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July 17, 1987

Mr. Jerome Wing, Supervisor
Project Support Group
Technical Services Division
U.S. Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, TN 37831

Dear Mr. Wing:

Enclosed are five copies of the report "Derivation of a Cesium-137 Residual Radioactivity Guideline for the Niagara Falls Storage Site", which has been finalized per your direction.

If you have any questions regarding this report, please feel free to call.

Sincerely,

Charley Yu

Charley Yu
Energy and Environmental Systems Division

CY:maz

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DERIVATION OF A CESIUM-137 RESIDUAL RADIOACTIVITY GUIDELINE FOR THE NIAGARA FALLS STORAGE SITE

by

Charley Yu, John Peterson, and YuChien Yuan

Energy and Environmental Systems Division

July 1987

work sponsored by

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office

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FIGURE

TABLE

DERIVATION OF A CESIUM-137 RESIDUAL RADIOACTIVITY GUIDELINE FOR THE NIAGARA FALLS STORAGE SITE

by

Charley Yu, John Peterson, and YuChien Yuan

ABSTRACT

The cesium-137 residual radioactivity guideline for the Niagara Falls Storage Site (NFSS), Lewiston, New York, was derived based on the requirement that the 50-year committed effective dose equivalent to a hypothetical individual who lives in the immediate vicinity of NFSS should not exceed a dose of 100 mrem/yr following decontamination of the vicinity property. Procedures specified in the U.S. Department of Energy manual for implementing residual radioactivity guidelines were used in this evaluation. The results of the evaluation indicate that the basic dose limit of 100 mrem/yr will not be exceeded in the foreseeable future, provided that the soil concentration of cesium-137 in the vicinity of NFSS does not exceed 30 pCi/g following decontamination.

1 INTRODUCTION AND BRIEF HISTORY

The Niagara Falls Storage Site (NFSS) is located in the town (township) of Lewiston, Niagara County, New York, about 30 km (19 mi) north of Buffalo, New York (Fig. 1). The 77-ha (190-acre) site is part of a former 610-ha (1,500-acre) Manhattan Engineer District (MED) site, which in turn was part of the former Lake Ontario Ordnance Works. Beginning in 1944, the MED used the site for storage of radioactive residues that resulted from the processing of uranium ores (pitchblende) during development of the atomic bomb. Additional residues were brought to the site for several years after World War II (U.S. Dept. Energy 1986b).

Subsequent to MED, responsibility for the site has been transferred to the U.S. Atomic Energy Commission (AEC), the U.S. Energy Research and Development Administration (ERDA), and the U.S. Department of Energy (DOE). The site is currently administered by the Oak Ridge Operations Office of DOE and operated by Bechtel National, Inc. It is fenced and access is limited (U.S. Dept. of Energy 1986b).

Remedial actions are currently being conducted by Bechtel National (1987). These remedial actions consist of decontaminating portions of NFSS, as well as nearby

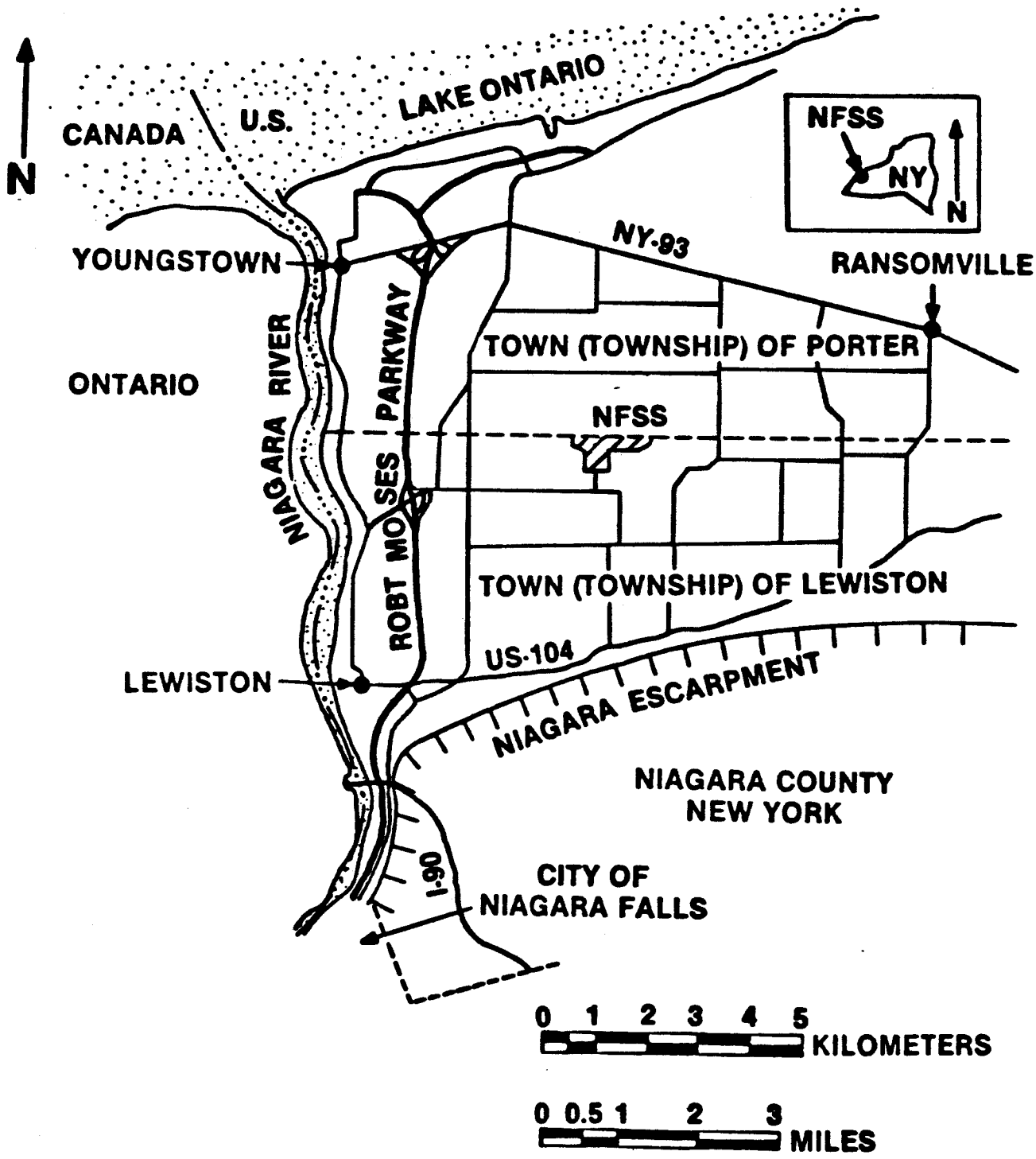

FIGURE 1 Location of the Niagara Falls Storage Site (Source: U.S. Dept. Energy 1986b)

off-site properties, to allow for unrestricted use of these areas. Upon completion of remedial actions, all radioactively contaminated materials will be consolidated within a 3.4-ha (8.5-acre) containment area in the southwest corner of NFSS (U.S. Dept. Energy 1986b). Current remedial actions are being guided by thorium and radium residual radioactivity guidelines (App. A). The purpose of this report is to evaluate the residual radioactivity guideline for cesium-137 that is applicable to the remedial actions for NFSS, i.e., the residual concentration of cesium-137 in soil that must not be exceeded if decontaminated portions of the site, as well as vicinity properties, are to be released for unrestricted use. The derivation of a site-specific cesium-137 guideline for NFSS is based on a dose limit of 100 mrem/yr (App. A), assuming that cesium-137 is the only radionuclide present at above-background concentrations. Procedures given in the DOE manual for implementing residual radioactivity guidelines (U.S. Dept. Energy 1985 -- hereafter referred to as "the Manual") were used to derive this guideline.

2 SCENARIO DEFINITION

The potential exposure scenario considered in this evaluation assumes unrestricted use, at some time in the future, of the areas of NFSS that have been decontaminated. A hypothetical person is assumed to take up residence in the immediate vicinity of NFSS, drink water from a well adjacent to the decontaminated area, ingest plant foods grown in a garden in the decontaminated area, ingest meat and milk from livestock raised in the decontaminated area, and ingest fish from a nearby pond. The seven pathways analyzed in this scenario are (1) direct exposure to external radiation from the decontaminated soil material, (2) internal radiation from inhalation of dust, (3) internal radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from a well adjacent to the decontaminated area, (4) internal radiation from ingestion of meat from livestock fed with fodder grown in the decontaminated area and water drawn from an adjacent well, (5) internal radiation from ingestion of milk from livestock fed with fodder grown in the decontaminated area and water drawn from an adjacent well, (6) internal radiation from ingestion of aquatic food (fish) from a nearby pond, and (7) internal radiation from drinking water from a hypothetical shallow well adjacent to the decontaminated area on the downgradient side.

The radiation dose to this hypothetical future resident was calculated according to the method described in the Manual, based on the following specific assumptions:

- The individual spends 50% of his or her time indoors in the decontaminated area, 25% outdoors in the decontaminated area, and 25% away from the decontaminated area.

- The size of the decontaminated area is sufficiently large that 50% of the plant food diet consumed by the individual is grown in a garden in the decontaminated area.

- The size of the decontaminated area is large enough to provide sufficient meat and milk for the individual from livestock raised (i.e., foraging) in the decontaminated area.

- Vegetables are irrigated by, and livestock are provided with, water from a well adjacent to the contaminated area.

- A nearby pond provides 50% of the aquatic food consumed by the individual.

3 DOSE-TO-SOURCE RATIO

The dose-to-source (D/S) ratio for cesium-137 was calculated using the method described in the Manual. The summation of D_p/S for all pathways p is the D/S ratio, i.e.,

$$D/S = \sum_p D_p/S \ .$$

The D/S ratio was used to determine the allowable residual radioactivity for cesium-137 in the vicinity of NFSS. The derivation of D_p/S for cesium-137 for the seven pathways applicable to NFSS is presented in Secs. 3.1-3.5. The various parameters used for this analysis are defined in App. B. All symbols are defined in App. C.

3.1 EXTERNAL RADIATION PATHWAY

The formula for the D_p/S ratio for the external radiation pathway (p = 1) is

$$D_1/S = (D/E)_1 \times \rho_b^{cz} \times FO_1 \times FA_1 \times FD_1 \ .$$

Using the parameter values listed in Table B.1, App. B, the D_1/S ratio for cesium-137 was calculated to be 3.0 (mrem/yr)/(pCi/g) (see Table 1, row p = 1).

3.2 DUST INHALATION PATHWAY

The D_p/S ratio for internal exposure from inhalation of dust (p = 2) was calculated using the following equation:

$$D_2/S = (D/E)_2 \times (E/A)_2 \times FO_2 \times FS_2 \times (A_2/S) \ .$$

The mass loading, A_2/S (i.e., the mass of airborne dust per unit volume of air), was assumed to be 2.0×10^{-4} g/m^3. This is a conservative estimate that takes into account short periods of high mass loading and sustained periods of normal activity on a typical farm (Gilbert et al. 1983). The source factor FS_2 was assumed to be 1.0, which takes no credit for the dilution of contaminated dust resuspended on-site by uncontaminated dust blown in from off-site. Using the parameters listed in Table B.1, App. B, the D_2/S ratio for cesium-137 was calculated to be 2.7×10^{-5} (mrem/yr)/(pCi/g) (see Table 1, row p = 2).

TABLE 1 D_p/S Ratios for Cesium-137

Pathway	D_p/S, (mrem/yr)/(pCi/g)
p = 1	3.0
p = 2	2.7×10^{-5}
p = 3	5.0×10^{-3}
p = 4	1.9×10^{-2}
p = 5	7.5×10^{-3}
p = 6	0
p = 7	5.3×10^{-3}
Total: $D/S = \sum_{p=1}^{7} D_p/S$	3.0

3.3 NONAQUATIC FOOD PATHWAYS

Nonaquatic food pathways include ingestion of plant food (p = 3), meat (p = 4), and milk (p = 5). Root uptake, foliar deposition from potentially contaminated dust, and irrigation using water drawn from a well adjacent to the decontaminated area were considered in the analysis.

The D_p/S ratio for internal exposure from ingestion of nonaquatic foods was calculated using the following equation:

$$D_p^q/S = (D/E)_p \times (E_p^q/S) \times FA_p \times FD_p^q$$

where q is an index for root uptake (q = 1), foliar deposition (q = 2), and irrigation (q = 3), and p is an index for plant food (p = 3), meat (p = 4), and milk (p = 5). The summation of D_p^q/S over q gives D_p/S. The environmental transport factors E_p^1/S and E_p^2/S for the plant food (p = 3), meat (p = 4), and milk (p = 5) pathways are given in Tables 4.3 and 4.4, respectively, of the Manual. The E_p^3/S values were calculated using the following equation:

$$E_p^3/S = (E^3/W)_p \times (W_7/S)$$

where the $(E^3/W)_p$ values were taken from Table 4.5 of the Manual and W_7/S was calculated for the drinking water pathway (p = 7) (Sec. 3.5). Using the parameters listed

in Table B.1, App. B, the D_3/S, D_4/S, and D_5/S ratios for cesium-137 were calculated to be 5.0×10^{-3}, 1.9×10^{-2}, and 7.5×10^{-3} (mrem/yr)/(pCi/g), respectively (see Table 1 -- rows p = 3, p = 4, and p = 5).

3.4 AQUATIC FOOD PATHWAY

The aquatic food pathway is based on the assumption that a nearby pond, constructed at some time in the future, provides 50% of the aquatic food consumed by the hypothetical individual living in the immediate vicinity of NFSS. The D_p/S ratio for internal exposure from ingestion of aquatic foods was calculated using the following equation:

$$D_6/S = (D/E)_6 \times (E/W)_6 \times (W_6/S) \times FR_6$$

The water-to-source concentration factor for the surface water pathway, W_6/S, was calculated as:

$$W_6/S = (1{,}000/K_d^{cz}) \times F^{sw} \times \exp[-\lambda(\Delta t^{uz} + \Delta t^{sz})] \ .$$

A site-specific distribution coefficient, K_d^{cz}, for cesium is not available. Reviewing cesium distribution coefficients in various soil materials published in the literature (Pietrzak et al. 1981; Gilbert et al. 1983; Till and Meyer 1983; Natl. Counc. Radiat. Prot. Measure. 1984; Sheppard et al. 1984; Yu 1984; U.S. Dept. Energy 1986a), a conservative value of 2.0 mL/g was used in this analysis. Using the parameters listed in Table B.1, App. B, D_6/S was calculated to be approximately 0 (mrem/yr)/(pCi/g) (see Table 1, row p = 6).

3.5 DRINKING WATER PATHWAY

The D_p/S ratio for internal exposure from drinking water (p = 7) drawn from a well adjacent to the decontaminated area was calculated using the equation:

$$D_7/S = (D/E)_7 \times (E/W)_7 \times (W_7/S) \ .$$

The water-to-source concentration factor for the groundwater pathway, W_7/S, was calculated as:

$$W_7/S = (1{,}000/K_d^{cz}) \times F^{uz} \times F^{sz}$$

The F^{uz} and F^{sz} factors were calculated using the method described in the Manual, except the retardation factor, R_d, was modified so that the radionuclide migration

velocity is more conservatively estimated. The retardation factor defined in the Manual reads:

$$R_d = 1 + \rho_b K_d/\theta_e$$

where θ_e is the effective water content. It was modified to read:

$$R_d = 1 + \rho_b K_d/\theta_t$$

where θ_t is the total water content. The rationale for this modification can be found in reports of the U.S. Department of Energy (1987) and Yu (1987).

Using the parameters listed in Table B.1, App. B, it was calculated that

$$F^{uz} = 1.0$$

and

$$F^{sz} = 5.1 \times 10^{-4} .$$

Hence, the D_7/S ratio for cesium-137 was calculated to be 5.3×10^{-3} (mrem/yr)/(pCi/g) (see Table 1, row p = 7).

4 RESIDUAL RADIOACTIVITY GUIDELINE

Based on the dose-to-source ratios derived in Secs. 3.1-3.5 for each pathway applicable to NFSS, the D/S ratio for cesium-137 was calculated by summing up D_p/S over all pathways (see Table 1). The residual radioactivity guideline is defined as the concentration of residual radioactive material that can remain in the decontaminated areas and still allow for unrestricted use of that area. Using the annual radiation dose limit of 100 mrem/yr (App. A), the residual radioactivity guideline S_G for cesium-137 for NFSS was calculated using the following equation:

$$S_G = 100/(D/S) \ .$$

The residual radioactivity guideline for cesium-137 was calculated to be 30 pCi/g (rounded to one significant figure).

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APPENDIX A

DOE GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL

U.S. DEPARTMENT OF ENERGY GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL AT FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

(Revision 2, March 1987)

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive material and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).* The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactive material, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Department of Energy 1986) and subsequent guidance. More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactive material from basic dose limits, is contained in "A Manual for Implementing Residual Radioactive Material Guidelines" (U.S. Department of Energy 1987), referred to herein as the "supplement".

"Residual radioactive material" is used in these guidelines to describe radioactive material derived from operations or sites over which DOE has authority. Guidelines or guidance to limit the levels of radioactive material and to protect the public and the environment are provided for (1) residual concentrations of radionuclides in soil,** (2) concentrations of airborne

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*A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

**"Soil" is defined herein as unconsolidated earth material, including rubble and debris that may be present in earth material.

radon decay products, (3) external gamma radiation levels, (4) surface contamination levels, and (5) radionuclide concentrations in air or water resulting from or associated with any of the above.

A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). The basic dose limits are used for deriving guidelines for residual concentrations of radionuclides in soil. Guidelines for residual concentrations of thorium and radium in soil, concentrations of airborne radon decay products, allowable indoor external gamma radiation levels, and residual surface contamination concentrations are based on existing radiological protection standards (U.S. Environmental Protection Agency 1983; U.S. Nuclear Regulatory Commission 1982; and DOE Departmental Orders). Derived guidelines or limits based on the basic dose limits for those quantities are used only when the guidelines provided in the existing standards cited above are shown to be inappropriate.

A "guideline" for residual radioactive material is a level of radioactivity or radioactive material that is acceptable if use of the site is to be unrestricted. Guidelines for residual radioactive material presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement. The basis for the guidelines is generally a presumed worst-case plausible-use scenario for the site.

An "authorized limit" is a level of residual radioactive material or radioactivity that must not be exceeded if the remedial action is to be considered completed and the site is to be released for unrestricted use. The authorized limits for a site will include (1) limits for each radionuclide or group of radionuclides, as appropriate, associated with residual radioactive material in soil or in surface contamination of structures and equipment, (2) limits for each radionuclide or group of radionuclides, as appropriate, in air or water, and, (3) where appropriate, a limit on external gamma radiation resulting from the residual material. Under normal circumstances, expected to occur at most sites, authorized limits for residual radioactive material or radioactivity are set equal to guideline values. Exceptional conditions for which authorized limits might differ from guideline values are specified in Sections D and F of this document. A site may be released for unrestricted use only if site conditions do not exceed the authorized limits or approved supplemental limits, as defined in Section F.1, at the time remedial action is completed. Restrictions and controls on use of the site must be established and enforced if site conditions exceed the approved limits, or if there is potential to exceed the basic dose limit if use of the site is not restricted (Section F.2). The applicable controls and restrictions are specified in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). For sites to be released for unrestricted use, the intent is to reduce residual radioactive material to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual material is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to levels that are as low as reasonably achievable. Procedures for implementing ALARA policy are discussed in the supplement. ALARA policies, procedures, and actions shall be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 100 mrem/yr. The internal committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), plus the dose from penetrating radiation sources external to the body, shall be used for determining the dose. This dose shall be described as the "effective dose equivalent". Every effort shall be made to ensure that actual doses to the public are as far below the basic dose limit as is reasonably achievable.

Under unusual circumstances, it will be permissible to allow potential doses to exceed 100 mrem/yr where such exposures are based upon scenarios that do not persist for long periods and where the annual lifetime exposure to an individual from the subject residual radioactive material would be expected to be less than 100 mrem/yr. Examples of such situations include conditions that might exist at a site scheduled for remediation in the near future or a possible, but improbable, one-time scenario that might occur following remedial action. These levels should represent doses that are as low as reasonably achievable for the site. Further, no annual exposure should exceed 500 mrem.

C. GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL

C.1 Residual Radionuclides in Soil

Residual concentrations of radionuclides in soil shall be specified as above-background concentrations averaged over an area of 100 m^2. Generic guidelines for thorium and radium are specified below. Guidelines for residual concentrations of other radionuclides shall be derived from the basic dose limits by means of an environmental pathway analysis using site-specific data where available. Procedures for these derivations are given in the supplement.

If the average concentration in any surface or below-surface area less than or equal to 25 m^2 exceeds the authorized limit or guideline by a factor of $(100/A)^{1/2}$, where A is the area of the elevated region in square meters,

limits for "hot spots" shall also be applicable. Procedures for calculating these hot spot limits, which depend on the extent of the elevated local concentrations, are given in the supplement. In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

Two types of guidelines are provided, generic and derived. The generic guidelines for residual concentrations of Ra-226, Ra-228, Th-230, and Th-232 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface
- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

These guidelines take into account ingrowth of Ra-226 from Th-230 and of Ra-228 from Th-232, and assume secular equilibrium. If either Th-230 and Ra-226 or Th-232 and Ra-228 are both present, not in secular equilibrium, the appropriate guideline is applied as a limit to the radionuclide with the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit or (2) the sum of the ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity"). Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR Part 192) is: In any occupied or habitable building, the objective of remedial action shall be, and a reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions by DOE are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive material is not the cause.

---

*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

C.3 External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released for unrestricted use shall not exceed the background level by more than 20 μR/h and shall comply with the basic dose limit when an appropriate-use scenario is considered. This requirement shall not necessarily apply to structures scheduled for demolition or to buried foundations. External gamma radiation levels on open lands shall also comply with the basic dose limit, considering an appropriate-use scenario for the area.

C.4 Surface Contamination

The generic surface contamination guidelines provided in Table 1 are applicable to existing structures and equipment. These guidelines are adapted from standards of the U.S. Nuclear Regulatory Commission (NRC 1982)* and will be applied in a manner that provides a level of protection consistent with the Commission's guidance. These limits apply to both interior and exterior surfaces. They are not directly intended for use on structures to be demolished or buried, but should be applied to equipment or building components that are potentially salvageable or recoverable scrap. If a building is demolished, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

C.5 Residual Radionuclides in Air and Water

Residual concentrations of radionuclides in air and water shall be controlled to levels required by DOE Environmental Protection Guidance and Orders, specifically DOE Order 5480.1A and subsequent guidance. Other Federal and/or state standards shall apply when they are determined to be appropriate.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVE MATERIAL

Authorized limits shall be established to (1) ensure that, as a minimum, the basic dose limits specified in Section B will not be exceeded under the worst-case plausible-use scenario consistent with the procedures and guidance provided or (2) be consistent with applicable generic guidelines, where such guidelines are provided. The authorized limits for each site and its vicinity properties shall be set equal to the generic or derived guidelines except where it can be clearly established on the basis of site-specific data -- including health, safety, and socioeconomic considerations -- that the guidelines are not appropriate for use at the specific site. Consideration should also be given to ensure that the limits comply with or provide a level of protection equivalent to other appropriate limits and guidelines (i.e., state or

*These guidelines are functionally equivalent to Section 4 -- Decontamination for Release for Unrestricted Use -- of NRC Regulatory Guide 1.86 (U.S. Atomic Energy Commission 1974), but they are applicable to non-reactor facilities.

TABLE 1 SURFACE CONTAMINATION GUIDELINES

Radionuclides[b]	Allowable Total Residual Surface Contamination (dpm/100 cm^2)[a]		
	Average[c,d]	Maximum[d,e]	Removable[d,f]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 β-γ	15,000 β-γ	1,000 β-γ

[a] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[b] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[c] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[d] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[e] The maximum contamination level applies to an area of not more than 100 cm^2.

[f] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

other Federal). Documentation supporting such a decision should be similar to that required for supplemental limits and exceptions (Section F), but should be generally more detailed because the documentation covers the entire site.

Remedial action shall not be considered complete unless the residual radioactive material levels comply with the authorized limits. The only exception to this requirement will be for those special situations where the supplemental limits or exceptions are applicable and approved as specified in Section F. However, the use of supplemental limits and exceptions should be considered only if it is clearly demonstrated that it is not reasonable to decontaminate the area to the authorized limit or guideline value. The authorized limits are developed through the project offices in the field and are approved by the headquarters program office.

E. CONTROL OF RESIDUAL RADIOACTIVE MATERIAL AT FUSRAP AND REMOTE SFMP SITES

Residual radioactive material above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A and subsequent guidance or superceding Orders require compliance with applicable Federal and state environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to interim storage, interim management, and long-term management.

a. 5000.3, Unusual Occurrence Reporting System

b. 5440.1C, Implementation of the National Environmental Policy Act

c. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations, as revised by DOE 5480.1 change orders and the 5 August 1985 memorandum from Vaughan to Distribution

d. 5480.2, Hazardous and Radioactive Mixed Waste Management

e. 5480.4, Environmental Protection, Safety, and Health Protection Standards

f. 5482.1A, Environmental, Safety, and Health Appraisal Program

g. 5483.1A, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities

h. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.

b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).

c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive material shall not exceed existing Federal or state standards.

d. Access to a site shall be controlled and misuse of on-site material contaminated by residual radioactive material shall be prevented through appropriate administrative controls and physical barriers -- active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The Federal government shall have title to the property or shall have a long-term lease for exclusive use.

E.2 Interim Management

a. A site may be released under interim management when the residual radioactive material exceeds guideline values if the residual radioactive material is in inaccessible locations and would be unreasonably costly to remove, provided that administrative controls are established to ensure that no member of the public shall receive a radiation dose exceeding the basic dose limit.

b. The administrative controls, as approved by DOE, shall include but not be limited to periodic monitoring as appropriate, appropriate shielding, physical barriers to prevent access, and appropriate radiological safety measures during maintenance, renovation, demolition, or other activities that might disturb the residual radioactive material or cause it to migrate.

c. The owner of the site or appropriate Federal, state, or local authorities shall be responsible for enforcing the administrative controls.

E.3 Long-Term Management

Uranium, Thorium, and Their Decay Products

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.

b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the wastes shall not (1) exceed an annual average release rate of 20 $pCi/m^2/s$ and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.

c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b. of this section (E.3) to be exceeded and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a. of this section (E.3).

d. Groundwater shall be protected in accordance with appropriate Departmental Orders and Federal and state standards, as applicable to FUSRAP and remote SFMP sites.

e. Access to a site should be controlled and misuse of on-site material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers -- active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The Federal government shall have title to the property.

Other Radionuclides

f. Long-term management of other radionuclides shall be in accordance with Chapters 2, 3, and 5 of DOE Order 5820.2, as applicable.

F. SUPPLEMENTAL LIMITS AND EXCEPTIONS

If special site-specific circumstances indicate that the guidelines or authorized limits established for a given site are not appropriate for a portion of that site or for a vicinity property, then the field office may request that supplemental limits or an exception be applied. In either case, the field office must justify that the subject guidelines or authorized limits are not appropriate and that the alternative action will provide adequate

protection, giving due consideration to health and safety, the environment, and costs. The field office shall obtain approval for specific supplemental limits or exceptions from headquarters as specified in Section D of these guidelines and shall provide to headquarters those materials required for the justification as specified in this section (F) and in the FUSRAP and SFMP protocols and subsequent guidance documents. The field office shall also be responsible for coordination with the state or local government of the limits or exceptions and associated restrictions as appropriate. In the case of exceptions, the field office shall also work with the state and/or local governments to ensure that restrictions or conditions of release are adequate and mechanisms are in place for their enforcement.

F.1 Supplemental Limits

The supplemental limits must achieve the basic dose limits set forth in this guideline document for both current and potential unrestricted uses of a site and/or vicinity property. Supplemental limits may be applied to a vicinity property or a portion of a site if, on the basis of a site-specific analysis, it is determined that (1) certain aspects of the vicinity property or portion of the site were not considered in the development of the established authorized limits and associated guidelines for that vicinity property or site and, (2) as a result of these unique characteristics, the established limits or guidelines either do not provide adequate protection or are unnecessarily restrictive and costly.

F.2 Exceptions

Exceptions to the authorized limits defined for unrestricted use of a site or vicinity property may be applied to a vicinity property or a portion of a site when it is established that the authorized limits cannot be achieved and restrictions on use of the vicinity property or portion of the site are necessary to provide adequate protection of the public and the environment. The field office must clearly demonstrate that the exception is necessary and that the restrictions will provide the necessary degree of protection and will comply with the requirements for control of residual radioactive material as set forth in Section E of these guidelines.

F.3 Justification for Supplemental Limits and Exceptions

Supplemental limits and exceptions must be justified by the field office on a case-by-case basis using site-specific data. Every effort should be made to minimize use of the supplemental limits and exceptions. Examples of specific situations that warrant use of the supplemental standards and exceptions are:

a. Where remedial action would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

b. Where remedial action -- even after all reasonable mitigative measures have been taken -- would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

c. Where it is clear that the scenarios or assumptions used to establish the authorized limits do not, under plausible current or future conditions, apply to the property or portion of the site identified and where more appropriate scenarios or assumptions indicate that other limits are applicable or necessary for protection of the public and the environment.

d. Where the cost of remedial action for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive material does not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial action will generally not be necessary where only minor quantities of residual radioactive material are involved or where residual radioactive material occurs in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples include residual radioactive material under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. A site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the level of residual radioactive material must be included in the appropriate state and local records.

e. Where there is no feasible remedial action.

G. SOURCES

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry model and dose limits	International Commission on Radiological Protection (1977, 1978)
Generic Guidelines for Residual Radioactivity	
Residual concentrations of radium and thorium in soil	40 CFR Part 192
Airborne radon decay products	40 CFR Part 192
External gamma radiation	40 CFR Part 192
Surface contamination	Adapted from U.S. Nuclear Regulatory Commission (1982)
Control of Radioactive Wastes and Residues	
Interim storage	DOE Order 5480.1A and subsequent guidance
Long-term management	DOE Order 5480.1A and subsequent guidance; 40 CFR Part 192; DOE Order 5820.2

H. REFERENCES

International Commission on Radiological Protection, 1977. Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977). ICRP Publication 26. Pergamon Press, Oxford. [As modified by "Statement from the 1978 Stockholm Meeting of the ICRP." Annals of the ICRP, Vol. 2, No. 1, 1978.]

International Commission on Radiological Protection, 1978. Limits for Intakes of Radionuclides by Workers. A Report of Committee 2 of the International Commission on Radiological Protection. Adopted by the Commission in July 1978. ICRP Publication 30. Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index. Pergamon Press, Oxford.

U.S. Atomic Energy Commission, 1974. Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors. June 1974.

U.S. Department of Energy, 1986. Formerly Utilized Sites Remedial Action Program. Summary Protocol: Identification - Characterization - Designation - Remedial Action - Certification. Office of Nuclear Energy, Office of Terminal Waste Disposal and Remedial Action, Division of Remedial Action Projects. January 1986.

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U.S. Environmental Protection Agency, 1983. Standards for Remedial Actions at Inactive Uranium Processing Sites; Final Rule (40 CFR Part 192). Federal Register 48(3):590-604 (January 5, 1983).

U.S. Nuclear Regulatory Commission, 1982. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, D.C. July 1982.

APPENDIX B

PARAMETERS USED IN THE PATHWAY ANALYSIS

The parameter values used in the pathway analysis and their sources are listed in Table B.1. All parameter values are reported to two significant figures. Definitions of the symbols used for all parameters are given in App. C.

TABLE B.1 Parameters Used in the Pathway Analysis for NFSS

Parameter	Unit	Value	Reference
External Radiation Pathway (p = 1)			
$(D/E)_1$	(mrem/yr)/(pCi/cm^3)	2.8	U.S. Dept. Energy (1985)
FA_1	-[a]	1.0	U.S. Dept. Energy (1985)
FO_1	-[a]	0.6	U.S. Dept. Energy (1985)
FD_1	-[a]	1.0	U.S. Dept. Energy (1985)
ρ_b^{cz}	g/cm^3	1.8	U.S. Dept. Energy (1985)
Dust Inhalation Pathway (p = 2)			
$(E/A)_2$	m^3/yr	8,400	U.S. Dept. Energy (1985)
FO_2	-[a]	0.5	U.S. Dept. Energy (1985)
FS_2	-[a]	1.0	U.S. Dept. Energy (1985)
A_2/S	g/m^3	2.0×10^{-4}	U.S. Dept. Energy (1985)
$(D/E)_2$	mrem/pCi	3.2×10^{-5}	U.S. Dept. Energy (1985)
Ingestion Pathway (p = 3,4,5,6,7)			
FA_3	-[a]	0.50	-[b]
FA_4	-[a]	1.0	-[b]
FA_5	-[a]	1.0	-[b]
FD_p^q (q = 1,2,3)	-[a]	1.0	U.S. Dept. Energy (1985)

TABLE B.1 (Cont'd)

Parameter	Unit	Value	Reference
Ingestion Pathway (p = 3,4,5,6,7) - Cont'd			
$(D/E)_p$	mrem/pCi	5.0×10^{-5}	U.S. Dept. Energy (1985)
$(E/W)_7$	L/yr	410	U.S. Dept. Energy (1985)
ℓ	m	120	-[b]
d	m	10	U.S. Dept. Energy (1986)
K_d^{cz}	mL/g	2.0	-[c]
K_d^{sz}	mL/g	2.0	-[c]
θ_e^{sz}	-	0.10	U.S. Dept. Energy (1986)
θ_t^{sz}	-	0.40	-[b]
K_h^{sz}	m/yr	3.5	Bechtel Natl. (1984)
ρ_b^{sz}	g/cm^3	1.7	U.S. Dept. Energy (1986)
J	-[a]	0.001	U.S. Dept. Energy (1986)
h	m	0.0	U.S. Dept. Energy (1986)
R	m/yr	0.11	U.S. Dept. Energy (1986)
A	m^2	3.7×10^4	-[b]
A_w	m^2	1.0×10^6	U.S. Dept. Energy (1985)
P_r	m/yr	0.89	U.S. Dept. Energy (1986)
E_t	m/yr	0.60	U.S. Dept. Energy (1986)
L	m	120	-[b]

[a] A hyphen means the parameter is dimensionless.

[b] No data are available; conservative values are used in this analysis.

[c] See discussion in text.

REFERENCES (Appendix B)

Bechtel National, Inc., 1984, *Engineering Evaluation of Alternatives for the Disposition of Niagara Falls Storage Site, Its Residues and Wastes, Lewiston, New York*, DOE/OR/20722-1, prepared for U.S. Department of Energy, Oak Ridge Operations Office (Jan.).

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U.S. Department of Energy, 1986, *Final Environmental Impact Statement, Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site*, DOE/EIS-0109F, Washington, D.C. (April).

APPENDIX C

DEFINITION OF SYMBOLS USED IN THE PATHWAY ANALYSIS

The symbols used in the pathway analysis for derivation of the cesium-137 residual radioactivity guideline are defined in Table C.1.

TABLE C.1 Definition of Symbols Used in the Pathway Analysis for NFSS

Symbol	Definition
D/S	Ratio of dose from a radionuclide to the concentration of that radionuclide in soil material
D_p^q/S	D/S ratio for pathway p through root uptake (q = 1), foliar deposition (q = 2), and irrigation (q = 3) -- index q used only for pathways 3, 4, and 5
$(D/E)_p$	Dose conversion factor for pathway p
ρ_b^{cz}	Bulk density for the material in the contaminated zone
ρ_b^{sz}	Bulk density for soil in the saturated zone
FO_p	Occupancy factor for pathway p
FA_p	Area factor for pathway p
FS_2	Source factor for inhalation pathway
FD_p^q	Depth factor for pathway p through root uptake (q = 1), foliar deposition (q = 2), and irrigation (q = 3) -- index q used only for pathways 3, 4, and 5
$(E/A)_2$	Annual air intake
A_2/S	Mass loading of airborne dust for inhalation
E_p^q/S	Environmental transport factor for pathway p through root uptake (q = 1), foliar deposition (q = 2), and irrigation (q = 3) -- index q used only for pathways 3, 4, and 5

TABLE C.1 (Cont'd)

Symbol	Definition
$(E^q/W)_p$	Environmental transport factor for food products raised using contaminated water for irrigation -- index q used only for pathways 3, 4, and 5
W_p/S	Water-to-source concentration factor for pathway p (p = 6,7)
FR_6	Fraction of aquatic food diet taken from a nearby pond
K_d^{cz}	Distribution coefficient for radionuclide in the contaminated zone
K_d^{sz}	Distribution coefficient for radionuclide in the saturated zone
F^{sw}	Ratio of radionuclide concentration in a nearby pond to the concentration in water seeping from the ground
F^{uz}	Ratio of radionuclide concentration in percolating groundwater as it leaves the unsaturated zone to the concentration as the water enters the uncontaminated portion of the unsaturated zone
F^{sz}	Ratio of radionuclide concentration in well water (for the drinking water pathway) or in water seeping from the ground (for pathways involving surface water) to the concentration in the percolating water as it enters the saturated zone at the water table
λ	Radionuclide decay constant
Δt^{uz}	Water transport time for the unsaturated zone
Δt^{sz}	Water transport time for the saturated zone
R_d	Radionuclide retardation factor
θ_e	Effective water content
θ_t	Total water content
S_G	Residual radioactivity guideline
ℓ	Distance between the hypothetical well and the upgradient edge of the area of consideration

TABLE C.1 (Cont'd)

Symbol	Definition
d	Distance of well pump intake below the water table
K_h^{sz}	Hydraulic conductivity for the saturated zone
J	Hydraulic gradient
h	Depth of unsaturated zone
R	Recharge rate
A	Decontaminated area that is used for farming and on which a residence is constructed
A_w	Area of watershed that drains into the pond
P_r	Precipitation rate
E_t	Evapotranspiration rate
L	Distance from the area of contamination to the point where the groundwater reaches the surface