NATURAL ATTENUATION INVESTIGATION
ENGINEERING DESIGN AND POND CLOSURE

LOCATION: United Verde Mine, Arizona - USA

CLIENT: Phelps Dodge Corporation

PROJECT TYPE:

- Geochemical Site Characterization
- Hydrologic Investigation
- Natural Attenuation Investigation
- Engineering Design and Analysis for Pond Closure
- ARD Containment and Treatment
- Regulatory Compliance Support

As part of a Best Available Demonstrated Control Technologies (**BADCT**) assessment, various **investigations** and **engineering designs and analyses** were conducted to **close** a series of **settling ponds** covering approximately 3 acres. These ponds received **acid rock drainage (ARD)** from a tunnel draining underground mine workings at an inactive underground/open pit copper mine site in a mountainous, central Arizona location. Consequently, S.E.T.'s investigation and engineering improvements resulted in **delisting of a receiving stream** as an impacted waterbody, thereby effectively **reducing the overall remediation costs**.

S.E.T. also successfully demonstrated that ARD **impact from ponds to groundwater was insignificant**, with the natural attenuation capacity of the vadose zone exceeding 1,000 years. The projects conducted at this site were designed to support an **Aquifer Protection Permit (APP)** application for the mine.

GEOCHEMICAL SITE CHARACTERIZATION

S.E.T. conducted this characterization to define the nature of the pond water and sediments, soils and alluvial materials underlying the unlined ponds. Potential ARD impacts to groundwater also were assessed.

HYDROLOGIC INVESTIGATION

S.E.T. conducted a **water balance study** to simulate the infiltration of ARD through pond sediments and input the results into **PHREEQC®** to quantify the natural attenuation capacity of the pond system. The investigations also provided design criteria necessary to develop an engineering assessment of alternatives under BADCT guidelines.

NATURAL ATTENUATION INVESTIGATION

A natural attenuation investigation was conducted to demonstrate compliance with Arizona's BADCT requirements for ARD mitigation. The PHREEQC® geochemical equilibrium model was used to quantify the natural attenuation capacity of the soils and alluvial materials underlying the containment ponds. **Geotechnical tests** were conducted and **geochemical samples** collected to obtain input parameters for the model.

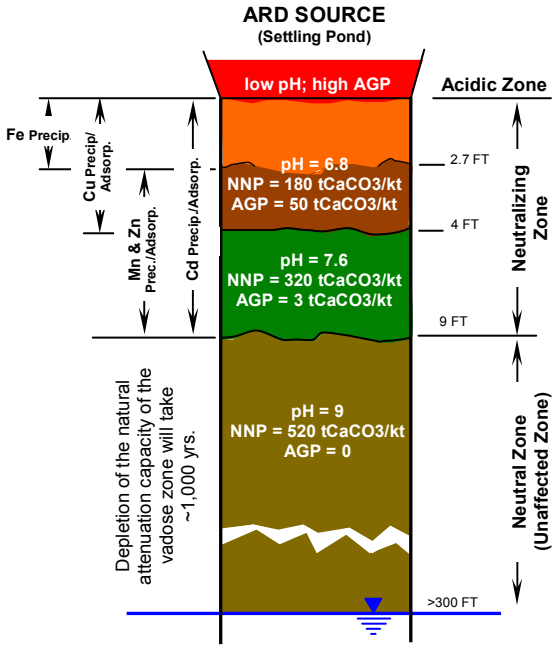

Figure 1. Geochemical Zones Related to ARD Infiltration

At this site, S.E.T. demonstrated that during the last 70 years the ARD impact from the ponds was minimal and that the soils and alluvial materials of the vadose zone contain more than 1,000 years of natural attenuation capacity before the groundwater could be potentially impacted (Figure 1).

☑ Unparalleled Quality ☑ Cost Effective Project Completion

ENGINEERING DESIGN AND ANALYSIS FOR POND CLOSURE —— ACID ROCK DRAINAGE CONTAINMENT AND TREATMENT

Based on the results of the natural attenuation investigation, four **remedial alternatives** were developed to close the existing ponds and to reduce the sulfate and metal concentrations in ARD draining from the tunnel.

The alternatives were assessed under the BADCT demonstration guidelines by first conducting an initial screening, followed by detailed evaluations of the alternatives passing the screening criteria. The alternatives included the **addition of crushed limestone** to three different locations within the mine settings. The fourth alternative required **addition of ammonia** to increase the pH of the ARD.

Three of the alternatives were eliminated during the initial screening. The remaining alternative, the construction of crushed limestone cells placed a few hundred feet in front of the tunnel (Figure 2), underwent detailed evaluation.

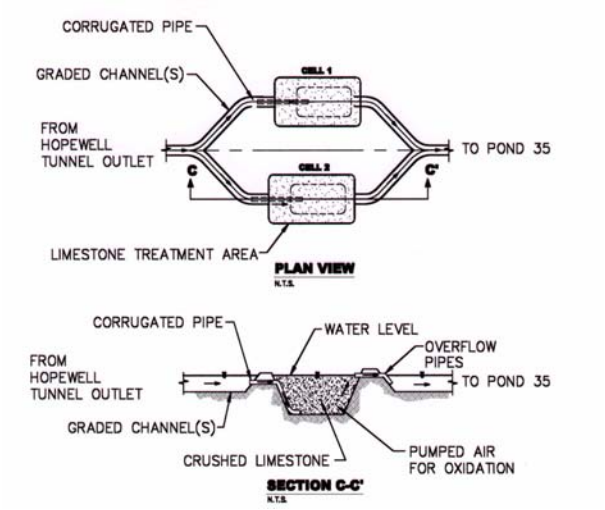

Figure 2. Schematic of Passive ARD Treatment Cells

The detailed evaluation indicated that:

- Native limestone found on-site effectively neutralized the ARD (Figure 3) and reduced the metal concentrations either to or below the design criteria; and
- Aeration of the ARD reduced the iron content of the discharged water through iron oxide precipitation.

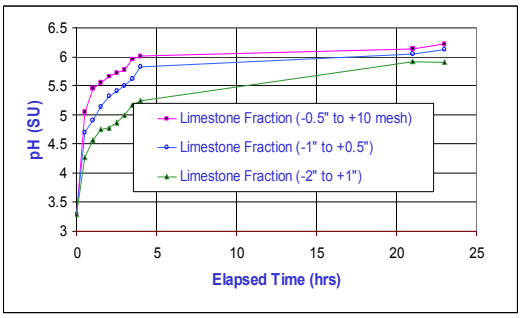

Figure 3. Pilot-scale Test Results (Limestone Fraction Size Evaluation)

The preferred alternative was a passive ARD treatment system (Figure 2). Treatment system design criteria were developed using **geochemical laboratory analyses** and **pilot-scale tests**.

Figure 3 summarizes pilot-scale test results used to develop design criteria, including optimum treatment material (limestone) size, retention time and treatment cell size.

REGULATORY COMPLIANCE SUPPORT

The BADCT assessment also was used to support a regulatory delisting of the receiving stream as an impacted waterbody. Investigation results were provided to the state agency and a summary report was submitted to support regulatory delisting (**e.g., Delisting under Clean Water Act - Section 303(d)**) of the impacted waterbody using the **Total Maximum Daily Load (TMDL)** process.

For more information please go to www.savci-env.com

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