FINAL VERIFICATION SUCCESS STORY USING THE TRIAD APPROACH AT THE OAK RIDGE NATIONAL LABORATORY'S MELTON VALLEY SOILS AND SEDIMENT PROJECT

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ABSTRACT

The United States Environmental Protection Agency recently published guidance on the *Triad* approach, which supports the use of smarter, faster, and better technologies and work strategies during environmental site assessment, characterization, and cleanup. The Melton Valley Soils and Sediment Project (Project) at the Oak Ridge National Laboratory embraced this three-pronged approach to characterize contaminants in soil/sediment across the 1000-acre Melton Valley Watershed. *Systematic Project Planning* is the first of three prongs in the Triad approach. Management initiated Project activities by identifying key technical personnel, included regulators early in the planning phase, researched technologies, and identified available resources necessary to meet Project objectives. *Dynamic Work Strategies* is the second prong of the Triad approach. Core Team members, including State and Federal regulators, helped develop a Sampling and Analysis Plan that allowed experienced field managers to make real-time, in-the-field decisions and, thus, to adjust to conditions unanticipated during the planning phase. *Real-time Measurement Technologies* is the third and last prong of the Triad approach. To expedite decision-making, the Project incorporated multiple in-field technologies, including global positioning system equipment integrated with field screening instrumentation, magnetometers for utility clearance, and an on-site gamma spectrometer (spec) for rapid contaminant speciation and quantification. As a result of a relatively complex but highly efficient program, a Project field staff of eight collected approximately 1900 soil samples for on-site gamma spec analysis (twenty percent were also shipped for off-site analyses), 4.7 million gamma radiation measurements, 1000 systematic beta radiation measurements, and 3600 systematic dose rate measurements between July 1, 2004, and October 31, 2005. The site database previously contained results for less than 500 soil samples dating back to the 1980s, and it contained no radiation measurement data. The result of this verification effort is a dataset of sufficient quantity and quality to demonstrate compliance with Project criteria and one that withstands Core Team scrutiny.

INTRODUCTION

The United States Environmental Protection Agency (EPA) published guidance on the *Triad* approach [1], which supports the use of smarter, faster, and better technologies and work strategies during environmental site assessment, characterization, and cleanup. This approach is based on a three-pronged strategy of *Systematic Planning*, *Dynamic Work Plans*, and *Real-Time Measurement Technologies* to conduct environmental studies such as final verification of environmentally contaminated sites. The Melton Valley Soils and Sediment Project (Project) at the Oak Ridge National Laboratory embraced Triad to characterize 16 contaminants of concern in soil/sediment across the 1000-acre Melton Valley Watershed. The objective of the Project was to conclusively demonstrate that residual soil/sediment concentrations satisfy Record of Decision (ROD) [2] criteria while integrating the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* [3] and Triad into the verification strategy. MARSSIM provides a widely accepted method for collecting, evaluating, and reporting verification data, and Triad allows technical experts to make real-time decisions using a combination of field screening and on-site analytical data, all while working toward compliance with the ROD.

Science Applications International Corporation (SAIC), as a subcontractor to Bechtel Jacobs Company LLC (BJC), identified key technical staff, defined data quality objectives (DQOs), and presented the verification strategy to the United States Department of Energy, EPA Region 4, and the Tennessee Department of Environment and Conservation. This “Core Team” evaluated the general strategy and the merits of utilizing the Triad approach. Field management and verification decision-making would rely heavily on large volumes of real-time field measurement data and “quick-turns” from on-site laboratory gamma spectrometer (spec) analyses. Off-site analyses would also be used to confirm the findings of the on-site laboratory and to quantify contaminants that were not adequately characterized using the gamma spec method. Finally, electronic data management systems were integrated into the Project, resulting in streamlined dataflow.

CHARACTERIZATION STRATEGY

Triad and MARSSIM provide the foundation for the Project planning, execution, and data interpretation effort. Specifically, Triad acknowledges that field screening and an on-site laboratory (presumably producing lower quality data than an off-site laboratory) may be used to make final decisions. Before Triad, regulators often resisted the use of field measurement or on-site analytical data, preferring, for example, Contract Laboratory Program-level data quality, which can be significantly more expensive and result in delays because of sample shipment, sample preparation and analysis, and formal reporting. Under Triad, real-time field and on-site analytical measurements may be used to demonstrate compliance using a larger number of data points than would be available solely from off-site laboratory results. That is, managers can use real-time data to expedite decisions that were especially important, for example, in excavations where Project costs can accumulate during the wait for off-site analytical results.

MARSSIM “provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance” with remedial objectives [3]. While designed for radiological investigation, the underlying framework works well for radiological and chemical contaminants both, as are found in the mixture of Melton Valley contaminants of concern (14 radionuclides and 2 chemicals). The Project referred to MARSSIM guidance for defining the type and quantity of data required for compliance testing, especially in the areas of measurement technologies, DQOs, and reporting. The combination of MARSSIM and Triad produced an optimal scenario for demonstrating compliance with the ROD: well defined DQOs and compliance testing methods with decision-making flexibility using real-time data collection methods.

Systematic Project Planning

Systematic Project Planning is the first of three prongs in the Triad approach and includes defining project goals and charting the most resource-effective course to reach the desired outcome. Project management initiated verification activities by identifying key technical personnel and subcontractors to develop the overall strategy and detailed Sampling and Analysis Plan (SAP) [4]. SAIC was tasked with developing the verification strategy document [5] and SAP, serving as the technical lead, validating analytical data packages, loading the data into the Oak Ridge Environmental Information System (OREIS), and reporting results of the verification effort. Safety and Ecology Corporation (SEC) was tasked with providing verification (i.e., sampling) technicians plus health and safety oversight, as well as operating the on-site analytical laboratory. Other subcontractors, such as off-site analytical laboratories and transportation specialists, were identified after approval of the strategy document and SAP. The Project organization chart, presented in Fig. 1, shows key Project personnel including Core Team participants, technical and management positions, field team members, and other key participants.

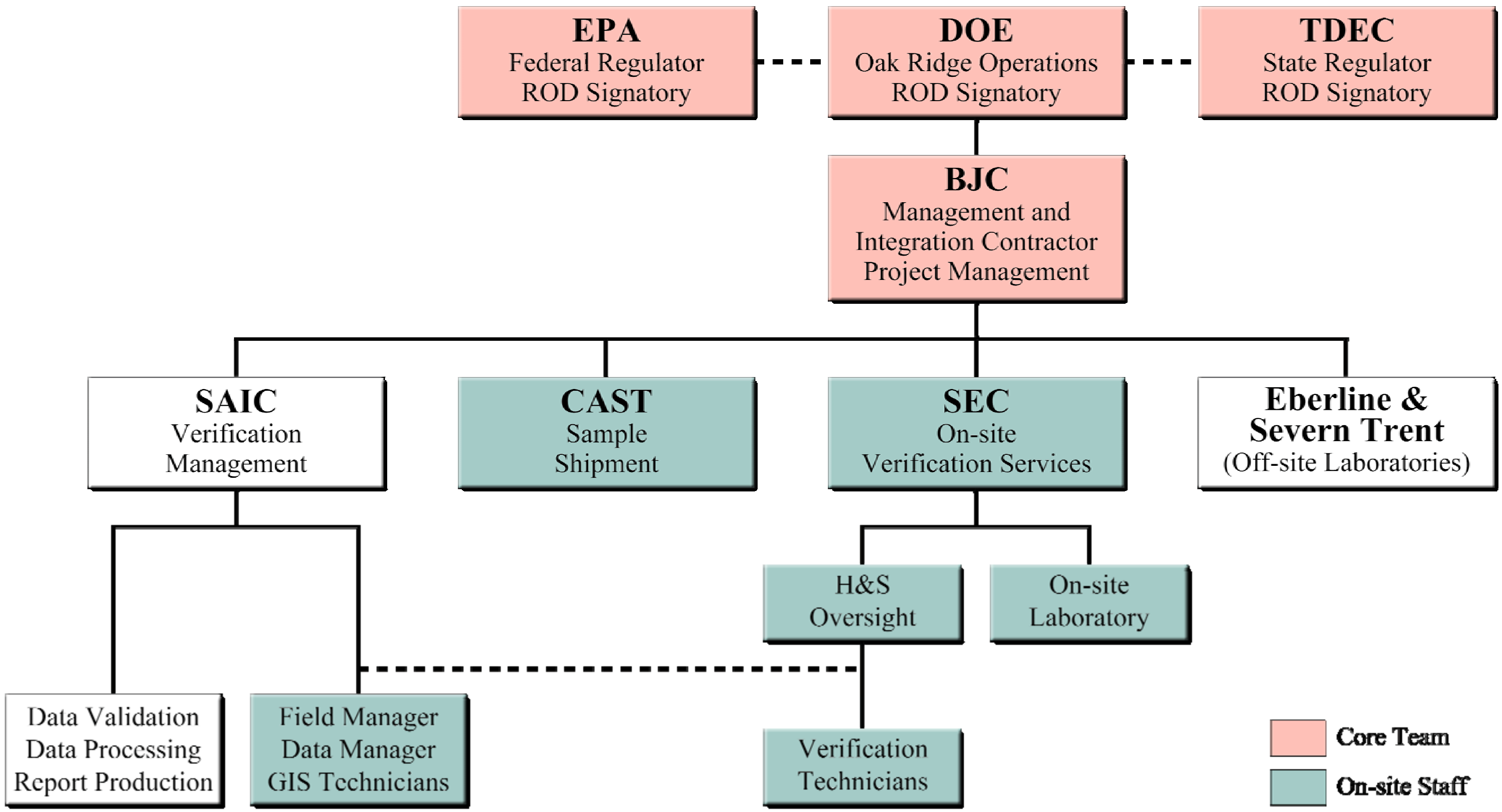
The ROD defines general Project goals and specifies that MARSSIM shall be used, but it does not provide specific detailed instructions for demonstrating how goals are satisfied. The strategy document and SAP were, therefore, prepared to establish DQOs; identify the type, quantity and quality of data to be collected; define analytical methods and reporting requirements; specify methods for the data interpretation; and outline verification reporting requirements. Key components of the strategy document /SAP are presented in Table I. The strategy document and SAP were presented to the Core Team, which approved them after comments were incorporated. The documents were issued as final documents in October 2004.

The integrated strategy also included a number of technologies aimed at achieving paperless data collection and processing to the extent possible. Global positioning system (GPS) and geographical information system (GIS) technologies streamlined the planning, collection, and presentation of verification data. The database tool Project Environmental Measurements System was used to produce sample labels, track samples, and transfer electronic data deliverables from on-site and off-site analytical laboratories to end users and, ultimately, to transfer approved datasets to the final repository: OREIS. Table II presents data analysis tools used to streamline data flow and, ultimately, to determine whether ROD criteria were satisfied.

Dynamic Work Strategies

Dynamic Work Strategies is the second prong of the Triad approach. Core Team members helped develop a SAP that allows experienced field managers to make real-time in-the-field decisions and, thus, to adjust to conditions unanticipated during the planning phase. The SAP provides unambiguous direction to field personnel without being overly prescriptive, thus maximizing field productivity by providing the framework for in-the-field decision-making. Updates on changing conditions were relayed to the entire Core Team at regular meetings or, when necessary, via e-mail and telephone.

Key to the success of the verification Project was the identification of experienced personnel. Experienced on-site technical staff was integrated into the Project, including dedicated GIS technicians, a dedicated Data Manager/Sample Coordinator (DM/SC), and dedicated on-site analytical laboratory technicians. These individuals coordinated their efforts to propagate the flow of data and feed field and project management personnel with continuous updates. Weekly reports were prepared to formally document progress and identify planning obstacles, but information could be relayed in real time as needed. BJC, SAIC, and SEC all maintained on-site offices and, more specifically, subcontractor field managers orchestrated the collection of all verification data. Additionally, competent subordinates were placed in deputy positions with direct-line reporting to field managers. The off-site Verification Manager (SAIC) addressed issues related to data quality and compliance testing; resolved differences between project documents and field decisions; and integrated data management, validation, and reporting aspects of the Project. The on-site DM/SC regulated the flow of data from field personnel to analytical laboratories, the data validators and other end users such as the Verification Manager. The DM/SC also monitored data collection activities to assure quality assurance/quality control objectives were satisfied, as identified in the strategy document and SAP. A well-established on-site laboratory with dedicated staff was also utilized to analyze every (~1900) volumetric sample collected during the verification effort.



BJC = Bechtel Jacobs Corporation, LLC
CAST = Commodore Advanced Sciences Team
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
GIS = geographical information system
H&S = health and safety
ROD = Record of Decision
SAIC = Science Applications International Corporation
SEC = Safety and Ecology Corporation
TDEC = Tennessee Department of Environment and Conservation

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Fig. 1. Melton Valley verification Project organization chart.

Table I. Melton Valley Verification General Strategy Overview

Component	Description
ROD	Identifies unit average remediation levels (RL_{UA}) and not-to-exceed remediation levels (RL_{NTE})
	Specifies collection of samples from three distinct intervals:
	Shallow (0 to 0.15 m), intermediate (0.15 to 0.6 m) and deep (0.6 to 3 m)
	Divides watershed into four industrial, one waste management, and one floodplain Exposure Unit(s)
	Final risk assessment to be performed at Exposure Unit level using systematic/random sample data
	Biased samples used to compare against RL_{NTE}
	Identifies the MARSSIM method for demonstrating compliance with ROD
Triad	With MARSSIM, establishes data quality objectives and advocates resource-effective approach
	Allows verification management team to make real-time decisions
	Relies heavily on field measurement data to make decisions (including on-site gamma spec data)
MARSSIM	Subdivides Exposure Units into Survey Units
	Identifies Class 1 Survey Units: highest potential for exceeding criteria; includes all excavations
	Limits Survey Unit size to < 20,000 m^2 (5 acres); modified from MARSSIM default per risk scenario [a]
	Objective of 100% gamma walkover survey coverage
	Collects biased samples at small areas of elevated activity
	Collects systematic samples on a triangular grid
	Identifies Class 2 Survey Units: low-to-moderate potential for exceeding criteria
	Limits Survey Unit size to < 80,000 m^2 (20 acres); modified from MARSSIM default per risk scenario [a]
	Objective of 10% gamma walkover survey coverage
	Collects biased samples at small areas of elevated activity
	Collects systematic samples on a triangular grid
	Identifies Class 3 Survey Units: lowest potential for exceeding criteria
	No limit on surface area
	No target for gamma walkover survey coverage
	Collects biased samples at small areas of elevated activity
	Collects samples at randomly selected locations
	Defines compliance testing requirements/reporting
	Follows MARSSIM Chapter 8 to perform data quality assessments
	Presents data using tabular and graphical methods
	Presents statistical test, if required (Sign test used)
	Draws conclusions on the data relative to ROD criteria
	Presents raw data
Other	Collects at least 100 beta measurements in each Exposure Unit on systematic grid
	Collects dose rate measurements in the floodplain, per the ROD, on a 10-m grid
	Validates 5 to 10% of analytical data
	Reports findings per Survey Unit (if all Survey Units satisfy criteria, so will aggregate Exposure Unit)

[a] MARSSIM sets the default Class 1 area at 2000 m^2, presumably to represent the size of a residential lot (~0.5 acres). The Melton Valley action is to assure residual concentrations are protective of future industrial workers. The surface area default was therefore adjusted to account for the less restrictive land use. A similar adjustment was made on the Class 2 MARSSIM default of 10,000 m^2.

MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual [3].

ROD = Record of Decision [2].

Table II. Melton Valley Verification Data Analysis Tools

Data Analysis Tool	Purpose
On-site Gamma Spec System	Analyze all (~1900) soil samples for gamma-emitting radionuclides such as Cs-137 and Co-60; turnarounds of a few hours were possible, and 1- to 2-day turnarounds were routine.
Off-site analytical laboratory	Quality assurance for on-site lab plus analysis of non-gamma-emitting contaminants.
On-site geographical information system capabilities	Used to generate field maps, direct sampling activities (e.g., provide coordinates), illustrate environmental data in reports, etc.
Project Environmental Measurements System	Data management system used by the field team and analytical laboratories to coordinate sample collection, shipping, analysis, validation, and reporting activities.
Electronic analytical data screening program	SAS® program to evaluate data usability, apply assessment qualifiers, and generate inquiries to the analytical laboratory; 100% of analytical data packages subject to screening assessment.
Oak Ridge Environmental Information System	Final on-line repository/database for verification data.

Real-time Measurement Technologies

Real-time Measurement Technologies is the third and last prong of the Triad approach. Real-time technologies facilitate real-time decision-making, which is especially important during excavation/remedial actions, when delays in sample analysis and interpretation can dramatically increase Project costs. To expedite decision-making, the Project incorporated multiple in-field technologies, including GPS equipment integrated with field screening instrumentation, magnetometers for utility clearance, and an on-site gamma spec for rapid contaminant speciation and quantification.

Table III presents the types of verification data collected, whether GPS was used, and which results were retained in OREIS. The physical collection of data was performed using traditional methods (e.g., hand augering) and instrumentation [sodium iodide and Geiger Mueller (GM) detectors] integrated with GPS technology. GPS position information was collected with each verification data point for same-day mapping (when required) and to facilitate real-time decision-making. Field personnel were also equipped with communication devises to alert field managers of unanticipated obstacles or unusual circumstances, such as the discovery of small areas of elevated activity (i.e., "hot spots") or health and safety concerns. The established data collection system resulted in rapid data processing and interpretation, an almost entirely electronic dataset, and powerful graphical abilities, making it easier to identify potential data gaps or other areas of interest.

Table III. Melton Valley Verification Data Collection Activities

Data Collection Activity	**Purpose**	**Target Medium**	**Beta Meas.**	**Gamma Meas.**	**Dose Meas.**	**Volumetric Sampling**	**Utilize GPS**	**Results to OREIS**
Sodium iodide (NaI) walkover surveys	Identify elevated gamma radiation levels (e.g., from Co-60 and Cs-137) and confirm MARSSIM classification	Soil		✓			✓	✓
Geiger Mueller (GM) systematic surveys	Identify elevated beta radiation levels (e.g., from Sr-90)	Soil	✓				✓	✓
Dose rate measurements	Identify elevates dose rate in the floodplain	Sediment			✓		✓	✓
Screen sampling locations with magnetometers	Identify buried utilities prior to intermediate depth sampling (permit required for penetrations deeper than 0.3 m)	Soil						
Hand auger to collect soil samples from surface (0 to 0.15 m) and intermediate (0.15 to 0.6 m) intervals	Collect systematic samples for comparison against ROD criteria; collect biased samples to characterize "hot spots"	Soil				✓	✓	✓
Geoprobe to collect soil samples from deep (0.6 to 3 m) interval	Collect systematic samples for comparison against ROD criteria	Soil				✓	✓	✓

GPS = global positioning system; used to collect coordinates for environmental data.
MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual [3].
OREIS = Oak Ridge Environmental Information System; final on-line repository for verification data.
ROD = Record of Decision [2].

RESULTS

The Project continually updated the database for Core Team presentations, report writing, and decision-making. Data are also loaded into OREIS, which is accessible to the public, after the analytical data were subjected to 100% data assessment screening and 5–10% hard-copy validation. By the end of the Project, OREIS should contain over 4 million field screening measurements and results for approximately 1900 soil samples, all from the period between July 1, 2004, and October 31, 2005. The site database previously contained results for less than 500 soil samples dating back to the 1980s, and it contained no radiation measurement data. Along with determining whether established criteria are satisfied, this wealth of data will be available to future risk assessors, land management stewards, and inquiring members of the general public. Table IV summarizes data collected as part of the Melton Valley Verification Project.

Figure 2 illustrates gamma walkover survey results across the 1000-acre watershed. Several highly radioactive non-environmental radiation sources were identified during the verification effort. These are generally represented in the figure as circular "bull's eyes," or high radiation readings emanating from illustrated buildings. The White Oak Creek and Melton Branch floodplains also produced high levels of radiation "shine," inhibiting gamma walkover survey data interpretation. This figure also illustrates a large number of small areas of elevated activity (i.e., hot spots) in the west-central portion of Melton Valley. These were unanticipated and, along with the shine issues, represented a significant field measurement and data evaluation problem. Management adjusted the verification strategy to rely more heavily on analytical results; thus, the volumetric sample density was increased in areas where radiation measurement data interpretation was diminished, resulting in greater confidence in the verification data obtained.

Table IV. Summary of Melton Valley Verification Data

Data Type	Units	Data Status	
		Final Footprint	**Removed by Excavation**
Non-Excavation Survey Units			
Radiation Measurement			
Gamma Measurements	cpm	4,600,000	--
Beta Measurements	cpm	660	--
Dose Measurements	μrem/hr	3600	--
Systematic Soil Samples [a]			
Surface (0–0.15 m)	pCi/g	812	--
Intermediate (0.15–0.6 m)	pCi/g	205	--
Deep (0.6–3 m)	pCi/g	34	--
Biased Soil Samples [a]			
Surface (0–0.15 m)	pCi/g	432	--
Intermediate (0.15–0.6 m)	pCi/g	52	--
Deep (0.6–3 m)	pCi/g	1	--
Excavation Survey Units [b]			
Radiation Measurement			
Gamma Measurements	cpm	93,000	20,000 [c]
Beta Measurements	cpm	340	70 [c]
Dose Measurements	μrem/hr	0	0
Systematic Soil Samples [a]	pCi/g	196	11
Biased Soil Samples [a]	pCi/g	61	59

[a] Excludes duplicates.
[b] Seven large-scale excavation units plus eight hot spot removal actions.
[c] Estimated at approximately 20% of final footprint value.

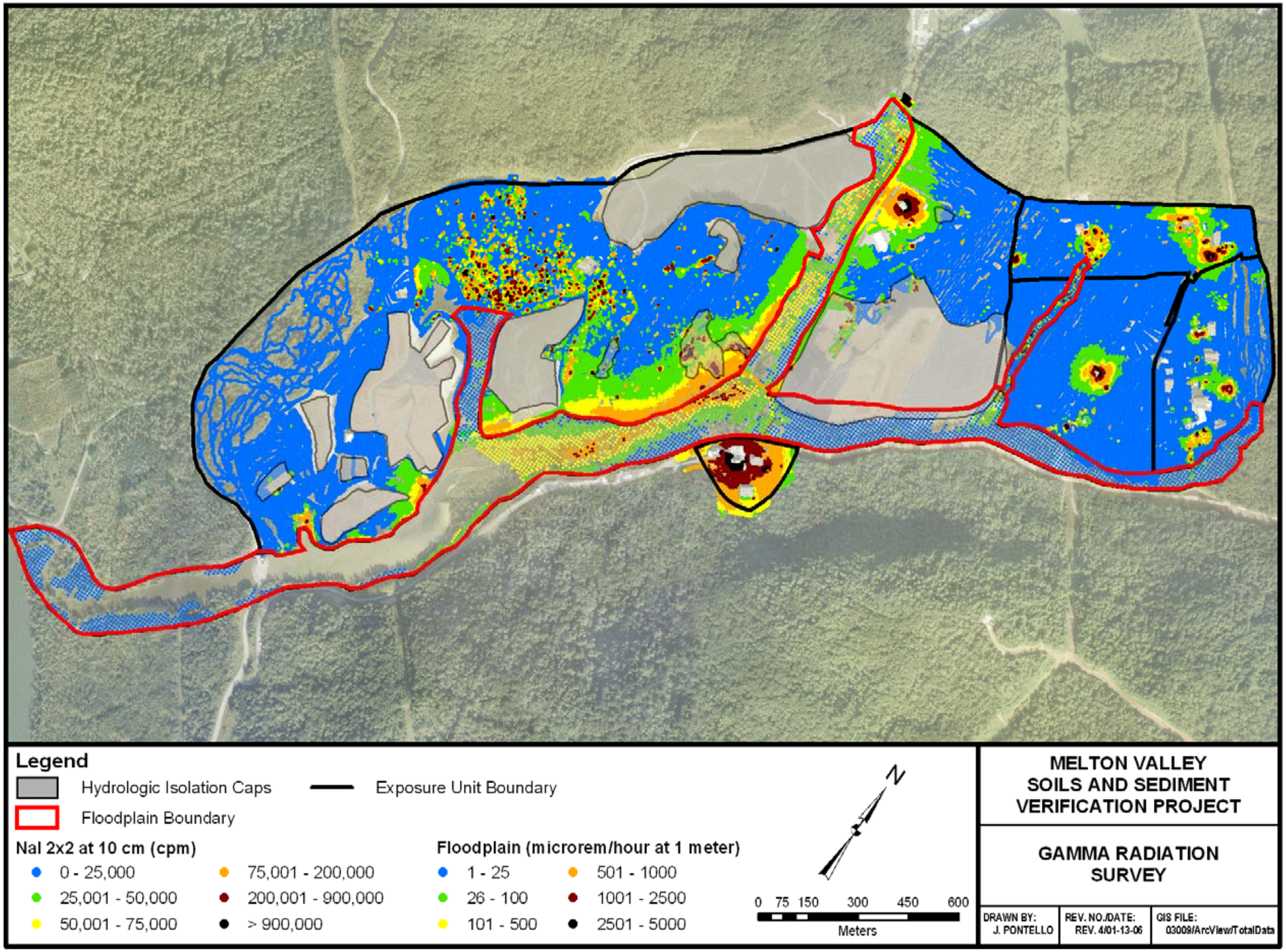


Fig. 2. Melton Valley verification gamma radiation measurements.

Figure 3 illustrates the location of beta measurements across the 1000-acre watershed. These results were also impacted by shine (the GM instrument has about 1 % gamma radiation detection efficiency). Results were, however, effective in identifying elevated radionuclide concentrations (specifically the pure beta emitter Sr-90) where no gamma signature was present. Almost 1000 beta measurements were collected across the valley.

Figure 4 illustrates volumetric sample locations. Three sample distributions are noted. First, there is a high concentration of samples in the west-central portion of Melton Valley corresponding with the high concentration of hot spots. These hot spots were unanticipated and, thus, were sampled heavily to assess ROD compliance. Almost 500 hot spots were subjected to a focused investigation, the majority of which were volumetrically sampled. The second distribution represents samples collected within seven large excavation units. Sampling efforts were focused in these areas, as they were known to contain contaminant concentrations above ROD criteria (thus the removal actions). Third, the bulk of the valley represents non-hot-spot, non-excavation land area. Samples were distributed on systematic, triangular grids (or, as in one case, randomly distributed) as defined by a Survey Unit's classification, size and number of samples assigned. Fifteen to 17 samples per Survey Unit were typical. Table V summarizes analytical results from volumetric samples collected across the entire valley, representing concentrations across five Exposure Units subdivided into 66 Survey Units. Tabulated results are grouped into systematic/random samples and biased samples, show the number of samples collected and number of detected results, present basic summary statistics, and count the number of results above Exposure Unit average and not-to-exceed criteria.

All verification data were subject to critical review, including Level 3 validation of 5–10% of analytical data. Data were reported by the smallest verification units (Survey Units) to focus on small-scale data quality and usability and to assure that the overall objectives would be satisfied once large-scale (Exposure Unit) compliance was assessed. Detailed analyses have indicated data are of sufficient quality and quantify and compliance with ROD criteria is easily and efficiently assessed. Field adjustments tended to result in the collection of additional (especially analytical) data, easing the decision-making process. Core Team updates resulted in no additional changes in strategy, as field decisions were deemed adequate and conservative, consistent with ROD requirements, and in the best interest of stakeholders.

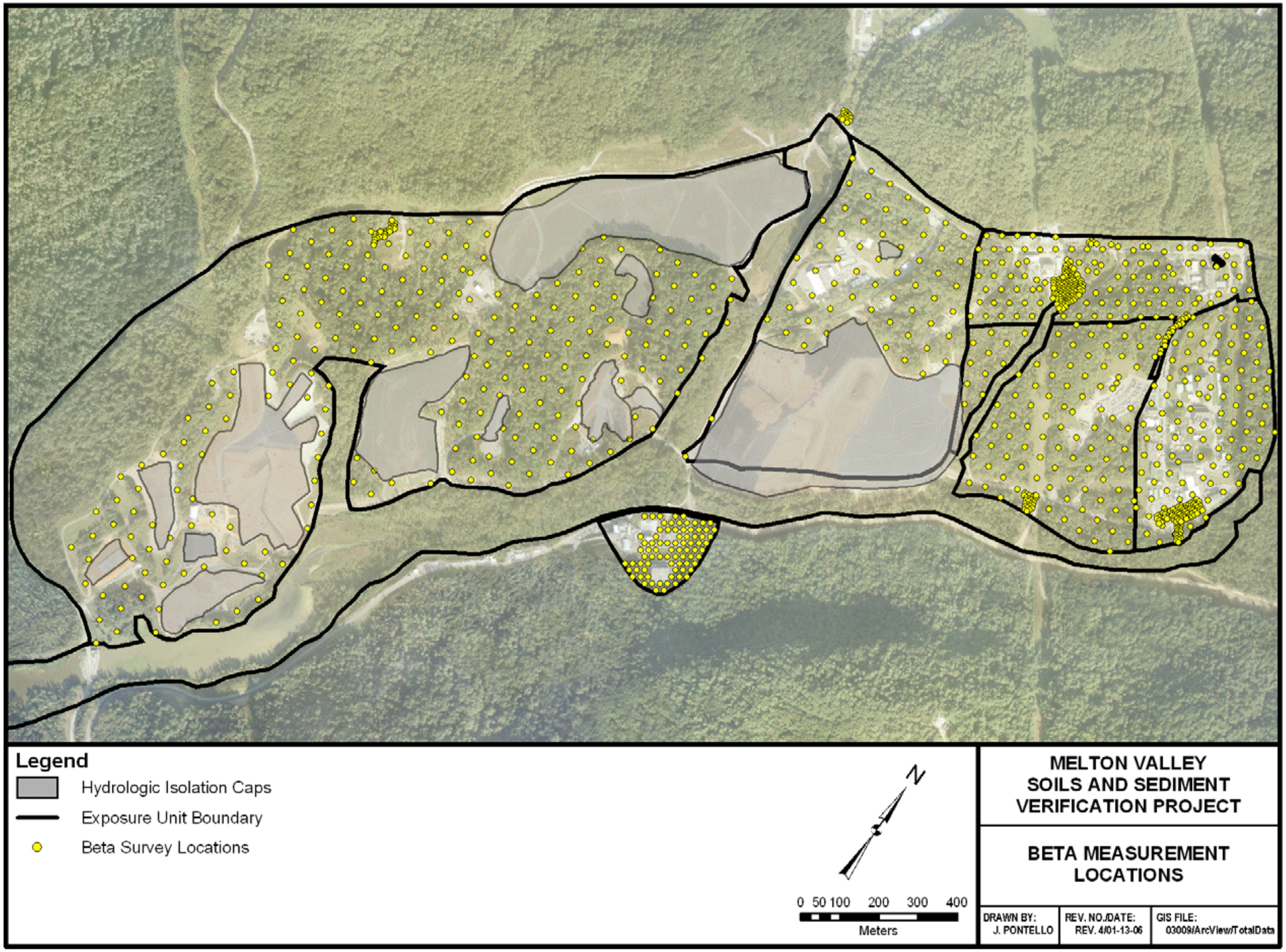
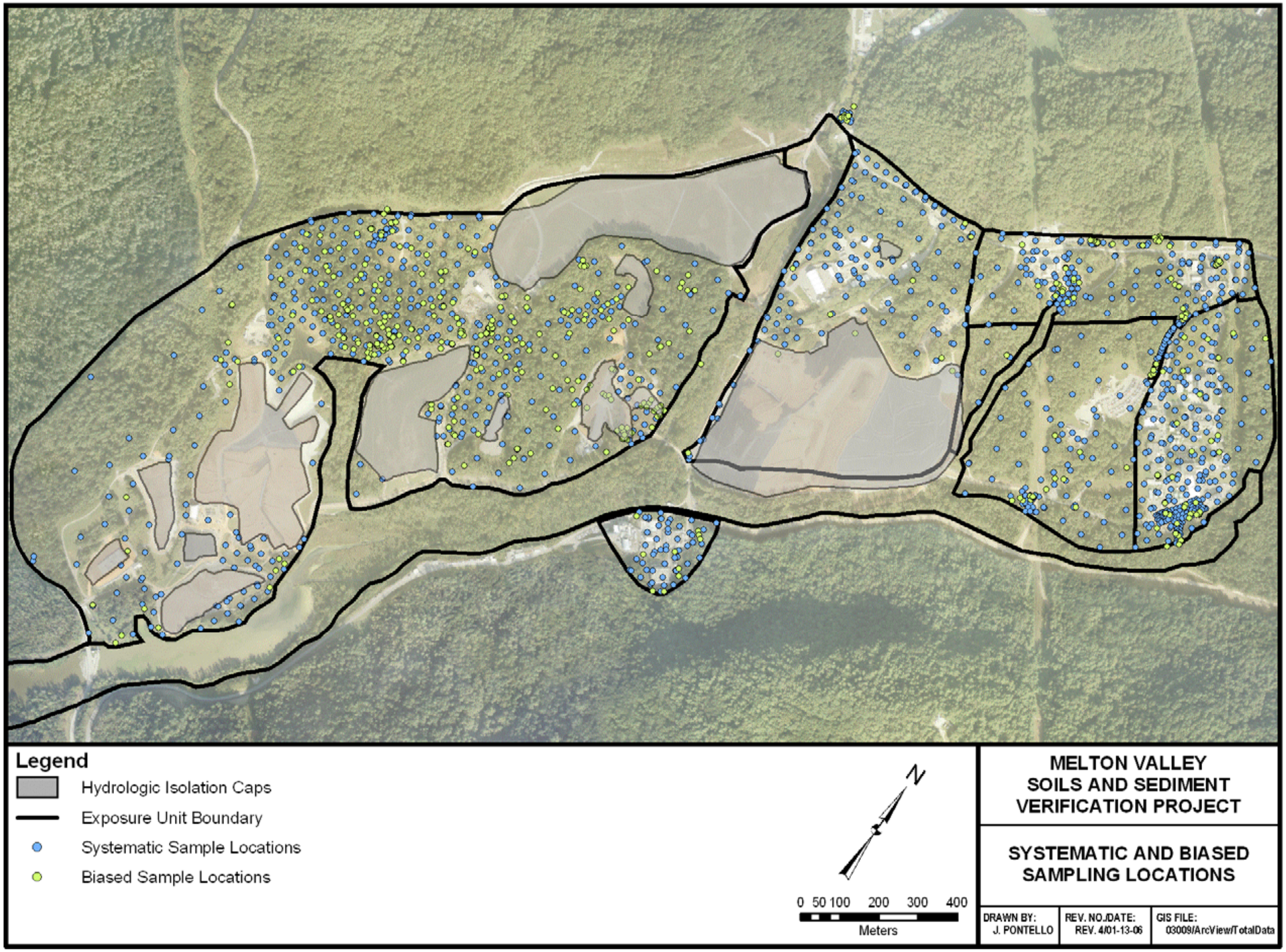


Fig. 3. Melton Valley verification beta radiation measurements.


Legend
Hydrologic Isolation Caps
Exposure Unit Boundary
Systematic Sample Locations
Biased Sample Locations
N
0 50 100 200 300 400
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MELTON VALLEY
SOILS AND SEDIMENT
VERIFICATION PROJECT
SYSTEMATIC AND BIASED
SAMPLING LOCATIONS
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Fig. 4. Melton Valley verification volumetric sampling locations.

Table V. Melton Valley Verification Project Final Dataset Summary Statistics

Contaminant	Freq. of detection	Units	Mean	Median	Std. Dev.	Detected Min.	Detected Max.	Dist.	Freq. > RL_{UA}	Freq. > RL_{NTE}
Biased samples										
Aroclor-1260	2 / 10	mg/kg	0.35	0.03	1.04	0.03	3.3	D	0 / 2	0 / 2
Arsenic	1 / 1	mg/kg	2.2	2.2	--	2.2	2.2	D	0 / 1	0 / 1
Cesium-137	598 / 621	pCi/g	1259	138.6	3910	0.02	44,679	X	455 / 598	221 / 598
Cobalt-60	170 / 620	pCi/g	21.9	0.01	179	0.02	3691	D	63 / 170	25 / 170
Curium-244	11 / 16	pCi/g	904	0.5	3599	0.25	14,400	X	1 / 11	1 / 11
Europium-154	52 / 621	pCi/g	0.29	0.01	3.18	0.11	77.1	D	1 / 52	0 / 52
Lead-210 [a]	--	--	--	--	--	--	--	--	--	--
Radium-226	376 / 621	pCi/g	0.39	0.4	0.35	0.15	2.09	X	0 / 376	0 / 376
Radium-228	418 / 621	pCi/g	0.67	0.68	0.44	0.18	3.75	X	0 / 418	0 / 418
Strontium-90	115 / 123	pCi/g	4855	37.9	32,328	0.43	326,000	X	12 / 115	4 / 115
Thorium-228	12 / 12	pCi/g	0.95	0.9	0.42	0.43	1.78	L	0 / 12	0 / 12
Thorium-232	12 / 12	pCi/g	0.99	0.94	0.57	0.38	2.38	L	0 / 12	0 / 12
Uranium-233 [b]	--	--	--	--	--	--	--	--	--	--
Uranium-234	14 / 14	pCi/g	3.82	0.88	11.6	0.17	44.0	X	0 / 14	0 / 14
Uranium-235	3 / 620	pCi/g	0.04	0.05	0.75	0.16	2.05	D	0 / 3	0 / 3
Uranium-238	131 / 620	pCi/g	0.73	0.74	2.73	0.38	34.7	D	0 / 131	0 / 131
Systematic samples										
Aroclor-1260	71 / 134	mg/kg	0.02	0.03	9.9E-03	5.7E-03	0.07	X	0 / 71	0 / 71
Arsenic	126 / 126	mg/kg	3.82	3.25	2.3	0.9	14.6	X	0 / 126	0 / 126
Cesium-137	948 / 1258	pCi/g	15.4	0.26	146	0.02	2783	X	48 / 948	12 / 948
Cobalt-60	130 / 1258	pCi/g	1.28	3.0E-03	16.9	0.03	478	D	22 / 130	5 / 130
Curium-244	12 / 129	pCi/g	0.37	0.01	3.83	0.1	43.5	D	0 / 12	0 / 12
Europium-154	16 / 1256	pCi/g	0.02	1.0E-03	0.31	0.05	9.46	D	0 / 16	0 / 16
Lead-210 [a]	--	--	--	--	--	--	--	--	--	--
Radium-226	1236 / 1257	pCi/g	0.49	0.49	0.12	0.15	1.33	X	0 / 1236	0 / 1236
Radium-228	1245 / 1258	pCi/g	0.77	0.78	0.16	0.09	1.46	X	0 / 1245	0 / 1245
Strontium-90	94 / 176	pCi/g	12.0	0.38	53.0	0.16	471	X	0 / 94	0 / 94
Thorium-228	108 / 108	pCi/g	1.16	1.2	0.32	0.36	2	N	0 / 108	0 / 108
Thorium-232	108 / 108	pCi/g	1.14	1.13	0.35	0.27	1.95	N	0 / 108	0 / 108
Uranium-233 [b]	--	--	--	--	--	--	--	--	--	--
Uranium-234	107 / 107	pCi/g	0.86	0.86	0.26	0.15	1.81	X	0 / 107	0 / 107
Uranium-235	5 / 1258	pCi/g	0.04	0.04	0.1	0.09	0.88	D	0 / 5	0 / 5
Uranium-238	1098 / 1256	pCi/g	0.96	0.94	0.77	0.24	24.6	X	0 / 1098	0 / 1098

[a] Not analyzed directly; assumed to be in secular equilibrium with Ra-226.

[b] The analytical laboratory cannot resolve alpha radiation peaks of U-233 and U-234. All activity for U-233/234 is assigned to the more prominent contaminant, U-234.

Excludes quality assurance samples and samples that were not entered into the final database.

Half the reporting limit was used as a proxy for non-detected arsenic and PCB-1260 results in the calculation of the mean, standard deviation, and 95% upper confidence limit of the mean concentration (UCL).

Dist. = distribution. Distribution flags are defined as:

D = 95% UCL cannot be calculated with fewer than five results or less than 50% detects.

L = lognormal. 95% UCL calculated using Land's statistic.

N = normal. 95% UCL calculated using t statistic.

X = neither normal nor lognormal. 95% UCL calculated using a nonparametric bootstrap or Chebyshev minimum variance unbiased estimator.

RL_{NTE} = not to exceed remediation level.

RL_{UA} = unit average remediation level.

-- = Not applicable, not available, or insufficient data to calculate the statistic.

CONCLUSIONS

Integration of Triad and MARSSIM into the Melton Valley verification project resulted in the collection of approximately 4.7 million data points, including 1900 volumetric samples, all between July 2004 and October 2005. This dataset approximately quadruples the number of volumetric samples previously in the Melton Valley database—the database originally contained no radiation measurement data. Experienced field personnel executed the strategy using real-time data collection/management technologies with the full participation of Project management and the Core Team, all the while maintaining a level of decision-making independence that streamlined the verification process. The overall result of this verification effort is a dataset that is of sufficient quantity and quality to demonstrate compliance with ROD criteria and that stands up against the scrutiny of all ROD signatories.

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