HYDROGEOLOGY OF LOWER SPEARFISH CANYON

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ABSTRACT

Presently Barrick Gold Corporation diverts Spearfish Creek into a tunnel in the lower portion of Spearfish Canyon. The water is taken through the tunnel and an aqueduct to Hydro #1, a hydroelectric power plant built by Homestake Mining Company in 1911. Just below the tunnel diversion site, the streambed crosses outcrops of the Madison Limestone and the Minnelusa Formation. While pre-diversion data is scanty, it appears that most of the water in Spearfish Creek continued past sinkhole zones in these formations to the present town of Spearfish. However, some recharge to these two aquifers most likely occurred in this reach prior to 1911. This recharge is believed to have supported the springs at the D.C. Booth Fish Hatchery. The tunnel diversion leading to Hydro #1 began in 1911, and the D.C. Booth Fish Hatchery springs failed approximately 5 years later, presumably because the springs were no longer being recharged in the upstream sinkhole zone. If, in the future, the tunnel diversion is abandoned and Spearfish Creek is returned to its natural condition, Spearfish Creek water should again recharge the two aquifers, and within approximately 5 years the D.C. Booth springs should flow again.

INTRODUCTION

Spearfish Creek is one of the major streams in the Black Hills, and it is a popular tourist attraction. The perennial flow of Spearfish Creek originates from cold spring water primarily discharging from the Madison Limestone and Minnelusa Formation. Route 14A is located in Spearfish Canyon, and is designated a “National Scenic Byway”. The 2003-2004 South Dakota Vacation Guide describes Spearfish Creek as “one of the prettiest streams in the Hills. Trout fishermen come to clear-running Spearfish Creek all year long.” However, through much of the lower Spearfish Canyon there is only a dry streambed. The water has been diverted into a 5.5 mile-long tunnel and aqueduct for the generation of electricity.

There is a long and complex history of the diversion of water in the northern Black Hills by Homestake Mining Company (HMC). Water has been diverted from numerous watersheds for the Homestake gold mine at Lead, SD. The diversions are based on the doctrine of appropriative rights, the water law in the western USA. In the late 1900s, HMC began diverting water in a series of aqueducts and tunnels from numerous springs in the headwaters of Rapid, Elk, and Spearfish Creeks. At the headwaters of Spearfish Creek and Little Spearfish...
Creeks, above Cheyenne Crossing, water today is still conveyed to the Hanna Pump Station and sent to Lead (Fig. 1). This water had been used by HMC for the operation of their gold mine. After metallurgical processing, the water and tailings were discharged into Whitewood Creek (Rahn et al., 1996). In 1977 enforcement of the Federal Water Pollution Control Act resulted in a cessation of direct disposal into Whitewood Creek. The Homestake Mine closed in 2001. Presently some water from the Hanna diversion is used by the towns and Lead and Deadwood as part of a contractual agreement between HMC and the Lead-Deadwood Sanitary District.

Miles downstream from Hanna there are two hydroelectric power plants where the remaining water in Spearfish Creek has been diverted to produce electricity for the Homestake mine. The upstream diversion is at Savoy, where, until November 2003, water was collected from Little Spearfish Creek (just below Roughlock Falls) and from Spearfish Creek and transferred to a flume on the eastern side of Spearfish Canyon. The flume carried the water approximately 6.3 miles downstream (distances measured along Rt. 14A which closely follows the stream channel) to HMC Hydroelectric Plant #2 at Maurice, SD (Fig. 1). Hydro #2 was built in 1917. In 2003 the South Dakota Department of Game, Fish and Parks obtained the water rights for Hydro #2. Because of the termination of these diversions to Hydro #2, water now flows down Spearfish Creek and Little Spearfish Creek to Savoy. Water in Little Spearfish Creek, famous for Roughlock Falls, now continues down into Spearfish Creek at “Spearfish Falls”, a scenic location made famous by early photographs of a train on a bridge over the falls.

One mile below Hydro #2, the water in Spearfish Creek is diverted into a tunnel (Fig. 1). The tunnel intake and aqueduct diversion is 5.5 miles long and ends at HMC Hydroelectric Plant #1, built in 1911. Hydro #1 is still functioning, although presently much of the diverted water reportedly bypasses the turbines since the mine is closed and large amounts of electricity are no longer needed. Hydro #1 is 2,000 ft upstream from the D.C. Booth Fish Hatchery, located just above the town of Spearfish. The water exits Hydro #1 and provides a sustained flow for Spearfish Creek through the city park and on through Spearfish. The average discharge in this reach is approximately 54 cfs (Driscoll and Carter, 2001). Above Hydro #1, the streambed of Spearfish Creek is essential dry all the way up to the tunnel diversion, a distance of approximately 7.3 miles. This reach includes the location of “Bridal Veil Falls”, where Rubicon Creek enters Spearfish Canyon.

PROPOSED TERMINATION OF DIVERSION TO HYDRO #1

It has been proposed (Rapid City Journal, October 19 and 23, 2003) that Hydro #1 be abandoned in a manner similar to Hydro #2. This would allow water to be returned to its natural streambed over the entire reach of Spearfish Canyon from Cheyenne Crossing to the town of Spearfish. The advantages of an additional 7.3 miles of spring-fed waters flowing in this beautiful canyon would be recreational use, including fishing, kayaking, and the increased value to tour-
ists who could see clear flowing water instead of bleached-white cobbles in a dry streambed.

The mechanism whereby the termination of the diversion to Hydro #1 could be accomplished is not known. The Homestake Mine is now owned by Barrick...
Gold Corporation, a Canadian mining company. They have legal water rights for the diversion. But the mine is no longer operating; and Hydro #1 is 92 years old and its continued life is limited.

SINKHOLES

The water that is returned to Spearfish Creek after passing through Hydro#1 presently flows through the town of Spearfish. There is concern that if the diversion to Hydro#1 is terminated and the water returned to its natural streambed there could be no more water flowing through town because it would be lost into sinkholes in the “loss zone” immediately below the tunnel diversion site. An opinion expressed in the January 19, 2002, editorial page of the Rapid City Journal is that water released from the tunnel diversion and allowed to flow down the natural streambed would be swallowed up by a fault. But a detailed geologic map (Lisenbee and Redden, 1991) shows there are no faults in this reach of Spearfish Canyon except a trivial one near Bridal Veil Falls.

Based on the geologic map, if the tunnel diversion is terminated it is very unlikely that there would be any water loss for the first 3 miles below the tunnel diversion site because the bedrock in this reach is the Cambrian Deadwood Formation to Devonian Englewood Formation. Swampy conditions exist in this reach of Spearfish Canyon and the water table seems to be higher than the streambed. Further downstream the Madison Limestone (Fig. 2) and Minnelusa Formation crop out and the hydrogeology changes from an effluent to influent conditions. As a result, some water may sink into these two aquifers in this loss zone.

The U.S. Geological Survey (Hortness and Driscoll, 1998) conducted some stream gaging below the tunnel diversion site leading to Hydro #1. In June 1996, 54 cfs was discharged below the tunnel into the streambed of Spearfish Creek and 33 cfs came out below the loss zone. Thus, after approximately one month of study, 21 cfs was lost to the alluvium and Madison Limestone. It may be that nearly all the water will eventually flow all the way into the town of Spearfish, but it may take months or even years for this to happen. The tunnel diversion to Hydro #1 has been going on for 93 years. If the tunnel diversion ceases, it will take a while to recharge the alluvium and Madison Limestone and Minnelusa Formation back to their original condition. Because of the tunnel diversion, the channel has been deprived of water for 93 years and in a sense is “thirsty”. More study is needed, especially an evaluation of the discharge conditions when Spearfish Creek has low discharge as it flows into lower Spearfish Canyon. It is my opinion that in all probability after cessation of the tunnel diversion these aquifers will be eventually recharged to their original water table elevation and most of the water will cross the loss zone.
Figure 2. Geologic map of the lower Spearfish Canyon showing the altitude (ft) of the top of the Madison Limestone (Carter and Redden, 1999). The D.C. Booth Fish Hatchery is located. The dark color is the outcrop area of the Madison Limestone and Englewood Formation. Original at 1:100,000 scale. Contour interval 200 ft.
HISTORIC REFERENCE

Draining from the Precambrian core of the Black Hills, many streams naturally lose all but flood flows to the Madison Limestone in the Black Hills (Rahn and Gries, 1973; Hortness and Driscoll, 1998). Examples are Elk Creek, Boxelder Creek, Spring Creek, and French Creek. This water is a source of recharge to large springs at the outer periphery of the Paleozoic carbonate belt such as Cleghorn Spring on Rapid Creek, Cascade Springs, the spring at Ranch A along Sand Creek, the spring along Beaver Creek above Buffalo Gap, and the springs supporting the Fall River in Hot Springs. Two large streams in the Black Hills maintain their flow across the Paleozoic belt: Rapid Creek and most likely Spearfish Creek.

The HMC diversions started so long ago that no one remembers if Spearfish Creek used to flow all the way through Spearfish Canyon. However, there is one published reference to the perennial flow of Spearfish Creek, described by Colonel Richard I. Dodge in 1875:

“Spear-Fish Creek. This creek is second only in volume to Red Water, being about three-fourths its size. It is purer, colder, clearer, softer, deeper, and much more rapid, rushing between its banks with the force of a cataract. It differs from all other streams which flow north through the mesa, in that it does not sink anywhere. Rising with a bound from the earth, not far from Crook’s Monument, it flows with the directness and force of a torrent, eating away its rocky bed until it has cut a canon for many miles of its course of not less than two thousand feet in depth. One of the surveying parties, getting into this canon from its head, found not a single place for more than thirty miles where its walls would have been scaled, and had to force a way through to where it comes out on the northern plain.”

D.C. BOOTH FISH HATCHERY

Many streams lose water to the Paleozoic limestone aquifers, but this water is not really lost because it helps recharge these aquifers. It helps support the big springs in the Black Hills such as Cleghorn Springs, Cascade Springs, Hot Springs, and many other springs (Rahn and Gries, 1973). Based on the hydrogeology of the lower Spearfish Canyon it is very likely that originally any water recharged in this loss zone helped sustain springs near or in the town of Spearfish. This would include the now defunct springs at the D.C. Booth Fish Hatchery as well as other springs that reportedly flowed in the 19th century such as Kroll’s spring, Randall spring, Saratoga spring, and a spring at the old grist mill.

Figure 3 is a graphical plot of the discharge at the D.C. Booth Fish Hatchery. This data was supplied by the files from the D.C. Booth Historic National Fish Hatchery (now maintained by the U.S. Fish and Wildlife Service). The D.C. Booth springs originally belonged to John Johnston; these springs included the “Upper Spring” in “Ames Draw,” which is a gully shown as “Fish Hatchery Gulch” on the 1:24,000 scale USGS topographic map of the Spearfish quad-
A reliable measurement made in 1892 by Evermann was 1,100 gpm (equivalent to 2.45 cfs). Later measurements in 1896 and 1897 are not as reliable. There is a hiatus of information until comments by the U.S. Fish Commission Annual Report in 1917 wherein “bad conditions” were observed. In 1919 “less discharge” was reported, and in 1920 the discharge was “as low as 22 gpm”. The main spring on Ames Draw was dynamited in a futile attempt to rejuvenate it. Essentially the D.C. Booth Fish Hatchery springs originally produced 1,100 gpm but by 1917 had all dried up.

Hydro #1 was built in 1911, and water was diverted from its normal course down Spearfish Canyon. The water originally crossed the Madison Limestone and the Minnelusa Formation at an elevation higher than the D.C. Booth Fish Hatchery springs. The Madison Limestone crosses under the streambed of Spearfish Canyon at an elevation ranging from 3,800 to 4,000 ft above sea level, whereas the “Upper Spring” at D.C. Booth Fish Hatchery is at 3,710 ft above sea level. Carter et al. (2003) show the potentiometric surface of the Madison

![Diagram of discharge data](image)

Figure 3. Discharge at the D.C. Booth Fish Hatchery\(^{(1)}\) for the years 1890 to 1970. From U.S. Fish and Wildlife Service files. The dashed line is the estimated discharge for all of “Johnston’s Springs” which includes all springs between the “Upper Spring” in Ames’ Draw\(^{(2)}\) all the way to Spearfish Creek.

\(^{(1)}\) In 1905 this property was acquired by the U.S. Fish Commission. Later it became the U.S. Fish and Wildlife Service “D.C. Booth Fish Hatchery”, and later the “D.C. Booth National Historic Fish Hatchery”.

\(^{(2)}\) “Ames Draw” is called “Fish Hatchery Gulch” on the U.S. Geological Survey 1:24,000 scale topographic maps of the Spearfish and Maurice quadrangles.
Limestone and the Minnelusa Formation; they are both approximately 3600 ft above sea level at the D.C. Booth Fish Hatchery. Based on the general hydrogeology of the Black Hills, water sinking in these two units in the canyon could be expected to reappear as “resurgent” springs at a low elevation of the outcrop of the Madison Limestone and Minnelusa Formation. An analogous hydrogeologic situation is Dark Canyon along Rapid Creek and the occurrence of Cleghorn Spring (Rahn and Gries, 1973).

“Upper Spring” in Ames Draw is located approximately 600 ft south of the old D.C. Booth Fish Hatchery ponds. The reason for its precise location here may be due to a “breccia pipe”. There is a small sinkhole approximately 50 ft southeast of the (now dry) spring outlet. Karst features like this are believed to reflect the presence of a permeable conduit through the Minnelusa Formation (Epstein, 2000). Presumably “Upper Spring” was a resurgent spring, recharged by Spearfish Creek in the loss zone. The water then travelled downgradient from the loss zone and discharged through a breccia pipe. [It is unlikely that this spring was unrelated to Spearfish Creek, possibly due to some local perched water table. Perched water table springs do exist in the Black Hills; for example “Jones’ Spring along Elk Creek is related to Tertiary intrusives. But there are no Tertiary intrusives within 2 miles of “Upper Spring”.

The nearby valley of Sand Creek, Wyoming, provides another hydrogeologic analogy to lower Spearfish Creek and its relationship to the D.C. Booth springs. Upper Sand Creek, draining the Cement Ridge area, has a good perennial discharge but it sinks into the Madison Limestone just above its confluence with the (normally dry) Cold Springs Creek. Approximately 4 miles downvalley, at the lowermost outcrop of the Madison Limestone, a large spring occurs at Ranch A. There is no doubt that this resurgent spring is largely supplied by the recharge 4 miles up-valley. If a tunnel diversion circumvented the recharge site the magnificent spring at Ranch A would be compromised.

In all probability prior to 1911 some water from Spearfish Creek percolated into the Madison Limestone and the Minnelusa Formation in Spearfish Canyon. This recharge contributed to the D.C. Booth Springs. When the tunnel diversion began in 1911, this source of recharge essentially ceased and within a few years the D.C. Booth springs failed. If, in the future, the tunnel diversion to Hydro #1 ceases, and water again flows across the loss zone, it stands to reason that recharge to the two aquifers will again occur and sometime thereafter the D.C. Booth springs will flow again. The exact time interval between recharge and the rejuvenation of the springs is hard to predict with certainty, but Figure 3 can be used as a guide. It appears that within approximately 5 years after Hydro #1 was put on line, the springs failed. Therefore, it can be anticipated that within approximately 5 years after the tunnel diversion is abandoned, the springs at D.C. Booth should produce their original discharge.

SUMMARY

If the tunnel diversion for Hydro #1 is abandoned the water will once again flow down the natural channel of Spearfish Creek. This action has the support of
many local landowners including the Spearfish Cabin Owners Association, and the Spearfish Canyon Preservation Trust.

There is concern that if the tunnel diversion to Hydro #1 is terminated, Spearfish Creek would sink into the Madison Limestone and there would be no more water at the Spearfish city park or through the city of Spearfish. But I believe that in all probability nearly all of the water will eventually flow through. Further, after approximately 5 years any water lost in Spearfish Canyon below the tunnel diversion site will help revive the flow of springs at the D.C. Booth Hatchery as well as other springs in the town of Spearfish. Future research needs to determine if 21 cfs is a constant loss or to what degree this changes with time. During preliminary releases to the streambed, the D.C. Booth springs and other springs should be monitored, as well as the potentiometric levels. Future research should also evaluate the trout habitat in the reclaimed reach since there is some concern that engineering structures along Rt. 14A have detrimentally changed the streambed. The cessation of the tunnel diversion must be carefully conducted so as to maintain a live stream through the town of Spearfish.

Presently Barrick Gold Corporation, a Canadian mining company, diverts Spearfish Creek to Hydro #1 for the purpose of generating electricity. The water right is not contingent on an operating mine. There is no longer mining, although electricity is being used for reclamation activities. This is an opportune time to restore Spearfish Creek back to its natural condition. Spearfish mayor Jerry Krambeck announced (Rapid City Journal, January 15, 2004) that city officials were trying to buy the water pipeline and Hydro #1. It would benefit South Dakotans to have a live stream once again. If the diversion to Hydro #1 were terminated, approximately 7.3 miles of a dry streambed could be turned into a beautiful flowing stream.

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REFERENCES CITED


