REVIEW OF LITERATURE ON CONNECTIONS BETWEEN RAPID CREEK AND OTHER WATER SOURCES:

IMPLICATIONS FOR GOLD MINING-RELATED ACTIVITY IN THE RAPID CREEK WATERSHED

"Complex interactions between Rapid Creek and ground water occur between Pactola Reservoir and central Rapid City. Streamflow losses west of Rapid City recharge aquifers in the Madison Limestone and Minnelusa Formation, and artesian springflow from these aquifers occurs in several locations in Rapid City."[1]

These sentences begin the Abstract for a report by Anderson, Driscoll, and Williamson written for the US Geological Survey (USGS) in 1999, in cooperation with the City of Rapid City and the SD Department of Game, Fish and Parks. For Rapid City residents facing gold exploration – and the possibility of a large-scale gold mine – in the Rapid Creek watershed, these sentences pose a warning. Rapid Creek, the Madison aquifer, and the Minnelusa aquifer are the three sources of water for Rapid City, the state's second largest city, and for enterprises and communities down the Creek and into the Cheyenne River. The fact that Rapid Creek and the aquifers are connected means that contamination in Rapid Creek could enter both aquifers, impacting the City's entire water system.

Large-scale modern gold mines are associated with the cyanide that is used to process the ore, with two Superfund sites[2] in the northern Black Hills (Homestake Mine and Gilt Edge Mine), and with a history of inability to clean up acid-laced water that perpetually seeps to the surface at old mine sites. The Gilt Edge Mine is an example of the latter situation.

The spill at the shuttered Gold King mine in southwestern Colorado -- and into Arizona -- in 2015 is another example of the problems that can result far downstream. There, a three-million-gallon spill of water, acid, arsenic, and sediment contaminated the Animas River. Impacts were felt for 150 miles downstream, stopping all uses of the river, including drinking water, agriculture, and recreation. The spill required the closure of not only municipal water intakes, but also 1,000 nearby wells.[3] The 103 holders of water rights to Rapid Creek, including the city of Rapid City, need to know about the possibility of a similar event as they plan for the future and face the issue of large-scale gold mining in their watershed.

There have been at least four studies of the connections among water sources in the Rapid City area. The first was completed in 1973 by Rahn and Gries of the SD School of Mines and Technology in cooperation with South Dakota State University, the University of South Dakota, and the South Dakota Geological Survey.[4] The study reports on research done between 1966 and 1969 that sought to find the

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[1] Anderson, M.T., Driscoll, D. G., & Williamson, J.E. (1999). *Ground-Water and Surface-Water Interactions along Rapid Creek near Rapid City, South Dakota.* U.S. Department of the Interior. U.S. Geological Survey. Water-Resources Investigations Report 98-4214.

[2] Superfund sites are locations that have been designated to be among the nation's most polluted places under the 1980 Comprehensive Environmental Response, Compensation, and Liability Act.

[3] Turkewitze, J. (August 10, 2015). Environmental Agency Uncorks its own Toxic Water Spill at Colorado Mine. *The New York Times*. https://www.nytimes.com/2015/08/11/us/durango-colorado-mine-spill-environmental-protection-agency.html

[4] Rahn, P. H., & Gries, J. P. (1973). *Large Springs in the Black Hills, South Dakota and Wyoming*. South Dakota Geological Survey. Report of Investigations No. 107.

sources of the large springs in the Black Hills. Among other things, the study sought to understand the seeming loss of water into "sinkholes" in creeks that crossed the limestone formations that also acted as aquifers.

In the study, Rahn and Gries did stream gauging, classified the area's springs into six categories, placed dye in sinkholes to see where it came out, and did other tests. They found out, for example, that some of the dye placed in Boxelder Creek came out of City Springs in northwestern Rapid City 34 days later.[5] Their research began to show that the water that went into the sinkholes went through the Pahasapa Limestone, now commonly called the Madison Limestone, on their way to the springs. The Madison Limestone is also a large aquifer that supplies a number of communities in the area, including Rapid City. This research was thorough by the standards of the time, but later studies added more detail.

The second study was reported in 1999 by Anderson, Driscoll, and Williamson, who were cited above. The study detailed the manner in which water in Rapid Creek "traverses outcrops of several bedrock formations," including the Madison and Minnelusa formations. When this happens, large amounts of water in Rapid Creek flow down into the Madison and Minnelusa aquifers – what Rahn and Gries called "sinkholes." Then there are "[c]omplex ground-water and surface-water interactions [which] result from large secondary permeability within these aquifers."[6] In other words, the water then flows around underground – sometimes in large amounts – and in ways that are complex. In some cases, the water comes back up out of the ground at springs, as discussed above and considered more below.

The study showed that the amount of water lost from Rapid Creek into the underground aquifers is substantial. In Dark Canyon, between Pactola Reservoir and Rapid City, net losses from the Creek average about 4 to 8 cubic feet per second. When losses are calculated to include the area from Pactola Reservoir through Rapid City, the net seepage is about 5,930 acre-feet per year,[7] or 1.93 billion gallons of water per year. This is not an isolated situation in the Black Hills. Boxelder Creek to the north and Spring Creek to the south "lose all of their base flow in crossing these outcrops."[8] This study provided important information about the relationships between surface water and key groundwater sources in the eastern Black Hills.

The third study was completed by Putnam and Long in 2007 and covered research that was done in 2003 and 2004 to analyze water flow among Rapid Creek, Spring Creek, and the Madison aquifer. The study used fluorescent dyes to track water movement – like Rahn and Gries, the scientists injected dye into the water at one place and watched for where it resurfaced. This study was done by the USGS in cooperation with the city of Rapid City and the West Dakota Water Development District.[9]

The authors of this study begin by again noting that streamflow recharges the Madison aquifer and that "the Madison aquifer, has extensive fractures and solution-enhanced openings that result in large

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[5] Rahn and Gries. P. 12.
[6] Anderson, Driscoll and Williamson. P. 4.
[7] An acre-foot is the amount of water needed to cover an acre of ground to a depth of one foot.
[8] Anderson, Driscoll, and Williamson. Pp. 10, 54, 57.
[9] Putnam, L.D., & Long, A.J. (2007). *Analysis of Ground-Water Flow in the Madison Aquifer using Fluorescent Dyes Injected in Spring Creek and Rapid Creek near Rapid City, South Dakota, 2003-04.* U.S. Department of the Interior. U.S. Geological Survey. Scientific Investigations Report 2007-5137.

secondary porosities and permeabilities…. Streamflow recharge to the Madison aquifer is associated with conduit formation in the limestone and rapid ground-water velocities."[10]

Putnam and Long's research then provides information on just how rapidly that groundwater is moving. Along Rapid Creek, the dye was injected into the creek upstream of the Madison outcrop over a period of 27.8 hours, and – using water flow calculations -- half of the dye was assumed to have entered the Madison Limestone/aquifer. The dye was detected in a well and a spring about a mile downstream in Dark Canyon within .5 day and 1.1 days, respectively. Other results were less clear, but the authors noted that it was important for the city of Rapid City to consider the difference between treating groundwater and treating "groundwater under the influence of surface water."[11]

The fourth study was completed in 2007 by Long and Putnam, along with Sawyer, who used environmental tracers, rather than dyes, to outline the locations of conduits in the Madison Limestone that would allow fast water movement through the aquifer. They noted that "Contamination issues are a major concern because these conduits are characterized by direct connections to sinking streams, high groundwater velocities, and proximity to public water supplies."[12]

Long, Sawyer and Putnam found that water moved through conduits in the area at speeds as high as 1,980 meters per day -- 1.2 miles.[13] Research by a South Dakota School of Mines graduate indicated that water in Rapid Creek moves from the current gold exploration area in the central Black Hills down to Pactola Reservoir in as little as 29 minutes. From Pactola, it is only a few miles to the area in which water drops through sinkholes into the Madison and Minnelusa aquifers. If a spill occurs, these high water speeds don't leave downstream communities with much time to protect themselves and their water supplies.

These studies make the situation clear. History – both in the Black Hills and elsewhere – indicates that gold mining contaminates water, and that the contamination cannot always be contained. Gold exploration is occurring in the Rapid Creek watershed, and the company that is doing that exploration wants to dig "another Homestake" mine. In Rapid City, contamination of Rapid Creek from gold activities could also contaminate the groundwater that the City uses, due to connections between Rapid Creek and the Minnelusa and Madison aquifers. This would mean that all three of the water sources used by the City could be negatively impacted – and at the same time. Pennington County water would be impacted for at least dozens of miles. City and County officials need to become familiar with this information, and they need to take action to protect water resources, businesses, citizens, ranches, and communities in the area.

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[10] Putnam and Long. P. 1.

[11] Putnam and Long, P. 20.

[12] Long, A.J., Sawyer, J.F., & Putnam, L. D. (2008). Environmental tracers as indicators of karst conduits in groundwater in South Dakota, USA. *Hydrogeology Journal* 16: 263-280. P. 263.

[13] Long, Sawyer, and Putnam. Pp. 275.