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Sent: Monday, September 15, 2008 10:35 AM
To: Burrows, Ronald
Subject: NaI Gamma Monitoring: The two papers
Attachments: from Uranium in the Environment Freiberg Germany Sept 2005.pdf; from ANS Proceedings Denver summer2005.pdf

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From: rmeyer7 [mailto:rmeyer7@mindspring.com]
Sent: Thursday, September 11, 2008 4:18 PM
To: Cash, John
Subject: The two papers

John - I extracted these from the CDs containing the entire proceedings for the Freiberg and Denver meetings. I renamed the files to show their sources. Let me know if you'd like copies of the complete Proceedings CDs, with information detailing the meetings, tables of contents, etc. -Bob Meyer

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Subject: NaI Gamma Monitoring: The two papers
Sent Date: 9/15/2008 10:35:07 AM
Received Date: 9/15/2008 10:38:09 AM
From: Cash, John

Created By: John.Cash@ur-energyusa.com

Recipients:
"Burrows, Ronald" <Ronald.Burrows@nrc.gov>
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A GPS-Based System for Radium/Uranium Contamination Gamma Scanning

Robert Meyer, Michael Shields, Scott Green, Janet Johnson

MFG Inc., Suite 100, 3801 Automation Way, 80525 Fort Collins, Colorado, USA,
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Abstract. MFG Inc. in 2001 developed a Global Positioning System (GPS)-based gamma scanning technique for use during site surveys at a large (16 km2) in-situ-leach uranium mine being developed in Kazakhstan. Since that time, the system has been improved and used at a total of eight radium/uranium-contaminated sites in the western U.S. At one former uranium mill site in Texas, data acquisition occurred at a rate of seven acres/hour on the 600 acre site. High-speed scanning allows 100% coverage of a site in a short period, providing color-coded output defining gamma exposure rates over the entire site.

The GPS/Gamma Scan System

With the deployment of the Global Positioning System (GPS) satellite constellation, a number of new data collection methods became possible. Development of handheld GPS receivers has made such approaches feasible and cost-efficient. MFG staff have been involved in radiation measurements work for years. We decided in the late 1990's to link gamma detection units with GPS and computer systems to allow the development of very high density mapped data sets. Such data are useful to identify contamination at sites including uranium mills and mines, other metal mine facilities (for example, copper, vanadium and rare earth) with secondary radioactive contamination, and facilities with other contamination, including accidental. The GPS-based detection systems may also be used to direct remedial action at such sites, and become especially valuable when providing a record of the final radiation status of a remediated site.

Each system used to collect gamma exposure rate data includes the following:

- Ludlum 2350-1 radiation detection datalogger
- Ludlum 44-10 2x2 inch NaI gamma detector
- Garmin iQue 3600 GPS/Personal Digital Assistant (PDA)

- MFG code to capture data on iQue memory, and to sort and view data.

The Ludlum 2350-1 datalogger includes a bidirectional RS-232 port, allowing communication with PC and PDA devices. The iQue GPS data can be captured internally with appropriate programming, and an RS-232-capable port on the iQue allows communication with the 2350-1 for data transfer initialization and capture. Fig. 1 presents views of the system in use in a "backpack" configuration.

The system may be deployed in a single-detector configuration, with the gamma detector carried 1 meter above the ground, either lead-shielded or unshielded. The single detector system scans an effective width of two meters. It may also be deployed, using a portable computer, a USB hub, and individual WAAS-enabled GPS units to replace the iQue 3600, with multiple detectors carried on a truck or all-terrain vehicle. The latter configuration increases data collection speed, with two or more gamma detectors each providing data once per second to the PC. Fig. 2 provides a view of a three detector system, with detectors spaced on 2 meter centers at 1 meter height. The three detector system scans an effective width of 6 meters.

Developing a correlation between soil radionuclide concentrations and gamma exposure rates requires careful attention to sample and gamma data collection. Relatively uniform areas of contamination (typically 10 m squares) must be selected prior to sampling. Ten to twenty aliquots of soil, taken to 15 cm depth, are composited from each square, and sent to a qualified laboratory for Ra-226 con-

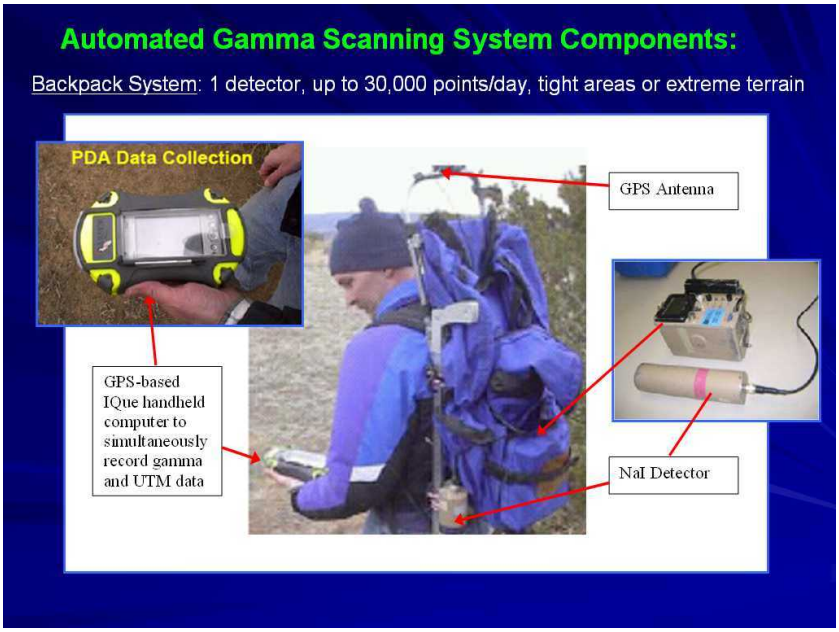

Fig. 1. System in Backpack Configuration.

centration analysis (after drying, grinding and homogenization). The sampled area is carefully scanned using either a backpack or truck-mounted GPS/gamma scan setup, to develop a useful correlation. Fig. 3 presents the results of such a correlation analysis, utilizing data collected at another client site in the western U.S.

Fig. 2. System in Three Detector Configuration.

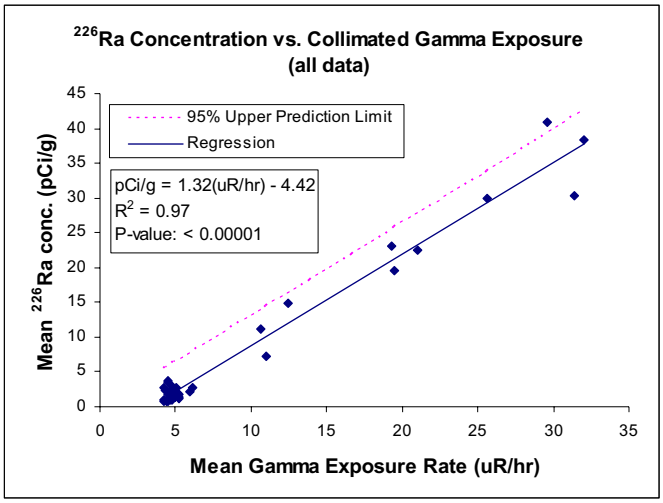

Fig. 3. Soil Analysis vs. GPS/Gamma Scan Exposure Data.

Using the GPS/Gamma Scan System

Figs. 4 and 5 show characterization data developed at a client facility currently being remediated Initially, a base drawing of the plant was evaluated using computer automated design (CAD) systems. Such a drawing, developed earlier using available information, may not accurately present the locations of the site's features. The base map for this site was therefore "ground-truthed" by collecting GPS data at several dozen points throughout the site. This information was used to "warp" the original CAD drawing to fit the GPS findings. Fig. 4 presents such a corrected drawing, ready for gamma data display.

Fig. 4. Initial base map of a facility, corrected using on-site GPS data.

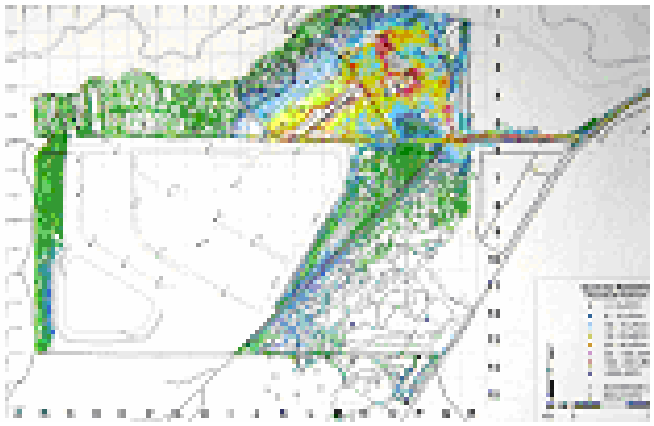

Fig. 5. Full Data Set Prior to Initiation of Remedial Action

Fig. 5 displays gamma exposure rate data collected using the MFG systems detailed above. The figure displays the facility's gamma status, as it exists prior to remedial action. Initial data were used to characterize site exposure rates, to identify areas from which soil samples could be taken to establish a site-specific correlation between gamma levels and actual soil Ra-226 concentrations. Note that such correlations are approximate only. Remedial action (cleanup) criteria, specified as allowable residual soil concentrations, may then be compared to color-coded data as shown, to allow quick identification of areas in which remedial action will be required. As excavation of contaminated soil proceeds during cleanup, new will be layered over this plot, providing a nearly real-time display of site remedial action status. Hand-held gamma detectors, of the same type used to develop the plot data, are used for excavation control.

Fig. 6 presents the status of another client site in the western U.S. This project is currently moving toward completion of remedial action. Given that a large number of soil samples have established a good correlation with gamma exposure rate for this site, the Geographical Information System (GIS) display has been modified to show green areas highly likely to meet the soil standard (6 pCi/g Ra-226 at this facility), or red areas requiring additional soil removal. Modification of the data presentation to this two-color format allows for quick identification of areas requiring additional work. All plots that we produce using the GPS/gamma system display high-resolution latitude/longitude (lat/lon) coordinates, allowing re-location of such contaminated areas easily, using "walk-back" features common to hand-held GPS units.

Fig. 7 presents the results of a "current status" check of another client's site in the southwestern U.S. The purpose of the survey was to check for potential con-

Fig. 6. Data Filtered to View Areas of Potential Remediation.

Fig. 7. Contamination Status Check Using GPS/Gamma Scan Data

taminated material left behind after completion of earlier remedial actions. Earlier survey techniques were unable to provide data at this resolution (the plot displays some two million data locations). Detailed soil sampling was used to establish a correlation between the GPS/gamma exposure rate and actual soil Ra-226 concentrations. Areas exceeding the allowable residual concentration, based on gamma levels, will be easy to find if additional remediation is determined by the client to be appropriate.

Summary

The MFG GPS/Gamma Scan system has been refined since 2001 for use on a variety of radioactive contamination sites. The current configuration allows for very rapid data collection, development of useful correlations between soil concentration and gamma exposure rate, and display of very large data sets in a flexible and easily reviewed format. The system is currently in use at several U.S. remedial action sites.

A GPS-Based System for Preliminary or Remedial Action Gamma Scanning

Robert Meyer, Michael Shields, Scott Green

MFG Inc., Suite 100, 3801 Automation Way, Fort Collins CO 80525

Abstract *–MFG Inc. developed a Global Positioning System (GPS)-based gamma scanning technique for use during initial site surveys at a large (16 km2) in-situ-leach uranium mine being developed in Kazakhstan. Since that time, the system has been enhanced and used at a number of contaminated sites in the U.S. At a site in Texas, data acquisition occurred at a rate of seven acres/hour. High-speed acquisition allows rapid site coverage, developing color-coded gamma exposure rates for the entire site. MFG experience at sites either completed or currently undergoing work indicates that regulatory response to the system may be very favorable. The system allows quick visualization of a site's contamination conditions during remediation, and rapid review of final data sets, leading to more time-efficient agency action.*

I. INTRODUCTION

MFG Inc. developed a Global Positioning System (GPS)-based gamma scanning technique for use during initial site surveys at a large *in-situ-leach* uranium mine being developed in eurasia. Since that time, the system has been enhanced and used at a total of eight radium/uranium-contaminated sites in the western U.S. At a Texas site, data acquisition occurred at a rate of seven acres/hour over 600 acres. Such high-speed input allows 100% coverage in a short period, providing color-coded output defining gamma exposure rates for the entire site.

The current system, using a handheld PDA/GPS unit from Garmin®, and a Ludlum® 2' sodium iodide detector unit, is easily hand-carried, or multiple systems may be run simultaneously from a four wheel drive platform (ATV or truck). Data units, each consisting of latitude, longitude, gamma exposure rate and elevation information, are taken at one second intervals with a transit speed of 1 m/s. System resolution is thus 1 meter. System accuracy is limited by acquisition conditions, but is typically 3-5 meters in the U.S., using WAAS-enabled GPS units. Precision, defined here as the ability to re-locate a specific point onsite, is typically 1-2 meters, adequate for remedial activities involving heavy equipment to remove contaminated soil.

All gamma measurements are taken using vendor-calibrated scintillator systems, with digital outputs linked to the GPS/PDA data collection device. Representative soil samples, composites of 10-20 aliquots over a 10x10 m area, are analyzed by a vendor laboratory for Ra-226. Each such soil sample area is individually scanned using the MFG system, and the resulting data are plotted to establish a "cut-off" gamma exposure rate for the site, below which soil concentrations in excess of a site-specific limit are unlikely to be present. A key (and difficult) aspect of system enhancement has been the linking of GPS, PDA and gamma detector units via MFG-developed software.

Because the system is simple to set up and operate, it is now being employed to pre-scan remedial action sites, then to perform follow-up scans as individual areas are subjected to contaminated earth removal. After contaminated soil has been removed to meet applicable standards (typically 6 pCi/g Ra-226 soil concentration), the site is again completely scanned, with a final output plot showing site areas that meet the standard.

MFG experience at sites either completed or currently undergoing scanning and remedial action indicates that regulatory response to the system's output is very favorable. The system allows quick visualization of a site's contamination conditions over time, and rapid review of final data sets, leading to more time-efficient regulatory agency action.

II. USING THE GPS/GAMMA SCAN SYSTEM

With the deployment of the U.S. Global Positioning System (GPS) satellite constellation, a number of new approaches to existing problems became possible. Development of small, inexpensive, handheld GPS receivers has since made such approaches feasible and cost-efficient. MFG staff have been involved in radiation protection and measurements work since the late 1960's. We decided in the late 90's to link gamma detection units with GPS and computer systems to allow the development of very high density mapped data sets. These data are useful to identify contamination at sites including uranium mills and mines, other metal mine facilities (copper, vanadium and rare earth, e.g.) with secondary radioactive contamination, and facilities with other contamination signatures, including accidental. The GPS-based detection systems may also be used to direct

remedial action at such sites, and become especially valuable when providing a record of the final radiation status of a remediated site.

Figures 1-3 show a progression of characterization data being developed at a client facility now being remediated in the western U.S. Initially, a base drawing of the plant was evaluated using our computer automated design (CAD) systems. Such a base drawing, developed at an earlier time using available site information, often does not accurately present the locations of the site's features. The base map for this site was therefore "ground-truthed" by collecting GPS location data at several dozen points throughout the site. This new information was used to "warp" the original CAD drawing to fit the GPS findings. Figure 1 presents such a corrected drawing, ready for gamma data collection.

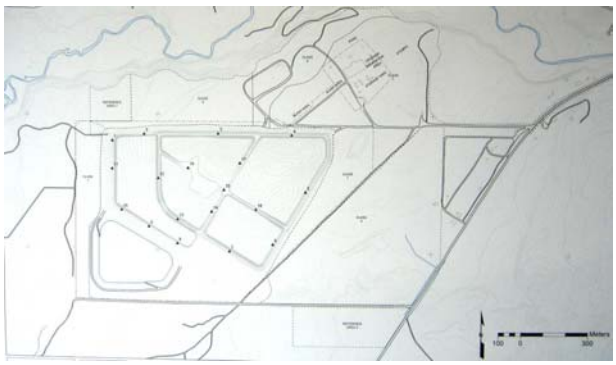

Fig. 1. Base Map.

Figure 2 displays a set of initial gamma exposure rate data, collected using the MFG systems discussed in detail later in this paper. These first hundred thousand locations were used to characterize site exposure rates, both to establish potential health physics protection areas around the site, and to identify areas from which soil samples would be taken to establish a site-specific correlation between gamma levels and actual soil Ra-226 concentrations. Note that such correlations are approximate only, for a variety of reasons to be discussed shortly, but generally provide a useful link between exposure rate and radium concentration. Remedial action criteria, specified as allowable residual soil concentrations, may then be compared to apparent soil concentrations as displayed on the developing site plot.

Fig. 2. Initial Data Collection.

Figure 3 displays a current plot of the facility as it exists prior to remedial action, scheduled to begin this year. The gamma exposure rates have been color-coded to allow quick identification of areas in which remedial action will be required. As excavation of contaminated soil proceeds during the year, additional high-density scanning will be layered over this plot, providing a nearly real-time display of site remedial action status. In addition, hand-held gamma detectors, of the same type and calibration as used to develop the GPS/gamma data displayed in the figure, will be employed to assist in interim excavation control.

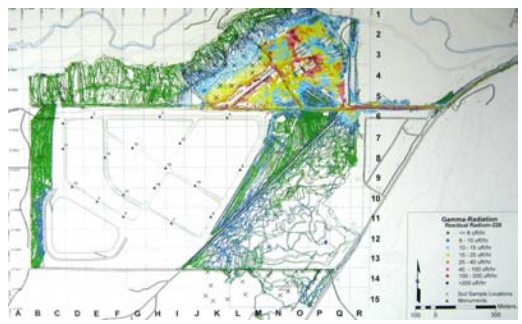

Fig. 3. Full Data Set Prior to Initiation of Remedial Action.

Figure 4 presents the status of another client site in the western U.S. This project is currently moving toward completion of similar remedial action. Given that a large number of soil samples have established a good correlation with gamma exposure rate for this site, our Geographical Information System (GIS) display of the data has been modified to show either green areas highly likely to meet the remedial action soil standard (6 pCi/g Ra-226 at this facility), or red areas requiring additional soil removal to clearly meet the standard. Modification of the data presentation to this two-color format allows for quick identification of areas requiring additional work. All plots that we produce using the GPS/gamma system display high-resolution latitude/longitude (lat/lon)

coordinates, allowing re-location of such contaminated areas easily, using "walk-back" features common to hand-held GPS units. The PC screen display of the plot presents the lat/lon details next to the screen cursor.

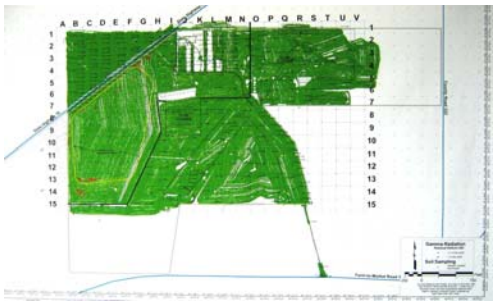

Fig. 4. GPS/Gamma Scan Data Filtered to View Areas for Potential Remediation.

Figure 5 presents the results of a "current status" check of another client's site in the southwestern U.S. The purpose of our survey at this location was to check for potential contaminated areas left behind, after completion of remedial action a number of years ago. Earlier survey techniques were unable to provide data at this resolution (the plot displays some two million data locations), and the figure indicates that some small contaminated areas may require additional remedial action prior to a request to the Department of Energy to take over long term surveillance and maintenance of the site. Again at this site, careful soil sampling was used to establish a correlation between the GPS/gamma exposure rate and actual soil Ra-226. The Figure 5 data are presented in the red/green decision display format. Areas exceeding the allowable residual concentration, based on gamma levels, will be easy to find if additional remediation is determined by the client to be appropriate.

Fig. 5. Contamination Status Check Using GPS/Gamma Scan Data.

II.A. Details: The MFG Inc. GPS/Gamma Scan System

Each system used to collect data displayed in the previous figures currently includes the following:

- Ludlum 2350-1 radiation detection datalogger
- Ludlum 44-10 2x2 inch NaI gamma detector
- Garmin iQue 3600 GPS/Personal Digital Assistant (PDA)
- Proprietary code written by MFG to capture exposure rate and GPS data on iQue flash memory, and to sort and view data as shown in above figures.

The Ludlum 2350-1 includes a bidirectional RS-232 port, allowing communication with PC and PDA devices. The iQue GPS data can be captured internally with appropriate programming, and an RS-232-capable port on the iQue allows communication with the 2350-1 for data transfer initialization and capture. Figure 6 presents views of the system in use in a "backpack" configuration.

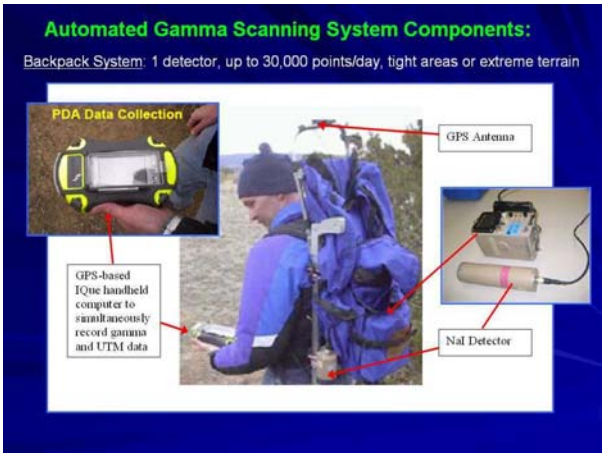

Fig. 6. System in Backpack Configuration.

The system may be deployed in a single-detector configuration, with the gamma detector carried 1 meter above the ground, either lead-shielded or unshielded. It may also be deployed, using a portable computer and a USB hub, with multiple detectors and GPS units carried on a truck or all terrain vehicle frame. The latter configuration increases data collection speed, with three or more detectors all providing data once per second to the PC. Figure 7 provides a view of a multi-detector system, with detectors spaced on 1 meter centers at 1 meter height.

Fig. 7. System in Multi-Detector Configuration.

Developing a correlation between actual soil radionuclide concentrations and measured gamma exposure rates requires careful attention to the collection procedure. In particular, relatively uniform areas of contamination (typically 10 m squares) must be identified prior to soil sampling. Between 10 and 20 aliquots of soil, typically taken to a 15 cm depth, are composited from each such sampling area and sent to a qualified laboratory for Ra-226 concentration analysis (after drying and homogenization). The sampled area is carefully scanned using either a backpack or truck-mounted GPS/gamma scan setup, to develop a useful correlation. Figure 8 presents the results of such a correlation analysis, utilizing data collected at another client site in the western U.S.

III. SUMMARY

The MFG GPS/Gamma Scan system, initially developed to perform an environmental analysis of a proposed in-situ-leach uranium mine site, has been refined since 2001 for use on a variety of radioactive contamination sites. The current configuration allows for very rapid data collection, development of good correlation between soil concentration and gamma exposure rate, and display of very large data sets in a flexible and easily reviewed format. The system is currently in use at several U.S. remedial action sites.

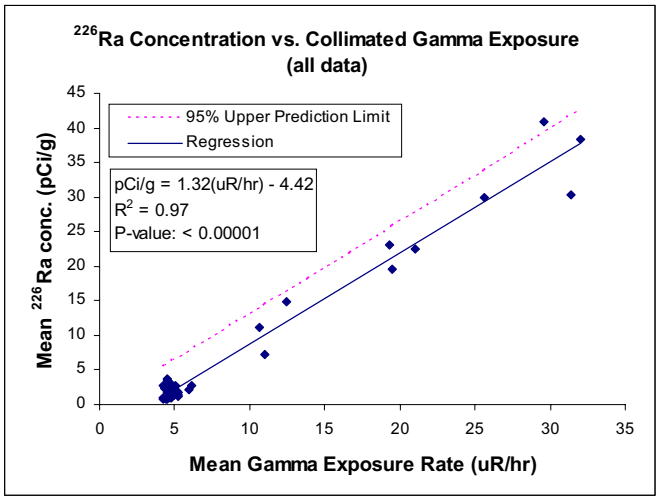

Fig. 8. Soil Analysis vs. GPS/Gamma Scan Exposure Data.