

In-Situ Radiological Surveys to Address Nuclear Criticality Safety Requirements
During Remediation Activities at the Shallow Land Disposal Area, Armstrong
County, Pennsylvania – 12268

Phillip Norris, Mark Mihalo, John Eberlin, Mike Lambert, Cabrera Services;
Brian Matthews, Nuclear Safety Associates

ABSTRACT

Cabrera Services Inc. (CABRERA) is the remedial contractor for the Shallow Land Disposal Area (SLDA) Site in Armstrong County Pennsylvania, a United States (US) Army Corps of Engineers – Buffalo District (USACE) contract. The remediation is being completed under the USACE's *Formerly Utilized Sites Remedial Action Program* (FUSRAP) which was established to identify, investigate, and clean up or control sites previously used by the Atomic Energy Commission (AEC) and its predecessor, the Manhattan Engineer District (MED). As part of the management of the FUSRAP, the USACE is overseeing investigation and remediation of radiological contamination at the SLDA Site in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), 42 US Code (USC), Section (§) 9601 et. seq, as amended and, the *National Oil and Hazardous Substance Pollution Contingency Plan* (NCP), Title 40 of the Code of Federal Regulations (CFR) § 300.430(f) (2).

The objective of this project is to clean up radioactive waste at SLDA. The radioactive waste contains special nuclear material (SNM), primarily U-235, in 10 burial trenches, Cabrera duties include processing, packaging and transporting the waste to an offsite disposal facility in accordance with the selected remedial alternative as defined in the *Final Record of Decision* (USACE, 2007). Of particular importance during the remediation is the need to address nuclear criticality safety (NCS) controls for the safe exhumation and management of waste containing fissile materials.

INTRODUCTION/SITE HISTORY

The Parks Township SLDA Site is located in Armstrong County, Pennsylvania, about 37 kilometers east-northeast of Pittsburgh. The SLDA site consists of approximately 18 hectare within a 46 hectare parcel owned by BWX Technologies (BWXT). There are nine waste disposal trenches and a backfilled settling pond which is treated as a separate trench. These trenches were identified from geophysical surveys completed at the site.

The SLDA Site was formerly owned by Nuclear Materials and Equipment Corporation (NUMEC), which also operated the Apollo Nuclear Fuel Fabrication Facility. The Apollo facility, originally located approximately eight kilometers south of the SLDA site, was decommissioned and all structures on-site have been removed. In the 1960's and 1970's, the SLDA site was used by NUMEC to dispose of radioactive (contaminated

primarily with uranium and thorium) and non-radioactive wastes generated at the Apollo facility reportedly in accordance with the regulations for burial in soil found in 10CFR20.304, which were rescinded in 1981. The Atlantic Richfield Company (ARCO) purchased all of the NUMEC stock in 1967. In 1971, ARCO then sold the stock to Babcock and Wilcox (B&W), who later became BWXT.

NUMEC also owned and operated the Parks Nuclear Fabrication Facility which was formerly located adjacent to and northwest of the SLDA site. Prior to 1995, the SLDA and Parks facilities were licensed by the NRC under one license. The Parks facility reportedly produced primarily enriched uranium fuels and, to a much lesser extent, plutonium-beryllium neutron sources and Americium devices. Between 1995 and 2001, all Parks facility buildings were demolished. Waste materials generated at the Parks facility were reportedly not authorized for disposal at the SLDA site.

METHOD

Comprehensive evaluations have been performed and controls specified to assure NCS (Nuclear Criticality Safety) requirements are addressed throughout the remediation process. This includes the ability to identify a potential NCS issue prior to disturbing the material in the trenches, and to delineate materials and/or areas of waste that require additional controls for removal. Extensive modeling was performed to derive in-situ action thresholds based on the radiological instrumentation to be used, survey methods to be employed and the fissile material mass of concern. However, the most important aspect of this is implementation, (i.e. how will this be performed to minimize personnel risks associated with in-situ measurements within a trench containing waste while also fully addressing the NCS requirements as efficiently as possible?).

The survey method of choice is a manual scan protocol using a 5 centimeter by 5 centimeter sodium iodide (NaI) detector. Based on the modeling completed for this site, the detector field of view is assumed to be a circular area with a radius of 20 centimeters from a standard detector height above ground of 6.35 cm. If a manual method was utilized, this would require an individual to physically walk the surface of the exposed trench numerous times while maintaining the detector at a fixed distance above the uneven surface and carrying global positioning equipment for radiological and position data logging. There is also concern for personnel safety due to the potential for a technician to step on a corroded storage drum and collapse the drum causing personal injury and release of the drum's chemical and/or radiological contents to the environment. To compound this issue, the NCS requirements impose redundancy, meaning that this would have to be performed twice. Once the data was collected, it would be downloaded for post-processed evaluation.

To minimize the risks associated with personnel access within the trenches, Cabrera Services, Inc. along with their partner, Measutronics Corporation devised a cart-mounted system that employs three (3) 5cm x 5cm detectors in-line with separation distance such that a single pass will cover a width of 122 centimeters. In consideration of the MARSSIM Gamma Walkover Survey Protocol, the cart and its deployment vehicle

were designed to be capable of maintaining a scan rate of ~0.5 meters/second with a detector height above ground surface ~6.35 centimeters. The SLDA calibration analysis (NSA-TR-SLDA-10-23) assumes the detector height above the ground surface is a maximum of 7.6 centimeters and application of the MARSSIM scan protocol (rate).

The equipment needed and the cost associated was minimized by designing a system such that radiological data output from these 3 detectors are coupled with a single global positioning system (GPS) unit to provide location coordinates associated with the radiological data. To improve the efficiency, the GPS coordinates are wirelessly transmitted to a remote on-site work station for real time mapping. To address the redundancy requirement, the cart design includes a separate set of 5cm x 5cm detectors and GPS system directly behind the first on the same cart, with wireless transmission of data to the same remote work station.

To further minimize personnel exposure and physical hazards, the cart is designed to be deployed within the trenches using a remote-controlled mini track loader as the deployment vehicle. The equipment operator remains outside the trench but within visual contact to monitor progress. To accommodate anticipated variation in excavated surface competence, the cart is mounted on a fork attachment at the fore-end of the mini track loader if rough terrain is encountered and the cart doesn't touch the surface of the trench while in operation. In smooth terrain, the cart can be pulled by the mini track loader using the optional wheeled chassis. The in-situ survey cart design achieves the following objectives:

- Fully addresses the NCS requirements for in-situ surveys of a trench excavation layer (30 cm thick); allowing immediate prioritization of investigations based on in-situ measurement results.
- Greatly minimizes the time personnel would have to spend within a trench compared to conventional survey methods.
- Control of cart movement within the trench by personnel outside the trench by means of remote control.
- Provides the data wirelessly to a remote computer in real time for immediate evaluation, with GPS coordinates to precisely identify the location of any anomalies requiring further investigation. This also minimizes time personnel may have to be within a trench since the locations are identified and easy to return to as necessary.
- Minimizes cost by using typical, off-the-shelf, equipment. Of great importance is the cost savings afforded by coupling multiple detector outputs with a single GPS.
- Indirectly, the survey results assist the MC&A program by identifying areas of potential elevated SNM concentrations that may warrant additional sampling, or simply providing data to indicate relative uniform distribution which minimizes the sampling needed.

Greater detail in the design requirements and anticipated outcome from this effort to maximize employee safety are provided.

DESIGNING A SOLUTION

In designing a solution to satisfy the SLDA Criticality Safety requirements, designers decided on the use of a collection of existing technologies and equipment for ease of operation and future serviceability. The essential equipment employed in the survey cart system consists of Trimble SPS 852 and SPS 552 GPS receivers, Trimble Tablet computers attached to Ludlum 2221 Ratemeters, and the associated communications equipment. These three systems facilitate the collection and management of radioactivity data related to Shallow Land Disposal Area excavation sites. The Trimble SPS 852 and 552 GPS systems consist of a Trimble GPS receiver with rechargeable Li-Ion batteries installed in a sturdy mounting box on the portable survey cart, to which is attached the GPS antenna. The Trimble Tablet computer consists of the computer with 2 internal rechargeable Li-Ion batteries, *Hydro Pro* software (version 5.2 or later) with USB Dongle, and capabilities for managing data acquisition and for downloading to a PC. The Trimble Tablet computers are located on a separate remote monitoring cart, allowing the operator to monitor the results of the survey from outside the trench area as described earlier. The Ludlum 2221 rate meters have RS-232 capabilities to allow the transmitting of the instrument output to the remote Trimble Tablet computers.

DISCUSSION OF GPS TECHNOLOGY USED

In addressing the need for the ability of the survey cart to accurately show survey data to an accuracy of within 15 centimeters required an understanding of how the Global Positioning System functions in field applications. As a review, the Global Positioning System is comprised of a constellation of 24 satellites operated by the U.S. Department of Defense, and is known as NAVSTAR. GPS provides all-weather, worldwide, 24-hour position and time information. Each satellite is at an altitude of about 17,440 kilometers, weighs almost 900 kilograms, and is 5 meters across with solar panels deployed. They orbit the earth every 12 hours.

The basis of GPS is “trilateration” from satellites. Data from four satellites is required to uniquely calculate the position of the survey cart in the excavation trench. To trilaterate, a GPS receiver measures distance using the travel time of radio signals, which requires very accurate timing. In addition, the accurate position in space of each satellite is required, achievable only through careful monitoring. And the final step in calculating a GPS “fix” at the earth’s surface (or high above it in an aircraft) is to correct for any delays the signal experiences as it travels through the atmosphere.

Differential GPS or “DGPS” can yield measurements good to a couple of meters in moving applications and even better in stationary situations. DGPS involves two receivers: one is stationary and another is “roving”, making position measurements. The stationary receiver ties all the satellite measurements into a solid local reference. Since the satellites are so far out in space, and the two receivers (base and rover) are fairly close, say within a few hundred yards, the signals that reach both of them will have traveled through virtually the same slice of atmosphere, and so will have virtually

the same errors. The base station measures the timing errors and provides correction information to the other roving receiver. In this manner, the accuracy of the roving measurements (i.e., survey data) increases down into the tens of centimeters or better. This correction takes place after field data collection by comparing field measurements to base station measurements.

Survey Cart designers employed the following established “best practices” for GPS systems in order to provide the maximum accuracy of the GPS signal.

- Use the GPS antenna in a location that has a clear line-of-sight to the sky in all directions. Avoid using the antenna near vertical obstructions such as buildings, deep cuttings, site vehicles, towers or tree canopy. The challenge for cart use in the excavation trench was to ensure that the site buildings were erected a sufficient distance away from the trench to prevent interference with the GPS signal. Also, trench depth is not predicted to exceed 4.3 meters, therefore minimizing the interference of the GPS signal with side slopes of each trench.
- Place the GPS antenna as high as possible to minimize multipath from ground sources. Each GPS Antenna installed on the mobile survey cart is mounted on a tall superstructure, which also serves as a “roll cage” to protect the instrumentation in the unlikely event that the cart tips over during use.
- GPS Planning software (included on Hydro Pro Software CD) can be used to identify the daily best and worst satellite coverage times for the trench location, which allows the operator to choose measurement times that coincide with optimal GPS performance. During the initial construction season and inaugural deployment of the survey cart, there was more than sufficient satellite coverage during the typical workday, which was during the daylight hours only.
- Do not use the rover receiver directly beneath or close to overhead power lines or electrical generation facilities to minimize electromagnetic interference. There were no overhead lines located near any of the excavation trenches. Other sources of electromagnetic interference that were considered during the design of the cart were: gasoline engines (spark plugs), televisions, computer monitors, alternators, generators, electric motors, fluorescent lights, and switching power supplies. None of these items were deployed in sufficient quantities or in a close enough proximity to the excavation trenches to present an electromagnetic interference problem.

SYSTEM MATERIALS AND EQUIPMENT

The following equipment was used in the design of the mobile survey cart, the remote operator cart, and the associated base station.

- Trimble SPS 852 GPS “Position” Receiver and antenna (Mobile)
- Trimble SPS 552 GPS “Heading” Receiver and antenna (Mobile)
- Trimble SPS 852 GPS Base Station with internal RTK Radio and Antenna with cables
- Trimble Tablet Computer (Windows 7 Operating System) with Hydro Pro Software Version 5.2 With USB Dongle
- Laptop or Desktop Computer (Windows 7 Operating System) with Ultra VNC Software
- Lemo to Lemo Cables
- RS 232 to RS 232 Serial Cable
- RS 232 – Single Port (for 2221 connection)
- B and B Electronics Multiplexer
- B and B Electronics Ethernet Switch
- Freewave 900Mhz 2 Serial/Single Ethernet Radio and Cables
- 12 vdc 20Ah Deep Cycle Non-Spillable Portable Battery
- Trimble SNM 920 4 Port Ethernet Router for each System
- Ludlum 2221 Ratemeters with Ludlum Model 44-10 Probes
- 12 vdc to 120 vac transformers
- Sturdy “Toolbox Type” Boxes for Main Control Box and Remote Operator Box
- Sturdy Mobile Cart with heavy gage aluminum frame (professionally designed to limit its weight and handling requirements). *Note: The mounting frame, when utilized on rough terrain, was designed to either be pulled behind the remote controlled mini loader on skids or mounted on a front-end fork attachment for above surface coverage.*
- Optional Chassis with wheels for smooth surface usage.

SETUP OF EQUIPMENT

GPS Base Station Setup:

In order to allow for the proper operation and accuracy of the GPS receivers located on the Mobile Cart, a stationary base station GPS is required to be installed and operational. The Base Station GPS is also required to be operational in order for the internal RTK Radio signal to be transmitted to the GPS Receivers on the Mobile Cart.

- The GPS Base Station antenna was mounted on a semi-permanent (mobile office trailer or equivalent) structure and the receiver is located inside the structure where it can be connected to a 120 VAC power supply.
- The GPS Base Station employs a Trimble SPS 852 receiver with an internal RTK Radio transmitter. This allows the GPS Base Station to transmit GPS correcting data to the field GPS receivers via a 900 Mhz radio signal.
- The Trimble SPS 852 receiver displays the number of satellites that are in range and whether or not the base station is transmitting to the field GPS receivers.

- Prior to use, the correct Coordinates were programmed into the SPS 852 GPS Base station receiver before it was used to provide correcting data to the field receivers.

Setting up a GPS Control Station

In order to ensure that the field GPS receivers (located on the mobile survey cart) display accurate signals, a stationary control station was established near the SLDA trenches outside the contamination area. This control station was clearly marked with a concrete pad and was designated as a GPS Control Point. Before use each day, the Mobile Cart with GPS receivers is positioned at the GPS Control Point to verify the displayed coordinates are within the established acceptable range. The acceptable range was established by taking ten separate GPS coordinate readings with the same instrument and performing a Chi Square analysis on those readings to set the range. This performance check is recorded for each day the mobile survey cart is in use.

Mobile Cart Setup



Fig.1 – Mobile Cart Shown in design stage with optional wheels

The Mobile Survey Cart (Fig. 1 above) houses all the equipment necessary to facilitate trench drive over surveys. The cart houses the GPS receivers and their associated antennas, the router, power supplies, multiplexers, radio transmitters, the Ludlum 2221 rate meters and probes, and all the associated connecting cables. Remember from previous discussion that there are two separate monitoring systems on the cart to allow for redundancy. Each system is setup as follows:

Each Ludlum 2221 ratemeter is connected to the main control box serial ports located on the back of the box using the *RS 232 – Single Port Cables*.

- From the serial ports in the main control box, the Ludlum 2221 data signal is routed to a multiplexer using the *RS-232 to RS-232* cables. There is one multiplexer for each system.
- The multiplexers are connected via the *Parallel to RS-232* cable to the “Freewave” radio, which provides telemetry to the remote operator. The

“Freewave” Radio has its own antenna that is mounted on the cart roll cage. This signal sends the data from the six (6) Ludlum 2221 sensors to the Trimble Tablet, which is operated remotely.

- There are two separate GPS Systems on the Mobile Cart. Each GPS system has a “Position” and a “Heading” receiver. Each system also has its own set of GPS antennas (Position and Heading antennas). Each GPS SPS 852 has its own internal RTK receiver that receives the correcting positioning signal from the base station internal RTK radio (transmitter). This comes into the bulkhead of the main control box.
- Each system’s GPS receivers connect to “Freewave” radios via routers and/or Ethernet switches. From the “Freewave” Radio, both systems transmit GPS data to the Trimble Tablet (remote operator).
 - There are Six (6) Ludlum 2221 Sensors on the cart as follows (3 sensors per system for redundancy). Each Ludlum 2221 and 44-10 Probe has been properly calibrated and for a 75-200 Kev Window. This window is used in order to detect the U-235 decay gamma.
 - The Ludlum 2221’s are set to the “Digital Rate” count mode with a “Slow” response. The “Window” setting is set to “WIn,” to allow for the calibrated window to be used during operation.

Operator Remote Control Station Setup

The Operator has a remote control station which allows for the operation and monitoring of all the equipment on the Mobile Cart. This function is accomplished by the use of telemetric equipment. As the Mobile Cart moves along the trench survey area, the remote operator can monitor the status of both survey systems to ensure a valid GPS signal is being received and whether or not the Ludlum 2221 Sensors are functioning properly. This is essential, since the hazardous environment in the trench would preclude an individual operating the equipment from a station on or adjacent to the Mobile Cart. The Remote Control Station is setup as follows:

- The Ludlum 2221 Sensor data (6 sets), and the GPS data (4 sets) are transmitted from the Mobile Cart via an RTK Radio signal to the remote operator control box. The signals are routed through a “Freewave” antenna into another “Freewave” radio located in the remote control box.
- The Ludlum 2221 Sensor data that is transmitted to the remote control box is routed from the “Freewave” receiving radio via an *RS-232 to Parallel* connection to the B and B Electronics Multiplexer. There are 3 sets of Ludlum 2221 Sensor data per cable that is sent to the Multiplexer.

- From the Multiplexer (3 cables per system, 6 total), the Ludlum 2221 data signal is routed via *RS-232 to RS 232 Cable* to a distribution Panel on the Remote Box. This distribution Panel is located on the bulkhead of the box. There are 6 serial ports located on this panel, one port for each Ludlum 2221 data stream.
- From the distribution Panel on the Box, all six (6) Ludlum 2221 data cables go to the Trimble Tablets via *RS-232 to RS-232 cables*. Each system's data is displayed on separate Trimble Tablet computers.
- The (4) GPS signals that are transmitted to the remote control box are received by an RTK antenna and routed to a "Freewave" radio via an Ethernet Cable to the Ethernet switch. From the Ethernet Switch, *System 1* and *System 2* are connected to their respective Trimble Tablets via Ethernet cables.
- From the Ethernet Switch another "Freewave" transmitter is connected using an Ethernet cable. This "Freewave" radio is used to send a signal to a remote desktop computer, which will provide the ability to monitor the Trimble Tablet displays (remotely).
- The remote desktop computer is connected to a "Freewave" radio (receiving signal). The remote desktop computer, using Ultra VNC software, provides the ability to remotely monitor each tablet simultaneously during operations.

OPERATION OF EQUIPMENT (Summary)

To perform a survey in the excavation trench area, the survey cart is loaded onto the mini track loader. All equipment is powered on and initialized in accordance with the operating procedure. A performance check is completed on each Ludlum 2221 ratemeter, which includes checking against a radioactive source that is selected based on the isotope of concern and the energy range of the selected window. The measured background counts are loaded into the *Hydro Pro* software which allows for the subtraction of background counts from the raw survey data. The survey cart is then placed on the GPS Control Station pad and the GPS positions for each detector are verified to be within the established accuracy. Each detector's position is determined by the use of an "offsetting" feature made possible by the use of a heading and positioning GPS signal.

Once the survey cart is verified to be operating properly, the remote operator creates a virtual work area on the Trimble Tablet display for each system. This "work area" represents an area of interest in the trench that is to be surveyed. The survey data from the cart will only be displayed on the Trimble Tablet when the cart is physically within the "work area" represented by the area on the display. The survey cart is then driven into the area to be surveyed in the trench by remote control from the remote operator cart that is physically located outside the trench. The operator can observe the cart's

location in the trench visually and via the Trimble Tablet to ensure it is positioned in the selected work area. Once in the work area, the survey cart data is displayed on the Trimble Tablet.

There are several visual aids available to the operator while operating the survey cart. The operator can refer to the Trimble Tablet display to ensure the cart is operating within the selected survey area, view the output of each survey instrument, ensure that the background counts are being subtracted, ensure that each GPS signal is functioning properly, and Toggle through each screen to ensure that the sensors are operating properly. Each sensor is color-coded to match the color of the probe mount on the Mobile Cart. Typical sensor data colors are red, black and blue. If either of the sensors is not operating properly, the sensor information text will flash.

Ranges of interest can be programmed into the Trimble Tablet to provide an output of the survey data that indicates raw data that is below action level, close to action level and above or significantly above action level (indicating locations of potential elevated U-235 concentrations that require further investigation to determine controls necessary for removal commensurate with the defined NCS requirements).

During the operation of the cart, the remote desktop computer (located a significant distance away from the trench area) can display a duplicate of the information being displayed on the Trimble Tablet. This allows supervisory personnel to monitor the cart operation from a safe distance. Additionally, The Trimble Tablets and the remote desktop computer can be monitored remotely by supervisory personnel by the use of commercially available remote-PC software, which is installed on the remote desktop computer. This software also allows a Technical Representative to logon to the system via the internet and perform troubleshooting in case there are issues with the system.

When the survey is completed, the operator can upload the cart survey data via flash drive or via the remote desktop via the Ultra VNC software capability. Data files are forwarded to a GIS technician who creates a useable output via ArcView software. A sample completed survey map is included below as Figure 2.

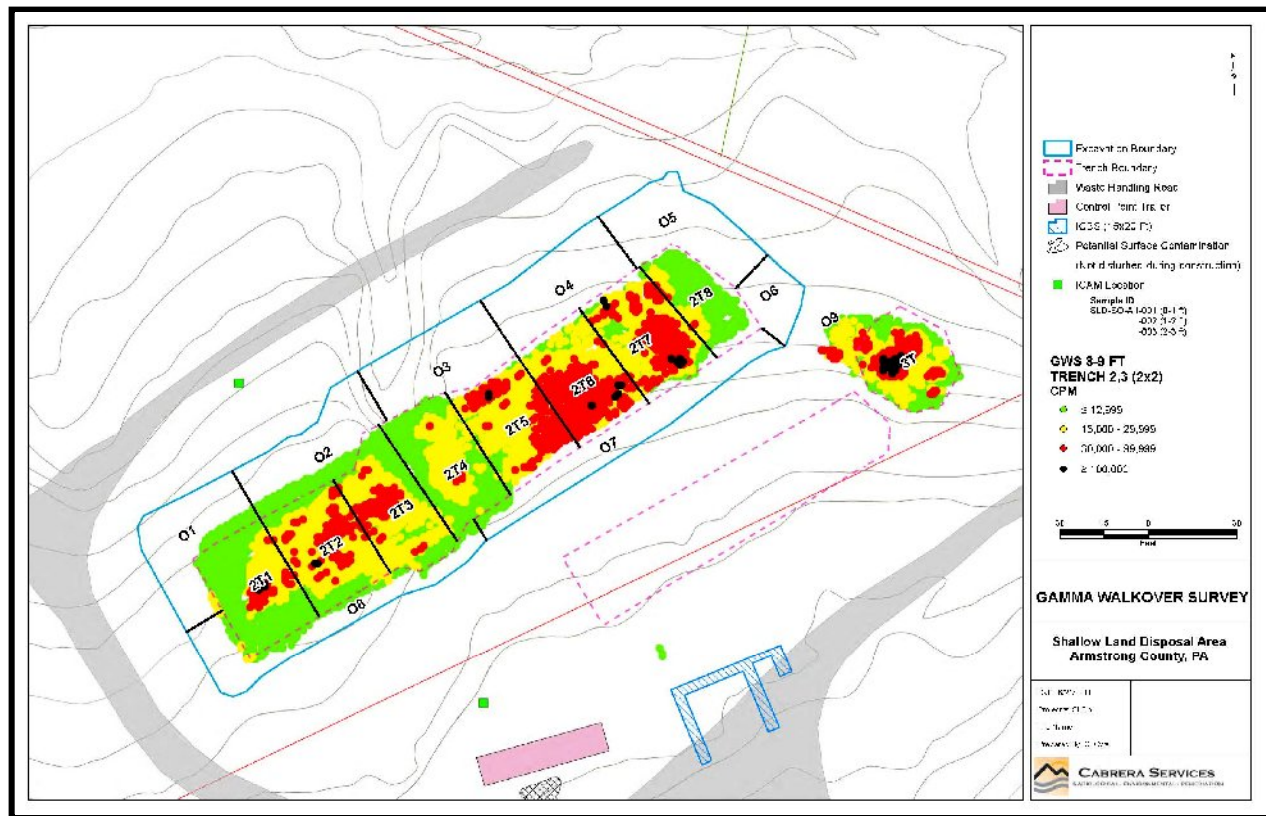


Fig. 2– Cart Survey Data Map

CONCLUSION

The partnership between Cabrera Services, Inc. and Measutronics Corporation led to the development of a valuable survey tool and operating procedure that are essential components of the SLDA Criticality Safety and Material Control and Accountability programs. Using proven existing technologies in the design and manufacture of the Mobile Survey Cart, the continued deployment of the Cart will allow for an efficient and reliable methodology to allow for the safe exhumation of the Special Nuclear Material in existing SLDA trenches.