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Executive Summary

As of October 2001, approximately 7,000 yd^3 of stockpiled soil remained at Brookhaven National Laboratory (BNL) after the remediation of the BNL Chemical/Animal/Glass Pits disposal area. The soils were originally contaminated with radioactive materials and heavy metals, depending on what materials had been interred in the pits, and how the pits were excavated. 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 directed at the remaining soil stockpiles. The project was co-funded by the Department of Energy Environmental Management Office (DOE EM) through the BNL Environmental Restoration program and through the DOE EM Office of Science and Technology Accelerated Site Technology Deployment (ASTD) program. The focus was 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. Soils with mercury concentrations above allowable levels would be separated for disposal as mixed waste.

Sorting and segregation were conducted simultaneously. Large stockpiles (ranging from 150 to 1,200 yd^3) were subdivided into manageable 20 yd^3 units after powered vibratory screening. The ½-inch screen removed almost all non-conforming items (plus some gravel). Non-conforming items were separated for further characterization. Soil that passed through the screen was also visually inspected before being moved to a 20 yd^3 "subpile." Eight samples from each subpile were collected after establishing a grid of four quadrants: north, east, south and west, and two layers: top and bottom. Field personnel collected eight 100-gram samples, plus quality assurance (QA) duplicates for chemical analysis, and a 1-liter jar of material for gamma spectroscopy. After analyses were completed and reviewed, the stockpiles were reconstructed for later disposal as discrete entities within a disposal site profile.

A field lab was set up in a trailer close to the stockpile site, equipped with instrumentation to test for mercury, RCRA metals, and gamma spectroscopy, and a tumbler for carrying out a modified Toxicity Characteristic Leaching Procedure (TCLP) protocol. Chemical analysis included X-ray fluorescence (XRF) to screen for high (>260 ppm) total mercury concentrations, and modified TCLP tests to verify that the soils were not RCRA hazardous. The modified TCLP tests were 1/10th scale, to minimize secondary (leachate) waste and maximize tumbler capacity and sampler throughput. TCLP leachate analysis was accomplished using a Milestone Direct Mercury Analyzer (DMA80). Gamma spectroscopy provided added assurance of previously measured Am-241, Cs-137, and Co-60 contamination levels.

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 subpiles. For most 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. 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 five cubic yards to two, resulted in further schedule acceleration. The resulting sample frequency, however, was still 22 times greater than the baseline frequency (1 per 55 yd^3).

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1. Introduction

Approximately 11,500 cubic yards (yd^3) of contaminated soil were excavated from Brookhaven National Laboratory's (BNL) 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 the remaining 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 18 stockpiles at the removal project site. The stockpiles range in size from 100 yd^3 to 1,800 yd^3. In the ensuing years, some of the stockpile soils, which had been characterized as non-radioactive and non-hazardous, were disposed at Subtitle D facilities. 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^3) 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^{th} 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 (nearly $450,000). Additional costs were identified at BNL before all the waste materials were shipped in this period. During loading of some of these wastes for disposal, "non-conforming items" were identified (e.g., vials, bottles, etc. less than 2 inches and potentially containing hazardous materials such as mercury) still entrained in the waste soil, requiring that about 380 yd^3 of soil from Stockpile 13 be 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. Thus, manual hand raking of non-conforming items from the remaining portion of Stockpile 13 was initiated. This was the baseline sorting technique, but it proved to be an extremely slow, labor-intensive, and expensive process. Following the occurrence investigation (ORPS No. CH-BH-BNL-BNL-2000-0002), the *Bulk Waste Determination Guidance Document* (also referred to here as the Toolbox [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, it requires relatively few samples be taken for large volumes of contaminated soil. For example, application of this methodology to Stockpile 6B, which contained a total of 440 yd^3 of soil, resulted in identification of only 8 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.

In order to continue disposal efforts and improve performance, BNL tested a powered ½-inch screen sorting method on Stockpile 6B, and conducted characterization sampling following the Toolbox method. Stockpile 6B was shipped and disposed of without incident in July 2001. As part of this effort, ten samples were collected from each of the other stockpiles, and analyzed for TCLP and total inorganic constituents. As of October 2001, approximately 7,000 yd^3 of soil in 10 stockpiles still remained, requiring final disposition.

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 ten remaining soil stockpiles. The project was co-funded by the BNL Environmental Restoration program 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. Soils with mercury concentrations above allowable levels would be separated for disposal as mixed waste.

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, other RCRA metals, and TCLP mercury. Samples were to be collected and carried to the field lab for analysis with a planned one-day turnaround. Cost-effective, timely analysis of soil contamination allowed many more samples be taken and analyzed, significantly improving confidence in the data.

The next two sections describe planning and preparation for the project, and the work completed. The final section compares the ASTD Field Lab to off-site and duplicate results, and discusses lessons learned.

2. Project Planning

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.

2.1 Stockpile Sorting and Sampling

The first goal involved the use of the power screening method applied to Stockpile 6B, as mentioned earlier. During the screening, soils were to be separated into 20 yd^3 subpiles for sampling and subsequent analysis. A field laboratory, set up in a trailer near the stockpile area, was to be the means of achieving the second goal. The field lab would have the capability to test soils directly for total mercury, and would conduct modified TLCP extractions and test the extract for mercury. Finally, an ISOCS unit would collect gamma spectra for radiological characterization.

BNL's EM Directorate completed the plans for the sorting and segregation activities. A health and safety plan [2], a sampling and analysis plan [3], and a technical work document [4] were prepared, following BNL EM standard procedures. The Environmental Research and Technology Division (ERTD) was responsible for the field laboratory and, prepared similar plans for its operation [5, 6].

Based on the earlier work with Stockpile 6B, stockpile sorting rates were estimated at a maximum of 100 yd^3 per day, or five 20 yd^3 subpiles per day. Sampling and analysis plans were designed around this sorting volume estimate and the assumption that 3 samples were to be collected for every 5 yd^3. Three samples per 5 yd^3 were considered more than adequate for statistical certainty, particularly in comparison to the 1 sample per 55 yd^3 determined to be acceptable for Stockpile 6B with the Toolbox.

Crumbling, et al [7] 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." [7] 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. For eight of the stockpiles, the power-screen was set up at the former Glass Holes Area between Stockpiles 12 and 8. (The power-screen is shown in Figure 2.) As sorting progressed and soil from each stockpile was placed as 20 yd^3 subpiles with a front-loader, samples were collected from the subpiles. The subpiles were placed in the area to the southeast of the power-screen, south of Stockpile 15, wet of and adjacent to the woods. This served as the staging area for stockpile reconstruction in the Animal/Chemical Pits Area (also shown in Figure 1 as red-outlined rectangles). Subpiles were placed on 3-mil polyethylene sheets, and, after sampling, covered with polyethylene as well, until reconstruction was approved. Once the eight stockpiles in the Glass Holes area were sorted and reconstructed, the power-screen was moved to the Animal Chemical pits area for sorting the last two stockpiles, 6C and 6R.

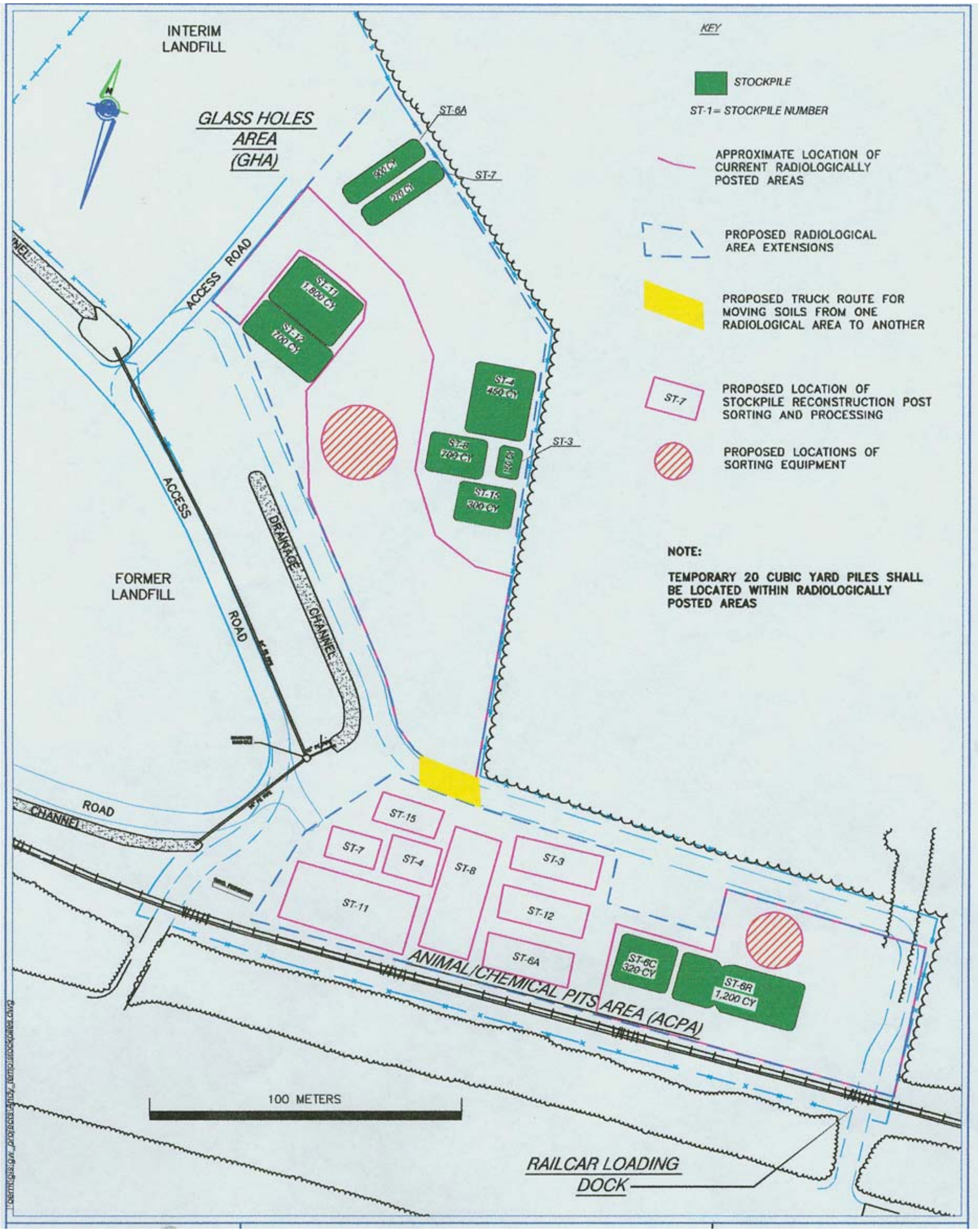

Figure 1. Stockpiles, sorting areas, and stockpile reconstruction areas at the former chemical/animal/glass disposal pits

Figure 2. The half-inch vibratory screen unit (Powerscreen Chieftain 600)

2.2 ASTD Field Laboratory

Samples from the subpiles were transported to the ASTD Field Laboratory for analysis each day they were collected. As noted earlier, 60 samples per day were expected, based on Stockpile 6B sorting experience. Sample analysis procedures were based on this throughput estimate, and on testing each sample for total mercury and most (but not all) samples using a modified EPA Toxicity Characteristic Leaching Procedure (TCLP). Originally, the testing scheme was to follow that shown in Figure 3. X-ray Fluorescence (XRF) was to be used as a screening tool to measure total mercury in the soil sample, since this mercury detection limit was identified by the manufacturer as achievable in solids with an analysis time of between 5 and 10 minutes. If mercury concentration for a sample was above 10 ppm, total mercury measurements were to be verified using the PDV 5000, and the sample was to be tested using the modified TCLP. If the XRF indicated that the sample was below 10 ppm mercury, the total mercury was to be verified with the Milestone Direct Mercury Analyzer (DMA) or the PDV 5000. From the latter test, if total mercury was less than 4 ppm, no further testing was deemed necessary, since a concentration of < 4 ppm total mercury could not result in TCLP concentrations in excess of the TCLP allowable limit of 0.2 ppm, assuming all of the mercury was leached. If more than 4ppm was detected, TCLP was still required.

TCLP failure means 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 collected radiological content information using the *In Situ* Object Counting System (ISOCS) to determine the presence of gamma-emitting radionuclides.

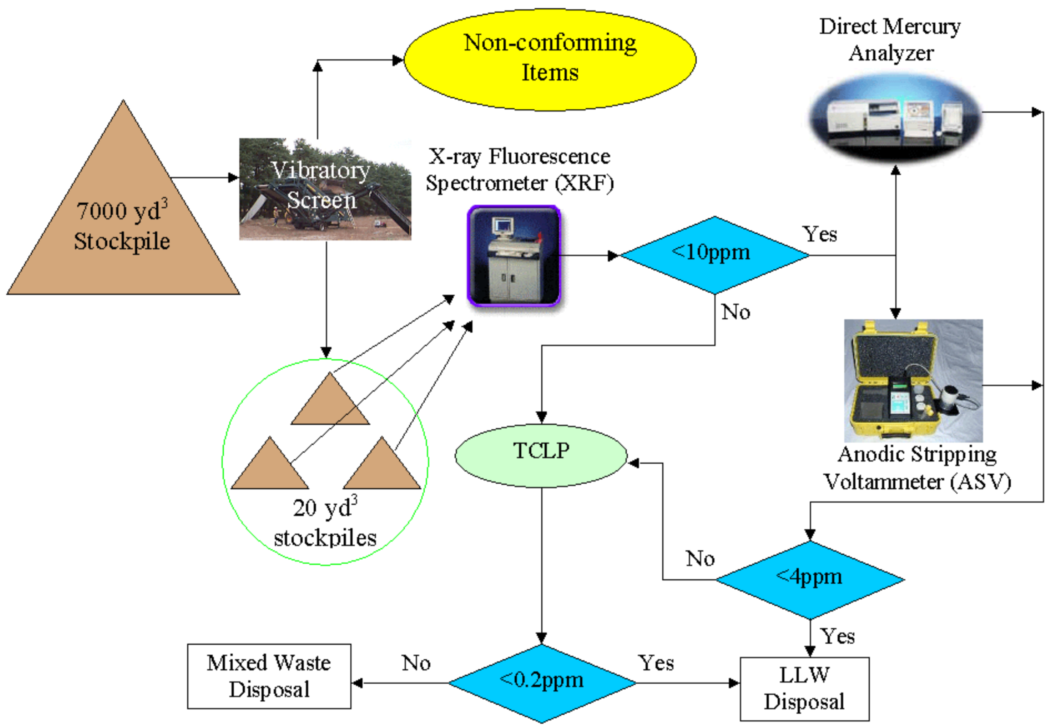

Figure 3. Planned process diagram for innovative waste segregation and near-real-time characterization of stockpiled soils

2.3 Field Laboratory Analytical Methods

2.3.1 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; the 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.

2.3.2 Anodic Stripping Voltammetry

The PDV 5000 was chosen for the project because it promised to be an inexpensive, simple, rapid technique for analyzing mercury and other toxic metals. It is a commercially available version of a method that in the past had been generally relegated to research laboratories. The method involves anodic stripping voltammetry (ASV), in which metals in solution are first electroplated onto an electrode. After this, current is reversed to strip the metals from the electrode back into solution. Each metal becomes stripped at a characteristic voltage, and the current density at that voltage is proportional to the total quantity of metal.

Because ASV involves the analysis of liquids, applications have usually focused on process liquid monitoring. Environmental applications have included river water testing for mercury and other metals. For soil testing, metals can be detected and quantified electrochemically after acid digestion with an acidic electrolyte. With the metal constituents in solution, electroplating followed by anodic stripping becomes possible. The detection limit for mercury in field applications was stated as 0.01 ppm in the liquid, which, according to the published procedure, corresponds to 0.02 ppm in the soil matrix.

2.3.3 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 limits, rapid throughput, and 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 Milestone DMA 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).

2.3.4 Modified TCLP

The modified Toxicity Characteristic Leaching Procedure (TCLP) used was essentially a $1/10^{th}$ scale version of the test recommended by the U.S. Environmental Protection Agency (EPA) [Ref. 8]. Extraction fluid #1 was used for all tests, as determined by the related EPA procedure [Ref. 9]. 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 in small bottles were placed inside a plastic 1-gallon jar to serve as 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.

2.3.5 *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 used 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^3 subpile was counted.

2.3.6 Integrated Operations and Quality Assurance

Since the stockpiles had been classified as low-level waste, the field lab was set up as a radioactive materials 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 in this half of the lab, it was designated as a radioactive dispersibles area when transfer operations were being conducted. The XRF, PDV5000, 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. A schematic layout of the Lab is shown in Figure 4.

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 to be stored and counted in the east end of the trailer. The remainder of the samples was to be transferred for processing and analysis by the chemical techniques described above.

After a targeted one-day turnaround, analytical 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 contained less than 260 ppm total mercury and less than 0.2 ppm TCLP mercury.

Quality assurance focused 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 to be calibrated according to manufacturer's recommended guidelines.

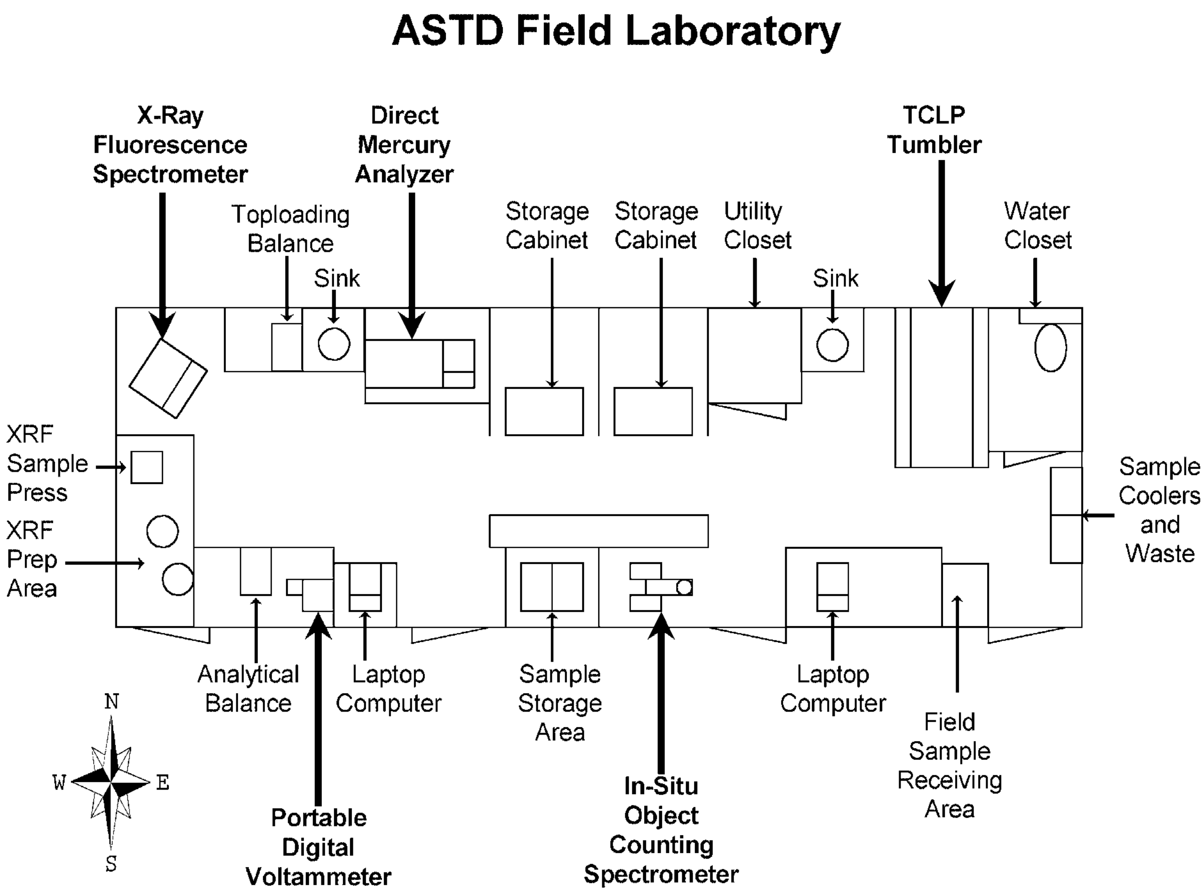

Figure 4. ASTD Field Lab - Schematic layout

3. Work Completed

3.1 Sample Production Rates and Chemical Analysis Capacity

Sorting began the first week of May, 2002, on Stockpile 8. After about 2 weeks, the soil sorting team had developed a standard routine for their activities, and they were processing more than 100 yd^3 per day. In fact, on their best days they processed as much as 230 yd^3, or more than twice the originally projected capacity. This resulted in a significantly higher production of analytical samples than was anticipated (60 samples per day).

In addition to receiving more samples than planned for, ASTD Field Lab operations required modification due to poor performance of the PDV 5000 (primarily unsatisfactory reproducibility) which eventually resulted in eliminating this method from the suite of analyses (see discussion below). Consequently a revised analytical strategy was implemented to improve productivity and provide the critical data needed for decision-making on the status of individual soil stockpiles. These three essential criteria were:

- confirmation that total mercury levels were < 260 ppm
- evaluation of TCLP mercury levels to ensure they did not exceed 0.2 ppm
- radiological analysis

Specifically, the XRF was used to screen for >260 ppm total mercury and the DMA-80 was assigned to measure mercury exclusively in the TCLP leachates.

The DMA-80 was assigned for TCLP results because it could be used for liquid as well as solid samples and gave highly reproducible results, as evidenced by blank and calibration standards tested after every five samples. With the DMA-80, preparation of the TCLP leach liquids for analysis was minimal, namely filtering the solution (0.45 μ) and pipetting 0.4 mL. Because of its reproducibility, the DMA-80 was deemed most important for application to the regulatory compliance test.

The XRF was assigned to total mercury analysis, but the procedure was modified to shorten preparation and analysis time. The Jordan Valley EX-6600 had been chosen because the company demonstrated detection limits of less than 10 ppm total mercury on samples provided by BNL. However, this was accomplished after milling/grinding the samples for ten minutes, and pressing the fine powder into pellets with a hydraulic press. With these steps, sample preparation time was about twenty minutes per sample, far too long for the throughput needed for the field lab application. In addition, the counting time on the x-ray unit was about fifteen minutes per sample. A shorter sample preparation time was developed which required 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 5-minute analysis time meant that the detection limit for the samples was approximately 20 ppm total mercury. The higher detection limit meant that the XRF unit was best used as a screening tool for higher levels of mercury, i.e. more than 260 ppm. Soils with this high a concentration require treatment before disposal under EPA land disposal restrictions. After Stockpile 15 was completed, it was determined that a shorter analysis time of 3 minutes, with a detection limit of 50 ppm was necessary to analyze 60 samples per day.

The PDV 5000 was dropped from use because reproducibility of calibration standards with it was often less than 20%. Discussions with the instrument manufacturer failed to resolve the issue completely, primarily because there was insufficient man-power to work on the recommended method modifications. Anodic stripping voltammetry depends on obtaining reproducibly dissolved mercury analyte in an interference-free electrolyte solution. It was not clear from the limited tests conducted whether:

1. Interfering elements were present in the soils and were being dissolved along with mercury,
2. The acid solution used was not dissolving mercury reproducibly from the soils, or
3. The active carbon electrode on the instrument was becoming fouled.

The revised laboratory procedure process flow diagram is shown in Figure 5. Several weeks were required to make all adjustments, and several important decisions about the data requirements were needed to make data production match sample production. The most important decision was to reduce the sample collection rate from three for every five cubic yards to two. The resulting sample frequency (1 per 2.5 yd^3) was still 22 times greater than the baseline frequency (1 per 55 yd^3).

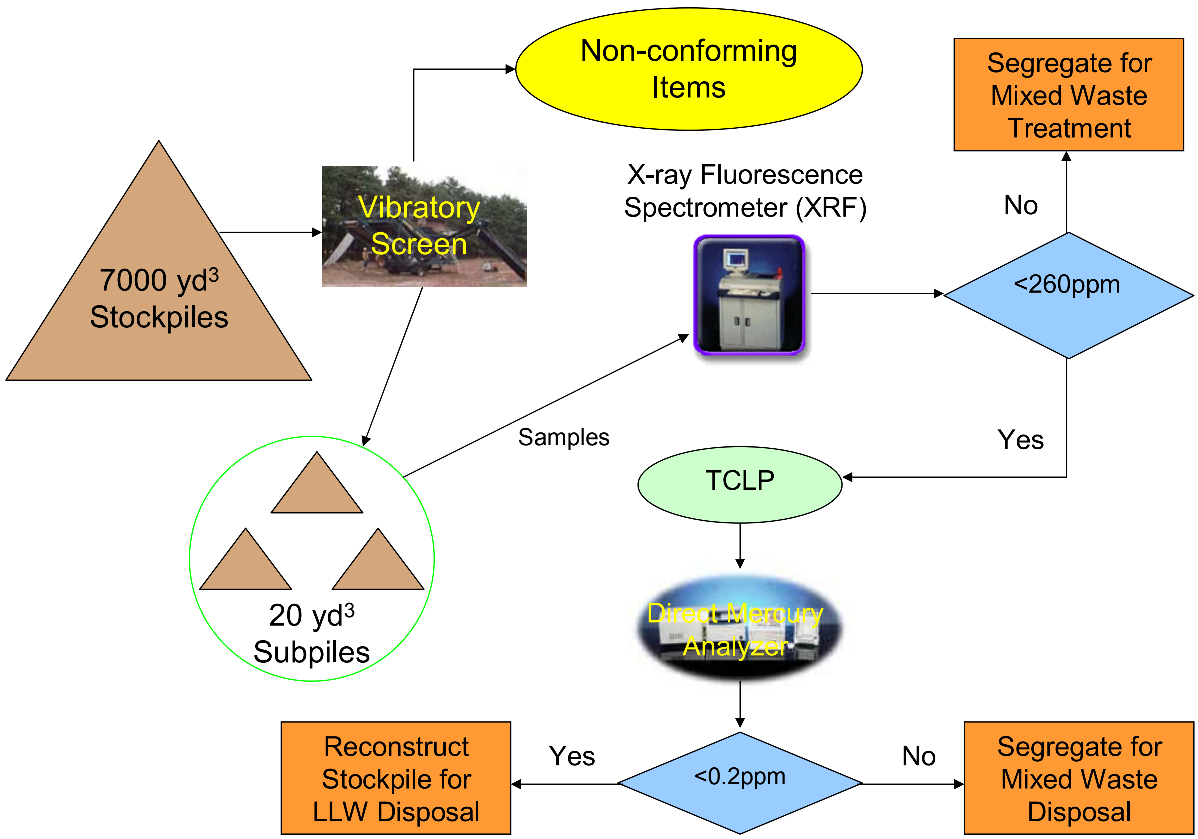

Figure 5. Final sorting and analysis scheme for ASTD Field Lab

3.2 Field Laboratory Results

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^3 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^3, was smaller than the original estimate of 6,790 yd^3. 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 ten new stockpiles, corresponding to the original ten. Radioactive measurements with the ISOCS unit and chemical test results are discussed separately.

3.2.1 ISOCS Results

The number of samples collected for ISOCS analysis totaled 283, or 1 for each subpile. Results are listed in full in Appendix 1, and 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 [10]. All are associated with some aspect of nuclear power or research, e.g., fuel (U-235, Th-232), 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 4 readings greater than 10 pCi/g. in 4 separate stockpiles. It is worth noting that in 3 of these stockpiles (St-6A, St-11, and St-12) more that 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, and cleanup levels for it are set at 23 pCi/g. The maximum concentration of Cs-137 found was 2.3 pCi/g in a subpile from Stockpile 11. The highest average concentration for a stockpile was 0.8 pCi/g, for St-7.

3.2.2 Total Mercury and TCLP Mercury Results

The total number of chemical analyses performed in this project was in excess of 2,264 (8 times 283). During sorting and sampling of the first stockpile, St-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 132 fewer samples (for Stockpiles 3, 4, and 8). (These can be identified in Appendix 2, which lists all total mercury and TCLP mercury results side-by-side.) After Stockpile 8 was completed, the sampling plan was modified so that 8 rather than 12 samples were collected for every 20 yd^3 (or 2 for every 5 cubic yards). Additionally, a sample for offsite analysis and a field duplicate (FD) were collected for every 20^{th} sample. For Stockpile 8, 28 of 132 "center level" samples collected were analyzed for

TCLP (subpiles 1 to 3 and 20 to 23, inclusive). Thus, TCLP analyses in the ASTD Field Lab totaled 2,406 (2,264 + 28 + 114 FDs). There were a total of 2,246 XRF analyses.

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 treatment 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 5 stockpiles. Stockpiles 8, 3, 4, 6A, and 7 had no samples with total mercury concentration greater than 100 ppm.

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 Stockpile 12 having the highest subpile average TCLP of 153.7 μg/L, and 5 subpiles with average TCLP mercury above 100 μg/L (see Table 4). As can be seen in Table 4, only two other subpiles, one in Stockpile 11 and one in Stockpile 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 below, 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. Those shown below were 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.

Sample	TCLP Hg	Sample	TCLP Hg	Sample	TCLP Hg
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		

4. Discussion and Conclusions

The ASTD Field Laboratory results presented above indicate that the soil stockpiles on average can be classified as non-hazardous, because total mercury is less than 260 ppm, and TCLP mercury is less than 200 μg/L. However, waste disposal facilities require that a certified laboratory must provide characterization data for waste disposal purposes. Thus, the QA program for the ASTD Field Laboratory included sending data to a certified off-site laboratory.

In this way, the ASTD Field Lab data serves as broad statistical support for higher confidence levels in limited sampling and analysis at an off-site lab.

4.1 Comparison with Off-site Results

The BNL EM Directorate Quality Assurance plan generally requires that one field duplicate and/or blind duplicate sample be sent to a contract lab for every twenty samples, or five percent. For the Chemical Holes Sorting And Analysis Project, a field duplicate was collected every 20 samples for analysis in the ASTD Field Lab, and a duplicate sent to an off-site laboratory for independent total mercury and TCLP mercury analysis. A complete listing of all off-site results tabulated side-by-side with the field lab results is contained in Appendix 3.

There are several approaches for inter-laboratory data comparisons. For the purposes of this discussion, two are used: one compares individual sample results with the off-site duplicates to determine if there is a correlation between the two sets of results. The second involves comparisons of subpile and stockpile averages obtained from the two data sets, to see if similar characteristics apply (i.e. do the data sets agree that the soils are not hazardous).

Figure 6 displays an X-Y plot of the ASTD Field Lab results *versus* results from the off-site contract laboratory. The slope of a best-fit line calculated by least squares regression is a quantitative means of demonstrating how well the two data sets' values match each other. Slope values close to unity (1.00) indicate that the data values match closely. Correlation coefficients can also be calculated mathematically; values close to one are indicative of a close correlation (lower scatter) between data sets. Both calculations are straightforward and accessible as functions through Microsoft Excel. The values obtained are shown below.

	Slope	**Correlation Coefficient**
TCLP Hg	0.76	0.58
Total Hg	0.82	0.46

The scatter shown by the data in Figure 6 is not unexpected, and a visual inspection of the plot along the slope = 1.0 line suggests that the data are distributed roughly evenly about the slope. However, the slope for the TCLP mercury is only 0.76, and the correlation coefficient is low at 0.58. A slightly "better" slope of 0.82 is found for total mercury, but scatter is worse, with a correlation coefficient of 0.46. In both instances, a slope of less than 1.0 indicates that the ASTD Field lab measurements were higher for any given sample. This in turn suggests that, if one assumes that the "true" value is that reported by the off-site contract laboratory, the ASTD field lab erred on the conservative side by providing mercury measurements slightly higher than the "true" value.

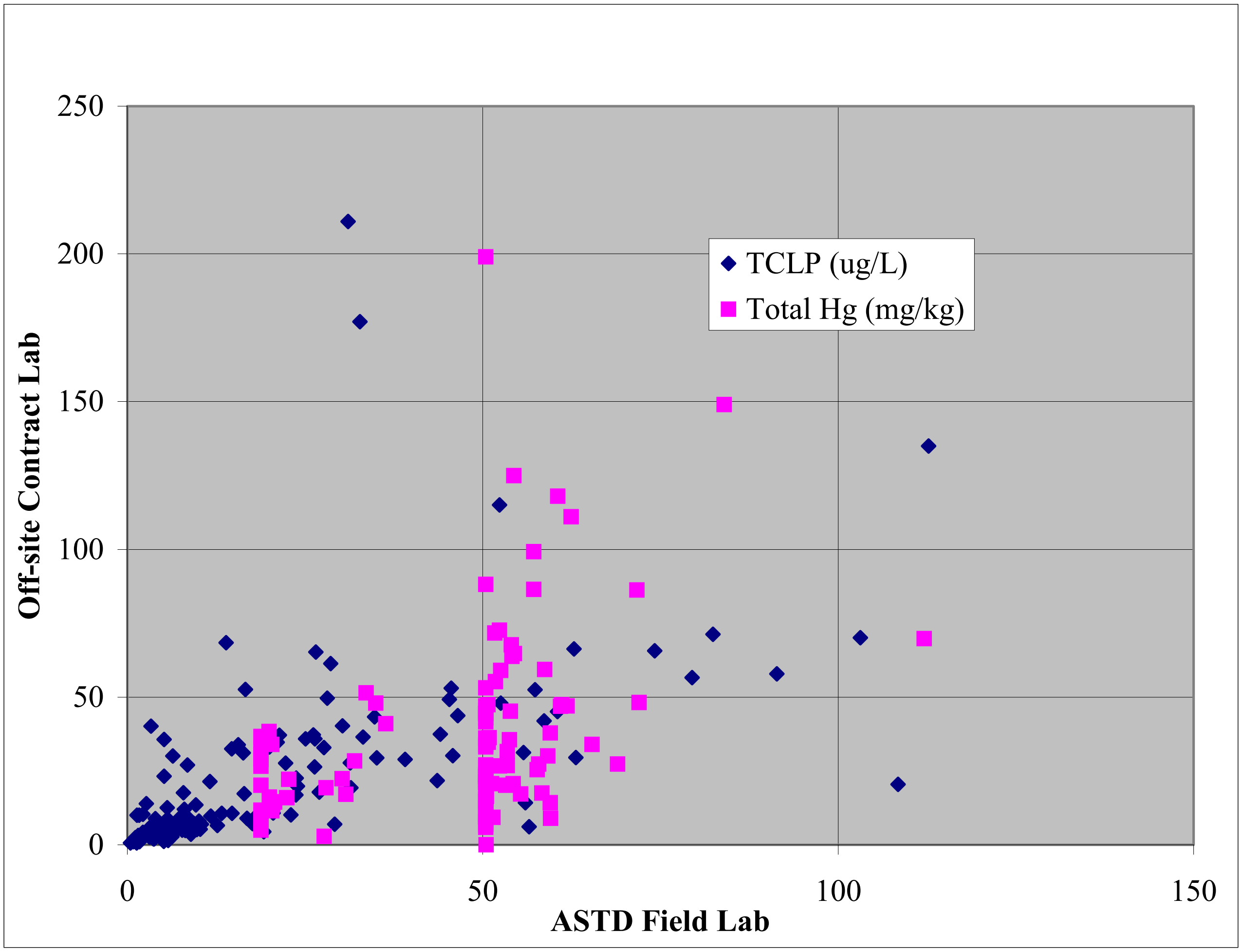

Figure 6. Field lab and contract lab data comparison

In spite of the observed scatter and the deviations of the slopes from 1.0, the agreement between the data sets is reasonable because of the type of contamination involved and the deposition method. As noted in the beginning of this report, the mercury contamination is believed to be primarily in the elemental, liquid form. It was originally placed in the disposal pits in whole containers (glass or plastic). The containers may have been broken at this stage or during the excavation phase in 1997. As a result of breakage, liquid mercury would physically disperse through the soil pores, driven by gravity, until the droplets became small enough the capillary forces would hold them up. Further dispersion would be expected during excavation or subsequent sorting and handling. In either event, the distribution of the mercury would not be uniform unless some sort of homogenization was conducted with the soils. A significant degree of heterogeneity can therefore be expected, as evidenced in the scatter seen in Figure 6, and can be expected from the proposed deposition model. The real question is – what valid average values can be used as data to describe the materials and be acceptable to disposal sites and regulators? Toward this end, independent sets of measurements can provide assurance that average values (as opposed to individual value comparisons displayed in Figure 6) and the error associated with those values are "true."

Data comparisons for TCLP mercury are listed in Tables 5 and 6, and shown as a bar graph in Figure 7. Table 5 compares stockpile averages calculated using the off-site samples and the corresponding ASTD Field lab samples. These common data point averages are less representative than those shown for the Field Lab in Table 6 because the number of points for the overall average is lower, e.g. for St 3, 6 points rather than 42, or for St 11, 25 rather than 545 points. St 8 is an anomaly, because 103 off-site data points represents the analysis of many additional samples collected under the initial sample rate of 12 per 20 yd^3. When the ASTD Field Lab was unable to complete all analyses at the pace that samples were being produced, many were sent off-site. Thus for St 8 there were only 41 common data points, as shown in Table 5.

St 7 was also a special case. The Contract Lab reported one sample (ST-7-06-NWB) as having TCLP mercury at 367 µg/L. A repeat analysis of the remaining sample at the contract lab (soil extraction then analysis of the leachate) was reported as being 5.7µg/L. The Field Lab had found 3.5 µg/L TCLP mercury in leachate from the same soil sample. The overall average and standard deviation for St 7 (79.3 ± 161.0 µg/L) based on off-site data and including the 367 µg/L were the highest found to that point in the project. Because the average plus the uncertainty suggested the stockpile might be at or slightly above the BNL 160 ppb action level, the Project Manager requested an off-site repeat of all Stockpile 7, and all samples stored in the Field Lab were transferred to the Contract Lab for extraction and analysis. The repeat run found the same average TCLP mercury, but one sample (ST-7-04-NET) was reported as having 4,520 µg/L!! When this sample was repeated, a value less than 50 was reported Thus the second run had a much greater uncertainty (standard deviation), with TCLP mercury equal to 79.1 ± 546.9 µg/L, if the value above 4,000 µg/L is used. (These latter data are listed in Appendix 3.) Even though the high levels in individual samples could not be repeated, Stockpile 7 was assigned for disposal as mixed waste. This was supported in part by total mercury values, which were highest for Stockpile 7, at 65 mg/kg, as determined in the ASTD Field Lab, and 61 mg/kg, as determined by the off-site contract Lab (Table 8).

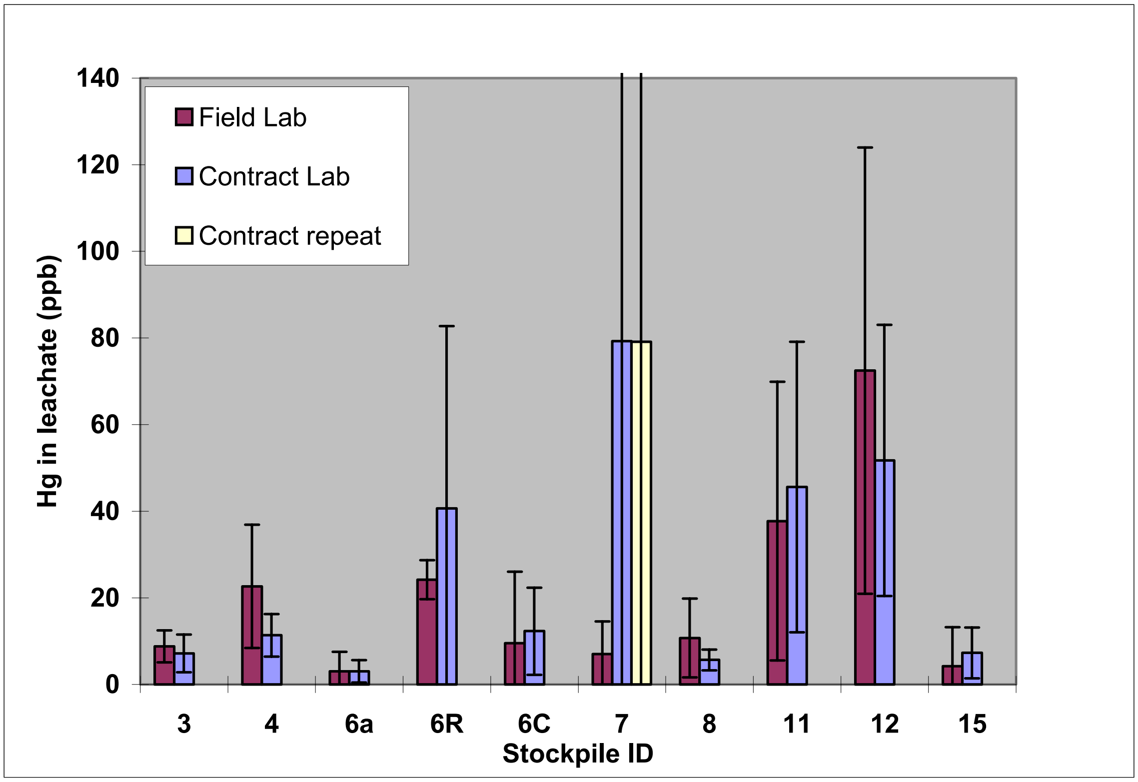

Figure 7. Comparison of TCLP mercury results for soil stockpiles

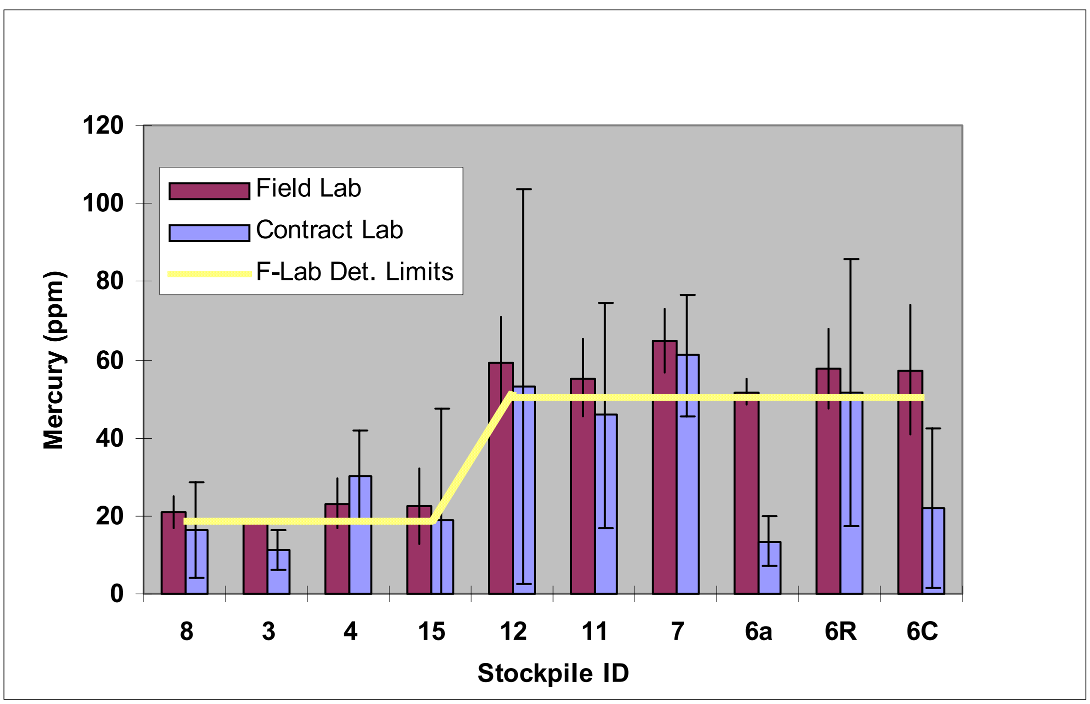

Figure 8. Comparison of total mercury results for stockpiled soils

4.2 Comparison with 2001 Sampling Campaign Results

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. 11]. 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 9. 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 the uncertainty (standard deviations) for all total mercury data. The general conclusion from the ASTD Field Lab TCLP data was that all Stockpiles were within acceptable levels for classification as non-hazardous.

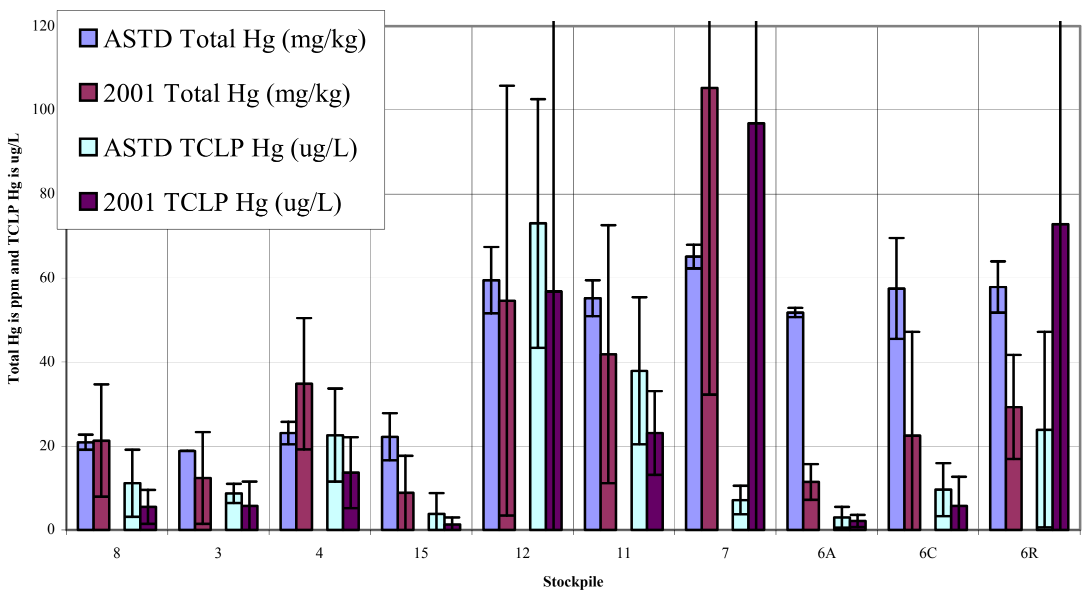

Figure 9. Comparison of field lab results with 2001 sampling campaign

4.3 Conclusions

The ASTD field laboratory completed more than 2,200 analyses for total mercury (XRF) and more than 2,400 TCLP mercury (DMA) analyses, over the project. Reliable statistical verification of the original characterization of the stockpiles as low-level wastes was accomplished. The Classification for Stockpile 12 Stockpile 12 was 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.

5. References

1. BNL Waste Management Division, "Bulk Waste Characterization for Offsite Disposal Sampling Guidance," Brookhaven National Laboratory, August 2000.

2. BNL EM Directorate, "Environment, Safety and Health Plan: Glass Holes Stockpiles Inspection, Loading & Disposal," Brookhaven National Laboratory, September, 2001.

3. BNL EM Directorate, "Sampling And Analysis Plan For Waste Characterization Of Stockpiled Soil," Brookhaven National Laboratory, January 2002.

4. BNL EM Directorate, "Sort, Inspect, Load & Ship Chemical Holes Soil Stockpiles: Technical Work Document," EM-GH-TP-02-01, Rev. 0, Brookhaven National Laboratory, March 2002.

5. BNL EM Directorate, "Environment, Safety and Health Plan, ASTD Field Laboratory," Brookhaven National Laboratory, March 2002.

6. BNL EM Directorate, "Glass/Chemical/Animal Holes Project ASTD Field Laboratory Technical Work Document," EMD-GH-TP-02-02, Rev.0, Brookhaven National Laboratory, March 2002.

7. Crumbling, D.M., et al "Managing Uncertainty in Environmental Decisions," Environmental Science and Technology, American Chemical Society, pp. 405-409, October 1, 2001.

8. U.S. Environmental Protection Agency, "Toxicity Characteristic Leaching Procedure," Method 1311, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm

9. U.S. Environmental Protection Agency, "Extraction Procedure (EP) Toxicity Test Method and Structural Integrity Test," Method 1310A, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm

10. W. de Laguna, "Geology of Brookhaven National Laboratory and Vicinity, Suffolk County, New York," Geological Survey Bulletin 1156-A, U.S. Geological Service (1963)

11. BNL EM Directorate, "Animal/Chemical Pits And Glass Holes Project Stockpile Characterization Summary Report," Brookhaven National Laboratory, March 28, 2002.

Table 1
Stockpiles Volumes and Samples Collected

Stockpile Number	Original Estimated Volume (yd^3)	Number of Subpiles	Actual Volume* (yd^3)	Samples**	Sorting Completed
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
Total	*6,790*	*283*	*5,660*	*2,372*	

* Based on the number of 20 yd^3 Subpiles

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

Total number of subpiles = 283 = number of ISOCS samples
Total Regular samples = 283x8 = 2,264
Total FD = 2372-2264 = 108
Total off-site is higher because all of ST 7 was re-analyzed off-site

Table 2
Stockpiles Radionuclide Contamination Summary

		Estimated Activity Concentration											
Stockpile	Total	Co-60				Cs-137				Ra-226			
	Samples	Maximum Value (pCi/g)	Subpile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Subpile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Subpile 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			
	Samples	Maximum Value (pCi/g)	Subpile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Subpile w/Max Value	Average (pCi/g)	Total ND's	Maximum Value (pCi/g)	Subpile 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

Table 3
Stockpile Summary Data – Total and TCLP Mercury Results

	Stockpile Average Results				Maximum Values	
Stockpile	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

Table 4
List of Subpiles Averages – Total and TCLP Mercury Concentrations

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
	Stockpile 8				
13442	st801	**21.6**	3.4	2.0	0.5
13444	st802	**20.8**	1.0	4.8	1.3
13445	st803	**20.7**	0.9	4.8	3.5
13446	st804	**25.2**	5.9	6.8	1.9
13447	st805	**24.2**	6.4	12.0	6.7
13448	st806	**22.3**	3.1	9.1	2.2
13449	st807	**20.4**	0.0	7.0	1.2
13450	st808	**22.1**	3.1	11.3	7.1
13458	st809	**21.7**	1.7	9.0	1.4
13459	st810	**21.8**	2.5	8.1	1.3
13461	st811	**20.3**	0.0	9.7	4.0
13462	st812	**20.3**	0.0	4.8	0.5
13464	st813	**23.3**	4.3	11.7	4.3
13465	st814	**21.0**	1.9	10.9	0.9
13467	st815	**20.3**	0.0	5.0	0.8
13505	st816	**20.6**	0.6	4.2	0.7
13506	st817	**20.5**	0.4	5.2	1.1
13507	st818	**24.7**	11.6	8.2	1.4
13508	st819	**23.0**	7.9	10.8	3.6
13509	st820	18.8	0.0	7.0	3.5
13510	st821	**18.9**	0.4	15.3	17.9
13511	st822	**21.3**	4.6	16.4	6.8
13512	st823	18.8	0.0	13.8	4.3
13513	st824	**22.1**	9.2	38.3	9.8
13514	st825	**19.2**	0.7	38.2	8.0
13533	st826	**19.7**	1.9	17.4	8.3
13534	st827	**18.8**	0.0	16.0	8.5
13535	st828	**19.7**	1.6	6.8	1.7
13536	st829	**20.1**	2.6	14.3	1.7
13537	st830	18.8	0.0	13.4	2.7
13538	st831	**20.9**	3.1	8.9	1.3
13539	st832	18.8	0.0	9.8	0.9
13540	st833	18.8	0.0	4.8	3.1
	St 8 Overall average	**20.9**	1.8	11.1	8.0
	Stockpile 3				
13541	ST301	18.8	0.0	7.6	2.7
13542	ST302	18.8	0.0	5.9	3.1
13560	ST303	18.8	0.0	8.3	3.6

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
13561	ST304	18.8	0.0	11.9	3.6
13562	ST305	18.8	0.0	9.9	3.2
	St 3 Overall average	18.8	0.0	8.7	2.3
	Stockpile 4				
13563	st401	**24.6**	12.7	8.5	1.2
13564	st402	**33.1**	15.9	11.9	3.9
13565	st403	**24.4**	7.6	13.0	3.0
13566	st404	**24.2**	7.1	14.1	2.7
13567	st405	**22.8**	3.3	20.8	9.1
13568	st406	**26.4**	8.9	21.4	2.5
13569	st407	**26.2**	5.5	22.7	3.3
13570	st408	**23.6**	4.6	17.3	13.6
13571	st409	18.8	0.0	12.2	7.2
13572	st410	**20.9**	3.8	13.3	7.4
13575	st411	**23.9**	5.4	13.5	5.0
13576	st412	**20.2**	2.6	17.3	5.3
13577	st413	**24.4**	4.7	18.8	3.5
13578	st414	**24.9**	7.7	18.1	4.2
13579	st415	**19.6**	1.7	12.2	3.9
13599	st416	**19.9**	2.7	10.5	6.2
13600	st417	**19.4**	1.1	8.8	2.7
13601	st418	**22.2**	5.2	11.0	2.2
13602	st419	**20.5**	2.8	24.6	6.3
13603	st420	**25.2**	6.0	24.9	9.7
13609	st421	**22.1**	3.7	35.5	5.8
13604	st422	**22.0**	4.0	32.0	2.9
13605	st423	**19.5**	1.3	35.3	7.2
13606	st424	**22.8**	4.4	28.4	6.5
13607	st425	**23.5**	4.5	36.4	25.7
13608	st426	**24.3**	6.1	39.0	6.8
13610	st427	**25.0**	7.0	47.0	12.3
13611	st428	**23.2**	4.1	44.5	28.0
13612	st429	**23.6**	6.1	35.1	20.6
13613	st430	**20.4**	2.8	29.6	12.9
13614	st431	**22.4**	4.9	31.3	4.2
13615	st432	**23.3**	4.3	30.5	8.4
13616	st433	**24.2**	5.8	21.2	2.2
13617	st434	**22.1**	6.4	6.3	3.3
	ST 4 - Overall Average	**23.1**	2.7	22.6	11.1
	Stockpile 15				
13618	st151	**19.4**	1.9	2.0	0.7
13619	sta52	**20.0**	2.4	5.5	1.6
16620	st153	18.8	0.0	4.1	1.3
13641	st154	18.8	0.0	1.5	1.4
13642	st155	18.8	0.0	1.0	0.6

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
13643	st156	18.8	0.0	3.2	1.3
13644	st157	18.8	0.0	2.4	2.6
13645	st158	18.8	0.0	3.6	4.5
13646	st159	18.8	0.0	0.6	0.3
13647	st1510	**36.2**	31.3	20.3	22.7
13648	st1511	18.8	0.0	1.7	0.3
13649	st1512	27.7	0.0	1.5	0.4
13650	st1513	27.7	0.0	1.5	0.5
13651	st1514	**29.1**	3.0	4.1	6.6
	St 15 Overall Average	**22.2**	5.6	3.8	5.0
	Stockpile 12				
13652	st1201	**54.6**	4.1	32.3	13.4
13653	st1202	**53.9**	3.9	39.2	13.8
13654	st1203	**54.3**	7.2	53.4	23.5
13655	st1204	**56.4**	8.3	**102.4**	96.7
13656	st1205	**61.3**	17.6	84.2	28.6
13657	st1206	**54.1**	8.8	34.2	14.6
13658	st1207	**51.3**	1.8	25.0	9.2
13739	st1208	**51.2**	1.8	43.7	7.0
13740	st1209	**51.1**	1.8	94.7	57.1
13741	st1210	**53.3**	4.0	57.4	14.4
13742	st1211	**52.2**	3.7	80.5	13.0
13743	st1212	**64.4**	20.6	80.0	11.8
13744	st1213	**59.7**	10.0	84.4	17.0
13745	st1214	**60.8**	10.9	60.8	9.2
13746	st1215	**61.1**	4.7	68.4	13.6
13749	st1216	**59.0**	12.4	70.5	24.3
13750	st1217	**56.7**	5.5	**153.7**	196.0
13751	st1218	**60.7**	9.0	85.2	19.0
13752	st1219	**56.4**	5.4	88.0	25.9
13753	st1220	**53.9**	4.0	89.2	83.0
13754	st1221	**51.3**	2.3	62.8	12.2
13755	st1222	**54.4**	6.2	56.0	14.0
13756	st1223	**56.2**	5.8	52.2	18.5
13757	st1224	**57.2**	4.7	52.7	8.5
13758	st1225	**60.0**	8.7	67.5	27.6
14315	st1226	**68.7**	6.9	98.4	36.3
14316	st1227	**69.5**	12.1	**103.0**	16.8
14317	st1228	**72.6**	11.1	**112.8**	14.2
14318	st1229	**76.0**	14.9	**122.5**	27.3
14319	st1230	**82.7**	20.2	83.0	18.4
14320	st1231	**70.1**	15.5	26.3	15.5
	St 12 Overall Average	**59.5**	7.9	73.0	29.6
	Stockpile 11				

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
14322	st1101	50.5	0.0	20.7	4.6
14323	st1102	**50.9**	1.2	26.2	3.1
14324	st1103	**55.7**	8.8	28.6	7.5
14325	st1104	**52.1**	2.3	29.8	7.9
14326	st1105	**59.7**	13.9	43.8	9.8
14327	st1106	**57.1**	6.1	46.6	18.2
14328	st1107	**55.7**	6.7	40.5	12.3
14329	st1108	**54.9**	4.3	23.9	3.7
14330	st1109	**51.7**	3.2	39.0	12.4
14331	st1110	**56.9**	4.9	33.3	23.1
14332	st1111	**54.5**	5.7	30.7	5.9
14333	st1112	**51.8**	3.3	30.9	6.3
14334	st1113	**51.2**	1.8	30.7	9.5
14341	st1114	**53.9**	6.9	27.7	3.8
14342	st1115	**51.7**	2.3	49.7	23.7
14343	st1116	**52.5**	5.2	30.3	8.1
14344	st1117	**52.5**	3.6	30.3	6.0
14345	st1118	**53.5**	5.2	29.9	6.0
14346	st1119	**59.1**	16.4	24.8	12.7
14347	st1120	**53.0**	2.6	48.0	23.7
14348	st1121	**52.3**	3.1	26.9	11.2
14349	st1122	**56.5**	10.0	22.1	15.8
14587	st1123	**51.7**	3.2	21.2	5.9
14588	st1124	**58.1**	15.6	16.8	5.7
14589	st1125	**51.7**	2.2	20.8	9.6
14590	st1126	**53.5**	2.9	26.7	6.2
14591	st1127	**52.1**	3.3	66.2	67.9
14592	st1128	**51.2**	1.4	39.7	11.0
14593	st1129	**54.5**	6.2	32.6	17.9
14594	st1130	**51.9**	4.2	32.3	8.6
14595	st1131	**59.5**	9.2	61.5	58.8
14596	st1132	**53.5**	4.5	40.6	7.8
14597	st1133	**56.6**	9.4	42.0	6.8
14599	st1134	**53.3**	3.0	17.1	3.2
14601	st1135	**59.6**	9.5	75.8	6.2
14602	st1136	**54.5**	5.5	50.4	10.6
14603	st1137	**56.9**	5.2	49.2	6.5
14604	st1138	**55.4**	5.5	31.4	5.5
14605	st1139	**57.1**	10.1	76.3	16.9
14606	st1140	**62.7**	11.7	54.6	8.9
14607	st1141	**57.3**	9.0	63.4	12.3
14608	st1142	**59.7**	22.3	28.9	5.7
14609	st1143	**59.8**	10.6	**113.4**	120.6
14610	st1144	**56.7**	10.9	63.2	14.5
14611	st1145	**55.6**	5.6	47.4	19.8

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
14612	st1146	**59.2**	3.9	43.3	6.7
14613	st1147	**58.0**	9.8	29.9	4.2
14614	st1148	**55.0**	5.2	38.8	12.9
14615	st1149	**76.1**	18.4	72.3	14.8
14616	st1150	**55.3**	5.8	47.4	28.5
14617	st1151	**55.4**	6.1	38.7	14.2
14644	st1152	**64.1**	20.1	29.9	3.9
14645	st1153	**53.0**	4.1	22.8	3.1
14646	st1154	**52.0**	2.4	26.4	4.8
14647	st1155	**51.6**	2.4	34.0	4.8
14648	st1156	**58.4**	10.6	37.0	8.1
14649	st1157	**64.2**	19.0	45.3	12.0
14650	st1158	**53.1**	3.4	36.6	2.6
14651	st1159	**53.4**	4.0	37.8	5.5
14652	st1160	50.5	0.0	35.3	5.0
14653	st1161	**56.3**	10.0	23.2	5.7
14654	st1162	**53.1**	4.7	33.6	4.0
14655	st1163	50.5	0.0	18.4	6.7
14656	st1164	50.5	0.0	8.8	1.5
14657	st1165	**50.7**	0.8	18.0	3.8
	St 11 Overall average	**55.2**	4.3	37.9	17.5
	Stockpile 7				
14659	st701	**66.9**	9.2	6.0	3.2
14660	st702	**63.8**	10.5	13.6	17.7
14661	st703	**68.1**	5.9	3.5	5.1
14662	st704	**64.2**	7.4	4.9	4.5
14663	st705	**60.6**	8.6	6.1	3.6
14677	st706	**66.6**	9.4	5.3	2.7
14678	st707	**68.3**	4.5	11.2	4.2
14679	st708	**62.6**	8.7	5.4	4.8
	St 7 Overall average	**65.1**	2.8	7.0	3.5
	Stockpile 6A				
14680	st6A01	50.5	0.0	1.3	0.5
14681	st6A02	50.5	0.0	4.3	4.1
14682	st6A03	**51.3**	2.5	10.7	17.3
14683	st6A04	**52.4**	3.9	4.5	4.1
14684	st6A05	**52.6**	5.7	4.1	1.2
14685	st6A06	**52.4**	4.5	4.4	3.1
14686	st6A07	**53.2**	3.9	3.5	0.9
14687	st6A08	**53.0**	2.8	5.6	2.6
14688	st6A09	**50.7**	0.4	5.1	1.6
14689	st6A10	**54.5**	9.2	7.3	9.3
14690	st6A11	**53.3**	4.5	6.2	1.7
14691	st6A12	**52.3**	3.4	6.1	2.0
14692	st6A13	**52.5**	2.9	5.0	3.0

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
14693	st6A14	**51.7**	1.4	2.5	0.7
14694	st6A15	**52.5**	3.1	2.4	1.0
14695	st6A16	50.5	0.0	1.2	1.1
14776	st6A17	**52.0**	3.0	1.2	1.4
14777	st6A18	50.5	0.0	1.0	0.8
14778	st6A19	**50.7**	0.5	0.9	0.3
14779	st6A20	**53.9**	4.6	1.2	0.5
14780	st6A21	**51.2**	1.3	0.9	0.2
14781	st6A22	**52.5**	4.2	3.2	1.6
14782	st6A23	**52.7**	3.7	1.4	1.4
14783	st6A24	**50.8**	0.9	1.3	0.4
14784	st6A25	50.5	0.2	1.2	0.8
14785	st6A26	**51.0**	1.5	1.3	0.3
14786	st6A27	**51.9**	3.1	0.8	0.3
14787	st6A28	50.5	0.0	0.7	0.7
14788	st6A29	**50.6**	0.2	0.6	0.1
14789	st6A30	**51.2**	1.2	0.8	0.4
	St 6A Overall Average	**51.8**	1.1	3.0	2.5
	Stockpile 6C				
14872	st6C01	**50.8**	0.8	2.3	2.1
14874	st6C02	**51.5**	2.8	3.2	1.1
14875	st6C03	50.5	0.0	7.3	2.5
14876	st6C04	**51.6**	2.8	19.3	32.6
14877	st6C05	**51.2**	1.7	3.3	1.3
14878	st6C06	50.5	0.0	15.9	37.6
14880	st6C07	**51.6**	2.5	7.2	11.0
14881	st6C08	**61.1**	15.3	8.9	11.6
14882	st6C09	**86.6**	36.4	18.2	2.8
14883	st6C10	**69.6**	11.2	10.3	3.1
	St 6C Overall average	**57.5**	12.0	9.6	6.3
	Stockpile 6R				
14884	st6R01	**55.6**	4.6	4.0	2.9
14885	st6R02	**53.8**	5.1	5.3	3.5
14886	st6R03	**53.8**	4.7	10.7	15.4
14887	st6R04	**59.4**	8.8	5.5	1.3
14905	st6R05	**52.7**	3.0	2.5	2.0
14906	st6R06	**52.9**	5.7	6.6	2.1
14907	st6R07	**55.6**	5.5	8.6	4.8
14909	st6R08	**55.6**	6.8	7.1	4.0
14910	st6R09	**83.2**	27.6	52.4	45.1
14911	st6R10	**69.0**	7.1	36.6	14.9
14912	st6R11	**59.6**	8.6	12.8	2.6
14913	st6R12	**67.9**	7.6	19.6	19.5
14914	st6R13	**62.7**	9.7	16.7	9.4
14915	st6R14	**59.3**	8.1	27.2	13.5

		Subpile Average Results			
COC	**Subpile**	**Total Hg**	**Std.Dev.**	**TCLP**	**Std.Dev.**
		(mg/kg)	**(mg/kg)**	**(ug/L)**	**(ug/L)**
14916	st6R15	**61.6**	12.6	10.3	3.0
14917	st6R16	**51.9**	2.7	21.5	14.5
14918	st6R17	**58.5**	11.2	44.2	11.7
14919	st6R18	**59.3**	11.8	22.8	5.4
14920	st6R19	**59.9**	5.8	23.9	9.2
14921	st6R20	**56.0**	6.6	12.5	7.6
14922	st6R21	**59.1**	10.3	18.5	3.2
14923	st6R22	**59.6**	6.5	15.3	4.3
14924	st6R23	**59.9**	10.8	24.4	6.8
14985	st6R24	**73.7**	8.3	37.3	43.1
14986	st6R25	**59.6**	6.7	20.2	9.6
14987	st6R26	**53.4**	2.8	33.5	21.8
14988	st6R27	**55.9**	4.9	23.6	25.0
14989	st6R28	**58.3**	13.2	7.2	5.2
14990	st6R29	**58.1**	4.3	63.7	111.2
14991	st6R30	**53.4**	5.0	32.7	45.9
14992	st6R31	**61.8**	11.4	16.2	3.4
15406	st6R32	**61.6**	8.1	25.8	11.0
15407	st6R33	**59.3**	5.6	97.1	228.2
15408	st6R34	**61.1**	18.9	19.8	16.6
15409	st6R35	**51.2**	2.2	16.9	7.9
15410	st6R36	**56.0**	6.8	13.8	5.4
15411	st6R37	**53.4**	4.3	15.0	19.0
15412	st6R38	**57.1**	6.0	11.0	3.2
15413	st6R39	**54.2**	4.0	8.0	0.7
15414	st6R40	**55.9**	4.3	7.1	1.0
15415	st6R41	**56.2**	5.3	5.8	1.3
15416	st6R42	50.5	0.0	4.2	1.3
15418	st6R43	**58.7**	6.0	11.6	6.2
15419	st6R44	**51.1**	1.3	16.3	8.8
15420	st6R45	**50.8**	0.6	21.0	10.0
15421	st6R46	**54.2**	5.4	21.4	4.5
15422	st6R47	**63.2**	22.7	35.9	14.1
15423	st6R48	**56.9**	11.9	53.2	62.9
15424	st6R49	**68.6**	10.3	77.9	39.6
15425	st6R50	**51.5**	2.0	30.9	6.3
15426	st6R51	50.5	0.0	**120.7**	312.1
15417	st6R52	**52.7**	3.2	5.8	2.0
15427	st6R53	**54.0**	4.8	3.4	1.8
	ST 6R Overall Average	**57.9**	6.1	23.9	23.3

Table 5
TCLP Mercury Results for Common Data Points

		ASTD Field Lab			Hits		Contract Lab		
Stockpile	# of Data	Average	Std.		>100 ppb		Average	Std.	
#	Points	μg/L	Dev.	95%*	F-lab	Con	μg/L	Dev.	95%*
3	6	9.1	4.8	18.7	0	0	7.2	4.3	15.9
4	14	19.2	10.2	39.6	0	0	11.3	4.9	21.2
6a	13	3.5	5.0	13.5	0	0	3.0	2.6	8.2
6R	22	20.7	19.8	60.3	0	1	40.7	42.0	124.7
6C	3	3.6	1.5	6.6	0	0	12.3	10.1	32.4
7	4	2.4	1.6	5.6	0	1	97.6	179.7	457.0
8	41	7.4	8.5	24.4	0	0	5.1	2.1	9.3
11	25	31.8	12.3	56.4	0	2	45.6	33.5	112.7
12	13	71.1	26.6	124.3	3	1	51.8	31.3	114.3
15	3	2.7	2.1	6.9	0	0	4.1	5.1	14.3

* Refers to the 95% confidence value, calculated as [Average + (2 x Std.Dev.)]

Table 6
TCLP Mercury Results Comparison for All Data Points

	ASTD Field Lab				Hits		Contract Lab			
Stockpile	Average	Std.		# of Data	>100 ppb		Average	Std.		# of Data
#	μg/L	Dev.	95%*	Points	F-lab	Con	μg/L	Dev.	95%*	Points
3	8.8	3.7	16.2	42	0	0	7.2	4.3	15.9	6
4	22.6	14.2	51.1	286	0	0	11.3	4.9	21.2	14
6a	3.1	4.5	12.0	251	10	0	3.0	2.6	8.2	13
6R	24.2	4.5	33.2	443	10	1	40.7	42.0	124.7	22
6C	9.5	16.5	42.6	83	1	0	12.3	10.1	32.4	3
7	7.0	7.5	22.1	66	0	1	79.3	161.0	401.2	5
8	10.7	9.1	28.9	322	0	0	5.7	2.4	10.5	103
11	37.7	32.2	102.1	545	8	2	45.6	33.5	112.7	25
12	72.5	51.5	175.5	260	42	1	51.8	31.3	114.3	13
15	4.2	9.0	22.3	117	0	1	7.3	5.9	19.0	5
all	27.2	34.8	96.9	2415	71	6	16.7	34.4	85.4	209

* Refers to the 95% confidence value, calculated as [Average + (2 x Std.Dev.)]

Table 7
Total Mercury Results for Common Data Points

		ASTD Field Lab			Contract Lab		
Stockpile #	**# of Data Points**	**Average mg/Kg**	**Std. Dev.**	**95%***	**Average mg/Kg**	**Std. Dev.**	**95%***
3	3	18.8	0.0	18.8	12.4	6.7	25.8
4	14	27.8	10.4	48.7	30.3	11.6	53.5
6a	13	51.2	2.5	56.3	13.4	6.4	26.3
6R	22	57.7	9.0	75.6	51.4	34.3	120.0
6C	3	51.6	2.0	55.6	21.7	20.4	62.6
7	4	64.2	12.0	88.1	61.1	15.7	92.5
8	17	20.3	2.8	25.8	13.8	8.1	30.1
11	25	54.4	4.6	63.6	45.8	28.8	103.4
12	12	52.2	3.7	59.5	53.1	50.6	154.3
15	5	39.2	40.9	121.1	18.9	28.6	76.0

* Refers to the 95% confidence value, calculated as [Average + (2 x Std.Dev.)]

Table 8
Total Mercury Results Comparison for All Data Points

	ASTD Field Lab				Contract Lab			
Stockpile #	**Average mg/Kg**	**Std. Dev.**	**95%***	**# of Data Points**	**Average mg/Kg**	**Std. Dev.**	**95%***	**# of Data Points**
3	18.8	0.0	18.8	20	11.3	4.9	21.0	6
4	23.1	6.3	35.7	253	30.3	11.6	53.5	14
6a	51.7	3.2	58.1	252	13.4	6.4	26.3	13
6R	57.8	10.1	78.0	445	51.4	34.3	120.0	22
6C	57.3	16.6	90.4	83	21.7	20.4	62.6	3
7	64.8	8.3	81.5	68	61.1	15.7	92.5	4
8	20.3	2.8	25.8	17	16.5	12.3	41.1	17
11	55.4	9.9	75.2	546	45.8	28.8	103.4	25
12	59.3	11.8	83.0	260	53.1	50.6	154.3	12
15	22.3	9.6	41.6	116	18.9	28.6	76.0	5
All	47.2	17.4	82.0	2,060	15.8	10.8	37.4	121

* Refers to the 95% confidence value, calculated as [Average + (2 x Std.Dev.)]

Appendices
(On Compact Disc)

1. *In-Situ* Object Counting System (ISOCS) – Gamma Spectroscopy Data Summaries
2. ASTD Field Lab – Total Mercury and TCLP Mercury Data
3. QA Data – Comparisons with Off-site Lab results