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## **Near-Real-time Characterization of BNL Stockpiled Soils – Another ASTD Success Story\***

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### **Abstract**

As of October 2001, approximately 7,000 yd<sup>3</sup> of stockpiled soil, contaminated to varying degrees with radioactive materials and heavy metals, remained at Brookhaven National Laboratory (BNL) after the remediation of the BNL Chemical/Animal/Glass Pits disposal area. During the 1997 removal action, the more hazardous/radioactive materials were segregated, along with, chemical liquids and solids, animal carcasses, intact gas cylinders, and a large quantity of metal and glass debris. Nearly all of these materials have been disposed of. In order to ensure that all debris was removed and to characterize the large quantity of heterogeneous soil, BNL initiated an extended sorting, segregation, and characterization project, co-funded by the BNL Environmental Management Directorate and the DOE EM Office of Science and Technology Accelerated Site Technology Deployment (ASTD) program. Project objectives were to remove any non-conforming items, and to assure that mercury and radioactive contaminant levels were within acceptable limits for disposal as low-level radioactive waste.

Sorting and segregation were conducted simultaneously. Large stockpiles, ranging from 150 to 1,200 yd<sup>3</sup>, were subdivided into manageable 20 yd<sup>3</sup> “subpiles” after powered vibratory screening. The ½ inch screen removed gravel and almost all non-conforming items, which were separated for further characterization. Soil that passed through the screen was also visually inspected before being moved to a subpile. Eight samples plus QA duplicates were collected from each subpile for chemical analysis, and a 1-Liter jar of material for gamma spectroscopy. A field lab equipped for chemical analysis and gamma spectroscopy was set up in a trailer close by the stockpile site. Chemical analysis included X-ray fluorescence (XRF) to screen for high (>260 ppm) total mercury concentrations, and modified Toxicity Characteristic Leaching Procedure (TCLP) tests to verify that the soils were not RCRA hazardous. The modified (1/10<sup>th</sup> scale) TCLP tests minimized secondary (leachate) waste and maximized tumbler capacity and sample throughput. TCLP leachate analysis was accomplished using a Milestone Direct Mercury Analyzer (DMA-80). Gamma spectroscopy provided verification of previously measured Am-241, Cs-137, and Co-60 contamination levels. After analyses were completed and reviewed, the stockpiles were reconstructed for later disposal as discrete entities within a disposal site profile.

The ASTD field laboratory completed more than 2,500 analyses of total Hg (XRF) and TCLP/DMA analyses over an 18-week period. Reliable statistical verification was accomplished for more than 98% of the stockpile sub-piles; for most sub-piles, TCLP analyses were completed within two days. This enhanced level of confidence in soil characterization was accomplished at a cost far below equivalent baseline techniques. One of the most significant aspects of the project success was schedule acceleration. The original schedule projected activities extending from early April until September 30. Due to efficiency and reliability of the vibratory screening operation and cooperative, dry summer weather, stockpile reconstruction was completed in the third week of August. Reduction of the planned sample collection rate, from three samples per 5 yd<sup>3</sup> to two, resulted in further schedule acceleration. The resulting sample frequency, however, was still 22 times greater than the baseline frequency (one per 55 yd<sup>3</sup>).

\*This work was performed under the auspices of the U.S. Department of Energy.

## INTRODUCTION

Approximately 11,500 cubic yards (yd<sup>3</sup>) of contaminated soil were excavated from BNL's former Animal/Chemical and Glass Holes (Chemical Holes) in 1997 as part of activities required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund). The Chemical Holes remedial action was initiated to remove laboratory glassware, chemicals, and related wastes from disposal pits used at BNL from 1958 through 1976. The soils were placed into separate stockpiles and characterized following an approved sampling plan (Procedure for Sampling Soil Stockpiles Chemical Holes Project, BNL, October 1997). As part of the removal action, the materials removed from the pits were segregated according to size and type. Larger items were collected manually, and remaining debris materials were separated using a 2-inch screen. The remaining (less than 2-inch) material, consisting mostly of soil and gravel, but also including small bottles and vials potentially containing hazardous material, was collected and stored in stockpiles at the removal project site. The stockpiles ranged in size from 100 yd<sup>3</sup> to 1,800 yd<sup>3</sup>. During the removal action, the more hazardous/radioactive materials were segregated, along with a large quantity of metal and glass debris. Nearly all of these latter materials have been disposed of. The majority of the stockpiled soil had been identified as low-level radioactive waste (LLW). One stockpile (Stockpile 12, 700 yd<sup>3</sup>) was to be handled as mixed waste based on the presence of visible mercury reported by workers during the original removal action.

From September 1999 to January 2000, 29 railcars that included materials from Stockpiles 10 and 13 were shipped to Envirocare of Utah for LLW disposal after obtaining the appropriate approvals. Envirocare's routine sampling program (every 10<sup>th</sup> rail car) indicated that the Stockpile 10 soils exceeded RCRA criteria for allowable mercury levels of 0.2 mg/L in TCLP leachate. Subsequently, some of the Stockpile 10 soils were re-classified as mixed waste, treated (stabilized), and disposed of at Envirocare. This resulted in a non-conformance incident, and significant additional treatment/disposal costs. Additional costs were also incurred at BNL before all the waste materials were shipped in this period, because "non-conforming items" were identified (e.g., vials, bottles, etc. less than 2 inches and potentially containing hazardous materials such as mercury) during loading of the wastes for disposal. As a result, about 380 yd<sup>3</sup> of soil from Stockpile 13 were sorted a second time.

Evaluations of the root causes of the Envirocare non-conformance incident focused on the need for improved segregation of non-conforming items, as well as improved sampling and analysis protocols applied to the stockpiles for characterization. The immediate response was manual hand raking of non-conforming items from the remaining portion of Stockpile 13. This was adopted as the baseline sorting technique, even though it proved to be an extremely slow, labor-intensive, and expensive process.

Following the occurrence investigation, the *Bulk Waste Determination Guidance Document* [Ref. 1] was prepared, based on sampling protocols identified in EPA SW-846. This procedure represents the baseline characterization currently in place for the stockpiles prior to disposal. While intended to provide a standard method for characterizing remaining stockpiles (and other

bulk wastes at BNL), it requires relatively few samples be taken for large volumes of contaminated soil. For example, application of this methodology for Stockpile 6B, which contained a total of 440 yd<sup>3</sup> of soil, resulted in identification of only eight soil samples for analysis. In the application of the procedure, an interactive spreadsheet (referred to as the Toolbox) is used to input characterization data. The Toolbox then gives an evaluation as to whether additional samples are needed for characterization to a 95% confidence level.

To prevent more non-conformance incidents (and potential regulatory problems) during subsequent soil disposal activities, BNL initiated an expanded sorting, segregation, and characterization project directed at the 10 remaining soil stockpiles. The project was co-funded by the BNL Environmental Management Directorate and the DOE EM Office of Science and Technology Accelerated Site Technology Deployment (ASTD) program. The focus was to remove non-conforming items and assure that mercury and radioactive contaminant levels were within acceptable levels for disposal as low-level radioactive waste. Extensive sampling was planned to provide a sound statistical basis for confidence in the measured contaminant levels.

The project involved the use of a power screen for sorting and segregation, and setting up and operating a Field Laboratory near the Stockpile area that would provide rapid sample analyses for total mercury, TCLP mercury, and gamma spectroscopy. Samples were to be collected and carried to the Field Lab for analysis with a planned 1-day turnaround. Cost-effective, timely analysis of soil contamination allowed many more samples be taken and analyzed, significantly improving confidence in the data.

The main project goals were:

1. The complete removal of all non-conforming items in a safe manner from the soil stockpiles, and
2. The analysis of each stockpile for total mercury and TCLP mercury, to demonstrate in a statistically reliable manner that the soil is non-hazardous on average.

The first goal involved the use of the power screening method. During screening, soils were separated into 20 yd<sup>3</sup> subpiles for sampling and subsequent analysis. A field laboratory, set up in a trailer near the stockpile area, was the means of achieving the second goal. The Field Lab had the capability to test soils directly for total mercury, and to conduct modified TLCP extractions and test the extract for mercury. Finally, an ISOCS unit collected gamma spectra for radiological characterization.

## **STOCKPILE SORTING AND SAMPLING**

The Chieftain 600 Power Screen was used for sorting activities. Stockpile materials were dropped onto the main screen, and sorted materials were dispersed out separate chutes. (See Figure 1.) Soil sorting rates were estimated at a maximum of 100 yd<sup>3</sup> per day, or five 20 yd<sup>3</sup> subpiles per day. Sampling and analysis plans were designed around this sorting volume estimate and the assumption that three samples were to be collected for every 5 yd<sup>3</sup>. Three samples per 5 yd<sup>3</sup> were considered more than adequate for statistical certainty.



**Figure 1. Power Screen Used for Stockpile Sorting**

Crumbling, et al [Ref 2] reported that uncertainty in environmental characterization is often a trade-off involving the number of samples and sampling methods, field screening analysis methods, and certified analytical laboratory methods. While precision in analytical methods has been steadily increasing with improved technology, accuracy in characterization is much more dependent on how well the sample reflects the actual condition of the waste. Uncertainty in the data therefore is much more closely tied to the extent of sampling. In many environmental remediation characterization efforts, sampling uncertainty offsets analytical laboratory reliability. Explicitly: “If representativeness cannot be established, the quality of the chemical analysis is irrelevant.”[Ref. 2] Data quality in support of remediation decisions can be improved considerably with increased sampling and field screening methods to supplement certified laboratory results.

Soil stockpiles were located in two areas, shown as green rectangles on the map in Figure 1. As sorting progressed and soil from each stockpile was placed as 20 yd<sup>3</sup> subpiles with a front-loader. The subpiles were marked into four quadrants, and three grab samples were collected from each quadrant. Samples were given unique identification numbers and transported to the ASTD Field Laboratory for analysis. Subpiles were placed on polyethylene, and, after sampling, covered with polyethylene sheets as well, until reconstruction was approved.

### **ASTD FIELD LABORATORY**

Samples from the subpiles were transported to the ASTD Field Laboratory for analysis each day they were collected. X-ray Fluorescence (XRF) was used as a screening tool to measure total mercury in the soil sample. If the XRF indicated that the sample was above 260 ppm mercury,

the subpile was to be segregated for mixed waste treatment. Modified TCLP tests were run also, with a Milestone Direct Mercury Analyzer (DMA-80) used to test the leachate. TCLP failure meant that the results for a particular subpile would have to be reviewed and averaged, to determine if the subpile or a portion of it had to be segregated for ultimate hazardous or mixed waste disposal. The Toolbox [Ref. 1] provides algorithms for determining the acceptability of the averages and confidence levels for subpiles and whole stockpiles.

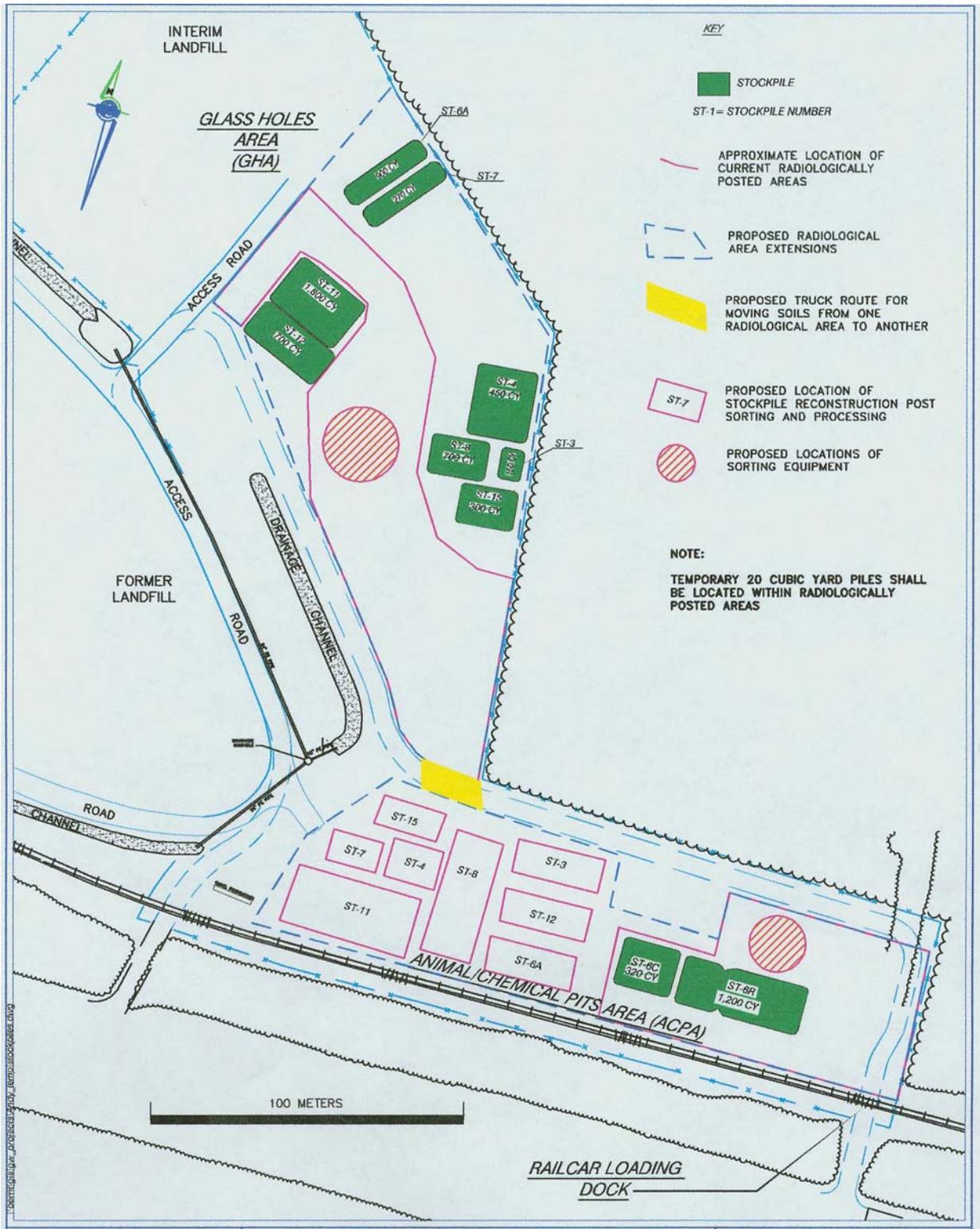
In addition to the chemical analyses, the ASTD Field Lab also obtained radiological content information using the *In Situ Object Counting System* (ISOCS) to determine the presence of gamma-emitting radionuclides.

### **Field Laboratory Analytical Methods: X-ray Fluorescence**

X-ray Fluorescence (XRF) is a mature technology that has been used for decades for elemental analysis in research laboratories and industrial process monitoring. Detection limits to between 10 and 100 ppm are easily achieved for most elements. With higher strength X-ray sources and secondary targets, sensitivities as low as 1.0 ppm or less are also possible. The Model EX-6600A field-deployable XRF unit was purchased for this project from Jordan Valley. Reported detection limit for mercury was 1.5 ppm.

An important advantage of the XRF method is that sample preparation is minimal, and, for mercury, the RCRA metal of concern in this project, detection can be achieved in air or a helium-flushed system, rather than vacuum. XRF is a non-destructive method that can be applied to solid, powdered, or liquid samples. Generally, no secondary wastes are generated as a result of sample preparation. Sample analysis time, including preparation, was expected to be approximately 10 minutes. A 10-position automatic sample-changer was included in the purchased unit.

For the Field Lab, the XRF was assigned to total mercury analysis, but the procedure was modified to minimize preparation and analysis time to maintain a throughput of 60 samples per day. Sample preparation involved sieving the soil to less than 2 mm and compacting it in a disposable plastic cup with a transparent Mylar film bottom. This and a 3-minute analysis time meant that the detection limit for the samples was approximately 50 ppm total mercury.



**Figure 2. Stockpiles, Sorting Areas, and Stockpile Reconstruction Areas at the Former Chemical/Animal/Glass Disposal Pits**

### **Field Laboratory Analytical Methods: Direct Mercury Analyzer**

The Milestone DMA-80 measures low concentrations of mercury in environmental samples, in accordance with EPA Method 7473, “Mercury In Solids And Solutions By Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry.” Its reproducibility, low detection limit, and rapid throughput, as well as the fact that it does not generate any secondary waste, makes it ideally suited for environmental applications.

The method involves weighing the sample and placing it directly in a small “boat”, for drying and thermal treatment in a stream of heated oxygen gas. The gas stream is passed through a gold amalgamation trap that captures all mercury in the vapor phase. The gold amalgam is subsequently heated and mercury vapor detected with an atomic absorption spectrophotometer tuned to the absorption wavelength for mercury, 254 nm. The DMA-80 detection limit is 0.11 nanograms mercury. For the listed maximum sample size of 0.5 grams, therefore, the theoretical detection limit in terms of concentration is 0.00022 ppm (0.22 ppb).

The DMA80 was assigned for TCLP leachate analyses because it could be used for liquid as well as solid samples. With the DMA-80, preparation of the TCLP leach liquids for analysis was minimal, namely filtering the solution (0.45  $\mu$ ) and pipeting 0.4 mL. Because of its reproducibility, as evidenced by blank and calibration standards tested after every five samples, the DMA-80 was deemed most important for use with the regulatory classification test.

### **Field Laboratory Analytical Methods: Modified TCLP**

The modified Toxicity Characteristic Leaching Procedure (TCLP) used was essentially a 1/10<sup>th</sup> scale version of the test recommended by the U.S. Environmental Protection Agency (EPA) [Ref. 3]. Extraction fluid #1 was used for all tests, as determined by the related EPA procedure [Ref. 4]. Soil samples of 10-gram size (rather than 100 g) were weighed out in 250 mL plastic bottles, and 200 mL (rather than 2L) of fluid #1 was added to the soil. Five leach samples were then placed inside a plastic 1-gallon jar for secondary containment, which was then placed into a compartment of the tumbler apparatus. A TCLP tumbler purchased from Miller Analytical, with 12 compartments, allowed for 60 samples to be tested simultaneously. The samples were tumbled for 18 hours, per the TCLP procedure. The modified small-scale procedure meant that more samples could be tumbled concurrently, and less waste was produced. Results were reported as parts per million (ppm) or parts per billion (ppb) TCLP mercury, representing mercury concentration in the leach solution, not the solid.

### **Field Laboratory Analytical Methods: *In Situ* Object Counting System**

The Canberra *In Situ* Object Counting System (ISOCS) consists of a portable germanium detector controlled by proprietary software for detector calibration and evaluation of specific activity. Standard sample configurations with shielding may be used, or large areas or equipment may be surveyed with the detector, provided models are available for geometric data

interpretation. ISOCS has been employed at BNL in two earlier ASTD projects. For the Chemical Holes Field Lab, a standard sample configuration was used for verifying gamma-emitting radionuclide contamination in the stockpiles. One sample per 20 yd<sup>3</sup> subpile was analyzed.

### **Field Laboratory Integrated Operations and Quality Assurance**

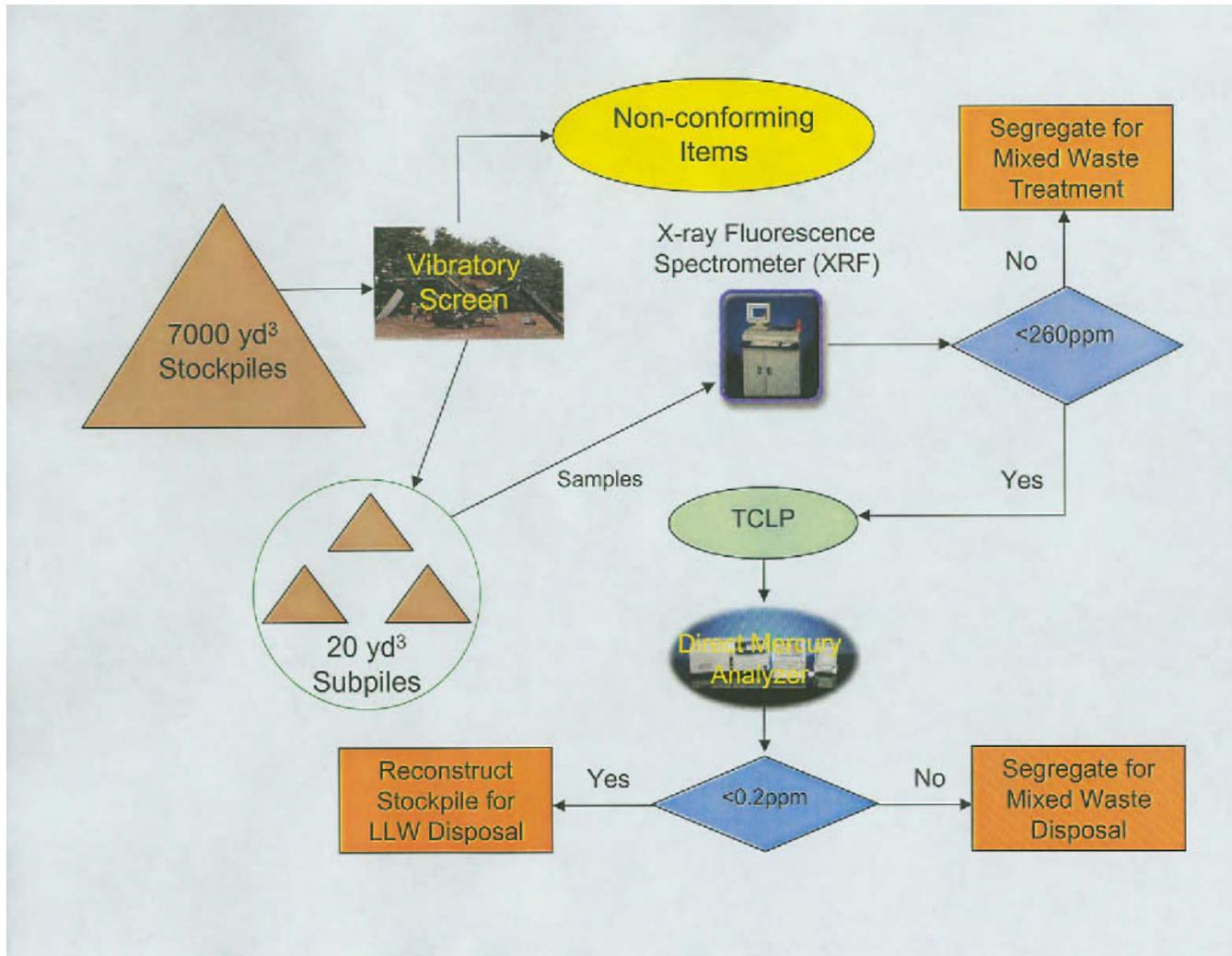
The Field Laboratory process flow diagram is shown in Figure 3. Several weeks were required to adjust sample production rates to sample analysis rates. The most important decision was to reduce the sample collection rate from three for every 5 yd<sup>3</sup> to two. The resulting sample frequency (one per 2.5 yd<sup>3</sup>) was still 22 times greater than the baseline frequency (one per 55 yd<sup>3</sup>).

Since the stockpiles had been classified as low-level waste, the field lab was set up as a radioactive material area for sample storage. Sample handling, namely opening bottles, weighing out soils, and preparing TCLP bottles for tumbling, was carried out in the west half of the trailer. Because of the potential for loose soil releases, this half of the lab was designated as a radioactive dispersibles area when transfer operations were being conducted. The XRF and DMA-80 were also located in this section. The east end of the lab trailer was used for receiving samples, ISOCS counting, and running the TCLP tumbling apparatus.

Sample receipt involved signing Chain of Custody (COC) forms after verifying that all bottles were labeled clearly and that the COC information was correct. ISOCS samples were stored and counted in the east end of the trailer. The remainder of the samples was transferred for processing and analysis by the chemical techniques described above.

After a targeted 1-day turnaround, test results were compiled and transferred to the Project Manager for review. Unused soils and liquid extracts were returned to the stockpiles for final disposal. When all data for a stockpile had been reviewed, the Project Manager approved Stockpile reconstruction. The criteria for reconstruction were that the soils contain less than 260 ppm total mercury and less than 0.2 ppm TCLP mercury.

Quality assurance was based on maintaining proper chain of custody protocols and taking a subset of field duplicates: one for analysis in the ASTD Field Lab, and one for analysis at an independent off-site laboratory. In addition, the analytical instruments were calibrated according to manufacturer's recommended guidelines.



**Figure 3. ASTD Field Lab Analytical Process**

## WORK COMPLETED

### Stockpile Volumes and Total Samples

Table 1 compares original estimated stockpile volumes to those determined during sorting operations. Stockpile sorting included moving sorted soils from the power-screen to the subpile staging area with a 1-yd<sup>3</sup> front-loader. Thus, the soil stockpile volumes were measured more accurately than when they were accumulated initially, because the subpiles were built to a specified number of front-loader loads. Overall, the total screened soil volume, 5,660 yd<sup>3</sup>, was smaller than the original estimate of 6,790 yd<sup>3</sup>. Final disposal volume may also be slightly smaller, depending on how much compaction occurs during loading and transport in railcars. Some of the volume reduction may be associated with the separation of old plastic cover material, which had been covered with new layers, as weather-induced tears required the replacement of the first covers. All cover materials were segregated for disposal as debris.

Soil sorting activities produced 283 subpiles, which were then re-assembled into 10 new stockpiles, corresponding to the original 10. Radioactive measurements with the ISOCS unit and chemical test results are discussed separately.

**Table 1**  
**Stockpiles Volumes and Samples Collected**

<b>Stockpile Number</b>	<b>Original Estimated Volume (yd<sup>3</sup>)</b>	<b>Number of Subpiles</b>	<b>Actual Volume* (yd<sup>3</sup>)</b>	<b>Samples**</b>	<b>Sorting Completed</b>
3	150	5	100	42	May
4	450	34	680	286	May
6A	900	30	600	243	July
6C	320	10	200	84	August
6R	1,200	53	1,060	446	August
7	270	8	160	68	July
8	700	33	660	278	May
11	1,800	65	1,300	546	June
12	700	31	620	261	June
15	300	14	280	118	June
<b>Total</b>	<b>6,790</b>	<b>283</b>	<b>5,660</b>	<b>2,372</b>	

\* Based on the number of 20 yd<sup>3</sup> Sub-piles

\*\* For total Hg/TCLP Hg analyses. Includes field duplicates but not ISOCS or Off-site samples.

## ISOCS Results

The number of samples collected for ISOCS analysis totaled 283, or one for each subpile. Results are summarized by stockpile in Table 2. The results include average values, maximum values, and the total number of non-detected measurements (NDs) for each stockpile. These quantities show that the stockpiles are slightly contaminated, overall.

Previous characterization data indicated that radioactive contamination was low and restricted to a few radionuclides, primarily cesium-137 (Cs-137) and americium-241 (Am-241). These general results are verified with the additional ISOCS data. Other isotopes detected include cobalt-60 (Co-60), radium-226 (Ra-226), thorium-232 (Th-232), and uranium-235 (U-235). Of all these isotopes, Ra-226 and Th-232 are potentially naturally occurring at low levels because of Long Island's geology [Ref. 5]. All are associated with some aspect of nuclear power or research, e.g., fuel (U-235, Th-232), or fuel by-products and waste (Co-60, Cs-137) or isotope application studies (Co-60, Cs-137, Am-241, Ra-226, Th-232).

Am-241 had the highest levels of contamination, with four readings greater than 10 pCi/g. in four separate stockpiles. It is worth noting that in three of these stockpiles (St-6A, St-11, and St-12) more than half of the subpiles had Am-241 non-detects, and in the fourth stockpile, 11 out of 34 subpiles were non-detected for Am-241. It is also significant that the average Am-241 values for the stockpiles were all less than 5 pCi/g, and that Am-241 was the only radionuclide that exhibited a concentration in excess of 1.0 pCi/g.

Cs-137 has been identified as a radionuclide of concern at BNL; the maximum concentration of Cs-137 found was 2.3 pCi/g in a sub-pile from Stockpile 11. The highest average concentration for a stockpile was 0.8 pCi/g, for St-7.

**Table 2  
Stockpiles Radionuclide Contamination Summary**

		Estimated Activity Concentration											
Stockpile	Total	Co-60				Cs-137				Ra-226			
		Maximum Value (pCi/g)	Sub-Pile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Sub-Pile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Sub-Pile w/Max Value	Average (pCi/g)	Total ND's
St-8	33	0.7	21	0.5	21	0.6	19	0.3	31	0.5	3,19	0.5	30
St-3	5	0.5	1	0.5	4	ND		ND	5	ND		ND	5
St-4	34	0.6	15,21,24,27,29,31,34	0.5	17	0.2	5,6,10,15,16,25	0.2	18	0.4	30	0.4	33
St-15	14	0.7	22	0.5	2	0.3	8	0.2	12	0.5	11	0.5	13
St 12	31	ND		ND	31	1.1	24	0.4	10	ND		ND	31
St-11	65	0.8	49	0.5	36	2.3	45	0.3	19	0.5	49	0.5	64
St-7	8	ND		ND	8	1.0	1	0.8	0	0.3	6	0.3	7
St-6A	30	0.8	23	0.5	19	0.3	4,5	0.2	23	ND		ND	30
St 6C	10	0.6	5,7	0.5	3	ND		ND	10	ND		ND	10
St-6R	53	0.5	58,56,55,45,35	0.4	44	0.3	2,41,48,50	0.2	39	0.5	24	0.6	52
		Estimated Activity Concentration											
Stockpile	Total	Th-232				Am-241				U-235			
		Maximum Value (pCi/g)	Sub-Pile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Sub-Pile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Sub-Pile w/Max Value	Average (pCi/g)	Total ND's
St-8	33	1.2	5	0.7	27	1.8	22	0.9	17	ND		0	65
St-3	5	0.5	3	0.5	4	ND		ND	5	ND		0	33
St-4	34	0.5	6,20,25	0.5	31	10.4	16	1.6	11	ND		0	31
St-15	14	0.5	11	0.5	12	0.8	8	0.8	13	ND		0	14
St 12	31	ND		0.0	31	11.4	11	3.1	17	ND		0	5
St-11	65	0.5	10	0.5	64	16.4	60	3.5	49	ND		0	34
St-7	8	0.7	3,4	0.7	6	1.1	5	1.0	3	ND		0	8
St-6A	30	0.5	13,15	0.5	35	20.1	29	2.7	20	ND		0	37
St 6C	10	ND		0.0	10	1.6	8	1.6	9	ND		0	10
St-6R	53	0.6	2	0.6	52	0.8	6	0.5	46	ND		0	53

## Total Mercury and TCLP Mercury Results

The total number of chemical analyses performed in this project was in excess of 2,264 (eight times 283). During sorting and sampling of the first stockpile (Stockpile 8), it was immediately obvious that stockpile soils were being screened and sampled at a rate that far exceeded the Field Lab's projected daily capacity. To keep up with sample production, the center level sample from the three-level sampling grid was ignored. Thus only four samples from the top and four from the bottom level quadrants were actually analyzed. Further, because it was being used as a higher-concentration screening tool, XRF analysis was performed on even fewer samples. After Stockpile 8 was completed, the sampling plan was modified so that eight rather than 12 samples were collected for every 20 yd<sup>3</sup> (or two for every five cubic yards). Additionally, a sample for offsite analysis and a field duplicate (FD) were collected for every 20<sup>th</sup> sample. For Stockpile 8, 28 of 132 "center level" samples collected were analyzed (subpiles 1 to 3 and 20 to 23, inclusive). Thus, TCLP analyses in the ASTD Field Lab totaled 2264 + 28 + 113 (field duplicates)= 2,377. XRF analyses were slightly below this number.

Table 3 lists average total and TCLP mercury concentrations for each stockpile. Stockpile 7 had the highest total mercury concentration of 65.1 (± 2.8) mg/kg, well below the EPA action level of 260 mg/kg for which mercury recovery is required. Stockpile-6C showed the highest statistical deviation of about 20% (or 57.5 ± 12.0 mg/kg), and Stockpile 3 was uniformly at the detection limit of 18.8 mg/kg total mercury. (Recall that later measurements with a shorter run time meant that the minimum detection level for stockpiles tested after St-15 was 50.5 mg/kg). The highest subpile average for total mercury was 86.6 mg/kg in St-6C. Stockpile 6C also had the highest single sample total mercury value at 174.0 mg/kg. In all, there were 16 single samples above 100 ppm, and these were distributed over five stockpiles. Stockpiles 8, 3, 4, 6A, and 7 had no samples with total mercury concentration greater than 100 ppm.

**Table 3**  
**Stockpile Summary Data – Total and TCLP Mercury Results**

Stockpile	Stockpile Average Results				Maximum Subpile Values	
	Total Hg (mg/kg)	Std.Dev. (mg/kg)	TCLP Hg (µg/L)	Std.Dev. (µg/L)	Total Hg (mg/kg)	TCLP Hg (µg/L)
8	20.9	1.8	11.1	8.0	25.2	38.2
3	18.8	0.0	8.7	2.3	18.8	11.9
4	23.1	2.7	22.6	11.1	33.1	47.0
15	22.2	5.6	3.8	5.0	36.2	20.3
12	59.5	7.9	73.0	29.6	82.7	153.7
11	55.2	4.3	37.9	17.5	76.1	113.4
7	65.1	2.8	7.1	3.4	68.3	13.6
6A	51.8	1.1	3.0	2.5	54.5	10.7
6C	57.5	12.0	9.6	6.3	86.6	19.3
6R	57.9	6.1	23.9	23.3	83.2	120.7

More importantly, in terms of classifying the soils as hazardous or mixed wastes, stockpile averages for TCLP mercury are all well below 200 µg/L, the hazardous waste definition for EPA’s Toxicity Characteristic. As can be seen in Table 3, the stockpile TCLP mercury averages are well below the BNL administrative action level of 160 µg/L. Stockpile 12 had the highest levels of TCLP mercury, at 73.0 (± 29.6) µg/L. This is consistent with St-12 having the highest subpile average TCLP of 153.7 µg/L, and 5 subpiles with average TCLP mercury above 100 µg/L. Subpile averages are not listed here but only two other subpiles, one in St-11 and one in St-6R, had an average TCLP mercury level above 100 µg/L.

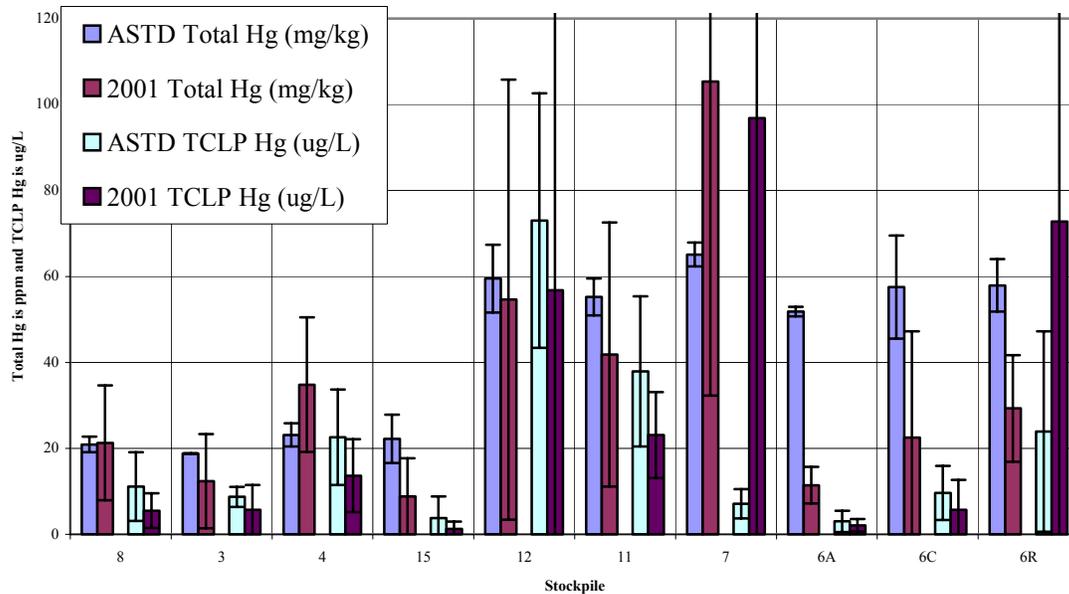
There were 14 individual samples with TCLP mercury above the administrative action level of 160 µg/L, as listed in Table 4, from Stockpiles 11, 12, and 6R. When TCLP leachate samples above the 160 µg/L level were found, the original leachates were re-analyzed in the DMA to verify the levels. Data in Table 4 show the higher of the two test results. Stockpiles 3, 4, 6A, 6C, 7, 8, and 15 had no single samples above the BNL administrative limit.

**Table 4**  
**Individual Sample Results with TCLP Greater than 160 µg/L**

<b>Sample</b>	<b>TCLP Hg</b>	<b>Sample</b>	<b>TCLP Hg</b>	<b>Sample</b>	<b>TCLP Hg</b>
6R29SWT	338.7	1204SET	336.0	1127SET	210.9
6R33SWT	661.7	1217NEB	238.5	131NWT	206.4
6R47FD	267.9	1217NWT	612.8	1143SWB	595.8
6R48NWT	203.5	1220SWT	285.6	1150NEB	161.5
6R51SWT	893.1	1229SET	183.4		

A significant point of comparison is a 2001 sampling and characterization campaign, undertaken with the Toolbox to address some of the uncertainties with the earlier characterization work. In this campaign, 10 samples were collected for analysis from each stockpile in random fashion [Ref. 6]. From that campaign results, eight of the ten Stockpiles could be classified as non-hazardous from all TCLP metals and total mercury. However, the Toolbox called for further characterization, with 293 and 647 samples, respectively, taken for Stockpiles 6R and 7. A comparison of the 10-sample 2001 data for TCLP mercury and total mercury with results from the ASTD Field Lab is shown in Figure 4. For Stockpiles 6R, 7, and 12, the 2001 data standard deviations (shown as error bars) for TCLP mercury are off-scale. The ASTD Field Lab data in general reduced standard deviations for all total mercury data. The general conclusion from the TCLP data was that all Stockpiles were within acceptable levels for classification as non-hazardous.

Figure 4. Comparison of ASTD Results with 2001 Sampling Campaign



## CONCLUSIONS

The ASTD field laboratory completed more than 2,500 analyses of total mercury (XRF) and TCLP mercury (DMA) analyses, over a six-month period. Reliable statistical verification as low-level waste characterization was accomplished for all of the screened stockpiles. For most of the subpiles, TCLP analyses were completed within two days. One of the most significant aspects of the project success was schedule acceleration. The original schedule projected activities extending from early April until September 30. Stockpile reconstruction was completed in the third week of August.

A significant lesson learned from this project is that thorough characterization through a large sampling campaign can be economically rewarding. This was true for this ASTD project, even with investments in new equipment and expenditures to set up a dedicated, albeit uncertified laboratory. Stockpile 12 was designated for disposal as mixed waste before this project began. With Field Lab results and certified analytical laboratory results (for a much smaller number of samples), Stockpile 12 is now destined for disposal as low-level waste. The cost savings from this change in waste status will not be definite until final disposal. However, the initial estimates indicate that the projected cost savings will offset the expenditures for the Field Lab.

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