Quality Assurance 9

Quality assurance is an integral part of every activity at Brookhaven National Laboratory (BNL). A comprehensive Quality Assurance/Quality Control (QA/QC) Program is in place to ensure that all environmental monitoring samples are representative and that data are reliable and defensible. The QC in the contract analytical laboratories is maintained through daily instrument calibration, efficiency, and background checks, and testing for precision and accuracy. Data are verified and validated, as required, by project-specific quality objectives before being used to support decision making. The multilayered components of QA monitored at BNL ensure that all analytical data reported for the 2017 Site Environmental Report are reliable and of high quality.

9.1 QUALITY PROGRAM ELEMENTS

As required by DOE Order 458.1, Radiation Protection of the Public and Environment, and DOE Order 436.1, Departmental Sustainability, BNL has established a QA/QC Program to ensure that the accuracy, precision, and reliability of environmental monitoring data are consistent with the requirements of Title 10 of the Code of Federal Regulations, Part 830 10 CFR 830, Subpart A, Quality Assurance Requirements (2000), and DOE Order 414.1D, Quality Assurance. The responsibility for quality at BNL starts with the Laboratory Director, who approves the policies and standards of performance governing work and extends throughout the entire organization. The purpose of the BNL Quality Management (QM) System is to implement QM methodology throughout the various Laboratory management systems and associated processes to do the following:

- Plan and perform operations in a reliable and effective manner to minimize any impact on the environment, safety, security, and health of the staff and public;
- Standardize processes and support continual improvement;
- Enable the delivery of products and services that meet customers' requirements and expectations;
- Support an environment that facilitates scientific and operational excellence.

For environmental monitoring, QA is deployed as an integrated system of management activities. These activities involve planning, implementation, control, reporting, assessment, and continual improvement. QC activities measure each process or service against the QA standards. QA/QC practices and procedures are documented in manuals, plans, and a comprehensive set of standard operating procedures (SOPs) for environmental monitoring (EM-SOPs). Staff members who must follow these procedures are required to document that they have reviewed and understand them.

The ultimate goal of the environmental monitoring and analysis QA/QC program is to ensure that results are representative and defensible, and that data are of the type and quality needed to verify protection of the public, employees, and the environment. Figure 9-1 depicts the flow of the QA/QC elements of BNL's Environmental Monitoring Program and indicates the sections of this chapter that discuss each element in more detail.

Laboratory environmental personnel determine sampling requirements using the EPA Data Quality Objective (DQO) process (EPA 2006) or its equivalent. During this process, the project manager for each environmental program determines the type, amount, and quality of data needed to support decision making, the legal requirements, and stakeholder concerns. An

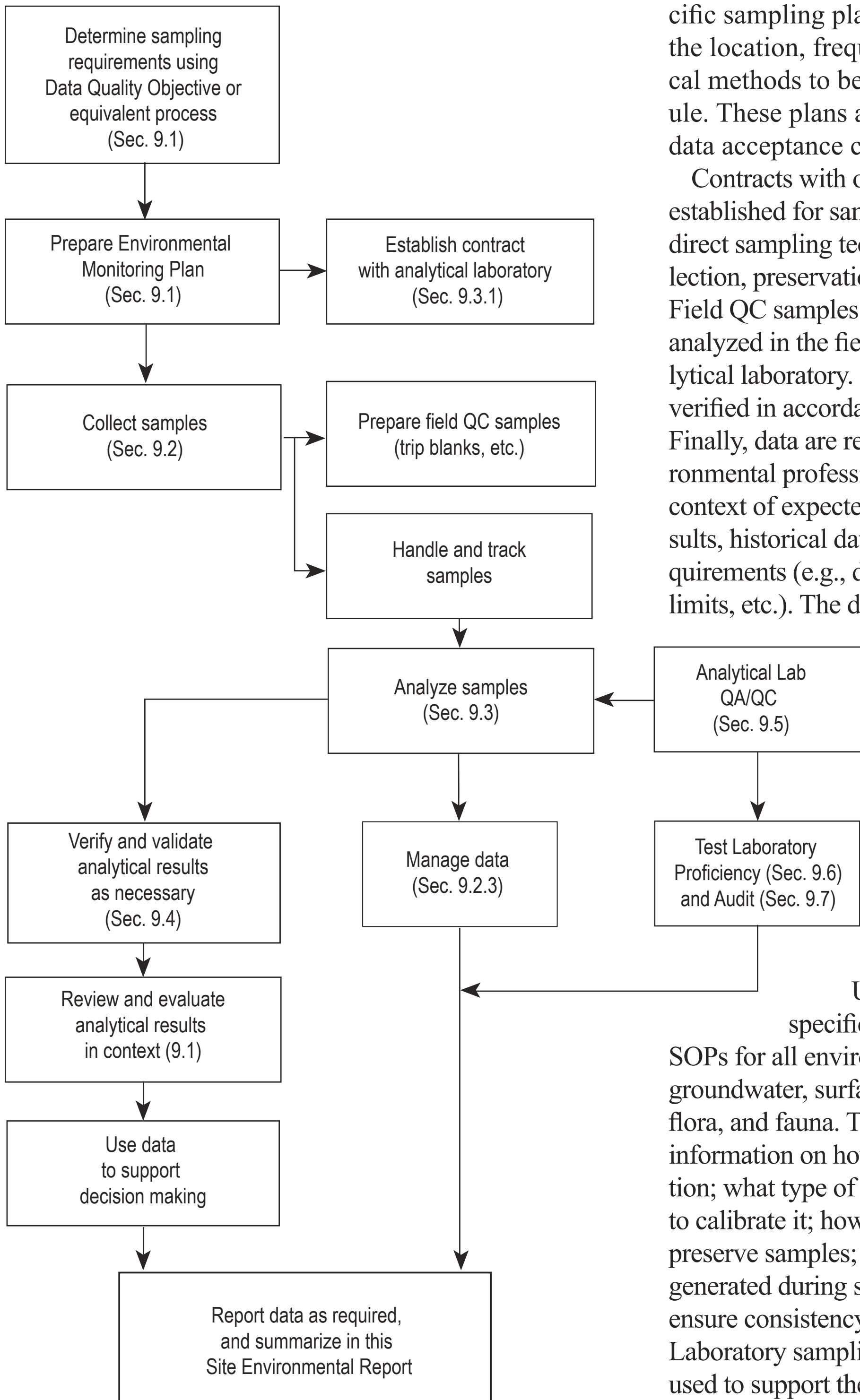


Figure 9-1. Flow of Environmental Monitoring QA/QC Program Elements.

environmental monitoring plan or project-specific sampling plan is then prepared, specifying the location, frequency, type of sample, analytical methods to be used, and a sampling schedule. These plans and the EM-SOPs also specify data acceptance criteria.

Contracts with off-site analytical laboratories are established for sampling analysis. The EM-SOPs direct sampling technicians on proper sample collection, preservation, and handling requirements. Field QC samples are prepared as necessary and analyzed in the field or at a certified contract analytical laboratory. The results are then validated or verified in accordance with published procedures. Finally, data are reviewed and evaluated by environmental professionals and management in the context of expected results, related monitoring results, historical data, and applicable regulatory requirements (e.g., drinking water standards, permit limits, etc.). The data are used to support decision making, reported as required, and summarized in this annual report.

9.2 SAMPLE COLLECTION AND HANDLING

In 2017, environmental monitoring samples were collected, as specified, by EM-SOPs, the BNL Environmental Monitoring Plan Update (BNL 2017), and project-specific work plans. BNL has sampling SOPs for all environmental media, including groundwater, surface water, soil, sediment, air, flora, and fauna. These procedures contain detailed information on how to prepare for sample collection; what type of field equipment to use and how to calibrate it; how to properly collect, handle, and preserve samples; and how to manage any wastes generated during sampling. These procedures also ensure consistency between samples collected by Laboratory sampling personnel and contractors used to support the environmental restoration, compliance, and surveillance programs.

QC checks of sampling processes include the collection of field duplicates, matrix spike samples, field blanks, trip blanks, and equipment blanks.

9.2.1 Field Sample Handling

To ensure the integrity of samples, chain-of-custody (COC) was maintained and documented for all samples collected in 2017. A sample is considered to be in the custody of a person if any or all of the following rules of custody are met: 1) the person has physical possession of the sample, 2) the sample remains in view of the person after being in possession, 3) the sample is placed in a secure location by the custody holder, or 4) the sample is in a designated secure area. These procedures are outlined in EM-SOP 109, "Chain-of-Custody, Storage, Packaging, and Shipment of Samples" (BNL 2015).

9.2.1.1 Custody and Documentation

Field sampling technicians are responsible for the care and custody of samples until they are transferred to a receiving group or contract analytical laboratory. Samples requiring refrigeration are placed immediately into a refrigerator or a cooler with cooling media and are kept under custody rules. The technician signs the COC form when relinquishing custody and contract analytical laboratory personnel sign the COC form when accepting custody.

As required by EM-SOP-201, "Documentation of Field Activities" (BNL 2012a), field sampling technicians are also required to maintain bound, weatherproof field logbooks, which are used to record sample ID numbers, collection times, descriptions, collection methods, and COC numbers. Daily weather conditions, field measurements, and other appropriate site-specific observations also are recorded in the logbooks.

9.2.1.2 Preservation and Shipment

Before sample collection, field sampling technicians prepare all bottle labels and affix them to the appropriate containers, as defined in the QA program plan or applicable EM-SOPs. Appropriate preservatives are added to the containers before or immediately after collection, and samples are refrigerated as necessary. The contract laboratory confirms preservation upon receipt of the samples. BNL is notified as soon as practical if a sample arrives unpreserved or at the wrong temperature. This notification typically occurs on the day or receipt, but for weekend deliveries, the notifications occur Monday morning. If a sample arrives with an incorrect pH, the lab has been instructed to attempt to correct the pH. If the sample matrix does not allow this correction, the analysis is conducted on a priority basis. Sample preservations, including incorrect preservation, is noted on the sign in documentation and included with every data package. If the BNL Project Manager, with the help of a QC chemist and/or radiochemist, determines that an incorrect preservation issue would result in data that does not meet the data quality objectives of the project, the analysis is cancelled prior to BNL receiving any data.

On three occasions during 2017, shipments of samples were delayed due to unforeseen circumstances. This resulted in volatile organic compounds (VOCs) samples arriving significantly above the required temperature. In these instances, the analyses were cancelled and the samples were recollected.

Sample preservation is maintained, as required, throughout shipping. If samples are sent via commercial carrier, a bill-of-lading is used. COC seals are placed on the shipping containers and their intact status upon receipt indicates that custody was maintained during shipment. These procedures are outlined in EM-SOP 109, "Chain-of-Custody, Storage, Packaging, and Shipment of Samples."

9.2.2 Field Quality Control Samples

Field QC samples collected for the environmental monitoring program include equipment blanks, trip blanks, field blanks, field duplicate samples, and matrix spike/matrix spike duplicate samples. The rationale for selecting specific field QC samples, and minimum requirements for their use in the Environmental Monitoring Program, are provided in the BNL EM-SOP 200 series, "Quality Assurance." Equipment blanks and trip blanks were collected for all appropriate media in 2017.

An equipment blank is a volume of solution (in this case, laboratory-grade water) that is used to rinse a sampling tool after decontamination. The rinse water is collected and tested to verify that the sampling tool is not contaminated. Equipment blank samples are collected, as needed, to verify the effectiveness of the decontamination procedures on non-dedicated or reusable sampling equipment.

A trip blank is provided with each shipping container of samples to be analyzed for VOCs. The use of trip blanks provides a way to determine whether contamination of a sample container occurred during shipment from the manufacturer, while the container was in storage, during shipment to a contract analytical laboratory, or during analysis of a sample at a contract analytical laboratory. Trip blanks consist of an aliquot of laboratory-grade water sealed in a sample bottle, usually prepared by the contract analytical laboratory prior to shipping the sample bottles to BNL. If trip blanks are not provided by the contract analytical laboratory, then field sampling technicians prepare trip blanks before they collect the samples. Trip blanks were included with all shipments of aqueous samples for VOC analysis in 2017.

Field blanks are collected to check for cross-contamination that may occur during sample collection. A field blank consists of an aliquot of laboratory-grade water that is poured into a sample container in the field. For the Groundwater Monitoring Program, one field blank is collected for every 20 samples, or one per sampling round, whichever is more frequent. Field blanks are analyzed for the same parameters as groundwater samples. For other programs, the frequency of field blank collection is based on their specific DQOs.

In 2017 (as in other years), the most common contaminants detected in the trip, field, and equipment blanks included trace to low levels of chloroform and methylene chloride. This is believed to be a byproduct of the hydrochloric acid preservative used for the samples. These compounds are commonly detected in blanks and do not pose significant problems with the reliability of the analytical results. Other compounds were also detected such as acetone at low levels. When these contaminants are detected, validation or verification procedures are used, where applicable, to qualify the associated data as "nondetects" (see Section 9.4). The results from blank samples collected during 2017 did not indicate any significant impact on the quality of the results.

Field duplicate samples are analyzed to check the reproducibility of sampling and analytical results, based on EPA Region II guidelines (EPA 2012, 2013). For example, in the Groundwater Monitoring Program, duplicates are collected for five percent of the total number of samples collected for a project per sampling round.

During 2017, a total of 35 duplicate samples were collected for non-radiological analyses and 23 duplicates were collected for radiologic analyses. Not all parameters were analyzed in every duplicate. The parameters in each duplicate were consistent with those required for the specific program the duplicate was monitoring. Of the 2,217 parameters analyzed, only 21 (0.09 percent) of the non-radiologic analyses failed to meet QA criteria. For the radiologic parameters, only three of the 97 parameters (three percent) failed to meet QA criteria. The results are indicative of consistency with the contract analytical laboratories and sampling methods, resulting in valid, reproducible data.

Matrix spike and matrix spike duplicates are used to determine whether the sample matrix (e.g., water, soil, air, vegetation, bone, or oil) adversely affected the sample analysis. A spike is a known amount of analyte added to a sample. Matrix spikes are performed at a rate specified by each environmental program's DQOs. The rate is typically one per 20 samples collected per project. No significant matrix effects were observed in 2017 for routine matrices such as water and soil. Non-routine matrices, such as oil, exhibited the expected matrix issues.

9.2.3 Tracking and Data Management

Most environmental monitoring samples and analytical results were tracked in BNL's Environmental Information Management System (EIMS), a database system used to store, manage, verify, protect, retrieve, and archive BNL's environmental data. A small number of environmental samples that were not tracked in the EIMS were analyzed at a contract analytical laboratory; Chemtex Lab cannot produce the electronic data deliverables needed to enter the data into the EIMS. Tracking is initiated when a sample is recorded on a COC form. Copies of the COC forms and supplemental forms are provided to the project manager or the sample coordinator and forwarded to the data coordinator to be entered into the EIMS. Each contract analytical laboratory also maintains its own internal sample tracking system.

Following sample analysis, the contract analytical laboratory provides the results to the project manager or designee and, when applicable, to the validation subcontractor. Once results of the analyses are entered into the EIMS, reports can be generated by project personnel and Department of Energy (DOE) Brookhaven Site Office staff using a web-based data query tool.

9.3 SAMPLE ANALYSIS

In 2017, environmental samples were analyzed by five contract analytical laboratories, whose selection is discussed in Section 9.3.1. All samples were analyzed according to Environmental Protection Agency (EPA)-approved methods or by standard industry methods, where no EPA methods are available. In addition, field sampling technicians performed field monitoring for parameters such as conductivity, dissolved oxygen, pH, temperature, and turbidity.

9.3.1 Qualifications

BNL used the following contract analytical laboratories for analysis of environmental samples in 2017:

- American Radiation Services (ARS) in Port Allen, Louisiana, for radiological analytes;
- Chemtex Lab in Port Arthur, Texas, for select nonradiological analytes;
- General Engineering Lab (GEL) in Charleston, South Carolina, for radiological and nonradiological analytes;
- PACE Lab in Melville, New York, for nonradiological analytes; and
- Test America (TA), based in St. Louis, Missouri, for radiological and nonradiological analytes.

The process of selecting contract analytical laboratories involves the following factors: 1) their record on performance evaluation tests, 2) their contract with the DOE Integrated Contract Procurement Team, 3) pre-selection bidding, and 4) their adherence to their own QA/QC programs, which must be documented and provided to BNL. Routine QC procedures that laboratories must follow, as discussed in Section 9.5, include daily instrument calibrations, efficiency and background checks, and standard tests for precision and accuracy. All the laboratories contracted by BNL in 2017 were certified by the New York State Department of Health (NYSDOH) for the relevant analytes, where such certification existed. The laboratories also were subject to PE testing and DOE-sponsored audits (see Section 9.7).

9.4 VERIFICATION AND VALIDATION OF ANALYTICAL RESULTS

Environmental monitoring data are subject to data verification and, in certain cases, data validation, when the data quality objectives of the project require this step. For example, groundwater samples undergo data verification, whereas analytical results for specific waste streams undergo a full validation.

The data verification process involves checking for common errors associated with analytical data. The following criteria can cause data to be rejected during the data verification process:

- *Holding time missed* – The analysis is not initiated or the sample is not extracted within the time frame required by EPA or by the contract.
- *Incorrect test method* – The analysis is not performed according to a method required by the contract.
- *Poor recovery* – The compounds or radioisotopes added to the sample before laboratory processing are not recovered at the recovery ratio required by the contract.
- *Insufficient QA/QC data* – Supporting data received from the contract analytical laboratory are insufficient to allow validation of results.
- *Incorrect minimum detection limit (MDL)* – The contract analytical laboratory reports extremely low levels of analytes as “less than minimum detectable,” but the contractually required limit is not used.
- *Invalid chain-of-custody* – There is a failure

to maintain proper custody of samples, as documented on COC forms.

- *Instrument failure* – The instrument does not perform correctly.
- *Preservation requirements not met* – The requirements identified by the specific analytical method are not met or properly documented.
- *Contamination of samples from outside sources* – Possible sources include sampling equipment, personnel, and the contract analytical laboratory.
- *Matrix interference* – Analysis is affected by dissolved inorganic/organic materials in the matrix.

Data validation involves a more extensive process than data verification. Validation includes all the verification checks, as well as checks for less common errors, including instrument calibration that was not conducted as required, internal standard errors, transcription errors, and calculation errors. The amount of data checked varies, depending on the environmental media and on the DQOs for each project. Data for some projects, such as long-term groundwater monitoring, may require only verification. Data from some waste streams receive the more rigorous validation testing, performed on 20 to 100 percent of the analytical results. The results of the verification or validation process are entered into the EIMS. When analyses are determined to be outside of QC parameters, a qualifier is applied to the result stored in the EIMS. Results that have been rejected are qualified with an R. Rejected results are not used in the preparation of this report.

The most common QC issue determined during 2017 was the presence of low-level contamination of trip, field, and method blanks used in VOC analyses. Results for the trip and field blanks are summarized on Table 1. This resulted in minor qualification of sample results. Minor violations of laboratory control sample results are also common. In most cases, the violation does not result in qualified sample results.

9.4.1 Checking Results

Nonradiological data analyzed in 2017 were verified and/or validated when project DQOs required using BNL EM-SOPs and EPA contract laboratory program guidelines (EPA 2012, EPA 2013). Radiological packages were verified and validated using BNL and DOE guidance documents (BNL 2012b). During 2017, the verifications were conducted using a combination of manually checking hard copy data packages and the use of a computer program developed at the Laboratory to verify that the information reported electronically is stored in the EIMS.

9.5 CONTRACT ANALYTICAL LABORATORY QA/QC

In 2017, procedures for calibrating instruments, analyzing samples, and assessing QC were consistent with EPA methodology. QC checks performed included: analyzing blanks and instrument background; using Amersham Radiopharmaceutical Company or National Institute for Standards and Technology (NIST) traceable standards; and analyzing reference standards, spiked samples, and duplicate samples. Analytical laboratory contracts specify analytes, methods, required detection limits, and deliverables, which include standard batch QA/QC performance checks. As part of the laboratory selection process, candidate laboratories are required to provide BNL with copies of their QA/QC manuals and QA program plans.

When discrepancies were found in field sampling designs, documented procedures, COC forms, data analyses, data processing systems, and QA software, or when failures in PE testing occur, nonconformance reports are generated. Following investigation into the root causes, corrective actions are taken and tracked to closure.

9.6 PERFORMANCE OR PROFICIENCY EVALUATIONS

Four of the contract analytical laboratories (ARS, GEL, PACE, and TA) participated in several national and state PE testing programs in 2017. Chemtex Lab did not participate in PE testing because there is no testing program for the specific analytes Chemtex analyzed for BNL (tolytriazole, polypropylene glycol monobutyl ether, and 1,1-hydroxyethylidene diphosphonic acid). Each of the participating laboratories took part in at least one testing program, and several

Table 1. Summary of Detections inTrip and Field Blank Samples.

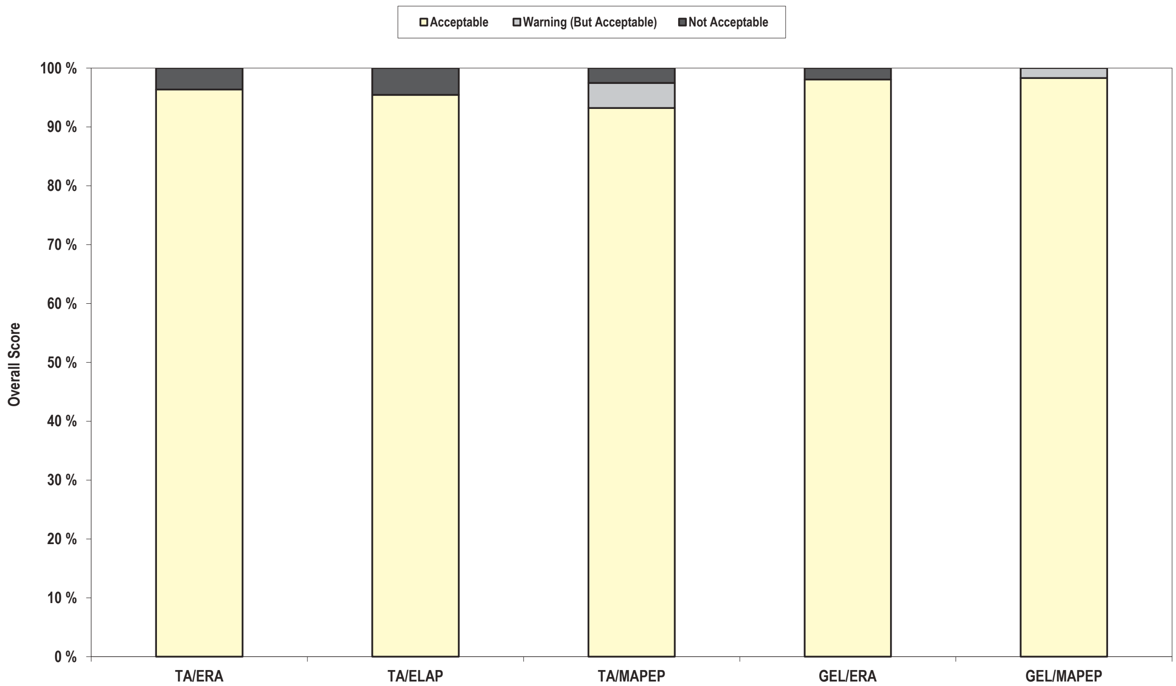
Constituent	Number of Analyses	Number of Detects	Minimum	Maximum	Typical Reporting Limit	Units
Trip Blank Results						
1,1,1-Trichloroethane	85	1	3.2	3.2	0.5	µg/L
1,1,2,2-Tetrachloroethane	85	1	0.33	0.33	0.5	µg/L
1,1-Dichloroethane	85	1	0.14	0.14	0.5	µg/L
1,1-Dichloroethylene	85	2	0.14	1.9	0.5	µg/L
Acetone	1	1	3.6	3.6	10	µg/L
Carbon tetrachloride	85	1	1.5	1.5	0.5	µg/L
Chlorobenzene	85	4	0.16	0.22	0.5	µg/L
Chloroform	85	2	0.1	0.34	0.5	µg/L
Methyl chloride	85	1	0.11	0.11	0.5	µg/L
Methylene chloride	85	43	0.26	12	0.5	µg/L
Tetrachloroethylene	84	2	0.38	40	0.5	µg/L
Trichloroethylene	85	1	1.1	1.1	0.5	µg/L
Field Blank Results						
Organic Compounds						
Acetone	2	1	2.3	2.3	10	µg/L
Chloroform	34	14	0.22	3.17	0.5	µg/L
Methylene chloride	37	2	0.17	0.33	0.5	µg/L
Metals						
Iron	2	1	39	39	30	µg/L
Potassium	2	1	54.9	54.9	50	µg/L
General Chemistry Parameters						
Ammonia (as N)	2	2	0.0249	0.0296	0.017	mg/L
Nitrate	2	2	0.0388	0.0446	0.033	mg/L
Chloride	2	2	0.102	0.107	0.067	mg/L
Total Dissolved Solids	2	2	11.4	27.1	3.4	mg/L

µg/L Micrograms per liter.
mg/L Milligrams per liter.

laboratories participated in multiple programs. Results of the tests provide information on the quality of a laboratory's analytical capabilities. The testing was conducted by Environmental Resource Associates (ERA), the DOE required Mixed Analyte Performance Evaluation Program (MAPEP), Resource Technology Corporation (RTC), Phenova, and the NYSDOH Environmental Laboratory Accreditation Program (ELAP). The results from these tests are summarized in Section 9.6.1.

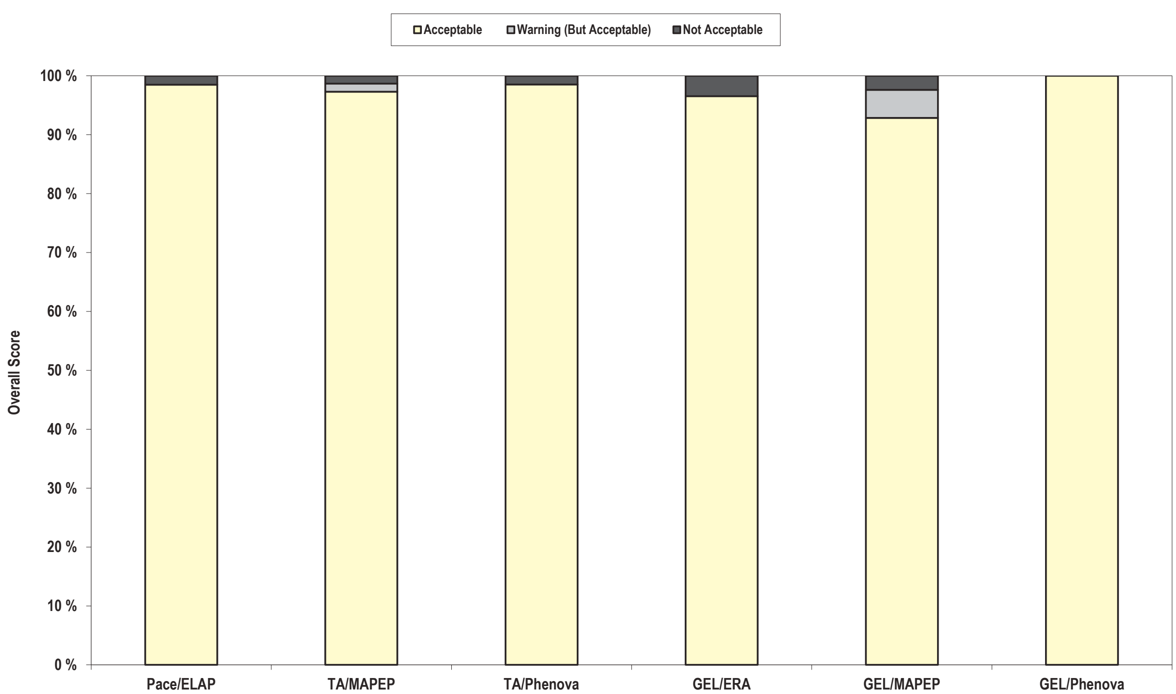
9.6.1 Summary of Test Results

In Figures 9-2 and 9-3, results are plotted as percentage scores that were "Acceptable," "Warning (But Acceptable)," or "Not Acceptable." A Warning (But Acceptable) is considered by the testing organization to be "satisfactory." An "average overall satisfactory" score is the sum of results rated as Acceptable and those rated as Warning (But Acceptable), divided by the total number of results reported. A Not Acceptable rating reflects a result that is greater than three standard deviations from the known



Note that the Acceptable scores and the Warning (But Acceptable) scores combined constitute the "overall satisfactory" category referred to in the text of this chapter.

Figure 9-2. Summary of Scores in the Radiological Proficiency Evaluation Programs.



Note that the Acceptable scores and the Warning (But Acceptable) scores combined constitute the "overall satisfactory" category referred to in the text of this chapter.

Figure 9-3. Summary of Scores in the Nonradiological Proficiency Evaluation Programs.

value—a criterion set by the independent testing organizations.

Figure 9-2 summarizes radiological performance scores in the ERA, MAPEP, and ELAP programs. GEL and TA had average overall satisfactory scores of 99 and 96 percent, respectively. Additional details about the radiological assessments are discussed in Section 9.6.1.1.

Figure 9-3 summarizes the nonradiological performance results of three of the four participating laboratories (GEL, Pace, and TA) in the ERA, MAPEP, Phenova, and ELAP tests. For nonradiological tests, the all three laboratories received overall satisfactory results of 98 percent. Additional details on nonradiological evaluations are discussed in Section 9.6.1.2.

9.6.1.1 Radiological Assessments

GEL and TA participated in the ERA and MAPEP radiological PE studies. Of GEL's radiological test results, 99 percent were in the Acceptable range; and of TA's radiological test results, 98 percent were in the Acceptable range. TA participated in the ELAP evaluations; 95 percent of TA's ELAP tests on radiological samples were in the Acceptable range. The ELAP testing is based on a small sample group (21 tests), while the ERA and MAPEP studies use a much larger sample size (more than 250 tests per year).

9.6.1.2 Nonradiological Assessments

During 2017, PACE participated in the NYSDOH ELAP evaluations of performance on tests of nonpotable water, potable water, and solid wastes. NYSDOH found 98 percent of PACE's nonradiological tests to be in the Acceptable range. GEL participated in the ERA water supply and water pollution studies. ERA found that 96 percent of GEL's tests were in the Acceptable range. TA and GEL participated in the MAPEP water supply and water pollution studies. MAPEP found that 99 percent and 98 percent of TA's and GEL's results were in the Acceptable range. TA and GEL participated in the Phenova Soil/Hazardous Waste and Water Pollution proficiency testing programs. Phenova found that 98 percent of TA's results were in the Acceptable range and 100 percent of GEL's results were in the Acceptable range.

9.7 AUDITS

As part of DOE's Consolidated Audit Program, TA, GEL, and ARS were audited in 2017 (DOE 2017a,b,c). During the audits, errors were categorized into Priority I and Priority II findings. Priority I finding results from a documented deficiency from a requirement that represents a substantial risk and liability to DOE. Priority II findings results from a documented deviation from a requirement Results are summarized on Table 2.

Both TA and ARS had Priority I findings documented in their audits. The TA Priority I finding resulted from the failure to pass two MAPEP studies for strontium-90 in a vegetative matrix. Since BNL did not use TA to analyze strontium-90 in this matrix, the finding does not affect BNL data. The ARS Priority I finding was for the failure of two MAPEP studies for americium-241 in a soil matrix. Since BNL only uses ARS for the analysis of tritium in groundwater, this finding did not affect BNL data.

With respect to the Priority II findings, many of these findings dealt with inaccuracies in SOPs used by the contractor laboratories. In all instances concerning parameters required by BNL, these findings indicated that the analyses were performed correctly, but the SOP needed to be updated to match the actual work practices. TA had one Priority II finding for incorrectly calibration pH analyses. The pH equipment was not calibrated correctly for pH values above seven. Since BNL does not use any pH results from TA for reporting purposes, this did not affect the use of data for BNL. Since the audit, TA has corrected its calibration procedure to correctly calibrate pH meters. The Audit for ARS did find a significant number of Priority II findings that would affect analytical results for nonradionuclide and radionuclide analyses. However, none of these issues affect the analysis tritium in a water matrix. As previously stated, BNL only uses ARS for the analysis of tritium. The tritium data from ARS undergoes 100 percent verification at BNL and the data also undergoes a comparison to historic results. Therefore, these findings do not affect the use of BNL data.

Based on the audits, the analytical laboratories met BNL criteria for Acceptable status.

Table 2. Summary Results of 2017 DOCAP Audits

Laboratory	Finding Priority	Area of Concentration	Number of Findings
Test America, Earth City Missouri			
	I	Radiochemistry	1
	II	Quality Assurance	1
	II	Organic Analyses	2
	II	Inorganic Analyses and Wet Chemistry	4
	II	Radiochemistry	3
	II	Materials Management	4
GEL Laboratories			
	II	Quality Assurance	4
	II	Radiochemistry	1
ARS International			
	I	Radiochemistry	1
	II	Quality Assurance	1
	II	Inorganic Analyses and Wet Chemistry	6
	II	Laboratory Information Management Systems	1
	II	Materials Management	2

9.8 CONCLUSION

The data validations, data verifications, and DQO checks conducted on analytical results at BNL are designed to eliminate any data that fails to meet the DQO of each project. The results of the independent PE assessments and audits of contractor laboratories summarized in this report are also used to assess the quality of the results. The data used in Site Environmental Report are of acceptable quality.

REFERENCES AND BIBLIOGRAPHY

10 CFR 830 Subpart A. U.S. Department of Energy. Quality Assurance Requirements. U.S. Code of Federal Regulations. 2000.

BNL 2012a. EM-SOP-201 Documentation of Field Activities. Brookhaven National Laboratory, Upton, NY.

BNL. 2012b. EM-SOP 209. Radiochemical Data Validation. Brookhaven National Laboratory, Upton, NY.

BNL. 2015. EM-SOP 109. Chain-of-Custody, Storage, Packaging, and Shipment of Samples. Brookhaven National Laboratory. Upton, NY.

BNL. 2017. Brookhaven National Laboratory Environmental Monitoring Plan Update. Brookhaven National Laboratory, Upton, NY. January 2015.

DOE Order 414.1D. Quality Assurance. U.S. Department of Energy. Washington, DC. August 16, 2011.

DOE Order 436.1. Departmental Sustainability. U.S. Department of Energy, Washington, DC. May 2, 2011.

DOE Order 458.1. Radiation Protection of the Public and Environment. U.S. Department of Energy, Washington, DC. February 2011.

DOE 2016a. Continuing Qualification Audit of Test America, Inc. Earth City, Mo. July 2017.

DOE 2016b. Continuing Qualification Audit of General Engineering Laboratories, Inc. Charleston, South Carolina. June 2017.

DOE 2017c. Continuing Qualification Audit of American Radiation Services, Inc. Port Allen, La. June 2017.

EPA 2006. Guidance on Systematic Planning Using Data Quality Objectives Process (QA/G-4). U.S. Environmental Protection Agency, Washington, DC.

EPA 2012. ICP-AES Data Validation. EPA Region-II SOP HW-2a. Rev. 15 U.S. Environmental Protection Agency, Washington, DC. December 2012.

EPA 2013. Low/Medium Volatile Data Validation. EPA Region-II SOP HW-33. U.S. Environmental Protection Agency, Washington, DC. Revision 3, March 2013.