Expansion and Upgrade of the RadNet Air Monitoring Network

Volume 2 of 2

Appendixes

Prepared for the
Radiation Advisory Committee
RadNet Review Panel
Science Advisory Board
U.S. Environmental Protection Agency

Prepared by the
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DISCLAIMER

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APPENDIX A

APPENDIX A: List of ERAMS/RadNet Stations by City

STATE	CITY	MEDIA	REGION
AL	Dothan	Drinking Water	4
	Montgomery	Air Particulates, Precipitation, Drinking Water, Milk	4
	Muscle Shoals	Drinking Water	4
	Scottsboro	Drinking Water	4
AK	Fairbanks	Air Particulates, Precipitation, Drinking Water	10
AZ	Phoenix	Air Particulates, Precipitation, Milk	9
AR	Little Rock	Air Particulates, Precipitation, Drinking Water, Milk	6
CA	Los Angeles	Air Particulates, Drinking Water, Milk	9
	Richmond	Air Particulates, Precipitation, Drinking Water	9
	Sacramento	Milk	9
	San Francisco	Air Particulates, Milk	9
CO	Denver	Air Particulates, Precipitation, Drinking Water	8
CT	Hartford	Air Particulates, Precipitation, Drinking Water, Milk	1
DE	Dover	Drinking Water, Milk	3
	Wilmington	Air Particulates, Precipitation	3
DC	Washington	Air Particulates	3
FL	Jacksonville	Air Particulates, Precipitation	4
	Miami	Air Particulates, Precipitation, Drinking Water	4
	Tampa	Drinking Water, Milk	4
GA	Atlanta	Air Particulates, Milk	4
	Baxley	Drinking Water	4
	Savannah	Drinking Water	4
HI	Honolulu	Air Particulates, Precipitation, Drinking Water, Milk	9
ID	Boise	Air Particulates, Precipitation, Drinking Water	10
	Idaho Falls	Air Particulates, Precipitation, Drinking Water	10
IL	Chicago	Air Particulates, Precipitation, Drinking Water	5
	Morris	Drinking Water	5
IN	Indianapolis	Air Particulates, Milk	5
IA	Cedar Rapids	Drinking Water	7
	Des Moines	Milk	7
	Iowa City	Air Particulates, Precipitation	7
KS	Kansas City	Air Particulates	7
	Topeka	Air Particulates, Precipitation, Drinking Water	7
	Wichita	Milk	7
KY	Louisville	Milk	4
LA	New Orleans	Drinking Water	6
ME	Augusta	Air Particulates, Precipitation, Drinking Water	1
	Portland	Milk	1
MD	Baltimore	Drinking Water, Milk	3
	Conowingo	Drinking Water	3
MA	Boston	Air Particulates, Precipitation, Milk	1
	Lawrence	Drinking Water	1
MI	Detroit	Air Particulates, Drinking Water, Milk	5
	Grand Rapids	Drinking Water, Milk	5
	Lansing	Air Particulates, Precipitation	5
MN	Minneapolis	Air Particulates, Precipitation, Drinking Water	5
	Red Wing	Drinking Water	5
	Welch	Air Particulates, Precipitation	5

STATE	CITY	MEDIA	REGION
MS	Jackson	Air Particulates, Drinking Water	4
	Port Gibson	Drinking Water	4
MO	Jefferson City	Drinking Water, Milk	7
MT	Helena	Drinking Water	8
NE	Lincoln	Drinking Water	7
NV	Las Vegas	Air Particulates, Precipitation, Drinking Water, Milk	9
NH	Concord	Air Particulates, Precipitation, Drinking Water	1
NJ	Trenton	Air Particulates, Drinking Water, Milk	2
	Waretown	Drinking Water	2
NM	Albuquerque	Milk	6
	Santa Fe	Air Particulates, Precipitation, Drinking Water	6
NY	Albany	Air Particulates, Precipitation, Drinking Water	2
	Buffalo	Milk	2
	New York City	Air Particulates, Drinking Water	2
	Niagara Falls	Drinking Water	2
	Syracuse	Air Particulates, Drinking Water, Milk	2
	Yaphank	Air Particulates, Precipitation	2
NC	Charlotte	Air Particulates, Precipitation, Drinking Water	4
	Wilmington	Air Particulates, Precipitation	4
	Raleigh	Drinking Water	4
ND	Bismarck	Air Particulates, Precipitation, Drinking Water	8
OH	Cincinnati	Drinking Water, Milk	5
	Cleveland	Milk	5
	Columbus	Drinking Water	5
	East Liverpool	Drinking Water	5
	Painesville	Air Particulates, Precipitation, Drinking Water	5
	Ross	Air Particulates	5
	Toledo	Drinking Water	5
OK	Oklahoma City	Drinking Water	6
OR	Portland	Air Particulates, Precipitation, Drinking Water, Milk	10
PA	Columbia	Drinking Water	3
	Harrisburg	Air Particulates, Precipitation, Drinking Water	3
	Philadelphia	Air Particulates, Drinking Water (3 sites), Milk	3
	Pittsburgh	Air Particulates, Drinking Water, Milk	3
RI	Providence	Drinking Water	1
SC	Barnwell	Air Particulates, Precipitation, Drinking Water	4
	Columbia	Air Particulates, Precipitation, Drinking Water	4
	Jenkinsville	Drinking Water	4
	Seneca	Drinking Water	4
SD	Pierre	Air Particulates	8
	Rapid City	Milk	8
TN	Chattanooga	Drinking Water, Milk	4
	Knoxville	Air Particulates, Precipitation, Drinking Water, Milk	4
	Memphis	Milk	4
	Nashville	Air Particulates, Precipitation	4
	Oak Ridge	Air Particulates (5 sites), Precipitation, Drinking Water	4
TX	Austin	Air Particulates, Precipitation, Drinking Water	6
	Dallas	Air Particulates, Precipitation	6
	El Paso	Air Particulates	6
	Ft. Worth	Milk	6
UT	Salt Lake City	Air Particulates, Precipitation	8
VT	Montpelier	Milk	1

STATE	CITY	MEDIA	REGION
VA	Ashland	Drinking Water	3
	Lynchburg	Air Particulates, Precipitation, Drinking Water	3
	Norfolk	Milk	3
WA	Olympia	Air Particulates, Precipitation	10
	Richland	Drinking Water	10
	Seattle	Drinking Water	10
	Spokane	Air Particulates, Milk	10
	Tacoma	Milk	10
WV	Charleston	Milk	3
WI	Genoa	Drinking Water	5
	Madison	Drinking Water	5

APPENDIX B

APPENDIX B: Evolution of ERAMS/RadNet

The EPA's radiological air particulate monitoring program evolved with changing times and needs. The program was originally designed to monitor for fallout from atmospheric nuclear weapons tests. As these atmospheric tests reduced in frequency due to agreements between the testing nations, the system was used to measure ambient radioactive air particulate levels and to be available to respond to radiological emergencies, such as Three Mile Island (TMI) and Chernobyl. In the 1990s, plans began to alter the mission of the program because radiological emergencies were not occurring frequently enough to warrant expansion of the program as it was configured at that time. The system did respond to several smaller events in the late 1990s and early 2000s.

The events of September 11, 2001, significantly changed the urgency and the focus of the system. The system was needed as a national emergency response network to provide data across the nation for potential radiological incidents. The program is now evolving to assist homeland security in the radiological monitoring for the nation on a large-scale basis.

Original Focus, Fallout Monitoring of the 1960s

As stated previously, the ERAMS air monitoring network was originally designed to monitor fallout from nuclear weapon tests. EPA inherited the system after atmospheric nuclear weapon testing had been banned.

Nuclear weapon tests produce a wide range of radioactive products. Many of these become and remain airborne for a relatively long time. Since many of these products are beta-emitting nuclides, the beta concentration of air particulate samples was chosen for measurement because beta concentration provided a quick and easy determination of abnormal radioactivity levels from airborne particulates following a nuclear weapon test.

As designed, the system collected airborne particulates on a filter. At the end of a sampling period, the filter was removed and replaced with a new filter. After approximately a five hour delay to allow radon progeny to decay, the filter was screened by the operator in the field for beta particle emissions. Filters were then sent to a fixed laboratory for a more precise, laboratory beta analysis and other analyses as needed.

Figure B.1 shows how the system detected beta emitters following the heavy atmospheric nuclear weapon testing of the early 1960s.

China and France were the only nations to conduct atmospheric tests after 1972. This allowed the system to respond more to an individual test than to the multiple atmospheric tests of the 1960s. Also, gamma spectrometric capabilities were becoming available in the 1970s as well. These gamma spectrometric detection systems were able to approximate concentrations for certain gamma-emitting radionuclides. Thus, along with gross beta concentrations that could be used for screening and comparison purposes, the gamma spectrometry conducted in the laboratory helped to confirm the presence of individual nuclides.

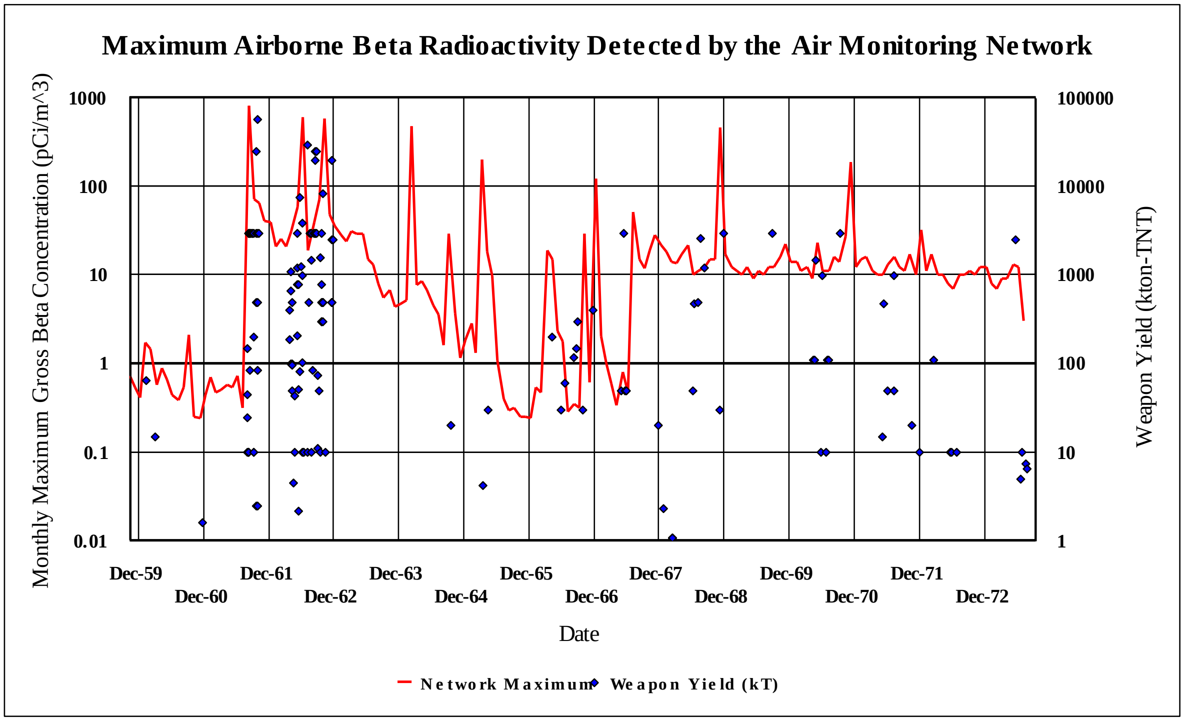


Fig. B.1. ERAMS detection of fallout from nuclear testing.

In the 1970s, the French tests were conducted in the southern hemisphere (Muruora Island, approximately 20° S latitude). A review of data collected in the 1960s at the 80th Meridian from 53° S to 77° N shows that transport of contamination across the equator typically is delayed and reduced in magnitude in comparison to contamination spread within the latitude range of the test. For that reason, it was not unexpected that the French tests had little impact on the United States. Figure B.2 shows the beta concentrations based on latitude as well as the latitude and magnitude of the test yield.

The system was expected to see an impact from the Chinese tests, because they were conducted at Lop Nor, which is approximately 41° N latitude, if the transport conditions were correct. Some examples of the impact of the Chinese weapon tests of the 1970s are shown following the latitude effect comparison on the following pages.

As can be seen in Fig. B.3, the maximum beta levels did not increase significantly from the French tests conducted in the southern hemisphere, but they did increase much more for the Chinese tests, which were performed at approximately 41.5° N latitude. Figure B.4 illustrates the value of gamma spectrometry along with the gross beta from the <20 kiloton test conducted by the Chinese on September 17, 1977. The ability to determine nuclide identity and concentration was a major step in being able to predict the potential health effects of these tests.

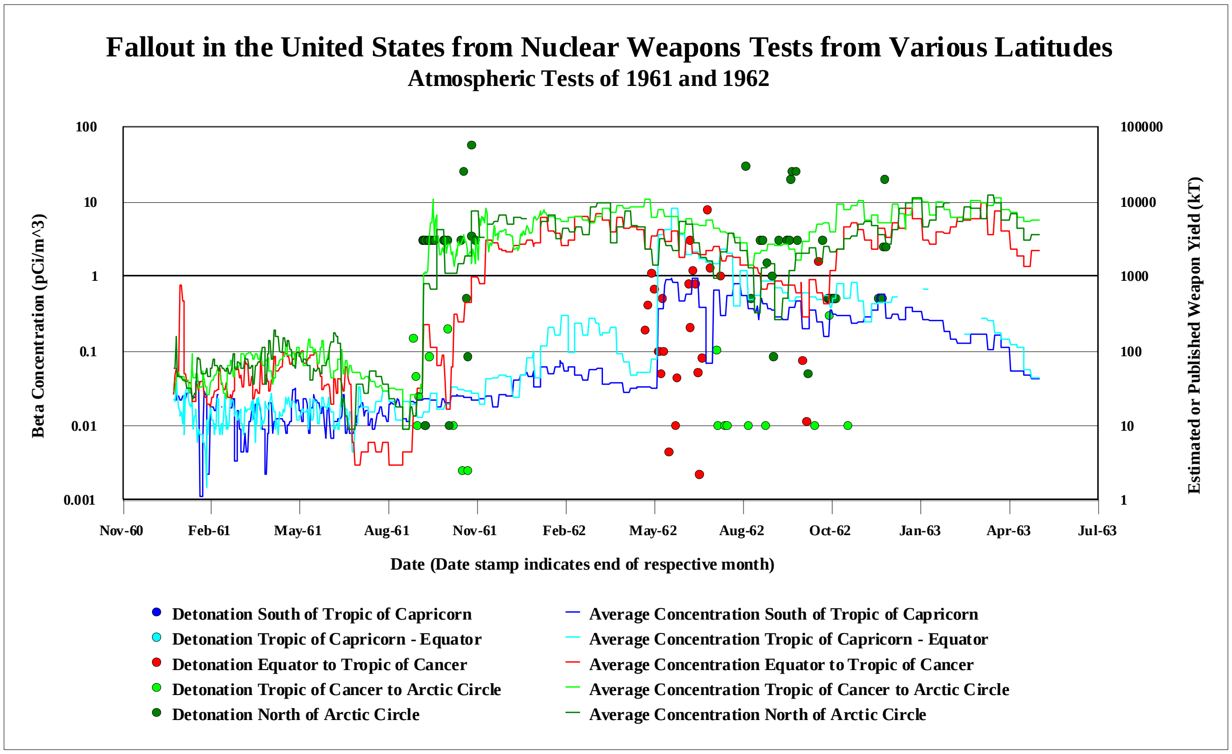


Fig. B.2. Beta concentrations based on latitude and magnitude of the test yield.

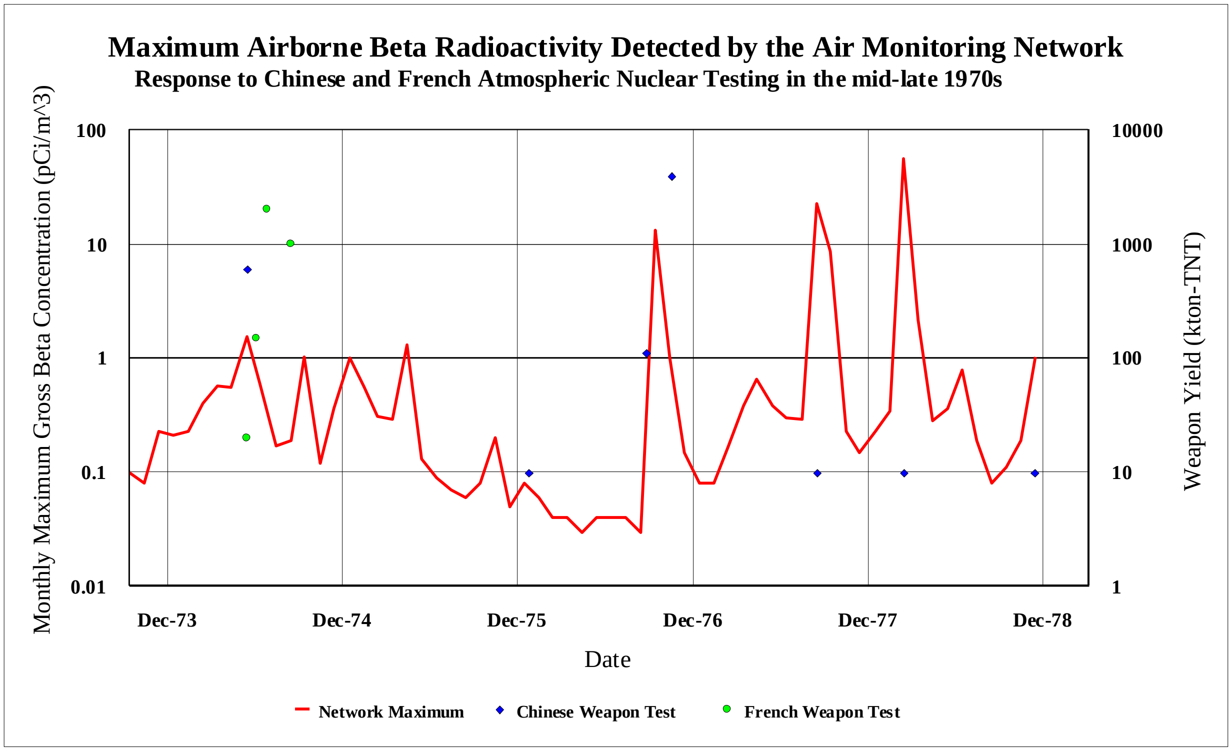


Fig. B.3. ERAMS beta-particle data from Chinese and French nuclear tests.

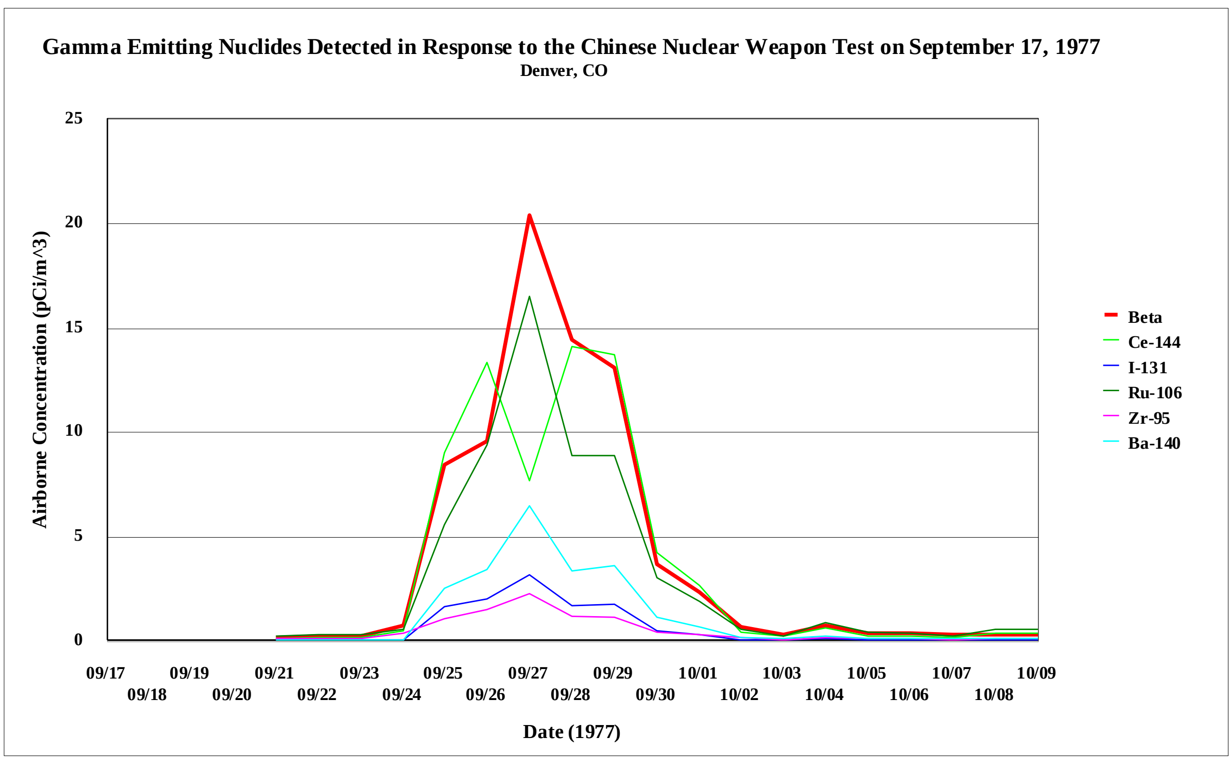


Fig. B.4. ERAMS gamma spectrometry data from Chinese nuclear testing.

Change in Focus, Nuclear Accidents

Since atmospheric nuclear weapon testing was significantly reduced in the 1970s, and essentially eliminated during and after the 1980s, the ERAMS air monitoring network essentially monitored “background” airborne particulate concentrations. The system also responded to two nuclear reactor accidents in the post-atmospheric nuclear weapon testing era. The first was the TMI nuclear reactor accident in 1979, and the second was the Chernobyl nuclear reactor accident in 1986. The system had not been designed for accident monitoring, but proved to be useful in responding to accidents that provided similar potential contamination to nuclear weapon tests.

On March 28, 1979, the reactor accident at TMI occurred. Although approximately 50% of the core melted, very little of the radioactive material associated with the core was released. Most of the material released was in the gaseous form, although some particulates were also released. The air monitoring network had an air particle detector in Harrisburg, PA, which is very close to TMI. This monitor could have detected increased particulates had they been transported from TMI to Harrisburg, but had no capability to detect the radioactive gases released. No noticeable increases in beta levels were noted (Fig.B.5).

Early in the morning on April 26, 1986 Chernobyl time (April 25, 1986, at approximately 6:20 PM EDT), Reactor 4 at the Chernobyl Nuclear Power Plant sustained the worst reactor accident in the history of nuclear power. Estimates show that over 100 million Curies of radioactive material were released to the environment as a result of this accident.

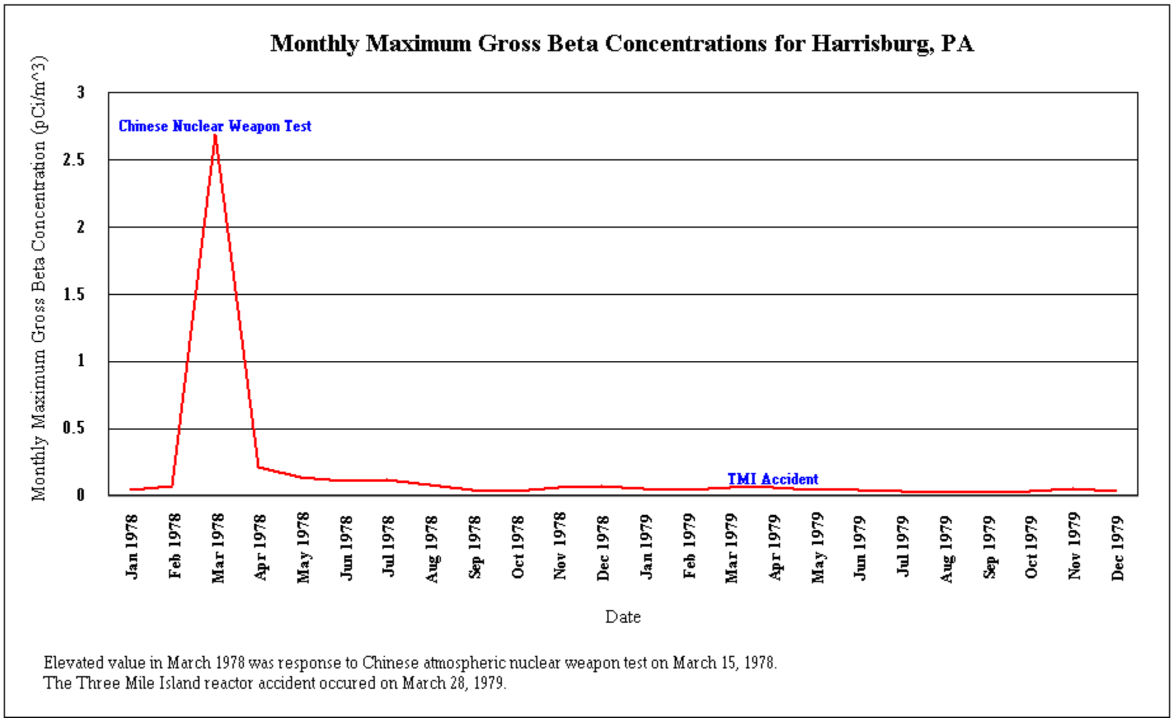


Fig. B.5. ERAMS beta radiation data at Harrisburg, PA, from TMI.

ERAMS was placed into emergency sampling mode following notification that there had been a reactor accident in the Soviet Union. Air samples were sent daily to the Eastern Environmental Radiation Facility (now NAREL) for analysis. Most stations showed increases in activity on the filters as a result of the Chernobyl accident. The filters were also analyzed for fission and activation products by gamma spectrometry. Some examples of the results are shown below (Fig. B.6).

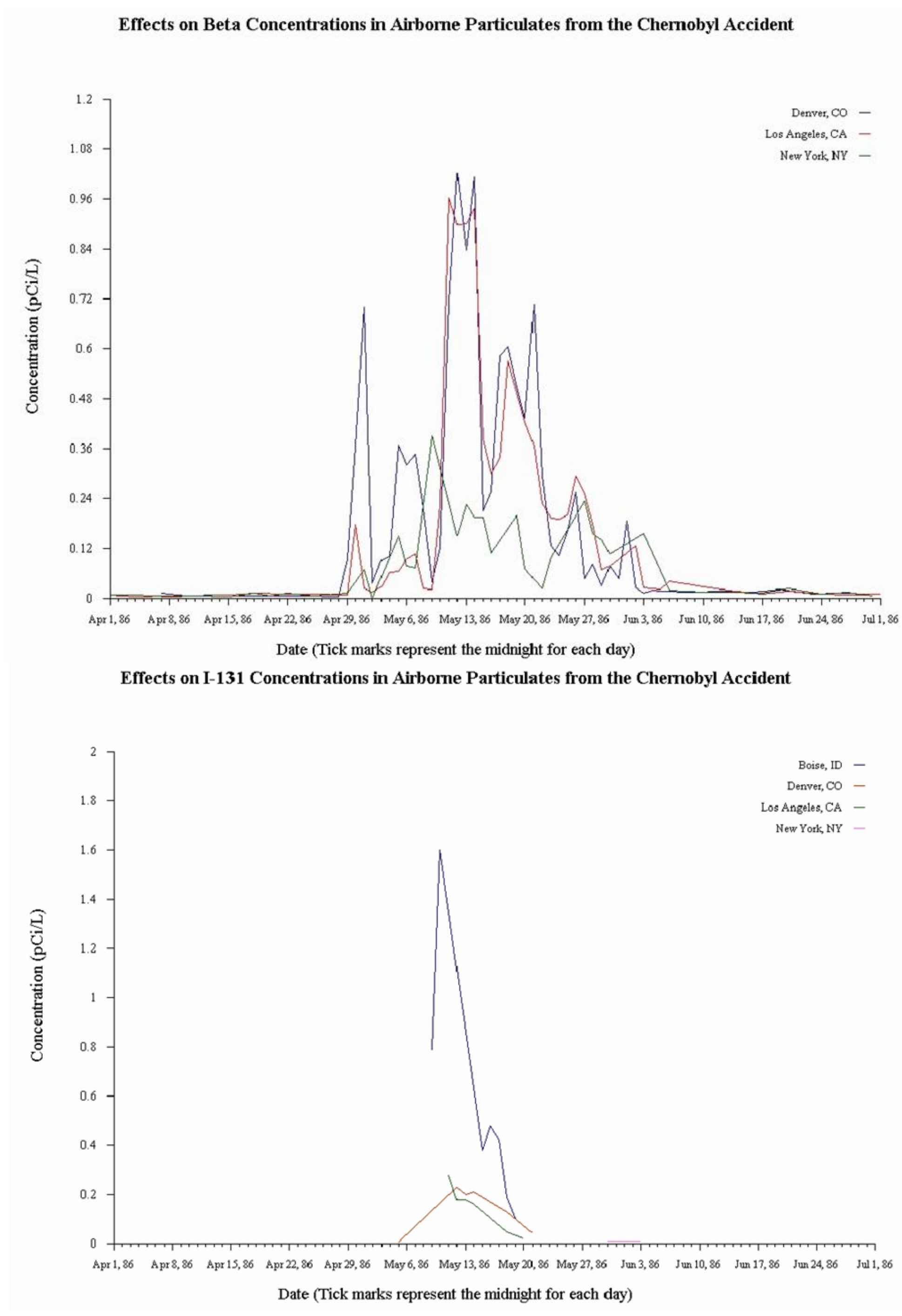
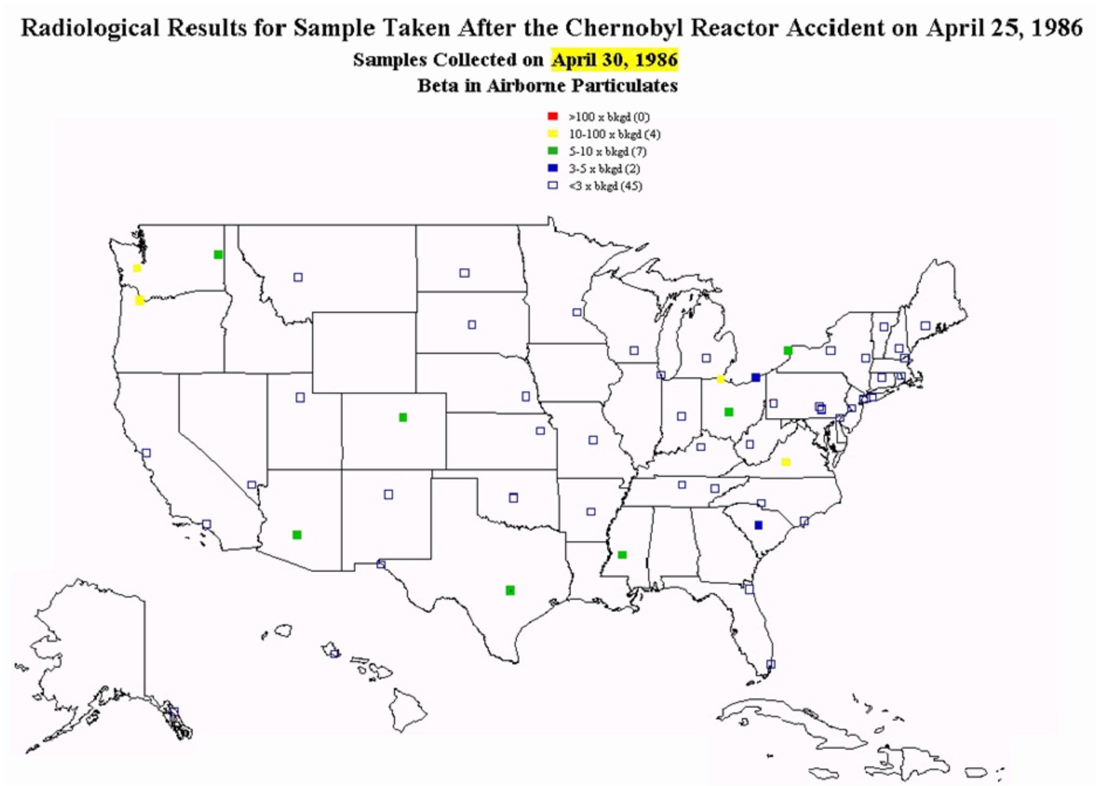


Fig. B.6. Chernobyl accident impacts on Iodine-131 and Beta concentrations.



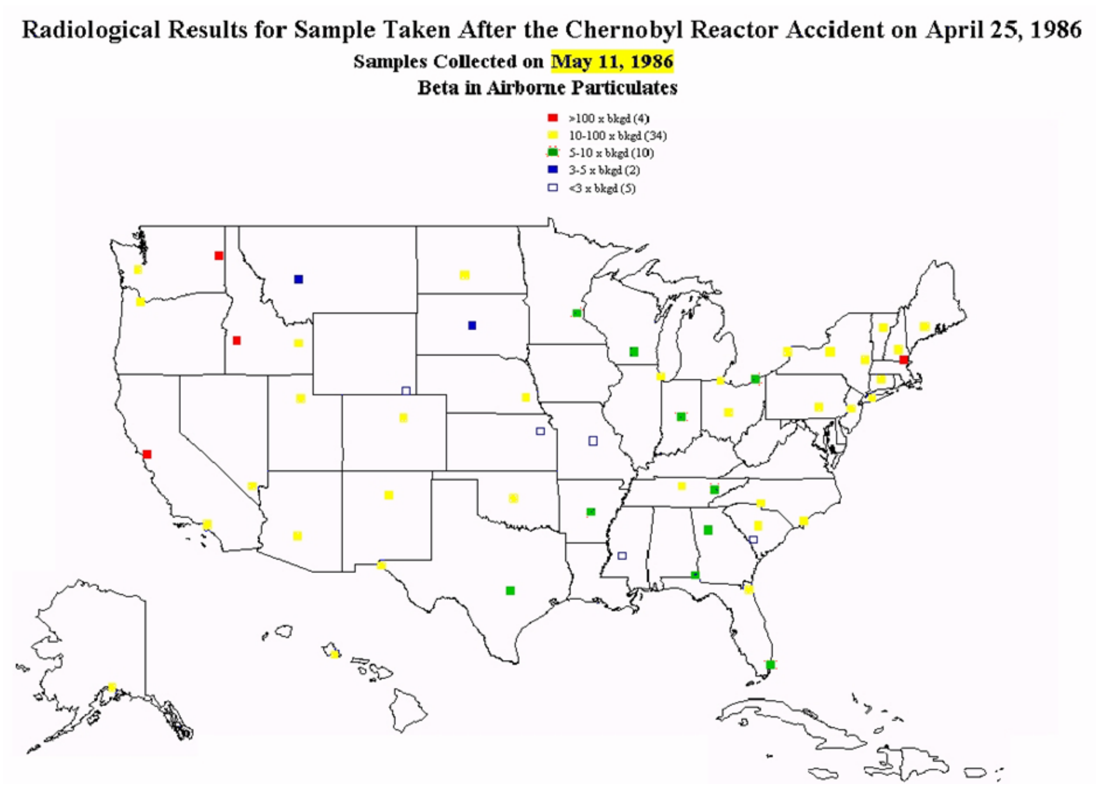


Fig. B.7. April and May 1986 post-Chernobyl radiological results.

Responses in the 1990s and Later

In the late 1990s and early 2000s, several minor events occurred for which the ERAMS air monitoring network was not well designed. The first occurred on September 30, 1999, when a criticality accident occurred in Tokaimura, Japan. Criticality continued off and on for about 20 hours. Very few particulates are believed to have escaped the containment building, but some contaminated noble gases may have been released to the environment. The activity of the gases was such that it was not believed there would be significant effect on the United States. However, for confirmatory purposes, ERAMS was placed in emergency operation mode. The system did not detect elevated levels of anthropogenic radionuclides, but a potential flaw in the system was noted because the system was not able to monitor for gamma radiation or for gases, which would have been the most likely exposure pathways for the United States during this accident.

The second was two uncontrolled fire incidents, one near DOE's Los Alamos National Laboratory and the other near DOE's Hanford Reservation. In these incidents, there were numerous radionuclides that may have been released, but neither the specific radionuclides nor their concentration ratios could be determined. These incidents provided the ERAMS air monitoring network with a new challenge: responding to radiological incidents with uncertain radionuclides released. These incidents also spawned the idea that a mobile air monitoring program was also needed to complement the fixed air monitoring network. In May 2000, a controlled burn in northwestern New Mexico raged out of control. The fire eventually burned areas of the Los Alamos National Laboratory. Although the fixed air monitoring network was not activated, portable air monitors were deployed by the EPA Radiological Emergency Response Team at the request of EPA Region 6. These air monitors had to be manually serviced at least daily, and the filters had to be analyzed after replacement, causing delays in obtaining data on potential contamination levels.

In July 2000, a fire in south-central Washington State was started after an automobile accident. The fire spread in the arid climate, and part of the Hanford Reservation caught fire. Although the high level wastes stored at Hanford were not threatened, potentially contaminated areas were threatened. ERAMS was not placed in emergency operational status, although some stations around that area were switched to daily operations (e.g., Spokane, WA, and Boise, ID). The Radiological Emergency Response Teams from the NAREL and R&IE responded to an area surrounding the Reservation to conduct additional air monitoring, similar to the Los Alamos response, except that no mobile laboratory support was available, meaning even longer times between sampling and data availability.

Several lessons were learned from the Los Alamos and Hanford fires. First, emergency response personnel needed better/more monitoring equipment to monitor a large area during a potential long-term radiological release, such as a fire. In response to this, ORIA developed the concept of the deployable component of ERAMS. Also, one of the potential radionuclides of concern was plutonium. However, the ERAMS system was not capable of routinely monitoring for alpha-emitting nuclides in the field screening process or in the laboratory. Finally, the additional samples from the ERAMS stations operating in emergency mode, as well as the numerous samples from the RERT, were all sent to EPA fixed laboratories, where rapid analysis was required due to the need to provide timely information concerning potential spread of plutonium and strontium contamination. This event emphasized the importance of maintaining a well manned fixed laboratory which is ready to respond to numerous samples requiring various analyses in a timely manner during an emergency.

Change in Focus, Nuclear Incidents, and Homeland Security

In 2001, the tragedies of September 11 provided another area for focus for the ERAMS air monitoring network. Terrorists attacked the United States on that day using commercial jet airliners. The result in New York City was a very large fire and dispersion of materials. Had the terrorists possessed a large radioactive source, the contents would probably have been released into the atmosphere.

As a result of these incidents, it was determined that the ERAMS air monitoring network needed to change from one of an event monitor to an accident and incident monitoring network. This change in focus would mainly include the need to be able to more rapidly provide data to decision makers, the need to be able to identify and quantify radionuclides, and the need to monitor many more locations because there are essentially an infinite number of possible source locations when considering terrorist attacks.

The event in New York City was very close to the ERAMS monitoring station. However, due to access restrictions and other issues associated with the cleanup from this event, the New York station operator was unable to change the filter for two weeks. This showed that, if possible, the system needed to be able to operate, monitor, and transmit data without operator action. The New York City monitor appears to have lost power for a portion of the two week period as well based on reduced total flow rate for that sample. It is important to maintain power to the station in an emergency, and methods to maintain alternate sources of power (and communications) are being planned for the system.

APPENDIX C

APPENDIX C: Other Radiation Monitoring Systems in the United States

Summary of Selected Radiological Environmental Monitoring Activities

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INTRODUCTION

This report describes a sample of radiological environmental monitoring activities being conducted by the United States and other countries and entities around the world. These monitoring activities represent long-term, sustained efforts to monitor radiation in both the ambient environment and specific local environments. Short-term monitoring programs do not fall within the scope of this report. The report focuses in particular on monitoring activities that utilize laboratory or real-time analysis of ambient air particulates, as this parallels the current RadNet monitoring upgrade. Other media and systems, including air emissions (e.g., at stacks), drinking water, milk, precipitation, and surface water, are addressed only briefly for most systems (depending on availability of information). There is also emphasis placed on those monitoring programs developed and maintained by local, State, or Federal governmental agencies; however, some monitoring administered by citizens' groups and non-governmental organizations are also briefly noted.

Section 2 of this report describes in more detail the approach used to identify and research the various radiological environmental monitoring activities. The radiation monitoring activities are organized into four sections according to the scope of their networks. That is, Section 3 describes site-specific systems, Section 4 describes State and local (sub-State) systems, Section 5 describes country-level systems, and Section 6 describes multi-country and global monitoring systems. Section 7 presents a summary of these networks. Appendix A contains an initial list of 35 selected monitoring systems from which a subset of systems were selected for more detailed review in the body of this report. Appendix B contains partial reviews for systems initially selected for detailed review but for which the detailed review was terminated and/or the data were not verified, for reasons such as a finding that the systems was vastly similar to another systems undergoing detailed review.

APPROACH

ICF conducted the following activities for this report:

1. Develop a form to complete for each radiological environmental monitoring system to examine;
2. Develop a list of candidate monitoring systems to examine;
3. Screen out irrelevant or highly redundant systems;
4. Conduct internet searches and contact relevant organizations to obtain information for completing the form for each screened system; and
5. Summarize systems and complete this report.

For step 1, develop a form to complete, the following criteria were included in a form to be completed for each system selected for review.

General:

1. Title of monitoring activity
2. Purpose of the monitoring activity
3. Entity/Agency that sponsors the monitoring activity
4. Organizations that perform the monitoring
5. General scope and content of any routine or special data reports or other data dissemination methods
6. Website
7. A point of contact for the organization conducting the monitoring activity for obtaining further information
8. Other

Sampling approach:

9. Environmental media collected and sampled
10. Radiation and/or radionuclides measured
11. Equipment used
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made
13. Number of monitoring stations
14. Location and size of area sampled by network
15. Local-scale siting criteria (e.g., height above objects)
16. Large-scale siting criteria (e.g., density of network stations)

If media samples are collected, then briefly describe the following:

17. Frequency and numbers of samples collected
18. Personnel utilized for sample collection
19. Analysis performed on each type of sample media
20. Analytical methods used
21. Laboratories performing the analysis
22. Data quality control methods

If near or actual real-time measurements are made, then briefly describe the following:

23. Frequency of measurements
24. How such measurements are reported and to whom
25. Extent to which such measurements are aggregated and analyzed
26. Methods used to either aggregate or analyze such information
27. Data quality control methods

This list was presented to EPA for review and approval.

For step 2, develop a list of candidate systems, the primary data sources used were:

1. "Other Ambient Monitoring Systems and Information," compiled by ICF Consulting and described at http://www.epa.gov/enviro/html/erams/related.html;

2. "List of Relevant State and Tribal Entities", memo from Jim Laurenson and Colin Cameron, ICF Consulting, to Jackie Dziuban, U.S. EPA, December 1, 2003;

3. "Radiation Monitoring Data and Data Quality", report by Trinity Engineering Associates for U.S. EPA, September 30, 2002; and

4. Limited internet searches and interviews.

The first three sources were expected to contain the majority of the systems of interest. To confirm this and to identify systems that have become available in subsequent years, we also conducted a brief internet (Google) and other (e.g., government database) search using combinations of the following search terms: radiation, monitoring, network, ambient, environmental, real time, continuous, and ERAMS (and other high profile monitoring systems, to identify systems based on their cross-referencing to the high profile systems). The result of this initial compilation was dozens of radiological environmental monitoring systems. After screening out the clearly irrelevant systems and adding countries identified by EPA as possibly having relevant systems (i.e., Canada, Mexico, Germany, Japan, France, Russia, the Ukraine and Finland), we developed the candidate list of 35 monitoring networks shown in Appendix A. We then attempted to obtain basic information on the sponsoring or managing organization for these systems, the type of system (e.g., air), the scope/size of the system, and the data source (i.e., URL). The systems were subsequently organized into four categories:

1. *Site-specific systems*, which monitor both current radiation-related operations (e.g., weapons research) and sites where past activities have left debris requiring clean-up or remediation;

2. *State and local (sub-State) systems*, which focus on larger community and regional monitoring of multiple sites (linked or reported together) or the ambient environment;

3. *Country-level systems*, which are generally larger scale systems similar to RadNet; and

4. *Multi-country and global systems*, which compile and analyze data from monitoring stations located in a number of different nations or around the world.

This list, which is shown in Appendix A, was presented to EPA for review and approval.

In step 3, screen out systems, we narrowed down list in Appendix A by excluding overlapping systems, systems for which little or no readily available information could be found, and systems meeting the criteria described in Section 1, Introduction (e.g., long-term, sustained efforts by government agencies). We also narrowed the list to be in line with available resources by selecting as representative a sample as possible for each of the following four categories of systems: site-specific; State and local (sub-State); country-level; and multi-country/global. The result of this screening was a subset of systems for further review, as indicated in the last column of Appendix A.

In step 4, obtain information and complete forms, we conducted the internet searches and interviews, obtained data from the relevant sources, and completed the form described above for each monitoring activity identified for detailed review in step 3 (to the extent possible). In most cases, only the air monitoring component of the system was described due to lack of readily available information on other components and the need to focus this effort on systems that are as similar as possible to the air component of RadNet. Also, some criteria could not be addressed for some systems or components, also due to lack of readily available information (represented by "--" in the forms below). Appendix B contains partial reviews for systems initially selected for detailed review but for which the detailed review was terminated for reasons such as a finding that the system was very similar to another system undergoing detailed review.

Step 5, summarize systems and develop report, involved compiling the information on the systems selected for detailed review into the following sections and concluding this report with a discussion about the similarities and differences among the systems.

SITE-SPECIFIC SYSTEMS

Site-specific systems monitor both current radiation-related operations (e.g., weapons research) and sites where past activities have left debris requiring clean-up or remediation. All of the systems reviewed were found to maintain some type of continuous sampling instrumentation with sampling media collected and analyzed on a regular basis (usually weekly, monthly, or quarterly) at a certified laboratory. Radionuclides of concern typically include tritium, gross alpha, beta, and gamma radiation. These facilities generally employ real-time or near real-time air monitors only for emissions (e.g., in stacks and vents) or for gamma radiation in the vicinity certain laboratories, accelerators, rooms, etc. General protocol for data gathered from continuous real-time monitors consists of telemetry from the system/data logger to an onsite, central computer for daily/weekly analysis/QA/QC. Typical QA/QC procedures for media samples consist of duplicate/replicate sampling and analyses, submittal of blind standard samples and blanks, and splitting samples between laboratories. Some monitoring programs periodically utilize more than one type of collection media in order to compare results (i.e., using two different filter systems or types of filters for collection of tritium or airborne particulate). Many facilities consider their data collection and/or QA/QC protocols to be proprietary, and so the specific details of their monitoring systems could not be included in this report.

Lawrence Livermore National Laboratory (LLNL)

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Radiation Monitoring – Ambient Air Monitoring (plus air effluent monitoring and other media not reviewed here)
2. Purpose of the monitoring activity	To monitor actual radionuclide releases from individual facilities and processes. To verify the air concentrations predicted by air dispersion modeling and to determine compliance with NESHAPs.
3. Entity/Agency that sponsors the monitoring activity	LLNL (in accordance with federal regulations and U.S. Dept. of Energy (DOE) Orders 5400.5)
4. Organizations that perform the monitoring	LLNL
5. General scope and content of any routine or special data reports or other data dissemination methods	General methodology, locations, and results summary are included in LLNL Environmental Reports.
6. Website	2003 LLNL Environmental Report, *Air Monitoring Programs* available at http://www.llnl.gov/saer/saer03_pdfs/Ch_3_Air.pdf
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Paris Althouse, (925) 422-3001, Althouse3@llnl.gov
8. Other	Radiological Air Quality Compliance document available at http://www.llnl.gov/es_and_h/hsm/doc_31.02/doc31-02.html#7.0

Sampling approach:	
9. Environmental media collected and sampled	Air particulates and gases (other media also monitored but are not reviewed here)
10. Radiation and/or radionuclides measured	Gross alpha & beta , 239+240 Pu, gamma & 235, 238U, tritium
11. Equipment used	The air particulate networks use high-volume air sampling units, which collect airborne particulate at a continuous rate of 0.42 m^3/min using Whatman 41 cellulose filters. The tritium samplers, operating at a flow rate of 500 cm^3/min, use a continuous vacuum pump to capture air moisture on silica gel contained in sampling flasks.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	The ambient monitoring does not use any near or actual real-time monitoring. In development by LLNL is a handheld device for real-time measurement called RadNet (not related to EPA's RadNet), http://www.llnl.gov/str/September04/Labov.html.
13. Number of monitoring stations	7 air particulate samplers on the Livermore site, 9 in the Livermore Valley, 1 in the City of Tracy, and 8 at Site 300. 12 air tritium samplers at the Livermore site, 6 in the Livermore Valley, and 1 at Site 300. In general, air sampling locations are grouped in categories representing the following areas; perimeter, upwind, downwind, diffuse sources or areas of known contamination, And special interest locations.
14. Location and size of area sampled by network	Livermore, CA site, 3.3 km^2; and Experimental Test Site (Site 300) located near Tracy, CA, 30.3 km^2
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If <u>media samples</u> are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Weekly gross alpha & beta Monthly 239+240 Pu Monthly Gamma & 235, 238U Monthly beryllium Biweekly tritium
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	Yes; http://www.llnl.gov/saer/saer03_pdfs/Ch_8_QA03.pdf
If <u>near or actual real-time measurements</u> are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Lawrence Berkley National Laboratory (LBL)

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Radiation Monitoring – Ambient Air Monitoring (plus air effluent monitoring and other media not reviewed here)
2. Purpose of the monitoring activity	To monitor radiological substances in stack emissions and ambient air
3. Entity/Agency that sponsors the monitoring activity	DOE Order 5400.1 and 5400.5, 40 CFR Part 61, Subpart H EPA
4. Organizations that perform the monitoring	LBL
5. General scope and content of any routine or special data reports or other data dissemination methods	General methodology, locations, and results summary are included in the Site Environmental Report for 2003, Volume 1.
6. Website	*Site Environmental Report for 2003, Volume 1* available at http://www.lbl.gov/ehs/esg/tableforreports/assets/03SERV1.pdf
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Ambient Air Sampling, contact Patrick Thorson, pathorson@llbl.gov; Gamma Radiation Offsite Assessments, contact Mike Ruggieri at mrruggieri@llbl.gov; Stack Emission Real-Time Monitoring – Rad, contact Mike Ruggieri at mrruggieri@llbl.gov. (617) 427-2944
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air particulates and gases (other media also monitored but are not reviewed here)
10. Radiation and/or radionuclides measured	Gross alpha/beta and tritium.
11. Equipment used	Active samplers with silica gel filters measure tritium; active samplers with filters measure airborne particulate gross alpha/beta
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	The ambient monitoring does not use any near or actual real-time monitoring.
13. Number of monitoring stations	5 on-site sampling systems (tritium) 3 onsite, 1 off-site sampling systems (particulate gross alpha/beta)
14. Location and size of area sampled by network	LBL area; approx. 6 km^2
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Silica gel filters and airborne particulate filters are collected and analyzed monthly.
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--

21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Brookhaven National Laboratory (BNL)

Criterion	Description
General:	
1. Title of monitoring activity	Facility Monitoring and Ambient Air Monitoring
2. Purpose of the monitoring activity	To monitor ambient air surrounding potential sources of radioactive particulate emissions at BNL (air emissions and other media sampled but not reviewed here)
3. Entity/Agency that sponsors the monitoring activity	BNL
4. Organizations that perform the monitoring	BNL
5. General scope and content of any routine or special data reports or other data dissemination methods	See below (6)
6. Website	http://www.bnl.gov/bnlweb/PDF/03SER/Chapter_4.pdf
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Paul Zahra, Radiological Control Division (631) 344-7727 Charles Schaefer (Radiological Control Division Manager), schaefer@bnl.gov
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air particulates and gases
10. Radiation and/or radionuclides measured	Gross alpha and gross beta (particulates); tritium (gas)
11. Equipment used	Continuous flow samplers with glass fiber filters (particulates) or silica gel absorbents (tritium)
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	No real-time ambient monitoring for ambient air
13. Number of monitoring stations	6 for particulates; 8 for tritium (5 co-located with particulate samplers and 3 pole-mounted)
14. Location and size of area sampled by network	BNL facility site
15. Local-scale siting criteria (e.g., height above objects)	--

16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Alpha/beta measured weekly; tritium measured every two weeks
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	Filters are analyzed for gross alpha/beta; silica gel is analyzed for tritium
20. Analytical methods used	Gas-flow proportional counter for alpha/beta; liquid scintillation analysis for tritium
21. Laboratories performing the analysis	BNL Analytical Services Lab
22. Data quality control methods	Periodically duplicate filter samples are analyzed by New York State Department of Health laboratories
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Hanford Site

Criterion	Description
General:	
1. Title of monitoring activity	Hanford Site Environmental Surveillance
2. Purpose of the monitoring activity	To measure and assess chemical and radiological contaminant concentrations in the environment on and around the Hanford site in Washington State
3. Entity/Agency that sponsors the monitoring activity	U.S. Department of Energy, Richland Operations Office
4. Organizations that perform the monitoring	Pacific Northwest National Laboratory's Public Safety and Resource Protection Project

5. General scope and content of any routine or special data reports or other data dissemination methods	Summary results are published in the Hanford Site environmental report. Individual results are tabulated in an appendix to the report. The report is sent to DOE and other federal and state agencies, regional libraries and schools, Indian tribes, activist organizations, newspapers, state and local elected officials, and the general public. Data are entered into the Hanford Environmental Information System (HEIS) database when they are received. HEIS is an integrated database and is intended to provide consistent and current information and data to its users; it enables the sharing of data by all Hanford Site personnel. Data in the database can be sorted and summarized or downloaded to a spreadsheet software such as Excel and sorted and summarized. Data are usually summarized annually for the site environmental report but are also compiled during the year for reports, posters, presentations, etc. The annual Hanford site environmental report and related documents in both electronic and hard copy formats. Electronically the reports are available in PDF format on compact disk, and on the internet at http://hanford-site.pnl.gov/envreport. CDs and report hard copies available from Bill Hanf (bill.hanf@pnl.gov) while supplies last.
6. Website	See above
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Ted.poston@pnl.gov, or Bill.Hanf@pnl.gov
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air, surface water, soil, vegetation, food products, sediment, fish and wildlife
10. Radiation and/or radionuclides measured	Gross alpha/beta levels and selected radionuclides, metals, anions, water quality.
11. Equipment used	Continuously operating air and water samplers, thermoluminescent dosimeters (TLDs), pressurized ionization chambers (PICs), air particulate monitors.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	Four PICs measuring external radiation
13. Number of monitoring stations	45 air-monitoring locations, 82 TLD locations, 24 radiation survey locations, 20 sediment sampling locations, 17 vegetation sampling locations, 42 soil sampling locations, 80 surface water sampling locations, two of which are continuously operating
14. Location and size of area sampled by network	Samples are collected at numerous locations on and around the Hanford Site, which occupies an area of approximately 586 square miles. Sampling is conducted in the vicinity of onsite facilities, in local and distant communities, along a portion of the Columbia River (the Hanford Reach), and on portions of the Hanford Reach National Monument, which is still owned by DOE but is managed by the U.S. Fish and Wildlife Service.
15. Local-scale siting criteria (e.g., height above objects)	--

16. Large-scale siting criteria (e.g., density of network stations)	Radioactive materials also sampled at Hanford Site, on-site perimeter, “nearby” communities, and “distant” communities.
If <u>media samples</u> are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	More than 3,000 samples collected weekly, biweekly, monthly, quarterly, semiannually, annually, biennially, triennially, and more than 17,000 analyses done annually
18. Personnel utilized for sample collection	One to four people. Usually one person.
19. Analysis performed on each type of sample media	Many samples, many analyses
20. Analytical methods used	Various
21. Laboratories performing the analysis	The primary laboratories include Severn Trent Laboratories in Richland, WA, and St. Louis, Missouri, and PNNL labs in Sequim and Richland, WA.
22. Data quality control methods	Samples are collected and analyzed according to documented standard analytical procedures. Analytical data quality was verified by a continuing program of internal laboratory quality control, participation in interlaboratory crosschecks, replicate sampling and analyses, submittal of blind standard samples and blanks, and splitting samples with other laboratories. Data are entered into a computer database and several mathematical tests are performed to determine whether the results are within the range of established limits. As data are collected they are compared to previous results to help identify unusual measurements. If the result is unusual or fails the computer tests an anomalous data report is generated that is investigated by project personnel.
If <u>near or actual real-time measurements</u> are made, then briefly describe the following:	
23. Frequency of measurements	PICs measuring continuously; no other information readily available.
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Savannah River Site

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Surveillance and Oversight Program, Environmental Monitoring
2. Purpose of the monitoring activity	Monitor radiological activity in various media in areas surrounding the Savannah River site
3. Entity/Agency that sponsors the monitoring activity	Department of Energy
4. Organizations that perform the monitoring	South Carolina Department of Health and Environmental Control

5. General scope and content of any routine or special data reports or other data dissemination methods	--
6. Website	http://www.scdhec.gov/envserv/esopmain.htm http://www.srs.gov/general/pubs/ERsum/ersum04/index.html
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Lee Smith (803) 208-3602 lee.smith@srs.gov
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Airborne particulates, gases/moisture (also monitored but not reviewed in this report are rainwater, ground/surface/drinking water, vegetation, aquatic insects, fish, surface soils, dairy milk, game animals)
10. Radiation and/or radionuclides measured	Gross alpha/beta and beta-gamma emitting radionuclides, tritium, other selected isotopes.
11. Equipment used	Glass fiber filters for collection of airborne particulates; silica gel columns are used to collect atmospheric water vapor, TLDs analyzed for ambient beta-gamma levels.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	15 monitoring stations
14. Location and size of area sampled by network	300 square miles of Savannah River Site
15. Local-scale siting criteria (e.g., height above objects)	Stations are housed in towers, all approximately 2 meters above the ground.
16. Large-scale siting criteria (e.g., density of network stations)	Monitoring stations located in areas of higher population density.
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Particulates were screened weekly (now biweekly); silica gel distillates analyzed monthly for tritium, TLDs are collected and analyzed every three months.
18. Personnel utilized for sample collection	SC Department of Health and Environmental Control employees
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	Tritium analyses are performed at the Dept. of Health and Environmental Control (DHEC) Lower Savannah District (LSD) Tritium Laboratory; unknown for other samples.
22. Data quality control methods	The program participates in a Radiation Environmental Monitoring Program, which includes other entities performing radiation monitoring; program labs have quality assurance protocols and control/blind samples, some samples sent to National Air and Radiation Environmental Laboratory (NAREL) for analysis.
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--

25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Massachusetts Department of Public Health

Criterion	Description
General:	
1. Title of monitoring activity	Massachusetts Dept. of Public Health (MDPH) Enhanced Environmental Monitoring Program
2. Purpose of the monitoring activity	--
3. Entity/Agency that sponsors the monitoring activity	MDPH
4. Organizations that perform the monitoring	MDPH, Pilgrim Station, area high schools
5. General scope and content of any routine or special data reports or other data dissemination methods	General methodology, locations, and results summary are included in the “Enhanced Environmental Monitoring in Plymouth, Massachusetts” report
6. Website	“Enhanced Environmental Monitoring in Plymouth, Massachusetts” report available at http://www.crcpd.org/pdf/larry_harrington.pdf
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Larry Harrington (MDPH Radiation Control Program) and Tom Sowdon (Entergy, Pilgrim Station).
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air
10. Radiation and/or radionuclides measured	Gamma radiation
11. Equipment used	Two separate networks: (1) The “ring” system, where each station consists of two Geiger-Mueller detectors and electronics permitting data conversion, storage, readout, and transmission to a central facility. (2) Dedicated computers with measurement instrumentation, system includes gamma radiation detector and instruments for gathering various met data parameters; equipment acquires and stores data automatically.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	(1) A network of real-time gamma radiation detection systems, and (2) a network of self-contained environmental modeling systems.
13. Number of monitoring stations	(1) 14 real-time stations (2) 8 stations
14. Location and size of area sampled by network	(1) Detectors located about every 10 to 12 compass degrees around Pilgrim Station in a ring (distance from facility ranges from ½ to 1½ miles. (2) Eight locations within ten miles of Pilgrim.
15. Local-scale siting criteria (e.g., height above objects)	Detection equipment is roof-mounted.

16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	(1) Detection systems are hard-wired to a central data concentrator and sends current radiation level data to PNPS Emergency Operations Facility and MDPH offices. (2) Unknown.
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

STATE AND LOCAL (SUB-STATE) SYSTEMS

State and local environmental radiation monitoring programs consist of sampling networks for the surveillance of multi-media radiological agents in state-wide or sub-state areas or in the vicinity of multiple nuclear facilities (e.g., similar site-specific systems that are combined in some way, such as for reporting). As with site-specific systems, these systems continuously collect air, surface water, drinking water, precipitation, and milk samples for periodic analysis. Air media samples are usually collected weekly or monthly and screened for gross alpha and beta radiation, then composited quarterly for gamma analysis. Several monitoring organizations also operate near real-time monitoring systems, all of which utilize pressurized ionization chambers (PICs). These instruments are connected to a datalogger and regularly transmit data to a central computer for aggregation, analysis, and display purposes. State government laboratories are primarily responsible for analysis of media samples. QA/QC procedures include duplicate/replicate sampling and analyses, submittal of blind standard samples, blanks, spiked samples, and splitting samples between laboratories. Quality control procedures vary for real-time measurements, but comparison of measured, aggregated radiation levels to historical data or to calculated decay rates for particular substances (based on an approximated half life) appears to be standard.

Minnesota Department of Health

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Radiation Monitoring
2. Purpose of the monitoring activity	To monitor environmental radioactivity in the vicinity of two nuclear-generating plants.
3. Entity/Agency that sponsors the monitoring activity	Minnesota Department of Health (MDH), Radiation Control Unit, Asbestos, Lead, Indoor Air, and Radiation Section
4. Organizations that perform the monitoring	MDH Public Health Laboratory
5. General scope and content of any routine or special data reports or other data dissemination methods	General methodology, locations, and results summary are included in the *2004 Environmental Radiation Data Report*
6. Website	*2004 Environmental Radiation Data Report* available at http://www.health.state.mn.us/divs/eh/radiation/monitor/annual2004.pdf http://www.health.state.mn.us/divs/eh/radiation/monitor/index.html
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	The Minnesota Dept. of Health, Radiation Control Unit, Tim Donakowski, Public Health Physicist Minnesota Dept. of Health 1645 Energy Park Dr., Suite 300 St. Paul, MN 55108 Timothy.Donakowski@state.mn.us Ph: (651) 643-2128 Fax: (651) 643-2152
8. Other	--
Sampling approach:	

9. Environmental media collected and sampled	Air (also surface water, sediment, crops, and milk; not reviewed here)
10. Radiation and/or radionuclides measured	Gross beta concentrations, gamma radiation; gross alpha is mentioned on the website FAQs but is not reported in the Environmental Report
11. Equipment used	High purity germanium detectors; TLDs; PICs (for Independent Spent Fuel Storage Installation, or ISFSI)
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	Real-time system used for two pressurized ion chambers at the ISFSI, computer memory and modems accessed every 15 minutes by MDH's St. Paul computers
13. Number of monitoring stations	2 or 3 air samplers 2 PICs 8 TLDs associated with Monticello plant; one is on-site and others are within several miles. 12 TLDs associated with Prairie Island plant; on-site location and others are within several miles.
14. Location and size of area sampled by network	Prairie Island to Monticello (100 miles distance); includes Minneapolis and Saint Paul.
15. Local-scale siting criteria (e.g., height above objects)	One PIC is located ~100 feet north of spent-fuel casks and the other is ~100 feet south.
16. Large-scale siting criteria (e.g., density of network stations)	Area represents about 70% of Minnesota's population.
If <u>media samples</u> are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Bi-weekly air samples; quarterly TLDs
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	MDH Public Health Laboratory
22. Data quality control methods	--
If <u>near or actual real-time measurements</u> are made, then briefly describe the following:	
23. Frequency of measurements	Radiation levels from PICs at ISFSI every 15 minutes
24. How such measurements are reported and to whom	Text messages to point of contact if alarm conditions observed.
25. Extent to which such measurements are aggregated and analyzed	Daily average radiation levels are computed and reported monthly
26. Methods used to either aggregate or analyze such information	Arithmetic averages
27. Data quality control methods	Radiation levels compared to calculated decay of spent fuel, based on approximate-15 year half life

New Jersey Department of Environmental Protection

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Surveillance and Monitoring Program
2. Purpose of the monitoring activity	To monitor environment surrounding nuclear power plants.
3. Entity/Agency that sponsors the monitoring activity	NJ Department of Environmental Protection, Bureau of Nuclear Engineering

4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	--
6. Website	http://www.state.nj.us/dep/rpp/nee/monitor.htm
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	email rpp@dep.state.nj.us Betty Sigafoos, Janice Bauman (609) 984-5400, (609) 984-7443
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air (also, surface and drinking water, milk, and aquatic biota, vegetation, sediment – not reviewed here)
10. Radiation and/or radionuclides measured	Gamma radiation, iodine-131, and iodine-133.
11. Equipment used	High volume air samplers with chemically treated cartridges and filters, in addition to the Continuous Radiological Environmental Surveillance Telemetry (CREST), a direct gamma radiation surveillance and monitoring system.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	CREST directly measures and records ambient gamma radiation levels.
13. Number of monitoring stations	Oyster Creek has 16 CREST system locations; Artificial Island has 10 CREST system locations.
14. Location and size of area sampled by network	TLDs are located in concentric circles around the facilities. CREST system is on-site at facilities.
15. Local-scale siting criteria (e.g., height above objects)	CREST equipment attached to utility poles in the vicinity of the nuclear facilities.
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Cartridges in air samplers are collected and exchanged weekly.
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	CREST information is transmitted via phone lines to a central computer in NJDEP Trenton offices.
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Pennsylvania Department of Environmental Protection

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Monitoring
2. Purpose of the monitoring activity	To monitor the radiological environment around each of the state's five nuclear facilities.
3. Entity/Agency that sponsors the monitoring activity	Pennsylvania EPA, the Environmental Surveillance Section
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	Annual reports describing environmental monitoring activities and including analysis results and interpretations are available online.
6. Website	Annual reports are available at http://www.dep.state.pa.us/dep/deputate/airwaste/rp/BRP_Info/Annual_Reports.htm http://www.dep.state.pa.us/dep/deputate/airwaste/rp/Decom_and_Env_Sur/Environmental_Monitoring.htm
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	David Allard, Director of the Bureau for Radiation Protection (717) 787-2480; Tonda Lewis (717) 346-8246 or tolewis@state.pa.us
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air (also precipitation, processed milk, surface and drinking water sources – not reviewed here)
10. Radiation and/or radionuclides measured	Alpha/beta, gamma radiation.
11. Equipment used	TLDs, samplers with particulate filters, iodine cartridges
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	Beaver Valley, Limerick Station, Susquehanna Station, and Three Mile Island each have 30 TLD stations and four off-site locations with filters continuously collecting particulates and radionuclides. Peach Bottom has 36 TLD stations, and four off-site locations with filters continuously collecting particulates and radionuclides.
14. Location and size of area sampled by network	Beaver Valley dosimeter stations range in distance from 0.4 to 29.2 miles from the facility site. Limerick Station dosimeter stations range in distance from 0.4 to 11.8 miles from the facility site. Peach Bottom TLD stations range in distance from 0.1 to 11.0 miles from the facility site. Susquehanna TLD stations range in distance from 0.1 to 11.0 miles from the facility site. Three Mile Island TLD stations range in distance from 0.5 to 16.4 miles from the facility site.
15. Local-scale siting criteria (e.g., height above objects)	Off-site monitoring: The intake and filter for each monitoring station (four for each facility) are mounted ~ 2 meters above the ground.
16. Large-scale siting criteria (e.g., density of network stations)	Monitoring stations were sited based on predominant wind direction and population density.
If <u>media samples</u> are collected, then briefly describe the following:	

17. Frequency and numbers of samples collected	TLDs are exchanged quarterly, filters are exchanged weekly., iodine cartridges are collected weekly.
18. Personnel utilized for sample collection	Bureau of Radiation Protection employees
19. Analysis performed on each type of sample media	Particulate filters are analyzed individually for gross activity and composite quarterly for gamma spectrometry analysis.
20. Analytical methods used	--
21. Laboratories performing the analysis	PA government contracts out to "Global Dosimetry" firm, whose labs are in charge of TLD analysis
22. Data quality control methods	TLD analysis are cross checked with Global Dosimetry and "RDC" labs. There is a "control" filter located in Harrisburg, PA. Labs each have their own QC procedures.
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Desert Research Institute Community Environmental Monitoring Program

Criterion	Description
General:	
1. Title of monitoring activity	Community Environmental Monitoring Program (CEMP)
2. Purpose of the monitoring activity	To monitor the airborne environment in nearby communities for radioactivity resulting from NTS activities.
3. Entity/Agency that sponsors the monitoring activity	Dept. of Energy National Nuclear Security Administration/Nevada Site Office (NNSA/NSO)
4. Organizations that perform the monitoring	Desert Research Institute (DRI), with assistance from local residents
5. General scope and content of any routine or special data reports or other data dissemination methods	Annual reporting in Nevada Test Site Environmental Report (NTSER, formerly Annual Site Environmental Report [ASER]), available on request from NNSA/NSO
6. Website	http://www.cemp.dri.edu/
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Desert Research Institute 755 East Flamingo Road Las Vegas, Nevada 89119 Phone (702) 862-5419 Fax (702) 862-5326 E-mail *Ted.Hartwell@dri.edu* *http://www.dri.edu*
8. Other	Greg.McCurdy@dri.edu
Sampling approach:	
9. Environmental media collected and sampled	Air (also some water; not reviewed)
10. Radiation and/or radionuclides measured	Gamma radiation, gross alpha and beta

11. Equipment used	Each monitoring station includes an active particulate sampler, TLD, Exposure Rate Recorder (PIC), microbarograph, weather instruments. The particulate sampler pulls two cubic feet of air per minute through a paper filter, which collects particles; filter is sent to independent laboratory for analysis; the TLD records background radiation; and the PIC makes continuous measurements of radiation exposure rates.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	PIC makes continuous measurements, air flow meter makes continuous measurements, all weather instruments make continuous measurements
13. Number of monitoring stations	26 monitoring stations located in Nevada and Utah communities surrounding and downwind of the Nevada test site
14. Location and size of area sampled by network	Stations are located in southern Nevada and southwest Utah
15. Local-scale siting criteria (e.g., height above objects)	Attempt to place twice distance times height of nearby structures in direction of potential source (NTS)
16. Large-scale siting criteria (e.g., density of network stations)	Siting is based on presence of significant human populations (1 network station per community or ranch site)
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Low-volume air sampler filters collected once weekly. TLDs collected quarterly.
18. Personnel utilized for sample collection	Local community environmental monitors (CEMs), often high school science teachers, maintain equipment, collect air filters, route filters to DRI for analysis.
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	Severn-Trent for gross alpha, beta, gamma
22. Data quality control methods	Detailed in DRI CEMP Quality Assurance Management and Assessment Plan (QAMAP) based on DOE Order 414.1A
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	For PIC and air flow meter, 3-second sampling and recording
24. How such measurements are reported and to whom	The instrumentation recording airborne radioactivity is connected to a datalogger, so real-time radiation levels are available immediately on the datalogger display. Data are transmitted via phone lines, cell phone, DSL or wireless internet, or satellite to the Western Regional Climate Center in Reno, Nevada. Near real-time updates available on the web at http://www.cemp.dri.edu/.
25. Extent to which such measurements are aggregated and analyzed	3-second PIC and air flow samples are aggregated into 10-minute averages for display purposes.
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	Detailed in DRI CEMP Quality Assurance Management and Assessment Plan (QAMAP) based on DOE Order 414.1A

COUNTRY-LEVEL SYSTEMS

Country-level systems utilize both laboratory sample analysis and some near real-time measurements. Samples for laboratory analysis are collected weekly, monthly, and quarterly depending on the environmental media. Near real-time measurements are collected and transmitted via satellite link to a central computer. Some country-level systems post their averaged near real-time data online. Country-level systems primarily analyze for gamma radiation, but some also screen for beta radiation, cesium-137, tritium, strontium-90, and plutonium-239. Detailed QA/QC protocols were not disclosed for country-level systems.

Neighborhood Environmental Watch Network (NEWNET)

Criterion	Description
General:	
1. Title of monitoring activity	The Neighborhood Environmental Watch Network (NEWNET)
2. Purpose of the monitoring activity	Radiation monitoring in communities, along transportation routes, and around DOE facilities, and so the public has constant access to station data.
3. Entity/Agency that sponsors the monitoring activity	Los Alamos National Laboratory (LANL)
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	The 2002 LANL Radionuclide Air Emissions Report is available at: http://www.airquality.lanl.gov/pdf/RadAir/LA-14058-PR_NoMaps.pdf
6. Website	http://newnet.lanl.gov/concept.asp
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	NEWNET Project Leader Mike McNaughton (505) 667-6130
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air
10. Radiation and/or radionuclides measured	Gamma radiation
11. Equipment used	Most stations consist of meteorological and radiological sensors attached to the data collection platform (DCP); gamma measured using Reuter-Stokes High Pressure Ionization Chamber, model RSS-120 (RSS-1013 includes the electronics).
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	Near real-time gamma measurements
13. Number of monitoring stations	6 stations in Alaska 12 stations in NM, around LANL site 5 stations in NM cities 1 station at NM high school CA and UT stations offline or discontinued

14. Location and size of area sampled by network	Northern – central New Mexico; map available at http://newnet.lanl.gov/usmap_lanl.asp
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	Radiological measurements are taken every minute.
24. How such measurements are reported and to whom	NEWNET data reported via satellite link to LANL data collection centers in New Mexico and Nevada (Las Vegas)
25. Extent to which such measurements are aggregated and analyzed	Radiological measurements are averaged every 15 minutes; every 4 hours data are transmitted via satellite link
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Canadian Radiological Monitoring Network

Criterion	Description
General:	
1. Title of monitoring activity	Canadian Radiological Monitoring Network
2. Purpose of the monitoring activity	Provides Canadians with health assessments regarding existing levels of radioactivity and nuclear or radiological accidents on a national scale. Measures natural background radiation levels and has a mechanism for measuring releases of radioactivity in the environment.
3. Entity/Agency that sponsors the monitoring activity	Health Canada
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	Link to annual reports archive: http://www.hc-sc.gc.ca/hecs-sesc/crmn/data_archive.htm Clickable map to data: http://www.hc-sc.gc.ca/hecs-sesc/crmn/monitoring_data.htm
6. Website	http://www.hc-sc.gc.ca/hecs-sesc/crmn/index.htm

7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Deborah Moir Division Chief, Radiation Surveillance and Health Assessment Health Canada 775 Brookfield Road Ottawa, ON K1A 1C1 Address Locator 6302D 613-954-6671 crmn-rcsr@hc-sc.gc.ca
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Airborne particulates, atmospheric water vapor, external gamma dose (also precipitation, drinking water, and milk—not reviewed).
10. Radiation and/or radionuclides measured	Gamma radiation, beta radiation, tritium
11. Equipment used	Airborne particulates are collected with an active high-volume air sampler; atmospheric water vapor is collected with a tritium cell containing a molecular sieve able to absorb water vapor pumped through. External gamma dose are performed using TLDs.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	26 monitoring stations 35 additional stations in the vicinity of nuclear reactor facilities
14. Location and size of area sampled by network	National network
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Air particulate samples collected weekly; atmospheric water vapor samples collected monthly; external gamma dose samples collected quarterly.
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	Radiation analysis
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Japan Nuclear Cycle Development Institute

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Monitoring
2. Purpose of the monitoring activity	To monitor environmental radioactivity levels and protect the public and surrounding environment surrounding nuclear facilities.
3. Entity/Agency that sponsors the monitoring activity	--
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	--
6. Website	http://www.jnc.go.jp/jncweb/04monitoring/04index.html
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Corporate Headquarters 4-49, Muramatsu, Tokai-mura, Naka-gun, Ibaraki, 319-1184 Japan TEL: 029-282-1122 FAX: 029-282-4934
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air, soil, water, agricultural products, plants, marine life.
10. Radiation and/or radionuclides measured	Gamma radiation
11. Equipment used	--
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	Continuous 24-hour monitoring
13. Number of monitoring stations	(?) Information inconsistent and garbled; difficult to summarize. 5 inside Monju facility site 2 inside Fugen facility site; 5 (at least) outside Monju and Fugen facility sites 10 inside Tokai facility site; 3 outside
14. Location and size of area sampled by network	Monitoring is focused in the regions surrounding nuclear power plants.
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	

23. Frequency of measurements	Hourly measurements
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Republic of Bulgaria, Executive Environment Agency

Criterion	Description
General:	
1. Title of monitoring activity	National System for Radiation Control
2. Purpose of the monitoring activity	To reliably detect significant changes in the level of radiation which might occur, and to provide the earliest possible warning to appropriate national authorities to notify other potentially affected countries.
3. Entity/Agency that sponsors the monitoring activity	Republic of Bulgaria, Executive Environment Agency
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	Measurements of radioactive elements in air, water, and soil samples, and gamma background radiation are provided in a database (not available online). Information is also available in the "Annual report for the state of environment in Bulgaria" (Green Book). An official request must be made to the Director of the Regional Inspectorate of Environmental and Water, specifying the required information and the need for this information.
6. Website	http://nfp-bg.eionet.eu.int/cds_eng/riewplo/riplo13.htm http://deploymentlink.osd.mil/du_balkans/du_balkans_refs/n64en073/radiological_kosovo.htm http://nfp-bg.eionet.eu.int/cds_eng/iaos31.htm
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Contact person: Hristina Halachliyska Position: Head of Ionization and Non-Ionization Radiation Sector, Environmental Monitoring Directorate Language skills: English, Russian Town/Village-mail code Sofia - 1618 Street 136, Tzar BorisIII Blvd., PO Box 251 Telephone (+359 2) 9406473 Fax (+359 2) 9559015 E-mail rad_ramo@nfp-bg.eionet.eu.int
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air, water, soil
10. Radiation and/or radionuclides measured	Gamma radiation
11. Equipment used	28. --
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	55 soil monitoring points; 11 surface water monitoring points; 6 waste products monitoring points; 1 aerosol (?) monitoring point

14. Location and size of area sampled by network	Monitoring points are spread throughout the country.
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	Analysis of soil samples and waste products by mine extraction industry, heat and power pant is performed in RL - Montana. Analysis of ore and surface waters is performed in RL - Vratza. The analysis of waste products and ore waters from uranium extraction, water and sediments according to Danube programme is performed in the central laboratory complex in Executive Environmental Agency.
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

The Hong Kong Observatory

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Radiation Ambient Monitoring Programme
2. Purpose of the monitoring activity	To ensure that our environment is not adversely affected by the operation of the nuclear power stations at Daya Bay, the Hong Kong Observatory implements an environmental radiation monitoring programme since 1987. These samples are then measured for their radioactivity in the Radiation Laboratory.
3. Entity/Agency that sponsors the monitoring activity	The Hong Kong Observatory
4. Organizations that perform the monitoring	The Hong Kong Observatory
5. General scope and content of any routine or special data reports or other data dissemination methods	Information on the environmental radiation levels in Hong Kong may be obtained from the report "Environmental Radiation Monitoring 1987 - 2002" published by the Hong Kong Observatory. A 2003 Summary Report can be found at: http://www.hko.gov.hk/radiation/ermp/bookshelf/other_references/annual_report/abstract.htm?chinese=0&flash=1?menu=monitoring_env_English&resultEnglish

6. Website	http://www.hko.gov.hk/radiation/ermp/frontpage/monitoring_env.htm?chinese=0&flash=1?menu=monitoring_env_English
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	mailbox@hko.gov.hk
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	The Hong Kong Observatory collects samples of all major environmental media: air (airborne particulates, gaseous iodine, water vapour, total deposition and soil, etc.), livestock, vegetables and fruit, drinking water, seafood, seawater, inter-tidal sediment, etc.
10. Radiation and/or radionuclides measured	cesium-137, tritium, strontium-90, plutonium-239, gamma emitting radionuclides
11. Equipment used	29. High pressure ionization chamber, radio-iodine sampler, high volume air sampler, total deposition collector (plastic bottle with plastic funnel), sodium iodide type gamma ray detectors
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	The fixed monitoring stations provide continuous sampling and data transfer. The mobile radiation monitoring station collects samples for laboratory analysis.
13. Number of monitoring stations	10 fixed, 1 mobile, and 1 aerial
14. Location and size of area sampled by network	Fixed monitoring stations are scattered throughout Hong Kong. Refer to map for specific locations: http://www.hko.gov.hk/radiation/ermp/rmn/applet/map/rmn_intro.htm?chinese=0&flash=1?menu=monitoring_env_English&networkEnglish A mobile radiation monitoring station regularly visits selected locations in Hong Kong to collect radiation data samples. An aerial monitoring system can be deployed in case of emergency to detect radioactive plumes in the atmosphere.
15. Local-scale siting criteria (e.g., height above objects)	Fixed and mobile monitoring station equipment is at ground-level
16. Large-scale siting criteria (e.g., density of network stations)	--
If <u>media samples</u> are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	Gamma Spectrometry, Liquid Scintillation Counting, Low Level Alpha-Beta Counting, or Alpha Spectrometry
21. Laboratories performing the analysis	Hong Kong Observatory Headquarters, Radiation Laboratory at King's Park
22. Data quality control methods	--
If <u>near or actual real-time measurements</u> are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	Each station transmits gamma dose rate data to the Observatory Headquarters.
25. Extent to which such measurements are aggregated and analyzed	An alarm at the Observatory Headquarters will sound when the radiation level at any one station exceeds pre-set criteria.
26. Methods used to either aggregate or analyze such information	--

27. Data quality control methods	Information is transmitted via two independent communication networks.

Slovenian Nuclear Safety Administration

Criterion	Description
General:	
1. Title of monitoring activity	External radiation monitoring
2. Purpose of the monitoring activity	Consists of an automatic monitoring system for measurement of external radiation, aerosol radioactivity, radioactive deposition.
3. Entity/Agency that sponsors the monitoring activity	Slovenian Nuclear Safety Administration, Ministry of the Environment and Spatial Planning
4. Organizations that perform the monitoring	The network is administered jointly by the Hydro-Meteorological Institute of Slovenia, the Krsko Nuclear Power Plant, the Milan Vidmar Institute of Electric Research, and the Slovenian Nuclear Safety Administration.
5. General scope and content of any routine or special data reports or other data dissemination methods	Real-time gamma dose rate levels are reported automatically on the following website: http://www.sigov.si/ursjv/en/index.php
6. Website	http://www.sigov.si/ursjv/en/index.php
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	snsa@gov.si
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air
10. Radiation and/or radionuclides measured	Qlpha and beta activity in the air, concentration of gamma emitting radionuclides, concentration of radioactive iodine I-131 in the air in all chemical forms (particles, gas, organically bound iodine) and concentrations of ^{222}Rn and ^{220}Rn.
11. Equipment used	30. The network uses probes with two GM tubes operating at different radiation ranges. Some are the Slovenian manufacturer AMES (type MFM-202); others are the Finish company RADOS Technology Oy (type RD-02L).
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	Both external radiation and aerosol radioactivity monitoring programs utilizes real-time measurements.
13. Number of monitoring stations	44 gamma probes
14. Location and size of area sampled by network	Scattered throughout Slovenia. Refer to map for specific locations: http://www.sigov.si/ursjv/en/index.php
15. Local-scale siting criteria (e.g., height above objects)	Fixed standard height 1 meter above the ground
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	

17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If <u>near or actual real-time measurements</u> are made, then briefly describe the following:	
23. Frequency of measurements	Measurements are reported every 30 min
24. How such measurements are reported and to whom	Automatic data transmission to the Slovenian Nuclear Safety Administration website
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	High resolution gamma spectrometry
27. Data quality control methods	All time is given in UTC; all dose equivalent rates are given in nano-Sievert per hour. Provided that there is no increased radioactivity observed in the air, data are presented in terms of detection limits. The detection limits are: for artificial alpha activity in air 0.01 Bq/m3, for artificial beta activity 0.1 Bq/m3, for 137Cs in the air 0.10 Bq/m3 and for 131I 0.01 Bq/m3.

MULTI-COUNTRY AND GLOBAL SYSTEMS

One of the multi-country systems presented in this report, Nuclear Transparency in the Asia Pacific, is a network of established monitoring systems at the state- and country-levels and near real-time monitoring data from each of the participating countries—Japan, Russia, and the United States—are posted on the network website. Detailed QA/QC protocol was not found for this multi-country system. All of the global systems reviewed conduct weekly, monthly, or quarterly air/soil sampling for laboratory analysis. Some near-real time measurements are conducted (for gamma). Some typical QA/QC procedures include submitting reference, duplicate, replicate, and blank samples to analysts together with routine monthly composite and weekly samples and comparing results to ensure accuracy.

Nuclear Transparency in the Asia Pacific

Criterion	Description
General:	
1. Title of monitoring activity	Nuclear Transparency in the Asia Pacific Airborne Radiation Monitoring Project
2. Purpose of the monitoring activity	This project provides links to near real-time monitoring data from selected monitoring programs in Japan, Russia, and the United States. The overall goal is to promote nuclear transparency, safety, and confidence among Asia-Pacific nations.
3. Entity/Agency that sponsors the monitoring activity	The Council for Security Cooperation in the Asia Pacific (CSCAP)—a non-governmental organization—hosts the website. The monitoring programs themselves are sponsored by each participating country.
4. Organizations that perform the monitoring	In Japan: (1) the Fukui Prefecture (comprised of both local government and private nuclear power companies) (2) JNC Oarai Engineering Center. In Russia: (1) Bilibino Nuclear Power Plant. In the U.S.: (1) Los Alamos National Laboratory's NEWNET (2) Desert Research Institute and Department of Energy's Nevada Operations Office's Community Environmental Monitoring Program. **Refer to the State/Local and Country Systems for all information pertaining to these U.S. systems*
5. General scope and content of any routine or special data reports or other data dissemination methods	The Nuclear Transparency Airborne Radiation Monitoring project provides limited monitoring information from Korea, Taiwan, Hong Kong, Japan, Russia, and the U.S. on their website (below). In Japan, the Fukui Prefecture Environmental Radiation Research and Monitoring Center (FERMC) and the JNC Oarai Engineering Center provide their real-time monitoring data on their websites: http://www.houshasen.tsuruga.fukui.jp/en/index.html http://www.jnc.go.jp/ztokai/kankyo_e/realtime/new_msr.html
6. Website	http://www.cscap.nuctrans.org/Nuc_Trans/links/frames/top-cooperationinair.htm
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Nuclear Transparency POC: webmaster@cmc.sandia.gov JNC Oarai Engineering Center: www-admin@jnc.go.jp

8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air
10. Radiation and/or radionuclides measured	Various, depending on subsystem
11. Equipment used	31. The Fukui Prefecture uses NaI Scintillation detectors.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	In Japan, data are collected hourly. In the U.S., data are collected every 15 minutes.
13. Number of monitoring stations	In the Fukui Prefecture: 80 radiation monitoring stations. JNC Oarai Engineering Center: 19 monitoring stations. Bilibino NPP: 9 monitoring stations.
14. Location and size of area sampled by network	Samples are limited to the region surrounding each nuclear facility.
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	Some hourly, some every 15 minutes
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	All data presented on the Nuclear Transparency website are converted to nano-Gray per hour (nGy/h).

Environmental Measurements Laboratory Global Fallout Program

Criterion	Description
General:	

1. Title of monitoring activity	Global Fallout Program
2. Purpose of the monitoring activity	In 1958, Environmental Measurements Laboratory (EML) instituted a global network of sampling sites to determine the global transport and fate of radionuclides released into the atmosphere during the testing of nuclear weapons. Only strontium-90 (Sr-90) was measured in the samples collected during the first 32 years of the program. Strontium-89 was also measured on selected samples. In recent years, the program focused on the global deposition of the naturally occurring radionuclides, beryllium-7 and lead-210.
3. Entity/Agency that sponsors the monitoring activity	Currently: Department of Homeland Security. Historically: U.S. Atomic Energy Commission, the U. S. Energy Research and Development Administration, and the U. S. Department of Energy.
4. Organizations that perform the monitoring	Currently: a sampling network sponsored by the United Kingdom Atomic Energy Authority
5. General scope and content of any routine or special data reports or other data dissemination methods	The EML Sample Archives makes available environmental radiological data collected for programs funded through the U.S. Atomic Energy Commission, the U. S. Energy Research and Development Administration and the U. S. Department of Energy. All of these programs appear to have been terminated. The databases were last updated in 1999. According to the website, no additional data will be added to these databases. The website also notes that, beginning in 1991, quarterly composites have been created but not analyzed due to very low fallout levels of Sr-90. Any inquiries about these programs should be made to webmaster@eml.doe.gov. http://www.eml.doe.gov/databases/fallout/fallout_sample_search.cfm http://www.eml.doe.gov/databases/fallout/fallout_data_search.htm
6. Website	http://www.eml.doe.gov/databases/fallout/about_fallout.cfm http://www.eml.doe.gov/databases/fallout/
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	webmaster@eml.doe.gov.
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air, Soils
10. Radiation and/or radionuclides measured	Historically: Sr-90 and Sr-89. Currently: Be-7 and Pb-210 (apparently)
11. Equipment used	32. Sample collections are performed using one of several types of collectors: a high-walled stainless steel pot; a plastic bucket; a funnel attached to an ion-exchange column; or a funnel and polyethylene bottle (UKAEA network).
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	Historically: 185 Currently: 45
14. Location and size of area sampled by network	Global; refer to website for specific locations
15. Local-scale siting criteria (e.g., height above objects)	--

16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Quarterly data composites
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	EML
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Environmental Measurements Laboratory Surface Air Sampling Program

Criterion	Description
General:	
1. Title of monitoring activity	Surface Air Sampling Program (SASP)
2. Purpose of the monitoring activity	The primary objective of this program is to study the spatial and temporal distribution of specific natural and anthropogenic radionuclides in the surface air. Air filter samples were collected at locations throughout the world and analyzed for nuclear debris.
3. Entity/Agency that sponsors the monitoring activity	The Department of Homeland Security sponsors the EML. The SASP database was funded by the Office of Nonproliferation Research and Engineering (NN-20) in the Office of Defense Nuclear Nonproliferation, U.S. Department of Energy.
4. Organizations that perform the monitoring	EML, continuing the work of the U.S. Naval Research Laboratory
5. General scope and content of any routine or special data reports or other data dissemination methods	The SASP online database provides information on EML's archived air filter samples and sample measurements. Data from SASP are also periodically reported in EML reports and are distributed to scientific organizations throughout the world (for example, the United Nations Scientific Committee on the Effects of Atomic Radiation).

6. Website	http://www.eml.doe.gov/databases/sasp/ http://www.eml.doe.gov/databases/sasp/aboutsasp.cfm
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	webmaster@eml.doe.gov
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air
10. Radiation and/or radionuclides measured	^{7}Be, ^{95}Zr, ^{137}Cs, ^{144}Ce, ^{210}Pb, ^{222}Rn
11. Equipment used	33. A Roots 24-AF or 24-URAI blower connected to a 1HP electric motor by a fan belt and a Fuji ring compressor directly connected to either a 0.5 or 1 HP electric motor. Dynaweb DW7301L filter material.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	Approximately 41 (varies depending on the year)
14. Location and size of area sampled by network	Global; refer to website for specific locations
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	At most SASP stations the filters are changed on the 1st, 8th, 15th, and 22nd of the month, or more frequently if the filter becomes clogged. At Remote Atmospheric Measurements Program (RAMP) stations the filters are changed once a week. The air filter samples that are collected on approximately a weekly basis are referred to as "weekly samples" or "individual samples". The weekly samples collected at all SASP sites are composited to form monthly samples. Monthly samples, which consist of weekly samples that represent a minimum of 14 days of exposure during any given month, are referred to as "monthly" or "composite" samples. The filters from most sites are returned to EML for analysis at the end of each month. Because of transportation difficulties, the samples collected at the South Pole Station, Mawson, Marion Island, Palmer and Marsh Antarctica during the winter months are retained at the sites until they can be shipped to EML.
18. Personnel utilized for sample collection	--

19. Analysis performed on each type of sample media	The monthly composite samples are compressed into 45-cm^3 plastic planchets and are analyzed for gamma-ray emitting radionuclides using either n-type low-energy coaxial, high-purity germanium (HPGe) detectors or p-type coaxial high-resolution germanium lithium (GeLi) or HPGe detectors. All weekly samples from sites using 20.3 cm by 25.4 cm rectangular filters are compressed into a 1-2 cm^3 cylinder, which is analyzed by gamma-ray spectrometry using a HPGe detector with a 1.5 cm diameter well. The activities of specific isotopes (^{7}Be, ^{95}Zr, ^{137}Cs, ^{144}Ce, and ^{210}Pb) are determined by computer analysis of the spectral data from both monthly composite and weekly samples. The total gamma-ray activity of each monthly composite sample is determined by summing the total counts obtained with germanium detectors between 100 keV and 2.0 MeV, without any correction for detector efficiency or radioactive decay.
20. Analytical methods used	--
21. Laboratories performing the analysis	EML
22. Data quality control methods	Four types of quality control samples (reference, duplicate, replicate, and blank) are regularly submitted to the analysts together with routine monthly composite and weekly samples. These quality control samples are submitted "blind" (i.e., in such a way as to be indistinguishable from the routine samples by the analyst) insofar as this is possible. Refer to website for more detail.
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

Comprehensive Nuclear-Test Ban Treaty (CTBT) International Monitoring System

Criterion	Description
General:	
1. Title of monitoring activity	Radionuclide Monitoring Network

2. Purpose of the monitoring activity	The Radionuclide Monitoring Network measures radionuclides in the atmosphere as part of a global system of monitoring stations established to record data necessary to verify compliance with the CTBT. The global system uses four complementary technologies: infrasound-, hydroacoustic-, radionuclide- and seismic monitoring. Using air samplers, radioactive particles released from atmospheric explosions and vented from underground and underwater explosions can be detected.
3. Entity/Agency that sponsors the monitoring activity	Comprehensive Nuclear-Test Ban Treaty Organization (CTBTO)
4. Organizations that perform the monitoring	NORSAR (in cooperation with Kongsberg Satellite Services)
5. General scope and content of any routine or special data reports or other data dissemination methods	The International Data Centre (IDC) analyzes and archives monitoring data for the CTBTO. IDC makes their data and products available to the CTBT States Signatories for final analysis.
6. Website	http://www.norsar.no/NTB/general/monitoring/ http://www.norsar.no/NTB/general/monitoring/radionuclide.html
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	NORSAR P.O. Box 53 N-2027 Kjeller Norway OR Electronic Contact Form: http://www.norsar.no/NORSAR/contact.html
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air
10. Radiation and/or radionuclides measured	Fission byproducts in the atmosphere
11. Equipment used	34. The monitoring stations use samplers for airborne particulate monitoring. Half of the monitoring stations are capable of monitoring for radioactive noble gases.
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	80
14. Location and size of area sampled by network	Global
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	Automatic data transmission from remote sites using satellite links, land lines, and the internet.
19. Analysis performed on each type of sample media	--

20. Analytical methods used	--
21. Laboratories performing the analysis	The IDC within the CTBTO Preparatory Commission in Vienna
22. Data quality control methods	
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

SUMMARY

The 20 monitoring systems reviewed for this report were selected from a larger list of 35 systems that were identified using a variety of data sources. The 20 systems represent long-term, sustained efforts to monitor radiation in both the ambient environment and specific local environments. The report focuses in particular on monitoring activities that utilize laboratory or real-time analysis of ambient air particulates and that have been developed and maintained by local, State, or Federal governmental agencies, as these parallel the current RadNet monitoring upgrade. Other media and systems, including air emissions (e.g., at stacks), drinking water, milk, precipitation, and surface water, are addressed only briefly for most systems (depending on availability of information).

The systems reviewed for this report range from relatively small, site-specific systems to global systems and networks. They also range from relatively simple systems focused on only one type of radiation (e.g., gamma using PICs) to multi-radiation and radionuclide systems using a variety of equipment types (paper or glass fiber filters, silica gel absorbents, charcoal canisters, TLDs, PICs). Real or near-real time monitoring is limited to emission points (e.g., stacks, vents) using a variety of equipment and ambient gamma using PICs. We did not find a system comparable to RadNet's use of equipment that continuously measures both beta and gamma on filters.

Several caveats should be recognized for this report. First, the systems reviewed are only a sample of long-term, sustained efforts by government agencies, based primarily on readily available information. They are not necessarily representative of all radiation monitoring systems in the U.S. or worldwide. In some cases, only one component of a system (e.g., real-time air monitoring) was described due to a lack of readily available information on other components and to focus the effort on systems that most closely parallel the current RadNet monitoring upgrade. Also, some criteria could not be addressed for some systems or components, also due to lack of readily available information.

APPENDIX A: INITIAL LIST OF SELECTED MONITORING SYSTEMS

The appendix contains an initial list of 35 selected monitoring systems—other than ERAMS/RadNet—from which a subset of systems were selected for more detailed review in the body of this report.

No.	Organization	System Type	System Size/Scope	Source	Detailed Review?
			Site-Specific Systems		
1	Lawrence Livermore National Laboratory	Gamma radiation monitoring, thermoluminescent dosimeters (TLDs)	Site perimeter locations, valley locations, 16-plus additional and/or temporary locations.	http://www-cms.llnl.gov/	Yes
2	Lawrence Berkley National Laboratory	Continuous sampling, real-time monitoring systems analyze for gross alpha, gross beta, carbon-14, iodine-125, and tritium.	20 on-site monitoring locations with continuous air sampling and three locations with real-time sampling	http://www.lbl.gov/ehs/esg/99ser/t4-4	Yes
3	Brookhaven National Laboratory	Charcoal cartridges capture radioiodines, monthly collection and analysis by gamma spectroscopy; also filter papers for particulate matter (PM) and silica gel tubes (tritium).	Six stations are located in dedicated blockhouses, and 18 mounted battery-powered samplers are distributed along the perimeter.	http://www.bnl.gov/bnlweb/PDF/03SER/Chapter_4.pdf	Yes
4	Department of Energy Hanford Site	Continuous monitoring of radioactive emissions.	Samples collected at various points of discharge to the environment (i.e., a stacks, vents).	http://www.hanford.gov/docs/annualrp00/summonitor.stm	Yes
5	Savannah River Site	Monitoring stations are equipped with glass fiber filters, silica gel columns, and TLDs, analysis for gross alpha, gross beta, and beta-gamma emitting radionuclides.	Monitoring is conducted in the vicinity of the Savannah River site.	http://www.scdhec.gov/envserv/esopmain.htm http://www.srs.gov/general/pubs/ERsum/ersum04/index.html	Yes
6	Oak Ridge Reservation	High-volume air sampler on glass fiber filters (PM capture) and prefilter with adsorpent silica gel trap (tritium analysis); weekly collection is composited monthly for analysis.	Oak Ridge Reservation, 47 locations, includes air, soil, surface water, ground water samples.	http://www.state.tn.us/environment/doeo/EMR2001.pdf http://www.state.tn.us/environment/doeo/progs.php#emc	Partial; similar to other sites; see Appendix B.
7	Massachusetts Department of Public Health	Two systems include a network of 14 real-time gamma radiation detection systems and a network of environmental monitoring installations capable of measuring radiation and other parameters.	Real-time systems are located close to the site boundary of the nuclear facility, other installations are located within approximately 10 miles of the nuclear facility.	http://www.crcpd.org/pdf/larry_harrington.pdf	Yes
8	EFMR Monitoring Group, PA	Five stationary, low-level air samplers and various hand-held Geiger counters.	The stationary systems are located within a two-mile radius of the Three Mile Island Nuclear Generating Station and Peach Bottom Atomic Power Station.	http://efmr.enviroweb.org/	No, does not appear to be a sustained effort by a government entity.

No.	Organization	System Type	System Size/Scope	Source	Detailed Review?
9	The Community Radiological Monitoring program (ComRad), CO	Continuous data are collected on a variety of parameters including plutonium levels. Filters are changed once a month for analysis.	Four monitoring stations are located in communities near the facility in Rocky Flats.	http://www.comrad.org/download/download.htm	No, does not appear to be a sustained effort by a government entity.
		State and Local (Sub-State) Systems			
10	Michigan Department of Environmental Quality	Radio analyses for direct radiation are performed on different types of samples, including air, surface water, precipitation.	A monitoring network exists around each of Michigan's nuclear facilities.	http://www.deq.state.mi.us/documents/deq-dwrpd-rad-RadRept.pdf	Partial; appears similar to other multi-site systems; see Appendix B
11	Minnesota Department of Health	TLDs and pressurized ionization chamber (PICs) are used to monitor radiation levels, including alpha particles, beta particles, gamma rays, and neutrons.	Monitoring is conducted in communities around the Monticello and Prairie Island nuclear facilities.	http://www.health.state.mn.us/divs/eh/radiation/monitor/	Yes
12	New Jersey Department of Environmental Protection	Continuous Radiological Environmental Surveillance Telemetry (CREST) (ambient monitoring) collects and measures samples at two nuclear facility sites. Samples also include TLDs for radiation detection	Monitors the environment surrounding the nuclear facilities.	http://www.state.nj.us/dep/rpp/nee/monitor.htm	Yes
13	Pennsylvania Department of Environmental Protection	Background monitoring program, routine sampling of air, milk, surface water, etc. Dosimeters monitor radiation levels.	Monitoring is conducted around five nuclear facilities.	http://www.dep.state.pa.us/dep/deputate/airwaste/rp/BRP_Info/Annual_Reports.htm http://www.dep.state.pa.us/dep/deputate/airwaste/rp/Decom_and_Env_Sur/Environmental_Monitoring.htm	Yes
14	National Oceanic and Atmospheric Administration (NOAA) and Idaho Environmental Monitoring Program of the Idaho National Engineering and Environmental Laboratory (INEEL)	High-volume, remotely activated air samplers, pressurized ionization chamber (PICs) are used to measure gamma radiation. Water, soil, milk, and external radiation also monitored.	Ten monitoring stations in and around INEEL, including in Idaho Falls, Fort Hall, Big Lost River Rest Area, Terreton	http://www.noaa.inel.gov/projects/iemp/ http://www.oversight.state.id.us/index.cfm	Partial; see Appendix B; similar to site-specific energy sites
15	State of Idaho INEEL Oversight Program	Gross alpha and gross beta measurement, measurement of gamma-emitting radionuclides, measurement of tritium, tritium enrichment	Provides independent monitoring of the Idaho National Engineering and Environmental Laboratory (INEEL).	http://www.physics.isu.edu/health-physics/eml.html	Partial, but also combined with above INEEL system.

No.	Organization	System Type	System Size/Scope	Source	Detailed Review?
16	Desert Research Institute Community Environmental Monitoring Program	Stations monitor airborne radioactivity (TLD, exposure rate recorder, microbarograph) and weather conditions. Real-time radiation levels are available on the data logger; data are transmitted to Reno and updated on the web several times daily.	A network of monitoring stations is located in communities surrounding the Nevada Test Site.	http://www.cemp.dri.edu/cemp.html	Yes
Country Systems					
17	Neighborhood Environmental Watch Network (NEWNET)	The Data Collection Platform (DCP) measures ionizing gamma radiation every minute, averaged every 15 minutes, every four hours data are transmitted to New Mexico and Nevada and made available on the web.	Multiple monitoring locations in New Mexico and Alaska. Historical data are available for California and Nevada as well.	http://newnet.lanl.gov/concept.asp	Yes
18	U.S. Geological Survey (Water Monitoring for Radionuclides)	General techniques include alpha spectrometry, gamma spectrometry, and low-background gas proportional beta counting to analyze water samples.	Samples areas in 27 states.	http://water.usgs.gov/pubs/wri/wri004273/pdf/wri004273.pdf	No, this was a survey, not a sustained effort.
19	Canadian Radiological Monitoring Network	Monitoring focuses on gamma emitting radionuclides in air, gross beta activity and external radiation dosimetry	26 monitoring stations are located throughout Canada, not including additional locations around nuclear facilities.	http://www.hc-sc.gc.ca/hecs-sesc/crmn/who_we_are.htm	Yes
20	Japan Nuclear Cycle Development Institute	Real-time gamma radiation monitoring of air, soil, water, agricultural products, plants, and marine life.	Monitoring network is focused mainly in the communities surrounding nuclear power plants.	http://www.jnc.go.jp/jncweb/04monitoring/04index.html	Yes
21	Republic of Bulgaria, Executive Environmental Agency	Measurements of radioactive elements in air, water, and soil samples, and gamma background radiation are provided in a database (not available online).	Monitoring points are spread throughout Bulgaria.	http://nfp-bg.eionet.eu.int/cds_eng/riewplo/riplo13.htm http://deploymentlink.osd.mil/du_balkans/du_balkans_refs/n64en073/radiological_kosovo.htm http://nfp-bg.eionet.eu.int/cds_eng/iaos31.htm	Yes
22	The Hong Kong Observatory	The radiation monitoring network monitors ambient gamma dose. PICs are installed at each station, transmitting gamma dose rate data to Observatory HQ. Sample analysis includes alpha and gamma spectrometry, low level alpha-beta counting system, and a liquid scintillation counting system.	10 fixed radiation monitoring stations around Hong Kong and 2 mobile monitoring stations.	http://www.hko.gov.hk/radiation/ermp/frontpage/monitoring_env.htm?chinese=0&flash=1?menu=monitoring_env_English	Yes

No.	Organization	System Type	System Size/Scope	Source	Detailed Review?
23	Slovenian Nuclear Safety Administration	Consists of an automatic monitoring system for measurement of external radiation, aerosol radioactivity, radioactive deposition.	Real-time gamma dose rate levels are reported automatically on their website.	http://www.sigov.si/ursjv/en/index.php	Yes
24	NATO, Ministry of the Environment and Water	Monitoring stations measure real-time gamma radiation.	26 stations in 50-km boundary zone in the region near the former border with Yugoslavia.	http://deploymentlink.osd.mil/du_balkans/du_balkans_refs/n64en073/radiological_kosovo.htm	No, not a sustained effort, and also part of the Bulgaria monitoring.
25	Mexico	--	--	--	No, not found.
26	Germany	Not only the environment of nuclear power plants and facilities but also the environment in general is surveyed regularly.	The operators of nuclear facilities are responsible for the surveillance of the environment within a radius of 25 km. The environment in general is monitored by authorities of the federal states (Bundesländer) and the Federation (Bund).	www.ec-sage.net/D04_01.pdf http://www.bfs.de/bfs?setlang=en	No, complexity of multiple state networks appears too great
27	France	Teleray is a French national network made up of early-warning stations that continuously monitor environmental radioactivity from all (artificial and natural) gamma-emitting sources.	Each probe, made up of two Geiger-Müller tubes and a memory for storing measurements, measures the gamma radiation dose rate in the surrounding air (from 10 nGray/h to 10 Gray/h). The measurements are then sent over the telephone network and switched to a data processing system at Le Vésinet, where a constantly updated radioactivity map is plotted and recorded. In April 2002, the network comprised 180 stations.	www.ec-sage.net/D04_01.pdf http://www.irsn.fr/scripts/net-science/publigen/content/templates/show.asp?P=1311&L=EN&SYNC=Y	No, insufficient information readily available.
28	Russia	--	--	--	Partly, via no. 31
29	Ukraine	--	--	http://www.snrcu.gov.ua/eng/index.html www.snrcu.gov.ua/eng/docs/reports/2002/rep2002e.pdf	No, insufficient information readily available beyond Chernobyl system.
30	Finland	--	--	http://www.stuk.fi/english/emergency/monitoring.html	No, insufficient information readily available.

No.	Organization	System Type	System Size/Scope	Source	Detailed Review?
Multi-Country and Global Systems					
31	Nuclear Transparency in the Asia Pacific	This program provides links to near real-time monitoring data from selected monitoring programs in Japan, Russia, and the United States.	This program creates a network of the country level monitoring systems in Japan, Russia, and the United States.	http://www.cscap.nuctrans.org/Nuc_Trans/links/frames/top-cooperationinair.htm	Yes
32	Environmental Measurements Laboratory Global Fallout Program	Air samples are collected and analyzed quarterly for Be-7 and Pb-210. Historical data are available for Sr-90 and Sr-89.	Consists of a global network of sampling sites.	http://www.eml.doe.gov/databases/fallout/	Yes
33	Department of Energy, Environmental Measurements Laboratory, High Altitude Sampling Program	The HASP database was created to track the global dispersion of radioactive debris (from nuclear testing), and provides archived information on stratospheric air filter samples and measurements.	Stratospheric air filter samples and gas samples collected for North and South America.	http://www.eml.doe.gov/databases/hasp/	No, program discontinued.
34	Environmental Measurements Laboratory Surface Air Sampling Program (SASP)	Established to study the spatial and temporal distribution of radionuclides in the surface air (radioactive debris from nuclear testing, natural, etc). The SASP online database provides information on EML's archived air filter samples and sample measurements.	Consists of a global network of sampling sites.	http://www.eml.doe.gov/databases/sasp/ http://www.eml.doe.gov/databases/sasp/aboutsasp.cfm	Yes
35	Comprehensive Nuclear-Test Ban Treaty (CTBT) International Monitoring System	This global network of radionuclide monitoring stations capable of measuring radionuclides in the atmosphere for the detection of nuclear explosions. Technologies include infrasound-, hydroacoustic-, radionuclide-, and seismic monitoring.	Consists of a global network of sampling sites.	http://www.norsar.no/NTB/general/monitoring/ http://www.norsar.no/NTB/general/monitoring/radionuclide.html	Yes

APPENDIX B: PARTIALLY REVIEWED MONITORING SYSTEMS

This appendix contains partial reviews for systems initially selected for detailed review but for which the detailed review was terminated and/or the data were not verified, for reasons such as a finding that the systems was vastly similar to another systems undergoing detailed review. Because some data in the following reports were not verified, these reviews should be used with caution.

B.1. Oak Ridge Reservation

Criterion	Description
General:	
1. Title of monitoring activity	(1) Environmental Radiation Ambient Monitoring System (ERAMS) Air Program (2) Fugitive Radiological Air Emissions Monitoring (RMO) (3) Oak Ridge Perimeter Ambient Air Monitoring Program (RMO) (4) Radiological Monitoring and Oversight Program
2. Purpose of the monitoring activity	Oversight of radiological activities on and around Oak Ridge Reservation, with regard to environment/public health.
3. Entity/Agency that sponsors the monitoring activity	TN Dept. of Environment and Conservation, DOE Oversight Division
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	General methodology, locations, and results summary are included in the Environmental Monitoring Report *Environmental Radiation Data* available at http://www.epa.gov/narel/erams.html Results published in quarterly EPA report *Environmental Radiation Data* available at http://www.epa.gov/narel/erams.html
6. Website	(1), (2), (3) *Environmental Monitoring Report* available at http://www.state.tn.us/environment/doeo/EMR2003.pdf (4) http://www.state.tn.us/environment/doeo/progs.php#emc
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	John Owsley, Director of the Department of Energy Oversight Division 761 Emory Valley Road Oak Ridge, TN 37830-7072 (865) 481-0995 or Gary Riner (above number)
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air, suspended particulate matter (included but not reviewed are ground, surface, and drinking water, biological/fish and wildlife, sediment)
10. Radiation and/or radionuclides measured	Gross alpha, gross beta, and gamma spectroscopy on samples with high beta activity.
11. Equipment used	Synthetic fiber filters, 10cm diameter, portable high volume air sample, 47mm borosilicate glass fiber filters for particulate collection (pump and flow controller).

12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	Gamma-tracers (6) are located primarily at sites where fluctuations are expected (e.g., a demolition site)
13. Number of monitoring stations	2 high volume air samplers (one is mobile), one background, off-site location. 12 low volume air samplers near reservation boundaries and at one background location.
14. Location and size of area sampled by network	On-site Oak Ridge Reservation and locations where there is potential for release of diffuse air emissions, and facility perimeter.
15. Local-scale siting criteria (e.g., height above objects)	High volume air samplers mounted ~ 2 meters above the ground; low-volume air samplers mounted 1 to 2 meters above the ground.
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--
18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	--
20. Analytical methods used	--
21. Laboratories performing the analysis	--
22. Data quality control methods	--
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

B.2. Michigan Department of Environmental Quality

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Monitoring Program
2. Purpose of the monitoring activity	To collect data and perform radioanalyses of different sample types from an environmental monitoring network around nuclear power sites in Michigan.
3. Entity/Agency that sponsors the monitoring activity	Michigan Department of Environmental Quality (MDEQ)
4. Organizations that perform the monitoring	--
5. General scope and content of any routine or special data reports or other data dissemination methods	General methodology, locations, and results summary are included in the *Michigan Radiation Environmental Monitoring Program Report*

6. Website	*Michigan Radiation Environmental Monitoring Program Report* available at http://www.michigan.gov/deq/0,1607,7-135-3312-10374--,00.html
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	Environmental Assistance Center 1-800-662-9278 or email deq-ead-env-assist@michigan.gov
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air (also surface water, precipitation, milk)
10. Radiation and/or radionuclides measured	--
11. Equipment used	Automatic gas flow proportional counter
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	None of the measurements are real-time
13. Number of monitoring stations	17 monitoring stations dispersed among four separate nuclear stations
14. Location and size of area sampled by network	The sampling network for a plant generally consists of an on-site sampler and several other sampling systems in the vicinity (within several miles). A background sampling system is located in Lansing, Michigan.
15. Local-scale siting criteria (e.g., height above objects)	Varies from 3 to 25 feet above ground
16. Large-scale siting criteria (e.g., density of network stations)	Population density and between 1 to 5 miles from the N-Plant
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	Samples are collected weekly.
18. Personnel utilized for sample collection	Local area part-time MDEQ sampling contractor
19. Analysis performed on each type of sample media	Gross beta analysis 3 days after collection and 13 week quarterly composite gamma scan
20. Analytical methods used	MDEQ procedures
21. Laboratories performing the analysis	MDEQ
22. Data quality control methods	Verification review, duplicates and blanks
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	--

B.3. State of Idaho INEEL Oversight Program

Criterion	Description
General:	
1. Title of monitoring activity	Environmental Monitoring Program (EMP)

2. Purpose of the monitoring activity	To provide independent radiological monitoring of Idaho National Engineering and Environmental Laboratory (INEEL) by a public institution. Also provides educational opportunities for students.
3. Entity/Agency that sponsors the monitoring activity	State of Idaho INEEL Oversight Program
4. Organizations that perform the monitoring	Idaho State University (ISU), Health Physics Program
5. General scope and content of any routine or special data reports or other data dissemination methods	The EMP publishes data in quarterly reports to the INEEL Oversight Program.
6. Website	http://www.noaa.inel.gov/projects/iemp/ http://www.oversight.state.id.us/index.cfm http://www.physics.isu.edu/health-physics/eml.html#Qa
7. A point of contact for the organization conducting the monitoring activity for obtaining further information	EMP Program Director: Thomas F. Gesell Laboratory coordinator: Roy Dunker QA Officer: Tom Baccus Department of Physics School of Arts and Sciences Idaho State University Campus Box 8106 Pocatello, Idaho 83209 (208) 282-4308
8. Other	--
Sampling approach:	
9. Environmental media collected and sampled	Air, water
10. Radiation and/or radionuclides measured	Gross alpha/beta, gamma-emitting radionuclides, tritium
11. Equipment used	Air particulate filters (alpha/beta), high resolution shielded intrinsic germanium detectors - charcoal cartridges, airborne particulate filter and water are analyzed (gamma-emitting radionuclides); these two detectors are linked to the same system which simultaneously acquires data, which is then analyzed using the same software. Liquid scintillation counter (tritium) and electrolysis to concentrate tritium in aqueous samples (follow by liquid scintillation counting)
12. Scope of the monitoring in terms of the types of near or actual real-time measurements made	--
13. Number of monitoring stations	--
14. Location and size of area sampled by network	Onsite at INEEL and also in the region surrounding the site.
15. Local-scale siting criteria (e.g., height above objects)	--
16. Large-scale siting criteria (e.g., density of network stations)	--
If media samples are collected, then briefly describe the following:	
17. Frequency and numbers of samples collected	--

18. Personnel utilized for sample collection	--
19. Analysis performed on each type of sample media	Liquid scintillation
20. Analytical methods used	--
21. Laboratories performing the analysis	ISU Environmental Monitoring Laboratory (EML)
22. Data quality control methods	Instrument performance checks (background and source counts) are performed on days which the system is used or after events that might lead to changes in the system (e.g., maintenance, calibration). Water samples are split and analyzed, some percentage of air filters are recounted. The ISU EML participates in the EPA Cross Check Program (blind samples provided by EPA and analyzed by ISU). "Chain of Custody and Sample Tracking"; specific procedures are followed for collection, relinquishing, and acceptance of samples.
If near or actual real-time measurements are made, then briefly describe the following:	
23. Frequency of measurements	--
24. How such measurements are reported and to whom	--
25. Extent to which such measurements are aggregated and analyzed	--
26. Methods used to either aggregate or analyze such information	--
27. Data quality control methods	Germanium detector data analyzed by software which performs background subtraction, efficiency correction, nuclide identification, interference correction, weighted mean activity, uncertainty, and minimum detectable activity. Detectors are calibrated.

APPENDIX D

APPENDIX D: SAB Advisory I Recommendations: July 1995

Mission

- A mission statement is needed with objectives that support the mission (a critical component in determining the objectives is defining the uses for ERAMS data).
- ERAMS mission/goal should include the following components (order does not indicate priority):
    a) To gather baseline data on environmental levels of natural and man-made radiation and radionuclides (These data should be independent, reliable, and capable of revealing trends.)
    b) To gather data that help the assessment of population exposures/doses
    c) To monitor radionuclides released into the environment during radiological emergencies
    d) To inform the public, as well as public officials

Location

- Consider monitoring outside the U.S., including territories and trustees of the U.S. and its Antarctic bases.
- Consider a limited ERAMS monitoring effort in the area of nuclear facilities (including waste facilities) to provide data on radiation and radioactivity levels. This will respond to public concerns for corroborating monitoring performed by ERAMS with that of the NRC Agreement States licensees and DOE and its contractors. The limitations of data generated from such an effort should be appropriately noted.
- To assess the population dose associated with a specific nuclear facility will require many monitoring stations and a level of effort that is probably not feasible for ERAMS. However, a limited ERAMS effort could lead to partnerships with other Agencies, such as NRC and DOE, that would enhance the capability of ERAMS, as well as provide independent correlation of a facility=s monitoring data with that of ERAMS.

Media

- Consider monitoring total external gamma radiation as well as radionuclide-specific activities in environmental media
- Consider collection of additional environmental samples such as soil, food items, and biological media.

Analysis

- Consider whether routine analysis of precipitation samples is needed
- If most results are below the detection level, effort should be made to make some measurements at lower detection levels in order to quantify the levels. This extra effort would not be necessary on a routine basis, but should be done on limited occasions, as part of an overall quality assurance program. Specifically, this process would be of a limited nature, and would have the following two objectives:
  a) Ascertain the background level of radionuclides in all monitoring stations, and
  b) Become a part of a Quality Assurance program to ensure that measuring devices can perform appropriate analyses.

Data

- **An overarching recommendation is that NAREL increase its emphasis on interpretation of ERAMS data (historical and current)**. It should include discussion and explanation of anomalous data; trend analysis; and dose assessment. The RAC members had different opinions on whether NAREL=s interpretation of ERAMS data should include risk assessment.
- Report data using the International System of units to facilitate coordination with international organizations.
- Information regarding the sampling and measurements performed by local and state agencies for the monitoring and compliance measurements required by the Safe Drinking Water Act, the Clean Water Act, and the Clean Air Act, could be extremely useful if available as part of the ERAMS database. This could result in having an almost complete universe of sites for regulatory evaluation when standards need to be revised.
- The Agency could explore electronic techniques for the integration and dissemination of data.
- Organize a data collection and reporting system that can process environmental radiation data from DOE=s Environmental Measurements Laboratory, DOE contractors, nuclear power stations, and state regulatory agencies.
- Consider the opportunity to share ERAMS samples with other EPA programs so that a database can be extended for contaminants in addition to radionuclides
- ERAMS reports should include accurate and up-to-date information on detection and quantification limits.
- Current detection limits and uncertainties for ERAMS data should be used with models of nuclide transport, uptake, and dosimetry to determine whether the system can distinguish significant from insignificant dose levels. Some EPA programs are interested in annual doses as low as 15 or even 4 mrem (0.15 or 0.004 mSv). If not, more sensitive methods for some nuclides may be needed.
- Advertise the availability of *Environmental Radiation Data (ERD)* reports.

- The availability of ERAMS data is not widely known in the scientific community or by the public. The data produced by ERAMS is credible and deserves wider distribution.
- Publish ERAMS results in peer-reviewed journals on a regular basis and present results at professional society meetings. Interpretation of the data by the authors of the reports in terms of radionuclide distribution patterns and doses to humans will be needed.

Cooperative Sampling

- Consider (where feasible and beneficial) making the monitoring network available for sharing samples with other parts of the Agency and for coordinated monitoring of other substances of concern to public health.
- Continue the present partnership with state and local agencies for sample collection, and consider the possibility of obtaining additional assistance from colleges and universities.

Additional Advice

- Increase personal contacts with state and local government sample collectors to ensure adequacy of sample collection and to reinforce among collectors and their agencies the importance of their work. Consider the possibility of a Newsletter or similar communication to share with collectors.
- Incorporate emergency response information in the plan for a future ERAMS advisory. The role of ERAMS in the Federal Radiological Emergency Response Plan (FRERP) and the National Contingency Plan (NCP) should be clearly presented in the ERAMS plan.

APPENDIX E

APPENDIX E: SAB Advisory II Recommendations: November 1997

Mission

- The RAC suggests that the mission statement be strengthened. The RAC believes that the ERAMS mission is to provide the US government with the capability to assess on a regional basis, the radiation doses to the public and the environmental consequences of exposures to naturally occurring radionuclides as well as to radionuclides released into the environment by human activities. This assessment is to be accomplished by:
    - Developing and operating an environmental radioactivity monitoring program encompassing the US and its territories
    - Developing baseline and real time radioactivity and public dose data capable of revealing trends
    - Having in place a functioning radioactivity monitoring network that would operate routinely but also be responsive during emergency conditions, both immediate and long term
    - Developing and operating a program for communicating radiological information to the public and governmental officials routinely and during emergencies

- The ERAMS mission statement and objectives should be supplemented with an explicit statement describing what this monitoring system is **not** intended to do as well as providing reasons that such objectives would be infeasible or inappropriate. Examples of issues that ERAMS is not designed or intended to address are:
    - Providing site monitoring of potential radiation sources
    - Providing data for site-specific assessments of radiological doses
    - Monitoring radiation along transport routes for radioactive shipments
    - Providing an early warning system for nuclear accidents
      (Such a statement would minimize ambiguity for the states, other government agencies, and the public as to who has responsibility for the various functions.)

LOCATION

- Sampling sites for drinking water should be selected based on the size of the population served in order to address the objectives of evaluating ambient radiological conditions and informing the public. However, preference should be given to surface water supplies because these are more likely to be affected by a nuclear emergency than groundwater supplies.

- To address the objective of informing the public about levels of radiation in the environment, the RAC agrees that the size of the population served by a given system—regardless of whether the source is surface water or groundwater—is the most appropriate criterion for selecting a drinking water sampling location.

- The RAC recommends the following:
  - Sampling sites for drinking water be biased toward population centers that derive their drinking water from surface sources
  - For population centers that derive drinking water from both surface and ground sources, effort should be made to obtain samples from a point in the system where all or at least some of the water is from surface sources (This approach would help ensure that any effects on the drinking water supplies from nuclear emergencies would be detected and factored appropriately into the emergency response assessments.)

- The ERAMS program should cover the continental U.S. (including Alaska), and non-continental areas. Non-continental areas are defined in other EPA programs to include the State of Hawaii, Virgin Islands, Guam, American Samoa, Commonwealth of Puerto Rico, and the Northern Mariana Islands.

- For each of the sampling and monitoring categories, ERAMS should present a sensitivity analysis, for example in the form of a plot of fraction of population or geographic coverage versus number of optimally placed sites. This would indicate whether there are break points beyond which only minor benefits would accrue from large expenditures and how funds could be apportioned to maximize the geographic or population coverage.

- It may be desirable to give every state the opportunity to be included in each network, so that the citizens of each state can relate to results pertinent to them.

- Predominant global weather patterns should be taken into account in selecting ERAMS monitoring locations.

- Consideration should be given to other networks operated by DOE.

- EPA should use some algorithm (e.g., for plume width) to determine the number of border locations needed to meet objectives.

- Once a general location has been established for a sampling site, criteria for evaluating the suitability of a specific location for the sampling station should be explicitly stated. An example of a site-specific criterion would be the specification of a minimal acceptable distance from buildings for air and precipitation collectors.

- EPA should evaluate the technical basis for the number of real-time gamma radiation monitoring stations proposed in comparison with other strategies for assessing ambient gamma radiation levels. The Committee is concerned that the number of real-time gamma stations proposed may not be sufficient to provide much useful information. A plume from a radionuclide-releasing event could well miss all of the stations on its first pass, especially if it originated inside the U.S.

MEDIA

- Clarify or document what provisions exist for standby capability for collecting and analyzing specific food items (e.g., grains, vegetables), or typical diets in the event of an emergency or to establish baseline levels.

- EPA should position the ERAMS program to assure environmental radiological monitoring of U.S. surface waters in the event that a major international incident should occur.

- Before making the decision to end ERAMS monitoring of surface water, EPA should evaluate the utility of data collected by the USGS in meeting the ERAMS objectives.

- Precipitation sampling should be evaluated for its utility in meeting the ERAMS objectives as compared to the benefits of diverting those resources to enhancing drinking water sampling. EPA should clarify how data on radionuclides in precipitation would be useful in nuclear emergency response assessments or later dose assessments.

- Rainfall is the main vector for radionuclides moving from air to the ground. However, EPA should evaluate the utility of precipitation data against the advantages of diverting those resources into taking more drinking water samples, especially from surface water systems.

- EPA should consider reinstituting the environmental thermoluminescent dosimeter (TLD) system, or implementing a state-of-the-art TLD or Electret Ionization Chamber (EIC) system to supplement the planned pressurized ionization chamber (PIC) network. These integrating systems are cost-effective and can be operated at locations without electrical power.

FREQUENCY

- The sampling frequencies for the various media should be determined based on technical considerations and be sufficient to ensure that the volunteers collecting the samples retain their competence.

- Maintaining a high level of consistency and quality of samples when samples are collected only twice per year by volunteer collectors will require special effort and even then may not achieve a suitable state of readiness.

- EPA should consider increasing the sampling frequency for precipitation, milk, and drinking water samples and archiving those that are not analyzed immediately. Archived samples would have a limited storage time (e.g., not to exceed a year) or be held until analytical results are available for the next regularly scheduled collection. (Obviously, the archived samples could not be analyzed for short-lived radionuclides, so some information would be irretrievably lost.) Analyses of the archived samples would only be conducted if the more recent results showed a significant change relative to the previous results. This increased sampling would also keep the sample collectors Aup to speed and at the ready@ as well as have samples available in the event of an emergency.

- For those media to be sampled twice per year, as specified in the reconfiguration document, EPA should consider establishing a two-tiered system of sampling frequencies for each location and type of media, with more frequent sampling being conducted when a trend is apparent or suggested by the data, when an anomalous result has been confirmed, or when elevated concentrations have been observed in another sample from the same location but in a different medium or for a different radionuclide. Implementing such a recommendation would require the establishment of an action level for each category, e.g., based on dose levels corresponding to a particular concentration or trend. It would also require the establishment of Astopping rules,@ defining in advance how long the increased frequency of sampling should be in effect.

- The crucial point regarding frequency is not only how often a location should be monitored to avoid missing an increased level of a particular radionuclide, but also how often a sample should be collected so that sampling staff retains its competence. The experience with reliability of quarterly collections should be reviewed. If it has not already been done, collection reliability should be checked in the field.

- Seasonal effects and coordination with other sampling locations should be considered.

- Trend analysis may be useful in determining when the frequency of monitoring for radionuclides whose levels have been well defined should be reduced.

ANALYSIS

- Before implementing the reconfiguration plan, EPA should use available information to describe, by radionuclide, what is known and what must be measured in the future.

- Some radionuclides, such as Sr-90 and isotopes of U and Pu, are currently detectable at levels that are low and changing very slowly, so that once-yearly national coverage is sufficient.

- Other radionuclides are generally not detectable by NAREL=s present analytical techniques (Cs-137 and H-3), but would be detected if measured at 10 times lower detection limits. NAREL needs to decide if the lower detection levels are worth the added cost.

- Short-lived radionuclides such as I-131 are not in the category of defining the background conditions but may be present downstream from medical facilities and thus become part of Abackground@ relative to releases from nuclear accidents.

- Another radionuclide (Kr-85) has been dropped from ERAMS but should be reconsidered in the context of emergency response capability.

- Other radionuclides that have not been monitored such as Rn-222, Pb-210, I-129, Nd-147, Eu-152, should also be considered for future monitoring to meet the objectives of the ERAMS program because they may contribute significantly to population dose under normal or accident conditions.

- An additional criterion should be explicitly added to those listed for the selection of a given radionuclide for analysis "identified as a nuclide with the potential to pose a significant contribution to population dose, based on pathway modeling (or a surrogate for such a nuclide)." This criterion is included in the draft NAREL report rather obliquely, as a radionuclide of "concern to the system client." The explicit addition of this criterion merely reiterates a later statement in the document that "priority will be given to radionuclides that are significant contributors to dose and those that are short-lived."

- NAREL should consider adding gross alpha analysis to the air particulate sampling program. The Committee was somewhat surprised that no gross alpha analysis is contemplated for the air particulate matter sampling program. The RAC acknowledges the difficulties in detecting short-range alpha particles emitted from solid media; however, some additional sample preparation steps may permit such analyses at modest additional cost. Although an argument can be made that this measurement is not quantitative due to variable impaction in the filter and self absorption in the mass of material collected on the filter, it is still a reasonable qualitative indicator. In systems with which the RAC has had experience, significant differences between gross alpha results in the general environment and those near an elemental phosphorus plant, which emits natural Po-210, were routinely noted. In addition, considering the concern over the Pu-238 radioisotope thermal generators (RTGs) such as those launched recently in the Cassini spacecraft, a gross alpha capability for nuclear emergency response assessments and a baseline would seem to be timely.

- The DQO approach should be used systematically and up-front in the design of a reconfigured ERAMS including all aspects of sample analysis, such as analytical detection limits, uncertainties, quality control measures, and action levels.

- The RAC strongly supports the proposal to analyze samples periodically using more sensitive techniques and encourages the use of the Currie method for estimating minimum detectable activities.

DATA

- ERAMS reports should note the availability of radiological analyses of surface water from the USGS and provide proper references thereto.

- Dose assessment may be performed to enhance the effectiveness of ERAMS in meeting its objective or informing the general public about levels of radiation in the environment.

- Background information on the relevant characteristics of each sampling site should be compiled in a report or web-accessible database and made readily available to users of the data. Examples include the following:
  – For all sampling sites: longitude, latitude, elevation, objective of sampling site (monitoring potential point source, border station, global fallout), type of land use surrounding site
  – Air and precipitation sites: wind rose, population within specified distances of the site, site sketch
  – Milk sampling sites: wind rose, location and size of population served by milk suppliers in the area
  – Drinking water: type of source (river/stream, reservoir, groundwater well, mixture), population served by this particular source, location of sample, and collection site (if different from location of water supply) (All ERAMS data should be reported with uncertainty limits.)

- A statement should be published with each data set as to any other significant sources of uncertainty, in addition to analytical counting statistics, that would not be reflected in the reported uncertainty limits.

- NAREL should calculate dose levels from concentration data to lend perspective to the monitoring results. Reporting dose levels calculated from radionuclide concentrations resulting from release events is important because the estimated dose places a specific radionuclide measurement in perspective. On the other hand, the dose can vary widely because of assumptions made concerning intake pathways and amounts, and target populations. Hence, the assumptions underlying the dose calculations should be clearly stated.

- It is assumed that doses would not be assessed for individuals in the population but rather for specific segments of the population. These segments should be identified. A written plan should be developed to describe how, and within what time frame(s), dose assessments would be conducted based on ERAMS data. To the extent feasible, NAREL should consider reporting approximate dose levels corresponding to its current and extended detection limits. Underlying assumptions for these dose levels should also be clearly stated.

APPENDIX F

APPENDIX F: Fixed Monitor Prototype Project

In 2002, a prototyping project was initiated to verify the technical feasibility of, and develop specifications for, the proposed upgrade of the fixed air monitoring network to add real-time gamma spectrometric capability. Some general performance-based criteria that would have to be met were initially established:

- Quantitative isotopic measurements at required sensitivity
- Available commercial products (no R&D)
- Small size (must fit in available space inside existing air sampling equipment)
- Able to operate continuously at remote locations, with minimal attention by diverse mix of operators—
  - Rugged (weather enclosure, but no heating or cooling; vibration from sampler)
  - Automatic re-start after power interruption
  - Stable calibration

The assessment of currently available off-the-shelf radiation detector technologies was based on literature review and discussions with vendors. Beta and gross alpha Continuous Air Monitors (CAMs) were eliminated because they can not differentiate isotopes, and have varying degrees of radon progeny interference. Alpha CAMs with energy spectrometry were eliminated due to inadequate sensitivity. Gamma spectrometry was selected because it appeared to have the fewest limitations.

Potential gamma detectors evaluated included two that were not selected for testing: NaI scintillators, due to susceptibility to cracking from temperature changes, and GaAs because sufficiently large crystals were not commercially available. The detectors selected for testing included cadmium zinc telluride (CZT), electronically cooled CdTe, HgI, a High Pressure, High Purity Xenon pulse ion chamber, and a CsI Scintillator.

Five measurement systems, complete with the necessary electronics and software, were purchased. The five systems were installed by NAREL staff on four different air sampler platforms from two different vendors. The air sampler, radiation instrument, and telecommunications equipment were integrated using four different types of commercial computers. The prototype units were then deployed in Montgomery, AL, Las Vegas, NV, New York City, and Washington, DC.

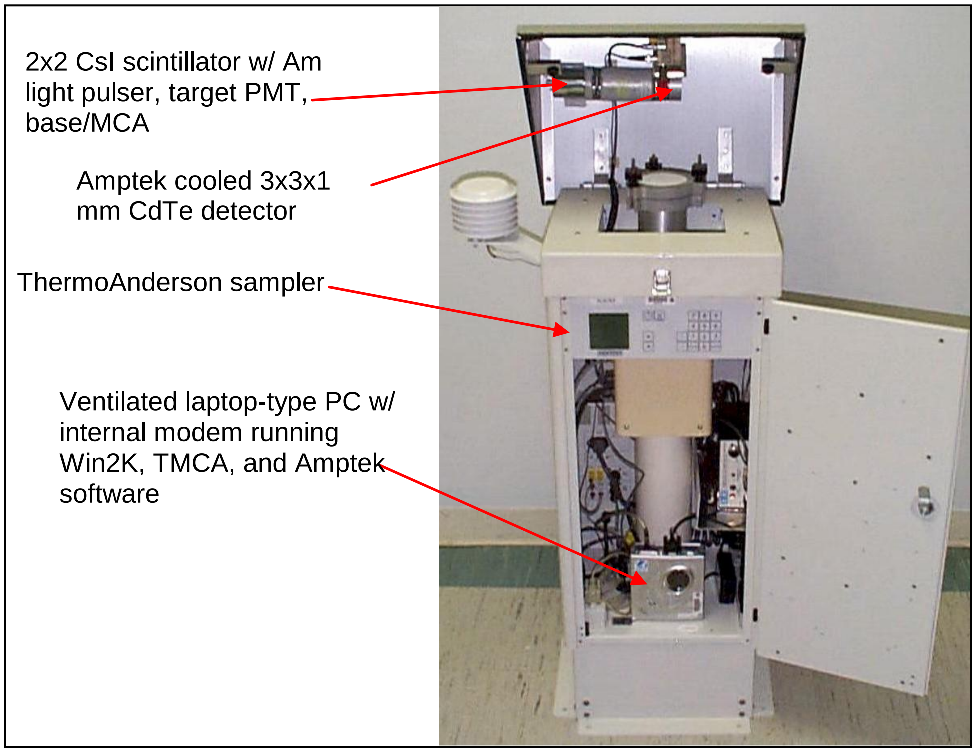

Fig. E.1. Las Vegas prototype.

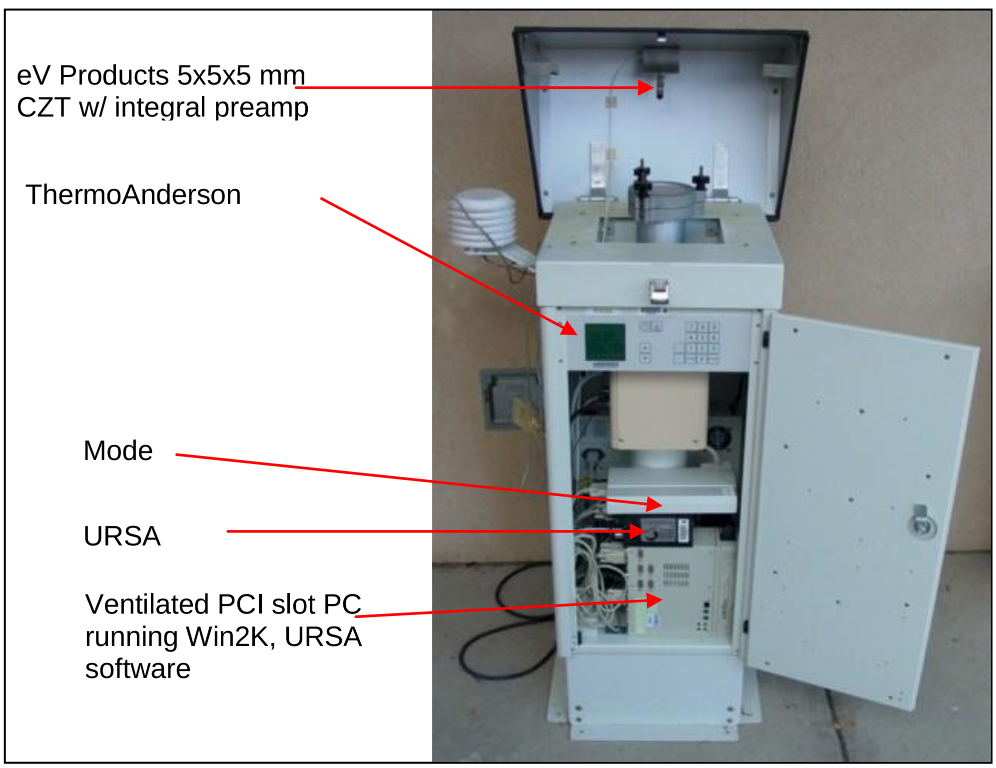

Fig. E.2. Montgomery prototype.

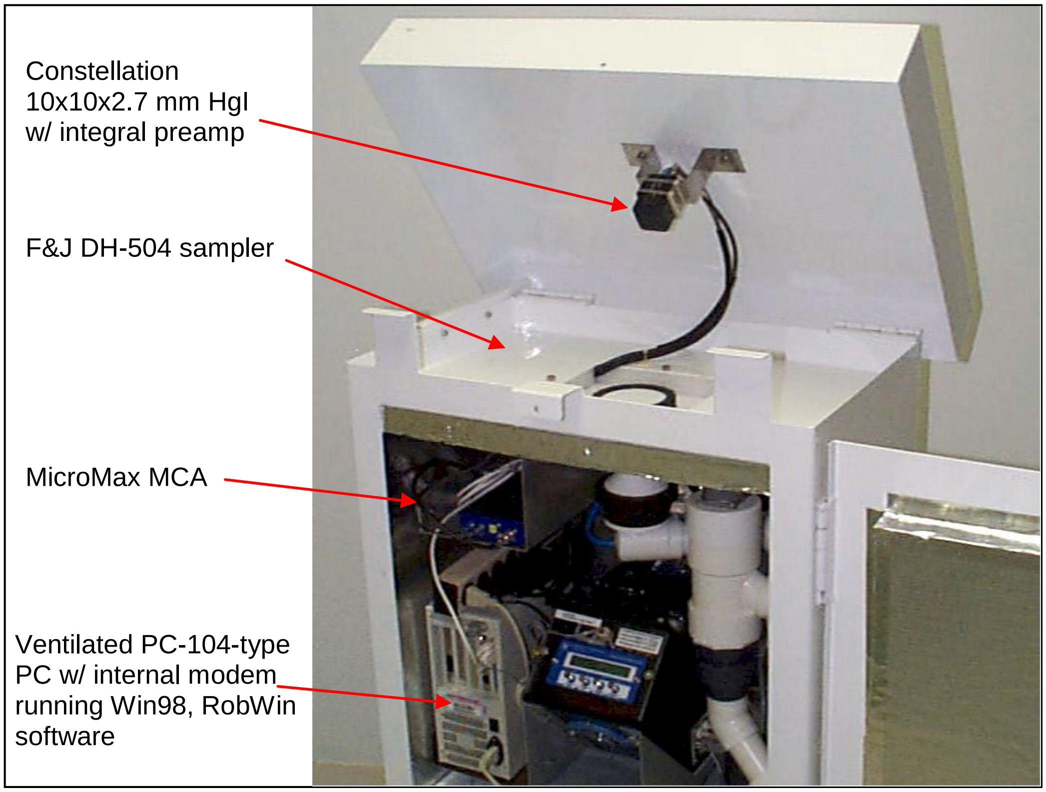

Fig. E.3. Washington, D.C. prototype.

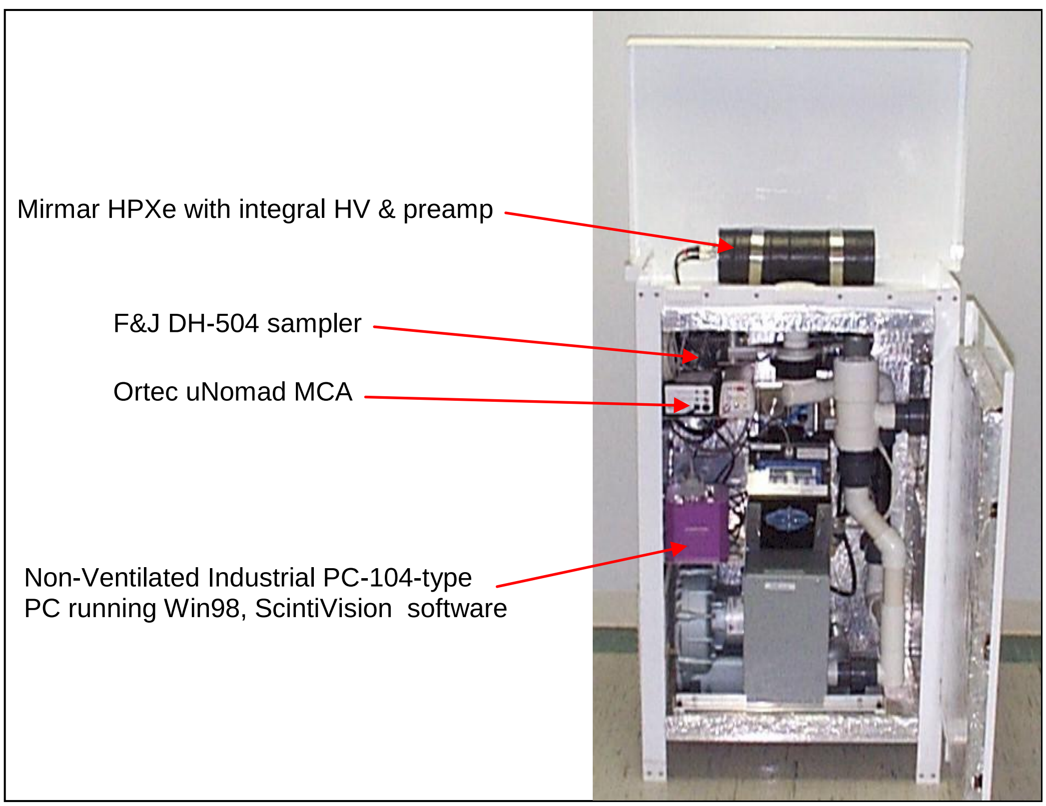

Fig. E.4. New York City prototype.

The prototypes were field tested for over a year. At the end of testing, it was concluded that all of the detector systems were rugged and reliable enough to be used as intended, but none of the tested detectors would be able by itself to meet all objectives:

- CZT – was too small to provide needed sensitivity > 150 KeV, but larger crystals are now available.
- Electronically cooled CdTe – had superior resolution to CZT with the same sensitivity limitations, and superior gain stability
- HPXe – had the best resolution and gain stability, adequate sensitivity, but it had severe microphonics and high compton at low energies.
- CsI – had excessive compton scattering interference at low energies.
- HgI – did not complete testing due to MCA/software problems.

Despite the limitations of the specific detectors tested, it was concluded that the concept was viable. Performance-based specifications were developed based on the experience gained during the prototype tests. A request for quotations was issued in July 2004 and, following a lengthy evaluation and negotiation period, a contract was awarded and an initial order placed in early February 2005 for the initial quantity of 52 fully integrated monitoring stations. The first unit was delivered to NAREL for testing in September 2005. If no significant deficiencies are identified during testing, delivery of production monitors is expected to begin in February 2006 at the rate of five units per month.

APPENDIX G

APPENDIX G: Local Siting Criteria for Fixed Monitors

TECHNICAL MEMORANDUM

To: Jacolyn White, USEPA

From: Ed Carr and Jim Laurenson, ICF Consulting, and Paul Demopoulos, ATL Inc.

Date: July 26, 2005

Re: Task 1: Evaluation of EPA's Draft Local Siting Criteria for Fixed Monitoring Stations, EPA, Contract GS-10F-0124J, Delivery Order EP05W002015

1. Introduction

The purpose of this memo is to provide EPA with feedback on the appropriateness, relevance, and potential flexibility on its draft local siting criteria as described in Evaluation of Potential RadNet Fixed Monitoring Station Sites (EPA, 2005a) and the Real-Time Monitoring of Radiation in Air in the United States (EPA, 2005b). This memo is an update of a June 17, 2005 draft and reflects EPA written comments and a meeting on that draft.

This evaluation was conducted with consideration for several important practical considerations for RadNet:

1. Each metropolitan area will have only a single monitor, due to resource constraints;
2. In some cases there will be a tradeoff between the location of the monitor and the ability to identify a volunteer to operate the monitor; and
3. There may be some efficiencies in locating the new radiation monitors at a site with other existing air monitors.

Thus, an important goal of this memo is to evaluate each siting criterion in terms of its flexibility and its ability to assure the quality of the resulting monitoring data.

This memo first focuses on the local siting criteria through a review and discussion of the applicability of EPA siting criteria for ambient air quality monitoring. Only local criteria as they pertain to the representativeness of measurements to ambient air are addressed, while criteria related to matters such as accessibility of electrical power and phone lines are not.

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Two additional sections are provided on criteria that came up during discussions with EPA. One section addresses the broader criteria of RadNet network design. The other section addresses several other broad criteria for location of monitors. While these sections are not directly specific to local siting criteria, they do encompass and address issues associated with the local siting of monitors.

A reference section is provided at the end of this memo. Attachment 1 presents the latest draft (as of the date of this memo) of the RadNet mission, scope, and objectives.

2. Local Siting Criteria

The draft local siting criteria for the new RadNet fixed monitoring are evaluated in this section for their relevance, appropriateness, and potential flexibility in terms of meeting the goals and objectives of RadNet (Attachment 1). The draft criteria are reflected in EPA, 2005a, an excerpt of which is provided in Table 1 (with relevant criteria highlighted). These criteria are evaluated in part against EPA siting criteria for ambient air quality monitoring, primarily Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring, 40 CFR, Part 58, Appendix E (EPA, 2004a; hereafter referred to more simply as Part 58, Appendix E), which are focused on minimizing the influence from any localized effects and thus on such issues as horizontal and vertical probe placement, spacing from obstructions, and spacing from roadways. As the introduction to Part 58, Appendix E states, "adherence to these siting criteria is necessary to ensure the uniform collection of compatible and comparable air quality data." Thus, the Part 58, Appendix E siting criteria are a good starting point for the RadNet siting criteria. As seen below, however, due to differences in the scope and objectives of the two types of systems, the criteria also can differ substantially.

Part 58, Appendix E criteria address both gaseous and particulate pollutants, as well as both reactive and non-reactive pollutants. RadNet, however, is designed to measure radiation from particulates only. Nevertheless, because the size of the particulates that RadNet may monitor during an event is unknown and may approach gases in terms of behavior in the environment, and because the reactivity of the particulates that RadNet may monitor likewise is unknown, we evaluated the RadNet local siting criteria using the most conservative of the Part 58, Appendix E criteria. Thus, for example, while Part 58, Appendix A states that equipment for monitoring gases must be at least 1 meter from supporting structures, the same criterion for PM-10 and Pb probes is 2 meters. The recommendation in this case, therefore, would be the more conservative 2-meter distance (as currently identified in the draft RadNet monitoring plan).

The remainder of this section steps through the relevant draft local RadNet siting criteria indicated by Table 1. A summary of this evaluation is provided in Table 2. This table includes a crosswalk to the relevant criteria in Table 1.

<u>Height Above Grade</u>

Part 58, Appendix E identifies a range of preferred vertical height of 2 to 15 meters above grade, while the current draft RadNet criterion is for a maximum of 50 meters above grade. This difference is reasonable and is principally because of the differences in the scope and objectives between the two programs. The air quality monitoring network is focused on human population exposure, source contribution, and maximum concentration. Emissions are emitted from a wide variety of sources at various heights and from nearby sources to very distant sources. In the case of RadNet, key objectives are focused on an expected single event with a large-scale release

Table 1. Questions from Evaluation of Potential RadNet Fixed Monitoring Station Sites[a]

1. Is the elevation less than 50 meters above grade (ground level)?

2. Can 15 amp, 120 VAC power be provided? Can telephone service be provided?

3. Can access to the location be controlled for security and to prevent vandalism?

4. Is the minimum space needed for the monitor of 65 inches height by 47 inches depth by 31 inches width available at the location?

5. Is the location far enough (>10 meters) from public access to minimize the potential for purposeful contamination?

6. Can the location be accessed safely during all anticipated weather conditions?

7. Is CDMA (e.g., Verizon Wireless or Alltel) cellular telephone service available? If yes, what is the signal strength (# of bars)?

8. Can access to the internet via a local or wide area network be provided?

9. Is there a clear line of sight to the southerly compass quadrant (for satellite communication)?

10. Can the location be kept clear of excessive dust or other materials that may inhibit air flow?

11. Is there unrestricted airflow in an arc of at least 270 degrees around the location?

12. Is the location at least 5 meters away from building ventilation exhausts and intakes? Please include in the sketch on the back of this page and label with approximate distances.

13. Is the location at least 2 meters from walls or other structures that might influence air flow?

14. Is the location away from obstacles such as buildings, so that the distance between obstacles and the monitor will be at least twice the height that the obstacle rises above the monitor?

15. If there are nearby trees, is the location at least 20 meters from any tree's drip line?

16. Is the location at least 2 meters away from any other air sampler intake?

17. If the location is at grade level, is it in a paved area? If not, is there vegetative ground cover year round, so that the impact of wind blown dusts will be kept at a minimum?

18. Is the location at least 50 meters from the nearest major street or highway? Please include in the sketch on the back of this page and label with the name or route number.

19. If the location is a rooftop, are there lightning rods on the roof? If yes, can a connection be provided to the building ground for the lightning arrestor on the monitor?

Source: EPA, 2005a
[a]Only italicized criteria pertain to the representativeness of measurements to ambient air and thus are evaluated in this report.

Table 2. Summary of Evaluation of Selected RadNet Draft Local Siting Criteria

Criterion[a]	RadNet	Evaluation Summary
Height above grade (1)	Up to 50 meters	Part 58, Appendix E (or simply Part 58 for purposes of this table) recommends ranges from 2 to 15 meters. The differences are reasonable, however, given the different scopes and objectives of the two systems. The RadNet height is a reasonable compromise between the competing needs of the system.
Unrestricted airflow arc (11)	270 degree minimum	This RadNet arc is reasonable and matches the main criterion of Part 58. The RadNet criterion should clarify that the predominant wind should be within this arc. The arc also could be relaxed to 180 degrees if monitoring site is on the side (windward) of a building (see "Proximity to wind direction" criterion).
Distance from building ventilation exhausts and intakes (12)	5 meter minimum	This is reasonable to avoid dilution/scavenging or contributions from most vents, and is similar to Part 58. An added note from Part 58 is that if a nearby exhaust stack is for combustion of fuel oil, coal, solid waste, or similar fuel and is sufficiently short or upwind so that the plume could reasonably be expected to impact on the sampler intake a significant part of the time, then other buildings/locations in the area should be considered for sampling.
Distance from walls or other structures (13)	2 meter minimum	This is reasonable for avoiding wake cavity and other effects, and it matches Part 58. This distance perhaps could be relaxed, especially if the predominant wind direction is from the monitor side of the wall or other structure.
Distance from obstacles such as buildings (14)	At least twice the height that the obstacle rises above the monitor	This is reasonable for avoiding wake cavity, scavenging, and other effects, and it matches Part 58, though perhaps this can be relaxed since the Part 58 criterion was also developed to avoid air flow interference, which is less of a concern for the large scale of RadNet. Also, shorter distances may be allowable if the predominant wind direction is from the monitor side of the obstacle.
Distance from tree drip line (15)	20 meter minimum	This is reasonable for avoiding wake cavity and other effects, and it matches Part 58, although Part 58 also indicates this could be relaxed to 10 meters. This distance could be relaxed given the large scale of RadNet and if the predominant wind direction is from the monitor side of the trees.
Distance from other air sampler intake (16)	2 meter minimum	Part 58 (Appendix A) specifies a 2-meter separation for co-located particulate samplers. This distance may be too small for a RadNet samplers rate—or at least should not be relaxed—assuming the Part 58 criterion was designed for lower volume samplers. Another co-location concern is whether other equipment uses radiation (e.g., a beta attenuation monitor).
Avoidance of intermittent dust (17)	Placement on pavement or vegetative ground cover	This is reasonable for avoiding local dust, and it matches Part 58.
Distance from the nearest major street or highway (18)	50 meter minimum	This distance likely can be relaxed, depending on the size of the road and given the predictable nature of the traffic flow and ability of the monitors to account for local contribution.
Proximity to local radiation sources (NA)	--	In general, RadNet monitors should not be located near facilities that involve the release of radioactive material, such as quarry operations or mining. At a minimum, the locations of these facilities should be identified.

[a]Only criteria affecting representativeness of measured concentrations are addressed. Numbers in parentheses, if present, refer to the criterion number in Evaluation of Potential RadNet Fixed Monitoring Station Sites.

of radiation impacting large portions of the country and major population centers. Most of the radiation likely will be transported at heights well above grade because the release scenario likely will have generated considerable plume rise and the winds are generally stronger with increasing height, up to 10 km. These two conditions will likely lead to higher measured radiation levels with increasing height. Thus, higher monitoring heights will be more likely to detect such plumes. Furthermore, the RadNet objectives include identifying un-impacted areas, developing a national impact picture, providing data to modelers and decision makers, and determining follow-up monitoring needs. For such objectives, a higher monitoring height than 15 meters may be preferred.

For the purpose of determining the levels of population exposure, however, at least in terms of average population risk versus maximum individual risk (i.e., representative risk to the largest population segments versus maximum real or hypothetical risk to any individual), the average breathing zone height above grade would be preferred. In many cases, this height is the top of buildings because that is where the air intake vents are located. Ground level is important too, however, because particulates over time will settle to the lower elevations and because re-entrainment of particulates from ground surfaces to the breathing zone may occur. Exposure at these various elevations, however, can be modeled using inputs such as the monitoring data from the higher elevations in conjunction with follow-up monitoring at the lower elevations. Furthermore, in most meteorological situations, the 50-meter height is well below the typical morning mixing height of hundreds of meters (Holzworth, 1972), which in effect reduces the difference between the concentrations anticipated at higher elevations and those at lower elevations. The higher height will typically be less representative during the night, however, when multiple stable layers frequently form close to the surface and prevent or reduce downward mixing of air that would likely have higher radiation levels from the distant source. Thus, the higher measurement elevation would, in most cases, have a tendency to overestimate radiation ground level concentration during the nighttime hours.

Unrestricted Airflow Arc

This RadNet arc of 270 degrees of unrestricted airflow is reasonable and matches Part 58, Appendix E. The RadNet criterion should clarify, however, that the predominant wind should be within this arc. Also, this arc could be relaxed to 180 degrees if the monitoring location is on the side (windward) of a building (see “Proximity to wind direction” below). A significant advantage of higher monitoring heights should make it easier to find locations with unrestricted airflow that is considerably greater than the recommended minimum. Such unrestricted airflow would increase the certainty of information regarding plume characteristics (e.g., direction of travel).

Distance From Building Ventilation Exhausts and Intakes

The current draft RadNet criterion recommends a location at least 5 meters from a building exhaust or intake vents, which is similar to recommendations in Part 58, Appendix E. In the case of avoidance of intake vents, this distance is likely sufficient to minimize changes in localized airflows that might affect the representativeness of the measurement. For avoidance of exhaust vents, however, Part 58 notes that if a nearby exhaust stack is for combustion of fuel oil, coal, solid waste, or similar fuel and is sufficiently short or upwind so that the plume could reasonably be expected to impact on the sampler intake a significant part of the time, then other buildings/locations in the area should be considered for sampling. This may be especially important for RadNet given the radiological components of some fossil fuels. Furthermore, the ideal distance should be a function of the exhaust vent flow rate (e.g., cubic meters per second or air exchange rate) and orientation of the exhaust (horizontal or vertical). The stronger the outflow rate or nearer the vent, the higher the possibility that the measurement contains building air (and thus radon and radionuclides entrained on cement and other indoor air dusts) and therefore is not representative of the ambient air.

Distance From Walls or Other Structures

This criterion is designed to minimize effects from structures that may impede airflow and contribute to wake cavity and other effects. The RadNet distance of 2 meters matches that in Part 58, Appendix E and thus appears to be a reasonable selection if wake effects are important. In the case of the relatively large scale and distant release involved in a radiological event for which this monitoring system is designed, this distance likely could be relaxed, especially if the predominant wind direction is from the monitor side of the wall or other structure.

Distance From Obstacles Such As Buildings

Both the current draft RadNet criterion and Part 58, Appendix E recommend a location away from obstacles such as buildings, so that the distance between large obstacles such as buildings and the monitor will be at least twice the height that the obstacle rises above the probe. As with walls, etc. discussed in the previous section, this represents a minimum distance between obstacle and probe if building/obstacle wake effects are important. In the case of the relatively distant and large scale releases involved in a radiological event for which this monitoring system is designed, this distance is most likely sufficient and may even be an overestimate of the distance needed to avoid measurement in the “wake cavity” (a zone in which a rotor or recirculation occurs) region of the obstacle. Shorter distances also may be allowable if the predominant wind direction is from the monitor side of the obstacle. For closer releases, however, this distance becomes more important, and in fact in some cases this wake cavity region distance may extend up to 3 times the obstacle height.

Distance From Tree Drip Line

The drip line interference distance is mainly a concern for interference in wind flow, rainfall measurements, and for uptake of some gas-phase pollutants through adsorption; however, for particulates and for the distant releases that are the subject of RadNet, these interferences are of minimal concern and a closer distance of 10 meters would be acceptable. This distance could be relaxed given the large scale of RadNet and if the predominant wind direction is from the monitor side of the trees.

Distance From Other Air Sampler Intake

Part 58, Appendix A, Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS; EPA, 2004c) specifies a 2-meter minimum separation for particulate sampler equipment for the prevention of airflow interference, or 1-meter separation for samplers having flow rates less than 200 liters/min. The 2-meter separation, however, may have been designed for lower volume particulate samplers than are used for RadNet, which is in the range of 10,000s of liters/minute, based on the design specifications (i.e., 35 to 75 cu. meters/minute, which equates to 35,000 to 75,000 liters/minute). In contrast, typical high volume particulate samplers are only in the range of 1 to 2 cu. meters/minute (1,000 to 2,000 liters/minute). Thus, the 2-meter distance specified for RadNet may be too small for the RadNet sampler rate (certainly the 1-meter distance is), or at a minimum probably should not be relaxed.

Another potential issue for co-located RadNet samplers with other monitoring equipment is whether the other equipment uses devices that employ radiation emitting sources that could interfere with the RadNet monitor (e.g., some type of neutron activation or x-ray device that releases bremsstrahlung, x-ray, or other type of radiation). One example of a common instrument where this would be of concern is a beta attenuation monitor (BAM). This device provides estimates of atmospheric particulate matter concentration. The instrument measures beta ray transmission across a clean and exposed section of filter tape to determine particulate matter concentration levels. A small beta source is coupled to a sensitive detector that counts the emitted beta particles. While the beta source in a BAM likely would result in insignificant amounts of ambient radiation, and RadNet specifications are designed to account for such ambient levels, other equipment that might use radiation sources—especially intermittently—and be co-located with a RadNet monitor should be evaluated.

Avoidance of Intermittent Dust

For grade level sites, avoidance of intermittent dust can be a significant issue. The RadNet criterion is that grade-level monitors must be placed on pavement or a vegetative ground cover. This is a reasonable approach to avoiding local dust, and it matches Part 58, Appendix E.

Distance From the Nearest Major Street or Highway

Current guidance suggests that regional monitors such as potential RadNet fixed monitors be located at least 50 meters from the nearest major street or highway. This requirement stems from possible concerns with automotive exhaust gases and particulate matter interfering with measurements. However, the amount of radiation emitted from the combustion of gasoline and diesel in motor vehicles likely is well below ambient background concentration levels and would not interfere with the objectives of the RadNet monitoring program. Thus, this distance could probably be safely relaxed, depending on the size of the road and given the predictable nature of the traffic flow and ability of the monitors to account for local contribution. Distances as low as 10 meters would still be sufficient to avoid any vehicle wake effects that may effect the ambient air flow pattern.

Proximity to Local Radiation Sources

The proximity of a monitor to local radiation sources can result in nonrepresentative measurements of the broader area surrounding the monitor. For example, concentrations of ground-level radionuclides vary considerably throughout the United States, and an understanding of the local ground-level radionuclide levels should be a part of the site selection process. A site survey could examine local soil gas radon and other radionuclide levels to assure that the levels are representative of the natural background for the local area. Allowing monitoring elevations of up to 15 meters or higher combined with careful site selection should make it possible to keep local background levels low enough.

In some cases, local industrial sites may affect background radiation levels. EPA's draft Dual Contamination Guidance (EPA 2003) lists numerous industries and products associated with enhanced natural radioactivity levels. Among them are several mining and resource extraction industries as well as waste and water treatment. In general, RadNet monitors should not be located next to industrial facilities that involve the movement of large quantities of earth such as quarry operations or mining.

More challenging is not siting monitors downwind of industries that release radionuclides directly into the atmosphere as fly ash or flue gasses. Such industries include coal combustion, municipal and medical waste incinerators, and elemental phosphorus production. In addition, care should be taken when siting monitors near facilities that use radioactive materials directly. In addition, as more uses are found for radioactive materials in medicine and product testing interference from these materials may pose a problem. It is not feasible to include a comprehensive list of such industries, but does include food irradiation, glass and ceramics processing, and fertilizer processing.

It may be preferable to site monitors in areas generally zoned for residential land use and thus tending to avoid industrial sources of radiation and more representative of the exposed and may make accessibility easier for volunteer operators.

Based on the RadNet calibration requirements, radon progeny range, detection criteria for radionuclides of concern stated in the specifications document, etc., even high ambient levels likely will not affect the results of the real-time measurements, at least in the sense of meeting the target minimum detectable activities (MDAs). Fluctuating background or TENORM radionuclides other than radon, however, still may be a concern that an area survey may help resolve.

3. Network Design Criteria

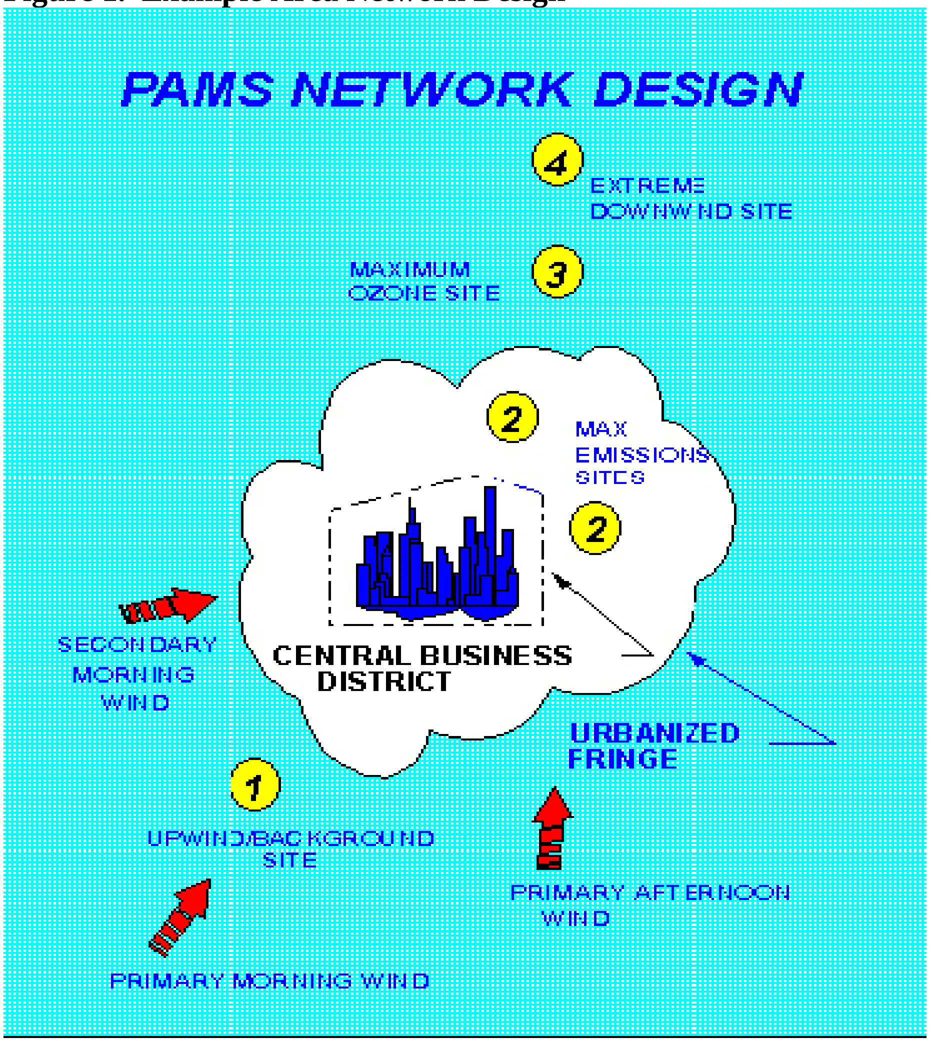
Part 58, Appendix D, Network Design for State and Local Air Monitoring Stations, National Air Monitoring Stations and Photochemical Assessment Monitoring Stations (EPA, 2004b), provides criteria to be implemented in establishing networks for State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), and Photochemical Assessment Monitoring Stations (PAMS). Each of these monitoring networks serves separate purposes and has a unique set of objectives.

Collectively, SLAMS sites are meant to meet a minimum of six major objectives:

1. To determine maximum pollutant concentrations in the area covered by the network.
2. To determine representative concentrations in areas of high population density.
3. To determine the effect on ambient air quality of specific pollution sources or source categories.
4. To determine the general background concentration levels.
5. To determine the extent of regional pollutant transport.
6. To determine welfare-related pollutant impacts in rural and remote areas (for example effects on visibility, vegetation, and watersheds).

Figure 1 illustrates how some sites address these objectives. For an expanded RadNet system, objectives two, three, four, and five are most applicable. Objective six is perhaps desirable but certainly of secondary importance. Objective one is not feasible given the limitation of one monitor per area. Objective three may be feasible, but perhaps not in near real-time, depending upon the number and types of radiological incidents.

Figure 1. Example Area Network Design[a]



Source: EPA, 2004b
[a]A numbered circle denotes a PAMS site.

NAMS are a subset of SLAMS with the objectives of monitoring highest concentrations and greatest population exposures in metropolitan areas. This is not the objective of RadNet in the foreseeable future. PAMS are meant to monitor ozone and its precursors. Because they are specific to the details and complexities of photochemistry it is also not applicable to RadNet. Thus SLAMS represent the closest parallel to the RadNet system.

In determining appropriate siting of SLAMS, EPA defines six monitoring scales:

1. Micro scale refers to areas with dimensions of under 100 meters.

2. Middle scale refers to areas of several city blocks with dimensions ranging up to about 0.5 km.

3. Neighborhood scale refers to extended regions of similar land use within a city with dimensions ranging from about 0.5 km to about 4 km.

4. Urban scale refers to overall, citywide concentrations with dimensions on the order of 10s of km.

5. Regional scale usually refers to rural areas and extends from 10s to 100s of km.

6. National and global scales are meant to characterize the nation or globe as a whole.

Table 3 relates monitoring objectives and representative scales for SLAMS. Given RadNet's projected total of 180 monitors, the urban and regional scales are most appropriate to RadNet. According to Table 3, those SLAMS monitoring objectives that best match RadNet's, as bolded, should be feasible with the urban and regional scales.

Table 3. RadNet Monitoring Objectives and Appropriate SLAMS Siting Scale

RadNet Monitoring Objective	Appropriate SLAMS Siting Scale
Maximum Concentration	Micro, Middle, Neighborhood
Population Exposure	**Neighborhood, Urban**
Source Impact	Micro, Middle, Neighborhood
General Background Levels	**Neighborhood, Urban, Regional**
Regional Transport	**Urban, Regional**
Welfare-Related Impacts	Urban, Regional

For SLAMS monitoring, general guidelines on monitor placement within local areas for each of the criteria pollutants is provided in Part 58, Appendix D. These guidelines consider emissions source inventories, traffic activity, climatological factors, and topography and land-use data. All of these are important in siting monitors for criteria pollutants. However, for ambient radiation measurements only, meteorological data (primarily wind speed, direction and rainfall) and topographical influences are of primary importance in siting representative RadNet monitors. Interference from traffic should be of minimal influence.

The SLAMS guidance recommends the use of the climatological wind rose as an easily interpreted graphical representation of wind directional frequencies. If further detail is needed, joint frequency distributions of stability classes and wind speeds and directions can be obtained from nearby National Weather Service sites. However, because it is expected that RadNet sites would be operated by volunteer organizations the simplest way to ensure climatological factors meet the needs for regional radiation monitoring would be to interview state or local air quality agencies about the representativeness of existing SLAMS sites. For most locations the preferred site location would be in the prevailing downwind direction of the central business district, although this may be of secondary importance relative to representativeness issues. Ideally measurements of wind speed, direction and rainfall would be collected at or near the site to aid in the interpretation of any high radiation events. Information on rainfall may be as important as wind speed and direction because removal of radiation from the atmosphere through wet deposition may produce some of the highest ground level concentrations at significant distances from the nuclear incident. Additionally, we would caution about siting monitors in or near (within a few kilometers) of the shoreline environment as local meteorological effects may not be representative of the larger scale air flow.

4. Other Criteria

Current plans are for 180 monitors in a network throughout the United States. It is hoped that this would cover at least 70% of the population and several other possible criteria are also suggested. These include: maximizing population coverage, filling in spatial gaps, siting monitors near nuclear power plants, covering border areas, monitoring territories, and focusing on state capitals.

If total population coverage was the only consideration then the top 180 metropolitan statistical areas (MSA's) could be selected for monitor locations. However, this is only one of the potential uses for this system. Limiting the network to only the largest MSA's is not advisable for several reasons:

- No monitoring sites would be found in the states of Montana, North Dakota, South Dakota, and Wyoming. If dispersion model verification is also a major objective, then this gap in coverage may be a problem as the states of Montana and North Dakota are directly south of the Canadian research reactors in Edmonton, Saskatoon, and Winnipeg.

- Another objective of the RadNet system is to inform the public and policy makers. In order to fulfill this function it must not only provide useful information but it must also be credible to the public. A network with large, uncovered areas would have less credibility. In addition, the network must be seen as protecting residents of all states.

- MSAs are often clustered such that monitor density may be greater than needed for meeting the objectives of RadNet. For example, Ohio has a cluster of MSAs including Cleveland, Akron, Canton, and Youngstown. It could be argued that four monitors may be more than adequate for this area. In some western states, such as Colorado and Utah, several MSA's are clustered near a major metropolitan center.

According to the 2000 Census, the U.S. population was 281 million. Covering 70% of this population would require monitors in 133 metropolitan statistical areas (MSAs), based on the project synopsis for the new air network when fully operational as described in EPA, 2005b. It also includes 33 state capitals, so adding the remaining state capitals would bring the total number of monitors to about 150, leaving the locations of about 30 monitors still open. There could be even more flexibility for monitor placement based on the other objectives if clusters of MSAs are lumped.

In addition to clustering small MSAs, multiple monitors could be sited in the largest MSAs (e.g. monitors in both Los Angeles and Orange Counties or both San Francisco and Oakland). As of February 2005 there is an additional classification, referred to as a "Metropolitan Division," that is a subset of a very large MSA. Currently 12 of the 15 largest MSAs are divided into Metropolitan Divisions. The three largest MSAs (Greater New York, Los Angels and Orange

Counties, and Chicago) are home to over 14% of the U.S. population. The ten largest MSAs are home to over a quarter of the U.S. population.

Adding state capitals would provide several benefits. First, it may provide advantageous political cooperation and public involvement. Second, it would add area coverage for model verification in the western states. Third, it would provide some level of border coverage. Fourth, state capitals could be likely terrorist targets (e.g., Oklahoma City).

5. References

EPA, 2003. U.S. Environmental Protection Agency, "Guidance – Risk Recognition and Avoidance at Superfund Manufacturing Sites with Chemical and Radiological (Dual) Contamination," Draft Memorandum. September 2003

EPA, 2004a. U.S. Environmental Protection Agency, "Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring," 40 CFR Part 58, Appendix E, 2004.

EPA, 2004b. U.S. Environmental Protection Agency, "Network Design for State and Local Air Monitoring Stations, National Air monitoring Stations and Photochemical Assessment Monitoring Stations," 40 CFR Part 58, Appendix D, 2004.

EPA, 2004c. U.S. Environmental Protection Agency, "Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS)," 40 CFR Part 58, Appendix A, 2004.

EPA, 2005a. U.S. Environmental Protection Agency, "Evaluation of Potential RadNet Fixed Monitoring Stations Sites", Version 1, 6/24/05.

EPA, 2005b. U.S. Environmental Protection Agency, "Background Information for the Radiation Advisory Committee of the EPA Science Advisory Board on EPA's Project to Implement Real Time Monitoring of Radiation in Air in the United States Updating and Expanding the Environmental Radiation Ambient Monitoring System (ERAMS)," January, 2005.

Holzworth, G.C., 1972. Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiguous United States, USEPA, Office of Air Programs, RTP, NC, AP-101.

Attachment 1
Mission, Scope, and Objectives of RadNet Air Network (7/12/2005)

Mission

The mission of RadNet is to:

- Provide data for nuclear emergency response assessments in support of Homeland Security and nuclear accidents;
- Provide data on ambient levels of radiation in the environment; and
- Inform the general public and public officials.

Scope

- Large scale atmospheric releases of radiation impacting large parts of the country and major population centers due to:
  1) Nuclear weapon detonations
  2) large Radiological Dispersion Device detonations
  3) nuclear facility incident / accident
  4) foreign radiological incident / accident

Outside of Scope

- impact to immediate locality of major incident/accident
- small localized releases of radiation
- monitoring individual sources (nuclear facilities, storage facilities, etc.)
- serving as an early warning / first detection system

Overview of Objectives and Data Uses for RadNet Air Monitors

	ONGOING OPERATIONS/PRE-INCIDENT	EARLY PHASE (0-4 days)	INTERMEDIATE PHASE (up to 1 year)	LATE PHASE (after 1 year)
Fixed Monitors				
Objectives	▪ Provide baseline data ▪ Maintain system readiness	▪ Provide data to modelers ▪ Develop national impact picture ▪ Provide data to decision makers ▪ Provide public information	▪ Continue national impact assessment ▪ Reestablish baseline	▪ Determine long-term impact ▪ Monitor baseline trends
Data Uses	▪ Pre and post event comparisons ▪ Provide public information	▪ Adjust model parameters and verify outputs ▪ Assist decision makers in allocation of response assets ▪ Identify un-impacted areas ▪ Help determine follow-up monitoring needs	▪ Assist in determining if delayed contamination transport is occurring ▪ Assure citizens and decision makers in unaffected areas ▪ Assist in dose reconstruction ▪ Determine short- or long-term baseline changes from event	▪ Assist in determining if delayed contamination transport is occurring ▪ Assure public that conditions are back to normal ▪ Ensure that recovery efforts are not causing contamination spread ▪ Verify return to previous baselines
Deployable Monitors	(If Deployed)			(Returned to Laboratories)
Objectives	▪ Provide baseline data	▪ Provide data to modelers ▪ Provide decision maker data ▪ Provide public information	▪ Assess regional impact	▪ Maintain readiness
Data Uses	▪ Pre and post event comparisons ▪ Provide public information	▪ Adjust model parameters and verify outputs ▪ Assist in identifying un-impacted areas ▪ Help determine follow-up monitoring needs	▪ Assist in determining if delayed contamination transport is occurring ▪ Assure citizens and decision makers in unaffected areas ▪ Assist in dose reconstruction ▪ Help determine when to relax or reduce protective actions	▪ Provide continuity of data in impacted or non-impacted areas

APPENDIX H

APPENDIX H: MDCs for Radionuclide Analyses at NAREL

Radionuclide	Media	Reporting Unit	Minimum Detectable Concentration
Gross Alpha	Water	pCi/L	2
Gross Beta	Air	pCi/m³	0.0015
	Water	pCi/L	2
	Precipitation	pCi/L	2
Tritium	Water	pCi/L	150
	Milk	pCi/L	150
* Plutonium-238,239/240	Air	aCi/m³	0.75
	Water	pCi/L	0.1
† Uranium-234,235,238	Air	aCi/m³	0.75
	Water	pCi/L	0.1
Radium-226	Water	pCi/L	0.02
Strontium-90	Milk	pCi/L	2
	Water	pCi/L	1
‡ Iodine-131	Milk (gamma)	pCi/L	4
	Water (gamma)	pCi/L	4
	Water	pCi/L	0.3
Cesium-137	Milk	pCi/L	5
	Water	pCi/L	5
‡ Barium-140	Milk	pCi/L	15
	Water	pCi/L	15
Potassium	Milk	g/L	0.06
	Water	g/L	0.06
Potassium-40	Water	pCi/L	50

* The MDC for air is based on an assumed total sample volume of 120,000 m³. Measurement by alpha spectrometry includes combined activities of ^{239}Pu and ^{240}Pu, since the relative contributions of these two isotopes cannot be determined.
† The MDC for air is based on an assumed total sample volume of 120,000 m³.
‡ Activity as of the day of counting.

APPENDIX I

APPENDIX I: Quality Control of Real-Time Data

Summary and Analysis of Quality Control Measures in Selected Real-Time Monitoring Programs

Prepared for

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Attachment A Best Practice Examples

List of Acronyms

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CASTNET	Clean Air Status and Trends Network
CEM	Continuous emissions monitoring
CEMP	Community Environmental Monitoring Program
CFR	Code of Federal Regulations
DQO	Data Quality Objectives
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE/NV	Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
EPA	U.S. Environmental Protection Agency
ERAMS	Environmental Radiation Ambient Monitoring System
LANL	Los Alamos National Laboratory
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols
MARSSIM	Multi-Agency Radiation Surveys and Site Investigation Manual
MQO	Measurement Quality Objective
NAREL	National Air and Radiation Environmental Laboratory
NDDN	National Dry Deposition Network
NEWNET	Neighborhood Environmental Watch Network
NOAA	National Oceanic Atmospheric Administration
NOx	Nitrogen Oxides
PIC	Pressurized Ion Chamber
PM2.5	Particulate Matter <2.5 micrometer diameter
PMTACS-NY	PM2.5 Technology Assessment and Characterization Study-New York
ppb	Parts Per Billion
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
QMP	Quality Management Plan
SO2	Sulfur Dioxide
SOP	Standard Operating Procedure
SOx	Sulfur Oxides
TLD	Thermoluminescent Dosimeter

1.0 Background

This Report of the Summary and Analysis of Quality Control Measures in Selected Real-Time Monitoring Programs, July 29, 2005 was completed in accordance with Task 3, Delivery Order EP05W002015 under Contract GS-10F-0124J to provide U.S. EPA National Air and Radiation Environmental Laboratory (NAREL) technical support for the RadNet program. The current report is an update of the June draft in response to EPA comments.

For nearly half a century, RadNet, formerly the Environmental Radiation Ambient Monitoring System (ERAMS), has monitored the nation's air, drinking water, precipitation, and pasteurized milk for environmental levels of radiation. RadNet provides baseline data on background levels of radiation in the environment and tracks increases above background from a variety of sources. Historically, the system has been used to track fallout associated with atmospheric nuclear weapons testing as well as from national and international nuclear accidents.

EPA is updating and expanding RadNet's air monitoring capability to be more responsive by adding new air monitoring stations across the country with the enhanced capability to detect and rapidly report environmental levels of radiation. Data from these fixed monitoring stations will be transmitted directly to NAREL for initial analysis, significantly decreasing the time required for detection, processing, and notification from days to hours. In addition, air sampling filters routinely collected twice per week from the fixed monitoring stations will be sent on a more frequent basis to the lab for more detailed analyses.

As part of this expansion of capabilities, the quality assurance systems must receive comparable updating both for new capabilities and to comply with most recent quality requirements.

Note that in this document, quality assurance (QA) is defined as a management or oversight function; it deals with setting policy and running an administrative system of management controls that cover planning, implementation, and review of data collection activities and the use of data in decision making. Quality control (QC), on the other hand, is a technical function that includes all the scientific precautions, such as calibrations and duplicate measurements that are needed to acquire data of known and adequate quality. See section 5 for EPA guidance that addresses these and related terms more thoroughly.

2.0 Purpose and Scope

The purpose of this current task is to evaluate QC measures routinely used for established real-time or near real-time environmental monitoring activities from fixed station locations, particularly for data review and decision-making (e.g., the procedures and outcomes for automated review, action limits for increased review, and limitations of the review procedures). The results will be used to better understand, develop, and implement a quality system for RadNet that is consistent with EPA and other guidelines and with established real-time environmental monitoring activities.

3.0 Methodology

A number of real-time and near real-time environmental data collection systems are currently operating at levels across the U.S and worldwide. These systems are comprised of a wide range of applications including weather stations, magnetic surge earthquake early alert systems, tide and current detection buoy grids, satellite based ocean temperature monitors, evaporotranspiration monitors for irrigation scheduling, and air pollution monitors. This current evaluation focuses on real-time or near real-time environmental data collected from fixed station locations with a preference for airborne contaminants including radiation.

The methodology to investigate the QC measures and processes involved in real-time or near real-time environmental monitoring initially utilized the list generated under Task 2, Summary of Radiological Environmental Monitoring Activities, of the above delivery order to identify appropriate organizations and monitoring systems. From this list, systems were eliminated that relied solely upon laboratory analysis in favor of systems that relied on critical real-time or near real-time data. Other systems that relied upon real-time or near real-time monitoring were added to the list to better represent the variety of monitoring situations, although only airborne or meteorological data collection systems—both radiological and nonradiological—from fixed sites were considered during this evaluation. The focus of this phase was to obtain and review quality planning documents, which are the critical documentation of the quality system. Where available, quality assurance project plans (QAPPs) were obtained and reviewed for completeness, consistency with guidelines, and specific QC measure details. Where QAPPs were not available, quality management plans (QMPs) containing comparable level of detail were also sought and reviewed in the same manner. Where neither planning documents were available, other documentation that contained specific documentation of QC measures, procedures, and systems were evaluated. The information on several example systems was compiled and provided in a table for side by side comparison of the QC measures. The similarities and contrasts were then evaluated.

4.0 Types of Monitoring and Measurement

The scope of the current report is limited to evaluation of QC measures in real-time and near real-time environmental monitoring data systems. For the purposes of this report, real-time is considered to be those systems where analysis is completely performed, data are relayed, and results interpretable prior to the need to initiate another analysis. An example of a real-time operation might be a GPS beacon that sends a spatial location signal to a transceiver. Near real-time data collection implies a minimal delay in the processing from analysis to data and to interpreted result. An example of near-real time might include instantaneous ozone instrumental reading that is then stored on a data logger for time averaging prior to relaying the time averaged result. QC measures for real-time and near real-time analyses are comparable and therefore are not distinguished in this evaluation.

Most current remote environmental data collection systems involve a third type of semi-automated data generation—one that uses automated samplers with subsequent analysis. ERAMS, the predecessor to RadNet, used this approach. With automated samplers and subsequent analysis, a sample is collected in an automated fashion but no result is determined without manual sample analysis either in the field and/or an off-site laboratory analysis. In either case, the data from automated samplers are not generated real-time or near real-time (as defined above). Many systems that contain real-time data systems also contain automated samplers either for confirmatory or additional analyses. RadNet is one such system. QC measures to ensure quality of automated samplers with subsequent analysis are substantially different than those required in real-time or near real-time systems. While hybrid systems containing both automated samplers and real-time analyses were evaluated in this report the focus remains on the real-time and near real-time components.

5.0 Quality Assurance Plan Specifications

Quality planning documents are the primary foundation of quality systems and the central method of documenting required QA and QC measures. Since 1979, EPA policy has required participation in an Agency-wide quality system by all EPA organizations (office, region, national center or laboratory) supporting environmental programs and by non-EPA organizations performing work in behalf of EPA. This has been reaffirmed most recently by EPA Order 5360.1 A2 issued May 5, 2000, which establishes EPA policy and program requirements for the preparation and implementation of organizational or programmatic management systems pertaining to quality and contains the minimum requirements for the mandatory Agency-wide quality system.

The key focus of the Agency-wide quality system is the preparation of quality planning documents to establish requirements to attain and ensure data quality. The Quality Management Plan (QMP) documents the organizations quality policy, describes its quality system, and identifies the environmental programs to which the quality system applies. For the purposes of specific QC measures associated with individual projects however, QMPs may not contain sufficient detail. Quality Assurance Project Plans (QAPPs) are required for all applicable projects and tasks involving environmental data. QAPPs must be approved and implemented prior to any data collection or use, except under circumstances requiring immediate action to protect human health and the environment or operations conducted under police powers. While there is no single resource dedicated to real-time and near real-time QC measures, the guidance documents are intended to apply generally to all types of data collection activities. EPA requirements and/or guidance for the documentation and implementation of quality programs are contained in a number of documents summarized below in Table 1.

Table 1 EPA Requirements and Guidance for Quality Programs

Internal EPA Quality Directives		
Title	**Reference**	**Description**
Policy and Program Requirements for the Mandatory Agency-wide Quality System	EPA Order 5360.1 A2 May 2000	Quality specifications for EPA organizations that produce or use environmental data.
EPA Quality Manual for Environmental Programs	EPA Manual 5360 A1 May 2000	Specifications for satisfying the mandatory Quality System defined in EPA Order 5360.1
Specifications for Non-EPA Organizations		
EPA Requirements for Quality Management Plans (QA/R-2)	EPA/240/B-01/002 March 2001	Specifications for Quality Management Plans for organizations that receive funding from EPA.
EPA Requirements for QA Project Plans (QA/R-5)	EPA/240/B-01/003 March 2001	Specifications for QA Project Plans prepared for activities conducted by or funded by EPA.
General Guidance		
Overview of the EPA Quality System for Environmental Data and Technology	EPA/240/R-02/003 November 2002	Information on existing Agency policies, responsibilities, and resources to use in implementing both the EPA Quality System and your organization's Quality System.
Guidance for Developing Quality Systems for Environmental Programs (QA/G-1)	EPA/240/R-02/008 November 2002*)*	Guidance on developing and documenting the elements of a functional quality system in organizations that carry out environmental data operations within, or on behalf of, EPA.
Guidance on Assessing Quality Systems (QA/G-3)	EPA/240/R-03/002 March 2003	Guidance on assessing the adequacy and effectiveness of an environmental quality system.
Guidance for the Data Quality Objectives Process (QA/G-4)	EPA/600/R-96/055 August 2000	Guidance on the Data Quality Objectives Process, a systematic planning process for environmental data collection.
Guidance for Quality Assurance Project Plans (QA/G-5)	EPA/240/R-02/009 December 2002	Guidance on developing Quality Assurance Project Plans that meet EPA specifications.
Guidance for Geospatial Data Quality Assurance Project Plans (QA/G-5G)	EPA/240/R-03/003 March 2003	Guidance on developing Quality Assurance Project Plans for geospatial data projects.
Guidance on Choosing a	EPA/240/R-02/005	Guidance on applying standard

Sampling Design for Environmental Data Collection (QA/G-5S)	December 2002	statistical sampling designs to environmental applications.
Guidance for Preparing Standard Operating Procedures (QA/G-6)	EPA/240/B-01/004 March 2001	Guidance on the development and documentation of Standard Operating Procedures.
Guidance on Technical Audits and Related Assessments for Environmental Data Operations (QA/G-7)	EPA/600/R-99/080 January 2000	Guidance to help organizations plan, conduct, evaluate, and document technical assessments.
Guidance on Environmental Data Verification and Data Validation (QA/G-8)	EPA/240/R-02/004 November 2002	Guidance to help organizations conduct data verification and data validation activities.
Guidance for Data Quality Assessment: Practical Methods for Data Analysis (QA/G-9)	QA00 Version EPA/600/R-96/084 July 2000	Guidance on a statistically-based method to evaluate the extent to which data can be used for a specific purpose.

In addition to the EPA general requirements and guidance, QA guidance has been developed by several federal agencies, and they include the following:

- 10 CFR 830.120
- 10 CFR 50, Appendix B
- ANSI N42.23
- ASME NQA-1
- DOE Order 414.1A on QA
- DOD QA requirement MIL-Q-9858A (1963)

Given the importance of a national strategy on collection, analysis, and interpretation of radioanalytical data along with the wide variety of guidance documents and standards, two large-scale multi-agency efforts have been employed to synthesize the various guidance and requirements into a consensus document. The Multi-Agency Radiation Surveys and Site Investigation Manual (MARSSIM) provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose- or risk-based regulation. MARSSIM focuses on the demonstration of compliance during the final status survey following scoping, characterization, and any necessary remedial actions. The Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual addresses the need for a nationally consistent approach to producing radioanalytical laboratory data that meet a project's or program's data requirements. MARLAP is the radioanalytical laboratory counterpart to the MARSSIM. These documents, however, are intended to provide guidance not requirements.

The EPA regulations, EPA guidance, and MARSSIM/MARLAP guidance provide the foundation for compliance of all environmental data quality plans including the real-time and near real-time systems evaluated in this report

6.0 Monitoring Programs Surveyed

Several monitoring programs were considered for inclusion in the current report, but due to limited information only selected examples were fully evaluated. The monitoring programs surveyed in this report include the following:

1. Neighborhood Environmental Watch Network (NEWNET)

2. Clean Air Status and Trends Network (CASTNET)

3. PM2.5 Technology Assessment and Characterization Study-New York (PMTACS-NY)

4. Acid Rain Program Continuous Emission Monitoring (CEM) System

5. Community Environmental Monitoring Program (CEMP)

These systems are described in the following sections. Table 2 below provides information on each aspect of data quality fully reviewed in Table 3.Table 3 summarizes the QC information on each of the evaluated monitoring organizations and systems.

Table 2 Summary of Quality Program Elements Reviewed

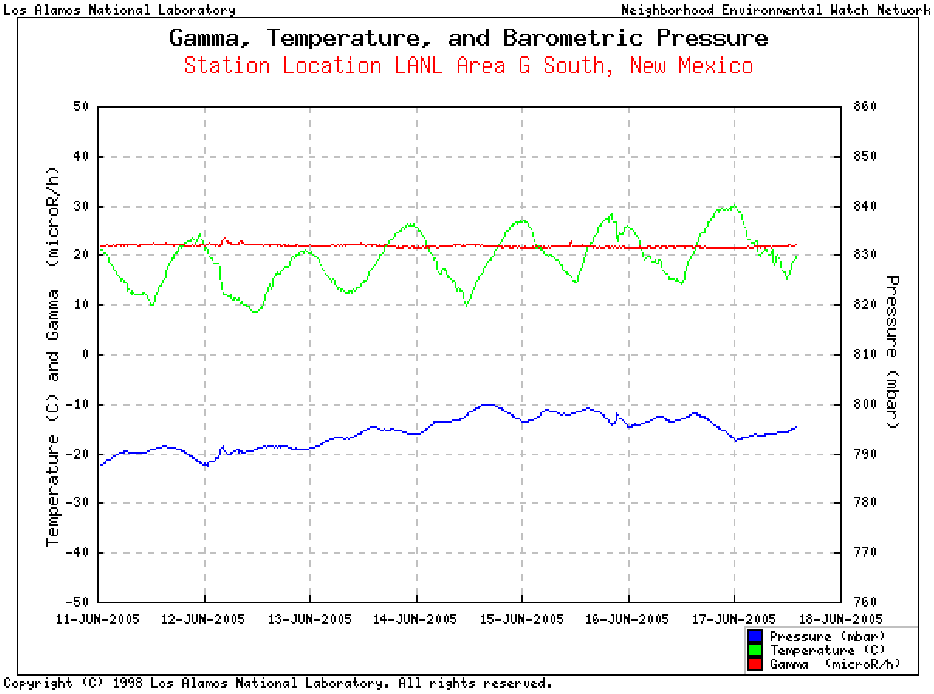
Planning Documents	Planning documents such as QMPs and QAPPs provide information on the quality structure and management approach developed for the program. Each system surveyed has a QAPP. Several have associated SOPs which vary in level of detail, scope, and thoroughness. The QAPP and associated SOPs are an important tool to ensure that the data generated from these activities meets the data quality objectives and is reliable enough to be used to make critical decisions
Set-up and Installation	All of the programs evaluated, provided information on the basic design principles of their network. What was available and presented in Table 3 are brief summaries of the decisions made related to site selection, detection system choice, equipment selection, and other elements that impact operation and maintenance.
Calibration	Calibration is the comparison of a measurement with a standard or instrument of known accuracy to detect, quantify, and allow adjustment for inaccuracies. Table 3 identifies the sampling and test methods used for data collection activities along with acceptance criteria and frequency to maintain performance and ensure usable data. Calibration can vary from simple (such as a zero check and a span check) to complex (such as multiple concentration standard calibration). The adequacy of the frequency and type of calibration is method and instrument dependent. For example, the pressurized ion chamber (PIC) use in NEWNET to determine gamma radiation is calibrated annually relying upon documented stability. Other developing technologies such as the NY- PMTACS Aerosol Mass Spectroscopy real-time instrument must be calibrated daily.
Verification	Verification is confirmation by independent means. Some real-time systems use sample collection for verification of real-time data while others build redundant sensors or collocated sample stations. Table 3 describes the steps taken to examine the data in order to determine conformance to the stated requirements for that parameter. Performance evaluation is a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst or system.
Data Review	Data review includes QA activities that occur after the data collection phase of the project is completed. Implementation of these elements ensures that the data conform to the specified criteria to achieve the project objectives. The review is an in-depth analysis and evaluation of documents, activities, material, data, or items that require technical verification or validation for applicability, correctness, adequacy, completeness, and assurance that established requirements are satisfied.
Precision	Precision measures mutual agreement among individual measurements of the same property expressed generally in relative percent difference or relative standard deviation. The approach used to determine precision in these systems depends on the parameters being measured and the scope of the precision test. For example precision may be evaluated by replicate measurements using the same equipment, by replicate sensors built into the same location, or by collocated sample locations. Each approach offers advantages and disadvantages as to what is included in the analysis of measurement precision.
Accuracy	Accuracy measures the degree of agreement of a measured value with the true or expected value of the quantity of concern. Basically, the degree of agreement with the standard often expressed as percent. The approach used to determine accuracy in these systems depends on the parameters being measured. For example, the pressurized ion chamber (PIC) use in NEWNET to determine gamma radiation is checked for accuracy annually as a calibration check. Accuracy for other analyses such as those of continuous gas monitors, utilize performance audits using independent, NIST traceable source not used for calibration.
Comparability	Data comparability represents an attempt to understand how well one measurement could be verified by other samples, methods, or instruments. Data comparability is particularly critical to real-time monitoring system where the instrumentation utilized for the analyses are located at different remote locations. The comparability of different data sets determines how they can be used collectively to support decision-making.
Sensitivity	When available the detection limits of the instruments are provided. The method detection limits for some of the continuous gas monitor are determined through statistical evaluation of the zero standard, followed by span and multiple point calibrations.
Reliability	Only two organizations make available very limited information on the limitations of this data. However, it is clear that the data generated by all the systems evaluated is not intended to be used for critical decisions.
Transmittal of Data	This section in Table 3 describes the mechanisms used to check for data transmission quality by the different organizations.

6.1 NEWNET

NEWNET (Neighborhood Environmental Watch Network; http://newnet.lanl.gov/) is a network of environmental monitoring stations and data storage and data processing systems, with public access to the data through the Internet. This system allows interested members of the public to have constant access to the stations so they can observe the results at any time. A station manager from each community has access to researchers and support organizations that can provide technical assistance if needed. Station Managers serve as liaisons to their communities and can help citizens understand measurements.

NEWNET was started in 1993 with stations in Nevada, California, Utah, and New Mexico. It is based on concepts developed by the Department of Energy for the Community Monitoring Program at the Nevada Test Site Nuclear Testing Facility. These concepts date back to the Three Mile Island Nuclear Power Reactor accident in the late 1970's.

Stations can vary in configuration. Most NEWNET stations have sensors for monitoring wind speed and direction, ambient air temperature, barometric pressure, relative humidity and ionizing gamma radiation.

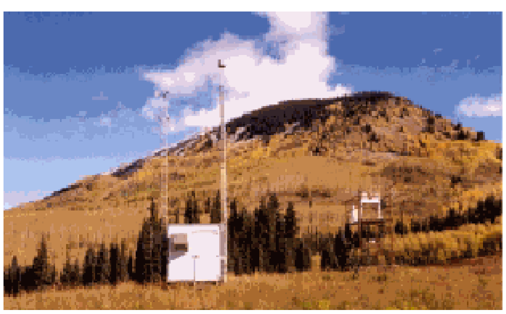


6.2 CASTNET

The Clean Air Status and Trends Network (CASTNET; http://www.epa.gov/castnet/) is the nation's primary source for data on dry acidic deposition and rural, ground-level ozone. Operating since 1987, CASTNET is used in conjunction with other national monitoring networks to provide information for evaluating the effectiveness of national emission control strategies. CASTNET consists of over 80 sites across the eastern and western United States and is cooperatively operated and funded with the National Park Service.

CASTNET originated in 1986 when EPA established the National Dry Deposition Network (NDDN) to obtain field data on rural deposition patterns and trends at different locations throughout the United States. NDDN consisted of 50 monitoring sites that derived dry deposition based on measured air pollutant concentrations and modeled dry deposition velocities estimated from meteorology, land use, and site characteristic data. In 1990, amendments to the Clean Air Act necessitated a long-term, national program to monitor the status and trends of air pollutant emissions, ambient air quality, and pollutant deposition. In response, EPA in cooperation with the National Oceanic Atmospheric Administration (NOAA) created CASTNET from NDDN.

CASTNET now comprises over 70 monitoring stations across the United States. The longest data records are primarily at eastern sites. EPA's Office of Air and Radiation operates a majority of the monitoring stations; however, the National Park Service operates approximately 30 stations in cooperation with EPA



Each CASTNET dry deposition station measures:

- Weekly average atmospheric concentrations of sulfate, nitrate, ammonium, sulfur dioxide, and nitric acid.
- Hourly concentrations of ambient ozone levels.
- Meteorological conditions required for calculating dry deposition rates.

6.3 PMTACS-NY

The PM2.5 Technology Assessment and Characterization Study-New York (PMTACS-NY) is one portion of the networked stations supporting the EPA AirNow system. In addition to supporting the PM portion of the EPA ambient air monitoring program, PMTACS-NY is a highly leveraged measurement, technology development and evaluation program designed to address a series of science policy relevant questions that relate to hypotheses to be tested using the extensive data sets collected as part of the program. Primary objectives of the program are the following:

- measure the temporal and spatial distribution of the PM2.5/co-pollutant complex including: SO_2, CO, VOCs/air toxics, NO, NO_2, O_3, NO_x, H_2CO, HNO_3, HONO, PM2.5 (mass, $SO_4^{=}$, NO_3^-, OC, EC, trace elements), single particle aerosol composition, CN, OH and HO_2

- monitor the effectiveness of new emission control technologies [i.e. Compressed Natural Gas bus deployment and Continuously Regenerating Technology]

- test and evaluate new measurement technologies and provide tech-transfer of demonstrated operationally robust technologies

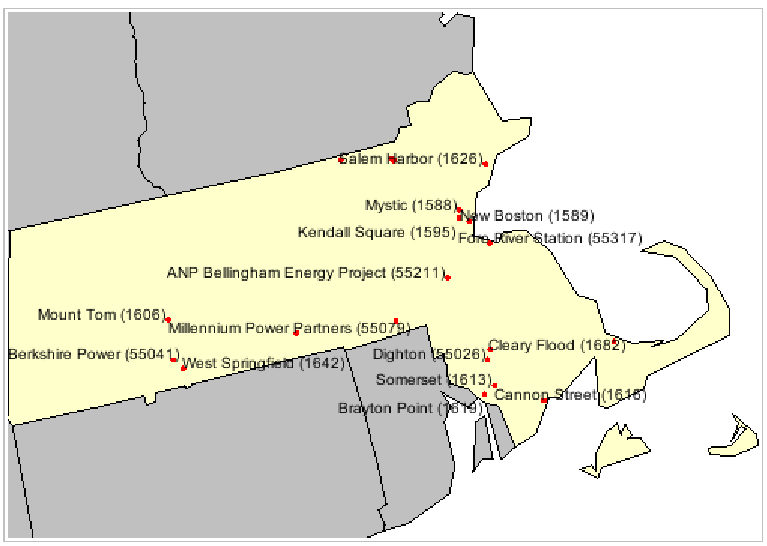
Comprehensive measurement of PM2.5 mass, chemical speciation and gaseous precursors will be collected at five monitoring sites located in the New York City metropolitan area and at regional representative locations in upstate NY. These sites include two research regional monitoring sites, Whiteface Mountain (Wilmington, NY) operational since 1973 and Pinnacle State Park (Addison, NY) operational since 1995 and three urban monitoring sites, Mable Dean Bacon (Manhattan, NY or alternate), Intermediate School I.S. 52 (South Bronx, NY) and Queens College/Public School PS 219 (Queens, NY).

These measurement sites constitute the backbone of the PM2.5 "Supersites Network". In addition to standard routine measurements of criteria pollutants and the mandated PM2.5 mass and chemical speciation measurements, these sites will be operating advance instrumentation that will compliment and provide more chemical and temporal specificity of the air quality at these locations. Over the course of this program, these highly relevant measurements will fill a substantial data need associated with the characterization of the chemical composition of PM2.5 within New York City and the transport-impacted regional background of upstate NY.

6.4 Acid Rain Program CEM

Continuous Emissions Monitoring (CEM); http://www.epa.gov/airmarkets/monitoring/factsheet.html is instrumental in ensuring that the mandated reductions of SO2 and NOx under the Acid Rain Program are achieved. CEM is the continuous measurement of pollutants emitted into the atmosphere in exhaust gases from combustion or industrial processes. While traditional emissions limitation programs have required facilities to meet specific emissions rates, the Acid Rain Program requires an accounting of each ton of emissions from each regulated unit. Compliance is determined through a direct comparison of total annual SO2 emissions reported by CEM and allowances held for the unit. The program discourages downtime by providing unfavorable default data to use in calculations in lieu of actual near real-time monitoring.

Unlike the other linked networks described in this document where the system is centrally operated by the government entity or sponsoring organization, CEM requires individual owner/operators to meet the requirements and specifications, collect data continuously (i.e., near real-time) and then requires electronic submittal of the data to a central government database following specific data handling and calculation procedures. While the data are near real-time, the various fixed stations are not actually linked. Rather, the specifications and highly detailed procedures for data handling and analysis allows CEM to be a virtual network of real-time monitors.



Operating Year	State	Program Code	SO_2 Tons	NO_x Tons	CO_2 Tons	Heat Input (mmBtu)
2003	MA	ARP	85,649.2	24,366.9	23,847,340.1	297,369,024

EPA established requirements for the continuous monitoring of SO2, volumetric flow, NOx, diluent gas, and opacity for units regulated under the Acid Rain Program. In addition, procedures for monitoring or estimating carbon dioxide are specified. CEM also details requirements for equipment performance specifications, certification procedures, data handling, recordkeeping and reporting.

6.5 CEMP

The Community Environmental Monitoring Program (CEMP; http://www.cemp.dri.edu/) is a network of 26 monitoring stations located in communities surrounding the Nevada Test Site that monitor the airborne environment for manmade radioactivity that could result from site activities. CEMP is a joint effort between the Department of Energy, Nevada Operations Office (DOE/NV), and the Desert Research Institute (DRI) of the University and Community College System of Nevada.

The network stations, located in Nevada and Utah, are comprised of instruments that collect a variety of environmental data. To manage the stations, DRI employs local citizens, many of them high school science teachers, whose routine tasks are to maintain the equipment, collect air filters, and route the filters to DRI for analysis. These community environmental monitor operators are also available to discuss the monitoring results with the public, and are available to speak to community and school groups. Program funding and equipment are provided by DOE/NV. DRI manages the program, provides technical direction, employs and trains monitor operators, conducts public outreach activities, and collects data to be analyzed by an independent laboratory.

The emphasis of the CEMP is to monitor airborne radioactivity and weather conditions, and make the results available to the public. Instrumentation that records these data is connected to a datalogger, and real-time radiation levels or weather conditions can immediately and easily be seen on a display on the front of the datalogger. These data are transmitted via telephone line of satellite transmission to the Western Regional Climate Center in Reno, Nevada, and are updated several times daily on the internet.

Each monitoring station is equipped with:

- Particulate Sampler.
- Thermoluminescent Dosimeter (TLD).
- Exposure Rate Recorder.
- Microbarograph.
- Weather Instruments.

7.0 Analysis

A side-by-side analysis of the QC measures of the selected systems described above and summarized in Table 3indicates a broad spectrum of compliance with standards, levels of detail, completeness, and adequacy to ensure quality data generation processes. Despite the wide variety of approaches and relative degrees of success, the comparison has yielded some critical information as to common approaches and best practices, as described in this section.

The format, level of detail, organization, and requirements of the systems evaluated were primarily dependent on the sponsoring organization regardless of presence of multi-agency agreements, requirements, or standards. DOE systems such as CEMP followed DOE guidance on quality plans and QC measures whereas primarily EPA systems such as NEWNET relied upon EPA requirements, guidance, and general expectations for QC measures.

The systems reviewed demonstrated diverse approaches on many aspects of the overall quality assurance program. Detailed below are the best practices identified in the surveyed systems that most impact the overall quality of the system. The categories highlighted are:

- Planning documentation/standard operating procedures
- Instrument maintenance programs
- Training
- Data review
- QC limits
- Alerts, Corrective Actions and Decision Making
- Action Levels/Decision-Making
- Verification
- Communication

7.1 Planning Documentation/Standard Operating Procedures

Documentation is a critical element of a quality assurance program. Primary factors that differentiated the documentation were depth of the detail provided; readability, usefulness, and accessibility of the material; scope of the procedures; frequency of review and updates; and availability and distribution of the documentation. Several of the monitoring networks relied upon highly detailed standard operating procedures (SOPs) to contain the details of procedures such as maintenance, calibration, and data collection. Only CASTNET and Acid Rain Program CEM provided SOPs on non-instrument procedures such as data assessments, interpretations, and computer based data handling. Several systems with multiple station operators utilized the internet to make SOPs available to personnel responsible for station visits. Whereas the Acid Rain Program

CEM is decentralized and requires the SOPs and planning documents, CASTNET demonstrated a best practice by not only maintaining but also making available the specific SOPs. NEWNET is the only program that has a clear process of documenting training by reading SOPs. Attachment A contain example SOPs from the CASTNET system.

7.2 Instrument Maintenance Programs

One critical aspect of the quality assurance programs of each of the systems was the routine maintenance, location inspections/visit, and repair programs implemented. Each of the systems included some approach to equipment maintenance. Primary factors that varied among the systems included level of training of personnel responsible for routine station visits, level of detail in maintenance programs and SOPs, frequency of planned routine station visits, geographic extent of the system, completeness of the maintenance programs, and ability to respond to non-routine episodes.

The real-time monitoring systems evaluated in this study rely on two approaches to maintenance – preventive and corrective. Preventive maintenance involves conducting planned service activities prior to, and in an effort to avoid, failures. Based on manufacturers' recommendations, historical information on previous application of the equipment, and sound knowledge, the following determinations must be made:

- What are the components that must be replaced at specific intervals and what are the intervals?
- What are the components that can receive servicing to extend their lifetime, and what is the service and interval for service?

NEWNET, CastNet and CEMP have developed formal schedules with the required service activities. In most cases these schedules consider the timing of these services to limit interruption of data collection or impact to data quality. Despite preventative maintenance, electromechanical devices and the network links occasionally fail. Given this fact, the primary purpose of corrective maintenance planning is to establish procedures that ensure that unscheduled repairs are completed as rapidly as possible. Maintenance programs are perhaps the most costly element of operation of real-time networks. Degree of complexity of the maintenance programs often correlates directly with criticality of data to be collected and relative funding. Given the critical decision making nature of the information gathered by RADNet, maintenance programs must be implemented in consideration of the importance of station downtime or uncertainty as to the proper functioning of instrumentation.

Overall the CASTNET system provides examples of best practices with regard to implementation of maintenance programs. With currently over 70 monitoring stations throughout the U.S., the CASTNET system manages to provide detailed step-by-step SOPs to specially trained individuals to perform weekly station visits that include virtually complete inspection and evaluation. Included in Attachment A is an example weekly visit SOP from the CASTNET program.

7.3 Training

Training of site personnel, data review personnel, and data users is a critical element of any quality assurance program but is particularly important in real-time measurements with mission critical implications. Primary factors which differentiated the systems evaluated included scope of the staff trained, completeness of the training materials, and documentation of the adequacy of training. All systems provided some level of training to station personnel; however CASTNET provides a unique example of best practices with regard to training by providing detailed training materials for data reviewers, database personnel, and even data users. Included in Attachment A is a CASTNET detailed SOP for data audits.

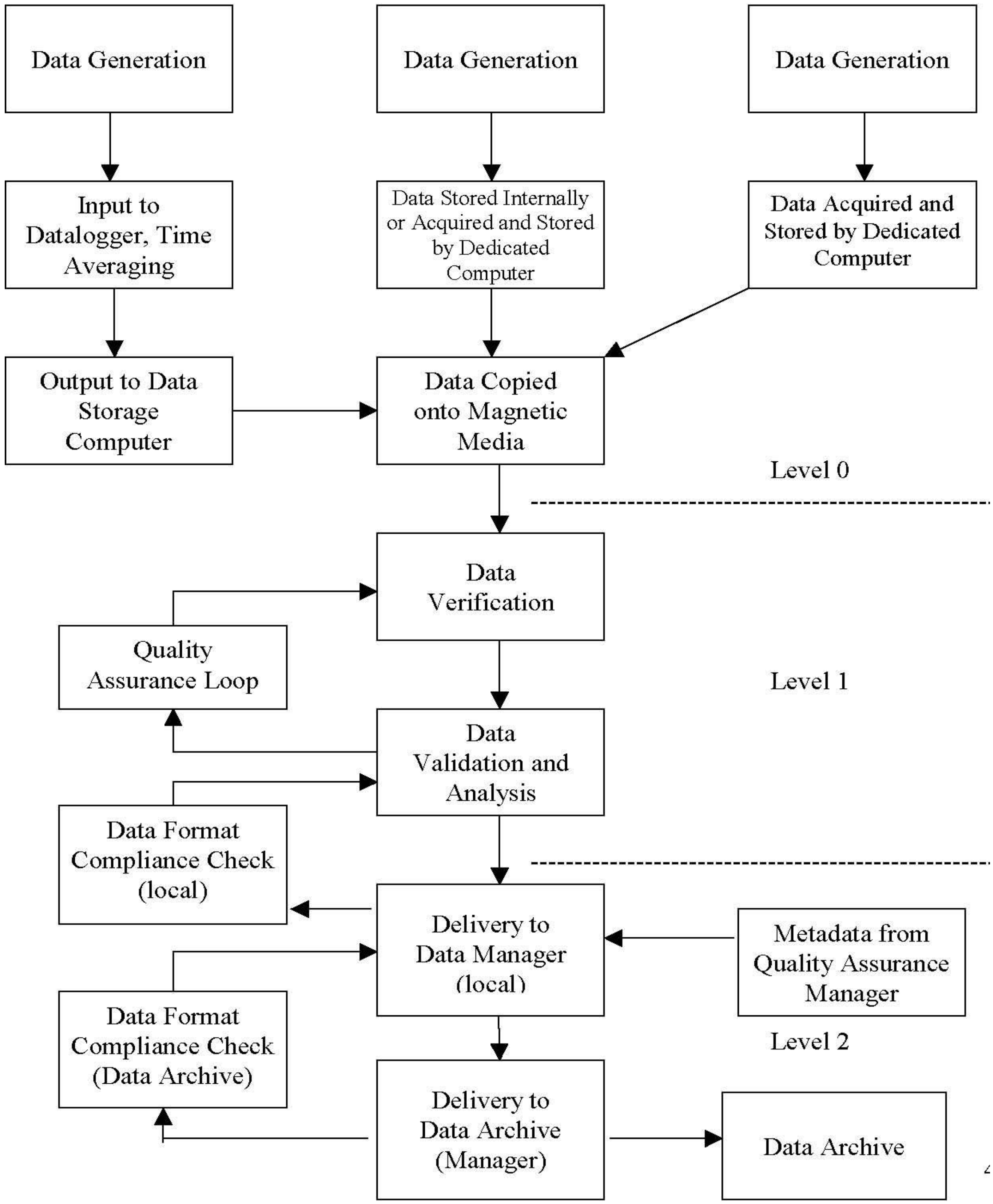
7.4 Data Review

Data review, validation, and qualification are perhaps the most critical element of a real-time quality assurance program. Detailed data procedures provide the quality control mechanism to ensure that the systems are operating to their potential and sufficiently in control to meet the project data quality objectives established as part of the system. In this regard the systems differ substantially in that while data from all systems are evaluated, not every system has mechanisms to modify the reported data with flags that indicate the confidence in the results. Both the CASTNET SOP and the PMTACS-NY system of data review, organization and data flags demonstrate best practices with regard to data review. As described earlier the detailed SOPs of CASTNET including for data review are a powerful quality assurance system. However the PMTACS-NY system provides a succinct overview of the process and a rudimentary system of data flags that are at once powerful and simple to grasp. The level of detail that serves as a best practice example is dependent on the implementation approach, funding, and criticality of the decisions based on the underlying system data. The approach must balance simplicity and transparency with the need for depth and detail.

The QAPP focuses the information reviewed during these stages to include

- Internal consistency (i.e., fall within normal operating ranges and do not exhibit excessive and rapid variations that are inconsistent with expected variations)
- Consistency with operator logbooks (i.e., all data acquired during calibration checks, instrument maintenance, and instrument outage periods be appropriately flagged)
- Consistency with calibration zero and span checks (i.e., checking verified data against all calibration data to assure that reported data provides the most accurate possible measure of each parameter)

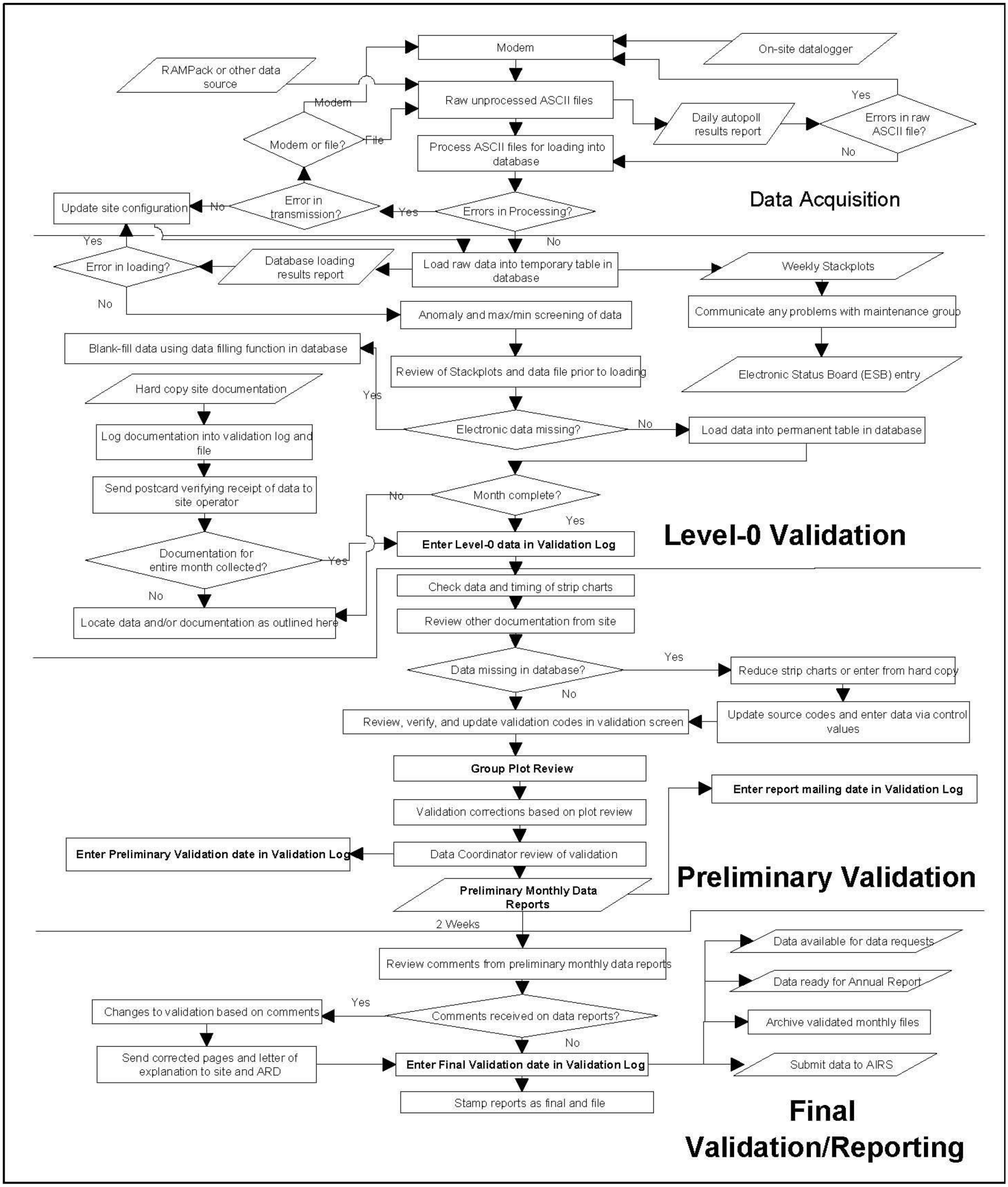
PMTACS-NY provides the following basic overview of data review systems:



The PMTACS-NY QAPP also provides details on the available data flags and their proper usage:

Code	*Data Quality Flag Definition*
V0	Valid value
V1	Valid value but comprised wholly or partially of below-MDL data
V2	Valid estimated value
V3	Valid interpolated
V4	Valid value despite failing some statistical outlier tests
V5	"Valid value but qualified because of possible contamination (e.g., pollution source, laboratory contamination source)"
V6	"Valid value but qualified due to non-standard sampling conditions (e.g., instrument malfunction, sample handling)"
M1	Missing value because no value is available
M2	Missing value because invalidated by Data Originator
MDL	Value reported is below the minimum detection limit of the analysis method
H1	Historical data that have not been assessed or validated

In a similar but substantially more detailed manner, the CASTNET SOPs provide details of the review process, information reviewed, and the flags applied. For example for comparison the following diagram provides the CASTNET overview of the data review process. An example CASTNET SOP is provided in Attachment A as an example best practice.


Modem
On-site datalogger
RAMPack or other data source
Raw unprocessed ASCII files
Yes
Modem
Daily autopoll results report
Errors in raw ASCII file?
Modem or file?
File
Process ASCII files for loading into database
No
Error in transmission?
Data Acquisition
Update site configuration
No
Yes
Errors in Processing?
Yes
No
Error in loading?
Database loading results report
Load raw data into temporary table in database
Weekly Stackplots
No
Anomaly and max/min screening of data
Communicate any problems with maintenance group
Blank-fill data using data filling function in database
Review of Stackplots and data file prior to loading
Electronic Status Board (ESB) entry
Hard copy site documentation
Yes
Log documentation into validation log and file
Electronic data missing?
No
Load data into permanent table in database
Send postcard verifying receipt of data to site operator
No
Month complete?
Yes
Documentation for entire month collected?
Yes
Enter Level-0 data in Validation Log
Level-0 Validation
No
Check data and timing of strip charts
Locate data and/or documentation as outlined here
Review other documentation from site
Yes
Data missing in database?
Reduce strip charts or enter from hard copy
No
Review, verify, and update validation codes in validation screen
Update source codes and enter data via control values
Group Plot Review
Enter report mailing date in Validation Log
Validation corrections based on plot review
Enter Preliminary Validation date in Validation Log
Data Coordinator review of validation
Preliminary Validation
Preliminary Monthly Data Reports
2 Weeks
Data available for data requests
Review comments from preliminary monthly data reports
Data ready for Annual Report
Yes
Changes to validation based on comments
Comments received on data reports?
Archive validated monthly files
No
Send corrected pages and letter of explanation to site and ARD
Enter Final Validation date in Validation Log
Submit data to AIRS
Stamp reports as final and file
Final Validation/Reporting

7.5 QC Limits

Data quality indicators and other QC measures in all systems were primarily driven by instrument specifications. Systems minimally relied upon strict instrument specifications but often explicitly required particular instrumentation (manufacturer, make, model and oftentimes even production year). Some of the monitoring systems followed the EPA DQO approach of identifying data needs prior to determining equipment specification requirements, whereas others appeared to base the data limits on the instrument specification without first establishing the appropriateness of these specifications for the project objectives (although this may have been done but not documented in the limited materials available). All programs required the specific equipment for consistency and comparability purposes. The consistency of instrumentation allowed for a high degree of specificity of the QA plans, for example with regard to calibration procedures and QC limits on sensitivity, accuracy, and precision. Only very mature systems used historical data to benchmark performance and establish control chart limits for acceptable data quality beyond the instrument specifications. Although not a fully surveyed system in this report, the best practice noted for use of control charts was noted with the California Irrigation Management Information System (CIMIS) system operated by the Office of Water Use Efficiency (OWUE), California Department of Water Resources (DWR) that manages a network of over 120 automated weather stations in the state of California since 1982 (http://wwwcimis.water.ca.gov/cimis/). This system not only considers control charts in data evaluation but evaluates the control charts in terms of time by examining annual and daily cyclical trends of the data. Contained in Attachment A is a discussion on the predictive value of control charts and specifically time variant control chart considerations and implications in data quality.
(http://wwwcimis.water.ca.gov/cimis/resourceArticleOthersQcStatControl.jsp)

7.6 Alerts, Corrective Actions, and Decision Making

Many systems appeared to use incomplete feedback systems where anomalies could be noted and data flagged but not readily corrected. CASTNET had a complete system that allowed data anomalies to be readily identified and corrective action required. This feedback was uses the results of CASTNET to provide additional logistical functionality. For example, if data analysis indicated anomalous temperature drift (a critical parameter in calculation of dry deposition), not only was the data qualified but a corrective action report was generated for maintenance personnel to check the station sensor. Further, the corrective action request had to be cleared by a response from the appropriate station personnel and the effectiveness of the corrective action verified by the data personnel. Although not a fully surveyed system, AIRNET (operated by LANL like NEWNET but for non-real-time analysis of airborne radionuclides) demonstrates the best practice of clearly establishing procedures to set investigation levels, action levels, and alert levels. An SOP for establishing these levels is provided in Attachment A.

What triggers a corrective action varies from program to program but they are consistent in the systems reviewed that the response is not considered time critical. In the NEWNET program for example, if the data fails to meet the data quality objectives, the Community

Monitoring Project Leader instructs the station manager to initiate a corrective action. In addition, the station managers are asked to routinely inspect NEWNET data for their stations on the web and at the station to identify problems. The real-time motoring systems surveyed do not evaluated support specific time critical decision making but are more focused on providing early information on long-term trends.

Often these critical decision making systems are distinct from systems responsible for collecting the data and ensuring data quality. The Real-time On-line Decision Support (RODOS) developed by European Commission Framework Command Research and Technological Development group is such a system that provides a framework for time critical decision making based on other data collection mechanism. RODOS (http://www.rodos.fzk.de/RodosHomePage/RodosHomePage) is an early warning monitoring, communication network for rapid and reliable exchange of radiological and other information and decision support system for emergency management. It is not a real-time monitoring system but rather designed as a comprehensive system incorporating models and databases for assessing, presenting and evaluating accident consequences over distances taking into account possible mitigating countermeasures. Its flexible coding enables it to cope with differences in site and source term characteristics, in the availability and quality of monitoring data, in national regulations and emergency plans, etc. The RODOS system is intended to provide decision support at four distinct levels:

- Level 0: acquisition and checking of radiological data and their presentation, directly or with minimal analysis, to decision makers, along with geographical and demographic information.

- Level 1: analysis and prediction of the current and future radiological situation (i.e., the distribution over space and time in the absence of countermeasures) based upon information on the source term, monitoring data, meteorological data and models.

- Level 2: simulation of potential countermeasures (e.g., sheltering, evacuation, issue of iodine tablets, relocation, decontamination and food-bans), in particular, determination of feasibility and quantification of their benefits and disadvantages.

- Level 3: evaluation and ranking of alternative countermeasure strategies by balancing their respective benefits and disadvantages (e.g., costs, averted dose, stress reduction, social and political acceptability) taking account of societal preferences.

Although RODOS does not define the technology or the approach used for the real-time monitoring of radiation it does provide an excellent framework for integrating existing systems into a useful decision support system.

7.7 Verification

Several of the hybrid real-time and automated sampling systems relied upon the sample collected for verification of the real-time analysis. However, with the exception of CASTNET neither the SOPs nor the QAPPs provided sufficient detail of the verification and data review process to clearly establish that the offsite laboratory analysis results were routinely taken into account when assessing the data. If offsite analysis of a sample collected from the automated sampler is providing critical QC information, the real-time data must be evaluated in conjunction with the laboratory data and problems that are identified must be applied to all affected real-time data.

Virtually all the systems required verification or certifications on at least an annual basis. All systems required more frequent visits for preventative maintenance of instruments and verification of either calibration or proper operation. The frequency of the station visits and the verification or certification process was highly dependent on the type of data, breadth of the network, and importance of the measurement to decision making.

7.8 Communication

Communication of data to end users and documented communication between the various aspects of the project team are critical to ensuring data quality. While several systems distributed data via the internet, NEWNET also demonstrated a best practice on how to provide readily available manual alerts between field station personnel and remote data validators and users. Below is an example dialogue from the NEWNET web pages exchanged from the station location and the remote data systems managers concerning aberrant values. Note that in some cases the station location personnel are warning of calibration or other field generated spikes whereas in other cases remote personnel are notifying station personnel of rationale for observed spikes.

Comments for Station Area G Entrance

8/11/2004

We will be calibrating some of the stations today, Wednesday August 11. We expect gamma spikes of about 240 to 300 micro-rem/hour.

Entered by: Mike McNaughton

4/5/2004

The small gamma spike (14.7 micoR/hr) on April 5, 2004, was cause by an incoming shipment (17 drums) from the Off-Site Source Recovery Project.

Entered by: Ed Lopez

3/5/2004

Several small spikes have been recorded during the first week of March 2004 due to the recent rain and snow storms. These are seen as small peaks with a longer tail on the right side of the peaks (evidence of radon/thoron decay).

Entered by: Mike McNaughton

Table 3 Summary of Quality Control Measures Used in Selected Real-Time Monitoring Systems

Attachment A

Best Practice Examples

1) Checklist Instruction # 3178-3126 - Weekly Station Visit
   - Ozone Analyzer (CSI OA 325-2)
   - Ozone Calibrator (Dasibi 1003-PC)
   - CASTNet Dry Deposition

2) CASTNET Ambient Air Quality Monitoring Audit Procedures
Standard Operating Procedure# 3755

3) Statistical Control Charts for Quality Control of Weather Data for Reference Evapotranspiration Estimation, CIMIS

4) CASTNET Ambient Air Quality And Meteorological Monitoring Data – Preliminary Validation, Technical Instruction# 3450-5010

5) CASTNET Ambient Air Quality And Meteorological Monitoring Data – Final Validation, Technical Instruction #3450-5020

6) Checklist Instruction #3178-3300- Multipoint Calibration
   - Ozone Analyzer (ML 8810)
   - Ozone Calibrator (Dasibi 1003 PC)

7) Establishing And Using AIRNET Action Levels, LANL ESH-17-201, R3

Attachment A:

1) Checklist Instruction # 3178-3126 - Weekly Station Visit
- Ozone Analyzer (CSI OA 325-2)
- Ozone Calibrator (Dasibi 1003-PC)
- CASTNet Dry Deposition

Attachment A:

2) CASTNET Ambient Air Quality Monitoring Audit Procedures
Standard Operating Procedure# 3755

Attachment A:

3) Statistical Control Charts for Quality Control of Weather Data for Reference Evapotranspiration Estimation, CIMIS

Attachment A:

4) CASTNET Ambient Air Quality And Meteorological Monitoring Data – Preliminary Validation, Technical Instruction# 3450-5010

Attachment A:

5) CASTNET Ambient Air Quality And Meteorological Monitoring Data – Final Validation, Technical Instruction #3450-5020

Attachment A:

6) Checklist Instruction #3178-3300- Multipoint Calibration
- Ozone Analyzer (ML 8810)
- Ozone Calibrator (Dasibi 1003 PC)

Attachment A:

7) Establishing And Using AIRNET Action Levels, LANL ESH-17-201, R3

APPENDIX J

APPENDIX J: Outreach Audiences

First Responders/Communicators

- State and local radiation protection officials
  - Conference of Radiation Control Program Directors

- State and local emergency response officials
  - State and city emergency management offices
  - National Emergency Management Association
  - Police
  - Fire
  - Traffic

- State and local health officials
  - State and city health departments
  - Regional hospitals
  - EMTs

Secondary Communicators

- Elected and appointed officials
  - Mayors/city managers (Conference of Mayors)
  - Governors/state cabinet officials (National Association of Governors)
  - Members of Congress

- Media
  - Television
  - Radio
  - Print
  - Web (rumor control)

- Local academia

Potential Partners

- Other EPA Offices
  - Regions
  - OSWER
  - OAR (OAQPS)
- Interagency Modeling and Atmospheric Assessment Center (IMAAC)
- National Response Team
- DHS, DOE, NRC, FEMA, DOD, DHS, Health Canada, HHS

APPENDIX K

APPENDIX K: List of Organizations for Outreach

Health and Emergency Groups

American Academy of Health Physics (AAHP)
American Association of Physicists in Medicine (AAPM)
American Association of Radon Scientists and Technologists (AARST)
American Board of Medical Physics (ABMP)
American College of Occupational and Environmental Medicine (ACOEM)
American Conference of Government Industrial Hygienists (ACGIH)
American Industrial Hygiene Association (AIHA)
American Nuclear Society (ANS)
American Public Health Association (APHA)
Association of State and Territorial Health Officers (ASTHO)
Conference on Radiation Control Program Directors (CRCPD)
Environmental Council of the States (ECOS)
Health Physics Society (HPS)
International Commission on Radiological Protection (ICRP)
International Radiation Protection Association (IRPA)
National Council on Radiation Protection and Measurements (NCRP)
National Emergency Management Association (NEMA)
National Environmental Health Association (NEHA)
National Homeland Security Consortium
National Radiological Emergency Planners (NREP)
National Radon Safety Board (NRSB)
National Registry of Radiation Protection Technologists (NRRPT)

Government Officials Organizations

American Association of Port Authorities
Association of State Drinking Water Officials
Association of State, Local and Territorial Emergency Response Officials
National Association of Counties
National Association of County and City Health Officials
National Association of State Departments of Agriculture
National Environmental Health Association
National Governors Association
National League of Cities
U.S. Conference of Mayors
State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials

APPENDIX L

APPENDIX L: Fixed Monitor Siting Methodology Proposed by Savannah River National Laboratory

National Siting plan for EPA's Fixed RadNet Air Network

Savannah River National Laboratory

Robert Kurzeja, Matthew J. Parker, Robert L. Buckley, and
Saleem R. Salaymeh

Prepared for

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Nonproliferation Technologies Section
Savannah River National Laboratory
Aiken, SC 29808

Prepared for the U.S. Environmental Protection Agency under IGA Number DW-89-92205701-0

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SAVANNAH RIVER NATIONAL LABORATORY

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SRNL SAVANNAH RIVER NATIONAL LABORATORY

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Executive Summary

The US Environmental Protection Agency has asked the Savannah River National Laboratory (SRNL) for assistance with developing a national siting plan for a fixed network of radiological sensors (RadNet). Based on SRNL's extensive experience in such matters, an Interagency Agreement (IAG) has been created to allow SRNL to provide a technically defensible, multifaceted plan for optimizing the benefits of RadNet. Specifically, SRNL will provide assistance in siting the monitors nationally and locally. National siting will be based primarily upon the population dose and most likely transport and release situations. This report provides two approaches to optimally select national sites for the RadNet through transport modeling of a variety of hypothetical releases and analysis of extreme conditions that could impact the RadNet monitors. This report also recommends criteria for local siting of monitors in urban areas.

National Siting plan for EPA's Fixed RadNet Air Network

Robert Kurzeja, Matthew J. Parker, Robert L. Buckley, and
Saleem R. Salaymeh

Savannah River National Laboratory

Introduction

The Environmental Protection Agency (EPA) requested technical assistance from the Savannah River National Laboratory (SRNL) in developing siting criteria for EPA's fixed RadNet air monitors, testing of EPA's fixed RadNet air monitors in various climatic extremes, and developing methodology for evaluating real-time data obtained from EPA's fixed RadNet air monitors.

Under the Nuclear/Radiological Incident Annex to the National Response Plan, the EPA is responsible for providing nationwide environmental monitoring data from the Environmental Radiation Ambient Monitoring System (ERAMS) for assessing national impact of a radiological accident/incident. EPA has recently renamed the ERAMS system as RadNet. The EPA plans to place as many as 180 RadNet air particulate monitors in cities across the nation to fulfill its responsibilities under the Nuclear/Radiological Incident Annex. These monitors will be capable of performing gamma spectrometry and determining gross beta radiation levels in near-real time on the airborne particulates collected on a fixed filter. The focus of the system is detection and quantification of radioactive contamination transported by air in cities not directly affected by the accident/incident. Only one monitor will be placed in a city. These data are expected to assist atmospheric dispersion modelers and decision makers during a radiological accident/incident.

An Interagency Agreement (IAG) provides some funding for initiating information exchange between the EPA and SRNL. Because of the vast amount of experience and expertise that SRNL has in this area, several tasks using SRNL consulting services will be provided to assist the EPA in completing this project. The consultation will include: 1) assistance in siting the monitors in a technically defensible way that balances population and area coverage, 2) performing atmospheric dispersion modeling for several hypothetical radiological incidents, 3) developing a test plan and then testing the monitors under various environmental extremes, 4) providing recommendations on methods and approaches for establishing "alarm" limits, and for efficient review of routine data, 5) evaluating the suitability of currently-available software for performing quantitative low-resolution gamma-ray software for analysis of data generated by the RadNet monitors, and 6) other emerging technical issues.

This report includes a review of methods/options for national siting of the RadNet monitors and recommends an optimal approach for selecting national sites for the EPA's

RadNet monitors based on the proposed siting criteria. The report will also include guidance for local siting and provides guidelines for optimum siting within a city.

Background

There have been numerous monitors deployed to measure environmental radiation in a variety of situations. The most common are fixed station deployments near nuclear facilities such as the Department of Energy (DOE) sites, (WSRC, 2004 and PNNL, 2003) and public utilities (Bellinger, 1991). Typically, these are deployed in an arc at or slightly beyond the plant boundaries. In other cases, field experiments have been conducted over larger areas (Telegadas et. al., 1981) where an effluent tracer (ETEX, 2005) was to be detected. Generally, in all cases, the monitoring stations were located at ground level, and the siting criteria were based on capturing the spatial extent of the plume.

One of the basic assumptions for RadNet is that the system will not be designed as an early warning system. Rather, measurements will be obtained to detect radiological releases that occurred well upstream (tens of miles) of the monitoring station. At these distances, it can also be assumed that the release will be well-mixed within the atmosphere.

Given these assumptions, the nature of the release cloud can be described. A release during a sunny day will produce a cloud that will quickly become mixed throughout most, if not all, of the atmospheric boundary layer by larger and larger eddies. Eventually, the entire cloud will become nearly uniformly mixed with very little variation from top to bottom. The cloud itself may extend vertically from around a 1,000 ft to several thousand feet depending upon the time of day and year. Releases during cloudy days will also eventually become dispersed evenly within the atmosphere, but the height of the cloud will be significantly less than for a sunny day. During a clear night, the release cloud will likely remain concentrated and near to the ground, but after sunrise, the mixing process will greatly increase and the cloud will eventually be readily dispersed upward and downwind.

At distances of tens of miles from the release, the time period for the release cloud to pass over a given monitoring site increases. Even a simultaneous "puff release will become almost plume-like and will likely take over 30 minutes to pass by. At greater distances, the time to pass by the monitor will increase even more. Of course, a continuous release source will produce a cloud that may be monitored continuously if the monitoring site is located directly downwind.

Since the release cloud will be well mixed within the atmosphere, the sampling site must be located at a place where the prevailing airflow can be monitored. Typically, this will occur above the ground (tens of feet) where there are fewer, if any obstructions to the general flow. Conversely, locations near the ground that are obstructed by buildings, forests, or other larger structures will be inhibited from monitoring the prevailing air flow. These obstructions could lead to delays in measuring the release cloud or even possibly causing the release to be missed altogether. Therefore, the best sites will be elevated and very open to the prevailing airflow of the region.

National Siting

1. Requirements

1.1. Mission and objectives of the RadNet

The objectives of the RadNet air network have been summarized in a draft statement from the EPA (Aug. 16, 2005). Three mission objectives were given: (1) Provide radiological data for emergency response assessment to radiological accidents. (2) Measure ambient radiation levels in the environment, (3) Inform public officials on the impact of radiological incidents/accidents. The system is designed to measure the impact over large parts of the country and on population centers from nuclear weapon detonation, radiological dispersion devices, and domestic and foreign nuclear facility incidents/accidents. The system is not designed to monitor the immediate vicinity around incidents/accidents or act as an early warning/first detection capability.

The Radnet document listed system objectives in the timeframe surrounding incidents. First, the system should provide continuous baseline radiological measurements before the incident. Second, the system's function in the first 4 days after an incident/accident is to provide support data for (1) atmospheric modelers, (2) for understanding the national impact in affected and unaffected regions, and (3) for decision makers. In the year(s) following the incident/accident the network's objectives continue those of the first 4 days but also include reestablishment of the baseline, dose reconstruction and delayed contamination transport.

Since plumes are typically narrow near the source (<1-10 miles across), their detection with a national network will only be possible at larger downwind distances, where the plume's dimensions become larger. Thus, in practice, the RadNet system should be more effective in monitoring plumes from distant points than from the city in which the monitor is located.

1.2. Other Considerations

1.2.1. Timely notification and long-term monitoring:

Although it is recognized that the utility of 180 monitors is limited as a comprehensive early-warning system, nevertheless it is hoped that RadNet will provide real-time data for decision-makers and the public. However, the practical benefit of a limited system needs to be determined since the goal of early warning may dictate different monitor placement than required for population and area monitoring. For example, early warning requires monitor positioning closer to potential release points, with closer spacing, to detect narrower plumes, while population and area monitoring imply larger spacing. This report will include timely notification in the optimization plan and also consider how one measures early warning performance.

1.2.2. Instrument detection threshold and source strength:

The instrument detection threshold and source strength are related factors that affect the monitor location. When the monitor detection threshold is high, or the source is weak, only monitors close to the release will be useful. On the other hand, with a low detection threshold, or strong source, radiation will be detected by more distant monitors.

The sensor detection limit also depends upon the filter accumulation time. For locations close to the release, the nominal one-hour collection time is reasonable considering the plume's relatively small size. Larger plumes will have a lower detection threshold because of longer sampling times (longer time for particles to accumulate on the filter).

Although the imposition of a minimum detection threshold is justified by the instrument performance, it diminishes the application of the analysis to large source terms. In Section 3.5 a method to preserve flexibility in the analysis is discussed.

1.2.3. Release locations:

Cities and nuclear facilities are much more likely release points than remote rural areas and should be weighted accordingly. The correlation between release and population densities will also tend to concentrate monitors. For example, a dense grouping of potential release points a few hundred miles upwind of a large city will lead to many, comparatively narrow plumes. These plumes will then require a high concentration of monitors to ensure adequate determination of population doses. The concentration will require further enhancement for short response times since monitors will have to be positioned close to release points.

The selection of locations for long-term monitoring is less complicated than for specific incidents/accidents since the background chemical distribution is more uniform. In addition, monitors in remote areas or on the west coast of the US will provide a good baseline database because they will be monitoring relatively pristine air.

1.2.4. Source/plume characteristics:

The source will be assumed to be a small explosion at 20 meters above ground level (AGL) with a near-instantaneous release that decreases to zero after one hour. The particle size distribution is critical but only the fine particles (< 10 micron) are expected to reach the RadNet monitors. Thus, variability in the particle size distribution can be included implicitly in the source strength.

The plume area is used in three different contexts in this report. The first is the area bounded by a surface concentration that exceeds a given fraction (~10%) of the maximum, at time t. We also define the 'design' plume area as a circle whose area equals the average plume area from many model simulations, as a function of time and downwind distance. The design plume area is important because it defines the area whose mean concentration is approximately equal to a value measured within the plume. The design plume area can be written as, $A_s = A_s$ (distance,time). We also will refer to plume segments, which are plume footprints at various stages in the plume lifetime.

The 99% plume area is the geographic area for which there is a 95% probability of enclosing 99% of the plume's integrated footprint from the release time to time t. In most cases, the 99% plume will be a cone-shaped area from the release point to the most distant point of plume transport. It will be found from the model simulations and its main purpose will be in defining areas unaffected by the plume.

1.2.5. Prevailing meteorology:

Wind patterns across the US will influence the location of network monitors. The most significant effects are prevailing westerlies which will tend to favor placement in the central and eastern US compared with western locations, except for real-time notification and baseline monitoring. Dispersion conditions can vary significantly from day to night and from season to season.

1.2.6. Use of models with measurements:

The proposed approach will use models extensively in the determination of optimum monitor placement and also in the application of the results. Therefore, it is essential to understand how these models will be used. The model uncertainties are discussed in Appendix 1. The most important use of models will be the simulation of possible incident scenarios. Since this function is not for prediction of an actual event, the main demand is that the model simulates average plume behavior reasonably well, without systematic defects, e.g., under prediction of long-distance transport by unrealistically large particle deposition. A second model function is in measurement extension. Thus, for example, a single measurement could be used to establish the overall validity of the model, or systematically adjust model results. In this way, a spatial variation in concentration can be inferred from a single reliable measurement.

It should also be mentioned that we are assuming model operation in the diagnostic rather than the forecast modes, i.e., actual meteorological observations rather than forecast data.

1.2.7. System performance:

The national siting plan should not only outline a defensible method for monitor siting, it should also explain the attributes of the plan and discuss the expected system performance for variety of scenarios. In particular, the plume detection probability as a function of time after release and source strength should documented. The role in real-time guidance just after an event should also be discussed. Finally, guidance on how best to make use of the network for long-term and real-time situations should also be discussed.

2. General Method

2.1. Optimization:

As noted in the Introduction, one goal of this study is to develop a method for siting 180 monitors within the continental US. Before siting criteria can be rigorously defined, a general framework for decision is necessary. As discussed above, the fundamental tradeoffs are between population or area monitoring, between long-term monitoring and real-time information, between probability weighting and random selection, and between reliance on observations only or in conjunction with models.

Monitoring of population exposure is usually expressed in terms of the population dose and implies monitor placement to ensure that the greatest fraction of the potential population dose is monitored. However, monitoring of all areas of the country is also desirable, at least for long term chronic doses. We will analyze the population and area approaches separately and discuss compromise solutions in Section 4.4.

As discussed above, we will address the tradeoff between timely information and long-term monitoring by duplicating the analysis: first for measurements within 18 hours of an incident and second, for all measurements. In Section 4.4 we suggest how these two results could be combined.

Probability enters the analysis in terms of the chosen release location and prevailing winds. Since the analysis will be based on hundreds of model plume simulations, selected from several years of data, most probable meteorology is inherent in the process. However, since light winds and/or warm weather will tend to enhance the radiation dose to the local population, additional simulations will be performed to illustrate how the siting plan performs for this case.

As noted above, the choice of release locations has a strong impact on the RadNet site selection. In general, it is assumed that remote (rural) locations are unlikely locations for a radiological release except when they contain nuclear facilities. Most release locations will not be geographic points, but instead, areas with uniform probability of release.

Our analysis will be based on the population dose. Population dose weighting seeks the most accurate population dose for each region in the US. Hence, closer monitor spacing is required in densely populated areas since dose errors result in correspondingly larger errors in the population dose.

The major difficulty in designing the RadNet national network is the relatively few number of monitors (180) available to accommodate a wide range of release scenarios. As a consequence, many incidents/accidents will be severely undersampled, especially in their early stages when plumes are small. Unfortunately, it is difficult to predict how a specific analysis will work for a large number of overlapping plumes. For this reason, we will approach the problem as both undersampled and oversampled, evaluate both approaches in the pilot study (Section 3.2), and choose one for the national siting network.

The oversampled approach assumes that the release plumes are continuous and smoothly varying and can be adequately defined by 180 monitors. The monitor locations are then determined by adjusting their positions until the variance between the measured and simulated population dose is minimized. This approach makes no assumptions about plume shape other than the requirement that its spatial variation is comparable to the monitor spacing.

The undersampled approach assumes that the plumes are often too small to be detected by more than one monitor and that additional information about the plume shapes and sizes must be drawn from other sources, e.g., models or dispersion studies. Models are also necessary for interpretation of actual incidents/accidents.

The division between oversampling and undersampling can be seen in terms of the nominal RadNet sampling area. If we divide the area of the US, approximately 3 million sq miles, by 180 monitors, the area for each monitor is ~16,000 sq miles - 125 mile spacing. Thus, plumes larger than ~ 100,000 sq miles (320 mile spacing) are considered to be oversampled while those with areas less than 16,000 sq miles are undersampled.

The oversampled (minimization) and undersampled (model) approaches are discussed below. These analyses are based on a series of model plume simulations carried out over the entire country for a range of meteorological conditions and release locations (see Section 3). Each plume will be divided into plume segments of ~1 hour long. These plumes are the ‘data’ which the monitor network will be designed to measure as accurately as possible.

Minimization:

This method distributes 180 monitors to minimize the variance between the simulated plume population dose density and values interpolated from the monitor network.

Each simulated plume, or plume segment p, will yield a population dose density on an (x, y) grid distributed over the US. Let the simulated population dose from plume segment p be denoted by $D_{p,i,j}$, where i and j denote the east/west, and north/south locations, respectively, and p denotes the particular plume. The number of grid locations exceeds the number of monitors (=180). We denote the 'measured' dose at location x,y for plume p as $F_{p,i,j}$. The measured dose is interpolated from the monitor locations $M_{i,j}$. The monitor locations will in general not fall on the (x,y) grid.

The minimization method adjusts the monitor locations so that,

$$Sum = \min \sum_{p} \sum_{i,j} P_{i,j}{}^{2} (D_{p,i,j} - F_{i,j})^{2} \qquad (1)$$

where, $P_{i,j}$ is the population density at location i,j.

For typical plumes, the minimization method will place monitors at function maxima and minima. Thus, more monitors will be required in a region with small plumes at the cost of reduced accuracy in measuring large plumes elsewhere. Minimization of the population dose will result in preferential monitor positioning toward populated areas.

One drawback to standard minimization techniques is their intractability when applied to partially-overlapping plumes, spread over a large domain like the continental US. One remedy is to sum the doses for all simulated plumes and then select optimum monitor locations for the composite function. Although this optimization will not be generally applicable to individual plumes, it may be a good initial estimate for monitor locations.

The most difficult part of the minimization process is the selection of a computationally efficient technique. Since the method will generate hundreds of plumes whose dose distributions will be minimized every hour, tests in a pilot study region of the US will be carried out, as described in Section 3.2.

The performance of the network will be evaluated regionally or by plume size by comparing the integrated population dose density variance with the population dose from individual plumes.

Model Method:

The model approach differs from the minimization method because the plumes are treated as individual targets rather than continuous functions. We assume that model results or observed plume statistics specify the plume size and its approximate location and that the monitor's purpose is mainly to determine the plume's concentration (dose) (see Appendix A). A monitor location's value is based on the number of plumes it detects and the accuracy of the population dose determined for each plume.

The basis for our approach is the population dose. The population dose is defined as:

Hp = population dose = radiation dose x population (2)

For a plume of radionuclides the radiation dose is the product of the radionuclide concentration, the dose conversion factor and the exposure time. Eq (2) can be rewritten as,

$$HP = b \iiint_{plume} P(x, y)\, Concentration(x, y, t)\, dxdydt \qquad (3)$$

Where;

b = dose factor

P(x,y) = population density (people/m2)

Eq (3) includes the dependence of the population and concentration on location and time. The spatial integral in Eq (3) is over all locations with a concentration above the background value.

Eq (3) integrates the product of the concentration and population density over the plume area. To simplify the analysis we define a 'design' plume area as a function of time and downwind distance. The population within A_s is P_s.

$A_s = A_s(t,d)$ = standard plume area (4)

$P_s = P_s(t,d)$ = population within A_s (5)

A_s is a function of d to account for the dependence of plume size on wind speed and is based on model results and dispersion studies. The definition of A_s could be refined to include realistic shape dependence on time and distance, but we shall assume a circular shape which approximates puff releases.

Eq. (3) can now be rewritten as,

$$HP = bA_s P_s C_s = b \iiint_{plume} P(x,y)\,Concentration(x,y,t)\,dxdydt \qquad (6)$$

C, the average concentration within the area A, and is <u>defined</u> by Eq. (6), i.e. Eq (6) is exact.

Eq (6) is applied to each plume or plume segment as follows.

(1) From the plume surface concentration and population density, calculate the population dose for a one hour time segment.

(2) Determine A_s for the plume and center it over the simulated plume.

(3) Calculate the population within A_s. This population will approximate the population in the simulated plume.

(4) Calculate the concentration, C_s, from Eq. (6).

(5) Evaluate the error variance for each x,y point on the grid

$$E_p(x,y) = (C(x,y)-C_s)_p^2 \qquad (7)$$

The process is repeated for each plume segment and other plumes to find the total error variance E_T at each x,y location.

$$E_T(x,y) = \sum_p E_p(x,y) \qquad (8)$$

Eq. (8) expresses the value of each grid point for estimating the population dose for the simulated plumes, i.e., the best monitor location is at the minimum E_T value.

The objective of the siting network is to 'reduce' the integral of E_T over the US by optimum placement of monitors. A simple way to view this reduction is to place the first monitor at the minimum in E_T and then delete all plume segments detected by that monitor. This operation would produce a new minimum in E_T for the next monitor, and so on. A more stringent criterion is to reduce the error variance from a plume segment by half when first detected and then delete it entirely when detected by a second monitor. The usefulness of the above process is limited because it requires regeneration of plumes after each monitor placement and because the supply of monitors may not be sufficient for the number of small plumes.

A more systematic approach is possible if the error variance frequency function is also calculated at each x,y point. The error frequency function EFF(x,y), is analogous to the well-known frequency distribution that shows the frequency of occurrence as a function of variable range. Similarly, the EFF expresses the population dose error variance as a function of plume area A.

The EFF will be found at each time step in a model simulation by 'binning' the error variance function according to the plume area A. Thus, monitors at long distances from release points will have EFF's mainly comprised of large plumes, while EFF's near release locations will be weighted toward smaller plume sizes.

The EF distributions summarize the results for future analysis and provide a framework for allocating sensors. As discussed above, the number of monitors will not be sufficient for good resolution of plumes near their source. Therefore, a reasonable approach is to locate monitors for the largest plumes first, and then for smaller plumes, until the monitor supply is exhausted. Since the ET will be known as a function of plume size, this process can be accomplished while also systematically reducing the error variance.

The EF distribution could also be used to account for detection threshold and source term variability. For example, since plume size is inversely proportional to the concentration (dose), a small source term or high detection threshold, requires closer monitor spacing since only the smaller plumes have concentrations large enough to be detected. In this case, one would begin the monitor allocation with a smaller, rather than a larger plume size.

2.2. Plume area:

The selection of monitoring locations is based on plume area and a general discussion of typical release scenarios will illustrate the problems involved. Figure 1 shows a multi-day HYSPLIT simulation releases from San Francisco, Salt Lake City, Dallas and Indianapolis. The first three were on April 2, 2003 at 0000GMT and the last, Indianapolis, on June 21, 2003. The HYSPLIT model will be discussed in more detail in Section 4.1 below. We note here that the simulations are instantaneous unit releases of an inert non-depositing gas. The concentrations shown are 24-hour averages ending at the listed times. The June 21 time of release for the Indianapolis simulation was selected specifically for the near-calm winds that are common over much of the continental US and would maximize radiological impact on the release area.

The plume shape after 24 hours is approximately elliptical, with the elongated axis in the trajectory direction. The largest plume (as defined by the 10-18 contour), from Dallas, is roughly four times larger than the smallest (from Indianapolis). By the fourth day, however, the plumes have comparable widths (smallest dimension). Moreover, the plume becomes increasingly deformed as they grow. This deformation is caused by wind shear, which becomes more important when the plume size exceeds ~100 miles. By the last day of the simulation the Salt Lake, San Francisco and Dallas plumes all have an 'L' shape.

The plume boundary is defined by a concentration isopleth. Although this selection is somewhat arbitrary, note that any selection less than 10^{-16} defines approximately the same plume size whereas a boundary concentration of 10^{-15} defines a much smaller plume. Note also that although some of the plumes are stretched, the smaller dimensions of the plumes are comparable after 4 days. The figures also show the general dependence of plume dimensions on time after release and downwind distance

Figure 2 shows the Indianapolis plume 6, 12, 18, and 24 hours after the release. The plume first drifts to southwest of the city on the first day and then to the northwest and then north of the city. In this case a monitor near the release point will be of greater value than at a downwind location.

Equation (6) requires a method for selecting the area A. Two approaches are possible:

1. Define a 'design' plume area to be a circle whose area is a function of downwind distance and time based on models and observations. This option avoids the computational burden of calculating the plume area from each model plume simulation. A circular plume also implies a radial decrease in confidence (representative ness) of a measurement.

2. The second option is to determine the plume area directly from the model simulation. This approach would represent unusual meteorological conditions better than the generic method above and also would position the plume more accurately with respect to the population density. It also permits 'calibration' of the plume concentration. For example, if the model plume concentration is given by C(x,y,t), and the concentration is measured at x_i, y_i, t_i, then the entire plume concentration could be adjusted to be,

$$Ca(x, y, t) = C(x, y, t) \times \frac{Cm(x_i, y_i, t_i)}{C(x_i, y_i, t_i)}.$$

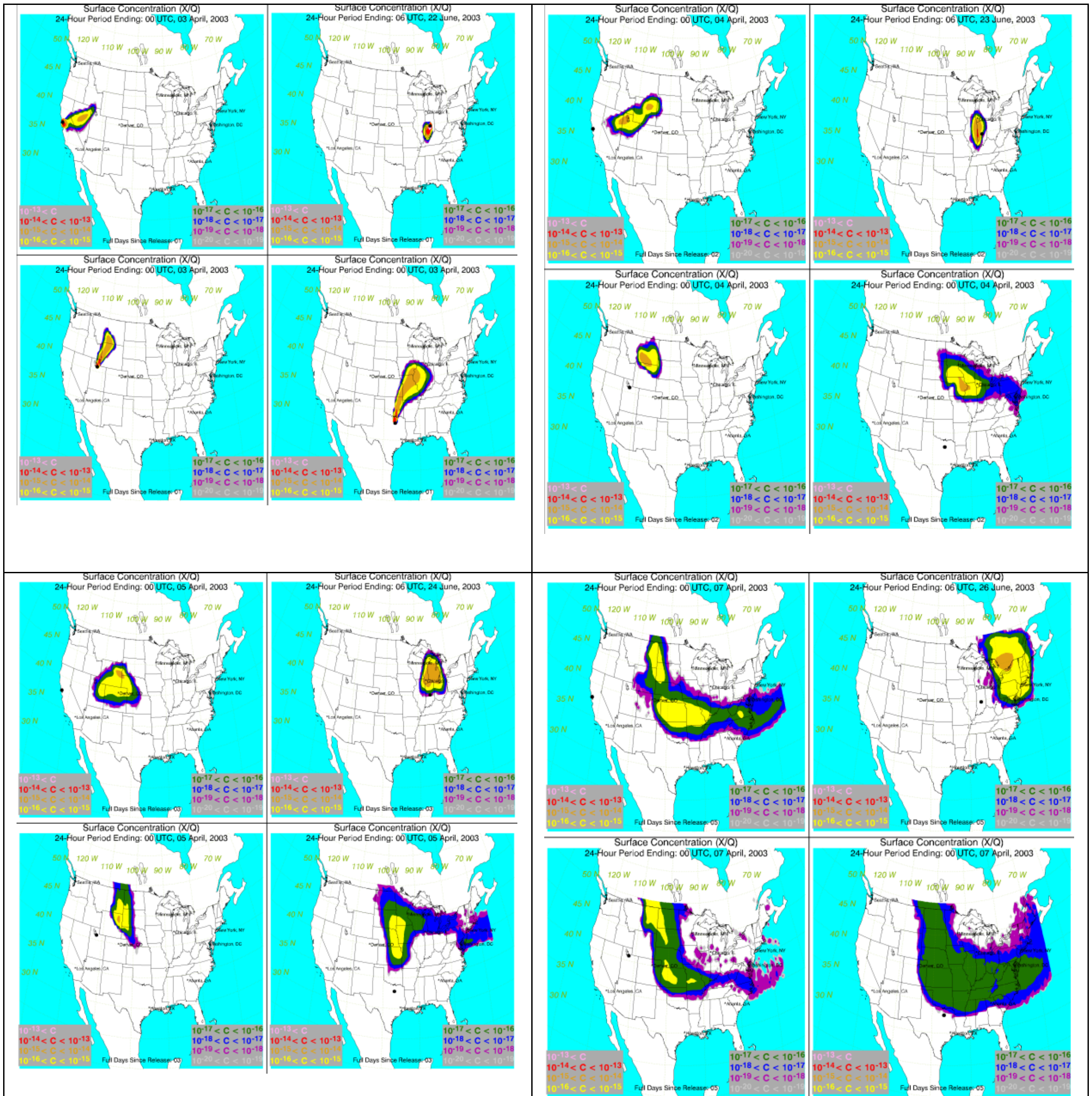

Fig. 1: HYSPLIT plumes for releases from San Francisco, Salt Lake City, Dallas on 0000z , April 2, 2003 and Indianapolis on June 21, 2003 Panels a,b,c and (d) show the 24-hour average concentration ending at 00z on April 3, 4, 5 and 7, respectively (June 22, 23, 24,and 25).

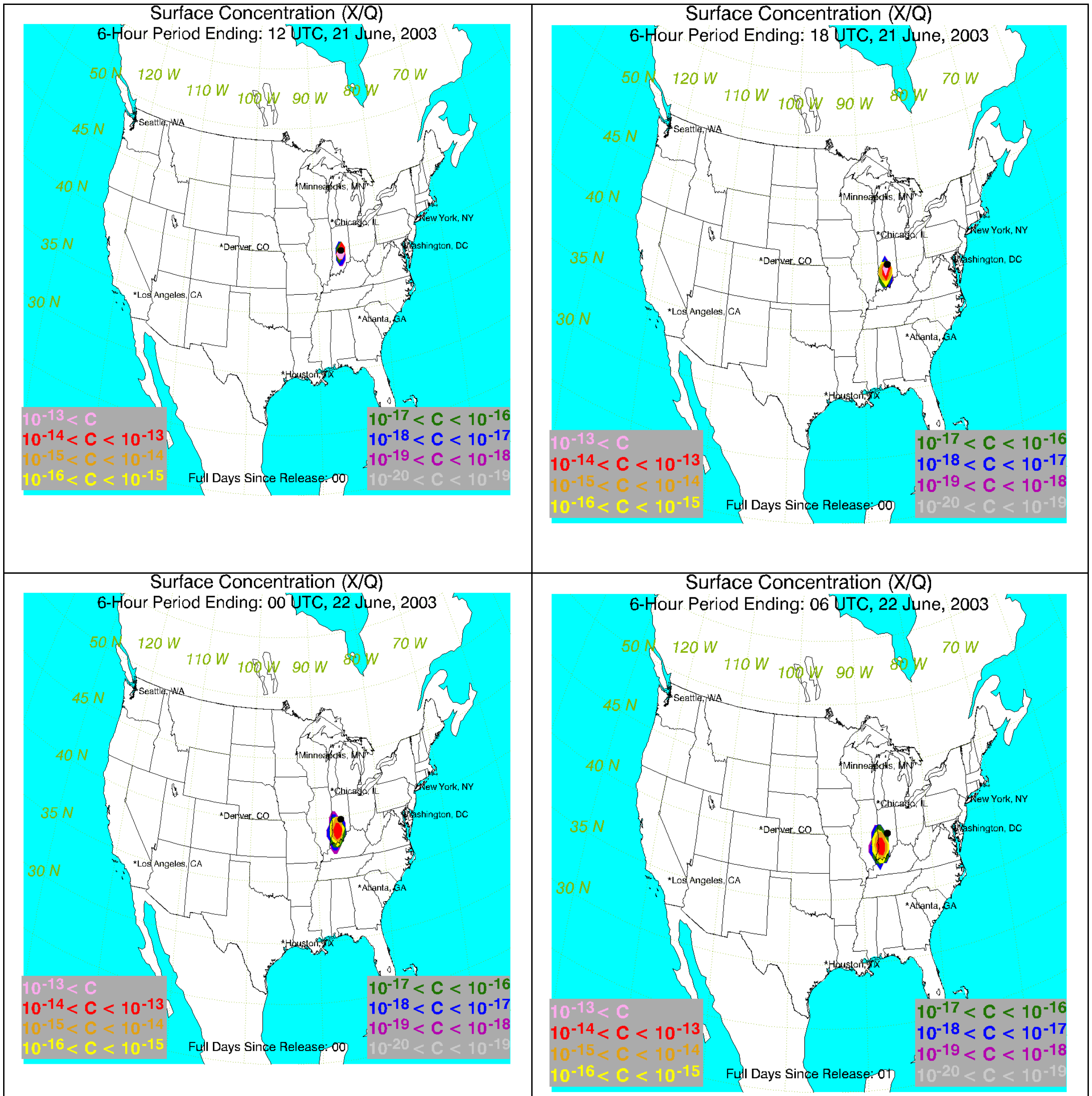

Fig. 2: HYSPLIT for and Indianapolis plume with light winds on June 21, 2003. Panels a,b,c,d are for 6-hour periods ending 6, 12, 18, and 24 hours after the release.

2.3. Timely notification:

As noted in the Section 1.2.1, one of the objectives of the RadNet is timely notification. The RADNET Concept and Plan lists a target notification time of 24 hours from the time of release. The 24 hours includes 6 hours of decision plus measurement time plus 18 hours of transport time. Eighteen hours of transport time includes releases up to 180 miles from the monitor location, if we assume a 10 miles/hr transport wind.
The minimization methods and model methods will position sensors for the 18-hour problem as for the longer simulations The geographical distribution of the 18-hour EF's

will differ from long-term values because locations far from release points will have large EF's because most plumes will not reach them in 18 hours. The 18-hr solutions are relevant for small source terms that will not be detectible at long downwind distances.

2.4. Confirmation of non-dose:

The concept of plume area A can be extended to estimate the locations that have not received a radiation dose. In addition to determining the plume size as a function of time and downwind distance, a larger area, called the 99% plume area, can be derived which defines the area size within which there is a 99% probability that the plume is located. In the absence of actual model simulations, this area will be several times larger than the actual plume area A to account for uncertainties in winds, etc.

The minimization method places monitors at minima in the population dose distribution. Thus, non-dose confirmation will be found by interpolation from monitors placed in remote areas.

2.5. Small source terms:

As discussed in Section 1.2.2, the monitor detection threshold and source term determine how far downwind an incident can be detected. However, the imposition of a detection threshold in the analysis would cause low concentrations to be deleted. Thus, the analysis would be skewed toward smaller source terms. To preserve, generality, we will not impose a detection limit. All source terms will be unit releases, i.e., the results will be normalized (scalable) based on the actual release amount.

However, as noted above, the breakdown of the error variance by plume size will permit an extension of the results to smaller plumes, which correspond to higher concentrations or smaller source terms.

2.6. Implications of optimization:

a) West Coast locations: Although cities on the west coast involve radiological releases, the plumes from these cities, moving eastward in prevailing westerlies, will be narrow just after release and thus, not likely to pass over coastal monitors. Hence, these monitors will have less value. Siting monitors inland ~100 miles, where the plumes are wider, will increase the detection probabilities, but with lower population densities.

b) Central US locations: Central US locations, although in low population areas, will have a good chance for monitoring west coast plumes, albeit at low concentrations. Furthermore, although plume areas will be large, concentrations and population densities will tend to be low, which will tend to reduce their value. Some of these locations may be redundant because the sampled plumes have large areas, i.e., cover many locations.

c) East coast locations: East coast locations will tend to have the greatest value according to the above plan because of their high populations, and high number of plumes released to the west. Issues of sampling equity will be discussed in Section 4.4.

3. Methodology

3.1. Outline:

This section lists the steps in the application of the proposed method, with addition explanation following each step.

a) Create a geographical grid across the US, with spacing of approximately 30 miles. Each grid point will be identified by its i,j indices and its latitude and longitude. High population areas of the US would be supplemented with a fine grid of approximately 10 mile spacing. The US population database would be used to assign a population to each grid point in the coarse and fine grids.

b) Selection of source locations. In general, these will be large population areas but defense or civilian facilities might also be included. It is anticipated that 20-60 source locations will be selected in major cities and nuclear or other facilities. The release probability for a given location will be a function of its population and importance. For example, New York City and Washington, DC will both have high release probabilities but for different reasons. Furthermore, the release probability will be distributed over the area of maximum concentration. For example, with NY City's release probability will be distributed over the entire island of Manhattan while the Washington, DC release distributed over federal facilities. This distribution will affect short-range detection but not at long range.

c) Specify the release information. This will include the release height, composition, release time of day, etc. An explosion (puff) will be assumed with a short (one hour decay time).

d) Set up the HYSPLIT model for multiple simulations. The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Hess 1997, 1998) was developed at the Air Resources Laboratory of the National Oceanic and Atmospheric Administration (ARL-NOAA). This model can calculate simple trajectories through advection in the atmosphere, as well as more complex dispersion and deposition. The name for the model comes from a calculation methodology that allows one to use a Lagrangian approach for transport calculations and an Eulerian approach for dispersion calculations. Although a variety of methods exist within HYSPLIT to determine atmospheric concentration, it will be calculated here by defining pollutants as particles. In the particle model, a fixed number of initial particles are transported about the model domain by the mean wind field and a turbulent component, and air concentrations are determined using cell averages. Emissions may be specified as a point, line, or area source, and removal mechanisms include wet and dry deposition, as well as radioactive decay.

The large scale meteorological datasets required to perform the simulations are already available in a format suitable for ingestion into HYSPLIT. Validation studies for HYSPLIT are numerous, and include comparison with tracers released during long-range field experiments (e.g. Across North America Tracer Experiment, ANATEX [Draxler et al. 1991]), simulations of the Chernobyl disaster, as well as application to balloon trajectories and volcanic ash eruptions. Extensive documentation may be found online at http://www.arl.noaa.gov/ready/hysp_info.html.

e) Select the meteorological data base. The NOAA FNL data base with special attention given to inclusion of rainfall and moisture for wet deposition.

f) Select the simulation times. We will select random weeks from each season from which to select release times. Approximately 20 times from each season will be selected, yielding a total of about 80 release times for each of the 20-60 release locations or 1600 to 4800 plume simulations.

g) Carry out the simulations.
The minimization method will store the concentrations on the x,y grid for each plume segment. After all plumes have been simulated with HYSPLIT, the concentrations on each plume segment will be used in an iterative method that adjusts the monitor locations to minimize the error variance.

The model method will calculate the value functions EF and EFF at each grid point for the simulated plumes. The totals after 18 hours will be saved for the short-term notification analysis. The final results will be stored in the monitoring phase. The EF's will be displayed as US and individual population center maps. The contour maps will be used for preliminary siting. Multiple siting will be selected based on the EFF's.

h) Determine the performance of the network for various plume categories. This will include estimates of dose accuracy and the probability of detection.

3.2. Pilot Study:

The pilot study is an abbreviated version of the final US analysis. It will test the software and methodology on a subset of the complete US solution. It will be conducted for a region of the US, in one season, and with a reduced set of plume simulations. The analysis will be complete and a final report submitted to the EPA for consultation. Knowledge gained from the effort will be used to modify the process before beginning the study of the entire US.

The pilot study will evaluate the sensitivity of the results to the number of monitors and the plume size. We will also study the application of the monitoring network for plumes not used in the original analysis.

Since the pilot study will use the same software and data as the final study, it will not involve duplication of effort. Another advantage will be that the EPA will have a good understanding of what the final study will look like and be able to suggest modifications.

The pilot study will also allow the testing of special cases. For example, we will study changes in the site selection resulting from additional plume simulations and the effect of anomalous meteorological conditions and release locations. We will also test the sensitivity of the results to source term variations and assess the uncertainties in the results.

3.3. National siting model runs:

The National Siting study will be similar to the pilot study but will be more automated and with less inspection of individual simulations. Possible systematic biases in the simulations will be studied, for example, HYSPLIT's deposition calculation will be compared with available data to avoid significant biases. In addition, the representative ness of the transport situations will be evaluated by comparison with climatological data at a few locations.

3.4. Discussion and recommendations:

An accurate determination of the spatial variation of the population dose requires at least a few monitors in remote locations to define the function minimums. The maximum plume size that can be defined by a regular spacing is equal to the area of the US divided by the number of monitors, or ~20,000 sq miles. Thus, a few of the 180 monitors will be reserved for unmonitored areas of this size or greater. These monitors will also monitor expected non-dose areas.

As discussed in Section 3.3, the solution must resolve the problem of trade-off between timely notification and long-term monitoring. This issue will be addressed by solving for time periods of less than 18 hours and again for unlimited periods (several days). These two solutions will define different sets of monitor locations. A compromise between the two will be sought by first, identifying locations that are nearly common to both solution sets, where slight repositioning can satisfy both solutions. The next step will be to relocate some of the long-term monitors to satisfy the 18 hour solution set. This task will be somewhat subjective; however, the main goal will be to reduce the 18-hour SVF by more than the long-term SVF is increased. Thus, we will be reducing the total SVF from the 18-hour and long-term solutions. Note, that an objective combination of these two solutions, i.e., the sum of the two SVF functions, is not acceptable because of the 18-hour cutoff for the 18-hour solution. Thus, even a slight displacement of an 18-hour monitor location might invalidate it for the purpose of short-term notification.

As discussed in Section 3.1, the use of model plumes can greatly enhance the value of widely separated monitor data. As suggested in the Appendix, the main benefit of the use of models will be in the determination of more accurate plume footprints, especially in high population areas when analyzing a particular release scenario. More accurate plume shapes can improve the siting analysis by substituting a more accurate plume area for the design plume circle defined in Section 3.2. The advantages of realistic plume shapes will be tested in the pilot study.

Some monitors (~10) will also be reserved for US borders. These locations will monitor background air entering the US and also be the last available points to identify plumes not detected by the interior network. In some cases, the role of these sensors will be assigned to monitors justified for other reasons, e.g., population or probability of plume detection.

The primary object of the siting plan is optimal siting of the monitors. A second goal is to assess the performance of the RadNet system. One measure of performance is the probability of detecting a plume as a function of time since the release, or more generally, the percentage of plumes detected as a function of time since release. This statistic could be evaluated from the simulated plumes used in the study or with plumes drawn from different times than used in the study. Similarly, the detection percentage could be found for release locations used in the original analysis and also for releases from locations not considered. The latter test is for conditions not in the design specifications. System performance will be evaluated in the pilot study.

4. Cost estimate

4.1. Man hours

Cost Estimates

The following is an estimate of what it would take to do the modeling for establishing a national siting scheme that is defensible and has scientific basis. The table bellow shows the required tasks and the estimated man-hours (MH) it will take to accomplish:

Task	Estimated MH
Assemble population and meteorological databases	120
Automate HYSPLIT plume simulations and store results	80
Configure software to process and display results	100
Design and execute pilot study	120
Issue a technical report on the pilot study	100
Execute plume simulations for full US analysis	180
Analyze results and write final report on National Siting	200
Provide tech support to EPA on specific local siting questions	200
Total MH	**1100**

The approximate cost for the above tasks is $225K.

4.2. Duration

The calendar time for completion of the tasks listed in the table above will be between 8 to 10 months depending on holiday time and priorities.

Local Siting

1. Criteria for Local Siting

Invariably, siting of monitoring stations becomes a compromise between the ideal objectives of the program and the available resources. However, some criteria are more than just ideal—they are critical. Without these, the project objectives cannot be met under any circumstances. Therefore, siting criteria can be divided between "critical" and those than can be negotiated or "compromised". Ultimately, when faced with a multitude of monitoring siting decisions at locations that will vary considerably, the goal is do create a guide that will ensure, within reason, that each site will be installed at a location that best meets the program's objectives and is founded on a technical basis. Also, the siting actions would be "reproducible" so that all of the chosen locations are consistent with each other. Sites that do not meet the critical program objectives would not be used. The following list provides the critical and compromised criteria for RADNET siting.

Critical Criteria	
Security	The site must be in a secure, protected location.
Power	Reliable electrical power must be available. In addition, the monitor must have access to an electrical ground point.
Communications	Access to communication infrastructure must be available. If satellite communications will be used, then a clear view of the southern sky must be available.
Access	The site must be reasonably accessible by the caretaker.
Compromise Criteria	
Above Ground	The siting platform should be located well above ground level in the free flowing atmosphere. In an urban setting, minimum height above ground level is 15 m with the ideal being 30 m or greater. For unobstructed rural sites, a ground level site is acceptable, otherwise a height of 10 m should be used (depending upon the obstructions).
Upwind	The site should be upwind of the location or region to be monitored. This increases the likelihood of detecting an upwind release promptly and before the release cloud passes through the region of interest.
Openness	The siting location should be free of obstructions that would inhibit free airflow.
Sources of Contamination	Any source of chronic sources (stacks) of dust, particulate, corrosive chemicals, etc. that could possibly contaminate the monitoring system should be avoided by 300 ft (100 m).

2. Additional Criteria Recommendations for Local Siting

2.1. Site Historical Record

After the initial installation, the monitor location should be documented. A sketch of the location and nearby structures should be made and accompanied by panoramic photographic images of a 360° horizon looking out from the monitor. This information should be stored as part of the site's historical record. This process should be repeated every three to five years, and dramatic changes to the locality should be noted and assessed against the siting criteria. If necessary, the monitoring site may have to be relocated if the criteria cannot continue to be met.

2.2. Supplemental Meteorological Measurements

In cases where the EPA budget allows, supplemental meteorological measurements, in particular wind speed and direction, are recommended to be collocated with the RADNET monitor. In the event that a monitor begins to provide positive detection readings, the first question will be, "Where is this coming from?" In such a case, the

ability to immediately check the wind speed and direction would be a key to answering this question.
Much practical guidance exists for the proper siting of meteorological instrumentation. Much of the information regarding meteorological measurements in "On-Site Meteorological Program Guidance for Regulatory Modeling Applications" (EPA, 1995a), "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements" (EPA, 1995b) and "Determining Meteorological Information at Nuclear Facilities" (ANS, 2005) can be adapted for use in RADNET. In many cases, installations will occur on top of existing buildings, so care must be given to ensuring that local influences upon the meteorological measurements are minimized. However, even with the best of intentions, it may be that the meteorological measurements taken are more representative of the locality whereas the RADNET measurements are more representative of the prevailing atmospheric cloud. This is because of the fact that the plume is well-mixed within the atmosphere and the air mass approaching the RADNET station can be deflected but still be captured. In such a case, the local meteorological measurements will have to be combined with regional measurements to properly ascertain the direction from which the release cloud is emanating.

It should be noted that, like any sensitive equipment, meteorological instrumentation requires a comprehensive maintenance regimen to ensure that valid data are collected. If proper support is not available, then it would probably be best to utilize other available sources of meteorological data in conjunction with the RADNET data. Also, if proper siting criteria cannot be met, then it would also be better not to collect meteorological data (especially wind) in order to avoid inaccurate trajectory assessments during positive detection readings.

6. Acknowledgements:

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7. References:

ANS, 2005: Determining Meteorological Information at Nuclear Facilities. ANS/ANSI 3.11. American Nuclear Society, La Grange Park, EL., 60525.

Bellinger, T. E., 1991: Information Processing for Emergency Response at IDNS. Third Topical Meeting on Emergency Preparedness and Response. April 16-19, Chicago, IL. American Nuclear Society, La Grange Park, IL.

Draxler, R.R., R. Dietz, R.J. Lagomarsino, and G. Start, 1991: Across North America Tracer Experiment (ANATEX): Sampling and analysis. *Atmos. Environ.* **25A**, 2815-2836.

Draxler, R. R., and G. D. Hess, 1998: An overview of the Hysplit_4 modelling system for trajectories, dispersion, and deposition. *Australian Meteorological Magazine* **47**, 295-308.

Draxler, R. R., and G. D. Hess, 1997: Description of the Hysplit Modeling System, NOAA Technical Memorandum ERL ARL-224, NOAA Air Resources Laboratory, Silver Spring, MD (latest revision, January 2004).

EPA, 1995a: On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87 013. US Environmental Protection Agency, RTF, NC.

EPA, 1995b: Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements. EPA-600/R-94 038d. US Environmental Protection Agency, RTP, NC.

ETEX, 2005: European Tracer Experiment Overview, http://rem.jrc.cec.eu.int/etex.

PNNL, 2003: Hanford Site Environmental Report for Calendar Year 2002. PNNL-14295. Pacific Northwest National Laboratory, Richland, WA., 99352.

Telegadas, K., G. J. Ferber, R. R. Draxler, M. M. Pendergast, A. L. Boni, J. P. Hughes and J. Gray, 1981: Measured Weekly and Twice-Daily Krypton-85 Surface Air Concentrations within 150 KM of the Savannah River Plant (March 1975 through September 1977) - Final Report. NOAA Technical Memorandum ERL ARL-80.

WSRC, 2004: Savannah River Site Environmental Report for 2003. WSRC-TR-2004-00015. Westinghouse Savannah River Company, Aiken, SC., 29808.

Mission and Objectives of the RadNet Air Network. EPA draft document Aug. 16, 2005, 2 pages.

Expansion and Upgrade of the Environmental Radiation Ambient Monitoring System (ERAMS)* Air Network: Concept and Plan. (DRAFT) Prepared for the Radiation Advisory Committee, Science Advisory Board, US EPA, 2005, 118 pages.

8. Appendices:

Appendix A

Model Uncertainties

To include model results and observations in the placement strategy we must first carefully weigh the confidence in models and observations. In order of increasing uncertainty we list relevant model and observational results.

1. Plume size as a function of downwind distance. Plumes become broader with downwind distance. For distances up to ~100 km, vertical and horizontal dispersion is governed by turbulence and boundary layer properties and plumes dimensions are known reasonably well. Beyond 100 km mesoscale wind shear becomes more important and plumes can become highly distorted. Nevertheless, the footpring area of a plume is known to within a factor of 3. Modeling can be expected to reduce this error to a factor of 2.

2. Plume speed: Within the first 100 km of release, plumes become confined to the boundary layer and tend to travel with the mean speed of the boundary layer, which can usually be reliably measured. Furthermore, dose projections are not very sensitive to the exact plume arrival.

3. Plume direction: Since the wind direction can vary significantly with time and location, and reliable wind direction data along the plume's path are often absent, the calculated plume path while the plume is within the boundary layer is subject to error. Better prediction is possible when the plume is transported mainly by tropospheric winds.

4. Plume concentration: The most uncertain model variable is the surface concentration, particularly for particulate releases. Generally, the initial particle chemical and size distribution is not known and particle deposition cannot be modeled accurately. With increasing time, there is a greater probability for rainfall in the plume, which would significantly enhance particle rainout. Downwind measurements are particularly valuable for calibrating model results at longer downwind distances where the plume has been uniformly mixed. In this case, precipitation events are the greatest source of error.

APPENDIX M

APPENDIX M: Special Topic Information: Particle Size, Monitor Height, and Meteorological Data

Particle Size

Particle size is an important parameter in transport of contamination and also in dose assessment. Under the same atmospheric conditions and release characteristics, large particles will not travel as far in the atmosphere as small particles. Since the design of the fixed monitors focuses on monitoring cities not directly affected by a radiological event, the smaller particle sizes (e.g., <100 um) are most likely to be collected by the monitors. Monitoring all particle sizes is important since all of these particles will contribute to external dose after deposition on the ground.

However, not all particle sizes are important for the inhalation pathway. Typically, particles in the 10 to 15 micron (um) range are considered inhalable (able to be inhaled, but captured in the nose or in the tracheal and bronchial regions of the respiratory tract such that they don't yield a significant dose to the sensitive tissue of the lung) [CO05, SE84] and particles less than 10 microns are considered respirable (able to get into the pulmonary region of the lung).

The filters being used on the fixed stations should collect small and large particles. This assists in monitoring for contamination of all particle sizes, allowing for better estimates of potential deposition of contamination. If desired, it also allows for a more conservative estimate of inhalation effects from contamination. Untraceable data believed to be from the same type of filter indicate that the filters collect 0.3 micron and greater particles at 95% or greater efficiency. A current study of the efficiency of the filters for the fixed monitors is being conducted for various combinations of particle size and sampler velocity. If it is found that the filters are unsatisfactory for collecting small particulates (e.g., 0.3 micron), an evaluation to consider alternative filter media will be conducted.

Resuspension of deposited material is also a potential pathway, particularly after the emergency phase of an event. In this case, both fixed and deployable monitors will be sampling for airborne particulates. Resuspension cannot be easily predicted based upon particle size. Limited experimental data can show that there doesn't seem to be a significant difference in resuspension rates versus particle size [SE84]. However, air sampling provides direct measurement of airborne particulates in an area which can assist in verifying inhalation dose from resuspension and provides estimates/confirmation of resuspension factors. Since the monitors are likely to be a long distance (i.e., greater than 30 miles) from a source, resuspended particles would be expected to be of similar particle size distribution as that from the original plume, and thus it is likely that most particle sizes will be within the inhalable range.

[CO05] Cooper, Douglas W., http://www.inhalation.net/particle_size_distributions.htm, referenced 7/5/05.

[SE84] Sehmel, George A.,Deposition and Resuspension," in *Atmospheric Science and Power Production*, Darryl Randerson, (ed.), DOE/TIC-27601, U.S. Department of Energy, 1984.

Monitor Height Issue

Particularly in the mid-latitudes, air flow is characterized by large systems where air motion is determined primarily by a balance between horizontal pressure gradients and the Coriolis effect, with minimal influence from surface friction, viscosity, and thermal differences. Airflow occurring under these conditions is known as geostrophic wind. Geostrophic wind occurs above an altitude where the effect of the surface is negligible, typically around 1 km. The portion of the atmosphere bounded by the ground and the altitude where geostrophic balance occurs is termed the atmospheric boundary layer (ABL). [RA84b]

Typically, the top of the ABL is higher in daytime than at night. In daytime, when solar heating of the ground occurs, air heated near the ground will rise buoyantly as thermals or large "eddies". As the day progresses, these eddies grow larger and effectively transfer heat from the ground to the atmosphere. The height of the ABL can vary greatly depending upon the characteristics of the general air mass. "Capping" of the ABL on a sunny day is usually due to an elevated temperature inversion that limits upward, buoyant air motions. On cloudy days, the height of the ABL is more difficult to define but is usually assumed to exist at or near the base of the cloud layer [St88].

The elevation of the boundary layer is a very important phenomenon for atmospheric dispersion of radiological contamination. Contamination released into the ABL will tend to mix nearly uniformly over time and distance. The top of the ABL will act as a lid on the dispersion of material when released below the top of the ABL, and this lid will limit the spread of contamination vertically (one major example where this is not true is a nuclear detonation where material is ejected throughout the troposphere and possibly into the stratosphere). This fact becomes particularly important for transport across long distances [BR83] (such as the objectives state for the fixed monitors). Once the plume has spread vertically to the point it is affected by the lid, the vertical distribution of the concentration of the contaminant becomes more uniform [BR83]. The vertical distribution of the contamination is frequently considered constant once the plume has traveled two times the theoretical distance where the Gaussian atmospheric diffusion parameter in the vertical direction is 0.47 times the elevation of the boundary layer [TU70]. Typically, the confines of the ABL will cause the vertical distribution to become constant within the first 20 km from the source.

Cities typically act as heat islands due to the buildup of heat in cities as compared to rural areas around cities. This is particularly evident at night, when surface inversions are less frequent. In the absence of a surface inversion, the ABL is much deeper [PA73]. This implies that a plume entering a city from a rural area at night will mix readily in the vertical direction [PA73]. So in general, radiological monitors can effectively measure plumes at or near ground level within cities. However, obstructions to the mean air flow, such as very large buildings, may limit or delay the transport and mixing of the plume to ground level locations. In fact, too many obstructions, as found in a courtyard, for example, could both cause a delay in measuring the release cloud or cause the detection of the release cloud to be missed altogether. Therefore, the optimal location for a plume monitor is at an elevated position where the prevailing air flow can be measured, especially if collocated meteorological stations (wind speed and direction) are planned.

References

[BR83] Brenk, H. D., J. E. Fairobent, and E. H. Markee, "Transport of Radionuclides in the Atmosphere," in *Radiological Assessment: A Textbook on Environmental Analysis*, J. E. Till and H. R. Meyers, (eds.), NUREG/CR-3332, U.S. Nuclear Regulatory Commission, Washington, D.C., 1983.

[PA73] Pack, D. H., "Behavior of Airborne Effluents," in *Recommended Guide for the Prediction of the Dispersion of Airborne Effluents*, second edition, Frankenberg, T. T., *et al*., (eds.), The American Society of Mechanical Engineers, New York, NY, 1973.

[RA84b] Randerson, Darryl, “Atmospheric Boundary Layer,” in *Atmospheric Science and Power Production*, Darryl Randerson, (ed.), DOE/TIC-27601, U.S. Department of Energy, 1984

[St88] Stull, R. B., “Introduction to Boundary Layer Meteorology,” ISBN 90-277-2769-6, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1988.

[TU70] Turner, D. Bruce, “Workbook of Atmospheric Dispersion Estimates,” Office of Air Programs Publication No. AP-26, U.S. Environmental Protection Agency, 1970.

Use of Meteorological Stations on RadNet Monitors

Meteorological stations (wind speed and direction) are options for both the fixed and deployable stations. Meteorological stations have been ordered for all of the deployable units and half of the first purchase option of the fixed units.

Instrument siting plays an absolutely critical role in determining whether resultant meteorological data will be useful. Urban meteorological stations may provide misleading wind information. For example, one building can cause significant, complex changes in air flow patterns, with the formation of separation zones, stagnation zones, turbulent wakes, and vortices [LL01]. Combinations of buildings cause even more altered flow patterns. Cities with streets bordered by large buildings can have "street canyons" where the wind travels through large parts of the city in the same direction, while in other areas of the city, winds may speed up, slow down, and possibly even reverse direction [NO01]. The wind speed downwind of a building can be anywhere from one-half to twice the upwind speed [NR76].

On the other hand, a well-sited meteorological station in an area essentially free of flow obstructions can provide very reliable data, especially if the nearest standard National Weather Service station is many miles away. Typically, a well-sited station will be located at an elevation above most, if not all, flow obstructions where the prevailing wind flow can be monitored. The decision whether to install meteorological instrumentation at a radiological monitoring site will depend upon siting factors as well as other critical items such as site security, availability of power and communication infrastructure, and ease of access. Like most sensitive equipment, meteorological instrumentation requires proper maintenance to ensure that accurate readings are collected.

Meteorological data for the deployable monitors may be of greater value to modelers. Since the deployable monitors may not be located in large urban areas, the wind characteristics measured by the monitor may be more representative of the overall wind flow in that region. Information concerning the exact location of each monitor relative to buildings, terrain level changes, other obstacles, along with a description of the surface terrain (for surface roughness determination) will need to be relayed to meteorologists so they can determine the value of the data prior to use [SR05].

References

[LL01] Lawrence Livermore National Laboratory Website, http://www.llnl.gov/str/October01/Lee.html

[NO01] National Oceanographic and Atmospheric Administration, http://response.restoration.noaa.gov/cameo/dr_aloha/terrain/terrain.html

[NR76] National Research Council Canada, http://irc.nrc-cnrc.gc.ca/cbd/cbd174e.html

[RA84] Hosker, R. P., Jr., "Flow and Diffusion Near Obstacles," in *Atmospheric Science and Power Production*, Darryl Randerson, (ed.), DOE/TIC-27601, U.S. Department of Energy, 1984.

[SR05] Personal discussions with meteorologists from Savannah River National Laboratory, June 20, 2005.