DEVELOPMENT OF A SUPPLEMENTAL RESIDUAL CONTAMINATION GUIDELINE FOR THE NFSS CENTRAL DRAINAGE DITCH

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1.0 INTRODUCTION AND SUMMARY

1.1 OBJECTIVE AND SCOPE

The objective of this report is to describe the methodology used for establishing a supplemental residual contamination guideline for the NFSS vicinity property known as the Central Drainage Ditch (CDD). Supplemental guidelines may exceed authorized guidelines if the resultant dose will not exceed the DOE radiation protection standard of 100 mrem/yr (Ref. 1). This evaluation is based on realistic exposure pathways that were determined from examination of the current topographical features of the CDD and land use in the area. While this analysis is directed toward a specific portion of the CDD, it can be applied to any other reach of the ditch.

1.2 BACKGROUND

The Niagara Falls Storage Site (NFSS) is a U.S. Department of Energy (DOE) surplus facility located in the Town of Lewiston, Niagara County, New York (see Figure 1-1). The 77-ha (191-acre) site is a small portion of the original Lake Ontario Ordnance Works (LOOW) and was formerly used for the storage and transshipment and radioactive materials. The site is currently being managed for DOE by Bechtel National, Inc. (BNI), Oak Ridge, Tennessee, as part of the DOE Surplus Facilities Management Program (SFMP) established to plan and manage the ultimate disposition of surplus DOE-owned facilities. Portions of the former LOOW site and other vicinity properties are within the jurisdiction of another DOE remedial action program, the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to evaluate former Manhattan Engineer District/Atomic Energy Commission (MED/AEC) sites and to conduct remedial action activities where residual radioactivity exceeds the remedial action guidelines established by DOE.

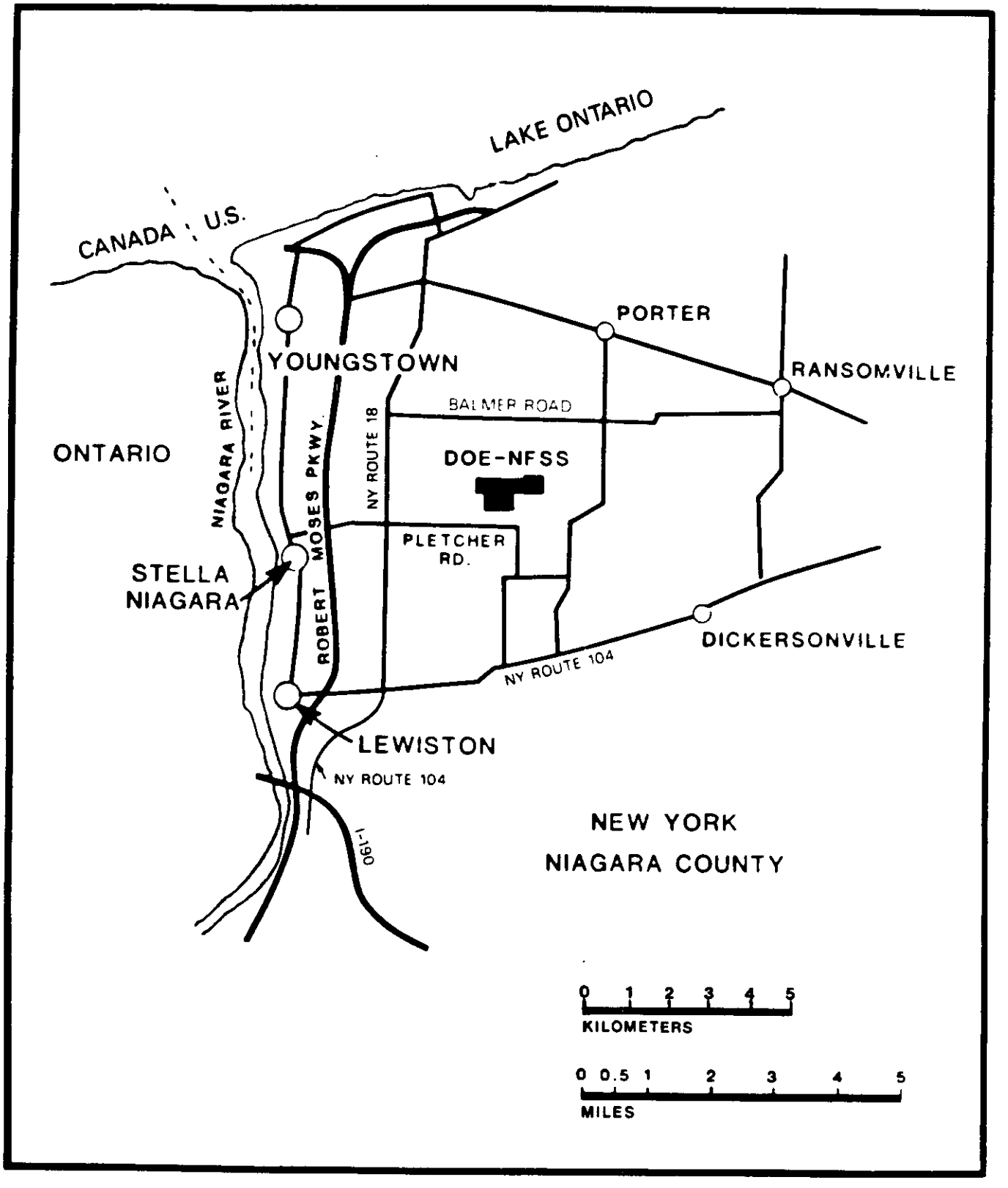

FIGURE 1-1 THE REGIONAL SETTING OF THE NFSS

Radioactive residues and contaminated soils are currently stored at the NFSS (Ref. 2). Some areas of the site also became contaminated from previous burial and spills of contaminated materials, and from radionuclide migration along drainage pathways such as the CDD. Since 1981 remedial action has been conducted at the NFSS and properties in the vicinity to consolidate the contaminated material in a waste containment facility at the NFSS.

2.0 DESCRIPTION AND RADIOLOGICAL STATUS OF THE CENTRAL DRAINAGE DITCH

2.1 DESCRIPTION OF THE CDD

The CDD originates on the NFSS property and flows northward for approximately 3.2 km (2 mi) before flowing northwest for another 1.6 km (1 mi) to its confluence with Fourmile Creek (see Figure 2-1). The creek discharges into Lake Ontario 2.4 km (1.5 mi) downstream from the point at which the CDD joins it.

On the NFSS property, the CDD is approximately 3 to 4 m (10 to 15 ft) deep, 3 to 6 m (10 to 20 ft) wide at the bottom of the channel, and 12 to 15 m (40 to 50 ft) wide at the top of the banks. Beyond the northern boundary of the NFSS, the width of the ditch varies between 6 m (20 ft) and 10 m (30 ft); for the purposes of this study, the average width is assumed to be 8 m (26 ft) (Ref. 3).

2.2 CURRENT RADIOLOGICAL STATUS OF THE CDD

The CDD has undergone remedial action excavation from its origin to a point approximately 500 m (1600 ft) west of Lutts Road (see Figures 2-1 and 2-2). The section of the ditch extending from 500 m (1600 ft) west of Lutts Road to its confluence with Fourmile Creek [approximately 1000 m (3280 ft)] remains unexcavated.

Concentrations of radium-226, uranium-238, and thorium-232 in the sediment have been determined for the unexcavated portion of the CDD (Refs. 4 and 5). Thorium-232 concentrations ranged from nondetectable to 4.8 pCi/g (Ref. 3). These are assumed to be background concentrations because the residues at the NFSS (the source of contamination in the ditch) contained primarily radionuclides in the uranium-238 decay series rather than radionuclides in the thorium-232 series (Ref. 6). Uranium-238 was generally not found, which was to be expected since the residues brought to the NFSS for storage resulted from the processing of ores

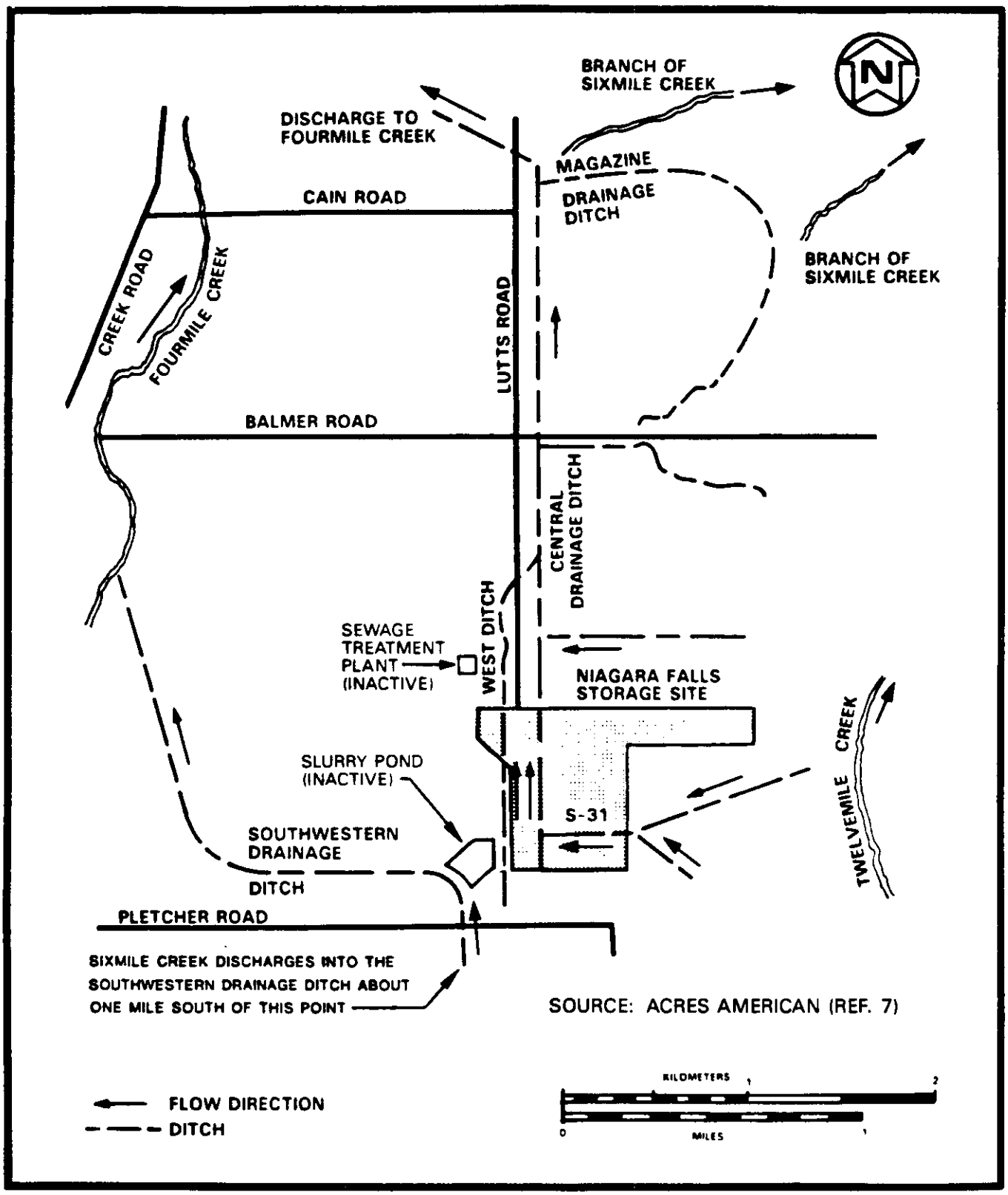

FIGURE 2-1 DRAINAGES OF THE NFSS

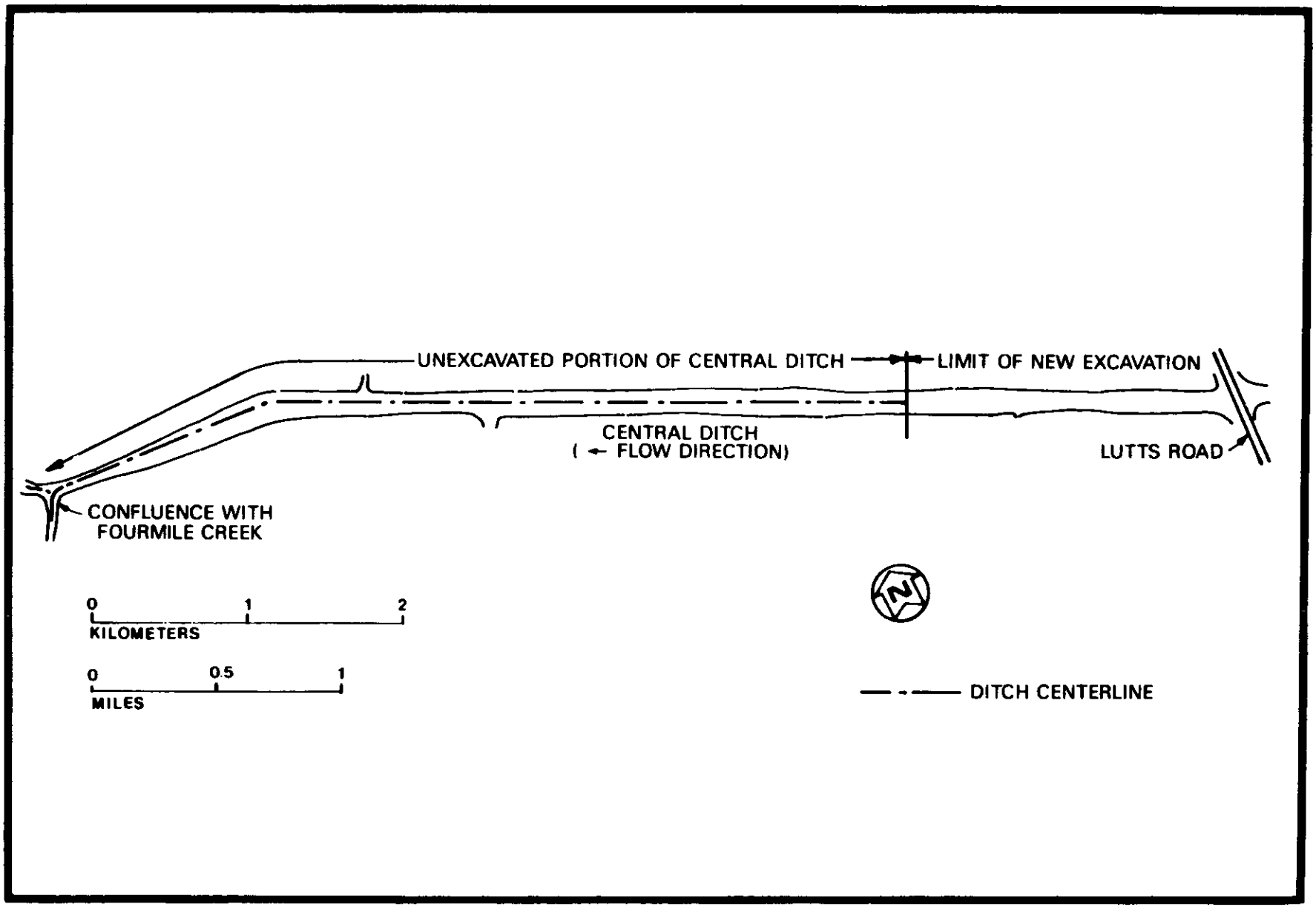

FIGURE 2-2 THE CENTRAL DITCH WEST OF LUTTS ROAD

to remove uranium (Ref. 6). Thorium-232 and uranium-238 contributions to total dose will not be considered further since they are at background concentrations.

For the sediments in the unexcavated portion of the CDD, the cross-sectional average concentration for radium-226 ranged from 3 to 12 pCi/g above background, with an average of 6 pCi/g. The dose contribution from thorium-230, the parent radionuclide of radium-226, was also evaluated and found to be insignificant.

3.0 RADIOLOGICAL ASSESSMENT

To assess the potential radiological effects from the unexcavated portion of the CDD, all reasonable exposure pathways to man were considered. Only those determined to be realistic were calculated.

3.1 SOURCE TERMS

Radioactivity in the sediment and water of the unexcavated portion of the CDD constitute the source terms. While soil samples collected were not analyzed for thorium-230, this radionuclide was assumed to be in equilibrium with its radium-226 daughter. During 1985, 60 soil samples were taken along the ditch, 30 at a depth of 0 to 15 cm (0 to 6 in.) and 30 at a depth of 15 to 30 cm (6 to 12 in.). The average radium-226 and thorium-230 concentrations in the soil at each of these depths are presented in Table 3-1. Quarterly water samples were taken at each of two locations in the ditch during 1984-85; the annual average radium-226 and thorium-230 concentrations in the water are presented in Table 3-2.

3.2 METHODOLOGY AND RESULTS OF EXTERNAL RADIATION DOSE CALCULATIONS

3.2.1 External Dose from Contaminated Sediment

The methodology for calculating external radiation dose from contaminated ground was based on the dose conversion factors calculated by Kocher and Sjoreen (Ref. 8). The dose conversion factors for contamination in soil are for exposures 1 m (3 ft) from the ground. The contamination is assumed to be uniformly distributed to an infinite depth and lateral extent. The dose conversion factors for radionuclides distributed in the soil will depend on the density of the soil, which in this case was assumed to be 1.5 g/cm^3. Other parameters considered in the calculations were an occupancy factor (average fraction of time the individual is

TABLE 3-1

AVERAGE CONCENTRATION OF RADIONUCLIDES IN SEDIMENT IN THE UNEXCAVATED SECTION OF THE CDD

Depth (cm/in.)	Average Concentration (pCi/g)*	
	Thorium-230**	Radium-226
0-15 / 0-6	6.1	6.1
15-30 / 6-12	3.6	3.6

*Source: ANL (Ref. 3).

**Thorium-230 is assumed to be in equilibrium with its radium-226 daughter.

TABLE 3-2

AVERAGE CONCENTRATION OF DISSOLVED RADIONUCLIDES IN CDD WATER

Year	Average Concentration (pCi/l)*	
	Thorium-239**	Radium-226
1984	0.35	0.35
1985	0.30	0.30
1984-85 Average	0.33	0.33

*Source: BNI (Refs. 9 and 10)

**Thorium-230 is assumed to be in equilibrium with its radium-226 daughter.

exposed to the source); an area factor (fraction of the area contributing to the external exposure) (Ref. 11); and a depth factor. The latter is the ratio of the external exposure from a layer of contamination of known thickness and cover depth to the external exposure from a layer of contamination of infinite thickness and no cover. In this case, no cover materials are present. Since averaging the radionuclide concentration over the entire thickness of the contaminated zone [30 cm (12 in.)] would give a lower dose, doses were calculated separately for the 0-to-15-cm (0-to-6-in.) and 15-to-30-cm (6-to-12-in.) depths, using the appropriate depth factor for each. The resulting doses were then summed for the total dose from external gamma radiation. Details of the calculation are presented in Appendix A.

Radium-226 would contribute the highest potential dose from the external gamma radiation pathway to a youth playing in the CDD. During periods of dry weather, some of the sediment in the bottom of the channel is left exposed. It is assumed that a youth might spend 2 h/day during the summer (for a total of 180 h/yr) playing in the ditch. The total external dose received would be 1.1 mrem/yr (see Table 3-3). Since the CDD is not used for other recreational purposes, this exposure scenario represents the maximum potential dose from exposure to the sediments.

The calculation in Appendix A is for the dose rate at the "standard" 1 m (3 ft) above the ground. For the above scenario, the height of 1 m (3 ft) would seem too far above the ground to be appropriate for the dose to a youth. To determine the increase in dose at a height of 0.5 m (1.6 ft), two different calculations were used. First, the percentage increase was calculated using the formula for an infinite plane source. Second, equations were used for a rectangular source plane with dimensions approximating the ditch, assuming it to be 8 m (26 ft) wide and 40 m (131 ft) long. The percentage increases were 23 and 39, respectively. Using the latter value, the external dose at 0.5 m (1.6 ft) would be 1.6 mrem/yr instead of 1.1 mrem/yr. Since the difference is not significant compared with a yearly dose limit of 100 mrem/yr, the 1.1 mrem/yr factor will be used because it

TABLE 3-3

SUMMARY OF COMMITTED EFFECTIVE DOSE EQUIVALENTS RESULTING FROM ENVIRONMENTAL PATHWAYS EXPOSURES TO THE UNEXCAVATED CDD

Pathway	Committed Effective Dose Equivalent (mrem/yr)		
	Thorium-230	Radium-226	Total
External Exposure	1.0×10^{-4}	1.1	1.1
Internal Exposure			
Milk Intake	5.1×10^{-6}	1.2×10^{-3}	1.2×10^{-3}
Beef Intake	5.5×10^{-5}	2.9×10^{-3}	3.0×10^{-3}
Fish Intake	2.9×10^{-4}	1.3×10^{-2}	1.3×10^{-2}
Total	0.001	1.2	1.2

represents the standard approach for calculating dose rate at 1 m (3 ft) from the ground surface.

3.2.2 External Dose from Contaminated Water

Any dose received from direct exposure to the water is insignificant for several reasons: (1) the volume of water is small, (2) the water contains concentrations of radium-226 and thorium-230 lower than the DOE concentration guides for release for unrestricted use, and (3) no recreational use is made of the CDD (e.g., boating or swimming).

3.2.3 External Dose from Dredged Sediments

A scenario of dredging the CDD and using the excavated soil from the ditch as topsoil for a building lot along the bank was also considered. Since concentrations of the radionuclides in the ditch are very near those permitted by the generic guidelines for residual contamination, physical handling during dredging activities would dilute the contamination to concentrations below these guideline values. Nevertheless, the dredging scenario was considered the most realistic of the scenarios evaluated and therefore was used as the basis for developing the supplemental guideline.

3.3 METHODOLOGY AND RESULTS OF INTERNAL RADIATION DOSE CALCULATIONS

The methodology for calculating internal dose from the ingestion of radionuclides was based on detailed information from Killough and McKay (Ref. 12) and the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (Ref. 13).

The dose conversion factors used in the calculations represent the effective committed dose equivalent per unit intake of radionuclide by the ingestion pathway. The dose conversion factors are taken from ORNL/NUREG/TM-19/V3 (Ref. 14) and are based on information in

Publication 30 of the International Committee on Radiation Protection (Ref. 15). The dose conversion factors are listed in Table A-1 of Appendix A.

Other parameters used in the dose calculations are shown in Tables A-2 through A-5 of Appendix A. Stable element transfer factors for milk and meat are taken from NUREG-0707 (Ref. 16), animal (cattle) consumption rates are taken from Regulatory Guide 1.109 (Ref. 13), and food (milk, beef, and fish) intake patterns for man are taken from Report No. 76 of the National Council on Radiation Protection (Ref. 17). The bioaccumulation factors for freshwater fish are taken from DOE/TIC/11468 (Ref. 18).

3.3.1 Internal Dose from Ingestion of Stream Water

Internal exposure from water consumption does not occur since water from the CDD is not used for drinking. Furthermore, the actual radionuclide concentrations are below those specified by DOE concentration guides for release of water for unrestricted use. If a person did take all of his drinking water from the ditch, his dose for a year's intake would be only 0.73 mrem. Consequently, the scenario of ditch water infiltrating into groundwater is also an insignificant dose pathway.

3.3.2 Internal Dose from Drinking Milk

A farmer in the area could theoretically receive all of his daily intake of milk from cows that obtain water only from the CDD. The committed effective dose equivalent from this pathway would be 0.0012 mrem/yr (see Table 3-3).

3.3.3. Internal Dose from Eating Beef

Assuming hypothetically that beef cattle grazing in the area could obtain their yearly intake of drinking water from the CDD and that a local resident could receive his yearly intake of beef from this

source, the committed effective dose equivalent from this pathway would be 0.003 mrem/yr (see Table 3-3).

3.3.4 Internal Dose from Eating Fish

Although fishing is not commonly practiced along the CDD, the conservative assumption was made that during most of the year, fresh fish could be taken from the CDD and would provide the entire dietary intake for a local fisherman. The committed effective dose equivalent from this pathway would be 0.013 mrem/yr (see Table 3-3).

3.3.5 Internal Dose from Inhaling Resuspended Dust

The low concentrations of radionuclides in the CDD, maximum mass loading of dust in air, moist condition of the streambed, and presence of vegetation along the bank, combine to render this exposure pathway insignificant. Occupancy factors near the ditch are low, and atmospheric dispersion of dust leaving the vicinity of the ditch further reduces airborne radionuclide concentrations to immaterial levels.

3.3.6 Internal Dose from Ingesting Crops

Irrigation and airborne deposition are two mechanisms by which crops could accumulate radionuclides that could be ingested by an individual.

Airborne deposition is not a realistic pathway for the same reasons as those listed in Subsection 3.3.5. There is no known use of the CDD as a source of irrigation water. However, since radionuclide concentrations in the water are below those specified by DOE guidelines for unrestricted release, the water could be used for unrestricted purposes without contributing significantly to dose.

3.3.7 Internal Dose from Radon Inhalation

Since radon gas is generated by the radioactive decay of radium-226, inhalation of the gas was considered as an internal exposure pathway. However, because concentrations of radium in the ditch sediments are low and because, in this case, radon can disperse freely into the atmosphere, no appreciable dose from this pathway is foreseen.

3.3.8 Use of the CDD by a Resident

The scenario of a house being built over a section of the CDD was considered. For this scenario, the assumption was made that the ditch would be either rerouted and filled with soil or routed through a covered culvert. Given these assumptions, the effects of this exposure pathway is reduced by several orders of magnitude.

4.0 SUMMARY AND DISCUSSION

Several exposure pathways were evaluated to develop a residual contamination guideline specifically for the CDD. This guideline will supplement the generic FUSRAP remedial action guidelines of 5 pCi/g and 15 pCi/g for radium-226 in surface and subsurface soil, respectively.

Of the exposure pathways evaluated, the scenario considered most realistic was that in which a residence was built on sediments that had been dredged from the ditch and spread along the bank.

Table 3-3 presents a summary of the potential doses associated with living near the section of the CDD along which no remedial action was performed. The total dose from the sediments in the ditch via all pathways is approximately 1.2 mrem/yr. This dose was received primarily from radium-226, the average concentration of which was 6.1 pCi/g, which equates to a dose factor of 0.2 mrem/yr per pCi/g. The dose from thorium-230 did not contribute significantly to the total dose. The external exposure pathway accounts for approximately 1.2 percent of the DOE radiation protection standard of 100 mrem/yr. Based on this analysis, the basic dose limit of 100 mrem/yr would not be exceeded unless radium-226 concentrations in the sediments exceeded 500 pCi/g.

However, use of a supplemental guideline as high as 500 pCi/g is not realistic based on the dredging scenario described above. Rather, calculation of the supplemental guideline was based on the predicted dilution that would occur as a result of spreading the sediments along the bank.

The assumptions made in calculating the supplemental guideline were: (1) the NFSS waste containment facility would not be the source of any increase in radionuclide concentrations in the CDD since modelling studies have shown no contaminant migration from the

facility during its 50-yr design life and no migration off-site for 10,000 years (Ref. 19); (2) the streambed in the CDD is 8 m wide; (3) contamination extends to a depth of 15 cm in the sediments in the ditch; (4) spoils from dredging the ditch would be spread evenly over a 30-m-wide area adjacent to the ditch.

Given the above assumptions and the topography of the CDD, calculations showed that the contamination in the sediments would be diluted by a factor of 4 when spread along the bank. The supplemental guideline was therefore set at 20 pCi/g, four times the generic remedial action guideline of 5 pCi/g for radium-226 in surface soil.

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APPENDIX A

METHODOLOGY AND PARAMETERS USED IN DOSE CALCULATIONS FOR DEVELOPING SUPPLEMENTAL RESIDUAL CONTAMINATION GUIDELINE FOR THE NFSS CENTRAL DRAINAGE DITCH

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DOSE CALCULATIONS

External Dose

Dose = concentration of radionuclide in soil (pCi/g) x density of soil (g/cm^3) x occupancy factor x area factor x depth factor x dose conversion factor (mrem/yr)/(pCi/cm^3)

where:
- o The density factor (g/cm^3) is included in order to convert the dose conversion factor (mrem/yr)/(pCi/cm^3) to (mrem/yr)/(pCi/g).
- o The occupancy factor is a unitless factor that gives the average fraction of time the individual spends exposed to the radiation source.
- o The area factor can be obtained by interpretation of data from NUREG/CR-3620 (Ref. 1).
- o The depth factor is the ratio of the external exposure from a layer of contamination of known thickness and cover depth to the exposure from a layer of contamination of infinite thickness and no cover.

1. Dose from drinking milk contaminated by a cow drinking contaminated stream water:

Dose (mrem/yr) = 0.33 pCi/l (average concentration of radium-226 in water) x 60 l/day (water intake by cow) x 4.5 10^{-4} days/l (milk transfer factor) x 0.26 l/day (milk intake by man) x 365 days/yr x 1.38 x 10^{-3} mrem/pCi (dose conversion factor for radium-226 ingestion) = 1.2 x 10^{-3} mrem/yr.

2. Dose from eating beef contaminated by cattle drinking stream water:

Dose (mrem/yr) = 0.33 pCi/l (average concentration of radium-226 in water) x 50 l/day (water intake by cattle) x 4 x 10^{-3} days/kg (flesh transfer factor) x 8.6 10^{-2} kg/day (beef intake by man) x 365 days/yr x 1.38 x 10^{-3} mrem/pCi (dose conversion factor for radium-226 ingestion) = 2.9 x 10^{-3} mrem/yr.

3. Dose from eating fish caught in contaminated stream:

Dose (mrem/yr) = 0.33 pCi/l divided by 1000 g/l x 5.0 x 10' (bioaccumulation factor) x 5.4 x 10^{2} g/yr (fish intake) x 1.38 x 10^{-3} mrem/pCi (dose conversion factor) = 1.3 x 10^{-2} mrem/yr.

4. External dose to youth playing in Central Drainage Ditch for 180 h/yr:

a. Dose from contamination at a depth of 0 to 15 cm (0 to 6 in.):

Dose (mrem/yr) = 6.1 pCi/g (concentration of radium-226 in soil) x 1.5 g/cm^3 (density of soil) x 0.02 (occupancy factor) x 0.61 (area factor) x 0.79 (depth factor) x 11.2 mrem/yr/pCi/cm^3 (dose conversion factor) = 9.9 x 10^{-1} mrem/yr.

b. Dose from contamination at a depth of 15 to 30 cm (6 to 12 in.):

Dose (mrem/yr) = 3.6 pCi/g (concentration of radium-226 in soil) x 1.5 g/cm^3 (density of soil) x 0.02 (occupancy factor x 0.61 (area factor) x 0.21 (depth factor) x 11.2 (mrem/yr)/pCi/cm^3) = 1.5 x 10^{-1} mrem/yr

c. Total dose from external exposure:

Total dose = 9.9 x 10^{-1} mrem/yr (dose from 0 to 15 cm) + 1.5 x 10^{-1} mrem/yr (dose from 15 to 30 cm) = 1.14 mrem/yr

Internal Dose

1. Dose from drinking milk contaminated by a cow drinking contaminated water:

Dose (mrem/yr) = concentration of radionuclide in water (pCi/l) x water intake by cow (l/day) x 365 days/yr x dose conversion factor (mrem/pCi)

2. Dose from eating beef contaminated by cattle drinking contaminated water:

Dose (mrem/yr) = concentration of radionuclide in water (pCi/l) x water intake by cattle (l/day) x flesh transfer factor (days/kg) x beef intake by man (kg/day) x 365 days/yr x dose conversion factor (mrem/pCi)

3. Dose from eating fresh fish caught in the stream:

Dose (mrem/yr) = concentration of radionuclide in water (pCi/l)/1000 g/l x bioaccumulation factor for fresh fish x fish intake by man (g/yr) x dose conversion factor (mrem/pCi)

PARAMETERS

TABLE A-1

DOSE CONVERSION FACTORS

Radionuclide	Internal Dose (mrem/pCi) Committed Dose Equivalent*	External Dose** (mrem/yr)/(pCi/cm^3)
Radium-226	1.38×10^{-3}	11.2
Thorium-230	5.48×10^{-4}	1.42×10^{-3}

*Reference 2.

**Reference 3. Based on a soil density of 1.5 g/cm^3.

TABLE A-2

TRANSFER FACTORS (STABLE ELEMENT)*

Radionuclide	Milk (days/l)	Meat (days/kg)
Radium-226	4.5×10^{-4}	4.0×10^{-3}
Thorium-230	5.0×10^{-6}	2.0×10^{-4}

*Reference 4.

TABLE A-3

ANIMAL CONSUMPTION RATES*

Animal	Water Intake (liters/day)
Milk Cow	60
Beef Cattle	50

*Reference 5.

TABLE A-4

BIOACCUMULATION FACTOR FOR RADIONUCLIDES*

Aquatic Food (Fresh Fish)	Factor
Radium-226	50
Thorium-230	50

*Reference 6.

TABLE A-5

DIETARY PARAMETERS FOR MAN

(GREATER THAN 18 YEARS OF AGE)*

Food	Intake
Milk	261 ml/day
Beef	86 g/day
Fresh Fish	1.48 g/day

*Reference 6.

APPENDIX A

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