BREDL

Bellefonte Efficiency & Sustainability Team

B.E.S.T.

A local chapter of Blue Ridge Environmental Defense League

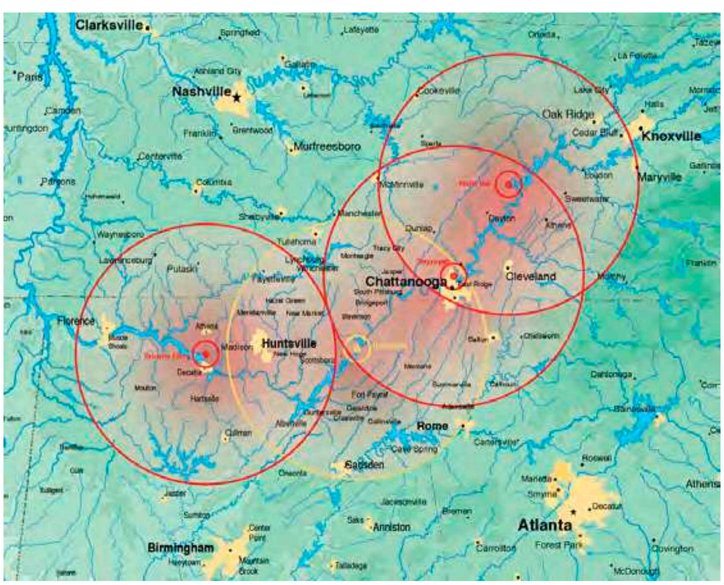
MATRR
MOTHERS AGAINST TENNESSEE RIVER RADIATION
BECAUSE IT MATTERS

BREDL / BEST / MATRR

Radiation Monitoring Manual

Advancing Environmental Justice at the Nuclear Crossroads in the Tennessee River Valley

Quality Assurance Procedures and Protocols (QAPP)/ Standard Operating Procedures (SOP)



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CAUTION

Before starting

- Energetic radiation (~~radioactivity~~) is harmful to you.
- If you are monitoring radioactivity, you are looking for hazards.
- Plan ahead. Look ahead, so you can stop or take precautions before you get into trouble.
- Be cautious in sample collecting and handling, sample preparation, sample analysis and sample archiving or disposal. Be cautious rather than adventurous. Be safe rather than regretful.
- Secure copies of this Manual and the *Citizens Guide to Monitor Radioactivity*, or get access to them.
- Read all of these procedures and guidelines and the *Citizens Guide to Monitor Radioactivity* carefully before beginning citizen-based radiation monitoring around any nuclear facility or any intensive source of radioactivity.
- Take warnings seriously; heed them.
- Be carefully protective of yourself, of your family, friends, co-workers, your neighbors, and your equipment.
- Begin your plan by getting informed about radioactivity and its dangers.
- Take personal responsibility to become well enough informed about radioactivity in the environment and about human health consequences.
- Use good sense.
- Become informed. Consider how what you have learned applies to what you plan to do in your particular situation. Carefully apply what you have learned. Learn more from your experiences. — This is good sense. Good sense is uncommon.
- Remember that most exposures to radioactivity are permanent and cumulative. Avoid exposing yourself, others, and your equipment to radioactivity.
- Be consciously aware of and guard against the three main pathways by which radioactivity will harm you:

    - Inhalation.
    - Ingestion.
    - Track off (taking contamination with you: on hands, clothing, and shoe soles).

- Use your Inspector Geiger Counter as your guide, your guard, your backup.
- Use this rule of thumb: Follow high Inspector readings to sampling sites, but stop before the Inspector reads four times your natural background readings and contact your team captain who will contact the Project Manager; see the Glossary in the *Citizens Guide to Monitor Radioactivity*.

CAUTION

- As you approach a hot-spot, slow down. Be increasingly cautious and careful.
- Avoid getting contaminated. Limit contact with contaminated materials. Prepare in case you might become contaminated. If you might have been contaminated, wash the contamination off with lots of water and change clothes. Until your hands are clean, don't eat anything.
- As you leave a hot-spot, check yourself and others for contamination, with your Inspector. Wash it off or bag it. Do not spread contamination.
- After leaving a contaminated area, check that your Inspector readings return to background levels to be sure your Inspector is not contaminated.

The following Chart is from the National Academy of Sciences BEIR VII - Phase 2 report, pg.12:

TABLE 1 Units of Dose

Unit[a]	Symbol	Conversion Factors
Becquerel (SI)	Bq	1 disintegration/s = 2.7×10^{-11} Ci
Curie	Ci	3.7×10^{10} disintegrations/s = 3.7×10^{10} Bq
Gray (SI)	Gy	1 J/kg = 100 rads
Rad	rad	0.01 Gy = 100 erg/g
Sievert (SI)	Sv	1 J/kg = 100 rem
Rem	rem	0.01 Sv

NOTE: Equivalent dose equals absorbed dose times *Q* (quality factor). Gray is the special name of the unit (J/kg) to be used with absorbed dose; sievert is the special name of the unit (J/kg) to be used with equivalent dose.

[a]International Units are designated SI.

The Chart below is an EPA Radiation Health Effects description of varying doses of radiation sickness:

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhea	
100	hemorrhage	
400	possible death	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	and death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness;	minutes
	and death	hours to days

A-1. Title and Approval Sheet

Organization's Name: BEST/MATRR, Bellefonte Efficiency and Sustainability Team (BEST) and Mothers Against Tennessee River Radiation (MATRR)

BEST/MATRR is made up of grassroots volunteers located in the Tennessee Valley Authority's (TVA) area of operations; and is a local chapter of the 501(c)3 organization, the Blue Ridge Environmental Defense League (BREDL).

Project Title: Advancing Environmental Justice at the Nuclear Crossroads in the Tennessee River Valley

Location: ______________________________ Date:__________

______________________________ Date:__________

______________________________ Date:__________

______________________________ Date:__________

Quality Assurance Officer: Louis A. Zeller, BREDL Quality Assurance Officer

Project Managers: BEST______________________________ Date:__________

Alabama ______________________________ Date:__________

Tennessee ______________________________ Date:__________

Team Captains: ______________________________ Date:__________

______________________________ Date:__________

______________________________ Date:__________

______________________________ Date:__________

Sampling Teams: ______________________________

____

____

A-2. Project/Task Organization

❖ **Key personnel:**

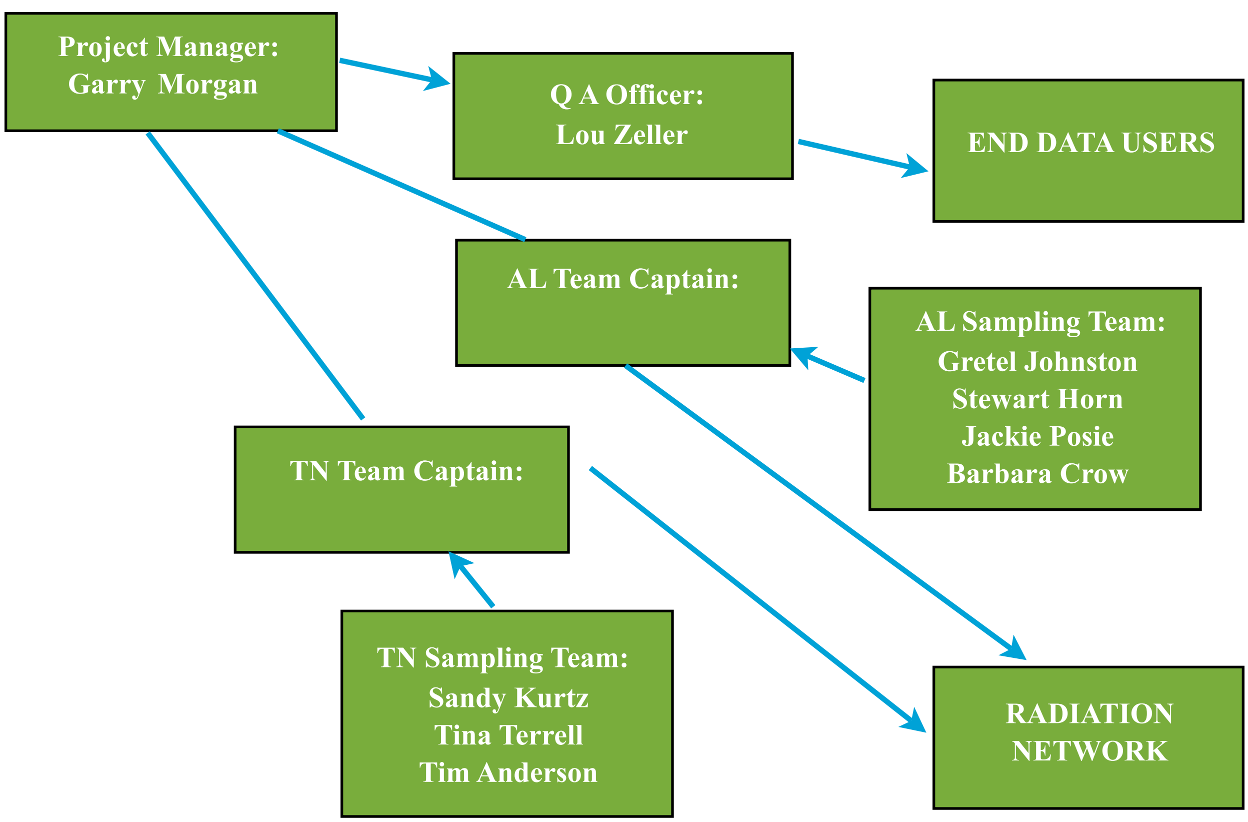
1) Project Manager: Garry Morgan will direct the on-the-ground operations throughout the duration of the project in consultation with the Quality Assurance (QA) Officer.

2) QA Officer: Louis Zeller - Mr. Zeller will train team captains and sampling teams in the proper procedures: that is, maintenance and use of equipment, survey protocols, chain-of-custody, sampling procedures, data recording, record keeping and reporting.

3) Team Captains will direct field investigations, ensure proper procedures and report to the Project Manager, Garry Morgan.

4) Sampling Teams will work together to gather primary data under the direct supervision of Team Captains, and Team Captains will upload data via GeigerGraph to the Radiation Network and report to the Project Manager.

Organizational Chart



A-3. Project/Problem Definition/Area of Operations

The local environmental/public health issues that this project seeks to address are the public's safety and health in the Tennessee River Valley surrounding Tennessee Valley Authority's (TVA) three nuclear power facilities, Browns Ferry Nuclear Power Plant (NPP) with three GE Mark I BWR reactors, Sequoyah NPP with two Westinghouse Four-Loop Ice-Condenser PWR reactors, and Watts Bar NPP with one Westinghouse Four-Loop Ice-Condenser PWR reactor already online and another under construction.

This project's purpose is to independently document and report radionuclide emissions which may be airborne, in the soil or in the water in communities surrounding TVA nuclear power facilities in a structured process for scientific data collection.

A-3.1 Browns Ferry Nuclear Facility near Athens, Alabama - TVA's first nuclear plant, built in 1973-76, is located on the Tennessee River 10 miles northwest of Decatur, Alabama; 10 miles southwest of Athens, Alabama; and 28 miles west of Huntsville, Alabama city-center.*[1] Located on the north side (right bank) of Wheeler Lake, the NPP has three General Electric boiling water reactor (BWR) nuclear generating units for electrical power generation and is owned by the Tennessee Valley Authority, a U.S. Government corporation. Browns Ferry was TVA's first nuclear power plant; its approval occurred on June 17, 1966 and construction began in September 1966.*[2] It was the largest nuclear plant in the world at the time of its initial operation in 1974; the first nuclear plant in the world able to generate more than 1 gigawatt of power.*[3] In 2006, the Nuclear Regulatory Commission (NRC) renewed the licenses for all three reactors, extending them for an additional twenty years.

Population: The Nuclear Regulatory Commission defines two emergency planning zones around nuclear power plants: a plume exposure pathway zone with a radius of 10 miles (16 km), concerned primarily with exposure to, and inhalation of, airborne radioactive contamination, and an ingestion pathway zone of about 50 miles (80 km), concerned primarily with ingestion of food and liquid contaminated by radioactivity.*[4]

The 2010 U.S. population within 10 miles (16 km) of Browns Ferry was 39,930, an increase of 12.3 percent in a decade, according to an analysis of U.S. Census data for MSNBC News. The 2010 U.S. population within 50 miles (80 km) was 977,942, an increase of 11.0 percent since 2000. Cities within 50 miles include Huntsville, AL (28 miles to city center).*[5]

The Browns Ferry Nuclear Reactors have been plagued with problems and are of the same design (GE-Mark1 design Boiling Water Reactor, BWR) as the exploded and melted down reactors at Fukushima-Daiichi, Japan. The Nuclear Regulatory Commission (NRC) has described the GE Mark 1 Reactor containment structure as “"the worst one of all the containments we have"—and in a complete blackout, "you're going to lose containment," noted U.S. Nuclear Regulatory Commission (NRC) Deputy Regional Administrator Charles Casto on March 16, 2011.” *[6]

In a 2005 analysis of significant nuclear safety occurrences in the US, the NRC concluded that the 1975 fire at Browns Ferry was the most likely (excluding the actual Three Mile Island accident) "precursor" incident to have led to a nuclear accident in the event of a subsequent failure.*[7], [8], [9]

In 2012, two BEST/MATRR members, Chairman Stewart Horn and Treasurer Garry Morgan, wrote a fact sheet on the Browns Ferry Nuclear Power Plant which can be found on the Nuclear Valley page of the MATRR.org website.*[10]

***References for TVA's Browns Ferry Nuclear Facility**

[1] NRC, Safety Evaluation Report, License Renewal, Browns Ferry Nuclear Plant, Units 1,2,3 http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1843/initial/title-index.pdf

[2] "TVA timeline by year," http://tva.com/75th/pdf/tva_timeline_by_year.pdf

[3]. "Browns Ferry Nuclear Plant," TVA http://www.tva.com/power/nuclear/brownsferry.htm

[4] NRC Document Collection, http://www.nrc.gov/reading-rm/doc-collections/fact- sheets/emerg-plan-prep-nuc-power-bg.html

[5] Nuclear neighbors: Population rises near US reactors, msnbc.com, April 14, 2011 http://www.msnbc.msn.com/id/42555888/ns/us_news-life/

[6] Scientific American, March 9, 2012 - "How Safe are U.S. Nuclear Reactors? Lessons from Fukushima" http://www.scientificamerican.com/article.cfm?id=how-safe-are-old-nuclear-reactors-lessons-from-fukushima

[7] Fisher, Brad (April 4, 1979). "Nuclear risk-benefit ratio needs a much closer look". The Tuscaloosa News. http://news.google.com/newspapers?id=bGstAAAAIBAJ&sjid=U4oFAAAAIBAJ&pg=6822,845656&dq=

[8] "IE Bulletin No. - 75-04A: Cable Fire at Browns Ferry Nuclear Plant". United States Nuclear Regulatory Commission. April 3, 1975. http://www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/1975/bl75004a.html

[9] Nuclear Regulatory Commission."NRC Commission Document SECY-05-0192 Attachment 2 http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2005/secy2005-0192/attachment2.pdf

[10] Horn, Stewart and Morgan, Garry, "Browns Ferry – Three Reactors, Multiple Problems" Fact Sheet on Browns Ferry Nuclear Power Plant, March 2012, on the Nuclear Valley page of the MATRR.org site. http://nuclearvalley.blogspot.com/

A-3.2. Sequoyah Nuclear Facility is utilized for electrical power generation. It is located on 525 acres 7 miles east of Soddy-Daisy, Tennessee, and 20 miles north of Chattanooga, abutting Chickamauga Lake, on the Tennessee River. The facility is owned and operated by the Tennessee Valley Authority (TVA). Sequoyah nuclear power units 1 & 2 are Westinghouse pressurized water reactors (PWR), both have ice condenser containment systems. In case of a large loss-of-coolant accident, steam generated by the leak is directed toward borated ice which helps condense the steam creating a lower pressure, allowing for a smaller containment building.

Sequoyah unit 1 began operating in 1980, unit 2 began operations in 1981. The operating license of Sequoyah's Unit 1 expires in 2020 *[1]; Unit 2's operating license expires in 2021.*[2]

TVA's Sequoyah operating license was modified in September 2002 to allow TVA to irradiate tritium-producing burnable absorber rods at Sequoyah for the U.S. Department of Energy. The process of irradiating tritium-producing rods produces tritium, which is used in nuclear weapons. Tritium was discovered in groundwater surrounding the Sequoyah Nuclear Facility in December 2011. *[3]

Population: The Nuclear Regulatory Commission defines two emergency planning zones around nuclear power plants: a plume exposure pathway zone of 10 miles (16 km) radius (concerned primarily with exposure to, and inhalation of, airborne radioactive contamination), and an ingestion pathway zone of about 50 miles (80 km) radius (concerned primarily with ingestion of food and liquid contaminated by radioactivity).*[4]

The 2010 U.S. population within 10 miles (16 km) of Sequoyah was 99,664, according to 2010 U.S. Census data analyzed for MSNBC News, an increase of 13.8 percent in a decade. The 2010 U.S. population within 50 miles (80 km) was 1,079,868 (increase of 13.8 percent). Cities within 50 miles include Chattanooga (14 miles to city center).*[5]

***References for TVA's Sequoyah Nuclear Facility**

[1] NRC, http://www.nrc.gov/info-finder/reactor/seq1.html

[2] NRC, http://www.nrc.gov/info-finder/reactor/seq2.html

[3] Chattanooga Times Free Press, Dec. 21, 2012 http://www.timesfreepress.com/news/2011/dec/21/tritium-detected-in-sequoyah-groundwater/

[4] NRC, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/emerg-plan-prep-nuc-power-bg.html

[5] "Nuclear neighbors: Population rises near US reactors," msnbc.com, April 14, 2011 http://www.msnbc.msn.com/id/42555888/ns/us_news-life/

A-3.3. The Watts Bar Nuclear Facility is a Tennessee Valley Authority (TVA) nuclear reactor used for electric power generation. It is located on a 1,770-acre site on the northern end of Chickamauga Reservoir in Rhea County, Tennessee, near Spring City, between the cities of Chattanooga and Knoxville (60 miles SW of Knoxville, TN). Watts Bar Unit 1 is a Westinghouse four-Loop, wet ice condenser, pressurized water reactor (PWR); the reactor became operational in 1996, its license expires in 2035 . *[1]

The operating Westinghouse PWR is one of two reactor units whose construction commenced in 1973. Unit 1 is the most recent civilian reactor to come on-line in the United States; unit 2 is under construction and is estimated to be completed in 2015. *[2]

The Nuclear Regulatory Commission operating license for Watts Bar was modified in September 2002 to allow TVA to irradiate tritium-producing burnable absorber rods at Watts Bar to produce tritium for the U.S. Department of Energy's (DOE's) National Nuclear Security Administration. The Watts Bar license amendment currently permits TVA to install up to 240 tritium-producing rods in Watts Bar Unit 1. Planned future license amendments would allow TVA to irradiate up to approximately 2,000 tritium-producing rods in the Watts Bar reactor.

TVA began irradiating tritium-producing rods at Watts Bar Unit 1 in the fall of 2003. TVA removed these rods from the reactor in the spring of 2005. *[3][4]

Population: The Nuclear Regulatory Commission defines two emergency planning zones around nuclear power plants: a plume exposure pathway zone with a radius of 10 miles (16 km), concerned primarily with exposure to, and inhalation of, airborne radioactive contamination, and an ingestion pathway zone of about 50 miles (80 km), concerned primarily with ingestion of food and liquid contaminated by radioactivity.*[5]

The 2010 U.S. population within 10 miles (16 km) of Watts Bar was 18,452, an increase of 4.1 percent in a decade, according to an analysis of U.S. Census data for msnbc.com. The 2010 U.S. population within 50 miles (80 km) was 1,186,648, an increase of 12.8 percent since 2000. Cities within 50 miles include Oak Ridge (37 miles to city center).*[6] Nuclear neighbors: Population rises near US reactors, msnbc.com, April 14, 2011

***References for TVA's Watts Bar Nuclear Facility**

[1] NRC, http://www.nrc.gov/info-finder/reactor/wb1.html

[2] TVA, http://www.tva.com/power/nuclear/wattsbar.htm

[3] TVA, http://www.tva.gov/news/tritium.htm

[4] NRC, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-bg.html

A.3.4. Radionuclides

Like all nuclear power reactors, the three TVA nuclear reactors (Browns Ferry, Sequoyah, and Watts Bar) produce electricity through the atom-splitting process called fission. Uranium-235 atoms are bombarded with neutrons, producing heat, which drives turbines to produce electricity. Fission also produces over 100 radionuclides from the breakup of Uranium-235 atoms. These are not found in nature, but only created when atomic bombs explode or when nuclear reactors operate. Each of the 100-plus radionuclides released during fission, also known as radionuclide isotopes, are radioactive.

The radionuclide isotopes decay at varying rates, called a "Half-life," and generally the correlation is radiation remaining dangerous for about ten times the Half-life. For instance, Cesium-137 with a Half-life of 30 years would remain toxic to humans for about 300 years. The following are some radionuclide decay rate examples:

Radionuclide	Half-life	Approximate Radioactivity Duration
• Cesium-134	2.06 days half-life	3 weeks
• Iodine-131	8.0 days	80 days
• Strontium-89	50.5 days	505 days
• Tritium	12.5 years	125 years
• Strontium-90	28.7 years	287 years
• Cesium-137	30.1 years	301 years
• Plutonium-239	24,200 years	242 thousand years
• Iodine-129	15.7 million years	157 million years

Despite efforts by reactor operators to contain these dangerous substances within the reactor building, some must be routinely emitted into the air and water during daily plant operation and refueling. These particles and gases are returned to the earth through precipitation and gravity. They enter the human body by breathing and the the food chain, where they kill and injure cells by emitting alpha particles, beta particles, or gamma rays. A damaged cell may or may not repair itself. If it fails to do so, it will replicate into similarly damaged cells, which can lead to mutations and cancer.

Studies of morbidity and mortality statistics compiled by the U.S. Centers for DiseaseControl and Prevention and private non-profit organizations indicate a substantial increase after Plant Vogtle Units 1 and 2 went online_26 miles south of Augusta, GA. One study compares cancer deaths during the period 1982-1990 with those occurring during the period 1991-2002. This study demonstrated that Burke County's cancer deaths per 100,000 population rose 24.2% after Nuclear Power Plant Vogtle went online, while the death rate fell 1.4% for all Georgians during the same period. A second study examined deaths among infants under one year old in Burke County. The findings, which compared the periods before and after the startup of Nuclear Power Plant Vogtle's operation, show a 70.1% increase in infant deaths after startup. Statewide, the rate of infant deaths fell 1.7% during the same period. These findings were published in 2005. References: http://www.radiation.org/reading/pubs/070104Vogtle.pdf and http://pbadupws.nrc.gov/docs/ML0734/ML073440163.pdf and learn more at http://radioactivepoison.blogspot.com/

A-4

A-4. Project/Task Description

- Lists measurements to be made includes on-site field analysis and off-site laboratory analysis
- Cites applicable or program-specific regulatory standards, criteria, or technical objectives
- Identifies types of personnel, equipment and instruments required to perform field sampling, field analysis and laboratory analysis
- Provides work schedule and data deliverable timelines
- Summarizes required project and QA records/reports

A-4.1

A-4.1. Field Measurements

The BEST Sampling Teams will collect samples of air, soil and water for the purpose of detecting the levels of radioactivity in communities, roadways and waterways near the nuclear plant. In addition to sampling, the team, working closely with the Quality Assurance Officer, BREDL's Lou Zeller, will monitor radiation around the three TVA Nuclear Power Facilities via a combination of screening methods.

Utilizing a vehicle and a Geiger counter, the Vehicle Forced Air Screen Method (VFAM)*[1] will be utilized to sample the air surrounding the three TVA nuclear power facilities. The team will screen large areas surrounding each nuclear power plant including making SAFE STOPS*[2] out of traffic-ways near a distinct landmark such as an intersection. The team will take air, soil, vegetation or a water sample and perform a 10 minute Geiger counter screen test on the sample taken. Each SAFE STOP sampling area and specific 10 minute VFAM interval test point with date, time, location and Geiger counter readings will be recorded on a computer or manual log. Based on the results of the Geiger counter count per minute readings, the team will perform further screening and actual sampling in areas of concern.

Through training of volunteers, we will develop TVA Sampling Teams to gather useful, credible scientific data in support of BREDL/BEST/MATRR's longstanding efforts to reduce radioactive emissions into the air, land and water. The training of the Sampling Team volunteers will efficiently and safely accomplish both the collection of scientific data and the empowerment of local residents.

SAFETY FIRST - Sampling team mission and safety briefings will be conducted by the Project Manager prior to each sampling team mission. No sampling team collection missions will be conducted without a safety and collections briefing.

A-4.2. Regulatory Dose Limit Standards

Radiation dose standards are set by both the US Nuclear Regulatory Commission and the US Environmental Protection Agency. EPA standards for air and water are lower than NRC Regulatory Standards. “Ionizing Radiation Dose Ranges” charts are included in the back of this BEST/MATRR Procedures Manual with Sievert on the last page and Rem on the back cover. *[1]

The **Radiation DOSE LIMIT Standards** are:

- General Public - **0.002 rem/hr or 2 mrem/hr (0.02 mSv/hr) in an HOUR** (NRC)
- General Public - **0.1 rem/yr or 100 mrem/yr (1mSv/yr) in a calendar YEAR** (NRC)
- General Public - **10 mrem/yr or 0.01 rem/yr (0.1 mSv/yr)** (EPA, air pathway)
- General Public - **4 mrem/yr or 0.004 rem/yr (0.04 mSv/yr)** (EPA, public drinking water systems dose limit)

Federal regulations at 10 CFR § 20.1301 Subpart D, states: “Radiation Dose limits for individual members of the public,” state: (a) Each licensee shall conduct operations so that (1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 mSv) in a year, exclusive of the dose contributions from background radiation, from any administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003. See 56 FR 23398, May 21, 1991.

Also, EPA has established drinking water standards for several types of radioactive contaminants combined radium 226/228 (5 pCi/L); beta emitters (4 mrems); gross alpha standard (15 pCi/L); and uranium (30 µg/L).

Radionuclide contamination from nuclear power plants can range from undetectable to background levels or higher. Georgia Environmental Radiation Surveillance tests near Plant Vogtle, Georgia reveal elevations of harmful radionuclides in several media expressed in multiples above background level radiation from 2 times to 50 times above background. Elevated concentrations of Cobalt-60 in sediment were measured below Plant Vogtle up to 15X that of background levels of radiation. Elevated tritium up to 50X Bkg in river water was detected below the Vogtle outfall; concentrations averaged 2,200 pCi/l (11% of MCL), with the highest concentration 11,000 pCi/l. MCL. The Maximum Contaminant Level (MCL) is the highest level of a contaminant that is allowed in drinking water. Our technical objective is to find such hotspots and measure the radiation levels without jeopardizing the Sampling Team. A rule of thumb for personnel protection is to avoid contamination levels above 4X background levels by withdrawing from the area until further measurements can be done with protective equipment.

References:

[1] DOE Office of Science, “Ionizing Radiation Dose Ranges” - http://lowdose.energy.gov/pdf/DoseRanges.pdf

[2] NRC §20.1301, “Subpart D - Radiation Dose Limits for Members of the Public” - http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html

A-4.3. Personnel, Equipment and Instruments required for Sampling and Analysis

The principal sampling device is a Geiger Counter (a Geiger-Müller particle detector) that measures ionizing radiation. A portable laptop computer is linked to the detector during preliminary field surveys to generate a graphic readout and map. Our selected model Geiger Counter, the SE International Inspector™, has a data cable to interface with a computer or data logger, and we use the Geiger-Graph Network Mineralab software, which uploads to the online real-time (national and international) Radiation Network database (radiationnetwork.com).

A count from the Geiger Counter is transmitted through the data cable to the computer and the software displays and graphs those Counts-per-minute (CPM) in terms of the Current reading, an Average, and Minimum and Maximum Counts-per-minute (CPM) over the test period. For safety, the software issues an audible and visual alert whenever the CPM exceeds a user-set level. The count data for each minute is recorded on an internal spreadsheet to which the user can add notes for each minute of analysis. The program also saves the radiation count data every minute to a text file that can be exported to an external spreadsheet program (like Excel) for further analysis.

***Notes for Field Measurements**

[1] Vehicle Forced Air Screen Method (VFAM) – A methodology of directing airflow from a moving vehicle over the monitoring sensor of the Geiger counter from an open vehicle window utilizing funneled air instead of a vehicle mounted detection device.

[2] SAFE STOPS- Always be safe, drive safe, think safety. Do not place yourself into harm's way. We need you to test for radiation safely within our communities, not become a victim of unsafe, dangerous circumstances. Always be conscious of your surroundings. Obey all laws and safety rules, and use common sense to avoid personal confrontations and unsafe stop points and operations of your vehicle. Always ask permission to enter private property, never trespass.

A-5

A-5. Objectives and Criteria for Data Measurement

- State project objectives - qualitatively and quantitatively
- Links measurement quality objectives to applicable action limits, criteria

A-5.1

A-5.1. Project Objectives

The objectives of the project are threefold: (1) to investigate radioactive air, water and soil pollution in the vicinity of the TVA commercial nuclear power facilities; (2) involve community residents living in the vicinity of the three sources of radioactive pollution in scientific investigations of their environment; (3) assist community residents in seeking solutions to the disproportionate environmental burdens they bear as neighbors of TVA's nuclear power facilities.

In 2006, the National Academy of Sciences published their latest study of the biological effects of ionizing radiation, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII-Phase 2* report. In addition to comprehensive risk estimates for cancer incidence and mortality and other health effects from exposure to low-level ionizing radiation, the report listed a series of research needs, gaps in knowledge requiring additional data. BEIR VII "Research Need 12" states, "Data from the [Life Span Study] LSS [cohort of 120,000 Japan A-bomb survivors] should be supplemented with data on populations exposed to low doses and/or dose rates, especially those with large enough doses to allow risks to be estimated with reasonable precision."*[1] To help meet this need, Advancing Environmental Justice at the Nuclear Crossroads in the Tennessee River Valley will provide new data on low-dose sources of radiation in the communities surrounding TVA's nuclear power facilities.

In order to assess radioactive contamination in a scientific manner, we will gather data from as many points as possible around the three radionuclide emission sources. Preliminary surveys will require the taking of mobile Geiger counter readings over hundreds of miles of paved and unpaved roads. Further data gathering on foot will be based on high reading areas detected in the preliminary survey. Scores of samples will be gathered of soil, sediment, water and biota for testing. Always remember the "Safe Stops" rule.

Reference: [1] National Research Council, National Academies of Science, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII-Phase 2,* National Academies Press, 2006, page 323. http://www.nap.edu/catalog.php?record_id=11340

A-5.2

A-5.2. Linking measurement quality objectives to action criteria

Geiger counters typically measure radiation in Counts-per-minute (CPM) or millirems (mrem) and milliSieverts (mSv). To convert radiation in units of CPM to radiation in units of mrem, one can use a conversion ratio of 1,000 CPM = 1 mrem. This conversion ratio is not exact due to the definition of the rem, but it provides a good benchmark for this study. One can convert from one radiation unit to another with the conversion factors compiled in the following tables:

Units of Radiation Doses and Unit Symbol Conversion Factors

100.0000 rem =	100000.0 mrem =	**1 Sv**	= 1.000000 Sv =	1000.000 mSv =	1000000 µSv
1.0000 rem =	1000.0 mrem =	**1 rem**	= 0.010000 Sv =	10.000 mSv =	10000 µSv
0.1000 rem =	100.0 mrem =	**1 mSv**	= 0.001000 Sv =	1.000 mSv =	1000 µSv
0.0010 rem =	1.0 mrem =	**1 mrem**	= 0.000010 Sv =	0.010 mSv =	10 µSv
0.0001 rem =	0.1 mrem =	**1 µSv**	= 0.000001 Sv =	0.001 mSv =	1 µSv

Unit	**Symbol**	**Conversion Factors**
Becquerel	Bq	1 disintegration/s = 2.7 × 10–11 Ci
Curie	Ci	3.7 × 1010 disintegrations/s = 3.7 × 1010 Bq
Gray	Gy	1 J/kg = 100 rads
Rad	rad	0.01 Gy = 100 erg/g
Sievert	Sv	1 J/kg = 100 rem
Rem	rem	0.01 Sv
Millirem	mrem	0.001 rem = 1 × 10-5 Sv

For example:

.1 Gy = 0.1 J/kg = 10 rads = 0.1 Sv = 10 rem = 10,000 mrem = 1 × 10(7thpower) CP

The Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation of the National Research Council publishes data on the health risks of low-level ionizing radiation. These data were published in the 2006 BEIR VII, Phase 2 report. A summary cancer data table from that report is reproduced below.

Lifetime Risk for All Solid Cancers and for Leukemia

TABLE ES-1 The Committee's Preferred Estimates of the Lifetime Attributable Risk of Incidence and Mortality for All Solid Cancers and for Leukemia

	All Solid Cancers		Leukemia	
	Males	Females	Males	Females
Excess cases (including nonfatal cases) from exposure to 0.1 Gy	800 (400, 1600)	1300 (690, 2500)	100 (30, 300)	70 (20, 250)
Number of cases in the absence of exposure	45,500	36,900	830	590
Excess deaths from exposure to 0.1 Gy	410 (200, 830)	610 (300, 1200)	70 (20, 220)	50 (10, 190)
Number of deaths in the absence of exposure	22,100	17,500	710	530

NOTE: Number of cases or deaths per 100,000 exposed persons.

[a]95% subjective confidence intervals.

Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2, pg 15. http://www.nap.edu/catalog/11340.html

A-6

A-6. Special Training Requirements/Certified Listed

- States how training is provided, documented and assured

How training is provided, documented and assured

Training of the Sampling Teams will take place in the Tennessee River Valley communities conducted by the Project Manager and QA Officer. Using a combination of lecture, reading materials, fact sheets, PowerPoint presentations and hands-on practice, instructors will guide team members through a series of exercises to familiarize them with data gathering procedures and QA. Attendance at training sessions will be documented by sign-up sheets and these will become part of the project record. Also, significant parts of the trainings will be photographed both to make a record of the session and to provide guidance to others. The QA Officer will ensure that these documents are compiled and preserved.

A-7

A-7. Documentation and Records

- Lists information and records to be included in data report (e.g., raw data, field logs, results of QC checks, problems encountered

In addition to training and instruction materials cited above, the Sampling Teams will compile test data including graphs and charts of Geiger counter readings, tests of samples, field logs, Project Manager and QA Officer notes.

During the first phase of data gathering with the Geiger counter utilizing the Vehicle Forced Air Screen Method (VFAM) , the Team Captains and their respective Sampling Teams under the guidance of the Project Manager and QA Officer will record raw information in Counts-per-minute (CPM) which is fed into the Inspector software installed in the laptop computer. Also, photographs and video of the route will be taken during the data gathering, field logs will be used to record observations of date, time, wind direction, weather, vehicle speed and route information.

In the second phase of data gathering, Sampling Teams will travel on foot to points of interest identified by the first phase. Walking with the same Geiger counter, computer and software, team members will again record raw information in Counts-per-minute (CPM) with the Inspector software installed in the laptop computer. Again, photographs and video of the route will be taken during the data gathering, field logs will be used to record observations of date, time, wind direction, weather and route information. For the third phase, actual samples will be gathered by the teams and the date, time, location, sampling conditions, sample identification and weight and any other observations will be recorded in field logs. Tracking numbers will also be assigned and recorded.

B. Sampling Process Design (Rationale for Design)

- Specified the type, number and matrix of samples slated for collection
- Discusses the rationale for the proposed sampling design
- Specifies sample locations and frequency of sample collection at each location

B-1. Rationale for the sample collection

The collection of samples—the number, distribution and type—will be based on Phase One and Phase Two surveys of the area. At minimum, the Teams will attempt to collect samples from as many areas around the TVA nuclear facilities as safety, geography and private property considerations will allow.

The first choice for sampling design will be systematic grid sampling, a probability-based methodology allowing quantitative conclusions to be made about the resident population.

Where this is not possible, judgmental sampling based on knowledge of the terrain, site history and other factors will be employed. Consequently, because variability of the data may be high, the economical methods of testing selected for Advancing Environmental Justice at the Nuclear Crossroads in the Tennessee River Valley will allow large numbers of samples to be collected. This will augment sampling design accuracy and reduce overall potential for error.

There are three fundamental types of radiation alpha (a), beta (b) and gamma (g). Alpha radiation are particles of high energy in the million electron volt MeV) range. Because of their large mass, alpha particles are stopped by a few inches of air or a piece of paper. Beta radiation is electrons with energy in a range of a few hundred keV to several MeV. Electrons are much lighter than helium atoms and can penetrate several feet of air, several millimeters of plastic or very light metal. Gamma radiation is photons, like light, but of high energy, typically from several keV to several MeV. Gamma is an electromagnetic phenomenon similar to X-rays. Depending on the source and level of energy, gamma can be stopped by aluminum foil or can penetrate several inches of lead.

Normal background radiation is below 50 CPM. Some areas in North Alabama will average 30 CPM. The highest levels above background detected by Phase One and Phase Two surveys will be the sites for sample gathering. Reminder: Use your Inspector as your shield against exposure.

Remember – Air-born Radiation DOSE LIMITS:

- **0.002 rem/hr or 2 mrem/hr (0.02 mSv/hr) in an HOUR** (NRC)
- **0.1 rem/yr or 100 mrem/yr (1mSv/yr) in a YEAR** (NRC)
- **0.01 rem/yr or 10 mrem/yr (0.1 mSv/yr)** (EPA, air pathway)

B-2

B-2. Sampling Methods Requirements

- Describes sample collection procedures and methods
- Lists equipment needs
- Identifies support facilities
- Identifies individuals responsible for corrective actions in the field
- Describes the process for preparation and decontamination of sampling equipment
- Describes selection and preparation of sample containers – and specifies sample volumes
- Describes sample container, volume, preservation and holding time requirements per each chemical, physical or biological parameter

B-2.1

B-2.1. Phase One Data Collection Procedure: Vehicle Forced Air Screen Method (VFAM)

REMEMBER, ALWAYS BE SAFE

The initial field survey will utilize the laptop computer and the VFAM notating all areas of increased radiation readings. SAFE STOP radiation data collection screening points will also be utilized depending on wind direction during initial survey period. All data collection screening points will be entered on data and/or manual logs. The Project Director and Team Captains will select daily routes of travel and screening points to be communicated to the sampling teams during the Phase One data collection. The teams will make at least two passes on each roadway. Based on these surveys, we will identify trends which point to areas requiring further investigation. Background radiation varies with concentrations of natural potassium-40 and other radionuclides. Since background radioactivity differs from location to location, random variations will be minimized by longer periods of data gathering.

During this phase, data gathering is done with the Geiger counter utilizing the VFAM and SAFE STOP screening methodology. The Team Captains and their respective Sampling Teams, under the guidance of the Project Manager and QA Officer, will record raw information in Counts-per-minute (CPM) which is fed directly from the Inspector into the RadiationNetwork software installed in the laptop computer. Also, photographs and video of the route will be taken during the data gathering, field logs will be used to record observations of date, time, wind direction, weather, vehicle speed and route information.

B-2.2

B-2.2 Phase Two Data Collection Procedure: Walking Survey

REMEMBER, ALWAYS BE SAFE

In the second phase of data gathering, Sampling Teams will travel on foot to points of interest identified by the first phase. Walking with the same Geiger counter and computer, team members will again record raw information in Counts-per-minute (CPM) with the GeigerGraph® software in the laptop computer. Again, photographs and video of the route will be taken during the data gathering, field logs will be used to record observations of date, time, wind direction, weather and route information.

B-2.3

B-2.3. Phase Three Data Collection Procedure: Sample Gathering

REMEMBER, ALWAYS BE SAFE

For the third phase, actual physical samples will be gathered. Collected samples are placed in plastic bags and labeled with an identifying number. Sampling Teams record the date, time, location, sampling conditions, sample identification and weight and any other observations on field logs. Tracking numbers are assigned and recorded. The samples to collect will be determined by identifying pathways carrying radioactive substances from a source and the first two phases of data collection. Pathways may include wind direction, surface water groundwater, animal tracks, and uptake by vegetation.

For data collection from samples, the Geiger Counter will be set to "total count" (instead of Counts-per-minute or CPM) and measured for a period of three (3) hours. After waiting one day and at the same time of day and location, a second reading is taken again for a period of three hours. The results of the two tests are compared. If the second value is higher than the first, radioactive in-growth has occurred; if the second value is lower, radioactive decay has occurred.

If necessary, a final testing stage, using the *Nfoils-jig™ is performed. It is similar to the previous tests but allows one to distinguish one radioactive source from another. The duration of the test is longer—23 hours duration, beginning at the same time of day and proceeding for five (5) days.*Note: See pg. 27 in *A Citizens Guide to Monitor Radioactivity* relating to the Nfoils-jig.

B-2.4

B-2.4. EQUIPMENT LIST

A concerned BEST/MATRR member who maintains a sensible, safe operations attitude and behavior

FIELD KIT CHECKLIST:

- Radiation Detection Procedures Manual and the *Citizens Guide to Monitor Radioactivity*
- Geiger Counter (Geiger-Müller particle detector) and users manual
- Laptop PC computer with installed software
- GPS device (and users manual) and county map
- Camera (and users manual)
- Field notebook
- Pencils & Pens
- Zip-loc® bags & garden spade
- Back-up Battery(s)

LABORATORY CHECKLIST:

- Laboratory notebook
- Rechargeable Cordless Handheld Vacuum
- Specimen drying oven
- Nfoils-jig™
- Weight scales
- Timepiece
- Aluminum foil
- Filters and lab ware
- Potassium chloride, 500 grams
- Potassium-40 for Geiger Counter calibrations
- Individual and Equipment protective gear-as needed

B-2.5. Support Facilities

Norm Buske, co-author of *A Citizen's Guide to Monitor Radioactivity* is advising Blue Ridge Environmental Defense League (BREDL) on this project. Mr. Buske's experience and technical expertise provide practical guidance in equipment preparation, sample collection, field work and laboratory testing.

Lou Zeller of BREDL is the Quality Assurance Officer providing guidance on methodologies, techniques and procedures for this BEST/MATRR radiation monitoring project in the Tennessee River Valley. Each Sampling Team Captain will report to the Project Manager who can appeal to the Quality Assurance Officer for additional technical assistance.

B-2.6. Corrective Action

All field work will be done by Sampling Teams under the guidance of trained Team Captains. Any corrective action needed will be taken by the captains to ensure sampling and information gathering is done correctly and recorded in field notebooks and/or computers. These data will also be reviewed by the Quality Assurance Manager.

B-2.7. Preparation of Sampling Equipment

In addition to calibration of the Geiger counter, ensure that all units have fresh batteries and that they are fully charged to prevent loss of data.

Always go through the complete FIELD EQUIPMENT CHECKLIST before leaving your home for field data collection.

FIELD KIT CHECKLIST:

- A concerned BEST/MATRR member who maintains a sensible, safe operations attitude and behavior
- Radiation Detection Procedures Manual and the *A Citizens Guide to Monitor Radioactivity*
- Geiger Counter (Geiger-Müller particle detector) and users manual
- Laptop PC computer with installed software
- GPS device (and users manual) and county map
- Camera (and users manual)
- Field notebook
- Pencils & Pens
- Zip-loc® bags & garden spade
- Back-up Battery (s)

B-3

B-3. Sample Handling and Custody Requirements

- Summarizes sample handling requirements
- Summarizes chain-of-custody procedures

B-3.1. Sample handing requirements

Vegetation, soil or dust samples are gathered, put into a plastic Zip-loc® bags, dried and measured for radioactivity with the Geiger counter. Once physical samples are collected and bagged, Radioactive decay and ingrowth require that the sample drying process begin as soon as possible, within two hours, and proceed for a period of 24 hours at a temperature <200ºF (95ºC). Sample geometry—weight, volume and shape—are standardized.

B-3.2. Chain of custody

To ensure samples collected are transported, treated and tested within the time frames necessary for quality assurance. Since there is no outside laboratory required, the QA Officer will review all chain of custody procedures and records to ensure best practices are followed. The Project Manager will insure chain of custody is maintained locally.

B-4

B-4. Analytical Methods Requirements

- Identifies the analytical methods to be followed (including method number – and sample preparation method such as digestion/extraction method where applicable)
- Provides validation information for non-standard methods
- Identifies individuals responsible for corrective action
- Specifies the laboratory turnaround time for analysis and data deliverables

B-4.1

B-4.1. Analytical methods

The project will use methods which were developed by Dr. Do Lee, Dr. Norm Buske and Dr. Sergey Pashenko respectively. In 2005 this group published a methodology entitled *A Citizen's Guide to Monitor Radioactivity* (attached)*[1] upon which Blue Ridge Environmental Defense League has based its investigations and training program. The project's Quality Assurance Officer is responsible for any corrective action.

[1] Sergey Pachencko (SSGR), Norm Buske (TRAC), Lucy Henry and Do Lee (ISAR), *A Citizens Guide to Monitor Radioactivity Around the Energy Department's Nuclear Facilities*, May 2005. (included in Sampling Team field kit)

B-5

B-5. Quality Control Requirements

- Identifies QC procedures and frequency for each sampling event, analysis, or measurement technique, as well as associated acceptance criteria and corrective actions
- References procedures and provides equations for calculating QC statistics including bias/ accuracy, precision - specifies acceptance criteria for completeness, comparability and representativeness.

The frequency of sampling events and respective analyses, bias/accuracy, criteria for completeness, comparability and representativeness are to be determined after the initial data survey is completed and under the guidance of the Project Manager and Quality Assurance Officer.

B-6

B-6. Instrument/Equipment Testing, Inspection and Maintenance Requirements

- Identifies acceptance testing of sampling and measurement systems
- Describes equipment preventive and corrective maintenance
- Summarizes availability and location of spare parts

The testing of sampling and measurement equipment and corrective and preventive maintenance will be done by Team Captains at the outset of each data gathering event. Maintenance will include inspection and cleaning of the Geiger counter and calibration with a known source.

B-7

B-7. Instrument Calibration and Frequency

- Identifies equipment needing calibration and frequency for such calibration
- Summarizes required calibration standards for equipment
- Cites calibration records and the manner traceable to equipment

To make accurate and reliable readings, the Geiger counter must be calibrated monthly and whenever there is a high result or any unusual reading. (It is not the Geiger-Muller tube that needs calibration, but the circuits around it.) Using known source potassium-40, for which the exact level of radioactivity is known, place the Geiger counter near the source making sure the Geiger-Muller tube window is facing the material directly. Read and record the result of the measurement on the Geiger counter. Compare the reading with the number for the known source. If they match, the Geiger counter is calibrated. If not, adjust the Geiger counter's circuit until the exact reading for the known source is reached to ensure the Geiger counter is calibrated and ready.

B-8

B-8. Inspection/Acceptance Requirements for Supplies and Consumables

- Provides a list of the supplies and consumables
- Identifies the individuals responsible for inspecting supplies and consumables to ensure compliance with requirements

Consumable supplies include aluminum foil, Ziploc® bags, filters and potassium chloride; The Project Manager will ensure these materials are in good supply.

B-9

B-9. Data Acquisition Requirements for Non-Direct Measurements

- Identifies type of data needed from non-measurement sources (e.g., computer databases, literature searches, models, etc.) and provides the acceptance criteria for using this information
- Describes the limitations of this information and specifies where and when it cannot be used
- Documents the rationale for original collection of data and its relevance to the project

The need for any non-direct measurements will be determined after the initial data gathering surveys are completed.

B-10

B-10. Data Management

- Describes record/data keeping, storage and retrieval policies/requirements for organization/project
- Provides attachments to this Quality Assurance Protocols and Procedures (QAPP) manual containing SOPs, Checklists, Analytical Methodologies, etc.
- Describes data handling equipment and procedures used to process, compile and analyze data (e.g., computer hardware and software) – identifies the type of software used, such as GeigerGraph®, Observer, Excel, Statistical, Data Validation, etc.

B-10.1

B-10.1. Data keeping, storage and retrieval

The records compiled during field data collection will be the responsibility of each team Captain. It is important that all log entries and data collected be accurate. All data and records will be turned over to the Project Manager upon completion of testing in an area. Questions concerning logs, data accumulation and assimilation will be addressed to the Project Manager. Any problems or questions concerning data collection or procedures that cannot be resolved by the Project Manager must be referred to the BREDL Quality Assurance Officer, Lou Zeller.

B-10.2

B-10.2. Standard Operating Procedures (SOP)

Attached to this QAPP manual is the *Citizen's Guide to Monitor Radioactivity*, which provides basic analytical methodology and other guidance for the project. In addition to the Citizen's Guide, this "BEST/MATRR Procedures Manual" also serves as part the Standard Operating Procedures (SOP).

B-10.3

B-10.3. Data handling equipment and processors

The information collected with the Geiger counter during the project surveying and sampling will be compiled using GeigerGraph® software for Windows. A data cable with a 3.5mm stereo plug connects the Geiger counter via a USB-adapted PC laptop computer. The count data is recorded on an internal spreadsheet along with notes for analysis. Also, radiation data may be monitored with radiation maps and graphs.

Manual hand written data log information is to be maintained by Team Captains and converted to informational spreadsheets where applicable. Project Managers are responsible for the completeness of this data. It is crucial that a free flowing line of communications exists between Team Captains and Project Manager(s).

C

C. Assessments, Response Actions, Reports and Audits

Assessments, Audits, Reports and Response Actions are to be determined by the Quality Assurance (QA) Officer and the Project Manager. Problems in the testing program are to be conveyed to the Project Manager. The Project Manager is responsible for communicating problems to the Quality Assurance Officer if there is a problem which cannot be resolved by the Project Manager.

Reports and data are to be submitted to the Project Manager from the Team Captain weekly. After review, final area reports are to be submitted to the BREDL QA Officer by the Project Manager.

Audits of testing methodology and data collection are to be performed per instruction from the BREDL QA Manager.

Appendix

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Appendix-2

2. Data Log Sample Requirements

DATE /TIME - Mth/Day/Year + Hour/Min + AM or PM + EST or CST
AREA LOCATION - Nuclear Facility - GPS Info - Landmarks and/or Measured Location
DATA - CPM or Sievert Count (Downstream + Non-Downstream, Downwind + Non-Downwind)
NOTES - Team Name - Team Members Present - Wind Direction (i.e., NW to SE) - Conditions

3. Equipment List

- A concerned BEST member who maintains a sensible, safe operations attitude and behavior

FIELD KIT CHECKLIST:

- Radiation Detection Procedures Manual and the *Citizens Guide to Monitor Radioactivity*
- Geiger Counter (Geiger-Müller particle detector) and users manual
- Laptop PC computer with installed software
- GPS device (and users manual) and county map
- Camera (and users manual)
- Field notebook
- Pencils & Pens
- Zip-loc® bags & garden spade
- Back-up Battery(s)

LABORATORY CHECKLIST:

- Laboratory notebook
- Rechargeable Cordless Handheld Vacuum
- Specimen drying oven
- Nfoils-jig™
- Weight scales
- Timepiece
- Aluminum foil
- Filters and lab ware
- Potassium chloride, 500 grams
- Potassium-40 for Geiger Counter calibrations
- Individual and Equipment Protective Gear - as needed

4. Units of Radiation Dose Examples and Unit Symbol Conversion Factors

100.0000 rem =	100000.0 mrem =	**1 Sv** =	1.000000 Sv =	1000.000 mSv =	1000000 µSv
1.0000 rem =	1000.0 mrem =	**1 rem** =	0.010000 Sv =	10.000 mSv =	10000 µSv
0.1000 rem =	100.0 mrem =	**1 mSv** =	0.001000 Sv =	1.000 mSv =	1000 µSv
0.0010 rem =	1.0 mrem =	**1 mrem** =	0.000010 Sv =	0.010 mSv =	10 µSv
0.0001 rem =	0.1 mrem =	**1 µSv** =	0.000001 Sv =	0.001 mSv =	1 µSv

TABLE 1 Units of Dose

Unit[a]	Symbol	Conversion Factors
Becquerel (SI)	Bq	1 disintegration/s = 2.7×10^{-11} Ci
Curie	Ci	3.7×10^{10} disintegrations/s = 3.7×10^{10} Bq
Gray (SI)	Gy	1 J/kg = 100 rads
Rad	rad	0.01 Gy = 100 erg/g
Sievert (SI)	Sv	1 J/kg = 100 rem
Rem	rem	0.01 Sv

NOTE: Equivalent dose equals absorbed dose times *Q* (quality factor). Gray is the special name of the unit (J/kg) to be used with absorbed dose; sievert is the special name of the unit (J/kg) to be used with equivalent dose.

[a]International Units are designated SI.

Appendix-5

5. Radiation Dose Limit Standards

Radiation dose standards are set by both the US Nuclear Regulatory Commission and the US Environmental Protection Agency. EPA standards for air and water are lower than NRC Regulatory Standards. An excellent "Ionizing Radiation Dose Ranges" chart is included in the Radiation Detection Field Kit with REM diagram on one side and Sievert on the other side.

The **Radiation DOSE LIMIT Standards** are:

- General Public - **0.002 rem/hr or 2 mrem/hr (0.02 mSv/hr) in an HOUR** (NRC)
- General Public - **0.1 rem/yr or 100 mrem/yr (1mSv/yr) in a calendar YEAR** (NRC)
- General Public - **10 mrem/yr or 0.01 rem/yr (0.1 mSv/yr)** (EPA, air pathway)
- General Public - **4 mrem/yr or 0.004 rem/yr (0.04 mSv/yr)** (EPA, public drinking water systems dose limit)

Appendix-6

6. EPA Dose / Radiation Sickness Symptoms

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhea	
100	hemorrhage	
400	possible death	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	and death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness;	minutes
	and death	hours to days

7. Radionuclide Decay Rates

The radionuclide isotopes decay at varying rates, called a "Half-life," and generally the correlation is radiation remaining dangerous for about ten times the Half-life. For instance, Cesium-137 with a Half-life of 30 years would remain toxic to humans for about 300 years. The following are some radionuclide examples:

Radionuclide	Half-life	Approximate Radioactivity Duration
• Cesium-134	2.06 days half-life	3 weeks
• Iodine-131	8.0 days	80 days
• Strontium-89	50.5 days	505 days
• Tritium	12.5 years	125 years
• Strontium-90	28.7 years	287 years
• Cesium-137	30.1 years	301 years
• Plutonium-239	24,200 years	242 thousand years
• Iodine-129	15.7 million years	157 million years

For more information on nuclear power

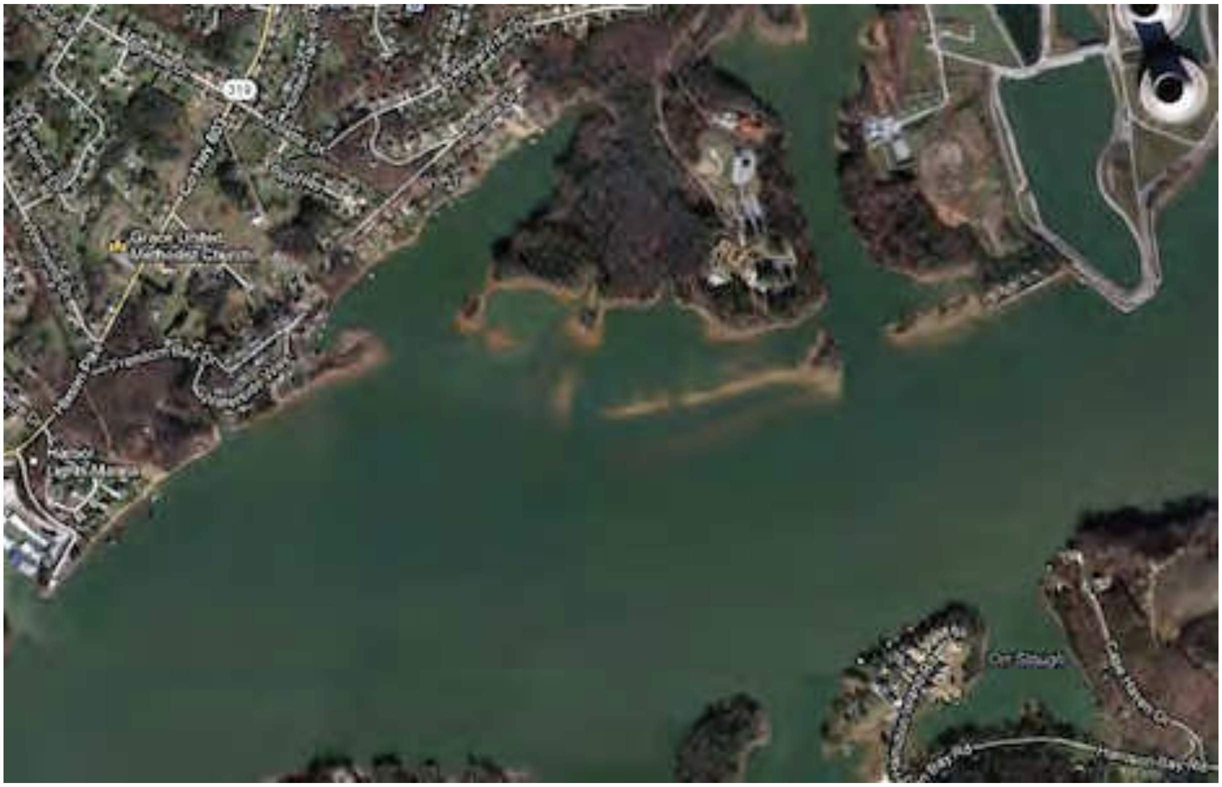
and radiation poisoning

visit the MATTR.org website.

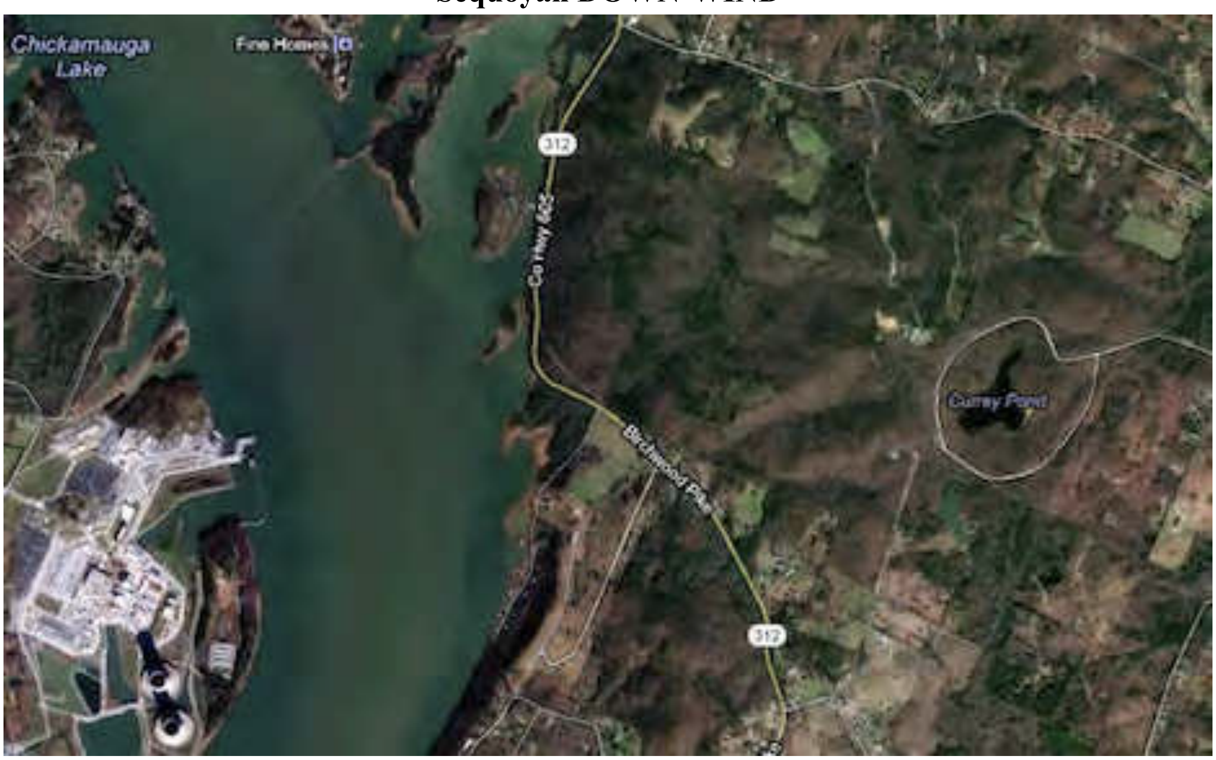
Browns Ferry DOWN-STREAM

Browns Ferry DOWN-WIND

Sequoyah DOWN-STREAM



Sequoyah DOWN-WIND



Watts Bar DOWN-STREAM

Watts Bar DOWN-WIND

NOTES

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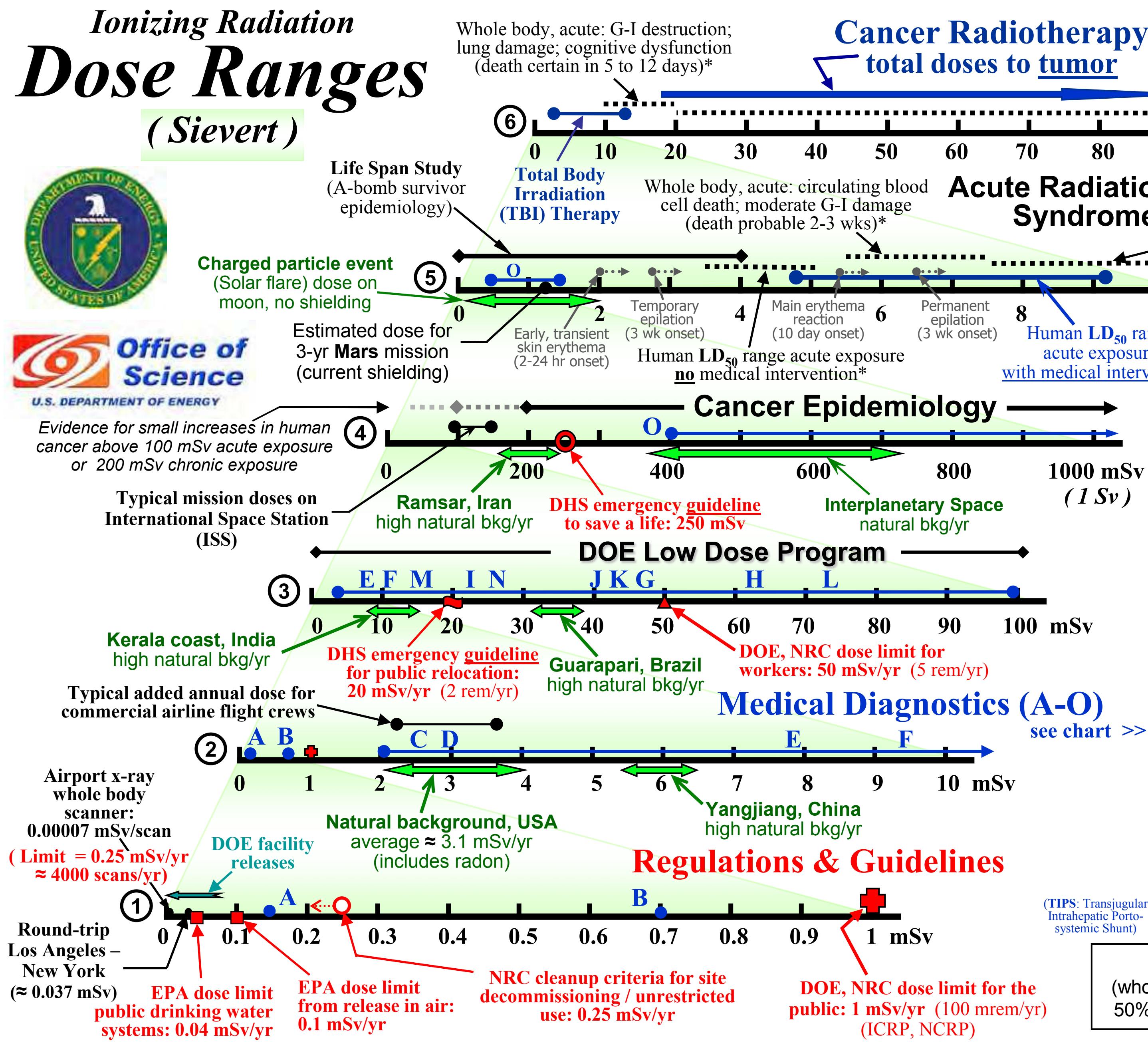


Medical Diagnostics mGy
(Estimated maximum organ dose)

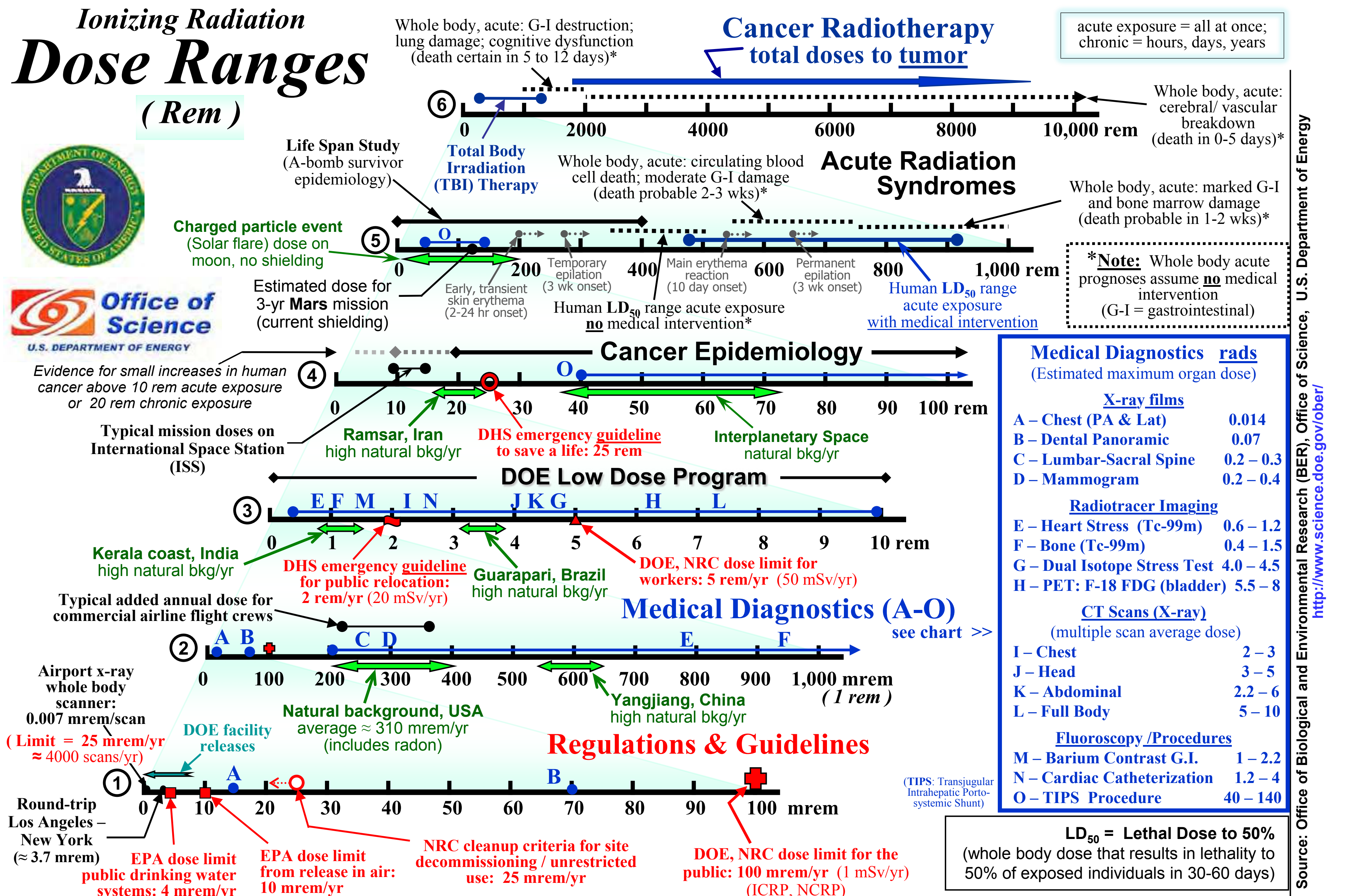
X-ray films	
A – Chest (PA & Lat)	0.14
B – Dental Panoramic	0.7
C – Lumbar-Sacral Spine	2 – 3
D – Mammogram	2 – 4
Radiotracer Imaging	
E – Heart Stress (Tc-99m)	6 – 12
F – Bone (Tc-99m)	4 – 15
G – Dual Isotope Stress Test	40 – 45
H – PET: F-18 FDG (bladder)	55 – 80
CT Scans (X-ray) (multiple scan average dose)	
I – Chest CT	20 – 30
J – Head CT	30 – 50
K – Abdominal CT	22 – 60
L – Full Body CT	50 – 100
Fluoroscopy/Procedures	
M – Barium Contrast G.I.	10 – 22
N – Cardiac Catheterization	12 – 40
O – TIPS Procedure	400 – 1400

LD_{50} = Lethal Dose to 50% (whole body dose that results in lethality to 50% of exposed individuals in 30-60 days)

Dose Equivalent: 1 Sievert = 100 rem = (absorbed dose x radiation quality)
Absorbed Dose: 1 Gray = 100 rad
1 Sv ≈ 1 Gy for x- and gamma-rays
("≈" stands for "approximately equal to")

NOTE: This chart was constructed with the intention of providing a simple, user-friendly, "order-of-magnitude" reference for radiation exposures of interest to scientists, managers, and the general public. In that spirit, most quantities are expressed as "dose equivalent" in the more commonly used radiation protection units, the rem and Sievert. Medical diagnostics are expressed as estimated maximum organ dose; as they are not in "effective dose" they do not imply an estimation of risk (no tissue weighting). Dose limits are in effective dose, but for most radiation types and energies the difference is numerically not significant within this context. It is acknowledged that the decision to use these units is a simplification, and does not address everyone's needs. (NRC = Nuclear Regulatory Commission; EPA = Environmental Protection Agency; DHS = Department of Homeland Security)

Chart compiled by NF Metting, Office of Science, DOE/BER. "Orders of Magnitude" revised June 2010
http://www.lowdose.energy.gov/



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Dose Equivalent: 100 rem = 1 Sievert
= (absorbed dose x radiation quality)
Absorbed Dose: 100 rad = 1 Gray
1 rem ≈ 1 rad for x- and gamma-rays
(" ≈ " stands for "approximately equal to")