Chapter 4

Monitoring Accidental Radiation Releases

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Each test is conducted under conditions in which remedial actions could be effective should an accidental release of radioactive material occur.

INTRODUCTION

Although nuclear tests are designed to minimize the chance that radioactive material could be released to the atmosphere, it is assumed as a precaution for each test that an accident may occur. To reduce the impact of a possible accident, tests are conducted only under circumstances whereby remedial actions could be taken if necessary. If it is estimated that the projected radioactive fallout from a release would reach an area where remedial actions are not feasible, the test will be postponed.

Responsibility for radiation safety measures for the nuclear testing program is divided between the Department of Energy (DOE) and the Environmental Protection Agency (EPA). The Department of Energy oversees monitoring within the boundaries of the Nevada Test Site (NTS). The Environmental Protection Agency monitors the population around the test site and evaluates the contribution of nuclear testing to human radiation exposure through air, water, and food.

WHAT IS RADIATION?

The nuclei of certain elements disintegrate spontaneously. They may emit particles, or electromagnetic waves (gamma rays or x-rays), or both. These emissions constitute radiation. The isotopes are called radionuclides. They are said to be radioactive, and their property of emitting radiation is called radioactive decay. The rate of decay is characteristic of each particular radionuclide and provides a measure of its radioactivity.

The common unit of radioactivity was the curie (Ci), defined as 3.7×10^{10} decays per second, which is the radioactivity of one gram of radium. Recently, a new unit, the becquerel (Bq), has been adopted, defined as one decay per second. Exposure of biological tissue to radiation is measured in terms of reins (standing for roentgen equivalent man). A roentgen (R) is a unit of exposure equivalent to the quantity of radiation required to produce one coulomb of electrical charge in one kilogram of dry air. A rem is the dose in tissue resulting from the absorption of a rad of radiation multiplied by a "quality factor" that depends on the type of radiation. A rad is defined as 100 ergs (a small unit of energy) per gram of exposed tissue. Recently accepted international units of radiation are now the gray (Gy), equal to 100 rads, and the sievert (Sv), equal to 100 reins.

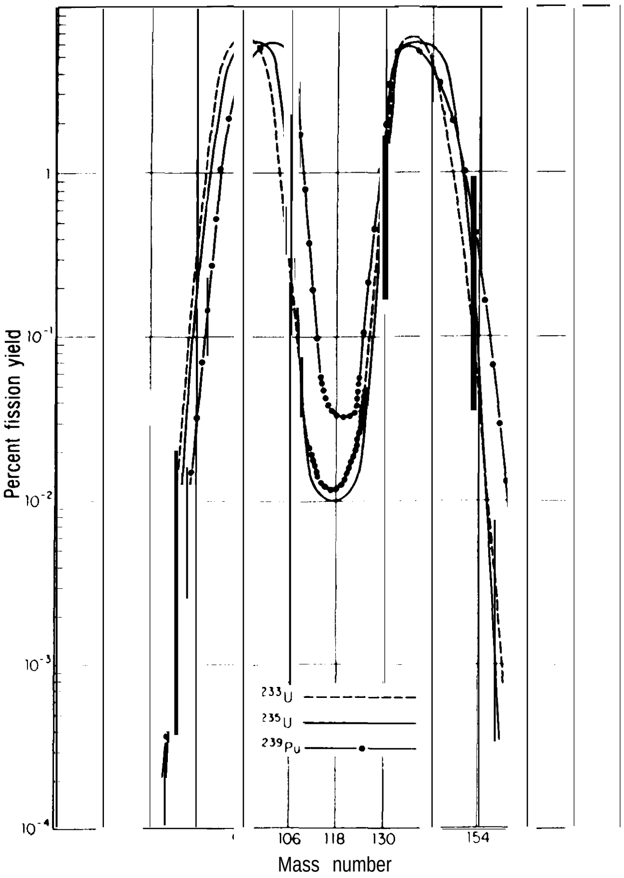
PRODUCTS OF A NUCLEAR EXPLOSION

A nuclear explosion creates two sources of radioactivity: the first source is the direct products of the nuclear reaction, and the second is the radioactivity induced in the surrounding material by the explosion-generated neutrons. In a fission reaction, the splitting of a nucleus creates two or more new nuclei that are often intensely radioactive. The products occur predominantly in two major groups of elements as shown in figure 4-1. The neutrons produced by the reaction also react with external materials such as the device canister, surrounding rock, etc., making those materials radioactive as well. In addition to these generated radioactivities, unburned nuclear fission fuel (especially plutonium) is also a radioactive containment. The helium nuclei formed by fusion reactions are not radioactive. ' However, neutrons produced in the fusion reaction still will make outside material radioactive. Depending on the design of the explosive device and its percentage of fission and fusion, a wide range of radioactive material can be released with half lives of less than a second to more than a billion years.[2] The debris from nuclear detonations contain a large number of radioactive isotopes, which emit predominantly gamma and beta radiation. Some of the more common radionuclides involved in a nuclear explosion are listed in table 4-1.

[1] This, incidentally, is why commercial fusion reactors (if they could be created) would be a relatively clean source of energy.

[2] The half-life is the time required for half of the atoms of a radioactive substance to undergo a nuclear transformation to a more stable element.

Figure 4-1-The Typical Bimodal Curve for Fission-Product Yield



Products of a nuclear explosion occur predominantly in two major groups of nuclides.

SOURCE: Modified from Lapp and Andrews, Prentice-Hall, Inc1972.

An individual radioactive species follows the half-life rule of decay—that is, half of the nuclei disintegrate in a characteristic time. called a "half-life. " However, a mixture of fission products has a more complicated decay pattern. The general rule of thumb for a nuclear explosion is that the total activity decreases by a factor of 10 for every sevenfold increase in time. In other words, if the gamma radiation 1 hour after an explosion has an intensity of 100 units, then 7 hours later it will have an intensity of 10. Consequently. the time after the explosion has a dramatic effect on the amount of radioactivity. A 1 kiloton explosion in the atmosphere will produce 41 billion curies 1 minute after determination, but this will decrease to 10 million curies in just 12 hours.

Table 4-1--Common Radionuclides Involved in a Nuclear Explosion

Radionuclide	Half-Life
Uranium-238	4,500,000,000 years
Plutonium-239	24,300 years
Carbon-14	5,800 years
Radium-226	1,620 years
Cesium-137	30 years
Strontium-90	28 years
Tritium	12.3 years
Krypton-85	10.9 years
iodine-131	8 days
Xenon-133	5.2 days
iodine-132	2.4 hours

The type of release is also important in predicting what radionuclides will be present. For example, atmospheric tests release all radionuclides created. Prompt, massive ventings have released a nonnegligible fraction of the radionuclides created. Late-time, minor seeps, like those since 1970, release only the most volatile radionuclides. In an underground explosion, radionuclides also separate (called fractionation") according to their chemical or physical characteristics. Refractory particles (particles that do not vaporize during the nuclear explosion) settle out fast underground, while more volatile elements that vaporize easily condense later. This has a strong effect on radioactive gases that seep slowly through the soil from an underground explosion. In an underground explosion, nearly all the reactive materials are filtered out through the soil column. and the only elements that come up through the soil to the atmosphere are the noble gases, primarily krypton and xenon.

CRITERIA FOR CONDUCTING A TEST

Although every attempt is made to prevent the accidental release of radioactive material to the atmosphere, several safety programs are carried out for each test. These programs are designed to minimize the likelihood and extent of radiation exposure offsite and to reduce risks to people should an accidental release of radioactive material occur. The Environmental Protection Agency monitors the population around the test site and has established plans to protect people should an accident occur. EPA's preparations are aimed toward reducing the whole-body exposure of the off-site populace and to minimizing thyroid dose to offsite residents, particularly from the ingestion of contaminated milk.[3] The whole-body dose is the main concern. However, deposition of radioactive material on pastures can lead to concentration in milk obtained from cows that graze on those pastures. The infant thyroid doses from drinking milk from family cows is also assessed.[4]

The Department of Energy's criteria for conducting a test are:

> For tests at the Nevada Test Site, when considering the event-day weather conditions and the specific event characteristics, calculations should be made using the most appropriate hypothetical release models which estimate the off-site exposures that could result from the most probable release scenario. Should such estimates indicate that off-site populations, in areas where remedial actions to reduce whole-body exposures are not feasible, could receive average whole-body dose in excess of 0.17 R/year (170 mR/year), the event shall be postponed until more favorable conditions prevail. In addition, events may proceed only where remedial actions against uptake of radionuclides in the food chain are practicable and/or indications are that average thyroid doses to the population will not exceed 0.5 R/year (500 mR/year).[5]

These criteria mean that a test can only take place if the estimate of the fallout from an accidental release of radioactivity would not be greater than 0.17 R/year in areas that are uncontrollable, i.e., where "remedial actions to reduce whole-body exposures are not feasible." Thus, tests are not conducted when the wind is blowing in the general direction of populated areas considered to be uncontrollable, except under persistent light wind conditions that would limit the significant fallout to the immediate vicinity of the NTS. Areas considered to be uncontrollable by EPA are shown in figure 4-2.

The EPA and DOE have also defined a *controllable area* (figure 4-2), within which remedial actions are considered feasible. Criteria for the controllable area, as defined by the DOE are:

> . . . those areas where trained rad-safe monitors are available, where communications are effective (where the exposure of each individual can be documented), where people can be expected to comply with recommended remedial actions, and where remedial actions against uptake of radionuclides in the food chain are practicable.

The controllable area is the zone within approximately 125 miles of the test control point (see figure 4-2) for which EPA judges that its remedial actions would be effective. Within this area, EPA has the capability to track any release and perform remedial actions to reduce exposure, including sheltering or evacuation of all personnel (as needed); controlling access to the area; controlling livestock feeding practices, i.e., providing feed rather than allowing grazing; replacing milk; and controlling food and water.

In the case of the controllable area, a test may be conducted if the fallout estimate implies that individuals in the area would not receive whole-body doses in excess of 0.5 R/year and thyroid doses of 1.5 R/year. If winds measured by the weather service indicate that the cloud of radioactive debris produced by the assumed venting would drift over controllable areas, such as to the north, the test is permitted when EPA's mobile monitors are in the downwind areas at populated places. EPA must be ready to measure exposure and to assist in moving people under cover or evacuating them, if necessary, to keep their exposures below allowable levels.

As a consequence of the geometry of the controllable area, tests are generally not conducted if winds aloft blow toward Las Vegas or towards other nearby populated locations. In addition, the test will not be conducted if there is less than 3 hours of daylight remaining to track the cloud.

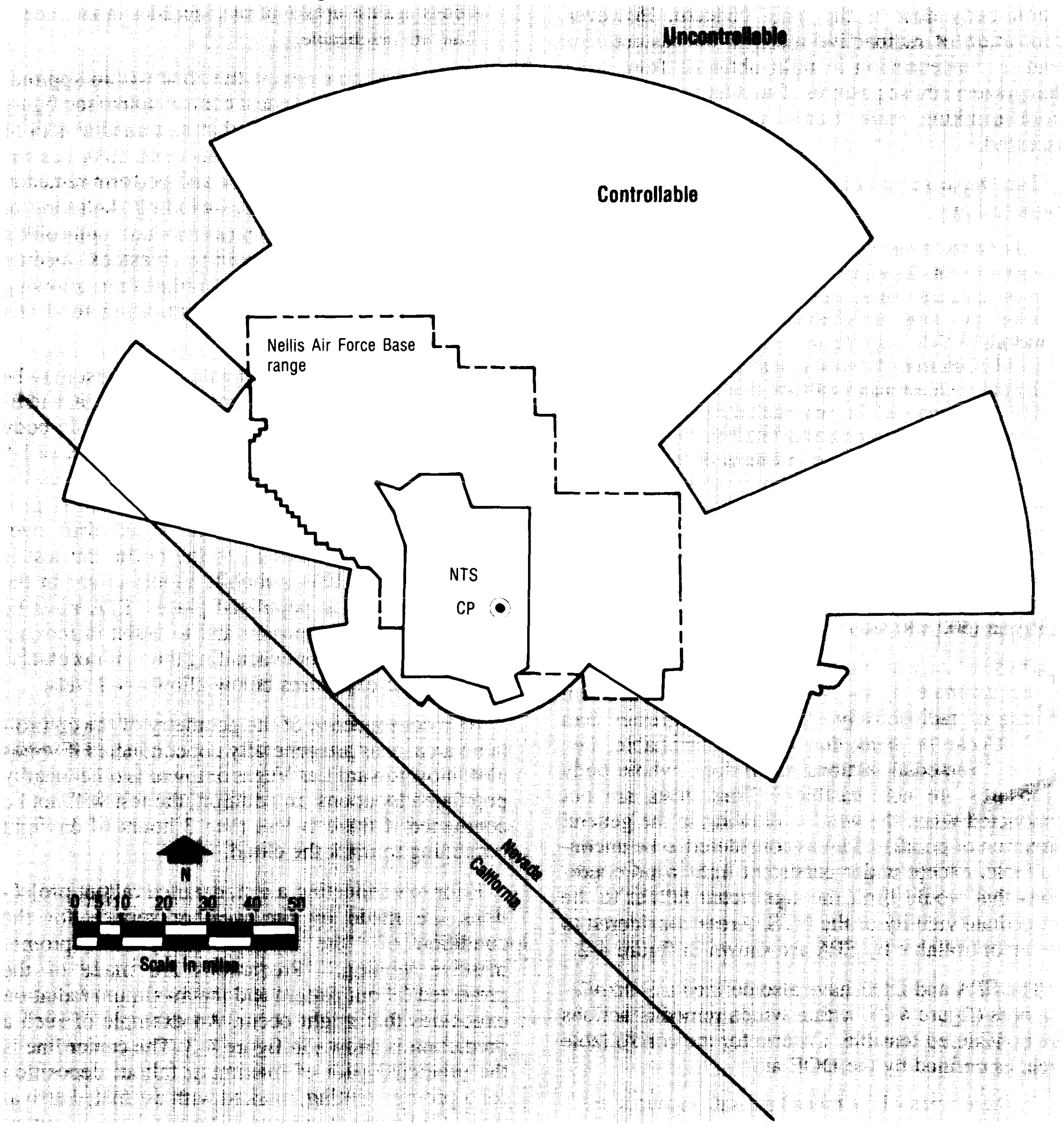
Prior to conducting a test, detailed fallout projections are made by the weather service for the condition of "the unlikely event of a prompt massive venting." Predictions are made of the projected fallout pattern and the maximum radiation exposures that might occur. An example of such a prediction is shown in figure 4-3. The center line is the predicted path of maximum fallout deposition for a prompt venting, marked with estimated arrival times (in hours) at various distances. Lines to either side indicate the width of the fallout area. The two dashed lines indicate the 500 mR/year area and the

[3] See "Offsite Remedial Action Capability for Underground Nuclear Weapons Test Accidents," U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory--La.. Vegas, NV, October 1988.

[4] In the case of an accident, however, the actual dose would be minimized because the milk would be replaced as much as possible.

[5] See "Offsite Remedial Action Capability for Underground Nuclear Weapons Test Accidents," U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory-Las Vegas, NV, October 1988.

Figure 4-2--Controllable and Uncontrollable Areas

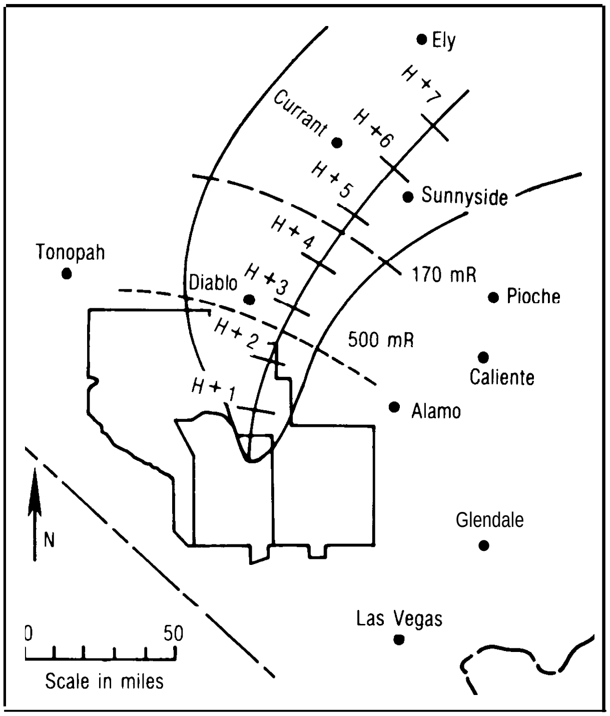


The controllable area is the region within which remedial actions are considered feasible.

SOURCE. Modified from Environmental Protection Agency

170 mR/year level. If 0.17 mR/year (the maximum external exposure allowed during a 12-month period for an uncontrolled population) or more is predicted to fall outside the controllable area, the test will be postponed. Within the predictions shown in figure 4-3, the test could be conducted if EPA monitors were prepared to be at each of the ranches, mines. and other populated areas within the dispersion

Figure 4-3-Projected Fallout Dispersion Pattern



Key: H+ number= time of detonation plus elapsed hours; mR= milliREM

Predicted fallout pattern for the case of an accidental venting.

SOURCE: Modified from. "Public Safety for Nuclear Weapons Tests," U.S. Environmental Protection Agency, January 1984.

pattern to measure exposure and perform remedial actions should they be necessary.

The preferred weather conditions for a test are a clear sky for tracking, southerly winds (winds from the south), no thunderstorms or precipitation that would inhibit evacuation, and stable weather patterns. During the test preparations, the Weather Service Nuclear Support Office provides the Test Controller with predicted weather conditions. This information is used by the Weather Service to derive the estimated fallout pattern should an accidental release occur. About one-third of all nuclear tests are delayed for weather considerations; the maximum delay in recent years reached 16 days.

PREDICTING FALLOUT PATTERNS

The predicted fallout pattern from an underground test depends on many variables related to the type of nuclear device, the device's material composition. type of venting, weather conditions, etc. With so many variables and so little experience with actual ventings, fallout predictions can only be considered approximations. The accuracy of this approximation, however, is critical to the decision of whether a test can be safely conducted. Fallout predictions are made by the Weather Service Nuclear Support Office using up-to-date detailed weather forecasts combined with a model for a "prompt massive venting. " The model uses scaling technique based on the actual venting of an underground test that occurred on March 13, 1964. The test, named "Pike,' was a low-yield (less than 20 kilotons) explosion detonated in a vertical shaft. A massive venting occurred 10 to 15 seconds after detonation.[6] The venting continued for 69 seconds, at which time the overburden rock collapsed forming a surface subsidence crater and blocking further venting. The vented radioactive debris, consisting of gaseous and particulate material, rose rapidly to about 3,000 feet above the surface.

The Pike scaling model has been used to calculate estimates of fallout patterns for the past 20 years because: 1) the large amount of data collected from the Pike venting allowed the development of a scaling model, and 2) Pike is considered to be the worst venting in terms of potential exposure to the public.[7]

The Pike model, however, is based on a very small release of radioactive material compared to what would be expected from an aboveground test of the same size.[8] The percentage of radioactive material released from the Baneberry venting (7 percent from table 3-l), for example, is many times greater than the percentage of material released from the Pike test.[9] It would therefore appear that Baneberry provides a more conservative model than Pike. This. however, is not the case because Baneberry was not

6Pike was conducted in alluvium in Area 3 of the test site. The release was attributed to a fracture that propagated to the surface. Other factors contributing to the release were an inadequate depth of burial and an inadequate closure of the line-of-sight pipe.

7. 1985 Analyses and Evaluations of the Radiological and Meteorological Data from the Pike Event, ' National Oceanic and Atmospheric Administration, Weather Service Nuclear Support Office, Las Vegas, NV, December, 1986, NVO-308.

8The exact amount of material released from [he 1964 Pike test remains classified.

9See table 3-1 for a comparison of various releases.

a *prompt* venting. Baneberry vented through a fissure and decaying radioactive material was pumped out over many hours. Baneberry released more curies than Pike; however, due to its slower release, a higher percentage of the Baneberry material was in the form of noble gases, which are not deposited. The data suggest that much less than 7 percent of the released material was deposited.[10] Therefore, it is thought that Pike is actually a more conservative model than Baneberry.

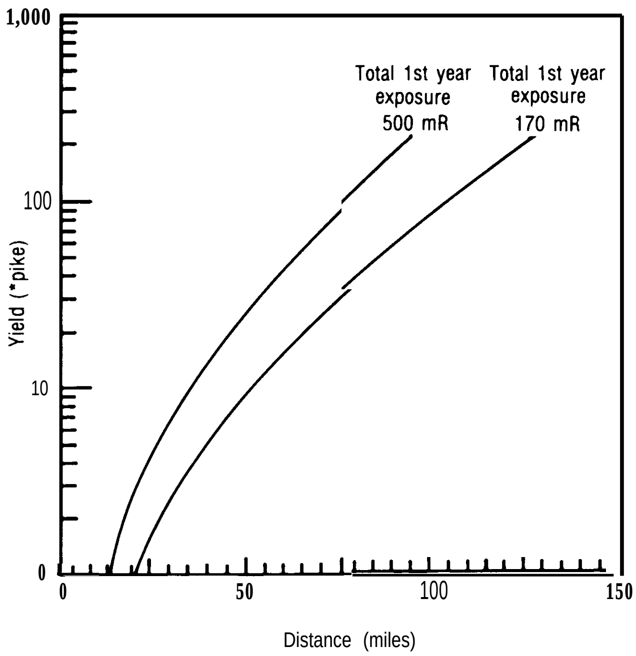
The sensitivity of the Pike model can be judged by looking at the degree to which its predictions are affected by the amount of material released. For example, consider a test in which 10 percent of the radioactive material produced by the explosion is accidentally released into the atmosphere; in other words, 10 percent of the material that would have been released if the explosion had been detonated aboveground. This also roughly corresponds to the amount of material that would be released if the explosion had been detonated underground at the bottom of an open (unstemmed) hole. The 10 percent release can therefore be used as a rough approximation for the worst case release from an underground test. To evaluate the adequacy of the Pike model predictions to withstand the full range of uncertainty of an accidental release, the question is: what effect would a release of 10 percent rather than, say 1 percent, have on the location of 170-mR and 500-mR exposure lines? As figure 4-4 illustrates, changing the yield of an explosion by an order of magnitude (in other words, increasing the release from say 1 percent to 10 percent) increases the distance of the 170-mR and 500-mR lines by roughly a factor of 2. Therefore, assuming a worst case scenario of a 10 percent prompt massive venting (as opposed to the more probable scenario of around a 1 percent prompt massive venting), the distance of the exposure levels along the predicted fallout lines would only increase by a multiple of 2. The Pike model therefore provides a prediction that is *at least* within a factor of about 2 of almost any possible worst-case scenario.

ACCIDENT NOTIFICATION

Any release of radioactive material is publicly announced if the release occurs during, or immediately following, a test. If a late-time seep occurs, the release will be announced if it is predicted that the radioactive material will be detected outside the boundaries of the test site. **If no detection off-site is predicted, the release may not be announced.** Operational releases that are considered routine (such as small releases from drill-back operations) are similarly announced *only* if it is estimated that they will be detected off-site.

The Environmental Protection Agency is present at every test and is therefore immediately aware of any prompt release. The Environmental Protection Agency, however, is not present at post-test drill-back operations. In the case of late-time releases or operational releases, the Environmental Protection Agency depends on notification from the Department of Energy and on detection of the release (once

Figure 4-4--Yield v. Distance



Constant Pike Parameters
Wind speed = 15mph
Vertical wind shear = 20°
Cloud rise = 5,000 ft

Variable
Yield x Pike

Yield (in kilotons) v. distance (in miles) for projected fallout using the Pike Model. TYE indicates total first year exposure. increasing the yield by a factor of 10 roughly doubles the downwind distance of the projected fallout pattern.

SOURCE: Provided by National Oceanic and Atmospheric Administration, National Weather Service Nuclear Support Office, 1888.

[10] Baneberry, however, had a limited data set of usable radioactive readings.

it has reached outside the borders of the test site) by the EPA offsite monitoring system.

Estimates of whether a particular release will be detected offsite are made by the Department of Energy or the sponsoring laboratory. Such judgments, however, are not always correct. During the drill-back operations of the Glencoe test in 1986, minor levels of radioactive material were detected offsite contrary to expectations. During the Riola test in 1980, minor amounts of radioactive inert gases were detected offsite. In both cases, DOE personnel did not anticipate the release to be detected offsite and therefore did not notify EPA.[11] Although the releases were extremely minor and well-monitored within the test site by DOE, EPA was not aware of the release until the material had crossed the test site boundaries. Both cases fueled concern over DOE's willingness to announce accidents at the test site. **The failure** of **DOE to publicly announce all releases, regardless of size or circumstance, contributes** to public **concerns over the secrecy of the testing program and reinforces the perceptions that all the dangers of the testing program are not being openly disclosed.**

Onsite Monitoring by the Department of Energy

The Department of Energy has responsibility for monitoring within the boundaries of the Nevada Test Site to evaluate the containment of radioactivity onsite and to assess doses-to-man from radioactive releases as a result of DOE operations. To achieve these objectives, DOE uses a comprehensive monitoring system that includes both real-time monitoring equipment and sample recovery equipment. The real-time monitoring system is used for prompt detection following a test, the sample recovery equipment is used to assess long-term dose and risk.

The heart of the real-time monitoring system is a network of Remote Area Monitors (RAMs). For all tests, RAMs are arranged in an array around the test hole (figure 4-5). Radiation detectors are also frequently installed down the stemming column so the flow of radioactive material up the emplacement hole can be monitored. In tunnel shots, there are RAMs above the shot point, throughout the tunnel complex, outside the tunnel entrance, and in each containment vessel (figure 4-6). In addition to RAMs positioned for each shot, a permanent RAM network with stations throughout the test site is in continual operation.

During each test, a helicopter with closed-circuit television circles the ground zero location. Nearby. a second helicopter and an airplane are prepared to track any release that might occur. A third helicopter and an airplane remain on stand-by should they be needed. In addition, a team (called the ''Bluebird Team' '), consisting of trained personnel in 2 four-wheel drive vehicles outfitted with detection equipment and personnel protection gear is stationed near the projected fallout area to track and monitor any release. Approximately 50 radiation monitoring personnel are available on the Nevada Test Site to make measurements of exposure rates and collect samples for laboratory analysis should they be needed. Prior to the test, portions of the test site are evacuated unless the operation requires manned stations. If manned stations are required. direct communication links are established with the workers and evacuation routes are set-up.

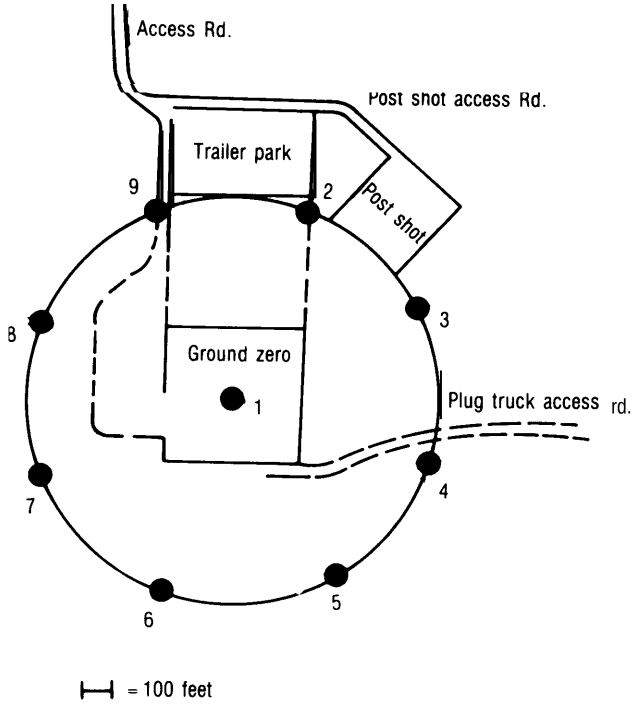
In addition to the real-time monitoring network, air and water samples are collected throughout the Test Site and analyzed at regular intervals. This comprehensive environmental monitoring program is summarized in table 4-2. The network of samplers located throughout the Test Site includes 160 thermoluminescent dosimeters; over 40 air samplers that collect samples for analysis of radioiodines. gross beta, and plutonium-239: and about half a dozen noble gas samplers. Each year over 4.500 samples are collected and analyzed for radiological measurement and characterization of the Nevada Test Site, All sample collection, preparation, analysis, and review are performed by the staff of the Laboratory Operations Section of REECO's Environmental Sciences Department.

In the case of a prompt, massive accidental release of radioactive material, the following emergency procedures would be initiated:

1. any remaining test site employees downwind of the release would be evacuated,
2. monitoring teams and radiological experts would be dispatched to offsite downwind areas,

[11] In the case of Riola, the release occurred in the evening and was not reported until the following morning, As a result, it was $12^1/2$ hours before EPA was notified.

Figure 4-5--Typical RAMs Array for Vertical Drill-Hole Shot



In addition to the RAMs located down the drill hole, nine RAMs are placed at the surface around the test hole.

SOURCE: Modified from Department of Energy

3. ground and airborne monitoring teams would measure radioactive fallout and track the radioactive cloud,
4. Federal, State, and local authorities would be notified, and
5. if necessary, persons off-site would be requested to remain indoors or to evacuate the area for a short time.[12]

Offsite Monitoring by the Environmental Protection Agency

Under an interagency agreement with the Department of Energy, the Environmental Protection Agency is responsible for evaluating human radiation exposure from ingesting air, water, and food that may have been affected by nuclear testing. To accomplish this, EPA collects over 8,700 samples each year and performs over 15,000 analytical measurements on water, milk, air, soil, humans, plants, and animals.[13] The sampling system and results are published annually in EPA's "Offsite Environmental Monitoring Report, Radiation Monitoring Around United States Nuclear Test Areas."

The heart of the EPA monitoring system is the network of 18 community monitoring stations. The community monitoring program began in 1981 and was modeled after a similar program instituted in the area surrounding the Three Mile Island nuclear reactor power plant in Pennsylvania. Community participation allows residents to verify independently the information being released by the government and thereby provide reassurance to the community at large. The program is run in partnership with several institutions. The Department of Energy funds the program and provides the equipment. The Environmental Protection Agency maintains the equipment, analyzes collected samples, and interprets results. The Desert Research Institute manages the network, employs local station managers, and independently provides quality assurance and data interpretation. The University of Utah trains the station managers selected by the various communities. Whenever possible, residents with some scientific training (such as science teachers) are chosen as station managers.

There are 18 community monitoring stations (shown as squares in figure 4-7) located around the test site. The equipment available to each station includes:[14]

Noble Gas Samplers: These samplers compress air in a tank. The air sample is then analyzed to measure the concentration of such radioactive noble gases as xenon and krypton.

Tritium Sampler: These samplers remove moisture from the air. The moisture is then analyzed to measure the concentration of tritium in the air.

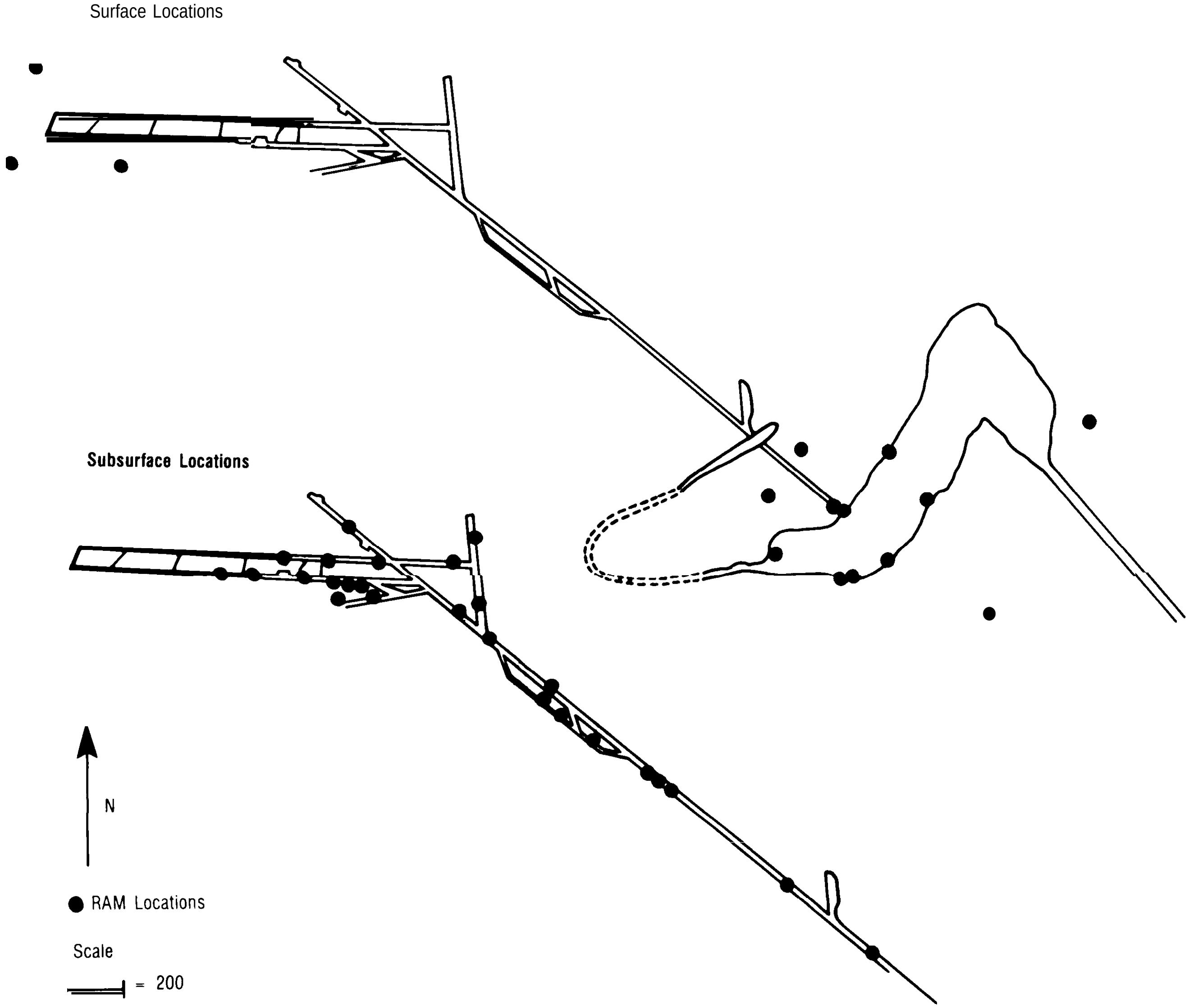
Particulate and Reactive Gases Sampler: These samplers draw 2 cubic feet of air per minute through a paper filter and then through a canister of activated charcoal. The paper filter collects particles and the charcoal collects reactive gases. Both are analyzed for radioactivity.

[12] Modified from "Onsite Environmental Report for the Nevada Test Site" (January 1987 through December 1987), Daniel A. Gonzalez, REECo., Inc., DOE/NV/10327-39.

[13] In addition, EPA annually visits each location outside the Nevada Test Site where a nuclear test has occurred.

[14] "Community Radiation Monitoring Program," U.S. Environmental Protection Agency, January 1984.

Figure 4-6--Typical RAMs Array for Tunnel Shot ("Mission Cyber," Dec. 2, 1988)



A total of 41 RAMs (15 above the surface, 26 belowground) are used to monitor the containment of radioactive material from a horizontal tunnel test.

SOURCE: Modified from Department of Energy.

Thermoluminescent Dosimeter (TLD): When heated (thermo-), the TLD releases absorbed energy in the form of light (-luminescent). The intensity of the light is proportional to the gamma radiation absorbed, allowing calculation of the total gamma radiation exposure.

Gamma Radiation Exposure Rate Recorder: A pressurized ion chamber detector for gamma radiation is connected to a recorder so that a continuous record of gamma radiation is obtained and changes in the normal gamma radiation level are easily seen.

Microbarograph: This instrument measures and records barometric pressure. The data are useful in interpreting gamma radiation exposure rate records. At lower atmospheric pressure, naturally occurring radioactive gases (like radon) are released in greater amounts from the Earth's surface and their radioactive decay contributes to total radiation exposure.

Table 4-2-Summary of Onsite Environmental Monitoring Program

Sample type	Description	Collection frequency	Number of locations	Analysis
Air	Continuous sampling through gas filter & charcoal cartridge	Weekly	44	Gamma Spectroscopy gross beta, Pu-239
	Low-volume sampling through silica gel	Biweekly	16	Tritium (HTO)
	Continuous low volume	Weekly	7	Noble gases
Potable water	1-liter grab sample	Weekly	7	Gamma Spectroscopy gross beta, tritium Pu-239 (quarterly)
Supply wells	l-liter grab sample	Monthly	16	Gamma Spectroscopy gross beta, tritium Pu-239 (quarterly)
Open reservoirs	l-liter grab sample	Monthly	17*	Gamma Spectroscopy gross beta, tritium Pu-239 (quarterly)
Natural springs	l-liter grab sample	Monthly	9*	Gamma Spectroscopy gross beta, tritium Pu-239 (quarterly)
Ponds (contaminated)	l-liter grab sample	Monthly	8*	Gamma Spectroscopy gross beta,tritium Pu-239 (quarterly)
Ponds (effluent)	l-liter grab sample	Monthly	5	Gamma Spectroscopy gross beta, tritium Pu-239 (quarterly)
External gamma radiation levels	Thermoluminescent Dosimeters	Semi-annually	1s3	Total integrated exposure over field cycle

*Not all of these locations were sampled due to inaccessibility or lack of water.

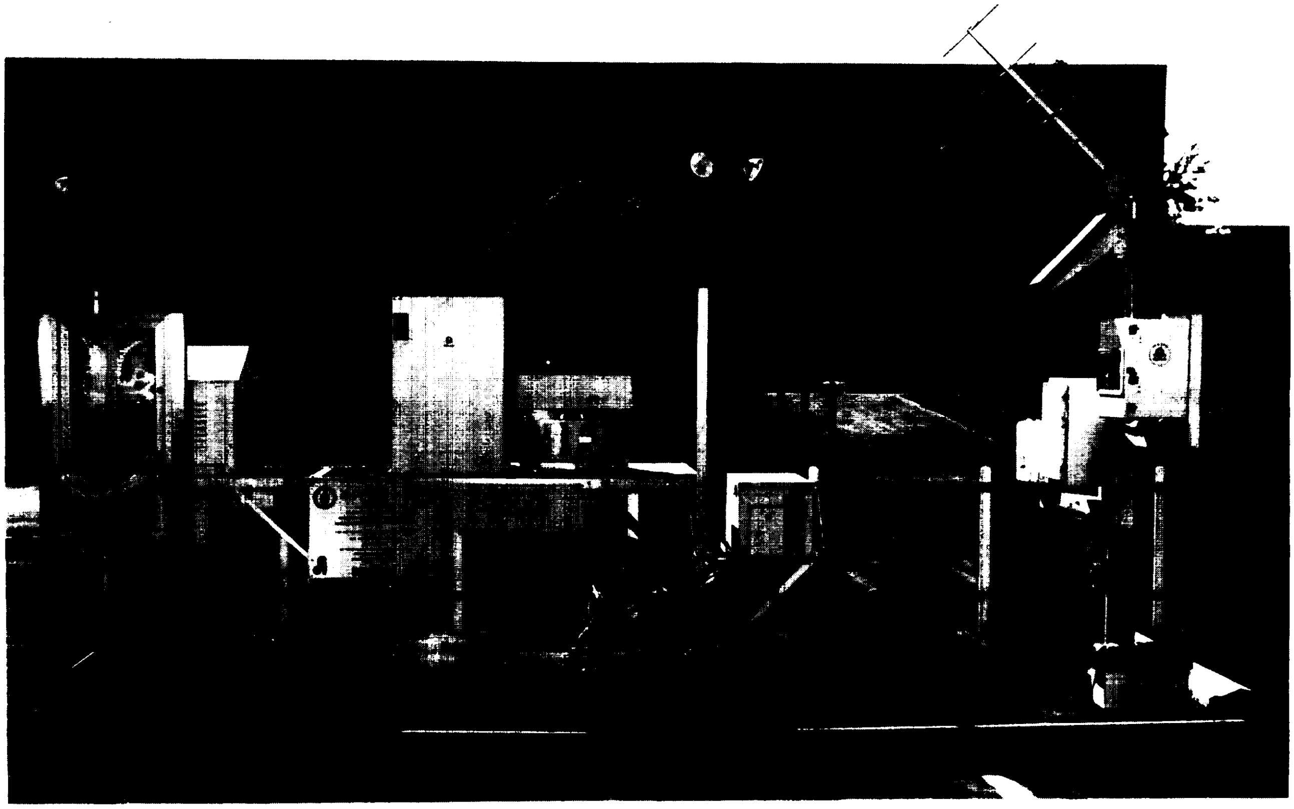
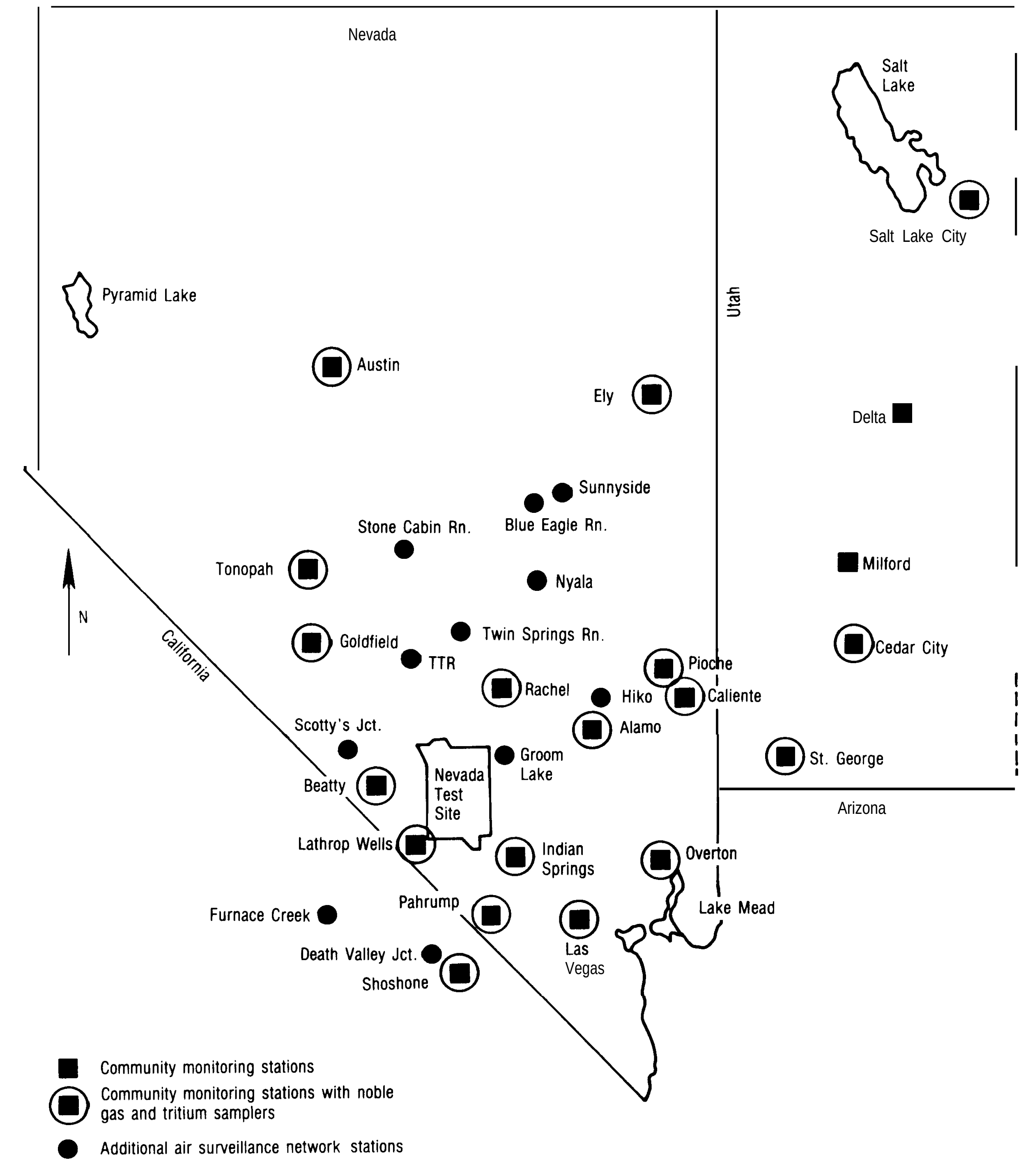


Photo credit: David Graham, 1988

Community Monitoring Station, Las Vegas, NV.

Figure 4-7-Air Monitoring Stations



SOURCE: Modified from Environmental Protection Agency.

The monitoring stations are extremely sensitive; they can detect changes in radiation exposure due to changing weather conditions. For example, during periods of low atmospheric pressure, gamma exposure rates are elevated on the order of 2 to 4 uR/hr because of the natural radioactive products being drawn out of the ground. To inform the public, data from the community monitoring stations are posted at each station and sent to local newspapers (figure 4-8).

In addition to the 18 community monitoring stations, 13 other locations are used for the Air Surveillance Network (shown as circles in figure 4-7) to monitor particulate and reactive gases. The air surveillance network is designed to cover the area within 350 kilometers of the Nevada Test Site, with a concentration of stations in the prevailing downwind direction. The air samplers draw air through glass fiber filters to collect airborne particles (dust). Charcoal filters are placed behind the glass fiber filters to collect reactive gases. These air samplers are operated continuously and samples are collected three times a week. The Air Surveillance Network is supplemented by 86 standby air sampling stations located in every State west of the Mississippi River (figure *4-9)*. These stations are ready for use as needed and are operated by local individuals or agencies. Standby stations are used 1 to 2 weeks each quarter to maintain operational capability and detect long-term trends.

Noble gas and tritium samplers are present at 17 of the air monitoring stations (marked with asterisk in figure 4-7). The samplers are located at stations close to the test site and in areas of relatively low altitude where wind drains from the test site. Noble gases, like krypton and xenon, are nonreactive and are sampled by compressing air in pressure tanks. Tritium, which is the radioactive form of hydrogen, is reactive but occurs in the form of water vapor in air. It is sampled by trapping atmospheric moisture. The noble gas and tritium samplers are in continuous operation and samples are recovered and analyzed weekly.

To monitor total radiation doses, a network of approximately 130 TLDs is operated by EPA. The network encircles the test site out to a distance of about 400 miles with somewhat of a concentration in the zones of predicted fallout (figure 4-10). The TLD network is designed to measure environmental radiation exposures at a location rather than exposures to a specific individual. By measuring exposures at fixed locations, it is possible to determine the maximum exposure an individual would have received had he or she been continually present at that location. In addition, about 50 people living near the test site and all personnel who work on the test site wear TLD's. All TLD's are checked every 3 months for absorbed radiation.

Radioactive material is deposited from the air onto pastures. Grazing cows concentrate certain radionuclides, such as iodine-131, strontium-90. and cesium-137 in their milk. The milk therefore becomes a convenient and sensitive indicator of the fallout. The Environmental Protection Agency analyzes samples of raw milk each month from about 25 farms (both family farms and commercial dairies) surrounding the test site (figure 4-11). In addition to monthly samples, a standby milk surveillance network of 120 Grade A milk producers in all States west of the Mississippi River can provide samples in case of an accident (figure 4-12). Samples from the standby network are collected annually.

Another potential exposure route of humans to radionuclides is through meat of local animals. Samples of muscle, lung, liver, kidney, blood. and bone are collected periodically from cattle purchased from commercial herds that graze northeast of the test site. In addition, samples of sheep, deer, horses, and other animals killed by hunters or accidents are used (figure 4-1 3). Soft tissues are analyzed for gamma-emitters. Bone and liver are analyzed for strontium and plutonium; and blood/urine or soft tissue is analyzed for tritium.

A human surveillance program is also carried out to measure the levels of radioactive nuclides in families residing in communities and ranches around the test site (figure 4-14). About 40 families living near the test site are analyzed twice a year. A whole-body count of each person is made to assess the presence of gamma-emitting radionuclides.

GROUNDWATER

About 100 underground nuclear tests have been conducted directly in the groundwater. In addition, many pathways exist for radioactive material from other underground tests (tests either above or below the water table) to migrate from the test cavities to the groundwater. To detect the migration of radioactivity from nuclear testing to potable water sources, a long-term hydrological monitoring program is

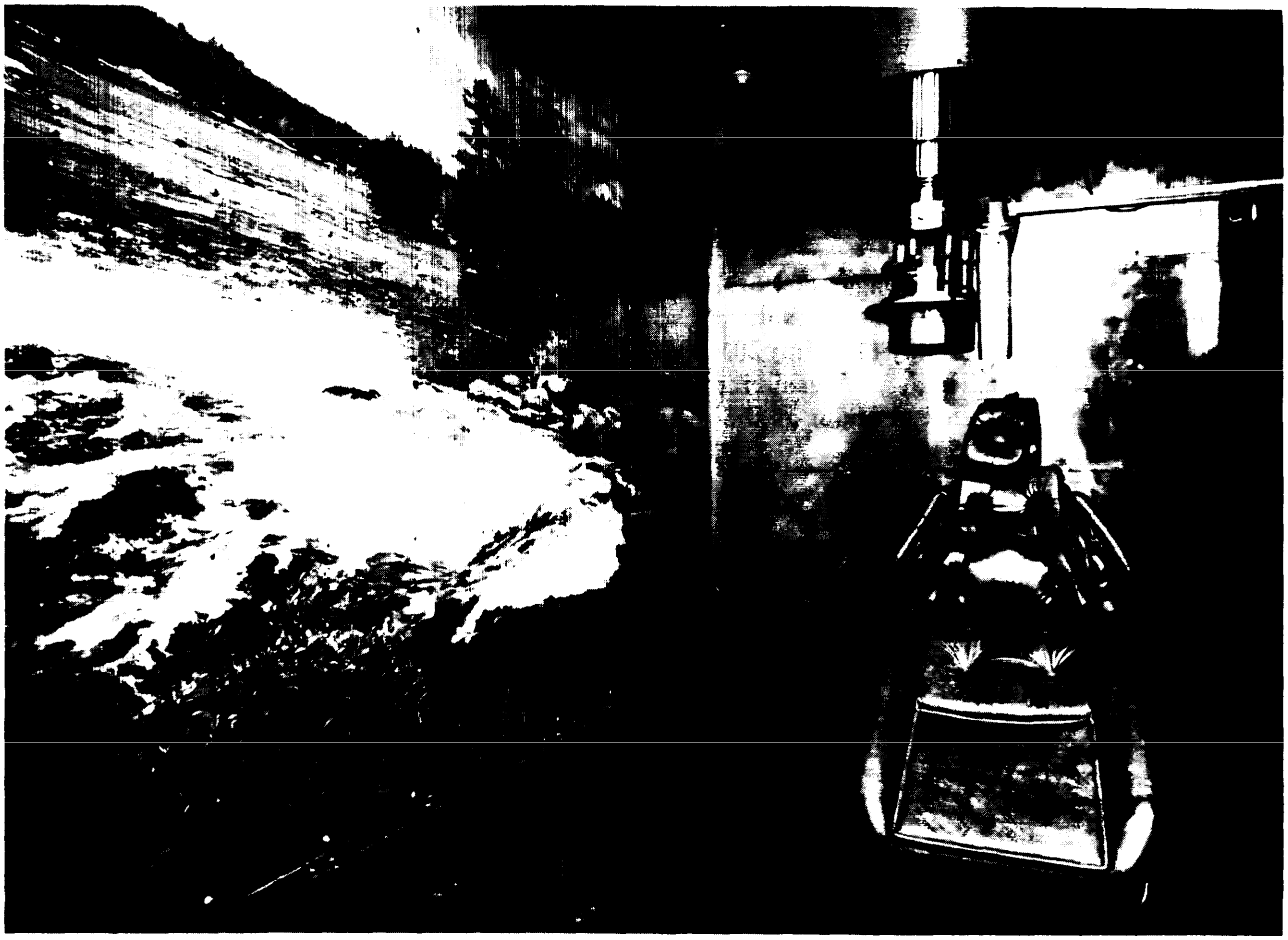


Photo credit: David Graham, 1988

Whole Body Counter, Environmental Protection Agency.

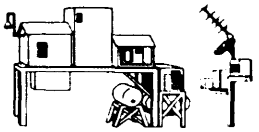
managed by the Environmental Protection Agency at the Department of Energy's direction with advice on sampling locations being obtained from the U.S. Geological Survey. Whenever possible, water samples are collected from wells downstream (in the direction of movement of underground water) from sites of nuclear detonations. On the Nevada Test Site, about 22 wells are sampled monthly (figure 4-15). The 29 wells around the Nevada Test Site (figure 4-16) are also sampled monthly and analyzed for tritium semiannually.

The flow of groundwater through the Nevada Test Site is in a south-southwesterly direction. The flow speed is estimated to be about 10 feet per year, although in some areas it may move as fast as 600 feet per year. To study the migration of radionuclides from underground tests, DOE drilled a test well near a nuclear weapons test named ''Cambric. Cambric had a yield of 0.75 kilotons and was detonated in a vertical drill hole in 1965. A test well was drilled to a depth of 200 feet below the cavity created by Cambric. It was found that most of the radioactivity produced by the test was retained within the fused rock formed by the explosion, although low concentrations of radioactive material were found in the water at the bottom of the cavity. A satellite well was also drilled 300 feet from the cavity. More than 3 billion gallons of water were pumped from the satellite well in an effort to draw water from the region of the nuclear explosion. The only radioactive materials found in the water were extremely small quantities (below the permitted

[15]See ''Radionuclide Migration in Groundwater at NTS, " U.S. Department of Energy, September, 1987.

Figure 4-8-Sample Press Release

Alamo, NV

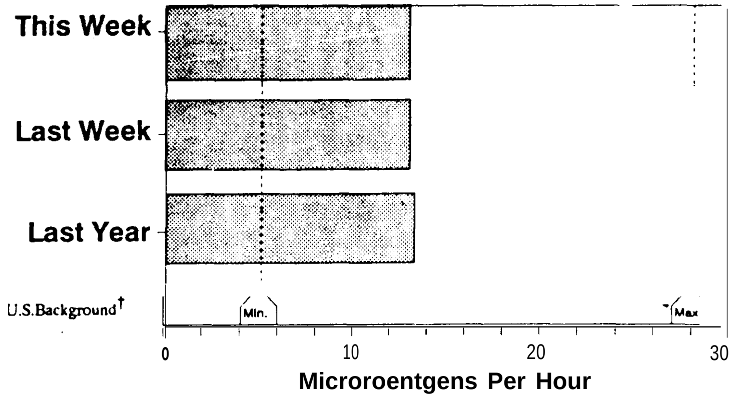


July 11 to July 20, 1988
The Nevada Test Site
COMMUNITY RADIATION MONITORING REPORT

EPA

Dell Sullivan, Manager of the Community Radiation Monitoring Station in Alamo, NV reported the results of the radiation measurements at this station for the period July 11 to July 20, 1988. The average gamma radiation exposure rate recorded by a Pressurized Ion Chamber at this station was 13.0 microroentgens* per hour as shown on the chart.

AVERAGE GAMMA RADIATION EXPOSURE RATE RECORDED ON THE PRESSURIZED ION CHAMBER AT ALAMO, NV, DURING THE WEEK ENDING JULY 20, 1988



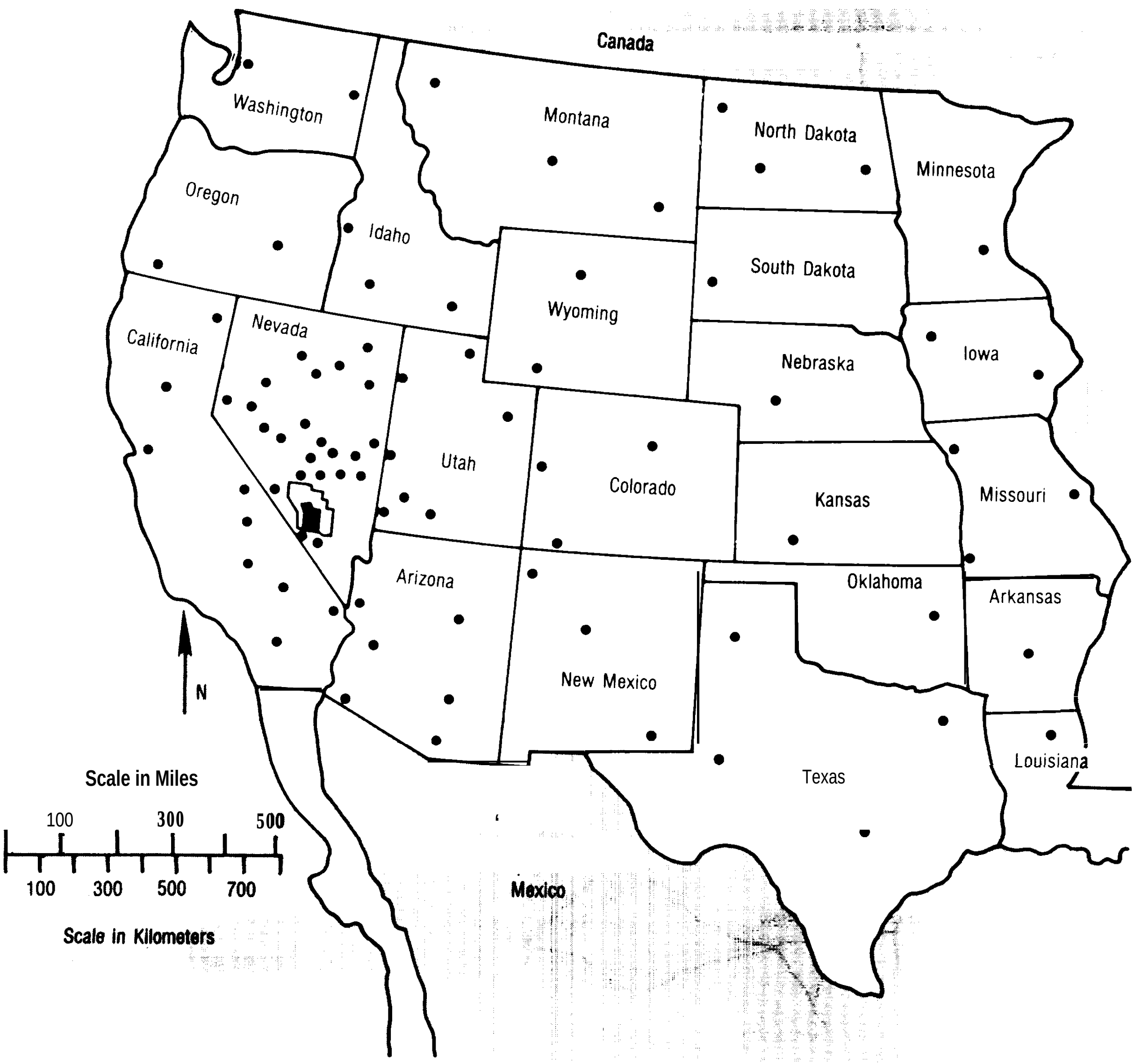
The averages of the 16 Community Monitoring Stations operated for the Environmental Protection Agency, Department of Energy and the Desert Research Institute varied from 6.2 microroentgens per hour at Las Vegas, NV to 20.2 microroentgens per hour at Austin, NV. All of the rates for the past week were within the normal background range for the United States as shown on the accompanying chart. Environmental radiation exposure rates vary with altitude and natural radioactivity in the soil. Additional information and detailed data obtained from Community Radiation Monitoring Network Stations, including an annual summary of the results from all monitoring around the Nevada Test Site, can be obtained from Mr. Sullivan (702) 725-3544 or by calling Charles F. Costa at the EPA in Las Vegas (702) 798-2305.

*The roentgen is a measure of exposure to X or gamma radiation. A microroentgen is 1 millionth of a roentgen. For comparison, one chest x-ray results in an exposure of 10,000 to 20,000 microroentgens.
† Sum of cosmic plus terrestrial dose rates in air in the U.S.(pp37,42, BEIR III, 1980).

Example of community radiation monitoring report that is posted at each monitoring station and sent to the press.

SOURCE. Environmental Protection Agency.

Figure 4-9-Standby Air Surveillance Network Stations



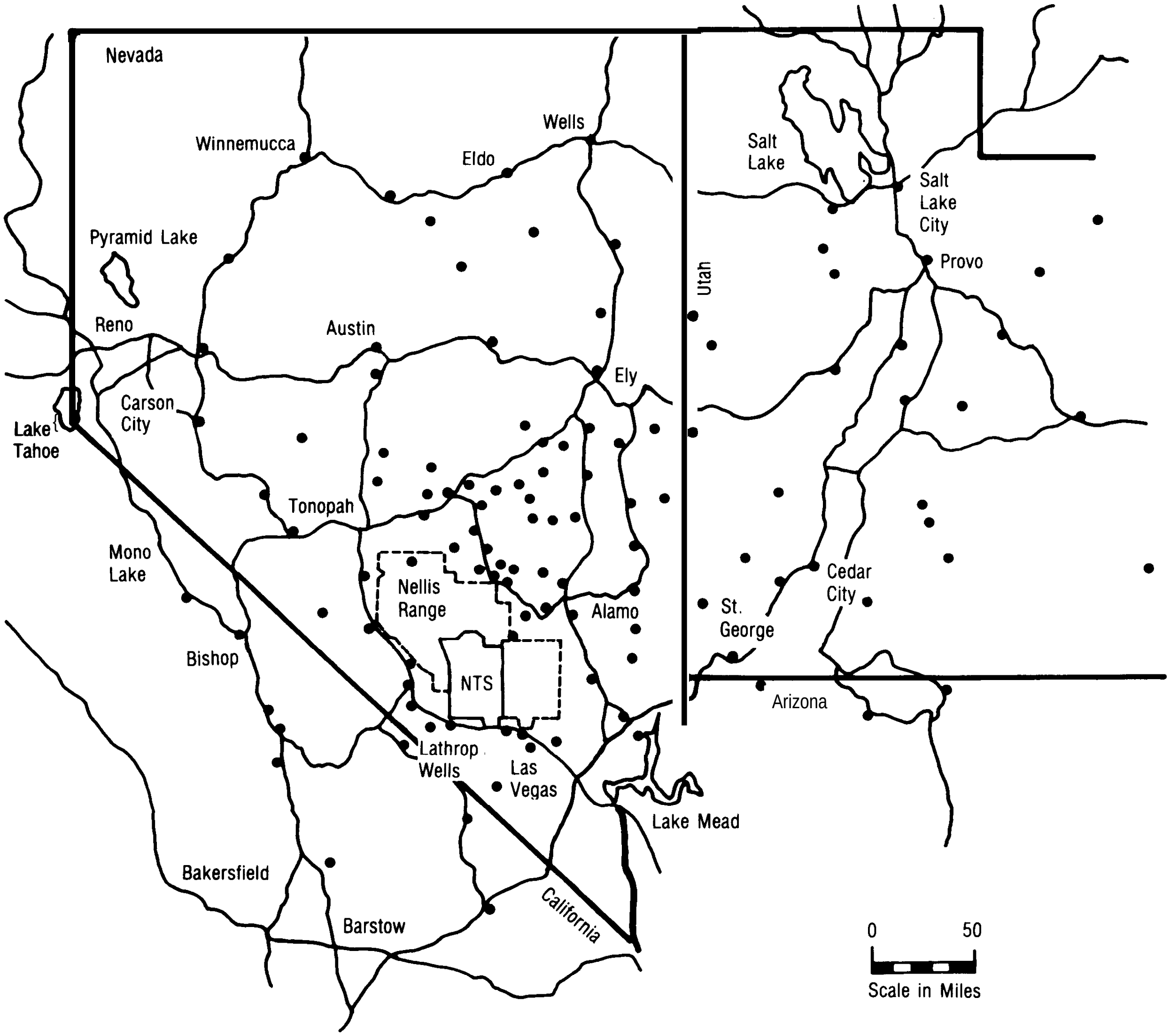
86 standby air surveillance stations are available and samples are collected and analyzed every 3 months to maintain a data base.

SOURCE: Modified from Environmental Protection Agency,

level for drinking water) of krypton-85, chlorine-36, ruthenium-106, technetium-99 and iodine-1 29.

Radioactive material from nuclear testing moves through the groundwater at various rates and is filtered by rock and sediment particles. Tritium, however, is an isotope of hydrogen and becomes incorporated in water molecules. As a result, tritium moves at the same rate as groundwater. Tritium is therefore the most mobile of the radioactive materials. Although tritium migrates, the short half-life of tritium (12.3 years) and slow movement of the groundwater prevents it from reaching the Test Site boundary. No analysis of groundwater has ever found tritium at a distance greater than a few hundred meters from some of the old test sites. None of the water samples collected outside the bounda-

Figure 4-10-Locations Monitored With Thermoluminescent Dosimeters (TLDs)



One hundred thirty locations are monitored with TLDs. All TLDs are checked every 3 months for absorbed radiation.

SOURCE: Modified from Environmental Protection Agency.

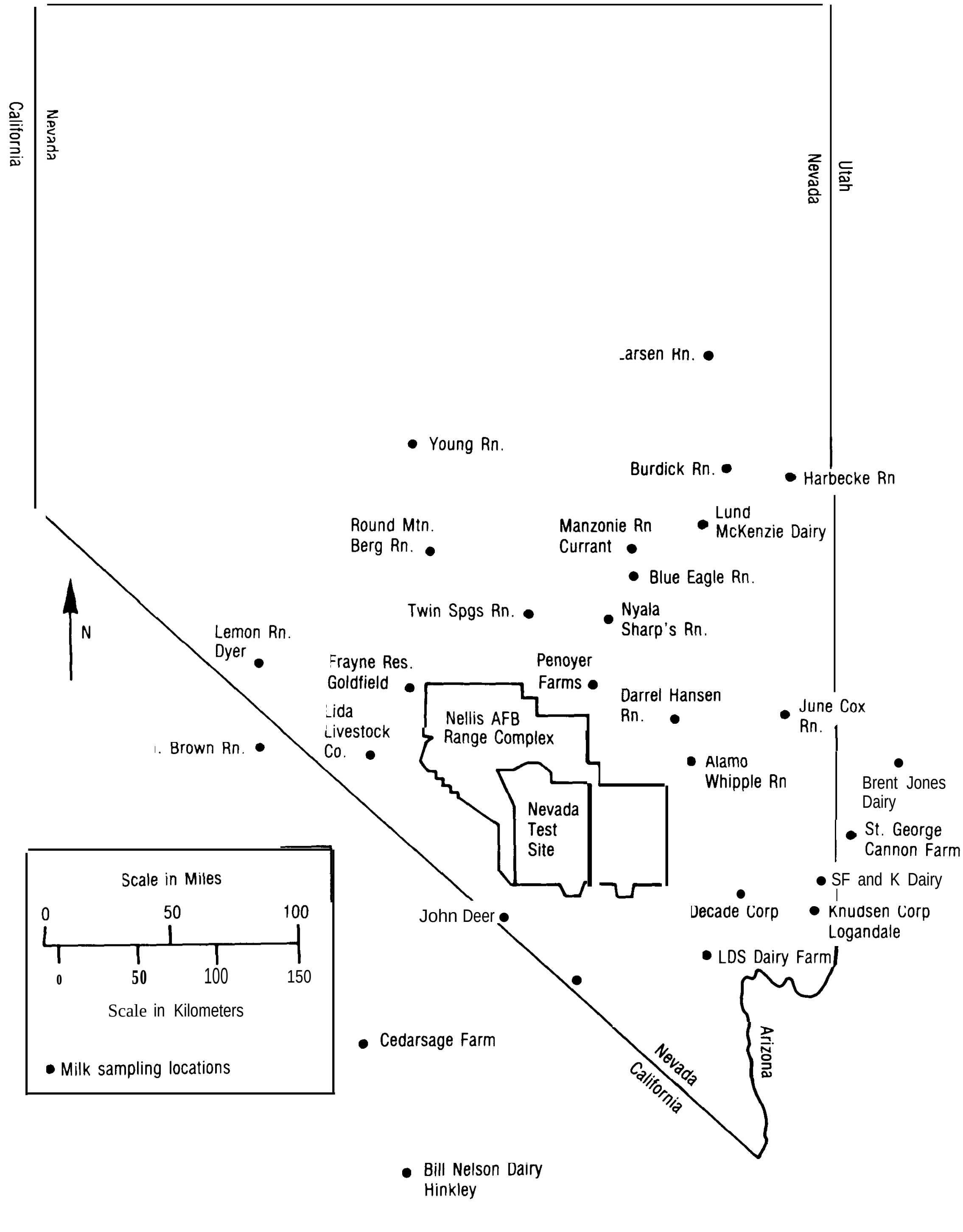
ries of the test site has ever had detectable levels of radioactivity attributable to the nuclear testing program. An independent test of water samples from around the test site was conducted by Citizen Alert (Reno, Nevada) at 14 locations (table 4-3).

Citizen Alert found no detectable levels of tritium or fission products in any of their samples. Withstanding any major change in the water table, there currently appears to be no problem associated with groundwater contamination offsite of the Nevada Test Site.

MONITORING CAPABILITY

The combination of: 1) the monitoring system deployed for each test, 2) the onsite monitoring system run by DOE, and 3) the offsite monitoring system run by EPA, forms a comprehensive detection system for radioactive material. **There is**

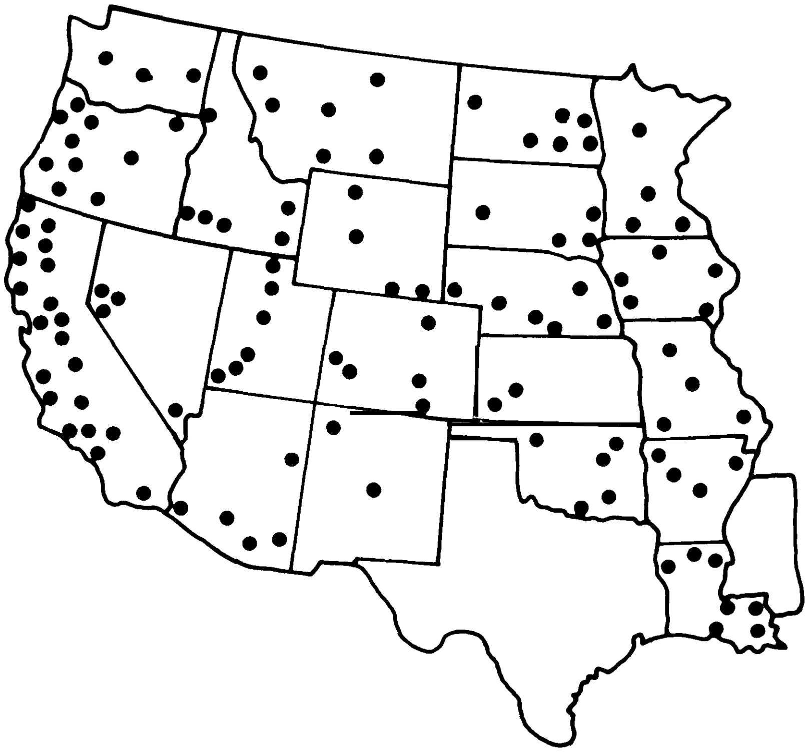
Figure 4-11-Milk Sampling Locations



Samples of raw milk are collected each month from about 25 farms surrounding the test site.

SOURCE' Modified from Environmental Protectlon Agency

Figure 4-12-Standby Milk Surveillance Network



All major milksheds west of the Mississippi River are part of the standby milk surveillance network. Samples are collected and analyzed annually.

SOURCE: Modified from Environmental Protection Agency

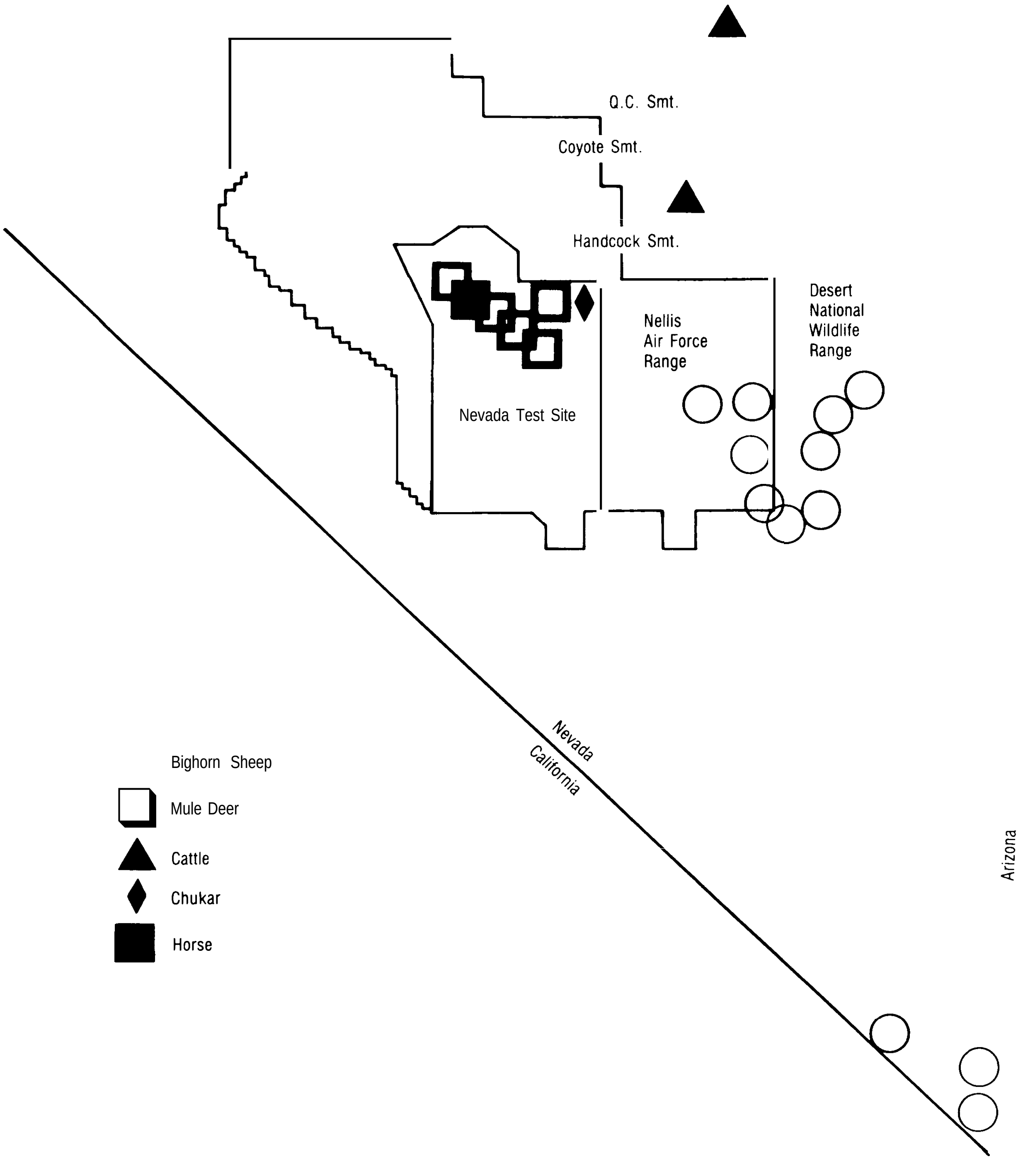
essentially no possibility that a significant release of radioactive material from an underground nuclear test could go undetected. Similarly, there is essentially no chance that radioactive material could reach a pathway to humans and not be discovered by the Environmental Protection Agency. Allegations that a release of radioactive material could escape from the test site undetected are based on partial studies that only looked at a small portion of the total monitoring system.[16] Such criticisms are invalid when assessed in terms of the total monitoring system.

The radiation monitoring system continues to improve as new measurement systems and techniques become available and as health risks from radiation become better understood. Assuming that the monitoring effort will continue to evolve, and that such issues as the migration of radioactive material in groundwater will continue to be aggressively addressed, there appear to be no valid criticisms associated with the containment of underground nuclear explosions. This is not to say that future improvement will not be made as experience increases, but only that essentially all relevant suggestions made to date that increase the safety margin have been implemented.

Public confidence in the monitoring system suffers from a general lack of confidence in the Department of Energy that emanates from the environmental problems at nuclear weapons production facilities and from the radiation hazards associated with past atmospheric tests. In the case of the

[16] See for example, ''A review of off-site environmental monitoring of the Nevada Test Site,' Bernd Franke, Health Effects of Underground Nuclear Tests, Oversight Hearing before the Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs, House of Representatives, Sept. 25, 1987, Serial No. 100-35, pp. 120-144.

Figure 4-13-Collection Site for Animals Sampled In 1987



Depending on availability, an assortment of animals are analyzed each year.

SOURCE **Modified from Environmental** Protection **Agency.**

Table 4-3-Citizen Alert Water Sampling Program

Location	Type of Sample
Springdale Ranch	Well (hose)
Barley Hot Springs	Stream
3 mi. south of Flourspar Canyon	Amargosa River
Lathrop Wells	Spigot at gas station
Point of Rock Spring, Ash Meadows	Pond
Devils Hole, Ash Meadows	Pool
Shoshone, CA	Stream
Amargosa Junction	Well (hose)
Goldfield	Well (spigot at gas station)
Moore's Station	Pond
Six Mile Creek	Stream
Tybo and Route 6 (DOE facility)	Well (tap)
Hot Creek and Route 6	Stream
Blue Jay	Well (hose)

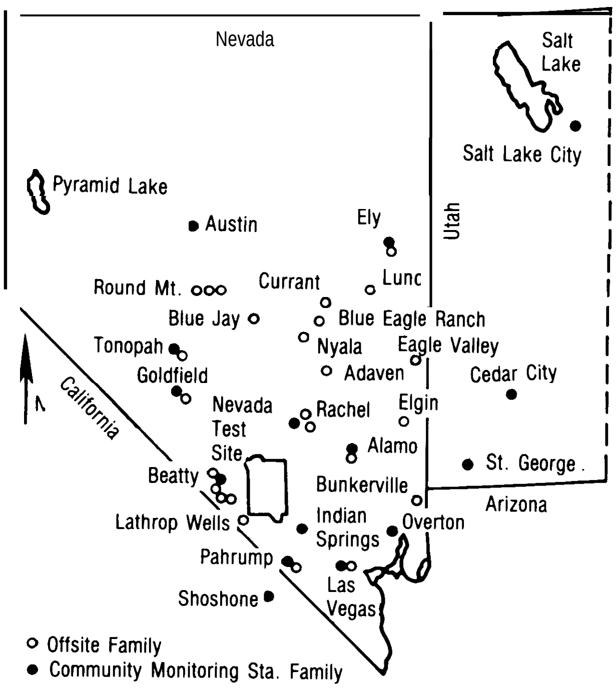
SOURCE: Citizen Alert, 1988

underground nuclear testing program, this mistrust is exacerbated by the reluctance on the part of the Department of Energy to disclose information concerning the nuclear testing program, and by the knowledge that not ail tests that release radioactive material to the atmosphere (whatever the amount or circumstances) are announced. This has led to allegations by critics of the testing program that:

> . . . the Energy Department is continuing its misinformation campaign by refusing to disclose the size of most underground tests, by hushing up or downplaying problems that occur and by not announcing most tests in advance, thereby leaving people downwind unprepared in the event of an accidental release of radioactive materials.[17]

Such concern could be greatly mitigated if a policy were adopted such that all tests were announced, or at least that all tests that released any radioactive material to the atmosphere (whatever the amount or circumstances) were announced.

Figure 4-14-Locations of Families in the Offsite Human Surveillance Program

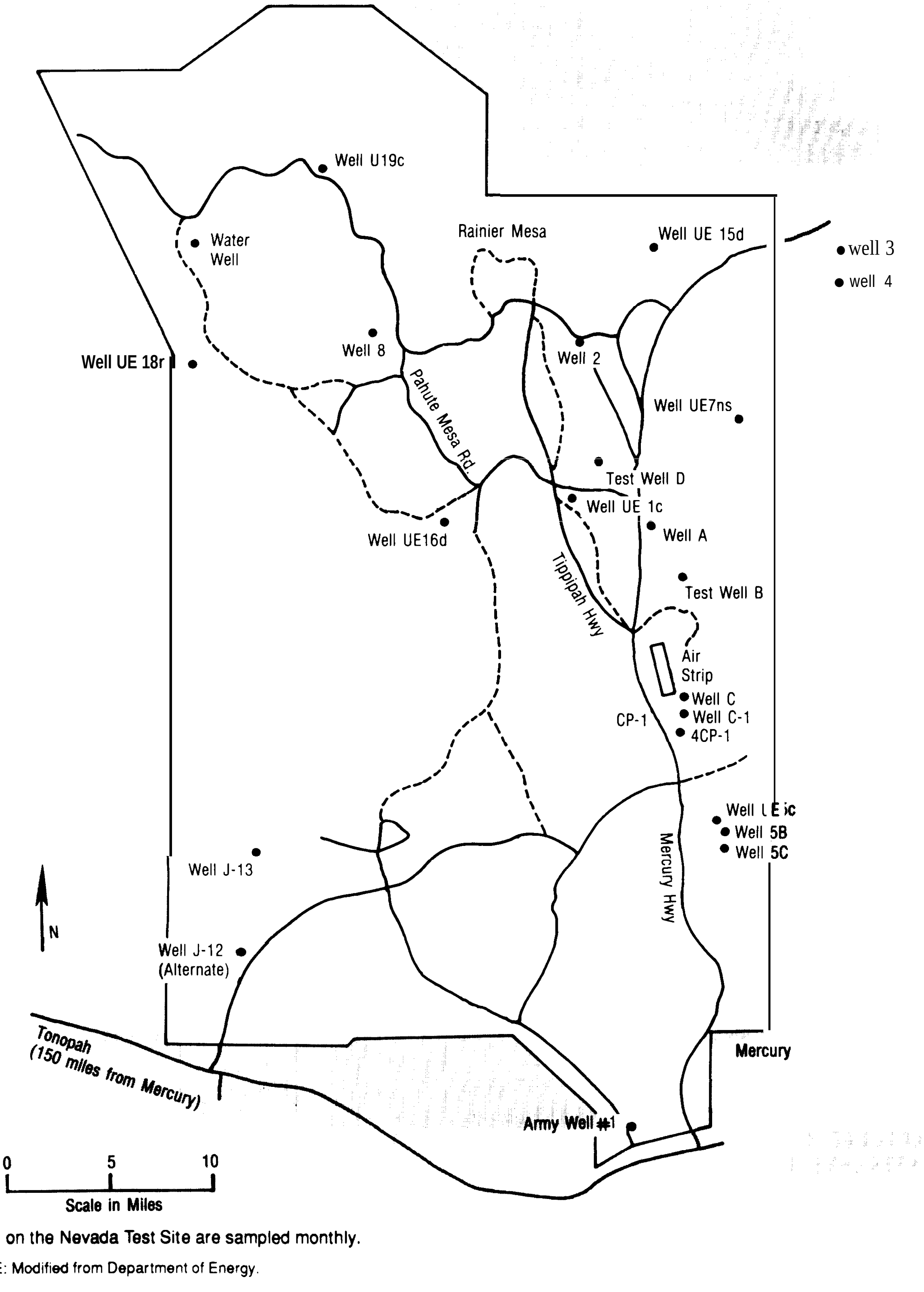


About 40 families from around the test site are brought in to EPA twice a year for whole-body analysis.

SOURCE: Modified from Environmental Protection Agency.

[17]John Hanrahan, "Testing Underground," *Common Cause*, vol. 15, No. 1, January/February 1989.

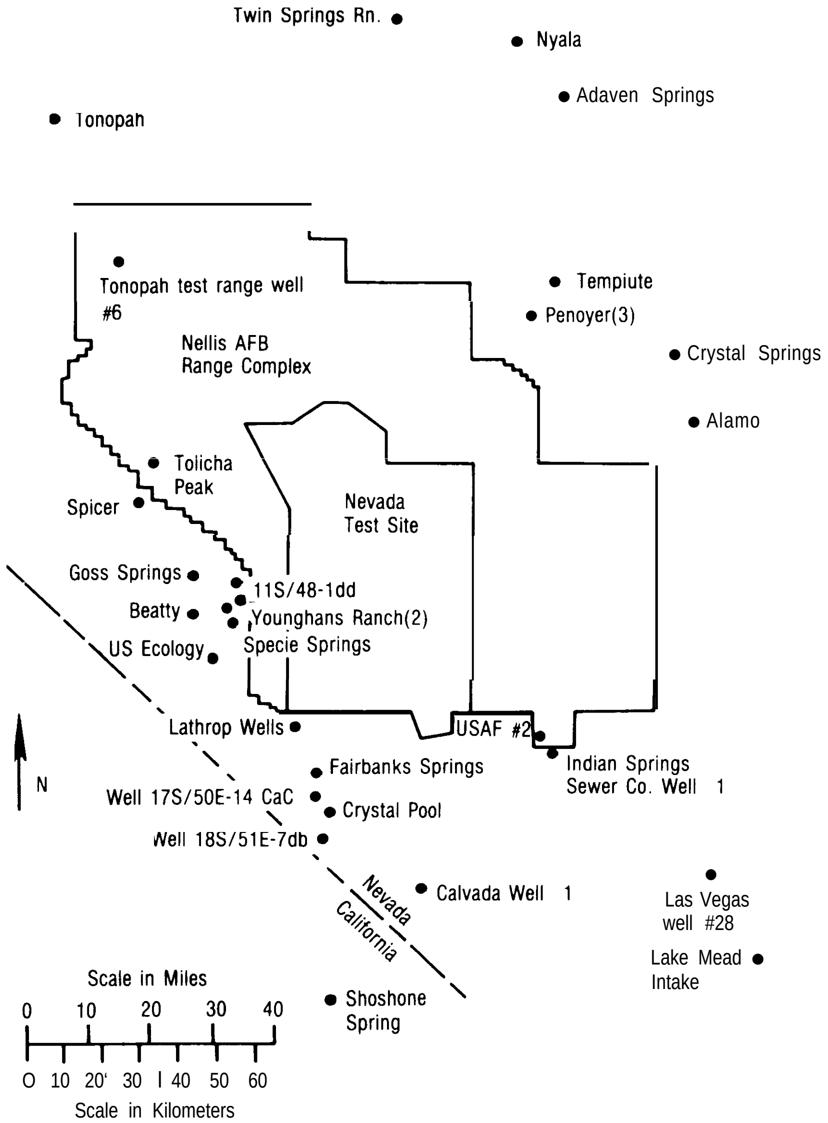
Figure 4-15-Well Sampling Locations Onsite



22 wells on the Nevada Test Site are sampled monthly.

SOURCE: Modified from Department of Energy.

Figure 4-16-Well Sampling Locations Offsite



31 wells around the Nevada Test Site are sampled twice a year.

SOURCE: Modified from Department of Energy.

Related OTA Report

- *Seismic Verification of Nuclear Testing Treaties.*
  OTA-ISC-361, 5/88; 139 pages. GPO stock #052-003-01 108-5; $7.50.
  NTIS order #PB 88-214 853/XAB.

NOTE: Reports are available from the U.S. Government priming Office, Superintendent of Documents, Washington, D.C. 20402-9325 (202-783-3238): and the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161-0001 (703-487-4650).