Missouri Department of Natural Resources (MODNR) and U.S. Environmental Protection Agency (EPA) Brownfields Program

Evaluation of Hyperspectral Imagery for Missouri Mine Waste Inventory

September 1, 2006 – June 30, 2007

1. Project Overview and Summary

1.1 Overview

The Missouri Department of Natural Resources (MDNR), through a U.S. Environmental Protection Agency (EPA) grant, conducted a pilot project in 2005 to evaluate potential applications of Hyperspectral Imagery (HSI) for identifying and characterizing contamination. The Civil Air Patrol (CAP) collected the HSI with their Airborne Real-Time Cueing Hyperspectral Enhanced Reconnaissance (ARCHER) system, and the University of Missouri Columbia (UMC), through the Missouri Resource Assessment Partnership (MoRAP) with MDNR and other state and federal agencies, analyzed the imagery. HSI was collected of a variety of contaminated sites, including several lead mining areas in southwest and southeast MO, and an operational lead smelter in Herculaneum, MO. The report is available at http://www.dnr.mo.gov/env/hwp/hsi/hsi-project.htm.

The initial pilot project had limited time and funding for follow-on ground truth data collection, and for evaluating analytical approaches to some investigations, such as using vegetation stress as a contamination indicator. The SFY '07 project used HSI from the 2005 Pilot Project, and focused on field data collection, re-analysis of the '05 imagery, and follow-on verification of three lead-zinc mining areas in southwest MO. Additionally, HSI of a portion of the Big River in eastern MO and Doe Run lead smelter in Herculaneum, MO was re-analyzed using a different process, end member versus Spectral Angle Mapper (SAM) analysis, to determine if another analytical approach would provide better results. The objective in southwest MO was to evaluate the potential use of HSI to determine lead levels in soil, to locate mine waste over large land areas, and to characterize the extent of contamination through vegetation stress. An end member analysis of Herculaneum and Big River was conducted to evaluate HSI potential to determine the extent of lead dust deposition from the smelter, and deposition of mine waste along the Big River from the collapse of part of a tailings dam.

In June 2007, project personnel were asked to submit areas for HSI collection as part of State Emergency Management Agency (SEMA) earthquake exercise. As a result, ARCHER collected HSI of parts of the Big River and city of Leadwood, where MDNR and EPA are removing tailings and chat piles and mitigating runoff and wind blown contamination from the piles, and Herculaneum, were airborne lead contamination continues to be deposited around the smelter. The SFY '08 Brownfields HSI project will

use the SEMA funded imagery to continue ground truth and evaluation of HSI applications to mine waste characterization.

The complete report and attachments can be found below and downloaded. For further information on this or other department HSI projects contact Shawn Muenks, MODNR, Hazardous Waste Program, Federal Facilities Section, at 573-751-3107, or email at shawn.muenks@dnr.mo.gov.

1.2 Summary of Findings

The report provides details of the tasks and activities, and relevant collected data. The following is a summary of findings:

- Lead Levels In Soil. Determining levels of lead contamination in soil from airborne deposition, particularly in differing types of soil, continues to be a challenge. The soil, not the lead contamination, determines the spectral signature, unless the contamination levels are high enough to provide a unique signature. The lead and zinc levels recorded by the project were too few and random to determine if there was a correlation. Based on the data collected, it does not appear HSI analysis of soil will help determine if lead contamination is above clean-up levels.

  - Recommendation: Using soil signatures to determine lead levels does not appear productive with current analytical approaches. Vegetation indicators may be more productive, particularly in residential areas.

- Mine Waste. Several locations surveyed in Wentworth and Granby, where spectral analysis from 2005 indicated mine waste existed, did include mine waste. One driveway that was identified in the analysis, did contain reused mine waste.

  - Recommendation: Continue evaluation of the use of HSI to support mapping abandoned and reused mine waste.

- Granular Mine Tailings. The majority of locations of suspected abandoned or reused mine waste in Aurora, identified using the signature of chat or chert-like material in Baldwin Park, were concrete parking areas and roads. The signature of relatively fine mine tailings appears to be similar to the aggregate in concrete. The concrete pads and roads that were sampled had very low or non-detectable lead and zinc levels.

  - Recommendation: Some mine waste was reused for gravel roads and may show up in the analysis. However, using fine grain chat for a signature may result in a high rate of false indication of potential mine waste.

- Mineralogical Differences. Mine waste varies in mineral composition, even within a geographic mining area. Overburden and other materials removed to reach desired ore also vary in composition and signature.

  - Recommendation: For more complete results, several signatures should be used for analysis.

- Airborne Deposition. The end member analysis of the Doe Run lead smelter in Herculaneum showed similar signatures between the slag pile and some residential streets, possibly those used as haul roads. There were also similarities between the smelter compound, several residential areas, the rail line that serves the smelter, and several areas along the river that surrounds the town and smelter. It appears that some of these anomalies may reflect airborne deposition. Unfortunately, the imagery was too old to be used for the ground survey.

  - Recommendation. Time lapse between imagery collection and analysis for some conditions, make ground truth collection impractical. New imagery of Herculaneum and more of the surrounding area, collected in June 2007, will be used for the SFY '08 project.

- Tree Species Differentiation. ARCHER HSI appeared to be capable of distinguishing different species of trees. However, the field survey showed minimal correlation. The dense canopy, presence of vines and variety of species may have complicated the analytical process. Additionally, because the original imagery was manually rectified, the location of trees used for signature development could have been off by as much as five meters.

  - Recommendation: ARCHER HSI may still be usable for characterizing tree species for other projects, and for distinguishing trees in contaminated and non-contaminated areas, but more analysis using current imagery will be required to verify the capability.

- Conifer Uptake. Conifers appear to provide a good year-round measure for characterizing contamination. Preliminary tests in southwest MO indicated that there is a strong correlation between zinc levels in soil and Cedar trees. These results are similar to a study conducted in Belgium in which Pine trees were used to define the area of zinc contamination from a zinc smelter. Based on the analysis of Cedar in Granby, MO, it appears that the higher the zinc levels in the needles and soil, the less trees, but more grassy areas were a match. If the grassy areas are masked out, this may be the best characterization of the areas of highest contamination based on the Cedar trees. Some types of grass have similar signatures to conifer, and this may be the cause for miss-correlation. Alternatively, the correlation may be an indication that the grass is in zinc contaminated areas. The lower the zinc levels, the lower the correlation to grass and higher correlation to trees. More trees, particularly outside the mining area, should have less zinc. Grass testing was limited.

  - Recommendation: More testing will be needed to confirm the tree - soil zinc correlation and to determine if the ARCHER sensor can provide sufficient spectral signature separation to distinguish contaminated from non-contaminated trees.

- Sycamore As An Indicator. The analysis of contaminated Sycamore in the Aurora and Baldwin Park areas matched relatively closely with the known mine sites. The contaminated Sycamores that were tested were identified in imagery as contaminated, and fell within the area of known mine sites. The one non-contaminated Sycamore that was tested was not identified as contaminated and fell outside the know mining area.

  - Recommendation. There may be sufficient difference in the signature of contaminated Sycamore to provide an indicator of contaminated areas.

- Visual Vegetation Indicator. Mullein may be a good visual indicator for lead/zinc contamination. The Mullein in Baldwin Park contaminated areas appeared small compared to normal Mullein. The zinc apparently inhibits growth, and field testing indicated that the higher the zinc levels the smaller the plant. Mullein also appears to uptake detectable levels of lead.

  - Recommendation. The Mullein data was collected during the February survey, when the plants were still dormant from the winter. However, they were much smaller than those observed in other parts of MO, and size appeared to correlate to zinc levels. In mining areas, Mullein may provide a visual indication of zinc levels.

- Imagery Collection And Analysis. Dated imagery is difficult to use for ground truth, particularly when analyzing vegetation. This project was conducted almost two years after imagery collection. Remediation or other activity had changed the landscape in areas where signatures were developed for the original project, and tree and vine canopy had changed

  - Recommendation: Analysis should be conducted soon after collection to improve accuracy of ground truth data analysis.

- ARCHER Imagery Processing. Current data output from ARCHER is not usable. Space Computer Corp (SCC), developer of the ARCHER software, has two applications that will process and geo-register the data for use on Geographic Information Systems (GIS) or imagery analysis applications.

  - Recommendation: Purchase the SCC HSI processing software for use in future projects.