EXECUTIVE SUMMARY

Results from this study benefit the state of Minnesota in two fundamental ways. First, this study has provided a large geochemical data set that can be compared to data collected by mining companies and their consultants as required by Minnesota Rule 6132.100. Second, data from this study has provided a quantitative measure of rock reactivity which can be used to aid state agencies regulatory decisions on projects that require excavation of rock similar in composition to the rock tested.

This study began in 2000 and is ongoing at the time of this report. The study includes both laboratory and field experiments of well characterized (particle size distribution, rock composition, modal mineralogy, mineral composition, and petrology) sulfide-bearing greenschist from the Ely Greenstone rock formation. For the laboratory experiment, standardized humidity cell tests were conducted on 18 samples (one kilogram each); four of the samples were duplicates. The field experiments included four rock piles (~65 tonnes each) and six rock filled tanks (~1.6 tonnes each). Four of the tanks were mixed with different amounts of dolostone to evaluate the effect of alkaline addition on rock leachate acidity. The rock samples were rinsed with deionized water in the laboratory and natural precipitation in the field. The leachate produced from rinsing was analyzed for composition and volume. From the leachate composition and volume sulfate and metal release rates were calculated.

Petrographic analysis indicated the rock used in this study was primarily composed of the minerals quartz, chlorite and muscovite. Compositional analysis of the laboratory samples indicated total sulfur (S_T) concentrations ranging from 0.04 to 1.22 wt% and CO_2 concentrations less than or equal to 0.05 wt% except for two samples with CO_2 concentrations of 1.76 and 6.85 wt%. Field rock piles 1, 2, 3, and 4 had respective S_T concentrations of 0.02, 0.22, 0.37, and 0.63 wt% and respective CO_2 concentrations of 0.16, 0.26, 0.08 and 0.47 wt%. The field tanks were filled with the same rock that was used to construct rock pile 4.

In general, leachate pH decreased (acidity increased) with increasing rock sulfur concentration. Humidity cell samples with a S_T concentration greater than or equal to 0.1 wt% and a CO_2 concentration less than or equal to 0.05 wt% produced a leachate pH less than 6. Only the 0.63 wt% S_T rock pile generated a leachate pH less than 6. Leachate from the 0.02, 0.22, and 0.37 wt% S_T rock piles generally had a pH greater than 7. Leachate from tanks with no dolostone added had a similar small leachate pH as that of the 0.63 wt% S_T rock pile. Leachate from the four tanks with dolostone added (both with dolostone amounts that should neutralize all the acid generated) consistently had a pH greater than 7. Collectively, these experiments have indicated Ely Greenstone greenschist with a S_T concentration greater than or equal to 0.1 wt% and CO_2 concentration less than 0.05 wt% has the potential to generate a fluid with a pH less than 6.

For both the field and laboratory experiments, sulfate release rates increased with increasing rock sulfur concentration. The ratio of field to laboratory sulfate release rates ranged from 0.05 to 0.20 with a preferred value of 0.14. The smaller field sulfate release rate was likely due to a smaller total reactive surface area of the field rock per unit mass, in particular the surface area of the sulfide minerals.

Data from the laboratory experiments was used to assign a level of environmental risk for carbonate mineral deficient, sulfide-bearing, Ely Greenstone greenschist if crushed and allowed to react with the natural environment. The categorization was based on the level of treatment that would be required to neutralize rock leachate acidity. Greenschist with wt% S_T concentrations between 0-0.5, 0.10-0.16, and 0.2-1.22 were assigned with environmental risk levels of low, moderate, and high, respectively.