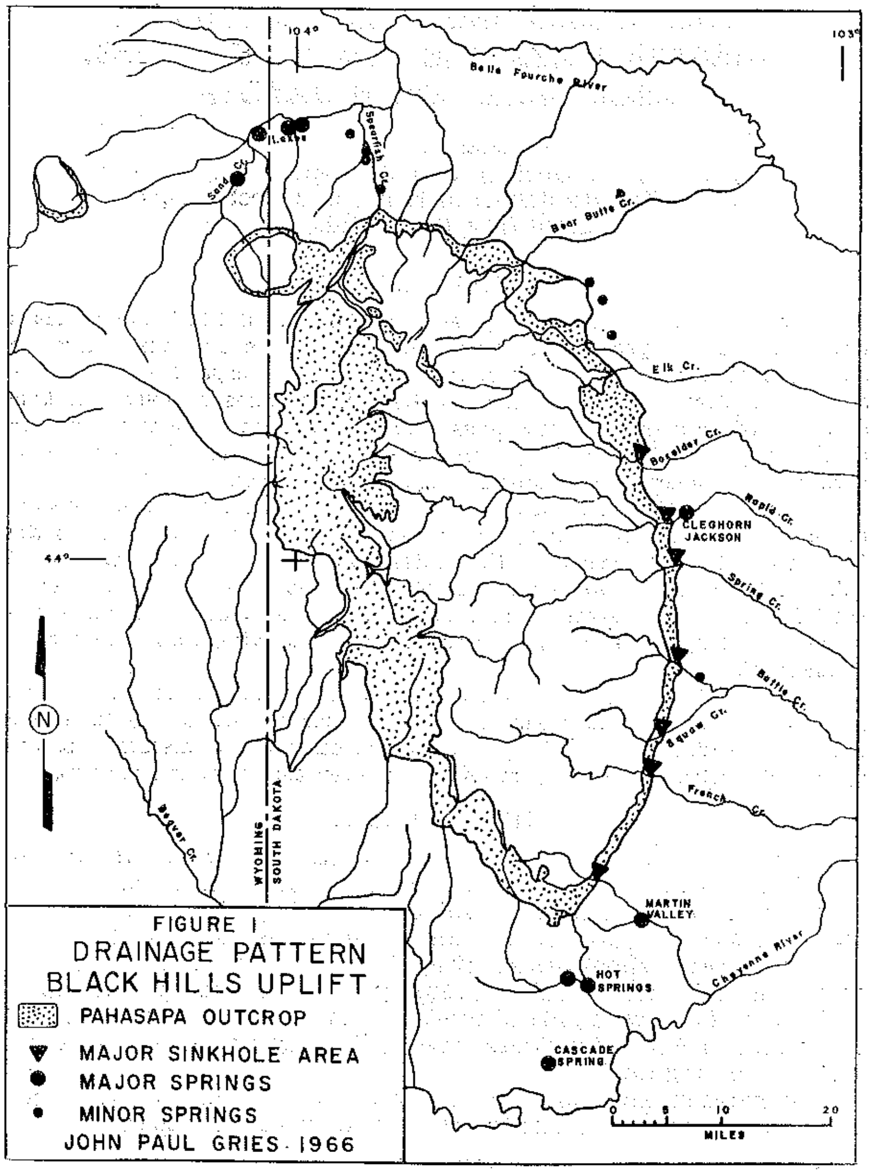

Figure 1. (after Gries, in press) Drainage Pattern, Black Hills Uplift

Minnelusa Formation:	Consisting of 450 to 800 feet of sandstones, dolomite, and shale of Pennsylvanian-Permian age.
Pahasapa Formation:	Consisting of 300 to 650 feet of limestone and dolomite of Lower Mississippian age.
Englewood Formation:	Consisting of 30 to 40 feet of dolomite and limestone of Upper Devonian-Lower Mississippian age.

Geology of the Box Elder Creek area. The three previously mentioned formations are present in the Box Elder Creek area and are generally as described. Their thicknesses range from 450 feet for the Minnelusa Formation to 425 feet for the Pahasapa Formation down to 40 feet for the Englewood Formation.

The Englewood outcrop in the creek bed has not seriously been considered as a water inductor although possibly a small amount is lost to fractures and bedding plains.

The regional dip of the Pahasapa Formation along Box Elder Creek (Figure 2) is about 5° east; the strike is approximately N 7° W. Minor variations in strike and dip which exist in the area are caused by undulations within the limestone.

The strike of a number of vertical or nearly vertical fractures were measured in the field, and bearings were taken of prominent gullies which appear to be controlled by fractures. No definite patterns were found although the similarity of the bearing of a number of straight sections of the creek to measured fractures seems to indicate that the path of the creek through the limestone is at least partly controlled by fractures. It is reasonable to suppose that solutions channels developed along fractures in this area would have similar trends.

From observations made in sink areas along the creek, it is felt that the water losses are almost entirely to cavern systems which have been intercepted by the creek bed and to vertical fissures or open fractures which may extend partially or completely through the limestone section. In a number of places, the sinks have greatly changed in appearance in a short time, becoming larger and deeper. These enlargements seem to indicate that a cavern system is involved in each case as it seems unlikely that open fractures would be able to accommodate the volume of material which has apparently collapsed into them. In some instances, chains of sinks have been located which are very well aligned with large open vertical fractures in the canyon wall immediately opposite. Also, loss has been observed to caverns and open fractures in the limestone on a number of other creeks and there is no reason to feel that the same does not occur on Box Elder Creek.

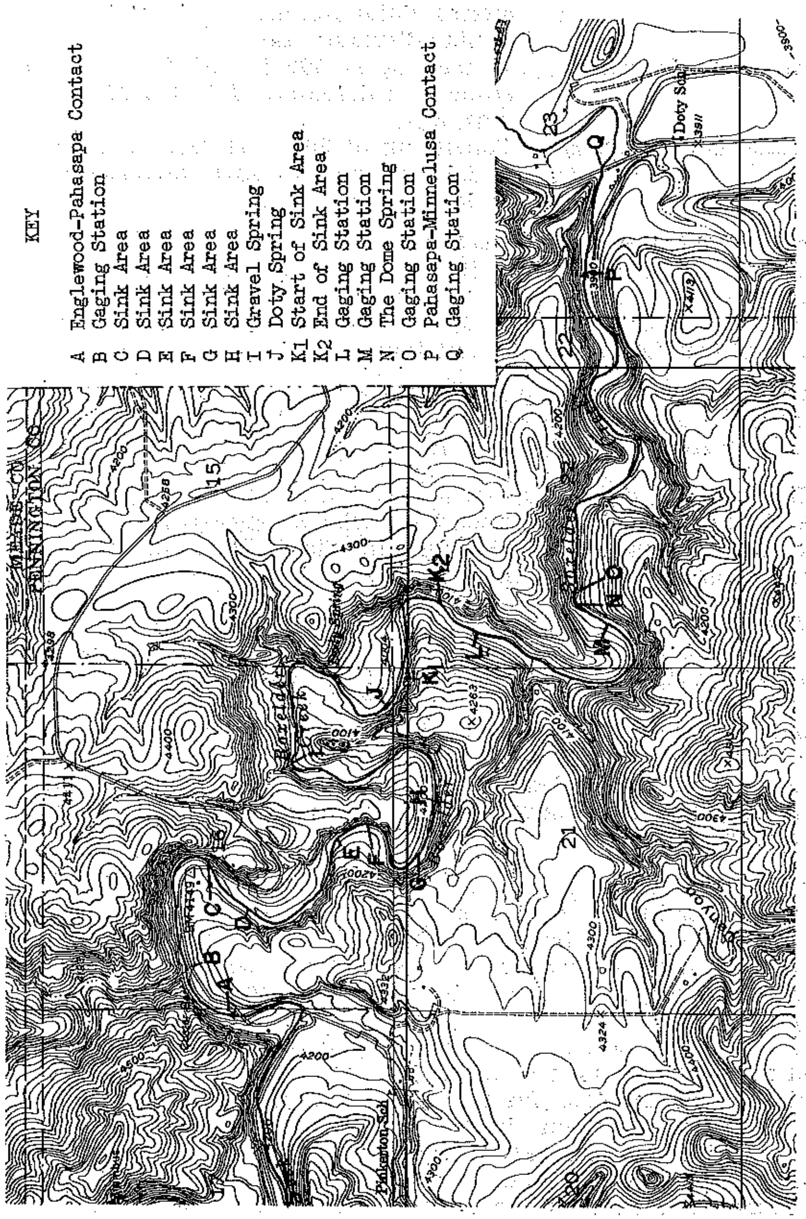

Figure 3. Comparisons of losses and gains, Box Elder Creek, Sept. 1966-April 1968

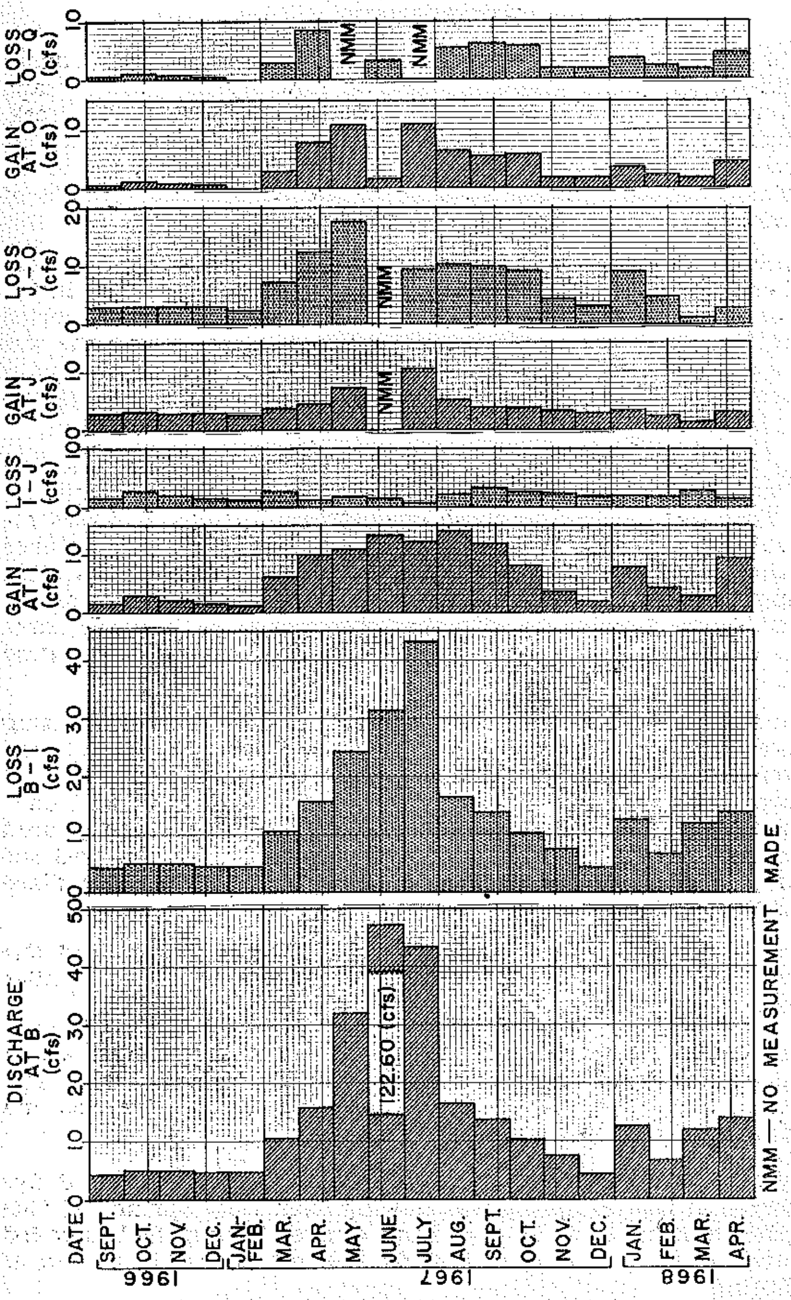

Figure 2. Topographic map of a portion of the Box Elder Creek drainage.

HYDROLOGY

The creek has a drainage area of approximately 100 square miles above the point where it starts to flow across the Pahasapa Limestone outcrop, just below the junction of Bogus Jim Creek. Although the creek must travel 5.8 miles to cross the limestone, the distance across in the true dip direction is only about 2 miles. As in most of the other major streams in the Hills, large volumes of water are lost to sinks throughout the length of the outcrop.

Specific monthly losses to the sinks and gains from the springs have been computed from the discharge data, and the correlation of losses to gains are evident during the drier months of the period (Figure 3). The correlations are not quite so close during the wet months of April through August 1967, and it is thought that this is a reflection of the high ground water level existing in the limestone during those months.

On the basis of the volumes of water disappearing into the sinks and the seemingly close correspondence with the amount being discharged from the three downstream springs, a direct relationship between the sinks and springs is inferred. This inference is further strengthened by temperature data which shows close correspondence of water temperature at the Custer Gap gaging station (Figure 2, point B) with that observed at each of the three springs (Figure 2, points I, J, and O) for each month of the gaging period.

On April 11, 1968, a dye tracing experiment was conducted using Fluorecein dye to determine, if possible, the relationship between the prominent School Section Bridge sink (Figure 2, point C) and the three major springs downstream. At 8:02 A.M., two and one-half quarts of concentrated Fluorecein dye solution were poured into the sink. Within ten minutes, most of the dye had entered the sink and, as far as could be determined, no dye entered the surface flow of the creek.

Water samples were collected from all three springs and the Henry Schmitz well which is approximately two and one-half miles southeast of the sink.

Gravel Spring discharged a heavy concentration of dye which started at 9:10 A.M. and continued for about an hour. The time elapsed between injection and the appearance of the dye was one hour and eight minutes.

By 11:55 A.M., virtually the same heavy concentration of dye as observed at Gravel Spring was flowing from Doty Spring. At this time, the overland flow of dye from Gravel Spring had traveled downstream to a point approximately 100 feet above the mouth of Doty Spring.

At The Dome Spring, the presence of dye was definitely established by the observation of a large dye cloud obscuring the previously visible bottom at 2:40 P.M. The dye at this time appeared considerably dilute compared to that seen at Gravel and Doty Springs. The time elapsed from injection to appearance at The Dome Spring was six hours and thirty-five minutes.

There is some uncertainty in the results obtained from examination of the water samples from the Schmitz well. Faint but definite fluorescence was observed in the samples taken 50, 75, and 100 hours after the dye injection.

CONCLUSIONS

Several conclusions have been reached in this investigation:

1. The speed with which the dye traveled from the School Section Bridge sink (Figure 2, point C) to the springs (points I, J, and O) and the high concentration of the dye indicates a much closer connection than previously suspected. Rather than a large network of small connected caverns and fractures, a nearly conduit-like connection is implied.

2. The subsurface water in these conduits moves faster than the surface water, as determined in the dye tracing experiment.