Radiological Environmental Monitoring Program

ACADs (08-006) Covered

1.1.8.3.2 1.2.1.9 3.1.1.7 3.1.1.14 3.2.4.1 3.2.4.4 3.3.10.8 3.3.15.1

3.3.15.2 3.3.15.5 4.2.7.26

Keywords

Direct radiation levels, gross beta activity, Cs-137, primary pathways, critical pathways, operating report, dose patterns, weather patterns, population distribution, land use.

Description

This instructor handout provides notes for accompanying Powerpoint presentation, as well as handouts for students.

Supporting Material

Power Point slide show Radiological Environmental Monitoring Program.ppt.

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I. PROGRAM: Radiological Protection Technician Initial Training

II. COURSE: Fundamentals Training

III. TITLE: Radiological Environmental Monitoring Program

IV. LENGTH OF LESSON: 3 hours

V. TRAINING OBJECTIVES

A. Terminal Objective

Upon completion of this module, participants will demonstrate knowledge of radiological environmental monitoring as it pertains to Radiological Control by achieving a score of $\geq$ 80% on a written examination.

B. Enabling Objectives

Standards and conditions apply to all enabling objectives. They include under the examination ground rules, without the use of training materials or outside assistance and utilizing information presented in this lesson plan. In order to successfully achieve the terminal objective each participant will:

1. State the objectives of the Radiological Environmental Monitoring Program (REMP).

2. Identify the TVA document that describes the requirements of the REMP.

3. List the two primary pathways by which radioactivity can move through the environment to humans and identify the means of exposure for the pathways.

4. Name four parameters of the critical pathway analysis and identify the components used for making dose projections.

5. Tell why the preoperational monitoring program is important.

6. Identify the equipment used to measure direct radiation levels in the environment.

7. Define local, perimeter, and remote monitoring stations and list their relative distances from the plant.

8. Identify the five categories of food products typically sampled in the REMP.

9. Describe the sampling technique used to sample surface water onsite well water and identify the sampling times for each.

10. Identify the two categories of fish sampled in the REMP.

11. Name at least three types of quality control samples used by the laboratory to verify the performance of different portions of the analytical process.

12. Identify the purpose of the land use survey, tell how it is conducted, how it is regulated, and how the data are used.

13. Identify the predominant fission or activation product typically found in the environment.

14. Identify the report which provides the results from the REMP to the NRC and tell how often and by what organization the reports are submitted.

VI. <u>TRAINING AIDS</u>

A. Whiteboard with markers.
B. Projector and Screen
C. Power Point Presentation of Key Points
D. Laser Pointer (optional)

VII. <u>TRAINING MATERIALS</u>:

A. Appendices

1. Handouts

   a. HO-01 – Enabling Objectives
   b. HO-02 – Pathways for Exposure
   c. HO-03 – Direct Radiation Levels, Browns Ferry Nuclear Plant
   d. HO-04 – Direct Radiation Levels, Sequoyah Nuclear Plant, Four Quarter Moving Average
   e. HO-05 – Annual Average Gross Beta Activity in Air Filters – BFN
   f. HO-06 – Annual Average Cs-137 Activity in Soil – BFN
   g. HO-07 – Annual Average Cs-137 Activity in Fish Flesh, Game Fish – BFN
   h. HO-08 – Radioactivity in Soil, BFN 2003

B. Attachments

1. Power Point slide show Radiological Environmental Monitoring Program.ppt.

   a. TP-01 – Radiological Environmental Monitoring Program (REMP)
   b. TP-02 – Enabling Objectives

c. TP-03 – Enabling Objectives
d. TP-04 – REMP Objectives
e. TP-05 – REMP Bases
f. TP-06 – REMP Descriptions
g. TP-07 – Critical Pathways
h. TP-08 – Airborne Pathways
i. TP-09 – Waterborne Pathways
j. TP-10 – Pathways for Exposure
k. TP-11 – Parameters for a Critical Pathway Analysis
l. TP-12 – Air-Related Pathways
m. TP-13 – Ranking Air-Related Pathways
n. TP-14 – Dose Distribution – SQN
o. TP-15 – Dose Distribution Times Population – SQN
p. TP-16 – Water-Related Pathways
q. TP-17 – Ranking Water-Related Pathways
r. TP-18 – Preoperational Monitoring Program
s. TP-19 – Background Fluctuations
t. TP-20 – Gross Beta in Air
u. TP-21 – Thermoluminescent Dosimeter
v. TP-22 – Direct Radiation Monitoring
w. TP-23 – Atmospheric Monitoring Stations
x. TP-24 – Air Monitor Station
y. TP-25 – Original Air Filter
z. TP-26 – Air Flow Measuring Equipment
aa. TP-27 – Present Air Sample Collector
bb. TP-28 – Air Filter Assembly
cc. TP-29 – Rainwater Collection Tray
dd. TP-30 – One Type of Soil Sampler
ee. TP-31 – Typical Food Products – 1
ff. TP-32 - Typical Food Products – 2
gg. TP-33 – Water Sampling Station
hh. TP-34 – Fish Samples
ii. TP-35 – Electrofishing
jj. TP-36 – Sample Analyses
kk. TP-37 – Liquid Scintillation Counting
ll. TP-38 – Sample Analyses
mm. TP-39 – Marinelli Beakers
nn. TP-40 – Counting Solid Samples
oo. TP-41 – Quality Control Program
pp. TP-42 – Quality Control Samples
qq. TP-43 – Land Use Survey
rr. TP-44 – Direct Radiation Levels, Browns Ferry Nuclear Plant
ss. TP-45 – Direct Radiation Levels, Sequoyah Nuclear Plant, Four Quarter Moving Average
tt. TP-46 – Annual Average Gross Beta Activity in Air Filters – BFN
uu. TP-47 – Cs-137 in Soil

vv. TP-48 – Annual Average Cs-137 Activity in Fish Flesh, Game Fish - BFN
ww. TP-49 – Annual Radiological Environmental Operating Report
xx. TP-50 - Annual Radiological Environmental Operating Report
yy. TP-51 – Summary – Analysis
zz. TP-52 – Summary – REMP

2. OE12361, Inadequate Seal on Charcoal Cartridge Filter, June 13, 2001. At web site: C:\WINDOWS\Temp\InpoReader531669.htm

VIII. REFERENCES:

A. ACAD 93-008, "Guidelines for Training and Qualification of Radiological Protection Technicians," National Academy For Nuclear Training, August 1993.

B. Code of Federal Regulations, Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Government Printing Office, Washington, 2003.

C. NRC Generic Letter 89-01, NUREG-1301 - "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors" (Generic Letter 89-01, Supplement No. 1)

D. Technical Specifications for Browns Ferry, Sequoyah, and Watts Bar.

E. Browns Ferry Nuclear Plant Final Safety Analysis Report, Amendment 20.

F. Sequoyah Nuclear Plant Final Safety Analysis Report, Amendment 17.

G. Watts Bar Nuclear Plant Final Safety Analysis Report, Amendment 4

H. Browns Ferry Nuclear Plant Offsite Dose Calculation Manual, Revision 16, 3/6/04.

I. Sequoyah Nuclear Plant Offsite Dose Calculation Manual, Revision 47, 1/15/03.

J. Watts Bar Nuclear Plant Offsite Dose Calculation Manual, Revision 11, 10/19/03.

K. Annual Radiological Environmental Operating Report, Browns Ferry Nuclear Plant, 2003.

L. Annual Radiological Environmental Operating Report, Sequoyah Nuclear Plant, 2003.

M. http://analytical.chem.wisc.edu/524class/Folders/Lois/overview.htm

N. http://laxmi.nuc.ucla.edu:8248/M248_99/autorad/Scint/scint_sum.html

IX INTRODUCTION:

Nuclear power plants include many complex systems to control the nuclear fission process and to safeguard against the possibility of reactor malfunction. The nuclear reactions produce radionuclides commonly referred to as fission and activation products. Very small amounts of these fission and activation products are released into the plant systems. This radioactive material can be transported throughout plant systems and some of it released to the environment.

The pathways through which radioactivity is released are monitored. Liquid and gaseous effluent monitors record the radiation levels for each release. These monitors provide alarm mechanisms to prompt termination of any release above limits.

Releases are monitored at the onsite points of release and through the environmental monitoring program which measures the environmental radiation in areas around the plant. In this way, not only is the release of radioactive materials from the plant tightly controlled, but measurements are made in surrounding areas to verify that the population is not being exposed to significant levels of radiation or radioactive materials.

X. LESSON PLAN | INSTRUCTOR NOTES

A. Radiological Environmental Monitoring Program Development — **(TP-1, 2, & 3) Handout # 01**

1. The Radiological Environmental Monitoring Program (REMP) is designed to sample the pathways between the plant and the people in the immediate vicinity of the plant. Sample types are chosen so that the potential for detection of radioactivity in the environment will be maximized.

2. ***Objectives of the REMP*** — **TP-04, Objective 1**

   a. Determine the effect of plant operations on people.

   b. Determine trends of radioactivity in the environment.

   c. Provide assurance to the general public.

   d. Meet regulatory requirements.

   e. Provide for monitoring during emergencies.

3. Bases for the program

   a. 10 CFR 50, Appendix A, Criterion 64, "Monitoring Radioactivity Releases. Means shall be provided for monitoring the reactor containment atmosphere, spaces containing components for recirculation of loss-of-coolant accident fluids, effluent discharge paths, ***and the plant environs*** for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents." — **TP-05**

   b. 10 CFR 50, Appendix I, Section B requires that appropriate surveillance and monitoring programs be established to:

      (1) Provide data on measurable levels of radiation and radioactive materials in the environment to evaluate the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure; and

      (2) Identify changes in the use of unrestricted areas (e.g. for agricultural purposes) to permit modifications in monitoring programs for

evaluating doses to individuals from principal pathways of exposure.

c. NRC Generic Letter 89-01 notes that programmatic controls for the radiological environmental monitoring program can be implemented in the Administrative Controls section of the Technical Specifications (TS) to satisfy the regulatory requirements and that the procedural details of the program can be incorporated into the Offsite Dose Calculation Manual (ODCM).

d. Section 2.6 of each plant's Final Safety Analysis Report provides a general description of the preoperational and operational Radiological Environmental Monitoring Programs (REMPs). **TP-06**

e. The site-specific ***Offsite Dose Calculation Manual (ODCM)*** for each plant describes the minimum requirements and the operational requirements for the REMP for each respective site. **Objective 2**

Emphasize

4. Program Development

a. Critical Pathways

The first step in the development of an REMP is the conduct of a critical pathway analysis. **TP-07**

There are two primary pathways by which radioactivity can move through the environment to humans:

(1) Air **Objective 3**

(a) Direct (Airborne Pathway) – Direct radiation and inhalation/ingestion of radioactive materials. **TP-08**

(b) Indirect (Ground or Terrestrial Pathway) – Radioactive materials deposited on the ground or plants and subsequently ingested by animals or humans.

(2) Water — **TP-09**

(a) Ingestion of water.

(b) Ingestion of fish or other aquatic plants or animals. — **TP-10**

Handout # 02

(c) Direct exposure at the shoreline.

b. Critical Pathway Analysis

In performing a critical pathway analysis for TVA's nuclear facilities, the first step was the identification of potential pathways. This determination was made after reviewing appropriate basis documents, such as NRC Generic Letter 89-01 or preceding documents and the plant FSAR.

The first parameter in the critical pathway analysis is the ***dose projection*** which is based on the amount of radioactive materials released from the plant. The doses may be based on the *design basis release values* or *measured release figures*. Other parameters considered in performing the analysis include ***weather patterns, population distribution,*** and ***land use***. — **TP-11** **Objective 4**

Emphasize the dose bases.

(1) Air-Related Pathways

(a) TP-12 shows the dose levels calculated for air, milk, and vegetable pathways for Browns Ferry. Similar calculations were made for Sequoyah and Watts Bar, with the range of doses being similar to those calculated for BFN. — **TP-12**

(b) Note that for many of the pathways, the calculated dose is significantly lower than the laboratory lower limit of detection (LLD). Consequently, many of the materials released from the plants are at such low levels that they cannot be measured by routine measurement techniques.

Instructor note: Note an example, such as a calculated concentration of 0.05 pCi/l of I-131 in milk with an LLD of 0.5 pCi/l.

(c) The next step involves ranking the materials according to the calculated dose, with each successive ranking level being an order of magnitude (1/10) lower than the preceding level.

Instructor note: **TP-13**

1) Note that if the most conservative assumptions are made regarding the presence of milk-producing animals in the vicinity (i.e.- a cow located at the site boundary), the calculated dose would be on the order of 1-10 mRem/yr, but for the actual situation where the nearest milk-producing animal is 3-10 miles from the site boundary, the calculated dose is two orders of magnitude less than that, or 0.09 mRem/yr.

2) Since noble gases are typically inert, they cannot be separated from the air for measurement. Doses from noble gases are included in the direct radiation levels measured by environmental TLDs.

3) This analysis indicates that the pathways most likely to produce higher doses to off-site personnel are vegetables (vegetation) and milk, with direct radiation and inhalation of air being the next most important pathways.

4) TP-14 shows how this information was used to determine the most important

Instructor note: **TP-14**

areas for locating atmospheric monitors at SQN. By ranking each sector around the plant by the percentage of the total dose estimated for the sector, we can identify the sectors where the higher doses are anticipated.

This transparency also shows the sectors where atmospheric monitors are located. Local Monitors (LM) are located within 3 miles of the site boundary, Perimeter Monitors (PM) are located between 3 and 10 miles from the plant, and Remote Monitors (RM) are located greater than 15 miles from the site.

However, this can be misleading since in some cases the sector with the highest projected dose may be over the river where few people could be exposed. To compensate for this, a population-weighted dose was calculated for the same site. The results are shown in TP-15.

TP-15

5) By comparing the two rankings of the projected doses, the most important areas for locating atmospheric monitoring stations can be identified.

(d) Additional factors considered in the selection of sampling locations include land use, the location of dairy animals, and the location of local gardens in the area.

(2) Water-Related Pathways

A similar technique is used to evaluate the water-related pathway. **TP-16**

(a) TP-16 shows the doses calculated for the water-borne pathways. Note again that many of the projected doses are orders of magnitude below the LLD.

(b) The ranking of the water-related doses is shown in TP-17. Fish and water ingestion represent the most likely pathways for exposure to water-borne radionuclides. **TP-17**

(c) The analysis indicates that the ingestion of water represents the lowest expected dose, however, additional factors must be considered when selecting sampling media. For example, since drinking water is taken from the river, prudence dictates that the water medium be sampled. Similarly, in our analysis of the air pathway, the city of Chattanooga is not a sector with a high predicted dose, but because of the large population potentially exposed in the event of an accident, a monitor was placed in the Chattanooga area.

(d) Other media are also sampled. Sediment has been shown to be one of the first indicators of the buildup of released radioactivity in the environment. Although stream sediment is not likely to present a significant dose pathway, sediment along the shoreline in the area of recreational areas has the potential to be a significant pathway for exposure, therefore, shoreline sediment is included in the monitoring program.

(e) In addition to the dose evaluations, water use information and the availability of media such as fish and sediment were considered in the selection of water-related sampling media and sites.

B. Radiological Environmental Monitoring Program Implementation

Most of the radiation and radioactivity generated in a nuclear power reactor is contained within the reactor itself or one of the other plant systems. Plant effluent monitors are designed to detect the small amount released to the environment. Environmental monitoring is a final verification that the systems are performing as planned.

1. To determine the amount of radioactivity in the environment prior to the operation of a plant, a preoperational radiological environmental monitoring program was operated for at least two, and typically four to five years before each plant began operation. Sampling and analyses conducted during the preoperational phase have provided data that can be used to establish normal background levels for various radionuclides in the environment. **TP-18**

   The preoperational monitoring program is a very important part of the overall program. During the 1950, 60s, and 70s, atmospheric nuclear weapons testing released radioactive materials to the environment causing fluctuations in background radiation levels. Most of these radioactive materials are the same type as those produced in nuclear power reactors. These fluctuations may be: **TP-19**

   a. Seasonal fluctuations,
   b. Yearly fluctuations,
   c. Random fluctuations.

Preoperational knowledge of radionuclide patterns in the environment permits a determination, through comparison and trending analyses, of whether the operation of the plants has impacted the environment and thus the surrounding population. The preoperational monitoring program can ***establish background levels*** of radiation and radioactivity and can help to ***identify fluctuations*** in the data.

Objective 5

However, this data by itself is not sufficient to make that determination in all cases. TP-20 is a plot of the gross beta activity in air filters from BFN from 1969-1973. Note that in every year through 1972, levels peaked in summer and reached a low in the winter. This pattern did not occur in 1973 but resumed in subsequent years. If 1973 were used for background data, one could come to the erroneous conclusion that the levels experienced in 1974 resulted from plant operations.

TP-20

Ask what types of fluctuations are demonstrated here.

(Seasonal and Yearly)

This demonstrates the importance of including the use of data from control stations. Results of the analysis of environmental samples taken at control stations (far from the plant) are compared with those from indicator stations (near the plant) to establish the extent of plant influence.

2. Direct Radiation Monitoring

   a. Direct radiation levels are measured at a number of stations around the plant site. These measurements include contributions from cosmic radiation, radioactivity in the ground, fallout from atmospheric nuclear weapons tests conducted in the past, and from radioactivity that may be present as a result of plant operations. Because of relatively large variations in background radiation as compared to the small levels from the plants, contributions from the plants are difficult to distinguish.

b. Direct radiation measurements are made with ***thermoluminescent dosimeters (TLDs)***. TVA uses the Panasonic Model UD-814 dosimeter for measuring environmental radiation levels. These dosimeters are similar to the ones used for personnel dosimetry except they have one lithium borate and three calcium sulfate phosphors. The calcium sulfate phosphors are shielded by approximately 1000 mg/cm^2 plastic and lead to compensate for the over-response of the detector to low energy radiation.

TP-21 **Objective 6**

Ask if anyone knows the composition of the phosphors in the personnel dosimeters.

(Two lithium borate and two calcium sulfate)

c. TLDs are placed approximately 1 meter above the ground, with two or more TLDs at each monitoring location. Monitoring points for TLDs are located in each of the sixteen compass sectors surrounding the site. One monitoring point is located in each sector near the site boundary and a second monitoring point is located at a distance of approximately five miles in each sector. Additional locations are distributed throughout the sectors at distances between 10 and 35 miles.

TP-22

d. The TLDs are exchanged every 3 months and read with a Panasonic Model UD-710A automatic reader interfaced with a computer system for analysis of the data. Since the calcium sulfate phosphor is much more sensitive than the lithium borate, the measured exposure is taken as the median of the results obtained from the calcium sulfate phosphors in all detectors from a monitoring location.

3. Atmospheric Monitoring

TP-23

a. The atmospheric monitoring network is divided into three groups identified as ***local, perimeter***, and ***remote***.

(1) Four to six ***local*** air monitoring stations (LM) are located on or adjacent to the site boundary in the general direction of greatest wind frequency.

Objective 7

(2) Three to four ***perimeter*** air monitoring stations (PM) are located in communities about 5-10 miles from the plants

(3) Two to four ***remote*** monitors used as controls (RM) are located at distances greater than 10

miles from the plant in areas of lower wind frequency.

The sampling equipment is mounted in a railroad type shelter.

TP-24

b. Initially, air particulate samples were collected on a 4 X 4 inch glass fiber filter mounted around a GM detector. Radiation levels measured on the filter were telemetered into the control room. A subsequent evaluation of the system determined that the telemetered data was primarily radioactivity from radon daughters and that the usefulness of the system was questionable.
As a result, the system was modified as described below.

TP-25

c. Air particulates are collected by continuously sampling air at a flow rate of approximately 2 cubic feet per minute (CFM) through a 2-inch glass fiber filter.

(1) The sampling system consists of a pump, a magnehelic gauge for measuring the drop in pressure across the system, and a dry gas meter This allows an accurate determination of the volume of air passing through the filter.

TP-26

(2) The filter is contained in a sampling head mounted on the outside of a metal building. The filter is replaced weekly and each filter is analyzed for gross beta activity about 3 days after collection.

TP-27 & 28

Ask why the 3-day delay before analyzing the air filters.

Every 4 weeks, composites of the filters from each location are analyzed by gamma spectroscopy.

(To allow time for the radon daughters to decay).

d. Gaseous radioiodine is collected using a commercially available cartridge containing TEDA-impregnated charcoal. This system is designed to collect iodine in both the elemental form and as organic compounds.

(1) The cartridge is located in the same sampling head as the air particulate filter and is downstream of the particulate filter.

TP-28
Note the charcoal cartridge in the assembly.

(2) The cartridge samples the same volume of air as the particulate filter and is changed at the same time the particulate filter is changed.

(3) Each cartridge is analyzed for I-131 by gamma spectroscopy analysis.

e. Rainwater is sampled by use of a collection tray attached to the monitor building. As water drains from the tray, it is collected in one of two 5-gallon jugs inside the monitor building.

TP-29

(1) A 1-gallon sample is removed from the collection containers every 4 weeks and the remainder of the water discarded.

(2) Rainwater samples are analyzed only if the air particulate samples indicate the presence of elevated activity levels or if fallout is expected.

4. Terrestrial Monitoring

a. Terrestrial monitoring is accomplished by collecting samples of environmental media that may transport radioactive material from the atmosphere to humans.

b. Milk samples must be collected every two weeks from dairy farms or individuals milking animals within 3 miles from the plant or out to 10 miles from the plant where doses are calculated to be greater than 1 mrem/yr.

Because of the small number of dairy farms or individuals milking animals in the vicinity of the plants, samples are usually collected from all locations producing milk within about 3 miles from the plants, or if none within 3 miles, from the first location within about 5 miles from the plants.

(1) Samples are also collected from control stations between 10 and 30 miles from the plants.

(2) A specific analysis for I-131 and a gamma spectral analysis are performed on each sample. In addition, the analysis for Sr-89,90 is performed at least annually and in some cases quarterly.

c. Soil samples are collected annually from the air monitoring locations

(1) Samples are collected with either a "cookie cutter" or an auger type sampler. **TP-30**

(2) After drying and grinding, the samples are analyzed by gamma spectroscopy. When the gamma analysis is completed, the sample is ashed and analyzed for Sr-89,90.

d. Samples representative of food crops raised in the area near the plants are obtained from individual gardens owners, corner markets, or cooperatives.

(1) Typical food products include: **TP-31** **Objective 8**

(a) ***Fresh leafy vegetables***
1) Lettuce
2) Cabbage
3) Greens

(b) ***Other vegetables***
1) Tomatoes
2) Green Beans
3) Corn

(c) ***Tubers*** — **TP-32**
1) Potatoes
2) Turnips

(d) ***Fruits***
1) Apples
2) Peaches

(e) ***Meat/Poultry***
1) Beef
2) Chicken

(2) The edible portion of each sample is analyzed by gamma spectroscopy.

5. Liquid Pathway Monitoring

Potential exposures from the liquid pathway can occur from drinking water, eating fish or other aquatic animals, and from direct radiation exposure to radioactive materials deposited in the river sediment along the shoreline.

a. Samples of surface water are collected from the Tennessee River using ***automatic sampling systems*** from at least one downstream and one upstream station. — **TP-33** **Objective 9**

(1) A timer turns on the system at least once every two hours. The line is flushed and a sample collected into a collection container.

(2) A 1-gallon sample is removed from the container every 4 weeks and the remaining water in the jug is discarded.

(3) The 4-week composite sample is analyzed by gamma spectroscopy and for gross beta activity. A quarterly composite sample is analyzed for tritium.

b. Samples are also collected by an automatic water sampler at the first downstream drinking water intake.

(1) These samples are collected at the intake for the water plant and are raw untreated water.

(2) Water collected from drinking water supplies is collected in the same manner as the surface water

samples.

(3) The monthly samples are analyzed by gamma spectroscopy and for gross beta activity. A quarterly composite is analyzed for tritium.

(4) At other downstream locations, grab samples are collected from drinking water systems which use the Tennessee River as their source. These samples are analyzed in the same manner as the other potable water samples.

(5) Since the drinking water sample is taken as raw untreated water, the upstream control surface water sample is considered as the control for downstream drinking water samples.

c. One groundwater well onsite is equipped with an automatic water sampler.

(1) A timer turns on the system at least ***once every 24-hours***. The line is flushed and a 400 ml sample is deposited into a collection container.

(2) A grab water sample is also collected from a private well in an area unaffected by the plant.

(3) Samples from the wells are collected every 4 weeks and analyzed by gamma spectroscopy.

(4) A quarterly composite sample is analyzed for tritium.

d. Samples of ***commercial*** and ***game*** fish species are collected semiannually from each of two reservoirs; the reservoir on which the plant is located and the upstream reservoir. **TP-34** **Objective 10**

(1) ***Commercial*** species include such fish as catfish and smallmouth buffalo.

(2) ***Game*** species include bass and crappie.

(3) Samples are collected using a combination of netting techniques and electrofishing. **TP-35**

(4) The fish are filleted to provide the edible portion for analysis.

(5) After drying and grinding, the samples are analyzed by gamma spectroscopy.

e. Samples of sediment from shoreline recreational areas are collected semiannually.

(1) Samples are collected at the normal water level shoreline.

(2) After drying and grinding, the samples are analyzed by gamma spectroscopy.

6. Sample Analysis Techniques

Analyses of environmental samples are performed at the Western Area Radiological Laboratory facility in Muscle Shoals, Alabama. All analysis procedures are based on accepted methods. A summary of the analysis techniques follows.

a. Gross beta measurements are made with an automatic low background beta counting system. Normal counting times are 50 minutes. **TP-36**

(1) Water samples are prepared by evaporating 500 ml of sample to near dryness, transferring the remainder to a stainless steel planchet and completing the evaporation process.

(2) Approximately 2-inch diameter portions of air particulate filters are counted directly in a shallow planchet.

b. The specific analysis of I-131 in milk or vegetation samples is performed by first isolating and purifying the iodine by radiochemical separation on an ion exchange column and then counting the final precipitate on a beta-gamma coincidence counting system.

(1) In a beta-gamma coincidence counting system, an event is "counted" only when a beta particle and a gamma ray are detected at precisely the same time.

(2) With this system background counts are virtually eliminated and extremely low levels of detection can be achieved.

(3) The normal count time for these samples is 50 minutes.

c. Chemical separations are also required to analyze samples for Sr-89, 90 content. Strontium in the sample is concentrated by the use of ion exchange separation techniques.

(1) The precipitate containing the strontium is initially counted on a low background beta counter.

(2) The sample is counted a second time after a 7-day in growth period for the Y-90.

(3) Using a mathematical equation comparing the two counts, the concentrations of the Sr-89 and Sr-90 can be determined.

d. Tritium concentrations in water samples are determined by first distilling a portion of the sample and then counting by liquid scintillation.

(1) Liquid scintillation counting is a process commonly used to detect radioisotopes that emit low energy β-particles.

(2) A sample with an unknown amount of a radioisotope is placed into an organic or aqueous solution. This solution, commonly called the **TP-37**

"counting cocktail" causes the radioisotope to emit small flashes of light. These flashes are detected and converted to amplified electrical pulses by a photomultiplier tube.

(3) Liquid scintillation counters can distinguish between different isotopes and different energy types emitted by an isotope.

(4) In general, Liquid Scintillation Counters carry out the following functions:

(a) Sense light flashes from the radioisotope and converts this energy to voltages that are proportional to the intensity of the light flash.

(b) Sort through these voltages and put them into energy ranges.

(c) Count the number of voltages in each energy category.

e. Gamma analyses are performed in various counting geometries depending on the sample type and volume. **TP-38**

(1) Examples of some of the counting geometries include:

(a) Water samples in a marinelli beaker. **TP-39**

(b) Solid samples like soil or fish in a "cottage cheese" type container. **TP-40**

(c) Food products can be counted in either a marinelli beaker or a "cottage cheese" type container.

(2) All gamma counts are obtained with germanium detectors interfaces with a computer based multichannel analyzer system.

(3) Spectral data reduction is performed by the computer program HYPERMET.

f. The charcoal cartridges used to sample gaseous radioiodine are analyzed by gamma spectroscopy using a high resolution spectroscopy system with germanium detectors.

Review OE12361, Inadequate Seal on Charcoal Cartridge Filter, Attachment 2.

7. Sample Collection

a. The majority of the samples are collected by ERM&I personnel. Some samples, like fish and other aquatic samples, are collected by other organizations on a sub-contract type arrangement under the direction of ERM&I

b. The schedule for the collection of all samples has been entered into a computer program. Each week, ERM&I personnel run a program that produces a list of all samples scheduled for collection in the coming week.

c. The sample schedule run also prints out a label for each sample. As each sample is collected, the appropriate label is attached to the sample. This helps to ensure that all scheduled samples are collected and properly labeled.

d. Perishable samples such as milk and some food products are packed in ice for preservation, while others, like fish, may be frozen for transport.

e. All samples are delivered to the Radioanalytical Laboratory in Muscle Shoals, AL for analysis.

8. Quality Assurance/Quality Control Program

   a. A thorough quality assurance program is employed by the laboratory to ensure that the environmental monitoring data are reliable. This program includes:

      (1) The use of written, approved procedures in performing the work;

      (2) Provisions for staff training and certification;

      (3) Internal self assessments of program performance;

      (4) Audits by various external organizations; and

      (5) A laboratory quality control program.

   b. The quality control program employed by the radioanalytical laboratory is designed to ensure that the sampling and analysis process is working as intended. The program includes: **TP-41**

      (1) Equipment checks and the analysis of quality control samples along with routine samples.

      (2) Instrument quality control checks include background count rate and counts reproducibility.

      (3) Other quality control checks performed on the variety of detectors used in the laboratory.

   c. To provide for an independent verification of the laboratory's ability to make accurate measurements, the laboratory participated in an environmental level cross-check program available through Analytics, Inc. In this program, participating laboratories all analyze the same samples and the results are compared. **TP-41**

   d. TVA splits certain environmental samples with laboratories operated by the States of Alabama and Tennessee and the EPA National Air and Radiation Environmental Laboratory in Montgomery, Alabama. **TP-41**

      When radioactivity has been present in the environment in measurable quantities, such as following atmospheric nuclear weapons testing, following the Chernobyl incident, or as naturally occurring radionuclides, the split samples have provided TVA with another level of information about laboratory performance. These samples demonstrate performance on actual environmental sample matrices rather than on the constructed matrices used in cross-check programs.

e. Quality control samples of a variety of types are used by the laboratory to verify the performance of different portions of the analytical process. These checks include:

TP-41 & 42
Objective 11

(1) The use of ***blank samples*** which contain no measurable radioactivity or no activity of the type being measured. Such samples are analyzed to determine whether there is any contamination of equipment or commercial laboratory chemicals, cross-contamination in the chemical process, or interference from isotopes other than the one being measured.

(2) ***Duplicate samples*** are generated at random by the sample computer program which schedules the collection of the routine samples. For example, if the routine program calls for four milk samples every week, on a random basis each farm might provide an additional sample several times a year. These duplicate samples are analyzed along with other routine samples. They provide information about the variability of radioactive content in the various sample media.

(3) Periodically, the laboratory staff can ***split a sample*** into two portions. Such a sample provides information about the variability of the analytical process since two identical portions of material are analyzed side by side.

(4) ***Analytical knowns*** are another category of quality control sample. A known amount of radioactivity is added to a sample medium. The lab staff knows the radioactive content of the sample. Whenever possible, the analytical knowns contain the same amount of radioactivity each time they

are run. In this way, analytical knowns provide immediate data on the quality of the measurement process. A portion of these samples are also blanks.

(5) ***Blind spikes*** are samples containing radioactivity which are introduced into the analysis process disguised as ordinary environmental samples. The lab staff does not know the sample contains radioactivity. Blind spikes can be used to test the detection capability of the laboratory.

(6) Approximately 5 percent of the laboratory workload is in the category of ***internal cross-checks***. These samples have a known amount of radioactivity added and are presented to the lab staff labeled as cross-check samples. This means that the quality control staff knows the radioactive content or "right answer" but the lab personnel performing the analysis do not. Such samples test the best performance of the laboratory by determining if the lab can find the "right answer".

(a) These samples provide information about the accuracy of the measurement process.

(b) Like blind spikes or analytical knowns, these samples can also be spiked with low levels of activity to test detection limits.

f. The quality control data are routinely collected, examined and reported to laboratory supervisory personnel. They are checked for trends, problem areas, or other indications that a portion of the analytical process needs correction or improvement.

The QA/QC program helps to improve Human Performance by checking results for errors, identifying, and correcting potential error-producing situations.

The end result is a measurement process that provides reliable and verifiable data and is sensitive enough to measure the presence of radioactivity far below the levels which could be harmful to humans.

It emphasized following procedures, self-checking, peer-checking, and questioning results.

9. Land Use Survey

a. A land use survey is conducted annually to identify the location of the nearest ***milk producing animal***, the

Objective 12

nearest residence, and the ***nearest garden*** of greater than 500 square feet producing fresh leafy vegetables in each of 16 meteorological sectors within a distance of 5 miles from the plant. Because of the elevated stack releases from BFN, that survey also identifies the location of all milk animals and gardens of greater than 500 square feet producing fresh leafy vegetables within a distance of 3 miles from the plant.

b. The land use survey is conducted between April 1 and October 1 using appropriate techniques such as door-to-door survey, mail survey, telephone survey, aerial survey, or information from local agricultural authorities or other reliable sources.

c. Information gathered in the survey includes: **TP-43**

(1) Locations of animals and gardens.

(2) Number of animals.

(3) Type use (dairy or home).

(4) Age of consumers.

(5) Substitutional feeding (percent).

d. From these data, we can project impacts (doses) from: **TP-43**

(1) Air submersion.

(2) Ingestion of foods.

(3) Ingestion of milk.

e. The collection and maintaining of land use survey information is regulated by the Privacy Act of 1974, 5 U.S.C. 552a and TVA's Privacy Act regulations (18 CFR 1301 Subpart B).

f. In order to identify the locations around the sites which have the greatest relative potential for impact by the plant, radiation doses are projected for individuals living near the plants. These projections use the data obtained in the survey and historical meteorological data. They also assume that releases are equivalent to the design basis source terms. The calculated doses are relative in nature and do not reflect actual exposures received by individuals living near the sites. Calculated doses to individuals based on measured effluents from the plant are well below applicable dose limits.

10. Data Analysis

The vast majority of radioactivity measured in environmental samples from the TVA's programs result from naturally occurring radioactive materials or from fallout following atmospheric weapons tests and the accident at Chernobyl. Transparency # 44 compares the results from routine samples with samples taken after these fallout events.

TP-44

Review the TP, emphasizing the levels of activity reported following fallout events.

Trace quantities of Cesium-137 (Cs-137) may be measured in soil, shoreline sediment and fish. ***Cs-137 is the predominant fission/activation product found in samples of environmental media***. The Cs-137 and the trace level of Strontium-90 (Sr-90) detected in milk samples are typical of the levels expected to be present in the environment from past nuclear weapons testing or operation of other nuclear facilities in the region. These levels would not represent a significant contribution to the radiation exposure to Members of the Public.

Objective 13

a. The measured direct radiation levels are corrected for gamma response, system variations, and transit exposure, with individual gamma response calibrations for each element. The system meets or exceeds the performance specifications outlined in Regulatory Guide 4.13 for environmental applications of TLDs.

(1) All results are normalized to a standard quarter (91.25 days or 2190 hours). For analysis purposes, the monitoring locations are grouped according to the distance from the plant. The first group consists of all locations within 1 mile of the plant. The second group lies between 1 and 2 miles, the third group between 2 and 4 miles, the fourth between 4 and 6 miles, and the fifth group is made up of all locations more that 6 miles from the plant.

(2) Past data have shown that the results from all monitoring points greater than 2 miles from the plant are essentially the same, therefore, for reporting purposes all locations 2 miles or less from the plant are identified as "onsite" stations and all others are considered "offsite."

(3) Measured radiation levels at the onsite stations at all TVA sites are typically 2-4 mR/quarter greater than levels at offsite stations. This difference is consistent with levels measured for preoperation and construction phases of TVA nuclear plant sites where the average radiation levels on site were generally 2-6 mR/quarter higher than the levels offsite.

Handouts # 03 & 04
TP-45 & TP-46
Direct Radiation Levels at BFN (average) and SQN (moving average).

Explain the concept of a moving average.

(4) The causes of these differences have not been isolated; however, it is postulated that the differences are probably attributable to combinations of influences such as natural variations in environmental radiation levels, earth-moving activities onsite, and the mass of concrete employed in the construction of the plants. Other undetermined influences may also play a part.

Instructor's Note: Because there is more data from the BFN monitoring program, most of the figures shown herein use BFN data. Similar patterns exist for the other sites.

b. Only naturally occurring radioisotopes are typically reported in air particulate samples. TP-46 presents a

Handout # 05, TP-47

plot of the gross beta activity reported at BFN from 1968-2003.

(1) The average gross beta activity for samples for indicator and control locations at all sites is typically approximately 0.020 pCi/m^3.

(2) Increased levels due to fallout from atmospheric nuclear weapons testing are evident, especially in 1969, 1970, 1971, 1977, 1978, and 1981. Evidence of a small increase resulting from the Chernobyl accident can also be seen in 1986.

c. I-131 is rarely detected in charcoal cartridge samples collected from any of the plants.

d. The predominant isotope reported in milk samples is the naturally occurring K-40. The average K-40 concentrations typically range from 1200-1400 pCi/l.

(1) In past years significant concentrations of Sr-89 and Sr-90 have been reported in milk samples. The presence of these radionuclides was a result of fallout from atmospheric nuclear weapons testing, with some small contribution from the Chernobyl accident.

(2) Low concentrations of Sr-90 are reported intermittently, especially from milk from non-dairy farms. The presence of low levels of Sr-90 in milk samples from these small farm is consistent with Sr-90 in the environment as the results of past nuclear weapons testing.

e. In general, the only fission or activation product identified in soil samples is Cs-137. The average concentrations are consistent with levels previously reported from fallout.

A plot of the annual average Cs-137 concentrations in soil is presented in Handout XX (TP-XX). The concentrations of Cs-137 in soil are steadily decreasing as a result of the cessation of weapons testing in the atmosphere, the 30-year half-life of Cs-137 and transport through the environment.

Handout # 06, TP-48

Note decrease from 0.7 pCi/g in 1970 to 0.25 pCi/g in 2000 (30 yrs). Represents half-life plus transport in soil, etc.

f. Only naturally occurring radioactivity is typically identified in food crops. The predominant natural radionuclide detected in food samples is K-40. Concentrations range from a few hundred to a few thousand pCi/g.

g. Fission and activation products are rarely identified in water samples. Only gross beta activity and some various naturally occurring radioisotopes are usually seen in this medium.

h. Cesium-137 is found in about half of the fish samples. (Handout 48) Note the decrease in Cs-137 activity generally follows the half-life of the isotope which would indicate that the material is not being added from the plants.

Handout # 07, TP-49

i. Only naturally occurring radioisotopes are typically reported in shoreline sediment samples.

11. Data Reporting

a. Plant Technical Specifications require that, "The Annual Radiological Environmental Operating Report covering the operation of the unit during the previous calendar year shall be submitted prior to May 1 (May 15 for Watts Bar) of each year. The report shall include summaries, interpretations, and analysis of trends of the results of the Radiological Environmental Monitoring Program for the reporting period. The material provided shall be consistent with the objectives outlined in (1) the ODCM and (2) Sections IV.B.2, IV.B.3, and IV.C of Appendix I to 10 CFR Part 50."

Handout # 08

In addition to the summarized data required for all sites, the WBN Tech Specs require that the report include, "…the results of analyses of all radiological environmental samples and of all environmental radiation measurements taken during the period."

b. The ***Annual Radiological Environmental Operating Reports*** include: — **TP-50 Objective 14**

(1) Site/Plant descriptions.
(2) Monitoring program description.
(3) Assessment and evaluation of the plant impacts.
(4) Any program modifications made during the year.

Example: The dairy farm providing milk samples at BFN went out of business in 2003 necessitating modifying the monitoring program.

(5) Missed samples and analyses (equipment malfunction, bad weather, etc.)
(6) Analytical procedures. — **TP-51**
(7) Nominal Lower Limits of Detections (LLDs).
(8) Quality Assurance/Quality Control program.
(9) Land use survey results.
(10) Data tables.

c. The reports are prepared by the Environmental Radiological Monitoring and Instrumentation staff, reviewed by the appropriate site personnel, and submitted to the NRC by ***site licensing***.

If available, pass around a copy of the most recent Annual Radiological Environmental Operating Report. The reports are available from the Environmental Radiological Monitoring and Instrumentation group in Muscle Shoals (386-2536).

XI. SUMMARY

The Radiological Environmental Monitoring Program is designed to sample the pathways between the plant and the people in the immediate vicinity of the plant. A critical pathway analysis is performed to identify appropriate sample types and locations so that the potential for detection of radioactivity in the environment will be maximized.

A number of factors were considered in determining the locations for collecting environmental samples. The locations for the atmospheric monitoring stations were determined from a critical pathway analysis based on weather patterns, dose projections, population distribution, and land use. Terrestrial sampling stations were selected after reviewing such factors as the locations of dairy animals and gardens in conjunction with the air pathway analysis. Liquid pathway stations were selected based on dose projections, water use information, and availability of media such as fish and sediment.

TP-52

Media sampled include air particulates, atmospheric charcoal canisters designed to collect iodine, rainwater, milk, soil, vegetation/vegetables, water (surface water, drinking water, and ground water), fish, and shoreline sediment. In addition, direct radiation measurements are made utilizing thermoluminescent dosimeters. A land use survey is conducted annually to ensure that appropriate sampling is being conducted.

TP-53

Note to Instructor: A field trip to the Western Area Radiological Laboratory in Muscle Shoals, AL should be conducted in conjunction with this lesson. The Laboratory conducts the REMP for all of TVAs nuclear power facilities. The trip can also include a visit to the Calibration Facility that is located at the Laboratory. This facility calibrates the portable radiation monitoring instruments for all of TVAs nuclear power plants. Contact William L. Raines at 386-2536 to coordinate the trip.

Analyses of environmental samples are performed by the radioanalytical laboratory located at the Western Area Radiological Laboratory facility in Muscle Shoals, Alabama. The analysis procedures are based on accepted methods. In addition, a thorough quality assurance program is employed by the laboratory to ensure that the environmental monitoring data are reliable. This program includes the use of written, approved procedures in performing the work, provisions for staff training and certification, internal self assessments of program performance, audits by various external organizations, and a laboratory quality control program.

The results obtained in the program are reported to the NRC annually in an Annual Environmental Radiological Operating Report. The reports include summaries, interpretations, and analysis of trends of the results of the Radiological Environmental Monitoring Program for the reporting period.

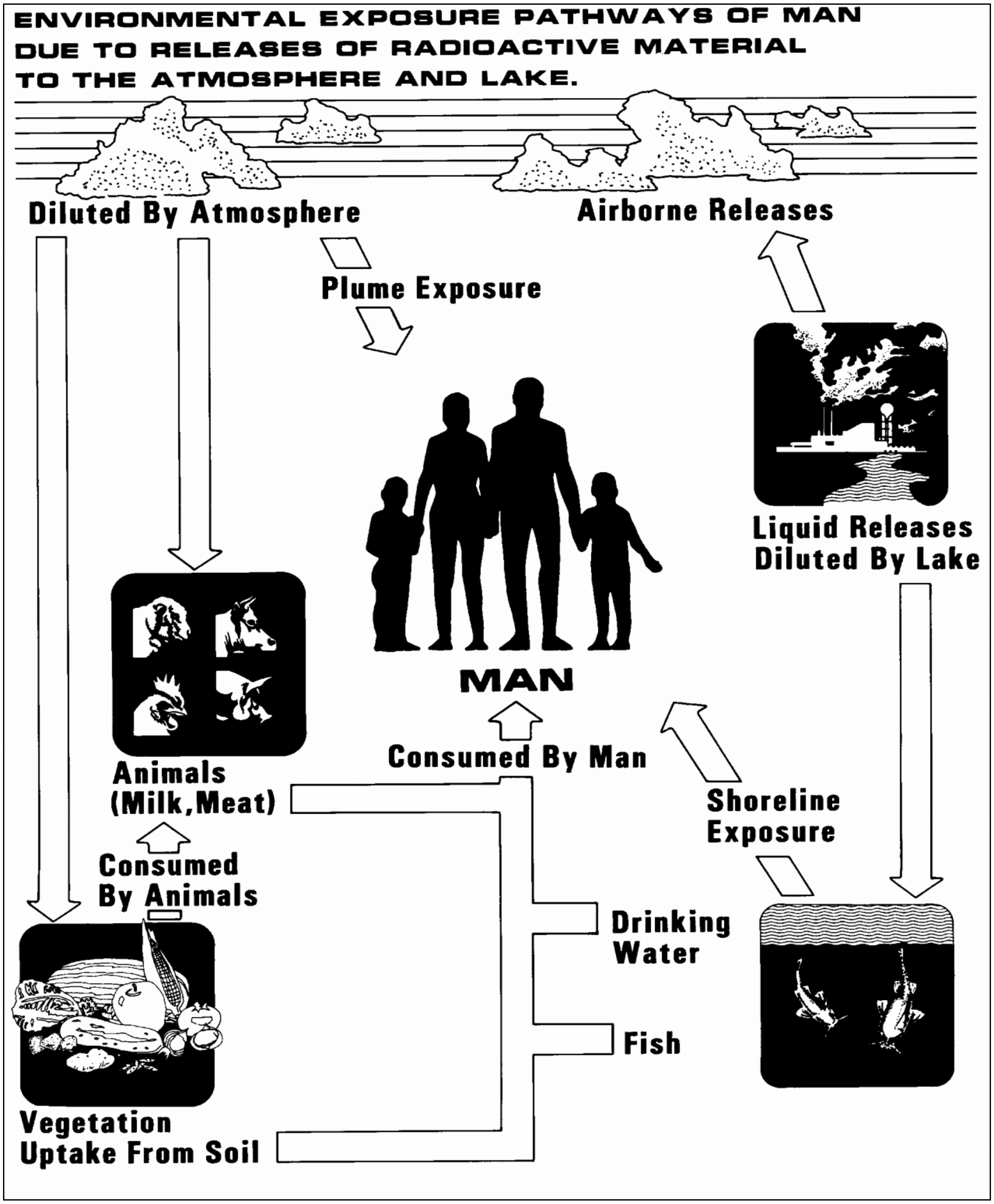
Handout # 01

Enabling Objectives

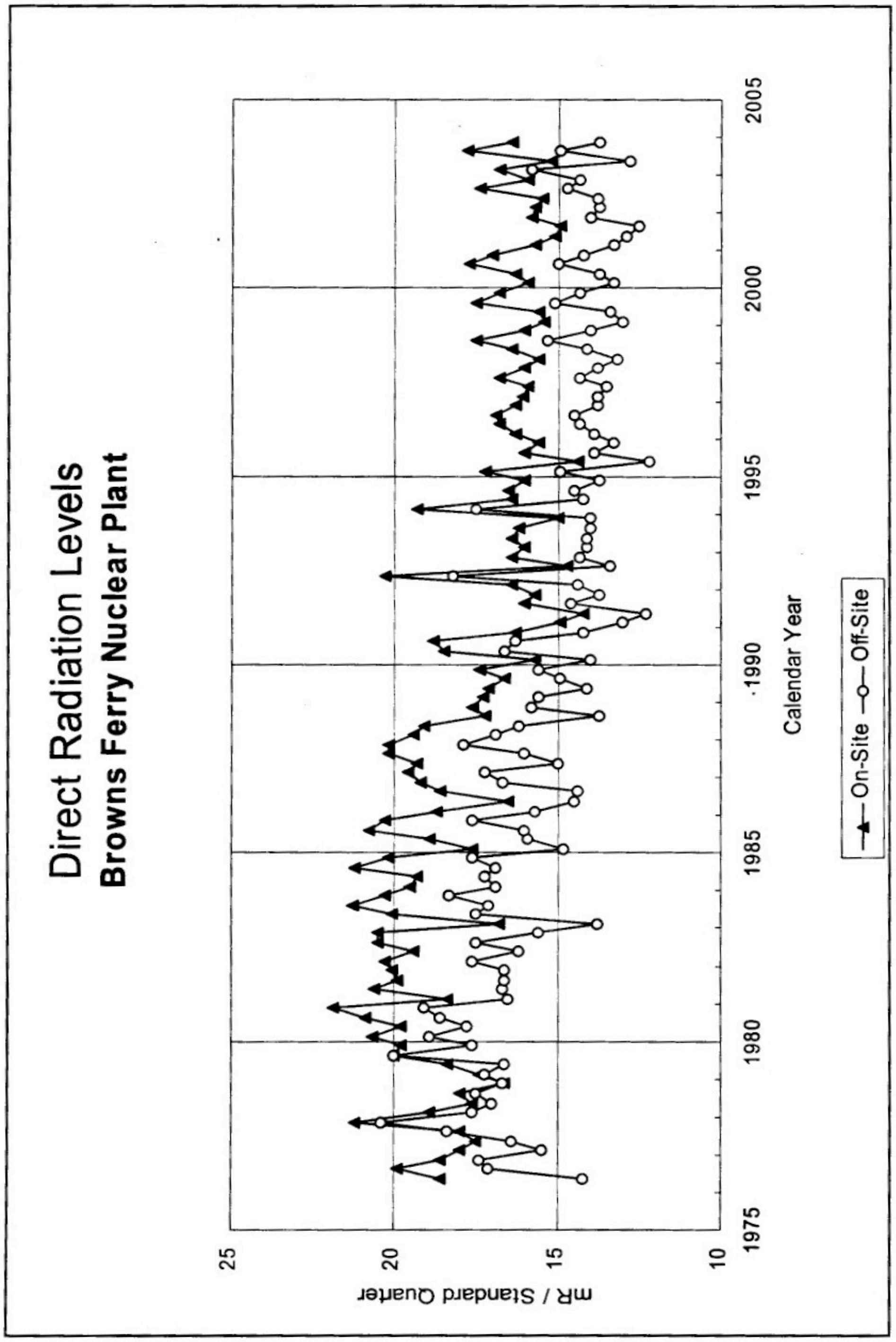
1. State the objectives of the Radiological Environmental Monitoring Program (REMP).
2. Identify the TVA document that describes the requirements of the REMP.
3. List the two primary pathways by which radioactivity can move through the environment to humans and identify the means of exposure for the pathways.
4. Name four parameters of the critical pathway analysis and identify the components used for making dose projections.
5. Tell why the preoperational monitoring program is important.
6. Identify the equipment used to measure direct radiation levels in the environment.
7. Define local, perimeter, and remote monitoring stations and list their relative distances from the plant.
8. Identify the five categories of food products typically sampled in the REMP.
9. Describe the sampling technique used to sample surface water onsite well water and identify the sampling times for each.
10. Identify the two categories of fish sampled in the REMP.
11. Name at least three types of quality control samples used by the laboratory to verify the performance of different portions of the analytical process.
12. Identify the purpose of the land use survey, tell how it is conducted, how it is regulated, and how the data are used.
13. Identify the predominant fission or activation product typically found in the environment.
14. Identify the report which provides the results from the REMP to the NRC and tell how often and by what organization the reports are submitted.

HANDOUT # 02

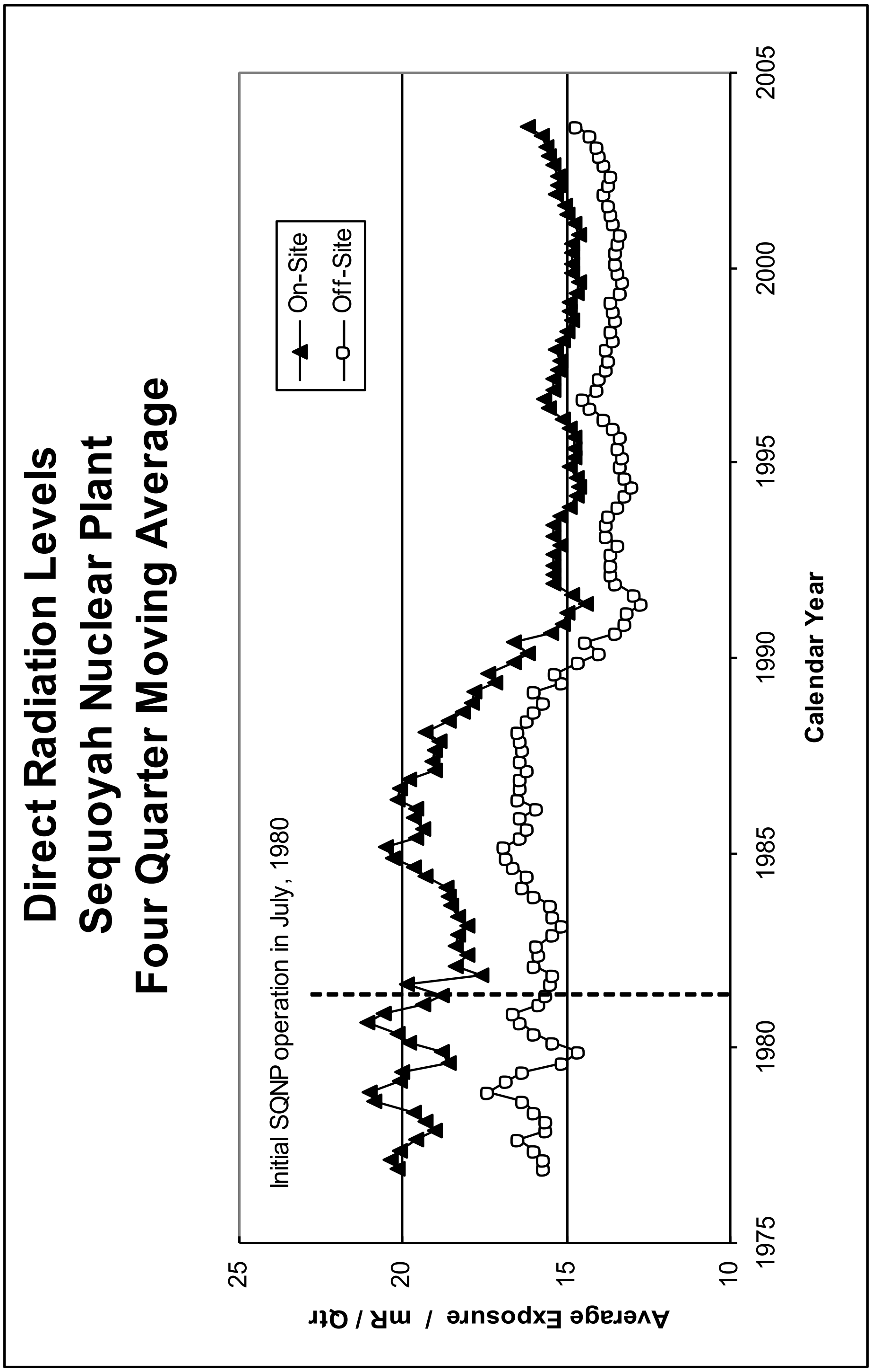
Pathways for Exposure



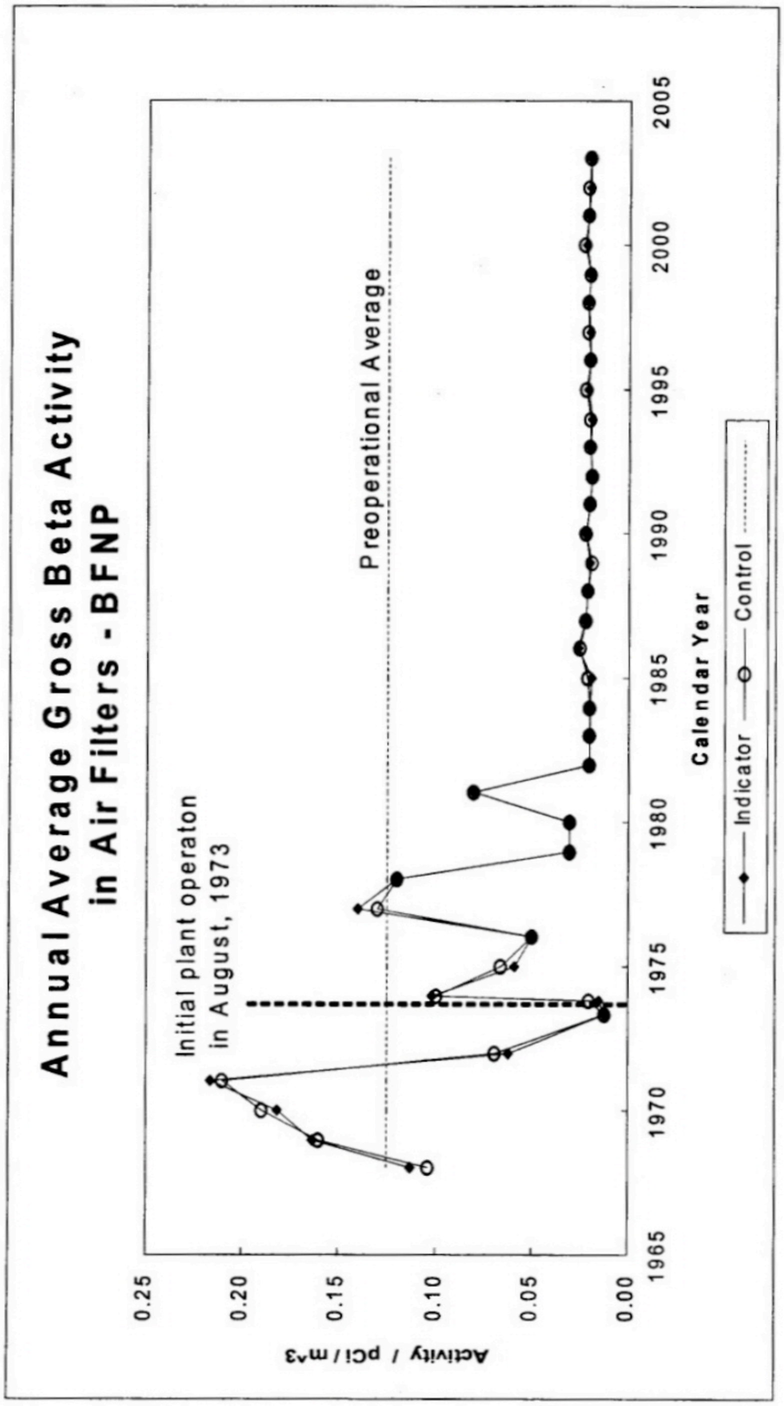
Handout # 03


Direct Radiation Levels
Browns Ferry Nuclear Plant
mR / Standard Quarter
25
20
15
10
1975
1980
1985
1990
1995
2000
2005
Calendar Year
On-Site
Off-Site

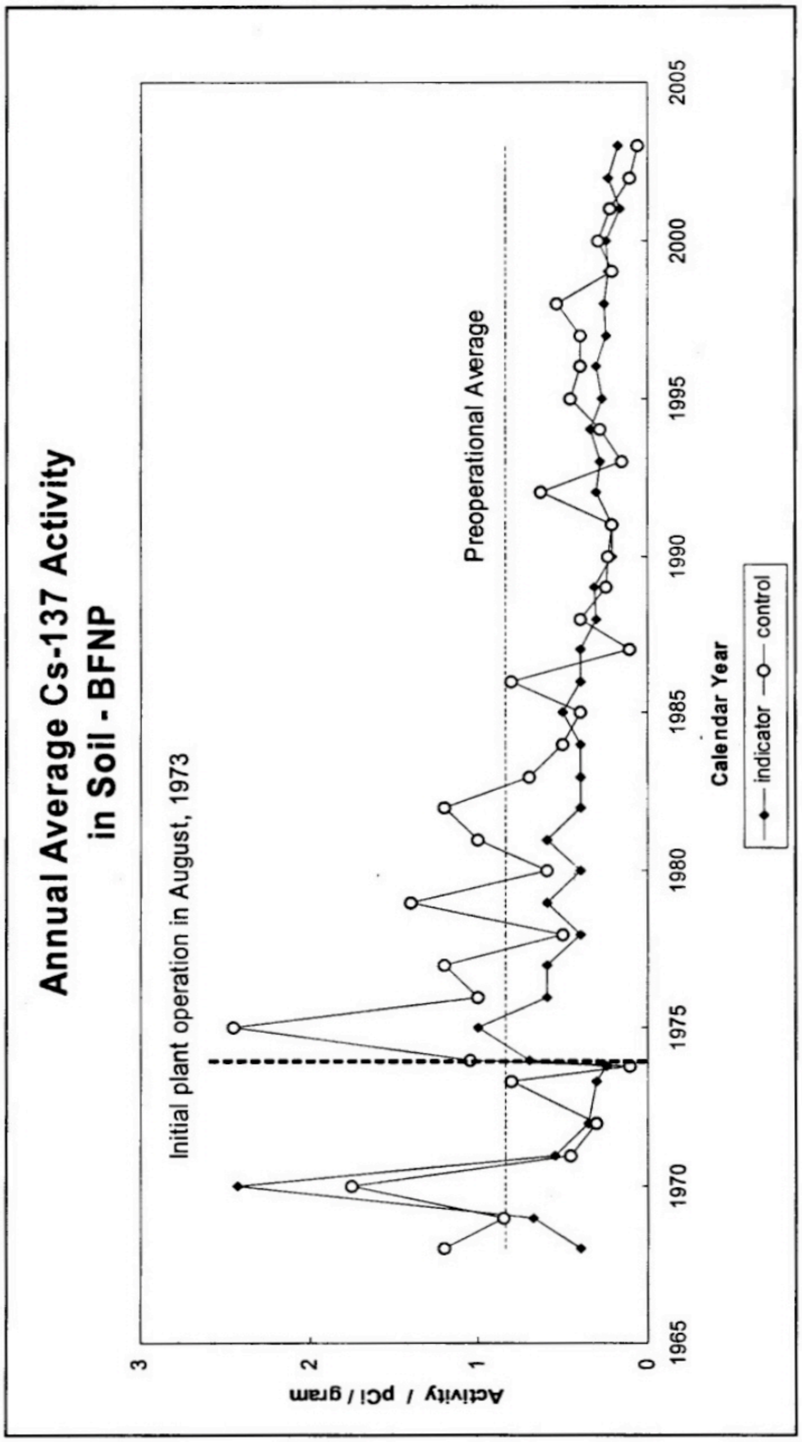
Handout # 04


Direct Radiation Levels
Sequoyah Nuclear Plant
Four Quarter Moving Average
Initial SQNP operation in July, 1980
On-Site
Off-Site
Average Exposure / mR / Qtr
25
20
15
10
1975
1980
1985
1990
1995
2000
2005
Calendar Year

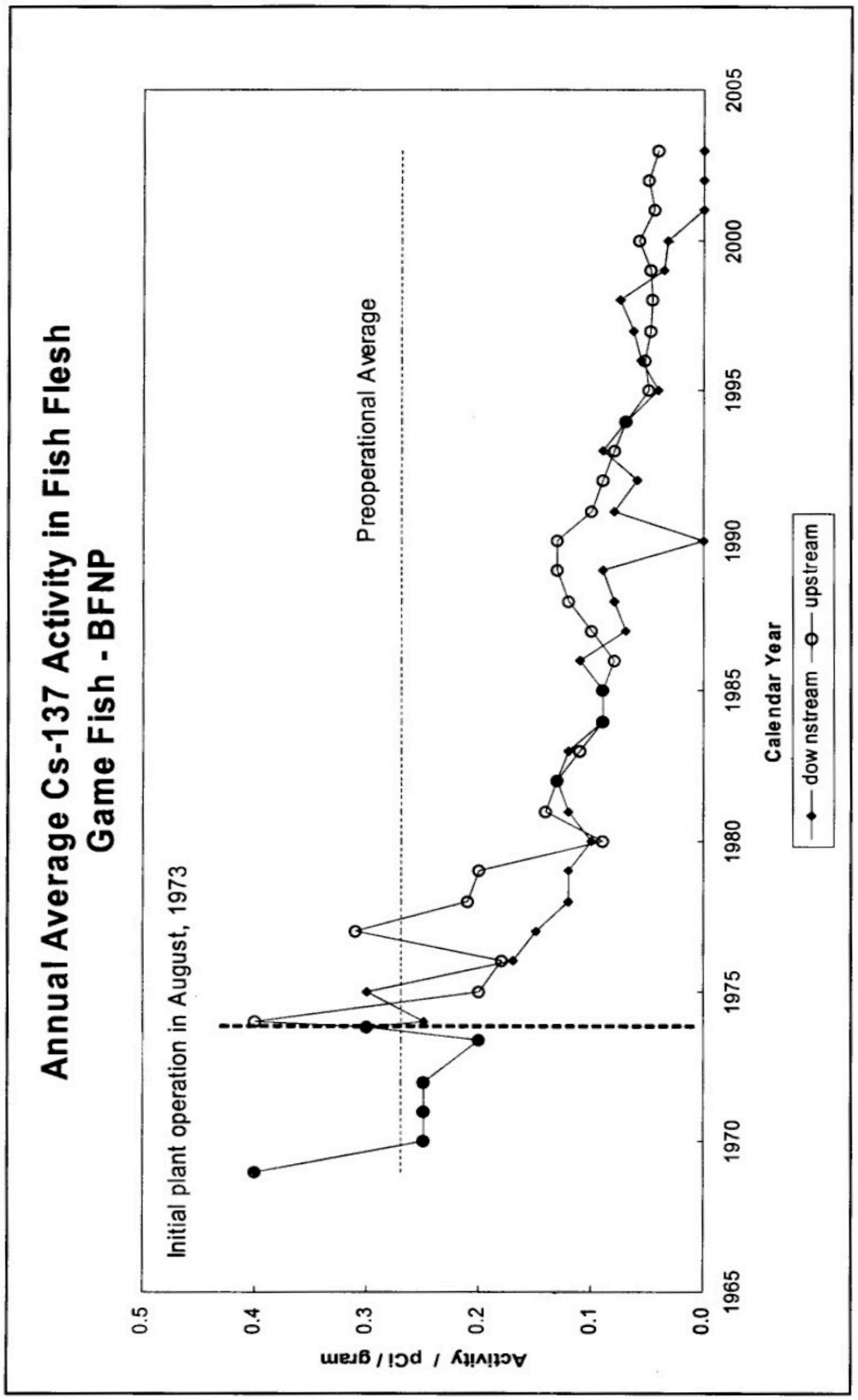
Handout # 05


Annual Average Gross Beta Activity
in Air Filters - BFNP
Initial plant operaton
in August, 1973
Preoperational Average
Activity / pCi / m^3
0.25
0.20
0.15
0.10
0.05
0.00
1965
1970
1975
1980
1985
1990
1995
2000
2005
Calendar Year
Indicator
Control

Handout # 06


Annual Average Cs-137 Activity
in Soil - BFNP
Initial plant operation in August, 1973
Preoperational Average
Activity / pCi / gram
Calendar Year
indicator
control
0
1
2
3
1965
1970
1975
1980
1985
1990
1995
2000
2005

Handout # 07


Annual Average Cs-137 Activity in Fish Flesh
Game Fish - BFNP
Initial plant operation in August, 1973
Preoperational Average
Activity / pCi / gram
0.0
0.1
0.2
0.3
0.4
0.5
1965
1970
1975
1980
1985
1990
1995
2000
2005
Calendar Year
downstream
upstream

Handout # 08
Radioactivity in Soil, BFN 2003

TENNESSEE VALLEY AUTHORITY
ENVIRONMENTAL RADIOLOGICAL MONITORING AND INSTRUMENTATION
WESTERN AREA RADIOLOGICAL LABORATORY

RADIOACTIVITY IN SOIL
PCI/GM - 0.037 BQ/G (DRY WEIGHT)

NAME OF FACILITY: BROWNS FERRY NUCLEAR PLANT — DOCKET NO.: 50-259,260,296
LOCATION OF FACILITY: LIMESTONE ALABAMA — REPORTING PERIOD: 2003

TYPE AND TOTAL NUMBER OF ANALYSIS PERFORMED	LOWER LIMIT OF DETECTION (LLD) SEE NOTE 1	ALL INDICATOR LOCATIONS MEAN (F) RANGE SEE NOTE 2	LOCATION WITH HIGHEST ANNUAL MEAN NAME DISTANCE AND DIRECTION	MEAN (F) RANGE SEE NOTE 2	CONTROL LOCATIONS MEAN (F) RANGE SEE NOTE 2	NUMBER OF NONROUTINE REPORTED MEASUREMENTS
GAMMA SCAN (GELI) 11						
AC-228	2.50E-01	1.28E+00(9/ 9) 7.25E-01- 1.81E+00	LM1 BF NORTHWEST 1.0 MILE N	1.81E+00(1/ 1) 1.81E+00- 1.81E+00	9.78E-01(2/ 2) 9.43E-01- 1.01E+00	
BI-212	4.50E-01	1.28E+00(9/ 9) 9.12E-01- 1.86E+00	LM1 BF NORTHWEST 1.0 MILE N	1.86E+00(1/ 1) 1.86E+00- 1.86E+00	9.57E-01(2/ 2) 9.34E-01- 9.80E-01	
BI-214	1.50E-01	1.09E+00(9/ 9) 7.15E-01- 1.40E+00	LM1 BF NORTHWEST 1.0 MILE N	1.40E+00(1/ 1) 1.40E+00- 1.40E+00	7.89E-01(2/ 2) 7.52E-01- 8.26E-01	
CS-137	3.00E-02	1.79E-01(9/ 9) 4.78E-02- 4.58E-01	PM-2 BF ATHENS AL 10.9 MILES NE	4.58E-01(1/ 1) 4.58E-01- 4.58E-01	6.13E-02(2/ 2) 5.09E-02- 7.16E-02	
K-40	7.50E-01	5.27E+00(9/ 9) 2.85E+00- 7.17E+00	PM-1 ROGERSVILLE AL 13.8 MILES NW	7.17E+00(1/ 1) 7.17E+00- 7.17E+00	3.86E+00(2/ 2) 3.85E+00- 3.88E+00	
PA-234M	4.00E+00	4.56E+00(1/ 9) 4.56E+00- 4.56E+00	LM4 BF TRAILER P 1.7 MILES NNW	4.56E+00(1/ 1) 4.56E+00- 4.56E+00	2 VALUES < LLD	
PB-212	1.00E-01	1.27E+00(9/ 9) 7.66E-01- 1.82E+00	LM1 BF NORTHWEST 1.0 MILE N	1.82E+00(1/ 1) 1.82E+00- 1.82E+00	9.65E-01(2/ 2) 8.87E-01- 1.04E+00	
PB-214	1.50E-01	1.22E+00(9/ 9) 7.79E-01- 1.51E+00	LM1 BF NORTHWEST 1.0 MILE N	1.51E+00(1/ 1) 1.51E+00- 1.51E+00	8.94E-01(2/ 2) 8.73E-01- 9.15E-01	
RA-224	7.50E-01	1.42E+00(7/ 9) 7.72E-01- 1.91E+00	LM1 BF NORTHWEST 1.0 MILE N	1.91E+00(1/ 1) 1.91E+00- 1.91E+00	2 VALUES < LLD	
RA-226	1.50E-01	1.09E+00(9/ 9) 7.15E-01- 1.40E+00	LM1 BF NORTHWEST 1.0 MILE N	1.40E+00(1/ 1) 1.40E+00- 1.40E+00	7.89E-01(2/ 2) 7.52E-01- 8.26E-01	
TL-208	6.00E-02	4.00E-01(9/ 9) 2.25E-01- 5.63E-01	LM1 BF NORTHWEST 1.0 MILE N	5.63E-01(1/ 1) 5.63E-01- 5.63E-01	3.01E-01(2/ 2) 2.69E-01- 3.33E-01	
SR 89 11	1.60E+00	9 VALUES < LLD			2 VALUES < LLD	
SR 90 11	4.00E-01	9 VALUES < LLD			2 VALUES < LLD	

NOTE: 1. NOMINAL LOWER LIMIT OF DETECTION (LLD) AS DESCRIBED IN TABLE E-1 .
NOTE: 2. MEAN AND RANGE BASED UPON DETECTABLE MEASUREMENTS ONLY. FRACTION OF DETECTABLE MEASUREMENTS AT SPECIFIED LOCATIONS IS INDICATED IN PARENTHESES (F).