U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF INSPECTOR GENERAL

Hyperspectral Imaging Can Be a Useful Evaluation Tool for Office of Inspector General Reviews Focused on Contaminated Land

Report No. 14-N-0360 **September 26, 2014**

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Abbreviations

EPA	U.S. Environmental Protection Agency
HSI	Hyperspectral Imagery
OIG	Office of Inspector General
RCRA	Resource Conservation and Recovery Act
USGS	U.S. Geological Survey
UST	Underground Storage Tank

Cover photos: *From left:* Civil Air Patrol's Airborne Real-Time Cueing Hyperspectral Enhanced Reconnaissance (ARCHER) sensor; example of a brownfields site where hyperspectral imagery was collected. (USGS photos)

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U.S. Environmental Protection Agency
Office of Inspector General

14-N-0360
September 26, 2014

At a Glance

Why We Did This Review

We conducted this review to determine whether hyperspectral imaging (HSI) data is a useful tool for the U.S. Environmental Protection Agency (EPA) Office of Inspector General (OIG) to assess conditions and effectiveness of cleanup actions at Superfund, Brownfields, Resource Conservation and Recovery Act Corrective Action, and Underground Storage Tank sites.

HSI is similar in concept to satellite images. HSI is a type of remote sensing technology used on an airborne hyperspectral sensor that records reflected and emitted electromagnetic energy in hundreds of very narrow wavelengths. The data can assist in the identification and analysis of environmental conditions and certain contaminants.

This report addresses the following OIG goal:

- *Contribute to improved human health, safety, and the environment.*

Send all inquiries to our public affairs office at (202) 566-2391 or visit www.epa.gov/oig.

The full report is at:
www.epa.gov/oig/reports/2014/20140926-14-N-0360.pdf

Hyperspectral Imaging Can Be a Useful Evaluation Tool for Office of Inspector General Reviews Focused on Contaminated Land

What We Found

Starting in December 2007, in coordination with the U.S. Geological Survey, the OIG has been assessing the feasibility of using remote sensing technologies for OIG oversight of the effectiveness of EPA cleanup actions. We conducted HSI work at 40 sites in seven states.

Hyperspectral imaging is an evaluation tool that has specialized value in designing and conducting Office of Inspector General assessments of cleanup actions.

Our work shows that HSI is useful in identifying vegetative stress on land related to the presence of certain heavy metals, such as lead and arsenic. HSI is also useful for identifying debris on land. HSI can be useful during the scoping phase of an audit or evaluation to screen multiple sites and select a smaller, more relevant sample of sites for on-site visits and further review. In our work, when the HSI indicated little vegetative stress, we also found that sites were generally free of any significant residual contamination

HSI is one available evaluation tool for collecting information and designing an assignment under the broad objective of assessing, on a case-by-case basis, the effectiveness of cleanup actions on land. OIG assignment timeframes, costs and objectives must ultimately be factored in when deciding the most appropriate evaluation methods.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
INSPECTOR GENERAL

September 26, 2014

MEMORANDUM

SUBJECT: Hyperspectral Imaging Can Be a Useful Evaluation Tool for Office of Inspector General Reviews Focused on Contaminated Land
Report No. 14-N-0360

FROM: Carolyn Copper, Assistant Inspector General
Office of Program Evaluation

TO: Charles Sheehan, Deputy Inspector General

Attached is a report assessing the use of remote sensing technologies in U.S. Environmental Protection Agency (EPA) Office of Inspector General oversight of the effectiveness of EPA cleanup actions. This report represents the culmination of work that the Office of Program Evaluation began in December 2007, in coordination with the U.S. Geological Survey. We made observations in determining whether hyperspectral imaging data is a useful tool for assessing contamination and cleanup at Superfund, Brownfields, Resource Conservation and Recovery Act Corrective Action, and Underground Storage Tank sites.

We will post this report to our website at http://www.epa.gov/oig.

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Appendices

Purpose

This report addresses whether hyperspectral imaging (HSI) is a useful tool for the Office of Inspector General (OIG) of the U.S. Environmental Protection Agency (EPA) to use in assessing contamination and cleanup at Superfund, Brownfields, Resource Conservation and Recovery Act (RCRA) Corrective Action, and Underground Storage Tank (UST) sites. Starting in December 2007, in coordination with the U.S. Geological Survey (USGS), we have been assessing the use of remote sensing technologies for OIG oversight of the effectiveness of EPA cleanup actions.

Background

Hyperspectral imaging is a type of remote sensing technology that records reflected and emitted electromagnetic energy in hundreds of very narrow wavelengths. Data can be captured using an airborne sensor. The data can assist in the identification and analysis of environmental conditions and certain contaminants.

In 2007, the EPA OIG determined that the EPA had failed to detect hazardous waste at the Ringwood, New Jersey, Superfund site, leading to the EPA's insufficient characterization of contamination and, consequently, insufficient cleanup at the site. The EPA OIG further concluded that the overlooked contamination may have been detected sooner if the EPA had made greater use of available aerial photographs.[1] As a result of that work, the OIG initiated a series of HSI research projects in December 2007 designed to test the use of HSI for OIG oversight of the effectiveness of EPA cleanup actions.

Scope and Methodology

We began our work in December 2007, and received our final HSI analyses in May 2014. This report evaluates the usefulness of HSI technology to identify certain conditions at contaminated sites. The scope of work performed for this report does not constitute an audit under generally accepted government auditing standards.

Working with USGS, we conducted our HSI work in three phases which involve different types of contaminated sites and different states. Each phase included the collection and analysis of hyperspectral imagery, soil sampling and soil analysis. The three phases encompassed a total of 40 sites in seven states, as shown in Table 1. We visited Superfund, Brownfields, RCRA Corrective Action and UST sites.

[1] *Limited Investigation Led to Missed Contamination at Ringwood Superfund Site*, (Report No. 2007-P-00039, September 25, 2007), http://www.epa.gov/oig/reports/2007/20070925-2007-P-00039.pdf.

Table 1: Sites sampled for HSI testing

Phase	Number of sites	Type of sites	States
1	5	Superfund	Maryland Virginia
2	11*	Superfund	Pennsylvania
3	24**	Brownfields (16)	Florida South Carolina Louisiana Texas
		RCRA Corrective Action (6)	
		UST (2)	

Source: OIG analysis.

* Soil samples were not taken at four sites because we did not visit the sites.
** Soil samples were not collected from three sites because the sites were paved over.

We reviewed site assessment and other site background documents and worked with EPA, state officials and site owners to obtain site access. To obtain HSI data, the USGS entered into an interagency agreement with the U.S. Air Force Civil Air Patrol. For all sites visited we conducted an inspection of general site conditions, and soil samples were collected at most sites in cooperation with USGS. Whenever possible, we used a portable X-ray fluorescence unit to obtain a field scan of the metal composition of the soil prior to taking each soil sample. Soil samples were analyzed in the USGS laboratory for heavy metal contamination and, in some cases, were also analyzed for asbestos. A subset of these samples was sent to an independent laboratory for confirmatory testing by Inductively Coupled Plasma analysis using EPA methods 3050 and 6010. The Inductively Coupled Plasma results were compared to HSI to determine whether there was any correlation between vegetation stress and high metals readings.

Since our work began in December 2007, we issued an early warning report to EPA[2] and we provided the EPA with early sampling results to give early notice of possible issues at sites. Other reports are in progress.

Further, the USGS has issued four final reports and a draft report as a result of its interagency agreement with the EPA OIG (see Appendix A).

[2] *Observed Conditions at Five Deleted Superfund Sites* (Report No. 11-P-0433), August 3, 2011.

Results of Review

Based upon the scope of the work performed and the sites OIG evaluated, remote sensing technology can be useful to inform on the status of site conditions and further detection of site anomalies. We determined that the current state of HSI technology is useful in identifying vegetative stress related to the presence of certain heavy metals. Three of the sites we sampled had areas that showed high concentrations of arsenic and/or lead in the soil. Some of the same areas on the hyperspectral images also showed vegetative stress. See Appendix B for an example of a hyperspectral image.

We determined that HSI technology is useful in identifying debris, and for screening out sites for further OIG work. HSI can also be useful during the scoping phase of an evaluation to screen multiple sites and select a smaller, most relevant sample of sites for on-site visits and further review. When the HSI indicated little vegetative stress, our review found that the site was generally free of any significant residual contamination. For example, HSI imagery showed little indication of vegetative stress or anomalies at eight of the 11 sites tested and visited in Pennsylvania. On-site observations confirmed that these sites were generally free of significant residual debris that would be detected by the anomaly detection routine used to process the hyperspectral images. Further, soil sample results indicated that these sites contained low levels of metal concentrations that were below the appropriate EPA risk-based screening levels. We believe this is an indicator that HSI could be a cost-effective means to periodically screen sites designated as ‘cleaned-up’ for new contamination or changed conditions.

In addition, the anomaly detection routine also reliably detected hard surface debris left at the site, as well as other site anomalies, such as surface areas that are different from the surrounding areas. For example, at one site in Virginia, HSI identified anomalies that proved to be scrap auto bumpers, empty metal containers and other materials. Thus, if HSI were collected for several sites, those that did not have indications of vegetative stress or anomalies might be eliminated from further review.

Conclusion

HSI is one evaluation tool that OIG staff have available when designing an assignment under the broad objective of assessing, on a case-by-case basis, the effectiveness of cleanup actions at contaminated, previously contaminated or potentially contaminated sites, depending on timeframes, costs and assignment objectives.

Appendix A

USGS Work Products as a Result of Interagency Agreement With EPA OIG

Slonecker, E.T., and Fisher, G.B. 2009. *Research Implementation and Quality Assurance Project Plan: An Evaluation of Hyperspectral Remote Sensing Technologies for the Detection of Fugitive Contamination at Selected Superfund Hazardous Waste Sites*. USGS Open-File Report 2009–1048, http://pubs.usgs.gov/of/2009/1048/.

Slonecker, E.T., and Fisher, G.B. 2011. *An Evaluation of Traditional and Emerging Remote Sensing Technologies for the Detection of Fugitive Contamination at Selected Superfund Hazardous Waste Sites*. USGS Open-File Report 2011–1050, http://pubs.usgs.gov/of/2011/1050/.

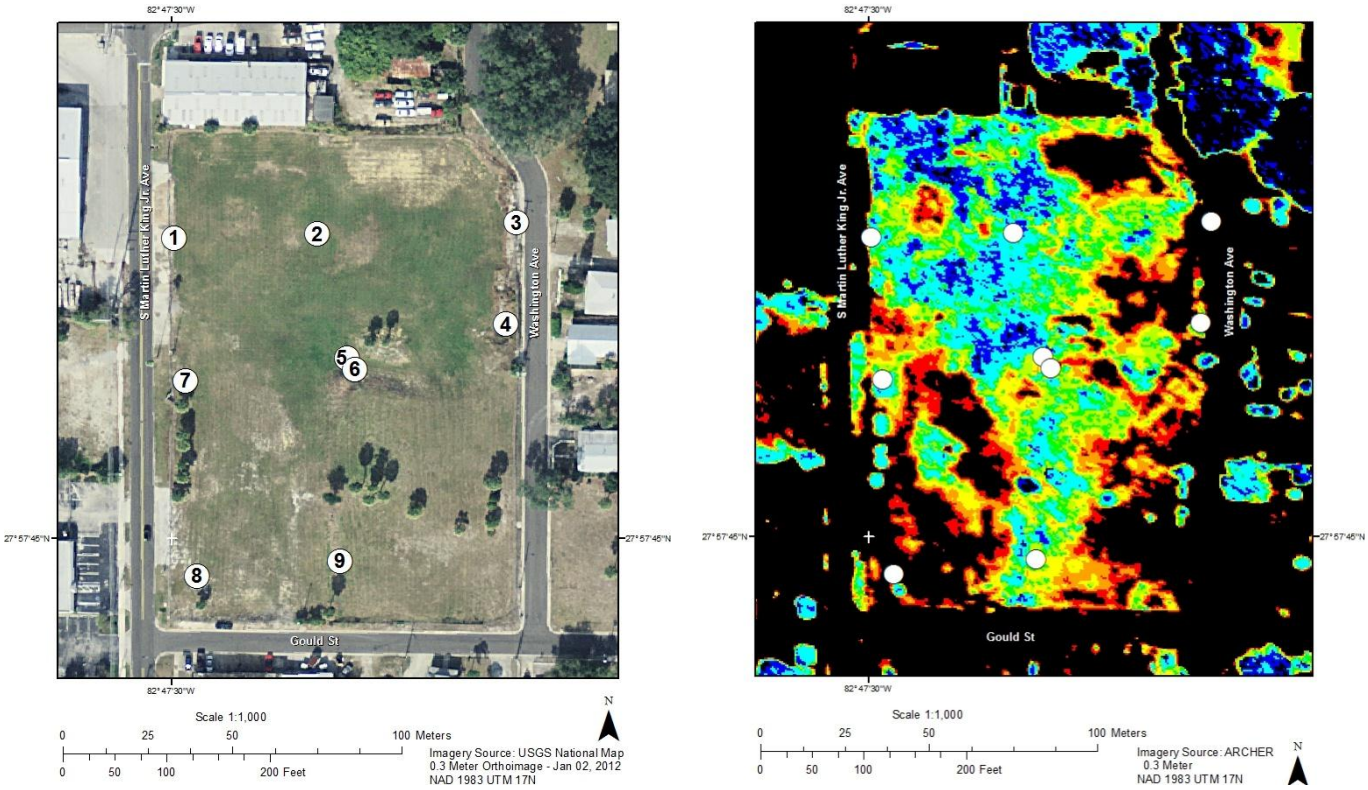
Slonecker, E.T., and Fisher, G.B. 2011. *Graphic Products Used in the Evaluation of Traditional and Emerging Remote Sensing Technologies for the Detection of Fugitive Contamination at Selected Superfund Hazardous Waste Sites*. USGS Open-File Report 2011–1068, http://pubs.usgs.gov/of/2011/1068/.

Slonecker, E.T., and Fisher, G.B. 2014. *An Evaluation of Remote Sensing Technologies for the Detection of Fugitive Contamination at Selected Superfund Hazardous Waste Sites in Pennsylvania*. USGS Open-File Report 2014–1081, http://dx.doi.org/10.3133/ofr20141081.

Slonecker, E.T., and Fisher, G.B. *An Evaluation of Remote Sensing Technologies for the Detection of Fugitive Contamination at Selected Sites under the EPA Cross-Program Revitalization Measures Program. (In Progress – Draft Report)*

Appendix B

Example of Hyperspectral Imagery



Hyperspectral Image Processing Results for the Clearwater Automotive Site, Clearwater, Florida. Left: USGS color image with field sampling points. Right: Image showing the agricultural stress composite index based on the hyperspectral imaging. In the stressed image, red and black indicate vegetative stress. Black also indicates paved areas.

Appendix C

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