3761

# State of New Jersey

Christine Todd Whitman
*Governor*

Department of Environmental Protection
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Robert C. Shinn, Jr.
*Commissioner*

July 1, 1999

The Honorable Greta Dicus, Chairman
Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Soil Remediation Standards for Radioactive Materials in New Jersey, New Rule Proposal

Dear ~~Chairman~~ Greta Dicus:

The New Jersey Commission on Radiation Protection, pursuant to its authority to promulgate rules in accordance with N.J.S.A. 26:2D et seq., and to the legislative direction in the Brownfield and Contaminated Site Remediation Act is proposing generic cleanup standards for sites contaminated with radioactive materials. Knowing your interest in state soil clean up standards, a copy of these proposed rules is enclosed for comment by your agency.

The state legislature directed the Department of Environmental Protection to prepare generic standards for hazardous substances, which include radionuclides. The statute provides two general criteria for developing standards. First, to achieve less than a one in a million lifetime risk, and second, so as not to exceed normal background levels of a contaminant. Because the risks associated with radioactive materials even in their natural state exceed the one in a million criteria, the program has utilized the background concept to develop the standards described below.

The basic radiation dose criterion used in the proposed rule is 15 millirems per year. This was derived based on the variation in natural background radiation (exclusive of radon) that is expected to consistently occur in New Jersey. A similar criterion of 3 picocuries per liter was derived for radon. These radiation dose and radon in air concentrations were translated, through fairly extensive pathway analysis into allowed radionuclide in soil concentrations. Additionally, radioactively contaminated ground water shall be remediated to comply with the New Jersey Groundwater Quality Standards rules, N.J.A.C. 7:9.6.

The proposed new soil standards facilitate compliance by increasing the likelihood that planned remediations are technically and financially feasible. Persons conducting remediation will be afforded latitude, depending on site characteristics and contaminant concentrations, in selecting remedies for meeting the dose standard. Rather than removing all contaminated soil to an authorized disposal facility, the allowed dose may be attainable by the following examples of possible remedies:

- Removing part of the contamination and placing uncontaminated surface soil over the residual contamination,
- Mixing the contaminated soil with uncontaminated portions of the site,
- Removing the most contaminated soil and mixing with uncontaminated soil on the surface, or
- Treating the contaminated soil, thus reducing the volume that requires disposal, and dispersing the clean portion of the treated material.

Additional flexibility is achieved by allowing variations in land use after clean up. Limited use remedial actions (commercial scenarios) require no engineering controls, but require a deed notice to ensure that only commercial properties could be constructed on the remediated site. Restricted use remedial actions require a deed notice to maintain the uncontaminated surface soil (an engineering control) and to ensure that only commercial properties could be constructed on the remediated site.

Persons conducting remediations may also petition the Department to accept alternatives to the generically derived remediation standards.

The proposed new rules should promote the consistent, timely, and cost-effective cleanup of sites contaminated with radioactive materials. Your comments would be welcome.

Sincerely yours,

Jill

Jill Lipoti, Ph.D.
Assistant Director

C: Paul Lohaus, Director, Office of State Programs
John T. Greeves, Director, Division of Waste Management,
George Pangburn, Director. Division of Nuclear Materials Safety, NRC

[Enclosures available in SECY]

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**ENVIRONMENTAL PROTECTION**
**COMMISSION ON RADIATION PROTECTION**

**Soil Remediation Standards for Radioactive Materials**
**Proposed New Rules: N.J.A.C. 7:28-12**

Authorized By: Robert Shinn, Jr., Commissioner, Department of Environmental Protection and the Commission on Radiation Protection, Dr. Henry Powsner, Chairman,

Authority: N.J.S.A. 26:2D-1 et seq. and 58:10B-1 et seq.

DEP Docket Number: 11-99-06/697

Proposal Number: PRN 1999-224

Submit written comments by August 5, 1999 to:
Ann Zeloof, Esq.
DEP Docket Number: 11-99-06/697
Office of Legal Affairs
New Jersey Department of Environmental Protection
P.O. Box 402
Trenton, NJ 08625-0402

In order to facilitate and reduce the time and resources necessary to respond to public comments on this proposal, the Department of Environmental Protection ("Department") strongly recommends that commenters submit comments on diskettes as well as on paper. Either 3½ inch (preferred) or 5¼ inch diskettes may be submitted. The Department will be able to upload the comments onto its office automation equipment, thereby saving the Department considerable time in not having to retype the comments. The Department will use the paper version of the comments to ensure that the uploading was accomplished successfully. Submission of the diskette is not a requirement. The Department will accept all comments submitted in writing prior to the end of the comment period.

The Department prefers Microsoft Word 6.0 or above; however, other word processing software which can also be read or used by Microsoft Word 6.0 is acceptable. MacIntosh formats should not be used.

Text enhancements such as underlines, bold, etc., are often not converted from one software to another. Therefore, when suggesting text revisions involving additions/deletions, the revised text should be presented without enhancements, as it would appear in the rule.

Comments on the proposal narrative statements should be included with the comments on the pertinent section of the rule text wherever possible to eliminate duplicate comments and help the Department organize and respond to comments. As comments will be sorted electronically, the following format should be used for each comment:

Citation COMMENT: Comment text. (Company name).
For example: 1.6(e) COMMENT: The process for approving remedial action reports should be streamlined. (XYZ Corporation)

The proposal follows:


**Summary**

The Commission on Radiation Protection (CORP), pursuant to its authority to promulgate rules in accordance with the Radiation Protection Act, N.J.S.A. 26:2D-1 et seq., and the Commissioner of the Department of Environmental Protection, pursuant to his authority to promulgate rules in accordance with N.J.S.A. 58:10B-1 et seq., the Brownfield and Contaminated Site Remediation Act, are proposing remediation standards for radioactive materials.

The Brownfield and Contaminated Site Remediation Act, N.J.S.A. 58:10B-1 et seq., directs the Department to establish minimum criteria for the remediation of contaminated sites and to apply soil remediation standards for the cleanup of contaminants, in conformance with the policies and criteria at N.J.S.A. 58:10B-12. Soil remediation standards are to be based on either: 1) an incremental lifetime risk of cancer of one in one million (see N.J.S.A. 58:10B-12(d)(1)), or 2) naturally occurring background levels that are consistently encountered in a region (see N.J.S.A. 58:10B-12(g)(4)). Pursuant to the Brownfield Act, the Department is charged with developing generic minimum soil cleanup standards for any discharged hazardous substance as defined pursuant N.J.S.A. 58:10-23.11b, hazardous waste as defined pursuant to N.J.S.A.13:1E-38, or pollutant as defined pursuant to N.J.S.A. 58:4-3.153. The definition of a hazardous substance includes any substance regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (42 U.S.C. §§9601 et seq.).

The proposed new rules apply to any person responsible for conducting the remediation of a site that is contaminated with radioactive materials. Radioactive materials include:

(1) Any naturally occurring radionuclide whose concentration has been enhanced by man-made physical or chemical processes,

(2) Accelerator produced radionuclides,

(3) Any radioactive materials remediated pursuant to any of the following: the Federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. §§9601 et seq., the Spill Compensation and Control Act, N.J.S.A. 58:10-23.11 et seq.; the Water Pollution Control Act, N.J.S.A. 58:10A-1 et seq.; the Industrial Site Recovery Act, N.J.S.A. 13:1K-6 et seq.; the Solid Waste Management Act, N.J.S.A. 13:1E-1 et seq.; the Comprehensive Regulated Medical Waste Management Act, N.J.S.A. 13:1E-48.1 et seq.; the Major Hazardous Waste Facilities Siting Act, N.J.S.A. 13:1E-49 et seq.; the Sanitary Landfill Facility Closure and Contingency Fund Act, N.J.S.A. 13:1E-100 et seq.; the Regional Low Level Radioactive Waste Disposal Facility Siting Act, N.J.S.A. 13:1E-177 et seq.; and any law or regulation by which the State may compel a person to perform remediation activities, or pursuant to N.J.A.C. 7:26.

The primary purpose of the proposed new rules is to establish minimum soil cleanup standards for radioactive contamination. These rules should reduce the amount of time it takes to complete cleanups. In the past, responsible parties and the Department have had to develop and agree on cleanup standards for each specific case. This often became a point of contention that required extensive correspondence and meetings to resolve. With the establishment of generic cleanup standards, a person responsible for conducting the remediation will know the cleanup goal early in the process and can proceed with the characterization of the site, remedial investigation, and remedial action. Review time for the Department is reduced because the need for a site-specific pathway analysis is no longer necessary.

Additionally, a party may petition the Department to accept alternative cleanup standards (see N.J.A.C. 7:28-12.10). The methodology of developing alternate standards is set forth. Moreover, the allowed dose increment is established so that any submitted alternative standards can also be reviewed more expeditiously.

The proposed cleanup standards establish an incremental annual total effective dose equivalent (TEDE) limit of 15 mrem (0.15 mSv) for the external radiation and intake from radioactive contamination for both residential sites and non-residential sites (see N.J.A.C. 7:28-12.8(a)1). For radon, an indoor air concentration of three pCi/L (111 $Bq/m^3$) above background is the proposed standard (see N.J.A.C. 7:28-12.8(a)2). The proposed cleanup standards take the New Jersey Groundwater Quality Standards rules (N.J.A.C. 7:9-6) into consideration when establishing residual soil radionuclide concentrations (see N.J.A.C. 7:28-12.8(a)3).

An explanation on how these values were derived is provided in the Department's publication *Development of Generic Standards for Remediation of Radioactively Contaminated Soils in New Jersey*. This document may be obtained by contacting the Bureau of Environmental Radiation at (609) 984-5400 or from the Radiation Protection Program's web site at http://www.state.nj.us/dep/rpp/index.htm. The allowed minimum soil radionuclide concentrations are different for each radionuclide because of their differing properties. For example, the radionuclide thorium-232 is a strong gamma emitter; therefore, the external exposure pathway is the major contributor to dose, whereas uranium-238 contributes the most dose via the groundwater pathway.

The proposed new cleanup standards provide a clear target and will assist persons responsible for conducting the remediation in their planning efforts. These new rules also promote an expedited review by the Department, thus conserving Department resources. Moreover, the standards are protective of public health and safety and furnish a cost-effective approach to Departmental oversight, and should result in less expensive remediations by eliminating the requirement for site-specific dose assessments.

The proposed new rules require the person responsible for remediating the site to provide for the costs of implementing and maintaining the requisite engineering and institutional controls for an appropriate period of time (see N.J.A.C. 7:28-12.11(c)3).

The proposed new soil standards facilitate compliance by increasing the likelihood that planned remediations are technically and financially feasible. Persons conducting remediation will be afforded latitude, depending on site characteristics and contaminant concentrations, in selecting remedies for meeting the dose standard (see N.J.A.C. 7:28-9). Examples of such possible remedies are: 1) rather than removing all contaminated soil to an authorized disposal facility, the allowed dose may be attainable by removing part of the contamination and placing uncontaminated surface soil over the residual contamination, 2) mixing contaminated soil with uncontaminated portions of the site, 3) removing the most contaminated soil and mixing with uncontaminated soil on the surface, or 4) treating the contaminated soil, thus reducing the volume that requires disposal, and dispersing the clean portion of the treated material. Such options encourage remediation by reducing the overall costs while maintaining public health and safety. Depending on the radionuclide involved, the initial concentration of the contaminated soil and its vertical extent, cost savings on the order of up to 85 percent relative to the cost of full removal and off-site disposal may be realized if these options are implemented.

## General Approach

The Brownfield and Contaminated Site Remediation Act (Brownfield Act) requires the Department to establish remediation standards that will not result in more than an additional cancer risk of one in one million (see N.J.S.A. 58:10B-(d)(1)). Since the risk associated with naturally occurring background radiation exceeds one in one million, regional background levels are therefore used as the remediation standards for radioactive materials in soils (see N.J.S.A. 58:10B-12(g)(4)), unless the Department determines that due to site-specific factors associated with a subject real property, the use of such standards would not be protective of public health or safety, or the environment (see N.J.S.A. 58:10B-12(g)(4)).

In doing so, the Department recognizes that background radiation varies with time and from place to place, and has utilized the naturally occurring variability in radiation that people encounter in their day-to-day lives as the radiation dose increment to be achieved by a remediation. The Brownfield and Contaminated Site Remediation Act further defines regional natural background levels as the concentration of a contaminant "consistently" present in the environment of the region of the site and which has not been influenced by localized human activities. Recognizing the statistical nature of background radiation, the Department has utilized one standard deviation of natural terrestrial and internally deposited radiation, or an approximation thereto, as the measure of the variation that is "consistently" encountered. Standard deviation is a statistical term which measures the spread of the data from the mean (average). Roughly speaking, it is the average distance of the data from the mean. For normally distributed data (a bell-shaped curve), approximately 68 percent of the data is within one standard deviation of the mean and 95 percent of the data is within two standard deviations of the mean. The radiation from soil remediated to this one standard deviation standard, when added to the average natural background radiation in New Jersey, would be less than or equal to the natural background radiation experienced by 16 percent of the New Jersey population. (100 percent - 68 percent = 32 percent. The resulting percentage is divided by 2 to get the 16 percent because only the upper half of the curve is of interest since the average is being added to.) To put it simply, the additional dose received from a site remediated to these standards would contribute no more dose to an individual than that individual would get by travelling from place to place within the State.

Consequently, the approach taken in this rule defines the one standard deviation in naturally occurring background radiation doses for each of the three pathways of radiation: external gamma radiation; intakes of radionuclides; and inhalation of radon gas. The standard deviations of the doses from external gamma and radionuclide intakes were then summed statistically to approximate a one standard deviation value for both pathways. Radon was kept separate because of its unique character. The resulting one standard deviation for the sum of the external and internal background doses is the Total Dose Increment (above background radiation levels) allowed following a remediation; this was used as the fundamental criteria for soil standard setting. For radium-226 the one standard deviation of background indoor radon concentration (Radon Concentration Increment) was also used as a limiting criteria.

In order to translate the radiation dose criterion into generic soil standards, the Department made extensive calculations, found in the Department's publication *Development of Generic Standards for Remediation of Radioactively Contaminated Soils in New Jersey*, which may be obtained by calling the Bureau of Environmental Radiation at (609) 984-5400 or from the Radiation Protection Program's web site at http://www.state.nj.us/dep/rpp/index.htm, of radiation doses to individuals, for both unrestricted use remedial actions (residential), limited use remedial actions (commercial), and restricted use remedial actions as a function of both the vertical extent (depth) of the contaminated material remaining and the depth of uncontaminated surface soil left or placed on the surface. For unrestricted use and limited restricted use, the residually contaminated layer and the uncontaminated surface soil must be mixed in order to achieve a uniform (and lower) concentration throughout the soil column and to eliminate the need to maintain the uncontaminated surface soil. No deed notice is required for the unrestricted use standards, thereby achieving a permanent remedy. No engineering controls would be required for the limited restricted use standards, although a deed notice would be required to ensure that only commercial properties could be constructed on the remediated site. The restricted use standards require a deed notice to maintain the uncontaminated surface soil (an engineering control), and to ensure that only commercial properties could be constructed on the remediated site.

For diffuse materials and soils, these doses are expressed as the ratio of the dose received per year (mrem/yr) divided by the activity in the material in picocuries per gram (pCi/g) and termed the dose factor (DF). These dose factors are then divided into the Total Dose Increment to determine what soil concentration increments are acceptable for various vertical extents and uncontaminated surface soil depths.

The allowed soil Concentration (C) above background is:

C = Total Dose Increment / Dose Factor.

For a given combination of residual contamination depth and uncontaminated surface soil depth, the maximum value of C, that does not cause either the Total Dose Increment or the Radon Concentration Increment to be exceeded, is then selected as the standard or the pre-mixing value for the case of unrestricted or limited restricted use. This method was used for each long-lived radionuclide and its decay chain. However, in order to account for the generation of more radioactive elements due to the decay of the parent element, the doses for certain decay chains were combined. An example of such a combination is the Ra-226 and Pb-210 decay chain.

**Site Use Scenarios**

In performing its generic dose calculations, the Department considered both unrestricted use (residential) remedial actions and limited restricted use (commercial) remedial actions uses of the site. For each use it considered future slab on grade and basement excavations for buildings -- which both result in contaminated material being brought to the surface -- as the scenarios from which to derive generic soil standards. Other scenarios are possible of course and can be addressed in the alternate standards provision of the rules (see N.J.A.C. 7:28-12.10).

For residential construction, a house of 25 feet by 40 feet and a plot size of 50 feet by 100 feet was assumed; for non-residential use a building of 40 feet by 60 feet and a plot size of one-quarter acre was assumed. For slab on grade construction, a footing excavation around the perimeter of the house four feet deep and two feet wide was assumed. For basement construction, a seven foot depth of excavation was assumed over the full area of the structure. In deriving the generic standards, the dose calculation results for slab on grade and basement excavation were compared and the more restrictive concentration was used. Thus, adherence to that concentration would allow any type of construction on site, in essence, unrestricted use of the site. If a person conducting the remediation wishes to restrict the type of construction on site, the alternate standard approach can be used. Such an approach can either be based on the generic analysis done by the Department for slab on grade and basement excavations or the applicant's own analysis pursuant to N.J.A.C. 7:28-12.12.

Persons conducting remediations may also petition the Department to accept alternatives to the generically derived remediation standards. Any such alternative soil remediation standards shall be based on a Department-approved dose assessment and be as protective of human health and the environment as the generic standards established in these rules (see N.J.A.C. 7:28-12.10).

Since radionuclides will remain in the environment for thousands of years, well beyond the time that institutional or engineering controls are expected to be effective, and the Brownfield Act specifies that the Department must make the determination that the alternate remediation standards are protective of the public health and safety, the proposed new rules specify that the dose resulting from failure of institutional or engineering controls may not exceed 100 mrem (one mSv) annual total effective dose equivalent (see N.J.A.C. 7.28-12.10(e)). The exception to this is a radon mitigation system, because radon mitigation systems are regulated under N.J.A.C. 7:28-27, which requires audible or visual mechanisms to indicate that the system is working properly.

The 100 mrem/yr (one mSv/yr) annual total effective dose equivalent was selected based on the Federal dose limits for members of the public (see Nuclear Regulatory Commission 10 CFR Part 20.1301), recommendations from the International Commission on Radiation Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP). These national and international bodies also agree that although 100 mrem/yr is considered protective of the public, it would seem appropriate that the amount of radiation that a person would receive from a single source should be further reduced to be a fraction of the limit to account for the possibility that an individual may be exposed to more than one source of man-made radioactivity, thus limiting the potential that an individual would receive a dose above the public dose limit. The Department's 15 mrem/yr limit is consistent with this recommendation.

## Purpose and Effect

These rules establish minimum soil remediation standards for radionuclides that are consistent with the legislative direction as outlined above. In establishing these soil remediation standards, the Department used the term "contaminant" as defined in N.J.S.A. 58:10B-1. For the purpose of these rules, "radiation" is considered the contaminant which must be controlled, and not each individual radionuclide. This position is based on the fact that it is the collective radiation, not the individual radionuclide, that causes the harmful health effect. Additionally, radiation from different sources may vary in energy intensity and physical state (gamma ray versus alpha particle), and cause different degrees of harm to the body. Only the use of established measures of radiation doses can reduce these differences to a relevant common measure. Furthermore, because "terrestrial" and "in the body" natural background radiation is the sum of all available ambient radionuclides, and because natural background in the region of the site is the soil remediation goal, it is logical to establish "radiation" as the contaminant for this application.

The proposed new rules should promote the consistent, timely, and cost-effective cleanup of sites contaminated with radioactive materials.

## Regulatory History

This proposal incorporates comments that were received in response to the interested party draft that was issued by the Department in March of 1996. The interested party draft was sent to over 300 recipients, including environmental groups, responsible parties, Federal and State government agencies, international radiation protection agencies, and academia. Two public hearings were held in which a total of 15 people attended. Twelve written comments were received.

The following is a brief discussion of the provisions of the proposed new rules:

N.J.A.C. 7:28-12.1 addresses the purpose and scope of the proposed new rules.

N.J.A.C. 7:28-12.2 addresses the applicability of the proposed new rules.

N.J.A.C. 7:28-12.3 sets forth the definitions of the terms which are used in the proposed new rules.

N.J.A.C. 7:28-12.4 explains general requirements.

N.J.A.C. 7:28-12.5 addresses the sampling, surveying and laboratory requirements.

N.J.A.C. 7:28-12.6 addresses remedial action selection requirements.

N.J.A.C. 7:28-12.7 addresses the remedial action requirements.

N.J.A.C. 7:28-12.8 sets forth the radiation dose standards applicable to remediation of radioactive contamination of all real property.

N.J.A.C. 7:28-12.9 sets forth the minimum remediation standards for unrestricted, limited restricted and restricted use and pre-mixing values for unrestricted use and limited restricted for radionuclide contamination of soil.

N.J.A.C. 7:28-12.10 addresses the requirements for petitions requesting alternative remediation.

N.J.A.C. 7:28-12.11 addresses the requirements pertaining to engineering or institutional controls.

N.J.A.C. 7:28-12.12 addresses the requirements pertaining to a change in land use, including notification to each affected municipality.

N.J.A.C. 7:28-12.13 addresses the requirements pertaining to the determination of whether the site meets the soil cleanup standards (the final status survey).

Appendix A provides the soil concentration numbers to use when performing the sum of the fractions calculations for radium-226.

## Social Impact

One positive consequence of the proposed new rule is that the public will be protected from unnecessary radiation exposure, at the same time that the responsible parties will be able to put contaminated land back into productive use. Another positive consequence is that a cost savings can be realized from traditional methods of disposal of up to approximately 85 percent, depending on the amount of contaminated material involved.

The proposed new rules will have a positive social impact in that contaminated property may be returned to productive use, either as residential or commercial property. These rules allow more latitude in site cleanups in that there are less stringent standards for limited restricted use remedial actions, the vertical extent of the remaining contamination is accounted for, and dispersal, treatment, and mixing of contaminated soil is allowed.

The public can be assured that properties that are remediated will result in no more than an allowable background increment of radiation dose, which would be normally encountered as one travels throughout the State. Responsible parties whose sites are contaminated with radioactive materials (approximately 35 known sites) are affected by these rules in that they will be required to comply with these standards in order for their properties to be considered remediated.

## Economic Impact

The following analysis compares the proposed new standards to the only currently allowable cleanup remedy, which is disposal at facilities licensed to accept radioactive waste:

The economic impact of the proposed cleanup standards for radioactive materials will fall primarily on those agencies, businesses and individuals responsible for the discharge of such material onto the lands and into waters of the State. Because the approximately 35 known and/or suspected sites contaminated with radioactive materials generally involve large volumes of material and because options for remediation, other than full removal, have not previously been well-defined, the remediation of these sites could be very costly. These rules creates several options for remediation that could significantly reduce those costs.

For example, by developing the proposed soil cleanup standards as a function of the vertical extent of the remaining contamination, remediations can be achieved in many cases without full removal of all contaminated material from the site. Additionally, on-site dispersion is permitted as long as it achieves a desired combination of Vertical Extent and Uncontaminated Surface Soil, as specified in Tables 3A or 3B in N.J.A.C. 7:28-12.9.

To illustrate the potential cost savings for remediating radioactive contamination, four remedial action scenarios are compared for **restricted use** sites contaminated with thorium-232 (Table A below). The remediation options evaluated range from full removal of all contamination to an off-site radioactive waste disposal facility to soil treatment and backfilling with the resultant material. The Table was derived by normalizing the cost of Option A to one and presenting the costs of the other options as a fraction of the cost of Option A.

In making these comparisons, several cost assumptions were made. Although the Department reviewed numerous documents to ascertain the costs associated with previous remediations, it is cognizant that the figures used in this analysis may not, due to site- specific characteristics and market conditions, reflect actual site remediation costs. This analysis is intended to illustrate how the standard setting methodology developed allows for options that may reduce overall remediation costs. The options contained herein may not represent all potential remediation options and are not intended to limit those planning remediations of contaminated sites.

Cost assumptions are based on reviews of "Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC Licensed Nuclear Facilities" (NUREG-1496), "A Review of Processes for the Removal of Selected Radionuclides from Soils" by CTS, Inc. (November, 1996), and contaminated site files. Discussions with owners of disposal facilities, personnel in the US Department of Energy and personnel in the Department's Site Remediation Program were also utilized. Costs used in the Department's analysis were estimated to be: $1,020/yd$^3$ for off-site disposal at a radioactive material disposal facility (including loading and transportation), $360/yd$^3$ for soil treatment (gravity-based, including disposal of concentrated material at a licensed disposal facility), $145/yd$^3$ for soil blending, $120/yd$^3$ for soil dispersal and $3/yd$^3$ for clean soil to be used as backfill.

In order to compute the amount of soil requiring excavation to achieve the dose standard, a curve plotting the allowable radionuclide in soil concentration versus the vertical extent of contamination was utilized. For this exercise the Department assumed two feet of uncontaminated surface soil remaining after remediation. Figure 1 shows, for example, that if the soil thorium-232 concentration for an eight-foot depth of contamination before remediation is less than five pCi/g (0.19 Bq/g) over background, the incremental limited restricted use standard can be met without any soil excavation. If the soil radionuclide concentration prior to remediation is twice the soil concentration needed to meet the incremental dose standard without any excavation, (that is, 10 pCi/g over background), then according to Figure 1, the vertical extent of the remaining contamination cannot exceed 3.5 feet. Therefore, the incremental dose standard can be met by removing about 4.5 feet (8 ft. – 4.5 ft. = 3.5 ft.) of the contaminated material, or about 56 percent, thus resulting in a significant cost savings.

In accordance with Option A, row A of Table A depicts the cost for removal of all contaminated soil to licensed disposal facility as follows:

| | |
|---|---|
| Excavation Cost | $180/yd$^3$ |
| Disposal | $ 837/yd$^3$ |
| Backfill | $ 3/yd$^3$ |
| Total | $1,020/yd$^3$ |

The ratio across the top of the tables represents the radionuclide in soil concentrations above background before remediation to the post-remediation concentration standard. For example, column 2 indicates that soil concentrations are twice the standard, 4 indicates soil contamination concentrations are four times the standard etc. As noted in Table A, an eight foot depth of contamination is assumed in all cases.

For remediation scenarios Options B through E, cost savings as a fraction of the cost for total contaminated soil removal to an off-site disposal facility are presented. For the restricted use Th-232 scenario, as shown in Table A, the largest potential cost savings are realized if the minimum amount of soil is excavated and is dispersed on site, assuming enough clean soil exists on site. In this instance a cost savings greater than 80 percent is realized relative to the costs of full excavation of all contaminated soil and disposal off-site at a radioactive waste disposal facility. Excavating the entire volume of contaminated soil and then blending it with clean soil shows minimal potential cost savings at fairly low radionuclide concentrations, but actually increases costs over total removal at higher concentrations (103 percent to 130 percent). Soil treatment is expected to save from 55 percent to 65 percent depending on the effectiveness of the treatment. These soil treatment cost saving estimates are conservative based on a report prepared for the Department by CTS, Inc., *A Review of Processes for the Removal of Selected Radionuclides from Soils*. Based on a literature search, it appears as though optimization of soil treatment technologies could increase efficiency to a point that would allow either leaving the treated portion of the soil in place, or some other combination of blending, landfilling, or dispersal. The efficiencies used to estimate cost in Table A are approximations and depend on site specific factors such as the soil characteristics and radionuclides present.

Figure 1

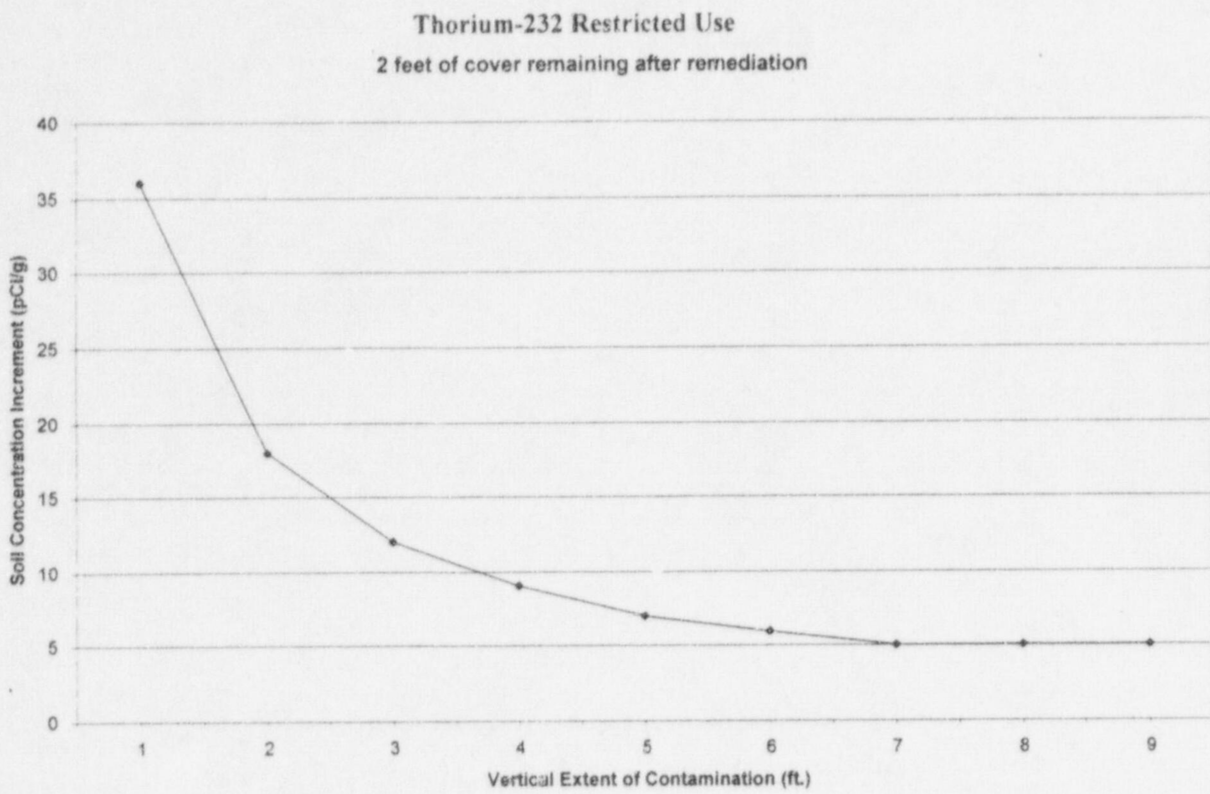

Thorium-232 Restricted Use
2 feet of cover remaining after remediation
Soil Concentration Increment (pCi/g)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
Vertical Extent of Contamination (ft.)

TABLE A

REMEDIATION COST AS A PERCENTAGE OF REMEDIATION COST FOR FULL EXCAVATION AND DISPOSAL AT RADIOACTIVE WASTE DISPOSAL FACILITY

RESTRICTED USE-- Th-232

| Remediation Scenarios | R = Ratio of Pre to Post-Remediation Concentrations over background [1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| (A) Full removal of volume to licensed facility[2] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| (B) Excavation of just enough material to meet the allowed dose with disposal at licensed facility | -- | .56 | .69 | .75 | .81 | .84 | .87 | 1.0 |
| (C) Excavation of full volume and blending/backfill | -- | .46 | .60 | .74 | .88 | 1.03 | 1.2 | 1.3 |
| (D) Same as B but disperse material on-site | -- | .16 | .20 | .22 | .24 | .25 | .26 | .29 |
| (E) Soil Treatment w/Disposal at licensed facility | -- | .35 | .35 | .35 | .35 | .35 | .35 | .35 |

[1] This example assumes an 8 ft. depth of contamination. [2] Assumes cost of excavation, disposal, backfill = $1,020 per cubic yard.

## Economic Impact Calculations

Sample economic impact calculations are presented below to allow the reader to review how the factors in Table A were derived.

Restricted Use: Th-232

Option A. Full Removal of Volume to a Licensed Disposal Facility

| | | |
|---|---|---|
| \$ | 180 $yd^3$ | Excavation, Backfilling, Grading |
| \$ | 837 $yd^3$ | Disposal |
| \$ | 3 $yd^3$ | Clean Fill |
| \$ | 1020 $yd^3$ | |

Option B. Excavation of No More Material than Required to Meet the Allowed Dose, With Disposal At a Licensed Facility.

| R(Ratio of Pre- to Post-Remediation Concentration) | Fraction of Material to be Removed |
|---|---|
| 2 | (8 - 3.5)/8 = .56 |
| 3 | (8 – 2.5)/8 = .69 |
| 4 | (8 - 2)/8 = .75 |
| 5 | (8 - 1.5)/8 = .81 |
| 6 | (8 - 1.25)/8 = .84 |
| 7 | (8 - 1.0)/8 = .87 |
| 8 | (8 - 0)/8 = 1.0 |

Option C. Excavation of Full Volume and Blending/Backfilling

| | | |
|---|---|---|
| \$ | 180 $yd^3$ | Excavating, Backfilling, Grading |
| \$ | 145 $yd^3$ | Blending |

For the scenario when R = 2, the relative cost is;
{180 + (145 x 2)}/1020 = .46
For the scenario when R = 3, the relative cost is;
{180 + (145 X 3)}/1020 = .60

The factors multiplying the \$145 per $yd^3$ blending cost are derived by finding the volume of clean material necessary to blend down to the required concentrations, and adding that volume to the volume of contaminated soil. For example when R=2, one $yd^3$ of clean material must be blended with one $yd^3$ of contaminated material to reduce the concentration by one-half. Thus twice as much soil volume is processed, as compared to the contaminated volume.

Option D. Same as B, But Disperse Material On Site

| | | |
|---|---|---|
| \$ | 180 $yd^3$ | Excavating, Backfilling, Grading |
| \$ | <u>120 $yd^3$</u> | Spreading |
| \$ | 300 $yd^3$ | |

For the scenario when R=2, the relative cost is;
$\{(180 + 120) \times .56\}/1020 = .16$
For the scenario when R=3, the relative cost is;
$\{180 + 120) \times .69\}/1020 = .20$

Option E. Soil Treatment (gravity-based) and Backfilling. Assumes 80 percent of volume can be left on-site.

| | | |
|---|---|---|
| \$ | 350 $yd^3$ | Excavation, Disposal at Licensed Facility (20 percent of volume), Backfilling |
| \$ | <u>13 $yd^3$</u> | Soil Treatment (plant operation cost) |
| \$ | 363 $yd^3$ | |

For the scenario when R=2, the relative cost is;
$(363/1020) = 0.35$

The same cost fraction is obtained for other values of R because in each case the full amount of contaminated material on site must be processed.

The proposed new rules allow for options that were not available in the past and, therefore, result in a cost savings to the person conducting the remediation. Additionally, responsible parties who follow the proposed standards may realize a cost savings because they have the option of not hiring a consultant to perform a site specific dose and risk assessment.

With regard to the implementing agency, the time required to perform site reviews will decrease, resulting in a cost savings to the Department. Traditionally, individual sites submitted site-specific remediation criteria. The Department had to review a risk and dose assessment analysis for each separate site.

## Environmental Impact Analysis

The proposed new rules will have a positive effect in New Jersey. Environmental damage is reduced because the concentration of radioactive materials will be reduced once a remediation is completed. Animals are exposed to the same pathways as humans, through external exposure, inhalation, and ingestion of contaminated water and plants. Environmental damage may include abnormalities in plants and animals and malignancies in animals. Plant, animal and marine life directly benefit from a reduction of radioactive materials in their environment because ecosystems are protected and interrelationships among New Jersey's plant and animal life are preserved.

## Federal Standards Statement

Executive Order No. 27 (1994) and P.L. 1995, c.65 require State agencies which adopt, readopt or amend State regulations that exceed any Federal standards or requirements to include in the rulemaking document a Federal standards analysis.

The only Federal rules that can in any way be compared to this proposal are the U.S. Nuclear Regulatory Commission's (NRC) 10 C.F.R. Part 20 Subpart E, "Radiological Criteria for License Termination" (although this NRC rule is not applicable to state-regulated naturally occurring or accelerator-produced radioactive materials), and the Environmental Protection Agency's (EPA) 40 C.F.R. Part 192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings."

Comparison to 10 C.F.R. Part 20 Subpart E

There are four reasons why it is impossible to determine if the NRC standards are more or less stringent than the proposed standards.

- The NRC dose limit for license termination is 25 mrem per year, but soil remediation standards were not promulgated in these rules. Instead, the NRC has a process to determine a site-specific soil remediation number using a NRC dose model. In contrast, as required by the Brownfield and Contaminated Site Remediation Act, the proposed new rules develop generic soil remediation standards, expressed in picocuries per gram (pCi/g) of soil. Since the NRC rule does not contain concentration values, it is impossible to determine if one is more stringent than another.

- Furthermore, the NRC's final rule requires measures be taken to reduce doses to below 25 mrem/year by applying the concept that doses should be as low as reasonably achievable (ALARA). The proposed rules have no ALARA requirement, but are based on a 15 mrem/year dose standard. An examination of the methodology used by NRC to determine compliance with the ALARA limit shows that it is reasonable to assume that a 15 mrem/year dose standard would be achieved. The uncertainties due to modeling assumptions and measurement of radioactivity as described below would cause the person responsible for remediating a site to perform clean-up activities in a manner such that 15 mrem and 25 mrem with ALARA are virtually interchangeable. Therefore, the Federal rule and the State proposed rules can be considered to provide equivalent protection of public health.

- Some of the modeling assumptions used by the NRC that differ from those used by the Department include breathing rate, time spent indoors, time spent outdoors, amount of water consumed per year, and the amount of home-grown vegetation consumed each year. In addition, the NRC includes some pathways that are not included in the Department's model such as ingestion of fish from a contaminated surface water source, ingestion of animal products grown on-site, and ingestion of plant products from gardens irrigated with contaminated groundwater. On a site-specific basis, if any of these pathways were deemed appropriate, the Department could require the development of standards that include one or more of these pathways in accordance with N.J.A.C. 7:28-12.4(b). Again, the only accurate way to determine which rule is more stringent would be to compare soil radionuclide concentration values. The NRC did not publish concentration values as part of its decommissioning rule.

- Radioactivity measurements are subject to a random variation arising from the nature of the radioactive decay process itself. The rate of radioactive decay is not a constant with time, but fluctuates randomly about a mean or expectation value. Although the true value can never be known exactly, limits to the uncertainty can be inferred and estimated from the measurement process itself. This uncertainty is usually reported as a 95 percent confidence interval. Data are reported thus: $5 \pm 1.2$ pCi/g. This means that there is a 95 percent confidence that the true result is between 3.8 pCi/g and 6.2 pCi/g. Given this uncertainty in sample reporting, it is possible that the difference between a site-specific remediation standard for a NRC site and the proposed standard would be inconsequential because of the uncertainty in the analysis.

For example, assume that a site-specific NRC standard is determined to be 3.6 pCi/g and the proposed standard is 2.6 pCi/g. On the surface it appears that in this case, the proposed standard is more stringent than the NRC standard. However, when the samples are analyzed to show compliance, they are reported as 3.6$\pm$0.8 pCi/g, 2.6$\pm$0.4 pCi/g, 3.0$\pm$0.6 pCi/g and 2.9$\pm$0.5 pCi/g. Based on these reported results, one can conclude that there is a 95 percent confidence that the true value ranges from 2.2 to 4.4 pCi/g. Both standards are included within this range; therefore it can be said that the standards are equivalent. All the above uncertainties associated with modeling, sample analysis, and the radioactive decay process itself support the premise that the NRC dose limit of 25 mrem/yr cannot be directly compared to the proposed remediation standards.

For the reasons stated above, a direct comparison of the NRC decommissioning rule and the proposed rule is impossible due to the lack of soil concentration standards under 10 C.F.R. Part 20 Subpart E.

**Comparison to EPA regulations and Guidance Documents**

The EPA regulation, 40 C.F.R. Part 192, was promulgated for specific use at either Federally or state-owned uranium or thorium mill tailing sites. The standard for applications involving unrestricted use is found in Subpart B. This standard is for radium-226 only and is summarized as follows:

> Averaged over any 100 square meters, 5 pCi/g averaged over the first 15 centimeters (cm) of soil below the surface, and 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface. In any occupied or habitable building, a reasonable effort shall be made to achieve, an annual average radon decay product concentration (including background) not to exceed 0.02 Working Levels. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

However, in 1983, when 40 CFR Part 192 was published, the basic radiation protection criteria for members of the public was 500 mrem/yr (five mSv/yr). It is now 100 mrem/yr (one mSv/yr) TEDE. As explained in USEPA Directive No. 9200.4-25 (signed 2/12/98), the 15 pCi/g standard is not a health-based standard, but rather was derived as a practical measurement tool for use in locating discrete caches of high activity tailings that were deposited in subsurface locations at mill sites or at vicinity properties. It was not developed for situations where significant quantities of moderate or low activity materials are involved. It is only appropriate for use, as a cost-effective tool to locate radioactive waste, when contaminating subsurface materials are of high activity and are not expected to be significantly admixed with clean soil. The Directive states that "if the radioactive contamination at the site is unlike that at the uranium mill tailings sites regulated under 40 CFR Part 192, in that significant subsurface contamination exists at a level between 5 pCi/g to 30 pCi/g, the use of the 15 pCi/g standard is not generally appropriate. In this situation, we recommend 5 pCi/g as a suitable cleanup level for subsurface contamination, if a site-specific risk assessment demonstrates that 5 pCi/g is protective."

In Directive No. 9200.4-18 (signed August 20, 1997), the EPA establishes 15 mrem/yr as the acceptable annual dose that will meet the CERCLA risk range (3 $\times 10^{-4}$ ). It can accordingly be concluded that when a site-specific risk assessment is performed, it would have to demonstrate that the residual radioactive materials would contribute no more than 15 mrem/yr in order to be protective. This is the same requirement as is set forth in the proposed new rule at N.J.A.C. 7:28-12.8.

A direct comparison with 40 C.F.R. Part 192 cannot be made because it does not specify vertical extent of the remaining contamination or amount of uncontaminated surface soil. However, if a vertical extent of six inches and no uncontaminated surface soil is assumed, then the EPA rule and the proposed new rule would be the same. (The proposed rules would allow five pCi/g of radium-226 under these conditions.)

Therefore, based on the above analysis, the Department has determined that the proposed new rules do not contain any standards or requirements that exceed the standards or requirements imposed by Federal law to date. Accordingly, Executive Order 27 (1994) and P.L. 1995, c.65, do not require any further analysis.

## Jobs Impact

The number of jobs that will be created as a result of these rules depends on the methodology employed to clean up a site and the size of the site. The responsible party will most likely hire a consultant to perform the site characterization and feasibility studies and to write the reports required under N.J.A.C. 7:26E, Technical Requirements for Site Remediation. For a large, complex site, consultants would include technical project managers, site managers, scientists, engineers, health physicists, and statisticians. Implementing soil treatment as an option rather than removal and disposal may also create jobs.

Equipment would have to be purchased and trained operators would be needed to run the equipment.

If a site is remediated to limited restricted use or restricted use standards, redevelopment of the land will most likely include industrial or commercial operations which may add to the tax base and create job opportunities for the affected community.

No jobs would be lost by complying with these proposed rules.

## Agriculture Industry Impact

In accordance with P.L. 1998, c.48, an act amending the Right to Farm Act, the Department has reviewed the proposed new rules and has determined that they will have no impact upon the agriculture industry.

## Regulatory Flexibility Analysis

Persons responsible for conducting a remediation are usually not small businesses as defined by the Regulatory Flexibility Act, N.J.S.A. 52:14B-16 et seq.; however, there have been two recent remediation proposals submitted to the Department by businesses that would qualify as small businesses.

The compliance requirements of the proposed new rules (regarding cleaning up a site to the established standards) are designed to assist small businesses in that a site-specific risk and dose assessment can be avoided. By using the generic standards established in the rules, a small business will no longer have to hire a consultant to perform a site-specific risk and dose assessment and derive clean up standards. Depending on the complexities of the site, the costs associated with developing a site-specific risk and dose assessment, with subsequent revisions required by a Departmental review, could be substantial. It is also possible to develop less complex alternate remediation standards by using the Department's spreadsheet, which was developed to implement the proposed new standards. The spreadsheet, RaSoRS, and the accompanying user's manual, may be obtained by calling the Bureau of Environmental Radiation at (609) 984-5400 or by downloading them from the Radiation Protection Program's web site at http://www.state.nj.us/dep/rpp/index.htm and clicking on Contaminated Site Assessment.

In addition, a small business could save costs by choosing to comply with the limited restricted use or restricted use standards, thus saving on disposal costs.

Depending on the radionuclides at the site, this could translate into substantial cost savings, on the order of 50 to 75 percent. The disposal options outlined in the above Economic Impact Statement should also result in a savings of disposal costs. If a small business decided to petition the Department to accept an alternative standard because of site-specific features, the petitioning process will be simplified by the use of the Department's spreadsheet. The spreadsheet, along with the accompanying user's manual, allows a person responsible for remediating a site the flexibility of eliminating pathways, or changing certain parameters, while still complying with the dose limits of 15 mrem/year and three pCi/L (111 Bq/$m^3$) of radon (if radium is one of the contaminants). Some persons responsible for remediating a site may opt not to retain a consultant, possibly saving on costs.

Costs due to compliance with the reporting and sampling requirements as outlined in N.J.A.C.7:26D will not be increased as a consequence of the proposed new rules.

Due to the cost savings which are expected to result from the proposed new rules, the Department believes that no special exemption for small businesses is warranted.

Full text of the proposed new rules follows:

SUBCHAPTER 12. REMEDIATION STANDARDS FOR RADIOACTIVE MATERIALS

7:28-12.1 Purpose and scope

The purpose of this subchapter is to establish minimum standards for the remediation of real property contaminated by radioactive materials. This subchapter also provides direction on remediating a site contaminated with radioactive materials with regard to sampling, surveying, and laboratory requirements, remedial action selection, and remedial action requirements.

7:28-12.2 Applicability

(a) The standards in this subchapter are applicable to:

1. Remediation of radioactive contamination of real property by any naturally occurring radionuclide whose concentration has been enhanced by man-made physical or chemical processes;

2. Remediation of radioactive contamination of real property by

accelerator-produced radionuclides; and

3. Any other remediation of radioactive contamination including, without limitation, any remediation pursuant to: the Spill Compensation and Control Act, N.J.S.A. 58:10-23.11 et seq.; the Water Pollution Control Act, N.J.S.A. 58:10A-1 et seq.; the Industrial Site Recovery Act, N.J.S.A. 13:1K-6 et seq.; the Solid Waste Management Act, N.J.S.A. 13:1E-1 et seq.; the Comprehensive Regulated Medical Waste Management Act, N.J.S.A. 13:1E-48.1 et seq.; the Major Hazardous Waste Facilities Siting Act, N.J.S.A. 13:1E-49 et seq.; the Sanitary Landfill Facility Closure and Contingency Fund Act, N.J.S.A. 13:1E-100 et seq.; the Regional Low Level Radioactive Waste Disposal Facility Siting Act, N.J.S.A. 13:1E-177 et seq.; any law or regulation by which the State may compel a person to perform remediation activities; or N.J.A.C. 7:26C.

(b) The standards in this subchapter are not applicable to:

1. Materials containing naturally occurring radionuclides whose concentrations have not been enhanced by man-made physical or chemical processes, such as coal or quarry stone; or

2. Coal ash that has been or is being used in:

i. The manufacture of construction materials including, but not limited to, cinder blocks, concrete products and roofing materials;

ii. Road construction materials including, but not limited to, asphalt filler or road base material; or

iii. Landfill cover.

(c) The Department shall apply the radiation soil standards in this chapter at applicable sites as "Applicable or Relevant and Appropriate Requirements" as defined in the Comprehensive Environmental Response, Compensation and Liability Act, 42 U.S.C. §§ 9601 et seq.

7:28-12.3 Definitions

The following words and terms, when used in this subchapter, shall have the following meanings, unless the context clearly indicates otherwise:

"Appropriate period of time" means the length of time required for the radionuclide to decay seven half-lives.

"Committed dose equivalent" means the total dose equivalent averaged throughout any body tissue in the 50 years after intake of a radionuclide into the body.

"Committed effective dose equivalent" means the sum of the products of the committed dose equivalents to individual tissues resulting from an intake of a radionuclide multiplied by the appropriate weighting factor ($W_T$) indicated below:

| Organ or Tissue | $w_T$ |
|---|---|
| Gonads | 0.25 |
| Breast | 0.15 |
| Red bone marrow | 0.12 |
| Lung | 0.12 |
| Thyroid | 0.03 |
| Bone Surfaces | 0.03 |
| Remainder | 0.30* |
| Whole Body (external) | 1.00 |

*0.30 results from 0.06 for each of five "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

"Deep-dose equivalent" means, applied to external whole-body exposure, the dose equivalent at a tissue depth of one centimeter.

"Design features" means those features of a remediation that do not rely on additional expenditures after installation to achieve their intended purpose.

"Dose equivalent" means the product of the absorbed dose (D), the quality factor (Q), and other modifying factors (N). For the purposes of this definition, N = 1.

"Engineering controls" means any mechanism to contain or stabilize contamination or ensure the effectiveness of a remedial action. Engineering controls under this subchapter may include, without limitation, caps, covers, dikes, trenches, leachate collection systems, radon remediation systems, signs, fences and physical access controls.

"Enhanced" means raised to a higher concentration. For example, if the concentration of radium-226 in native soil was one pCi/g (0.04 Bq/g), and a physical or chemical separation process raised the concentration of radium-226 to two pCi/g (0.07 Bq/g), this would be considered "enhanced."

"Final status survey" is a survey or analysis, performed after remediation, which provides data that demonstrates that all radiological parameters satisfy the remediation standards.

"Institutional controls" means a mechanism used to limit human activities at or near a contaminated site, or to ensure the effectiveness of the remedial action over time, when contaminants remain at a site in levels or concentrations above the applicable remediation standard that would allow unrestricted use of that property. Institutional controls under this subchapter may include, without limitation, structure, land and natural resource use restrictions, well restriction areas, classification exception areas, deed notices, and declarations of environmental restrictions.

"Intake dose" means the annual radiation dose to a person from all potential intake pathways (exclusive of radon inhalation) including the ingestion of water, direct ingestion of soil, intake of foods, and the inhalation of resuspended particulate matter (in committed effective dose equivalent).

"Limited restricted-use remedial action" means any remedial action that requires the continued use of institutional controls but does not require the use of an engineering control.

"Natural background radionuclide concentration" means the average value of a particular radionuclide concentration in soils measured in areas in the vicinity of the site, in an area that has not been influenced by localized human activities, including the site's prior or current operations.

"Quality factor" means the factor by which absorbed doses are multiplied to obtain a quantity that expresses the effectiveness of the absorbed dose on a common scale for all types of ionizing radiation.

"Radioactive contamination or radioactive contaminant" means the collective amount of radiation emitted from one or more radionuclides in the soil at concentrations above natural background levels.

"Radionuclide" means a type of atom that spontaneously undergoes radioactive decay.

"Regional natural background variation" means the best Department estimate, based on available data, of a region's naturally experienced variation in radiation dose from mean levels that are commonly and consistently experienced by persons in the State.

"Remedial action" means those actions taken at a site, or offsite if a radioactive contaminant has migrated or is migrating there from a radioactively contaminated site as may be required by the Department, including, without limitation, removal, treatment, containment, transportation, securing, or other engineering or treatment measures, whether to an unrestricted use or otherwise, designed to ensure that any discharged radioactive contaminant at the site, or that has migrated or is migrating from the site, is remediated in compliance with the applicable remediation standards in this subchapter.

"Remediation" or "remediate" means all necessary actions to investigate and cleanup or respond to any known, suspected, or threatened discharge of radioactive contaminants, including, as necessary, the preliminary assessment, site investigation, remedial investigation, and remedial action.

"Remediation standards" means the combination of numeric standards that establish a level or concentration, and narrative standards, to which radioactive contaminants must be treated, removed or otherwise cleaned for soil, ground water or surface water, as provided by the Department pursuant to N.J.S.A. 58:10B-12, in order to meet the health risk or environmental standards.

"Residual radionuclides" means the concentration of radionuclides remaining after the remediation is successfully completed.

"Restricted use remedial action" means any remedial action that requires the continued use of engineering and institutional controls in order to meet the established health risk or environmental standards.

"Total effective dose equivalent" means the sum of the deep- dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

"Uncontaminated surface soil" means soil whose average natural background radionuclide concentrations are less than the concentrations of the residual radionuclides, and cannot exceed the background established for the site by more than 20 percent.

"Unrestricted use remedial action" means any remedial action that does not require the continued use of engineering or institutional controls in order to meet the established standards.

"Vertical extent" means the average depth, measured in feet, of the post-remediation radioactive contamination over an affected area.

7:28-12.4 General requirements

(a) Any person conducting remediation pursuant to this subchapter shall comply with the requirements of N.J.A.C. 7:26E, Technical Requirements for Site Remediation, excluding those sections related to sampling, surveying, and background investigations. Sampling, surveying and laboratory requirements shall be in accordance with N.J.A.C. 7:28-12.5.

(b) Compliance with this subchapter shall not relieve any person from complying with more stringent cleanup standards or provisions imposed by any other applicable statute, rule or regulation.

7:28-12.5 Sampling, surveying and laboratory requirements

(a) Facilities licensed under 10 C.F.R. Part 50 that have Nuclear Regulatory Commission-approved quality assurance plans, are exempt from the requirements of this section. Otherwise, in addition to the requirements in N.J.A.C. 7:26E Appendix A IV.1, persons responsible for conducting remediations shall include the following in the radionuclide analysis reports:

1. Report final results as a value plus or minus the associated error for each sample;

2. Report data as calculated, and not report "less than" values for any sample;

3. Calculate results for single sample and composites to the sample collection period mid point;

4. Provide a quantitation report; and

5. Provide copies of the instrument run logs.

(b) As appropriate, persons responsible for conducting remediations shall provide:

1. The Gamma Spectroscopy Report which includes sample specific header information, peak search, peak identification, background subtraction, activity, and minimum detectable activity;

2. The Gross Beta calculation worksheets and computer generated result forms;

3. Radiochemical Iodine calculation worksheets and computer generated result forms;

4. Liquid Scintillation calculation worksheets and computer-generated result forms; and

5. Gross Alpha and Gross Beta, radium-226, uranium, and strontium-89 and 90 calculation worksheets and computer- generated result forms.

(c) For radionuclides, analytical methods contained in the following publications, incorporated herein by reference, or equivalents as approved by the Department, shall be used for determining radionuclide concentrations and/or radiation levels:

1. U.S. Environmental Protection Agency; "Prescribed Procedures for Measurement of Radioactivity in Drinking Water," EPA 600/4-80-32, as amended and supplemented. This document may be obtained from the USEPA National Air and Radiation Environmental Laboratory, 540 S. Morris Ave., Montgomery, AL 36115-2601;

2. U.S. Department of Energy; "Environmental Measurements Laboratory -- Procedures Manual," HASL-300, 27th Ed., Vol. 1., as amended and supplemented. This document may be obtained from the US Department of Energy, Environmental Measurements Laboratory, 201 Varick St., 5th Floor, New York, NY 10014-4811; and/or

3. U.S. Environmental Protection Agency Eastern Environmental Radiation Facility; "Radiochemistry Procedures Manual," EPA 520/5-84-006, as amended and supplemented. This document may be obtained from the address in (c) 1 above.

(d) Any laboratory providing radiological analysis for soil shall be certified pursuant to N.J.A.C. 7:18 for radionuclide analysis in water and, in addition, shall have participated in and passed a soil intercomparison analysis administered by either the International Atomic Energy Agency or the U.S. Department of Energy's Environmental Measurements Laboratory within the year preceding the radiological analysis.

(e) Sampling and surveying for radioactive contamination shall be done in accordance with the protocol specified in that version of the Department of Environmental Protection's Field Sampling Procedure Manual's section on Radiological Assessment, incorporated herein by reference, in effect at the time of sampling and surveying which may be obtained by calling the Bureau of Environmental Radiation at (609) 984-5400 or from the Radiation Protection Program's web site at http://www.state.nj.us/dep/rpp/index.htm.

7:28-12.6 Remedial action selection

Remedial action selection for all sites contaminated with radioactive material shall be in accordance with N.J.A.C. 7:26E-5.

7:28-12.7 Remedial action requirements

The remedial action requirements for all sites contaminated with radioactive material shall be in accordance with N.J.A.C. 7:26E-6, with the exception of N.J.A.C. 7:26E-6.4, Post-remedial action requirements. Post-remedial sampling shall be conducted in accordance with the guidance provided in that version of the Department of Environmental Protection's Field Sampling Procedure Manual's section on Radiological Assessment, in effect at the time of the post-remedial sampling.

7:28-12.8 Radiation dose standards applicable to remediation of radioactive contamination of all real property

(a) Sites shall be remediated so that the incremental radiation dose to any person from any residual radioactive contamination at the site above that due to natural background radionuclide concentration, under either an unrestricted use remedial action, limited restricted use remedial action, or a restricted use remedial action, shall be as specified below:

1. For the sum of annual external gamma radiation dose (in effective dose equivalent) and intake dose (in committed effective dose equivalent): 15 millirem

(0.15 milliSievert) total annual effective dose equivalent (15 mrem/yr TEDE).

2. For radon: three picocuries per liter (pCi/L) of radon gas (111 $Bq/m^3$).

3. Radioactively contaminated ground water shall be remediated to comply with the New Jersey Groundwater Quality Standards rules, N.J.A.C. 7:9-6.

7:28-12.9 Minimum remediation standards for radionuclide contamination of soil

(a) For radioactive contamination in soils, the requirements of N.J.A.C. 7:28-12.8 shall be considered to be met for a specific radionuclide if:

1. Where only one radionuclide adds to the radioactive contamination of the site, the incremental concentration of the radionuclide above the natural background radionuclide concentration does not exceed the value in Table 1A, 1B (for unrestricted use), 2A, 2B (for limited restricted use), 3A, or 3B (for restricted use) below;

**Table 1A Allowed Incremental Concentration of Individual Radionuclides in Soils; Unrestricted Use Standards for Radioactive Contamination (pCi/g)(1)**

| Radionuclide | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238(2) | 59 | 37 | 27 | 21 | 17 | 15 | 13 | 11 | 10 |
| U234(2) | 63 | 37 | 27 | 21 | 17 | 14 | 12 | 11 | 10 |
| Ra226(3) | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| U235(2) | 36 | 25 | 19 | 15 | 13 | 11 | 10 | 8 | 8 |
| Ac227 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Th232 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

**Table 1B Allowed Incremental Concentration of Individual Radionuclides in Soils; Unrestricted Use Standards for Radioactive Contamination (Bq/g)(1)**

| Radionuclide | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238(2) | 2.19 | 1.36 | 0.99 | 0.77 | 0.64 | 0.54 | 0.47 | 0.41 | 0.37 |
| U234(2) | 2.32 | 1.38 | 0.99 | 0.77 | 0.63 | 0.53 | 0.46 | 0.41 | 0.36 |
| Ra226(3) | 0.13 | 0.11 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| U235(2) | 1.35 | 0.92 | 0.70 | 0.55 | 0.48 | 0.41 | 0.36 | 0.29 | 0.29 |
| Ac227 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| Th232 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.06 | 0.06 |

**Table 2A Allowed Incremental Concentration of Individual Radionuclides in Soils; Limited Restricted Use Standards for Radioactive Contamination (pCi/g)[1]**

| Radionuclide | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238[2] | 71 | 44 | 32 | 25 | 20 | 17 | 15 | 13 | 12 |
| U234[2] | 72 | 43 | 31 | 24 | 20 | 17 | 14 | 13 | 11 |
| Ra226[3] | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| U235[2] | 50 | 33 | 25 | 20 | 17 | 14 | 12 | 11 | 10 |
| Ac227 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Th232 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 |

**Table 2B Allowed Incremental Concentration of Individual Radionuclides in Soils; Limited Restricted Use Standards for Radioactive Contamination (Bq/g)[1]**

| Radionuclide | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238[2] | 2.63 | 1.62 | 1.17 | 0.92 | 0.75 | 0.64 | 0.55 | 0.49 | 0.44 |
| U234[2] | 2.65 | 1.59 | 1.14 | 0.89 | 0.73 | 0.61 | 0.53 | 0.47 | 0.42 |
| Ra226[3] | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| U235[2] | 1.83 | 1.24 | 0.93 | 0.74 | 0.61 | 0.52 | 0.46 | 0.40 | 0.36 |
| Ac227 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.21 | 0.21 | 0.21 |
| Th232 | 0.24 | 0.24 | 0.23 | 0.22 | 0.21 | 0.20 | 0.19 | 0.17 | 0.17 |

**Table 3A Allowed Incremental Concentration of Individual Radionuclides in Soils; Restricted Use Standards for Radioactive Contamination[1] (pCi/g)**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238[2] | USS 1 | 84 | 47 | 33 | 25 | 21 | 17 | 15 | 13 | 12 |
| | USS 2 | 85 | 47 | 33 | 25 | 21 | 17 | 15 | 13 | 12 |
| | USS 3 | 85 | 47 | 33 | 25 | 21 | 17 | 15 | 13 | 12 |
| | USS 4 | 85 | 48 | 33 | 25 | 21 | 18 | 15 | 13 | 12 |
| | USS 5 | 86 | 48 | 33 | 26 | 21 | 18 | 15 | 14 | 12 |
| U234[2] | USS 1 | 81 | 45 | 31 | 24 | 20 | 17 | 14 | 13 | 11 |
| | USS 2 | 81 | 45 | 31 | 24 | 20 | 17 | 14 | 13 | 11 |
| | USS 3 | 81 | 45 | 32 | 25 | 20 | 17 | 15 | 13 | 11 |
| | USS 4 | 81 | 46 | 32 | 25 | 20 | 17 | 15 | 13 | 11 |
| | USS 5 | 83 | 46 | 32 | 25 | 20 | 17 | 15 | 13 | 12 |
| Ra226[3] | USS 1 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 2 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 3 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 4 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 5 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| U235[2] | USS 1 | 67 | 39 | 27 | 21 | 17 | 14 | 12 | 11 | 10 |
| | USS 2 | 72 | 40 | 28 | 21 | 17 | 14 | 12 | 11 | 10 |
| | USS 3 | 73 | 40 | 28 | 21 | 17 | 14 | 13 | 11 | 10 |
| | USS 4 | 73 | 40 | 28 | 21 | 17 | 15 | 13 | 11 | 10 |
| | USS 5 | 73 | 40 | 28 | 21 | 18 | 15 | 13 | 12 | 10 |
| Ac227 | USS 1 | 20 | 11 | 8 | 6 | 6 | 6 | 6 | 6 | 6 |
| | USS 2 | 122 | 12 | 8 | 8 | 8 | 7 | 7 | 7 | 7 |
| | USS 3 | 22 | 12 | 12 | 10 | 8 | 8 | 8 | 8 | 8 |
| | USS 4 | 22 | 18 | 13 | 10 | 9 | 9 | 9 | 9 | 9 |
| | USS 5 | 32 | 18 | 13 | 12 | 12 | 12 | 12 | 12 | 12 |
| Th232 | USS 1 | 21 | 15 | 11 | 9 | 7 | 6 | 5 | 5 | 5 |
| | USS 2 | 36 | 18 | 12 | 9 | 7 | 6 | 5 | 5 | 5 |
| | USS 3 | 36 | 18 | 12 | 9 | 7 | 6 | 6 | 6 | 6 |
| | USS 4 | 36 | 18 | 12 | 9 | 7 | 7 | 7 | 7 | 7 |
| | USS 5 | 36 | 18 | 12 | 9 | 9 | 9 | 9 | 9 | 9 |

**Table 3B** **Allowed Incremental Concentration of Individual Radionuclides in Soils; Restriced Use Standards for Radioactive Contamination[1] (Bq/g)**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238[2] | USS 1 | 3.11 | 1.74 | 1.21 | 0.92 | 0.76 | 0.64 | 0.55 | 0.49 | 0.44 |
| | USS 2 | 3.15 | 1.75 | 1.21 | 0.94 | 0.76 | 0.64 | 0.56 | 0.49 | 0.44 |
| | USS 3 | 3.16 | 1.75 | 1.23 | 0.94 | 0.76 | 0.64 | 0.56 | 0.49 | 0.44 |
| | USS 4 | 3.16 | 1.78 | 1.23 | 0.94 | 0.77 | 0.65 | 0.56 | 0.50 | 0.45 |
| | USS 5 | 3.20 | 1.78 | 1.23 | 0.95 | 0.78 | 0.66 | 0.57 | 0.50 | 0.45 |
| U234[2] | USS 1 | 3.01 | 1.67 | 1.16 | 0.89 | 0.73 | 0.61 | 0.53 | 0.47 | 0.42 |
| | USS 2 | 3.01 | 1.67 | 1.16 | 0.90 | 0.73 | 0.62 | 0.54 | 0.47 | 0.42 |
| | USS 3 | 3.01 | 1.67 | 1.18 | 0.91 | 0.74 | 0.62 | 0.54 | 0.47 | 0.42 |
| | USS 4 | 3.01 | 1.71 | 1.19 | 0.91 | 0.74 | 0.62 | 0.54 | 0.48 | 0.43 |
| | USS 5 | 3.07 | 1.71 | 1.19 | 0.92 | 0.74 | 0.63 | 0.54 | 0.48 | 0.43 |
| Ra226[3] | USS 1 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 2 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 3 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 4 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 5 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| U235[2] | USS 1 | 2.49 | 1.43 | 1.00 | 0.77 | 0.63 | 0.53 | 0.46 | 0.40 | 0.36 |
| | USS 2 | 2.68 | 1.48 | 1.03 | 0.78 | 0.63 | 0.53 | 0.46 | 0.41 | 0.37 |
| | USS 3 | 2.69 | 1.48 | 1.03 | 0.78 | 0.63 | 0.53 | 0.47 | 0.42 | 0.38 |
| | USS 4 | 2.69 | 1.48 | 1.03 | 0.78 | 0.64 | 0.54 | 0.48 | 0.42 | 0.38 |
| | USS 5 | 2.69 | 1.48 | 1.03 | 0.79 | 0.65 | 0.56 | 0.48 | 0.43 | 0.39 |
| Ac227 | USS 1 | 0.75 | 0.43 | 0.30 | 0.23 | 0.23 | 0.23 | 0.21 | 0.21 | 0.21 |
| | USS 2 | 0.80 | 0.44 | 0.30 | 0.30 | 0.29 | 0.25 | 0.24 | 0.24 | 0.24 |
| | USS 3 | 0.81 | 0.44 | 0.44 | 0.36 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| | USS 4 | 0.81 | 0.67 | 0.47 | 0.36 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | USS 5 | 1.17 | 0.67 | 0.47 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Th232 | USS 1 | 0.81 | 0.55 | 0.42 | 0.33 | 0.26 | 0.22 | 0.19 | 0.17 | 0.17 |
| | USS 2 | 1.31 | 0.66 | 0.44 | 0.33 | 0.26 | 0.22 | 0.19 | 0.19 | 0.19 |
| | USS 3 | 1.31 | 0.66 | 0.44 | 0.33 | 0.26 | 0.22 | 0.22 | 0.22 | 0.22 |
| | USS 4 | 1.31 | 0.66 | 0.44 | 0.33 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| | USS 5 | 1.31 | 0.66 | 0.44 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |

[1]The allowed Incremental Concentrations are added to the natural background radionuclide concentration to obtain the absolute value of the allowed radionuclide concentration following site remediation.

[2]These allowable concentrations may however, further be limited by the chemical toxicity of uranium. Applicants should inquire with NJDEP's Site Remediation Program for the additional applicable chemical cleanup standards for uranium.

[3]When more than one nuclide is present, use the Radium-226 Table in Appendix A, incorporated herein by reference, for applying the sum of the fractions rule. Then use whatever number is more restrictive for radium-226.

2. Where more than one radionuclide contaminant is present at the site, their concentrations meet the sum of the fractions as described below:

$$\text{Sum of } \frac{CA_i}{C_i} \leq 1$$

where:

$CA_i$ = the incremental concentration of radionuclide i at the site, and

$C_i$ = the incremental allowed concentration of radionuclide i from Table 1A, 1B, 2A, 2B, 3A, or 3B above, if it were [illegible]ly remaining radionuclide at the site; and

3. Natural background radionuclide concentration shall be established by the methods presented in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, EPA 402-R-97-018, and any subsequent revisions thereto.

(b) As an alternate, the requirements of N.J.A.C. 7:28-12.8 shall be considered to be met for a specific radionuclide if:

1. Where only one radionuclide adds to the radioactive contamination of the site, the incremental concentration of the radionuclide above the natural background radionuclide concentration and the amount of uncontaminated surface soil meet the pre-mixing values in Table 4A, 4B (for unrestricted use), 5A, or 5B (for limited restricted use) below;

**Table 4A Allowed Incremental Concentration of Individual Radionuclides in Soils and Required Depth of USS; Pre-Mixing Values-Unrestricted Use (pCi/g)[1]**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclides (VE) VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
|---|---|---|---|---|---|---|---|---|---|---|
| U238[2] | USS 1 | 74 | 40 | 28 | 21 | 17 | 15 | 13 | 11 | 10 |
| | USS 2 | 77 | 41 | 28 | 22 | 18 | 15 | 13 | 11 | 10 |
| | USS 3 | 78 | 42 | 29 | 22 | 18 | 15 | 13 | 11 | 10 |
| | USS 4 | 79 | 42 | 29 | 22 | 18 | 15 | 13 | 12 | 10 |
| | USS 5 | 79 | 42 | 29 | 22 | 18 | 15 | 13 | 12 | 10 |
| U234[2] | USS 1 | 75 | 40 | 27 | 21 | 17 | 14 | 12 | 11 | 10 |
| | USS 2 | 75 | 40 | 27 | 21 | 17 | 15 | 13 | 11 | 10 |
| | USS 3 | 75 | 40 | 28 | 22 | 17 | 15 | 13 | 11 | 10 |
| | USS 4 | 76 | 42 | 28 | 22 | 18 | 15 | 13 | 11 | 10 |
| | USS 5 | 78 | 42 | 28 | 22 | 18 | 15 | 13 | 11 | 10 |
| Ra226[3] | USS 1 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 2 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 3 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 4 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 5 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| U235[2] | USS 1 | 55 | 29* | 22 | 17 | 13 | 11 | 10 | 8 | 8 |
| | USS 2 | 58* | 31* | 22 | 17 | 14 | 11 | 10 | 9 | 8 |
| | USS 3 | 62* | 34 | 22 | 17 | 14 | 11 | 10 | 9 | 8 |
| | USS 4 | 67 | 34 | 22 | 17 | 13 | 12 | 10 | 9 | 8 |
| | USS 5 | 67 | 34 | 22 | 17 | 14 | 12 | 11 | 9 | 8* |
| Ac227 | USS 1 | 5* | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| | USS 2 | 5* | 5 | 4 | 4 | 3* | 3 | 3 | 3 | 3 |
| | USS 3 | 9 | 6 | 5* | 4* | 4 | 4 | 3* | 3* | 3* |
| | USS 4 | 12* | 7* | 6 | 5 | 4 | 4 | 4 | 4 | 3* |
| | USS 5 | 14* | 9 | 6 | 5* | 5* | 4* | 4* | 4* | 4* |
| Th232 | USS 1 | 7 | 5 | 4 | 3 | 3 | 2 | 2 | 2 | 2 |
| | USS 2 | 11* | 7 | 5 | 3 | 3 | 2 | 2 | 2 | 2 |
| | USS 3 | 11* | 7 | 5 | 3 | 3 | 2 | 2 | 2 | 2 |
| | USS 4 | 14 | 7 | 5 | 3 | 3 | 3 | 3 | 3 | 3 |
| | USS 5 | 15 | 7 | 5 | 3 | 3 | 3 | 3 | 3 | 3 |

**Table 4B Allowed Incremental Concentration of Individual Radionuclides in Soils and Required Depth of USS; Pre-Mixing Values-Unrestricted Use (Bq/g)(1)**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclides (VE) VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
|---|---|---|---|---|---|---|---|---|---|---|
| U238(2) | USS 1 | 2.73 | 1.49 | 1.03 | 0.79 | 0.64 | 0.55 | 0.47 | 0.41 | 0.37 |
| | USS 2 | 2.86 | 1.53 | 1.05 | 0.81 | 0.65 | 0.55 | 0.47 | 0.42 | 0.38 |
| | USS 3 | 2.88 | 1.55 | 1.07 | 0.81 | 0.65 | 0.55 | 0.48 | 0.42 | 0.38 |
| | USS 4 | 2.92 | 1.57 | 1.07 | 0.81 | 0.66 | 0.56 | 0.48 | 0.43 | 0.38 |
| | USS 5 | 2.93 | 1.57 | 1.07 | 0.82 | 0.67 | 0.56 | 0.49 | 0.43 | 0.39 |
| U234(2) | USS 1 | 2.77 | 1.48 | 1.01 | 0.77 | 0.63 | 0.53 | 0.46 | 0.41 | 0.36 |
| | USS 2 | 2.77 | 1.48 | 1.02 | 0.79 | 0.64 | 0.54 | 0.47 | 0.41 | 0.37 |
| | USS 3 | 2.78 | 1.50 | 1.04 | 0.80 | 0.64 | 0.54 | 0.47 | 0.41 | 0.37 |
| | USS 4 | 2.82 | 1.54 | 1.05 | 0.80 | 0.65 | 0.55 | 0.47 | 0.42 | 0.37 |
| | USS 5 | 2.88 | 1.54 | 1.05 | 0.81 | 0.65 | 0.55 | 0.47 | 0.42 | 0.37 |
| Ra226(3) | USS 1 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 2 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 3 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 4 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 5 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| U235(2) | USS 1 | 2.05 | 1.07* | 0.81 | 0.62 | 0.48 | 0.42 | 0.36 | 0.29 | 0.29 |
| | USS 2 | 2.15* | 1.15* | 0.81 | 0.63 | 0.51 | 0.42 | 0.36 | 0.32 | 0.29 |
| | USS 3 | 2.30* | 1.26 | 0.81 | 0.63 | 0.51 | 0.42 | 0.37 | 0.33 | 0.30 |
| | USS 4 | 2.49 | 1.26 | 0.81 | 0.63 | 0.48 | 0.43 | 0.38 | 0.34 | 0.31 |
| | USS 5 | 2.49 | 1.26 | 0.81 | 0.63 | 0.52 | 0.45 | 0.40 | 0.33 | 0.30* |
| Ac227 | USS 1 | 0.18* | 0.15 | 0.11 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | USS 2 | 0.18* | 0.17 | 0.13 | 0.13 | 0.11* | 0.11 | 0.11 | 0.11 | 0.11 |
| | USS 3 | 0.34 | 0.21 | 0.18* | 0.15* | 0.14 | 0.13 | 0.11* | 0.11* | 0.11* |
| | USS 4 | 0.44* | 0.26* | 0.22 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.11* |
| | USS 5 | 0.52* | 0.32 | 0.22 | 0.18* | 0.18* | 0.15* | 0.15* | 0.15* | 0.15* |
| Th232 | USS 1 | 0.27 | 0.19 | 0.15 | 0.11 | 0.11 | 0.09 | 0.08 | 0.06 | 0.06 |
| | USS 2 | 0.41* | 0.27 | 0.18 | 0.11 | 0.11 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 3 | 0.41* | 0.28 | 0.18 | 0.11 | 0.11 | 0.09 | 0.09 | 0.09 | 0.09 |
| | USS 4 | 0.52 | 0.28 | 0.18 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| | USS 5 | 0.52 | 0.28 | 0.18 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |

**Table 5A Allowed Incremental Concentration of Individual Radionuclides in Soils and Required Depth of USS; Pre-Mixing Values-Limited Restricted Use (pCi/g)[1]**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclides (VE) VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
|---|---|---|---|---|---|---|---|---|---|---|
| U238[2] | USS 1 | 84 | 47 | 33 | 25 | 21 | 17 | 15 | 13 | 12 |
| | USS 2 | 85 | 47 | 33 | 25 | 21 | 17 | 15 | 13 | 12 |
| | USS 3 | 85 | 47 | 33 | 25 | 21 | 17 | 15 | 13 | 12 |
| | USS 4 | 85 | 48 | 33 | 25 | 21 | 18 | 15 | 13 | 12 |
| | USS 5 | 86 | 48 | 33 | 26 | 21 | 18 | 15 | 14 | 12 |
| U234[2] | USS 1 | 81 | 45 | 31 | 24 | 20 | 17 | 14 | 13 | 11 |
| | USS 2 | 81 | 45 | 31 | 24 | 20 | 17 | 14 | 13 | 11 |
| | USS 3 | 81 | 45 | 32 | 25 | 20 | 17 | 15 | 13 | 11 |
| | USS 4 | 81 | 46 | 32 | 25 | 20 | 17 | 15 | 13 | 11 |
| | USS 5 | 83 | 46 | 32 | 25 | 20 | 17 | 15 | 13 | 12 |
| Ra226[3] | USS 1 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 2 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 3 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 4 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| | USS 5 | 7 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| U235[2] | USS 1 | 67 | 38* | 27 | 21 | 17 | 14 | 12 | 11 | 10 |
| | USS 2 | 72 | 40 | 28 | 21 | 17 | 14 | 12 | 11 | 10 |
| | USS 3 | 73 | 40 | 28 | 21 | 17 | 14 | 13 | 11 | 10 |
| | USS 4 | 73 | 40 | 28 | 21 | 17 | 15 | 13 | 11 | 10 |
| | USS 5 | 73 | 40 | 28 | 21 | 18 | 15 | 13 | 12 | 10 |
| Ac227 | USS 1 | 12* | 9* | 8 | 6 | 6 | 6 | 6 | 6 | 6 |
| | USS 2 | 18* | 12 | 8 | 8 | 8 | 7 | 7 | 7 | 7 |
| | USS 3 | 22 | 12 | 12 | 10 | 8 | 8 | 8 | 8 | 8 |
| | USS 4 | 22 | 18 | 13 | 10 | 9 | 9 | 9 | 9 | 9 |
| | USS 5 | 32 | 18 | 13 | 12 | 12 | 11* | 10* | 10* | 9* |
| Th232 | USS 1 | 15* | 11* | 10* | 9 | 7 | 6 | 5 | 5 | 5 |
| | USS 2 | 22* | 15* | 12 | 9 | 7 | 6 | 5 | 5 | 5 |
| | USS 3 | 30* | 18 | 12 | 9 | 7 | 6 | 6 | 6 | 6 |
| | USS 4 | 36 | 18 | 12 | 9 | 7 | 7 | 7 | 7 | 7 |
| | USS 5 | 36 | 18 | 12 | 9 | 9 | 9 | 9 | 9 | 9 |

**Table 5B** **Allowed Incremental Concentration of Individual Radionuclides in Soils and Required Depth of USS; Pre-Mixing Values-Limited Restriced Use[1] (Bq/g)**

| Feet of Uncontaminated | | Feet of Vertical Extent of Residual Radionuclides (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Surface Soil (USS) | | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| U238[2] | USS 1 | 3.11 | 1.74 | 1.21 | 0.92 | 0.76 | 0.64 | 0.55 | 0.49 | 0.44 |
| | USS 2 | 3.15 | 1.75 | 1.21 | 0.94 | 0.76 | 0.64 | 0.56 | 0.49 | 0.44 |
| | USS 3 | 3.16 | 1.75 | 1.23 | 0.94 | 0.76 | 0.64 | 0.56 | 0.49 | 0.44 |
| | USS 4 | 3.16 | 1.78 | 1.23 | 0.94 | 0.77 | 0.65 | 0.56 | 0.50 | 0.45 |
| | USS 5 | 3.20 | 1.78 | 1.23 | 0.95 | 0.78 | 0.66 | 0.57 | 0.50 | 0.45 |
| U234[2] | USS 1 | 3.01 | 1.67 | 1.16 | 0.89 | 0.73 | 0.61 | 0.53 | 0.47 | 0.42 |
| | USS 2 | 3.01 | 1.67 | 1.16 | 0.90 | 0.73 | 0.62 | 0.54 | 0.47 | 0.42 |
| | USS 3 | 3.01 | 1.67 | 1.18 | 0.91 | 0.74 | 0.62 | 0.54 | 0.47 | 0.42 |
| | USS 4 | 3.01 | 1.71 | 1.19 | 0.91 | 0.74 | 0.62 | 0.54 | 0.48 | 0.43 |
| | USS 5 | 3.07 | 1.71 | 1.19 | 0.92 | 0.74 | 0.63 | 0.54 | 0.48 | 0.43 |
| Ra226[3] | USS 1 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 2 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 3 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 4 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| | USS 5 | 0.28 | 0.13 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 |
| U235[2] | USS 1 | 2.49 | 1.41* | 1.00 | 0.77 | 0.63 | 0.53 | 0.46 | 0.40 | 0.36 |
| | USS 2 | 2.68 | 1.48 | 1.03 | 0.78 | 0.63 | 0.53 | 0.46 | 0.41 | 0.37 |
| | USS 3 | 2.69 | 1.48 | 1.03 | 0.78 | 0.63 | 0.53 | 0.47 | 0.42 | 0.38 |
| | USS 4 | 2.69 | 1.48 | 1.03 | 0.78 | 0.64 | 0.54 | 0.48 | 0.42 | 0.38 |
| | USS 5 | 2.69 | 1.48 | 1.03 | 0.79 | 0.65 | 0.56 | 0.48 | 0.43 | 0.39 |
| Ac227 | USS 1 | 0.44* | 0.33* | 0.30 | 0.23 | 0.23 | 0.23 | 0.21 | 0.21 | 0.21 |
| | USS 2 | 0.67* | 0.44 | 0.30 | 0.30 | 0.29 | 0.25 | 0.24 | 0.24 | 0.24 |
| | USS 3 | 0.81 | 0.44 | 0.44 | 0.36 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| | USS 4 | 0.81 | 0.67 | 0.47 | 0.36 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | USS 5 | 1.17 | 0.67 | 0.47 | 0.45 | 0.45 | 0.41* | 0.37* | 0.37* | 0.33* |
| Th232 | USS 1 | 0.55* | 0.41* | 0.37* | 0.33 | 0.26 | 0.22 | 0.19 | 0.17 | 0.17 |
| | USS 2 | 0.81* | 0.55* | 0.44 | 0.33 | 0.26 | 0.22 | 0.19 | 0.19 | 0.19 |
| | USS 3 | 1.11* | 0.66 | 0.44 | 0.33 | 0.26 | 0.22 | 0.22 | 0.22 | 0.22 |
| | USS 4 | 1.31 | 0.66 | 0.44 | 0.33 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| | USS 5 | 1.31 | 0.66 | 0.44 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |

[(1)]The allowed Incremental Concentrations are added to the natural background radionuclide concentration to obtain the absolute value of the allowed radionuclide concentration before mixing.

[(2)]These allowable concentrations may however, further be limited by the chemical toxicity of uranium. Applicants should inquire with NJDEP's Site Remediation Program for the additional applicable chemical cleanup standards for uranium.

[(3)]When more than one nuclide is present, use the Radium-226 Table in Appendix B, incorporated herein by reference, for applying the sum of the fractions rule. Then use whatever number is more restrictive for radium-226.

* Values were back-calculated to ensure 15 mrem/yr TEDE after mixing.

2. After it is established that the concentrations in Table 4A, 4B, 5A, or 5B above are met, the layer of residual radionuclides shall be mixed thoroughly with the layer of uncontaminated surface soil to achieve a uniform concentration throughout the soil column;

3. Where more than one radionuclide contaminant is present at the site, their concentrations meet the sum of the fractions as described below:

$$\text{Sum of } \frac{CA_i}{C_i} \leq 1$$

where:

$CA_i$ = the incremental concentration of radionuclide i at the site, and

$C_i$ = the incremental allowed concentration of radionuclide i from Table 4A, 4B, 5A, or 5B above, if it were the only remaining radionuclide at the site; and

4. The requirement in (a) 3 above shall be met.

7:28-12.10 Petition for alternative remediation standards for radioactive contamination

(a) In lieu of using the minimum remediation standards for radioactive contamination of soil found at N.J.A.C. 7:28-12.9, a person may petition the Department for an alternative soil standard for radioactive contamination. Such an alternate soil cleanup standard:

1. Shall not result in incremental doses, for sum of annual external radiation dose and intake dose, exceeding 15 mrem/yr (0.15 mSv/yr) total effective dose equivalent;

2. Shall not result in incremental concentrations exceeding three pCi/L (111 $Bq/m^3$) of radon in indoor air in the lowest level of the building; and

3. Shall not result in radionuclide in groundwater levels exceeding those in the New Jersey Groundwater Quality Standards in N.J.A.C. 7:9-6.

(b) The Department shall not consider a petition for an alternative soil standard for radionuclides that is supported by increasing, in any manner, the allowed incremental background dose value of 15 mrem/yr (0.15 mSv/yr) or the allowed incremental radon in air concentration of three pCi/L (111 $Bq/m^3$), or varying the parameters listed in Tables 6 or 7 below.

**Table 6**

| Parameter | Unrestricted | Limited or Restricted |
| --- | --- | --- |
| Indoor onsite breathing rate ($m^3/hr$) | 0.63 | 1.20 |
| Outdoor onsite breathing rate ($m^3/hr$) | 1.40 | 1.20 |
| soil ingestion rate (g/yr) | 70 | 12.5 |
| Homegrown crop ingestion rate (g/yr) | 14,235 | 0 |
| Drinking water consumption rate (L/yr) | 700 | 700 |
| Shielding factor through basement or slab | 0.20 | 0.20 |
| Shielding factor through walls | 0.80 | 0.80 |
| Shielding factor outside | 1.00 | 1.00 |
| fraction of time spent indoors on site | 70% | 18% |
| fraction of time spent outdoors on site | 5% | 5% |

**Table 7**
**Soil to Vegetation Transfer Factors**

| Element | pCi/g plant (wet) to pCi/g soil (dry) |
|---|---|
| Th | 1E-3 |
| Ra | 4E-2 |
| Pb | 1E-2 |
| Po | 1E-3 |
| U | 2.5E-3 |
| Ac | 2.5E-3 |
| Pa | 1E-2 |
| Bi | 1E-1 |

(c) The Department shall consider petitions only in cases where site-specific or waste specific factors, and/or site design features are used in performing the dose assessment, which are different than those used by the Department in establishing the soil concentrations in N.J.A.C. 7:28-12.9. Factors which the Department shall consider in a petition for an alternate soil standard include, but are not limited to:

1. The chemical or physical state of the radioactive material;

2. Site-specific soil characteristics, depth to groundwater and other geological and hydrogeological characteristics which may substantially change the potential dose from radionuclides, as compared to the values listed in Tables 8 and 9 below.

**Table 8**
**Generic Site Input Parameters for Groundwater Pathway Analysis**

| | |
|---|---|
| Dimensions of contaminated zone, LxW (m) | 100x100 |
| Percolation rate (vertical Darcy velocity, m/yr) | 0.5 |
| Volumetric water content in contaminated zone ($m^3/m^3$) | 0.35 |
| Volumetric water content in unsaturated zone ($m^3/m^3$) | 0.2 |
| Bulk density of contaminated zone ($g/m^3$) | 1.6 |
| Bulk density of saturated zone ($g/m^3$) | 1.6 |
| Unsaturated zone thickness(distance from bottom of source to aquifer, m) | 0.5 |
| Porosity of aquifer | 0.45 |
| Longitudinal dispersivity in aquifer (m) | 9 |
| Transverse dipersivity in aquifer (m) | 4 |
| Pore velocity in aquifer (m/yr) | 4 |
| Well screen thickness (mixing depth, m) | 10 |

**Table 9**
**Sorption Coefficients used for Groundwater Pathway Analysis**

| Isotopes | Kd (mg/L) |
|---|---|
| uranium | 35 |
| thorium | 3,200 |
| radium | 500 |
| lead | 270 |
| proactinium | 550 |
| actinium | 450 |

3. Use of caps, covers, sealants, geotextile membranes, limits on the vertical extent of radioactive contamination remaining on site and/or other engineering or institutional controls that reduce potential exposures to radioactive materials; and

4. Changes in indoor and outdoor occupancy times, which are justified by land uses other than residential or commercial.

(d) A petition for an alternate soil standard shall include an analysis demonstrating how and why the difference in factors such as those in Tables 6 through 9 above will result in substantially different soil standards than those in N.J.A.C. 7:28-12.9.

(e) Regardless of the factors used by the petitioner, the Department shall not approve alternative standard petitions that include institutional and engineering controls where failure of those controls, not including the failure of a radon remediation system, would result in more than 100 mrem (one mSv) total annual effective dose equivalent.

(f) In the event the Department determines that sufficient evidence exists to support consideration of an alternative soil standard, the petitioner shall submit a written analysis which demonstrates compliance with the dose limits in N.J.A.C. 7:28-12.9 including:

1. The remedial action informational requirements of N.J.A.C. 7:26E-6; and

2. A dose assessment analysis, including:

i An estimate of the radiation doses received by a post-remediation on-site resident for an unrestricted use remedial action, or by a resident or an employee (of a proposed commercial use facility) for a limited restricted use remedial action;

ii A presentation of all equations or other mathematical techniques used, either directly or embodied in a computer model, to predict the movement of radionuclides and/or their resulting radiation dose;

iii Groundwater radionuclide concentration calculations which shall be extended for a period of 1,000 years;

iv A presentation of all numerical input parameters to equations or computer models, the range of values for those parameters, including reference sources, the value selected for use and the basis for that selection;

v A presentation of other relevant factors and assumptions used in the analyses, such as site-specific geology, land use, etc.;

vi An analysis of which input parameters, when varied, would most significantly affect radiation dose results, commonly referred to as a sensitivity analysis; and vii An analysis of both continued use of existing structures and future use scenarios. Future use scenarios shall include, if applicable, the construction of buildings for either unrestricted use remedial actions or limited restricted use remedial actions, including excavations for basements and/or footings.

(g) Engineering controls or institutional controls may be incorporated as part of a petition for an alternative remediation standard provided that these controls will be durable and implemented for an appropriate period of time to achieve their intended purpose.

(h) Computer models acceptable to the Department may be used by the petitioner for an alternative soil standard to confirm that the requirements of N.J.A.C. 7:28-12.9 have been and will continue to be met.

7:28-12.11 Requirements pertaining to engineering or institutional controls

(a) All remediation proposals shall designate the intended use(s) of the property. Such intended use(s) shall be restricted as necessary to prevent future exposure, and shall otherwise be consistent with current and projected State and local zoning designations or land uses. For sites not remediated to the unrestricted use standards in N.J.A.C. 7:28-12.9, the Department shall define the nature and duration of all appropriate engineering or institutional controls necessary to meet the standards in N.J.A.C. 7:28-12.9 or 12.10(a), based upon the particular conditions of the site.

(b) In order for any remediation under this subchapter requiring engineering controls or institutional controls to meet the standards in N.J.A.C. 7:28-12.9 or 12.10(a), the person responsible for conducting the remediation shall, in addition to meeting the provisions of N.J.S.A. 58:10B-13:

1. Implement all necessary actions, as determined by the Department, to assure that such engineering or institutional controls are being implemented and maintained for an appropriate period of time; and

2. Provide for the costs of implementing and maintaining the requisite active engineered or institutional controls for an appropriate period of time.

7:28-12.12 Requirements pertaining to a change in land use

(a) Any subsequent proposed use of a property that is different from the intended use (other than unrestricted use remedial actions) described in the original remediation proposal shall require a prior review and prior approval by the Department. To initiate this review, 90 calendar days prior to a proposed change in land use, the person proposing such use shall prepare and submit to the Department, at the Bureau of Environmental Radiation, PO Box 415, Trenton, NJ 08625-0415, and to each affected municipality, a brief written description of the new proposed use as compared to the intended use upon which the original remediation was based including all planned soil excavations, and any additional remedial actions to be implemented.

(b) If the Department determines that the proposed new use may cause the dose limitations of N.J.A.C. 7:28-12.8 to be exceeded, the person requesting the use change shall be required to prepare and submit to the Department's Bureau of Environmental Radiation, PO Box 415, Trenton, NJ 08625-0415, a dose assessment analysis, containing the information required under N.J.A.C. 7:28-12.10(f)2, (g), and (h), to ascertain whether the dose limitation requirements of N.J.A.C. 7:28-12.8 will be met for the proposed new use.

(c) In preparing the dose assessment analysis, the person may incorporate into the new use plan new remedial measures such as different radionuclide in soil concentrations, or radioactive contamination vertical extents, and/or new engineering or institutional controls, provided that for engineering or institutional controls, the person responsible for conducting the remediation provides for the cost of implementing and maintaining them as specified in N.J.A.C. 7:28-12.11(c)3.

7:28-12.13 Requirements pertaining to the final status survey

The final status survey is performed to demonstrate that a site meets the remediation standards. It shall be done in accordance with that version of the Department of Environmental Protection's Field Sampling Manual's section on Radiological Assessment, which is incorporated herein by reference, in effect at the time of the survey which may be obtained by calling the Bureau of Environmental Radiation at (609) 984-5400 or from the Radiation Protection Program's web site at http://www.state.nj.us/dep/rpp/index.htm.

## Appendix A

**Allowed Incremental Concentration (pCi/g) for the Gamma and Intake Pathways [1]**

| Nuclide | Feet of Vertical Extent of Residual Radionuclide (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| Ra226 **Unrestricted Use Standards** | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| Ra226 **Limited Restricted Use Standards** | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 |

**Allowed Incremental Concentration (pCi/g) for the Gamma and Intake Pathways[1]**

| | Feet of Uncontaminated Surface Soil (USS) | Feet of Vertical Extent of Residual Radionuclide (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| **Ra226** | USS 0 | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 |
| **Restricted Use** | USS 1 | 30 | 23 | 18 | 13 | 11 | 9 | 8 | 7 | 7 |
| **Standards** | USS 2 | 44 | 25 | 18 | 13 | 11 | 9 | 8 | 8 | 8 |
| | USS 3 | 44 | 25 | 18 | 13 | 11 | 9 | 9 | 9 | 9 |
| | USS 4 | 44 | 25 | 18 | 13 | 11 | 11 | 11 | 11 | 11 |
| | USS 5 | 44 | 25 | 18 | 13 | 13 | 13 | 13 | 13 | 13 |

## Appendix A

**Allowed Incremental Concentration (Bq/g) for the Gamma and Intake Pathways [1]**

| Nuclide | Feet of Vertical Extent of Residual Radionuclide (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| Ra226 **Unrestricted Use Standards** | 0.13 | 0.11 | 0.11 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 |
| Ra226 **Limited Restricted Use Standards** | 0.38 | 0.38 | 0.37 | 0.35 | 0.33 | 0.31 | 0.29 | 0.26 | 0.26 |

**Allowed Incremental Concentration (Bq/g) for the Gamma and Intake Pathways[1]**

| | Feet of Uncontaminated Surface Soil (USS) | Feet of Vertical Extent of Residual Radionuclide (VE) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
| Ra226 | USS 0 | 0.38 | 0.38 | 0.37 | 0.35 | 0.33 | 0.31 | 0.29 | 0.26 | 0.26 |
| Restricted Use | USS 1 | 1.11 | 0.84 | 0.65 | 0.50 | 0.40 | 0.34 | 0.29 | 0.26 | 0.26 |
| Standards | USS 2 | 1.64 | 0.93 | 0.65 | 0.50 | 0.40 | 0.34 | 0.29 | 0.29 | 0.29 |
| | USS 3 | 1.64 | 0.93 | 0.65 | 0.50 | 0.40 | 0.34 | 0.34 | 0.34 | 0.34 |
| | USS 4 | 1.64 | 0.93 | 0.65 | 0.50 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| | USS 5 | 1.64 | 0.93 | 0.65 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.49 |

(1) These Ra226 concentration numbers may be used only when more than one radionuclide is present for the sum of the fractions rule at N.J.A.C. 7:28-12.9(b).

# Appendix B

**Allowed Incremental Concentration (pCi/g) for the Gamma and Intake Pathways[(1)]**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclide (VE) VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ra226 | USS 0 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| **Unrestricted Use** | USS 1 | 8 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 2 |
| **Pre-mixing Values** | USS 2 | 12 | 7 | 5 | 4 | 3 | 3 | 2 | 2 | 2 |
| | USS 3 | 15 | 8 | 6 | 4 | 3 | 3 | 3 | 3 | 3 |
| | USS 4 | 15 | 8 | 6 | 4 | 3 | 3 | 3 | 3 | 3 |
| | USS 5 | 15 | 8 | 6 | 4 | 4 | 4 | 4 | 4 | 4 |
| Ra226 | USS 0 | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 |
| **Limited Restricted** | USS 1 | 23* | 17* | 15* | 13 | 11 | 9 | 8 | 7 | 7 |
| **Use Pre-mixing** | USS 2 | 34* | 23* | 17* | 13 | 11 | 9 | 8 | 8 | 8 |
| **Values** | USS 3 | 44 | 25 | 18 | 13 | 11 | 9 | 9 | 9 | 9 |
| | USS 4 | 44 | 25 | 18 | 13 | 11 | 11 | 11 | 11 | 11 |
| | USS 5 | 44 | 25 | 18 | 13 | 13 | 13 | 13 | 13 | 13 |

* Back-calculated to ensure 15 mrem/yr TEDE after mixing

**Allowed Incremental Concentration (Bq/g) for the Gamma and Intake Pathways[(1)]**

| Feet of Uncontaminated Surface Soil (USS) | | Feet of Vertical Extent of Residual Radionuclide (VE) VE1 | VE2 | VE3 | VE4 | VE5 | VE6 | VE7 | VE8 | VE9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ra226 | USS 0 | 0.13 | 0.11 | 0.11 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 |
| **Unrestricted Use** | USS 1 | 0.28 | 0.19 | 0.15 | 0.13 | 0.12 | 0.10 | 0.09 | 0.08 | 0.08 |
| **Pre-mixing Values** | USS 2 | 0.47 | 0.28 | 0.21 | 0.16 | 0.13 | 0.11 | 0.09 | 0.09 | 0.09 |
| | USS 3 | 0.57 | 0.32 | 0.22 | 0.17 | 0.14 | 0.11 | 0.11 | 0.11 | 0.11 |
| | USS 4 | 0.59 | 0.32 | 0.22 | 0.17 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| | USS 5 | 0.59 | 0.32 | 0.22 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Ra226 | USS 0 | 0.38 | 0.38 | 0.37 | 0.35 | 0.33 | 0.31 | 0.29 | 0.26 | 0.26 |
| **Limited Restricted** | USS 1 | 0.85* | 0.63* | 0.56* | 0.50 | 0.40 | 0.34 | 0.29 | 0.26 | 0.26 |
| **Use Pre-mixing** | USS 2 | 1.26* | 0.85* | 0.63* | 0.50 | 0.40 | 0.34 | 0.29 | 0.29 | 0.29 |
| **Values** | USS 3 | 1.64 | 0.93 | 0.65 | 0.50 | 0.40 | 0.34 | 0.34 | 0.34 | 0.34 |
| | USS 4 | 1.64 | 0.93 | 0.65 | 0.50 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| | USS 5 | 1.64 | 0.93 | 0.65 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.49 |

* Back-calculated to ensure 15 mrem/yr TEDE after mixing

(1) These Ra226 concentration numbers may be used only when more than one radionuclide is present for the sum of the fractions rule at N.J.A.C. 7:28-12.9(b).

# Chapter 12.
# RADIOLOGICAL ASSESSMENT

## Introduction

The purpose of this chapter is to provide guidance on conducting and documenting environmental radiological surveys and sampling episodes and demonstrating compliance with N.J.A.C. 7:28-12, "Soil Remediation Standards for Radioactive Materials". This chapter does not address building contamination.

The person responsible for remediating a radiologically contaminated site must obtain a copy of the December 1997 Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (available at http://www.epa.gov/rpdweb00/marssim/index.html) for reference. Please note that some of the requirements in this chapter are different than the guidance presented in the MARSSIM. This chapter instructs the reader when to use the MARSSIM.

Figure 1 shows the relationship between MARSSIM terminology and the NJDEP Technical Requirements.

Any questions regarding this chapter should be directed to the NJDEP, Bureau of Environmental Radiation (BER) staff (609) 984-5400 or through the radiation protection program's web site at http://www.state.nj.us/dep/rpp/index.htm. A complete list of references, a glossary (statistical terms are defined in the MARSSIM glossary), and list of acronyms can be found at the end of this chapter.

## A. The Planning Stage (Data Life Cycle)

The process of planning, implementing, assessing and evaluating survey results is known as the Data Life Cycle. Survey designs should be developed and documented using the Data Quality Objectives (DQO) Process outlined in the MARSSIM (Appendix D, *The Planning Phase of the Data Life Cycle*, and Section 2.3.1, *Planning Effective Surveys – Planning Phase*). The expected output of planning surveys using the DQO process is a Quality Assurance Project Plan (QAPP) which should integrate all the technical and quality aspects of the Data Life Cycle. It should define in detail how specific quality assurance and quality control (QA/QC) activities will be implemented during the various surveys.

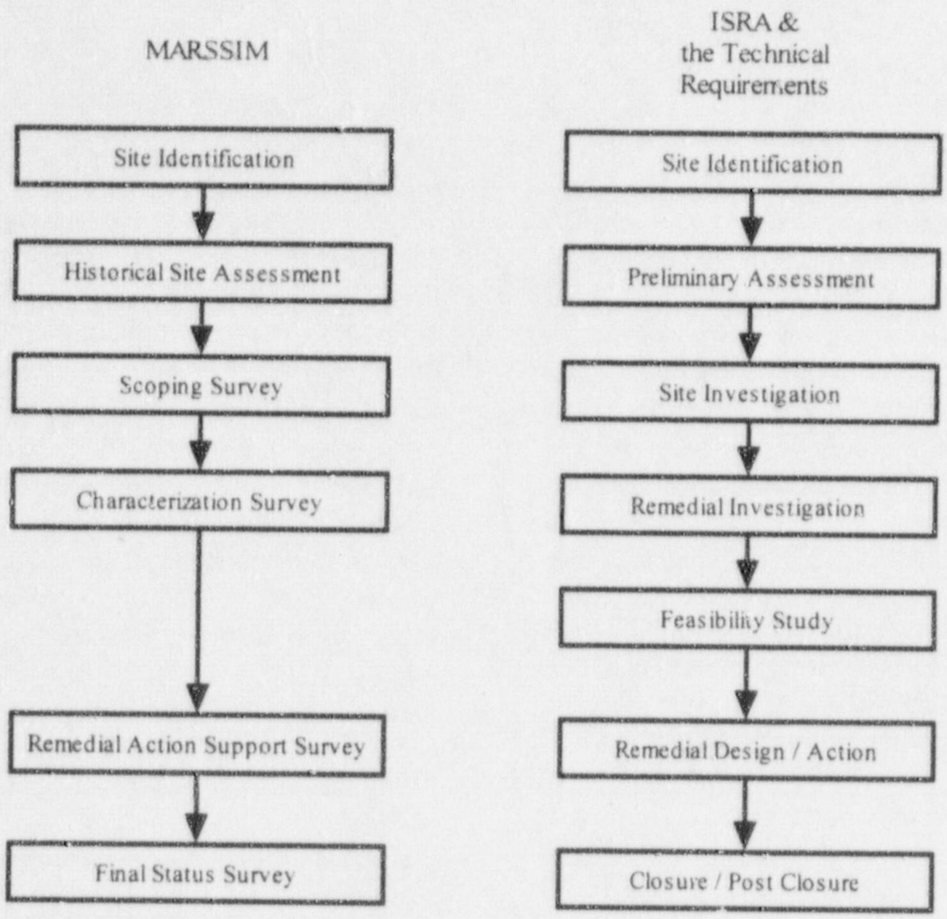
Specific sampling, survey and laboratory requirements as they relate to QA/QC are found in N.J.A.C. 7:28-12.5, N.J.A.C. 7:26E-2, and Chapter 2 of this DEP Sampling Manual.

## B. Site Identification/Historical Site Assessment

The purpose of the Historical Site Assessment (HSA) is to collect as much existing information as possible on the

Figure 1:

**Comparison of the Radiation Survey & Site Investigation Process (MARSSIM) with ISRA & the Technical Requirements**




Note: Although not directly applicable, a discussion of the relationship between the MARSSIM process, CERCLA process and RCRA process can be found in Appendix F of the MARSSIM.

site and its surroundings. A *site* is considered to be any installation, facility, or discrete, physically separate parcel of land that is being considered for survey and investigation.

The objectives of the HSA are to identify potential or known sources of contamination, determine if the site, or any portion of it, poses a threat to human health and the environment, differentiate between impacted and non-impacted areas, provide input for scoping and characterization surveys, assess the likelihood of contaminant migration, if migration off site is possible, and identify additional potential radiation sites related to the site being investigated (such as neighboring properties). The three steps of the HSA are 1) identify the candidate site, 2) perform a preliminary investigation of the site, and 3) visit or inspect the site.

The checklist on page 3-5, *Table 3.1 Questions Useful for the Preliminary HSA Investigation*, of the MARSSIM should be used to collect existing information on the site. Further guidance on conducting a historical site assessment is provided in Chapter 3 and Appendix A, *Example of MARSSIM Applied to a Final Status Survey*, of the MARSSIM, including documentation (Section 3.8, *Historical Site Assessment Report*, of the MARSSIM).

C. The Scoping Survey

The purpose of the scoping survey is to provide site-specific information based on limited measurements. The objectives of the survey may include performing a preliminary risk assessment and prioritizing data to complete the site prioritization scoring process (CERCLA and RCRA sites only), supporting classification of all or part of the site as a Class 3 area[1] (area classification is discussed further in section C.3 of this chapter), evaluating the suitability of the survey plan for use in characterization or final status surveys, providing input into the design of the characterization survey, obtaining an estimate of the variability in the residual radioactivity of the site, and identifying non-impacted areas that may be appropriate for reference areas. These surveys typically consist of judgement measurements based on the results of the Historical Site Assessment. Sufficient data should be collected to facilitate the area classification process. Figure 4.1, *Sequence of Preliminary Activities Leading to Survey Design*, in the MARSSIM illustrates the preliminary steps necessary for planning a scoping survey.

**1. Identify Contaminants**

For sites with multiple radionuclide contaminants, one of the objectives of the scoping survey could be to establish the ratios between each nuclide. For some sites, a review of the operating history would be helpful in establishing a ratio, and a limited number of samples could be collected to verify the suspected ratio. For other sites, a ratio might be better established as part of the characterization survey. Parts of the site might have different ratios, or there may not be a consistent ratio. Determining a consistent ratio may be difficult. Before establishing the derived concentration

[1] an impacted area with little or no potential for delivering a dose above the release criterion, and little or no potential for small areas of elevated activity.

guidance levels[2] (DCGL's) based on a ratio, consultation with the BER is recommended.

To determine whether the radionuclides are correlated or not, MARSSIM states "a simple way to judge this would be to make a scatter plot of the concentrations against each other, and see if the points appear to have an underlying linear pattern." [3] The correlation coefficient should be calculated as well to see if it lies nearer to zero than to one. A curve fit and test of the significance of the results should also be performed.

**2. Establish the Derived Concentration Guideline Levels (DCGLs)**

The DCGLs (soil remediation standards) to be used in New Jersey for naturally occurring radioactive materials (NORM) are established in N.J.A.C. 7:28-12, "Soil Remediation Standards for Radioactive Materials" for unrestricted limited restricted, and restricted use. DCGLs for any radioactive material may be developed by the person responsible for remediating the site by following the methodologies in *Development of Generic Standards for Remediation of Radioactively Contaminated Soils in New Jersey, A Pathways Analysis Approach*. This document may be obtained by calling (609) 984-5400 or from the Radiation Protection Programs web site at http://www.state.nj.us/dep/rpp/index/htm. If an alternative standard is proposed, the requirements in N.J.A.C. 7:28-12.10, "Petition for alternative remediation standards for radioactive contamination", must be met. The DCGL's listed in N.J.A.C. 7:28-12.9, "Minimum remediation standards for radionuclide contamination of soil", are for use when only one radionuclide is present in the radioactive contamination on the site. If more than one nuclide is present, the sum of the fraction calculation must be performed as outlined in N.J.A.C. 7:28-12.9(b). It may be necessary to determine the ratio between the nuclides in order to establish the nuclide-specific DCGL's. The Radioactive Soil Remediation Standards spreadsheet, or RaSoRS, will be essential in determining the DCGL's for NORM and is available from the Radiation Protection Programs web site or by calling (609) 984-5400.

Section 4.3.3, *Use of DCGL's for Sites With Multiple Radionuclides*, of the MARSSIM discusses multiple radionuclides and how to apply the sum of the fractions rule. For sites with multiple radionuclide contaminants, it may be possible to measure just one of the contaminants and still demonstrate compliance for all the contaminants present through the use of surrogate measurements. A discussion of the use of surrogates is found in Section 4.3.2, *DCGLs and the Use of Surrogate Measurements*, of the MARSSIM.

The proper use of surrogate measurements takes into account the contribution to dose from multiple radionuclides by establishing a modified $DCGL_{mod}$, and in this case, the sum of the fraction calculation is not necessary. The surrogate method depends on establishing consistent ratios and this

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[2] derived from the activity / dose relationship through various exposure pathway scenarios; established in N.J.A.C. 7:28-12.

[3] Section I.11, *Multiple Radionuclides*, in the MARSSIM.

may be difficult for two or more radionuclides.

### 3. Classify the Area by Contamination Potential

The NJDEP supports the MARSSIM classification methods as discussed in Section 4.4, *Classify Areas by Contamination Potential*, of the MARSSIM. The area classification process looks at areas as either *non-impacted* or *impacted*, and further classifies *impacted* areas into Class 1, 2 or 3 based on the potential for residual radioactive contamination, with Class 1 having the greatest likelihood of being affected. The significance of survey unit classification is that this process determines the final status survey design and the procedures used to develop this design.

The scoping survey and historical site assessment can be used to determine initial classifications, but classification may change throughout the site investigation process. In order to classify an area, a comparison with the DCGL is made. All impacted areas are initially classified as Class 1 so that if a survey unit is classified incorrectly, the potential for making decision errors does not increase. Class 1 areas are known to have contaminant concentrations above the DCGL, while Class 2 and 3 areas have the potential to have contamination concentrations less than the DCGL.

The site should be broken down into smaller survey units if appropriate and each survey unit should have only one classification. Sections 2.5.2, *Classification*, and 4.6, *Identify Survey Units*, in the MARSSIM has further information on identifying survey units.

The suggested size of the survey units for each classification are given in this section. These are suggested maximum sizes and may be modified based on site-specific information. If an area greater than these suggested sizes is proposed, consultation with the BER is suggested before continuing with the site investigation process.

### 4. Determine Background

For radionuclides that are also present in background, Section 4.5, *Select Background Reference Areas*, of the MARSSIM provides information on selecting a background reference area. The scoping survey should be used to verify that the selected background reference area is non-impacted. Determination of the number of samples to collect in the background reference area is discussed under Section F. of this chapter, The Final Status Survey.

### 5. Perform the Survey

Information on how to conduct surveys is discussed in Section 4.7, *Select Instruments and Survey Techniques*, of the MARSSIM. The flow diagram (Fig. 4.2, *Flow Diagram for Selection of Field Survey Instrumentation for Direct Measurements and Analysis of Samples*) for selection of field instruments for direct measurements and analysis of samples should be used before proceeding with the survey. Criteria for selecting sample collection and measurement methods are discussed in Section 4.7.3, *Criteria for Selection of Sample Collection and Direct Measurement Methods*, of the MARSSIM.

For additional information regarding soil sampling, please refer to Section 7.B in this Sampling Manual (the *1992 DEP Sampling Manual*). For scanning soil with a NaI detector, the $MDC_{scan}$[4] values given in Table 6.7, *NaI(Tl) Scintillation Detector Scan MDCs for Common Radiological Contaminants*, of the MARSSIM provide an acceptable estimate of $MDC_{scan}$. The instruments selected must be capable of detecting the nuclides of interest at the levels of interest.

Section 4.8, *Site Preparation*, in the MARSSIM discusses how to prepare the site for the survey and how to lay out the reference coordinate system. Appendix A also has some useful information on the grid system and examples of scanning patterns. It may be useful to lay out the grid at this point for use later in the site investigation process. All Class 1 survey units must use a triangular grid as this is the more efficient of the grid patterns.

Chapter 7 of the *NJDEP Field Sampling Procedures Manual* (May, 1992) outlines the methodology for sampling surface soil, subsurface soil, ground water, streams, sediments, etc. These procedures shall be used. Water samples shall be analyzed for gross alpha and gross beta and isotopic gamma activity. If the gross alpha exceeds 5 pCi/L, additional tests shall be performed to identify and quantify specific radionuclides such as radium isotopes. If gross beta exceeds 50 pCi/L, the contributing radionuclides shall be identified. See N.J.A.C. 7:28-12.5, "Sampling, surveying and laboratory requirements", for information pertaining to laboratory requirements.

Quality Control is discussed in Chapter 2 of the *NJDEP Field Sampling Procedures Manual* and Section 4.9, *Quality Control*, of the MARSSIM.

**6. Document the Scoping Survey Results**

Documentation should include identification of the survey areas, classifications of each (and justification), proposed use of surrogates and the established ratios of nuclides, if applicable, the site-specific DCGL's and supporting documentation for these items. Guidance on reporting requirements can also be found in N.J.A.C. 7:26E, *Technical Requirements for Site Remediation*.

D. The Characterization Survey

The characterization survey may be used to satisfy a number of specific objectives, including those outlined in N.J.A.C. 7:26E-4.1. It is important to identify *specific* characterization objectives before planning to collect and analyze samples or make measurements in the field. Some examples of specific questions that might be asked in order to formulate the objectives are:

- How deep is the contamination in the survey unit (area of concern)?
- What is the concentration of $^{226}Ra$ in the pile of soil near the fenceline?

In order to answer these and other questions, measurements will have to be

[4] minimum detectable concentration – the *a priori* activity level that a specific instrument and technique can be expected to detect 95% of the time. The $MDC_{scan}$ is simply the minimum detectable concentration of the scanning survey.

taken for comparison with the established DCGL's.

Examples of some other objectives include: 1) evaluation of remedial alternatives (e.g. unrestricted use, limited restricted use, or alternative standards), 2) collect additional data to be used: as input to the final status survey design, to reevaluate the initial classification of survey units, to select instrumentation based on the necessary MDCs, to establish the acceptable Type I and Type II errors, and to fulfill the requirements for a Remedial Investigation/Feasibility Study (CERCLA sites only), and 3) evaluation of remediation technologies. The characterization objectives themselves determine the kinds of measurements, and in turn, the analyses and sensitivities needed for comparison with the DCGL's.

### 1. Determination of Lateral and Vertical Extent of Contamination

As discussed in Section B.5. above, the DEP soil sampling procedures shall be used for the characterization survey. Gamma logging of boreholes is performed to identify the presence of subsurface deposits of gamma-emitting radionuclides.

A sensitive gamma detector such as a NaI gamma scintillation probe is lowered into the hole and a count rate determined at 0.5 foot increments. The sensitivity and specificity of this technique may be improved by placing the detector inside a shielded collimator assembly. A geologic description of the subsurface shall also be made.

Soil samples shall be analyzed in a DEP-certified laboratory. A list of certified laboratories may be obtained by contacting the NJDEP Office of Quality Assurance at ((609)633-3840. It may be possible to limit the cost of analysis by correlating the gamma readings to concentration values. This may be acceptable provided enough data is collected to demonstrate a correlation. A correlation coefficient shall be calculated to support the assumed correlation. A minimum of 30 samples, representing the range of values shall be used to establish the correlation.

The number of samples to be taken depends on the objectives of the survey. If the characterization data is intended to be used for the final status survey, then the number of samples must be determined as outlined in Section F. The Final Status Survey. Otherwise, sufficient sampling shall be collected to determine the vertical and lateral extent and to identify areas that require remediation (by comparing to the DCGLs).

### 2. Determine Background

For radionuclides that are also present in background, Section 4.5, *Select Background Reference Areas*, of the MARSSIM provides information on selecting a background reference area. The characterization survey can be used to further define the background reference area by determining radionuclide concentrations in environmental media.

**3. Classify the Area by Contamination Potential**

Review the initial area classifications made during the Scoping Survey and determine if any of them have changed.

**4. Document the Characterization Survey Results**

Documentation of the characterization survey should provide a complete record of the radiological status of the site. All sampling and analysis data (including QA/QC data) should be included, along with justifications for changes made to area classifications (if any). There should be enough information in this report to support approaches or alternatives to site cleanup.

E. The Remedial Action Support Survey

The remedial action support survey is conducted in order to support remediation activities by monitoring the effectiveness of the decontamination efforts. This survey should be limited to activities such as direct measurements and scanning surveys. One of the goals of the remedial action support survey is to help determine when a site is ready for a final status survey.

As with any survey in the site investigation process, measurement methods should be chosen so as to be able to detect the radiation of interest well below the DCGLs.

Section 5.4, *Remedial Action Support Surveys*, of the MARSSIM provides specific guidance on this type of survey.

F. The Final Status Survey

The final status survey is performed in order to demonstrate that the residual radioactivity in each survey unit meets the predetermined criteria for release, whether it be for unrestricted, limited restricted, or alternate use. For the final status survey, the fundamental components being examined are the survey units.

Compliance is demonstrated through the use of statistical tests (either the Wilcoxon Rank Sum (WRS) Test when the contaminant is present in the background, or the Sign Test if the contaminant is not present in the background: Section 8.2.3, *Select the Tests*, in the MARSSIM discusses the choice of statistical tests). It is the primary goal of the final status survey to demonstrate that all radiological parameters satisfy the established guideline values and conditions. Data obtained at other points in the survey and site investigation process can provide useful information.

**1. Revisit the Area Classifications**

It is important at this stage in the process to be certain that all areas are classified correctly as this information will be used to determine compliance. The criteria used for designating areas as Class 1, 2, or 3 shall be described in the final status survey, and compliance with the classification criteria shall be demonstrated in the final status survey. More information on survey investigations and reclassifications can be found in Section 5.5.3, *Developing an Integrated Survey Strategy*, of the MARSSIM.

### 2. Determine the Relative Shift

To be certain that the conclusions drawn from the samples are correct, a minimum number of samples are needed to obtain statistical confidence. In order to determine the number of samples, you must first determine the relative shift ($\Delta/\sigma_s$). The relative shift is the ratio involving the concentration to be measured relative to the variability in that concentration, and can be thought of as an expression of the resolution of the measurements.

$\Delta/\sigma_s = (DCGL_W - LBGR) / \sigma_s$

where:

**$DCGL_W$** = derived concentration guideline

**LBGR** = concentration at the lower bound of the gray region; the LBGR is the concentration to which the survey unit must be cleaned in order to have an acceptable probability of passing the test (i.e., 1-$\beta$)

$\sigma_s$ = an estimate of the standard deviation of the concentration of residual radioactivity in the survey unit

The value for $\sigma_s$ is determined from either existing measurements or by limited sampling. If, during the survey process, a background reference area is used and the $\sigma_r$ in the reference area is greater than the $\sigma_s$ in the survey unit, the larger value should be used.

The DEP concurs with the MARSSIM recommendation to initially set the LBGR at 0.5 $DCGL_W$. If the relative shift exceeds 3, the LBGR should be increased until $\Delta/\sigma_s$ is less than or equal to 3.

Section 5.5.2.2, *Contaminant Present in Background-Determining Numbers of Data Points for Statistical Tests*, and Appendix D, *The Planning Phase of the Data Life Cycle*, in the MARSSIM provide greater detail.

### 3. Determination of Acceptable Type I and Type II Decision Errors

A decision error is the probability of making an error in the decision on a survey unit by passing a survey unit that should fail (alpha or Type I) or by failing a survey unit that should pass (beta or Type II). **The acceptable Type I (alpha) decision error rate is 0.05.** Any Type II (beta) decision error rate is acceptable to the NJDEP. However, the higher the Type II rate, the greater the probability that the site will not pass the statistical test, even though the site should pass.

Section 5.5.2.1, *Application of Decommissioning Criteria*, and Appendix D.6, *Specify Limits on Decision Errors*, of the MARSSIM provide greater detail on this process.

### 4. Determine the Number of Samples Needed

The minimum number of samples needed, **N**, can be determined from the equation for **N** found in Equation 5.1 in the MARSSIM. Remember that **N** is the minimum number of samples necessary *in each survey unit*. An additional **N** samples are needed in the reference area as well if contamination is present in the background. Fewer samples will increase the probability of an acceptable survey unit failing to demonstrate compliance.

Alternately, once the values for $\Delta/\sigma$ and the error types ($\alpha$ and $\beta$) have been established, the values for **N** can be found in Tables 5.3, *Values of N/2 for Given Values of the Relative Shift, $\Delta/\sigma$, when the Contaminant is Present in Background*, and 5.5, *Values of N for Given Values of the Relative Shift, $\Delta/\sigma$, $\alpha$, and $\beta$ when the Contaminant is Not Present in Background*, of the MARSSIM.

***As an example, suppose you had the following scenario***:

Background: A site has 14 survey units and 1 reference area. $^{238}U$ is the radionuclide of concern, and measurements will be of nuclide concentration.

$DCGL_W$ $^{238}U$ = 10 pCi/g
$\sigma_s$ = 3.2 pCi/g
Bkg. in reference area = 1.2 pCi/g
$\sigma_r$ = 0.6 pCi/g
LBGR is selected to be 5 pCi/g

$\Delta/\sigma$ is then = (10-5)/3.2= 1.56
If $\alpha$ is 0.05 and $\beta$ is 0.10, looking at Table 5.3, *Values of N/2 for Given Values of the Relative Shift, $\Delta/\sigma$, when the Contaminant is Present in Background*, in the MARSSIM gives a value of N/2 of 13 (meaning 13 samples from the reference area and 13 from the survey unit).

Section 5.5.2.2, *Contaminant Present in Background-Determining Numbers of Data Points for Statistical Tests*, in the MARSSIM outlines the process. If the radionuclides of interest are not present in the background, or they are a small percentage of the $DCGL_w$, then a determination will need to be made for the number of samples needed to perform a Sign Test, instead of the WRS Test. This information can be found in the same sections of the MARSSIM.

## 5. Additional Samples for Elevated Measurement Comparison in Class 1 Areas

Class 1 survey units may have small areas where concentrations exceed the $DCGL_W$ which the statistical tests described above may not successfully detect. Therefore, class 1 areas must be tested to demonstrate that they meet the dose criteria for release. This test is known as the elevated measurement comparison.

The number of survey data points needed for the statistical test is determined as discussed in section 4. above. These data points are then positioned throughout the survey unit by first randomly selecting a start point and establishing a systematic pattern. The systematic sampling grid must be triangular. The number of calculated survey locations, N, is used to determine the grid spacing, L, of the systematic sampling pattern (see Section 5.5.2.5 *Determining Survey Locations* in the MARSSIM). The grid area that is bounded by these survey locations is given by $A=0.866 \times L^2$ for a triangular grid. This is the size of the area that could be missed through the established sampling pattern. In order to avoid missing an elevated area of this size, a $DCGL_{EMC}$ must be determined using the equation below:

$DCGL_{EMC}$ = (Area Factor) X ($DCGL_W$)

Area factors were calculated using RESRAD[5] and are presented in Table

[5] The RaSoRS spreadsheet cannot be used when the size of the elevated area is smaller than the

F.1. These area factors were determined by running RESRAD for each nuclide and varying only the lot size. The area factors were then computed by taking the ratio of the dose per unit concentration generated by RESRAD for the default values ($5000 ft^2$) to that generated for the other areas listed. For sites with multiple radionuclides, the most conservative area factor (the smallest) must be used.

Next, the minimum detectable concentration (MDC) of the scan procedure-needed to detect an area of elevated activity at the limit determined by the area factor-must meet the following condition:

$$\text{Scan MDC}_{required} = \text{DCGL}_{EMC}$$

The actual MDCs of scanning techniques are then determined for the available instrumentation (see Section 6.7 *Detection Sensitivity* of the MARSSIM). If the actual scan MDC of the selected instrument is less than the required scan MDC, no additional sampling points are necessary for assessment of small areas of elevated activity. In other words, the scanning technique exhibits adequate sensitivity to detect the small areas of elevated activity that are missed by sampling. If the actual scan MDC is greater than the required scan MDC, then it is necessary to calculate the area factor that corresponds to the actual scan MDC using the following equation:

$$\text{Area Factor} = \frac{\text{scan MDC(actual)}}{\text{DCGL}_W}$$

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size of the house ($1000 ft^2$). However, since the area factors used in RaSoRS were obtained directly from RESRAD, the numbers in Table F.1are acceptable for determining a $\text{DCGL}_{EMC}$.

Next, find the grid area corresponding to that Area Factor from Table 5.1. Then calculate the number of sample points needed to produce that grid area as follows:

$$n_{EA} = \frac{\text{(Survey Unit Area)}}{\text{(Grid Area)}}$$

The calculated number of survey locations, $n_{EA}$, is used to determine a revised spacing, L, of the systematic pattern (refer to Section 5.5.2.5 *Determining Survey Locations* of the MARSSIM). Specifically, the spacing, L, of the pattern (when driven by areas of elevated activity) is given by:

$$L = \sqrt{\frac{A}{0.866 n_{EA}}}$$

where A is the area of the survey unit. Grid spacings shall be rounded down to the nearest distance that can be conveniently measured in the field. If $n_{EA}$ is calculated to be smaller than N (the number of data points calculated in section F.4. of this chapter), then N should be used to determine L.

Figure 5.3 (*Flow Diagram for Identifying Data Needs for Assessment of Potential Areas of Elevated Activity in Class 1 Survey Units*) in the MARSSIM provides a concise overview of the procedure used to identify data needs for the assessment of small areas of elevated activity.

If the following condition is met, then the elevated measurement comparison is acceptable:

$$(\delta / \text{DCGL}_W) + \{(\text{avg. conc. in elevated area} - \delta)/(\text{area factor for elevated area} \times \text{DCGL}_W)\} < 1$$

where $\delta$ = the average residual radioactivity concentration for all sample points in the survey unit that are outside the elevated area.

If there is more than one elevated area, a separate term should be included for each one.

The elevated measurement comparison method is described further in Section 8.5.1, *Elevated Measurement Comparison*, and Section 5.5.2.4, *Determining Data Points for Small Areas of Elevated Activity*, of the MARSSIM.

## 6. Determining Sample Locations

A reference coordinate system must first be established for the impacted areas. A single reference coordinate system may be used for a site, or different systems may be used for each survey unit or groups of survey units. Section 4.8.5, *Reference Coordinate System*, of the MARSSIM describes how to establish such a system.

Class 1 sampling locations are established in a triangular pattern. A square or triangular pattern may be used for Class 2 areas. Measurements and samples in Class 3 survey units and reference areas should be taken at random locations. More information on establishing survey locations can be found in Section 5.5.2.5, *Determining Survey Locations*, of the MARSSIM.

## 7. Investigation Levels and Scanning Coverage Fractions

Investigation levels are radionuclide-specific levels of radioactivity used to indicate when additional investigations may be necessary. Investigation levels also serve as a quality control check to determine when a measurement process begins to get out of control. For example, a measurement that exceeds the investigation level may indicate that the survey unit has been improperly classified or it may indicate a failing instrument.

The investigation levels in Table F.2 should be implemented. This is a departure from the MARSSIM methodology. When an investigation level is exceeded, the first step is to confirm that the initial measurement/sample actually exceeds the particular investigation level. This may involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose meets the release criterion.
Depending on the results of the investigation actions, the survey unit may require reclassification, remediation, and/or resurvey. If after further investigation it is determined that the area does exceed the DCGLw by more than a factor of 2, then it should be remediated. Further information on investigation levels is found in Section 5.5.2.6 *Determining Investigation Levels* of the MARSSIM.

Scanning is performed to locate small areas of elevated concentrations of residual radioactivity. Table 5.9 *Recommended Survey Coverage for Structures and Land Areas*, in the MARSSIM illustrates the acceptable scanning coverage based on Area Classification.

## 8. Special Survey Considerations Subsurface Residual Radioactivity

The MARSSIM final status survey method was designed specifically for residual radioactivity in the top 15 cm of soil. If previous surveys have shown that there is significant subsurface residual radioactivity, this must be taken into account. The characterization survey should determine the depth of the residual radioactivity. If RaSoRS was used to develop the $DCGL_W$, it was based on the assumption that this activity may be excavated in the future and that mixing of the residual radioactivity will occur in the process (note that since N.J.A.C. 7:28-12 bases the DCGL's on the vertical extent of contamination, subsurface residual radioactivity is permitted to be left in place).

When the appropriate DCGLs are established, the final status survey is

**Table F.1 Outdoor Area Dose Factors**

| Nuclide | Area Factor | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 $m^2$ | 3 $m^2$ | 10 $m^2$ | 30 $m^2$ | 100 $m^2$ | 300 $m^2$ | 1000 $m^2$ | 3000 $m^2$ | 10000$m^2$ |
| Ra-226 | 54.8 | 21.3 | 7.8 | 3.2 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 |
| Th-232 | 12.5 | 6.2 | 3.2 | 2.3 | 1.8 | 1.5 | 1.1 | 1.0 | 1.0 |
| U-238 | 30.6 | 18.3 | 11.1 | 8.4 | 6.7 | 4.4 | 1.3 | 1.0 | 1.0 |

**Table F.2 Final Status Survey Investigation Levels**

| Survey Unit Classification | Flag Direct Measurement of Sample Result When: | Flag Scanning Measurement Result When: |
|---|---|---|
| Class 1 | > 2 times $DCGL_w$ or site-specific based on consultation with BER | > $DCGL_w$ or $MDC_{scan}$ |
| Class 2 | > $DCGL_w$ | >$DCGL_w$ or $MDC_{scan}$ |
| Class 3 | > fraction of $DCGL_w$ | >$DCGL_w$ or $MDC_{scan}$ |

performed by taking core samples to the depth of the residual radioactivity. The number of cores to be taken is the number N required for the WRS or sign test, as appropriate. Since the final status survey is performed before any cover is placed over the area, the elevated measurement comparison test should be performed to detect any areas of elevated activity (on the surface). The grid spacing shall be adjusted if necessary.

Localized areas (subsurface) in excess of the DCGL's are allowable, provided the following criteria are met: concentration measurements may be averaged over depth if not more than 20% of the measurements exceed the $DCGL_W$, and none of the measurements exceed the $DCGL_W$ by more than a factor of 2.

Triangular grids are required due to their better efficiency in locating areas of elevated concentration.

## 9. Determining Compliance

The measurement data should first be reviewed to determine if the areas were properly classified. Refer to Section 8.2.2, *Conduct a Preliminary Data Review*, of the MARSSIM for an acceptable method. If it is shown during the final status survey that an area was misclassified with a less restrictive classification, the area should receive the correct classification and the final status survey for that area should be repeated.

If there are several areas that appear to be misclassified, it may be necessary to repeat the characterization, reclassify the areas, and re-survey them for the new classification.

The next step is to determine if the measurement results show that the survey unit(s) meets the release criteria. Chapter 8, *Interpretation of Survey Results*, of the MARSSIM provides an in-depth discussion of the interpretation of survey results, particularly for the final status survey.

Table 8.2, *Summary of Statistical Tests*, of the MARSSIM summarizes acceptable ways to interpret the sample measurements. Note that a description of the WRS test is found in Section 8.4, *Contaminant Present in Background*, of the MARSSIM, the Sign Test is found in Section 8.3, *Contaminant Not Present in Background*, and the elevated measurement comparison is described in Section 8.5 *Evaluating the Results: The Decision*.

If a survey unit fails, the measurement results should be evaluated to determine why. A survey unit fails when the null hypothesis is not rejected. When the null hypothesis is not rejected, it may be because it is in fact true, or it may be because the test did not have sufficient power to detect that it is not true. A retrospective power curve can be generated to determine if the test had sufficient power. If the retrospective power analysis shows that the test did not have sufficient power, then more samples may be all that is necessary rather than remediation. Of course some failures may be due to the fact that the residual radioactivity does not meet the remediation standards and further remediation will have to be performed.

Passing the statistical test is not the only criteria for determining compliance with the remediation standards. The following example illustrates this point. A Class 1 Survey unit passes the statistical tests and contains some areas that were flagged for investigation during scanning. Further investigation, sampling and analysis indicates one area is truly elevated. This area has a concentration that exceeds the $DCGL_W$ by a factor of 2.5. This area is then remediated. Remediation control sampling shows that the residual radioactivity was removed, and no other areas were contaminated with removed material. In this case one may simply document the original final status survey, the facto that remediation was performed, the results of the remedial action support survey, and the additional remediation data. In some cases, additional final status survey data may not be needed to demonstrate compliance with the release criterion.

Sections 8.2.2, *Conduct a Preliminary Data Review*, 8.5.3, *If the Survey Unit Fails*, and Appendix D, *The Planning Phase of the Data Life Cycle*, of the

MARSSIM provide acceptable methods for reviewing measurement results.

## 10. Documenting the Final Status Survey

Documentation for the final status survey should be complete, and provide a clear record of the radiological status of the survey unit(s) relative to the established DCGLs. Sufficient data and information should be provided so that an independent evaluation of the survey results can be performed.

While much of the information in the final status survey will be available in other reports generated during the site survey and investigation process, where practical, this report should be a stand alone document. Further guidance on documentation may be found in Appendix N, *Data Validation Using Data Descriptors*, of the MARSSIM.

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**ACRONYMS**

| | |
|---|---|
| *CERCLA* | Comprehensive Environmental Response, Compensation, and Liability Act |
| *DCGL* | derived concentration guideline level |
| *DQO* | data quality objectives |
| *DEP* | Department of Environmental Protection |
| *EMC* | elevated measurement comparison |
| *EPA* | Environmental Protection Agency |
| *HSA* | Historical Site Assessment |
| *LBGR* | lower bound of the gray region |
| *MARSSIM* | Multi-Agency Radiation Survey and Site Investigation Manual |
| *MDC* | minimum detectable concentration |
| *NORM* | naturally occurring radioactive material |
| *NRC* | Nuclear Regulatory Commission |
| *QA* | quality assurance |
| *QAPP* | quality assurance project plan |
| *QC* | quality control |
| *RCRA* | Resource Conservation and Recovery Act |
| *RI/FS* | Remedial Investigation/Feasibility Study |

## GLOSSARY

**Area of concern** – any existing or former location where radioactive materials are or were known or suspected to have been discharged, generated, manufactured, refined, transported, stored, handled, treated, disposed, or where radioactive materials have or may have migrated.

**Contaminated site** – all portions of environmental media at a site and any location where contamination is emanating, or has emanated, therefrom, that contain radioactive materials at a concentration which fails to satisfy any applicable remediation standard.

**Derived concentration guideline level (DCGL)** – a derived, radionuclide-specific activity concentration within a survey unit corresponding to the release criterion (regulatory limit expressed in dose or risk). The DCGL is derived from the activity/dose relationship through various exposure pathway scenarios and is established in N.J.A.A. 7:28-12.

**Data quality objectives (DQO)** – qualitative and quantitative statements derived from the DQO process that clarify study technical and quality objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

**Data Quality Objectives Process** – a systematic strategic planning tool based on the scientific method that identifies and defines the type, quality, and quantity of data needed to satisfy a specified use.

**Final status survey** - a survey or analysis, performed after remediation, which provides data that demonstrates that all radiological parameters satisfy the remediation standards.

**Impacted area** – any area with a possibility of containing residual radioactivity in excess of natural background levels.

**Natural background radionuclide concentration** – the average value of a particular radionuclide concentration in soils measured in areas in the vicinity of the site, in an area that has not been influenced by localized human activities, including the site's prior or current operations.

**Quality assurance** – the total integrated program for assuring the reliability of monitoring and measurement data which includes a system for integrating the quality planning, quality assessment and quality improvement efforts to meet data end-user requirements.

**Quality assurance project plan (QAPP)** – a document which presents in specific terms, the policies, organization, objectives, functional activities and specific quality assurance/quality control activities designed to achieve the data quality goals or objectives of a specific project or operation.

**Quality control** – the routine application of procedures for attaining prescribed standards of performance in the monitoring and measurement process.

**Remediation standards** – the combination of numeric standards that establish a level or concentration, and narrative standards, to which radioactive contaminants must be treated, removed, or otherwise cleaned for soil, ground water or surface water, as provided by the Department pursuant to N.J.S.A. 58:10B-12, in order to meet the health risk or environmental standards.

**Soil remediation standards** – these are the specific DCGL's determined for a particular site through the use and implementation of N.J.A.C. 7:28-12, *Soil Remediation Standards for Radioactive Materials*.

**Vertical extent** – the average depth, measured in feet, of the post-remediation radioactive contamination over an affected area not to exceed the limits specified in the Multi-Agency Radiation Survey and Site Investigation Manual (NUREG 1575, EPA 402-R-97-016) and any subsequent revisions thereto.