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To Steve Fluke	From Pete Hess	
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Results from "Red" water samples East Fork of Box Canyon

16 July 2004

Mr. Mike Davis
Canyon Fuel Company, LLC
Sufco Mine
397 South 800 West
Salina, Utah 84526

Mike,

At your request we have performed an investigation of surface-water quality in the East Fork of Box Canyon in the Sufco Mine permit area. Specifically, the purpose of this investigation is to evaluate the water quality in the stream in the vicinity of cracked stream substrate associated with the recent mining-related subsidence of the stream channel.

Overview

The East Fork of Box Canyon Creek is a small stream with a baseflow discharge typically ranging from about 8 to 21 gpm at the confluence with Box Canyon Creek. Longwall mining in the 3LPE panel occurred beneath the East Fork of Box Canyon during November and December 2003. As a result of longwall-mining-related subsidence, the stream substrate in the East Fork was cracked in some locations and some horizontal fracturing along bedding planes in thin-bedded rock strata occurred. Consequently, surface waters are routed through these fractures in the shallow subsurface in some locations. The presence of low-permeability strata beneath the stream channel prevents the downward migration of surface water into deeper horizons or into the mine. Rather, stream waters migrating through the fractures reenter the stream channel at downstream locations where the low-permeability (perching) horizons intersect the channel.

When the East Fork of Box Canyon was visited during April of 2004 (after being inaccessible the previous winter), it was observed that a short reach of the stream channel had been stained reddish-orange. The orange staining occurred at a location between stream monitoring sites EFB-11 and EFB-11A and appeared to originate from a relatively discrete location. The intensity of the staining gradually diminished downstream until becoming absent a few hundred feet downstream.

Data Collection

On 25 June 2004, surface water samples were collected at three locations in the East Fork of Box Canyon. These included a sample upstream of the orange-stained area, a sample

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from the most intensely orange-stained area, and a sample near the lowermost extent of the orange-staining. Water samples were analyzed for temperature, pH, specific conductance, and dissolved oxygen in the field. Samples for dissolved metals were filtered in the field through a 0.45µm filter and preserved with nitric acid. The water samples were delivered to SGS Minerals, Huntington Laboratory for analysis. The field water-quality parameters measured at each site and the laboratory analytical results are presented in Table 1. The SGS Laboratory reporting sheets are attached.

Data Analysis
Surface water sampled in the East Fork above the orange-stained area is of the calcium-magnesium-bicarbonate-sulfate chemical type with a TDS of 325 mg/l (Table 1). Concentrations of total and dissolved iron and manganese are at or below the laboratory detection limit. Water within the orange-stained area is of similar chemical type with a TDS concentration of 374 mg/l and somewhat increased concentrations of calcium, magnesium, bicarbonate and sulfate. These increases are most likely attributable primarily to the creek water coming into contact with pyrite or other sulfide minerals on freshly broken fracture surfaces in the rocks of the Blackhawk Formation. Pyrite is known regionally to exist in the coals and other rocks of the Blackhawk Formation.

Creek water downstream of the orange-stained area is of the same geochemical type and has a TDS concentration similar to that occurring in the orange-stained area. The pH and dissolved oxygen concentrations are similar to those measured above the orange stained area. Total and dissolved iron and manganese concentrations are below laboratory detection limits. Oil and Grease was not detected in any of the three surface water samples.

The geochemical evolutionary pathway most likely responsible for the observed water-quality characteristics in the East Fork of Box Canyon is described briefly below.

Pyrite is oxidized when it comes into contact with oxygenated water. This reaction is represented in a simplified form as:

$$FeS_{2\,(S)} + 7/2\ O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad \text{(pyrite oxidation)}$$

This reaction, which is commonly facilitated and enhanced by the presence of bacteria, yields free, reduced iron (Fe^{2+}), sulfate, and H^+ (acid), and removes oxygen from the water. The liberation of H^+ in this reaction results in a temporary lowering of the pH and facilitates the dissolution of carbonate minerals according to:

$$H^+ + CaCO_3 = Ca^{2+} + HCO_3^- \quad \text{(calcite dissolution)}$$
$$2H^+ + CaMg(CO_3)_2 = Ca^{2+} + Mg^{2+} + 2HCO_3 \quad \text{(dolomite dissolution)}$$

These two reactions result in an increase in the calcium, magnesium, and bicarbonate concentrations of the water and consume H^+, resulting in a rising of the pH. Because of the abundance of carbonate minerals in the coal fields of the western United States, the acid produced from pyrite oxidation is readily consumed in the reactions described above and acid-mine-drainage does not occur.

In some instances, ion-exchange may occur on clay minerals. These reactions can be represented in a simplified form as:

Ca^{2+} + Na-clay = $2Na^{+}$ + Ca-clay (ion exchange on clay minerals)
Mg^{2+} + Na-clay = $2Na^{+}$ + Mg-clay (ion exchange on clay minerals)

These reactions result in an increase in the concentration of sodium with corresponding decreases in calcium and/or magnesium concentrations.

Water flowing in a surface stream that is fully aerated with near neutral pH generally will generally not contain more than a few micrograms per liter of dissolved iron (Hem, 1985). This is because oxygen is continuously present in an actively flowing stream and the Fe^{2+} is rapidly oxidized to Fe^{3+} according to:

$Fe^{2+} + 1/4\ O_2 + H^{+} = Fe^{3+} + 1/2\ H_2O$ (iron oxidation)

The oxidized iron is subsequently precipitated as a solid (commonly as an amorphous iron hydroxide) and settles to the creek bottom. This simplified reaction may be expressed as:

$Fe^{3+} + 3H_2O = Fe(OH)_{3\ (s)} + 3H^{+}$ (iron hydroxide precipitation)

The H^{+} produced in this reaction is consumed in the carbonate mineral dissolution reactions described above. It should be noted that iron-hydroxide precipitation has been noted to lesser extents in the East Fork of Box Canyon in non-undermined stream reaches upstream of the 3LPE panel (most notably in the creek headwaters region above and near monitoring site EFB-6).

The occurrence of manganese in the creek water is likely controlled by oxidation, reduction, and precipitation reactions that are generally similar to those for iron.

Conclusions
The observed orange staining of the short reach of the stream channel and the modest increases in TDS observed in the East Fork are most likely the result of the exposure of creek water to pyrite or other sulfide minerals on freshly broken fracture surfaces and subsequent pyrite oxidation.

The fact that no dissolved iron was present in any of the three stream samples clearly indicates that any iron liberated through pyrite oxidation has been rapidly oxidized and removed from the water. The presence of total iron (1.39 mg/l) in the water sample from the most orange-stained area is likely attributable to the inclusion in the water sample of fine grained iron-hydroxide sediments disturbed at the time of sampling. Similarly, there is no manganese (total or dissolved) in the stream water below the orange-stained area, suggesting that the trace amount of manganese present in the orange-stained area (0.161 mg/l) has likely been removed by precipitation. Dissolved oxygen and pH levels in the East Fork below the orange-stained area are similar to upstream levels.

Other than a minor increase in TDS concentration (66 mg/l), there does not appear to have been any significant degradation in the water quality to the East Fork. In the future, pyrite oxidation in the East Fork will likely continue only until the exposed pyrite has been consumed. At such a time, TDS concentrations in the creek will likely decrease and the deposition of iron hydroxide in the stream channel will likely cease. It seems probable that during future torrential thunderstorm events, much of the amorphous iron hydroxide that has accumulated will be scoured from the stream channel.

Please feel free to contact me should you have any questions in this regard.

Sincerely,

Erik C. Petersen, P.G.
Principal Hydrogeologist
Utah PG #5373615-2250

Table 1 East Fork of Box Canyon water quality information, 25 June 2004.

	T (°C)	pH	D. Ox. (mg/l)	O&G (mg/l)	Cond (µS)	TDS (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	HCO_3^{-} (mg/l)	CO_3^{2-} (mg/l)	SO_4^{2-} (mg/l)	Cl^{-} (mg/l)	Fe(t) (mg/l)	Fe(d) (mg/l)	Mn(t) (meq/l)	Mn(d) (meq/l)	Cat. (meq/l)	An. (meq/l)	Bal. (%)
East Fork of Box Canyon																					
Above iron-stained area	7.4	8.18	7.79	<2	478	325	67.6	24.3	9.07	1.96	265.8	<5	77	10	<0.05	<0.03	0.002	0.002	5.8	6.2	-3.5
Within iron-stained area	8.4	7.93	6.36	<2	585	374	79.0	32.4	9.33	1.82	325.5	<5	98	11	1.39	<0.03	0.161	0.161	7.1	7.7	-4.3
Below iron-stained area	7.4	8.09	7.73	<2	593	391	77.1	35.2	10.20	1.92	329.2	<5	103	11	<0.05	<0.03	<0.002	<0.002	7.2	7.9	-4.1