SURRY POWER STATION

DISPOSAL OF LOW-LEVEL RADIOACTIVELY CONTAMINATED SOIL IN THE DREDGE SPOILS POND

Prepared by: C. A. Tarantino
C. A. Tarantino
Staff, Health Physics

Reviewed by: F. L. Thomasson
F. L. Thomasson
Supervisor, Health Physics

Approved by: W. Wayne Cameron
W. Wayne Cameron
Director, Health Physics

TABLE OF CONTENTS

DISPOSAL OF LOW-LEVEL RADIOACTIVELY CONTAMINATED SOIL AND GRAVEL IN THE ON-SITE DREDGE SPOILS POND AT SURRY POWER STATION

A. INTRODUCTION

Surry Power Station is planning to pave the yard area within the protected area, i.e., the area inside the security fence. Over the years, the grades inside the fence have been raised as a result of roadway repairs and the disposal of excess soil. Pavement construction would require the excavation of large quantities of soil from various construction projects. In some locations within the Radiological Control Area (RCA) the soil is low-level radioactively contaminated from previous steam releases and radioactive liquid spills.

A preliminary engineering study was conducted to determine the required pavement sections for the yard areas based upon actual onsite soil conditions, to estimate quantities of materials that must be excavated in order to construct the pavement, and to investigate options for final disposal of the excavated material outside of the protected area. The study concluded that approximately 6,000 cubic yards of contaminated soil and gravel would require disposal. In addition, the study recommended that the 6,000 cubic yards figure be increased to 10,000 cubic yards to incorporate future construction activities. The contaminated soil and gravel would be disposed in the dredge spoils pond which is located on Virginia Electric and Power Company's owner controlled property.

B. DESCRIPTION OF CONTAMINATED SOIL AND GRAVEL

Four test pits were excavated in order to define sub-grade conditions for pavement design. The following is a brief description of the materials that were encountered:

Stratum I - All pits except one encountered approximately 5 to 6.5 inches of dense graded crushed stone at the ground surface. Visually this material is similar to normal aggregate utilized for roadway bases and sub-bases.

Stratum II - A layer of old asphalt was encountered at three locations. The asphalt was only 1 to 2 inches thick and generally was observed below the crushed aggregate.

Stratum III - All pits encountered dense to very dense reddish brown sandy gravel either below the crushed stone or the asphalt. This material is a portion of the select granular backfill material that was used to fill the original plant excavation back to grade. A majority of the reactor containment area was excavated from an original grade of 34 feet to elevation 7 feet during construction. After completion of the major structures, the area was back-filled to plant design grade of 26.5 feet. The sandy gravel extended to variable depths of 18 to 36 inches below existing grade.

Stratum IV - Below the dense gravel, all excavations, except one outside the Administration Building, encountered dense tan silty sand with some fine gravel. This material was also part of the select back-fill for the general plant excavation.

Stratum V - One test pit and the excavation outside the Administration Building encountered stiff tan and gray silty clay immediately beneath Stratum III gravel. This material is a natural deposit occurring at the surface of the plant site. The above locations fall either outside or on the edge of the area that was excavated to elevation 7 feet. This explains why natural soil deposits were encountered at such a shallow depth.

An extensive sampling program was performed to determine the identity of the contaminating radionuclides and their concentrations in the soil and gravel. Fifty-seven (57) sampling locations were identified in the yard. Locations were representative of those areas in which paving activities would generate soil and gravel requiring disposal. Surface, 6 inch and 12 inch samples were obtained and analyzed for each location for a total of 171 samples. Sample results were averaged to determine the following concentrations (μCi/gm):

RADIONUCLIDE	AVERAGE CONCENTRATION (μCi/gm)
Co-60	1.56E-06
Cs-134	5.26E-07
Cs-137	2.38E-06
Mn-54	2.68E-09

These isotopic concentrations were used to perform the radiological dose assessments.

C. DESCRIPTION OF DREDGE SPOILS POND

Diagrams showing the dredge spoils area are provided in Attachment 1 for your reference.

1. The dredge spoils pond is located adjacent to the low-level intake structure, east of the plant. The pond is approximately 2,700 feet long and 600 to 1,300 feet wide. The facility was designed to accommodate dredged materials from the channel north of the intake structure in the James River. The pond has a top of dike elevation of 44 feet and the maximum permissible water elevation in the pond is 42 feet. If the water elevation approaches the maximum, a discharge pipe through the northwest corner of the dike can route excess water into the intake canal.

2. Results of slope stability analyses demonstrate that all slopes in the dredge disposal area are stable. Further, there would be no adverse impact on the function of the low-level intake canal even in the event of slope failure or erosion. The liquefaction potential under the dredge disposal area was also evaluated by comparing earthquake induced stresses with shear stresses necessary to cause liquefaction. Results of these examinations showed that the construction of the dredge disposal area effectively reduces the liquefaction potential under the dredge disposal basin and dike. The liquefaction potential at the high-level intake canal is not affected by the construction of the dredge spoils area. The dredge disposal dike has been designed to retain the spoil pile for both static and dynamic loading conditions.

The area within the toe of the dike at the base of the dredge disposal area is lined with a minimum of one (1) foot of compacted clay. This clay liner was designed and installed to minimize seepage from the dredge spoils pond into underlying groundwater and to prevent a resultant rise in the groundwater level in the vicinity of the pond. The dikes that comprise the perimeter of the pond were also constructed of compacted clay soils. Both the dike and liner materials were referenced as "Impervious Fill" in the project specifications. The complete design and installation specifications were perfomed by Stone and Webster Engineering Corporation and are contained in Reference 6.

D. SITE AREA CHARACTERISTICS

1. Meteorology

The Surry site is located in a humid sub-tropical climate area which receives an average monthly rainfall of 3.77 inches.

The total accumulated snow for the Surry region is approximately 10 inches each year.

An average of two hurricanes each year comes close enough to the coast to affect Virginia. However, less than one hurricane (0.6 per year) actually crosses the state.

Additional meteorological and climatological information may be obtained from Surry Power Station UFSAR, Volume I.

It is our assessment, given these meteorological conditions, that the disposal of contaminated soil in the spoils pond will not be impacted in a detrimental way by the climatological characteristics of the Surry region.

2. Hydrology

The hydrologic boundaries of the Surry site are the James River on the east and west, Hog Island Creek to the north, and Chippokes and Hunnicut Creeks about one mile to the south. A water analysis indicates that, of the total precipitation, 37% runs off and the remaining 63% is lost through evaporation and transpiration by the surrounding foliage. Low soil permeabilities preclude significant ground-water recharge from local precipitation.

An analysis of the probable rise in the James River mean water level at the site associated with the flood discharges indicates that even for a flood discharge recurrence interval of once in 50 years, the water level at the site would rise no more than one foot above the normal mean river level. Due to the wide floodplain at the site the rise above normal water levels of the James River is minor even under severe flooding conditions.

Additional ground water hydrology studies are provided in Surry Power Station UFSAR, Volume I.

3. Geology

The Surry site is located on Gravel Neck, in Surry County, Virginia. The site is situated in the Coastal Plain province approximately halfway between the Atlantic Ocean and the Fall Zone which is the boundary between the Piedmont and Coastal Plain Provinces.

Surface inspections and subsurface investigations in the immediate vicinity of the Surry site show no evidence of structural deformation. Borings indicate no offsets or strata holding. There is no surface or subsurface evidence of prior landslides, cratering, or fissures that may be indicative of prior intense earthquake effects.

E. ALTERNATIVE DISPOSAL METHODS

Two alternative disposal methods were evaluated. These included: (1) burying the contaminated soil outside the Radiological Control Area (RCA) but not in an area of proposed construction and (2) shipping the contaminated soil to a licensed disposal facility.

1. Burial of Contaminated Soil

The excavated materials from the yard area within the RCA could be buried onsite in an area which is not under proposed construction. However, since there exists a "permitted" dredge spoils pond which affords a confinement for the 10,000 cubic yards of low-level radioactively contaminated soil, the option of burying elsewhere

on-site is not a preferred choice. The various engineering and environmental studies that have been performed on the spoils pond demonstrate its viability.

2. Shipment to a Licensed Disposal Facility

The volume allocation necessary for the disposal of the contaminated soil at a shallow land burial site far exceeds the current annual volume allocation at the Barnwell Waste Management Facility of approximately 25,000 cubic feet for Surry Power Station. Furthermore, a cost estimate for the disposal of 10,000 cubic yards of soil at a licensed disposal facility shows the cost to be prohibitive.

F. DISPOSAL OF CONTAMINATED SOIL IN DREDGE SPOILS POND

A station Health Physics procedure will be developed to address the disposal of contaminated soil in the Surry dredge spoils pond. The key elements of the procedure would include: (1) a tracking system for accountability of the amount of contaminated soil disposed in the pond; (2) requirements for transfer of the contaminated soil from the yard area within the RCA to the dredge spoils pond; and (3) Health Physics considerations to include adequate surveys, contamination control, and personnel monitoring. The transfer and disposal operations will be performed under the technical guidance and review of Health Physics personnel.

G. RADIOLOGICAL ASSESSMENT

1. The following exposure pathways were examined in assessing the radiological impact of disposing the low-level radioactively contaminated soil in the dredge spoils pond:

   a. The unrestricted area liquid effluent percent maximum permissible concentration (MPC) was determined for the instantaneous release of all contaminated soil activity disposed in the spoils pond.

   b. The unrestricted area liquid effluent percent maximum permissible concentration (MPC) was determined for the release of contaminated soil activity disposed in the spoils pond during dredging operations.

   c. The total body and critical organ doses to a member of the general public from radioactive material in liquid effluents released during dredging operations were determined.

   d. The total body and critical organ (lung) doses from inhalation of radionuclides resuspended in air were calculated for the Company worker(s) and member(s) of the general public.

   e. The annual dose from external irradiation due to radionuclides deposited onto the ground surface of the dredge spoils pond was determined for the Company worker(s) and member(s) of the general public.

Unless otherwise specified, the radiological assessment was performed using assumptions and methodologies contained in Regulatory Guide 1.109, Rev. 1, 1977, Surry Power Station Offsite Dose Calculation Manual, and Reactor Shielding Design Manual by T. Rockwell III.

2. The dredge spoils pond is located on Virginia Electric and Power Company owned property. It is an isolated area, routinely patrolled. Consequently, use of the property would be restricted, thereby precluding the growing of food crops and grazing by milk or meat producing animals. Therefore, these ingestion exposure pathways were not considered.

3. Estimates for public use of adjacent land and water surrounding the dredge spoils pond site for recreational and contractual work activities has been conservatively estimated to occur approximately one month (744 hours) during the year. Therefore, the annual inhalation and direct radiation doses to the member(s) of the general public were calculated based on an occupancy period of one month in a given year. The annual inhalation and direct radiation doses to Company personnel working at the dredge spoils pond are based on an annual occupancy period of 2000 hours per year.

4. The inhalation and direct radiation doses to the member(s) of the general public have been calculated for the site boundary location. Doses at the nearest resident location, which is approximately 1.65 miles from the dredge spoils pond, are negligible.

5. Attachment 2 provides the dose assessment assumptions and calculations.

6. Results:

   a. The percent of unrestricted area liquid effluent MPC for the instantaneous release of all contaminated soil activity is 8.16.

   b. The percent of unrestricted area liquid effluent MPC for the total release of contaminated soil activity during dredging operations is 1.33E-02.

   c. The total body and critical organ (GI-LLI) doses to the member(s) of the general public from radioactive materials in liquid effluents released during dredging operations are 5.22E-03 mrem and 8.48E-03 mrem respectively.

   d. The annual total body and critical organ (lung) doses to the member(s) of the general public from the inhalation of radionuclides resuspended in air are 1.35E-01 mrem and 1.33 mrem respectively for 744 hours per year (one month) occupancy. The annual total body and critical organ doses to the Company worker from the inhalation of radionuclides resuspended in air are 3.63E-01 mrem and 3.56E+00 mrem respectively for 2000 hours occupancy period.

e. The annual dose from external radiation due to radionuclides deposited onto the ground surface within the dredge spoils pond to the member(s) of the general public is 8.33E-04 mrem for 744 hours per year (one month) occupancy. The annual dose from external radiation to the Company worker is 2.24E-03 mrem for 2000 hours occupancy period.

H. CONCLUSIONS

The results reported in section G.6 are well below the regulatory limits contained in 10 CFR Part 20. Furthermore, the transfer and disposal of low-level radioactively contaminated soil and gravel from the yard area within the protected area to the dredge spoils pond has negligible radiological impact and poses no health hazards to members of the public and/or on-site personnel.

This disposal method is a cost effective means of handling large quantities of material in a contained and efficient manner.

I. REFERENCES

1. Regulatory Guide 1.109, Rev. 1, Oct. 1977, Calculation of Annual Doses to Man from Routine Releases from Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50, Appendix I.

2. Surry Power Station, Offsite Dose Calculation Manual, November 5, 1985.

3. J. W. Healy, Los Alamos Scientific Laboratory, LA-4558-MS, September 1971 "Surface Contamination: Decision Levels".

4. Report of Extended Type I Study: Contaminated Soil and Gravel in the RCA; Surry Nuclear Power Station, NP-0536, Virginia Electric and Power Company, December, 1984.

5. Surry Power Station UFSAR, Volume I, Chapter 2.

6. Stone and Webster Engineering Project, J.O. #12313.

7. Reactor Shielding Design Manual, T. Rockwell III, D. VanNostrand Company, Inc., 1956.

8. NBS Handbook No. 29, Cross Sections, Attenuation Coefficients and Energy Absorption Coefficients From 10 keV to 100 GeV, 1969.

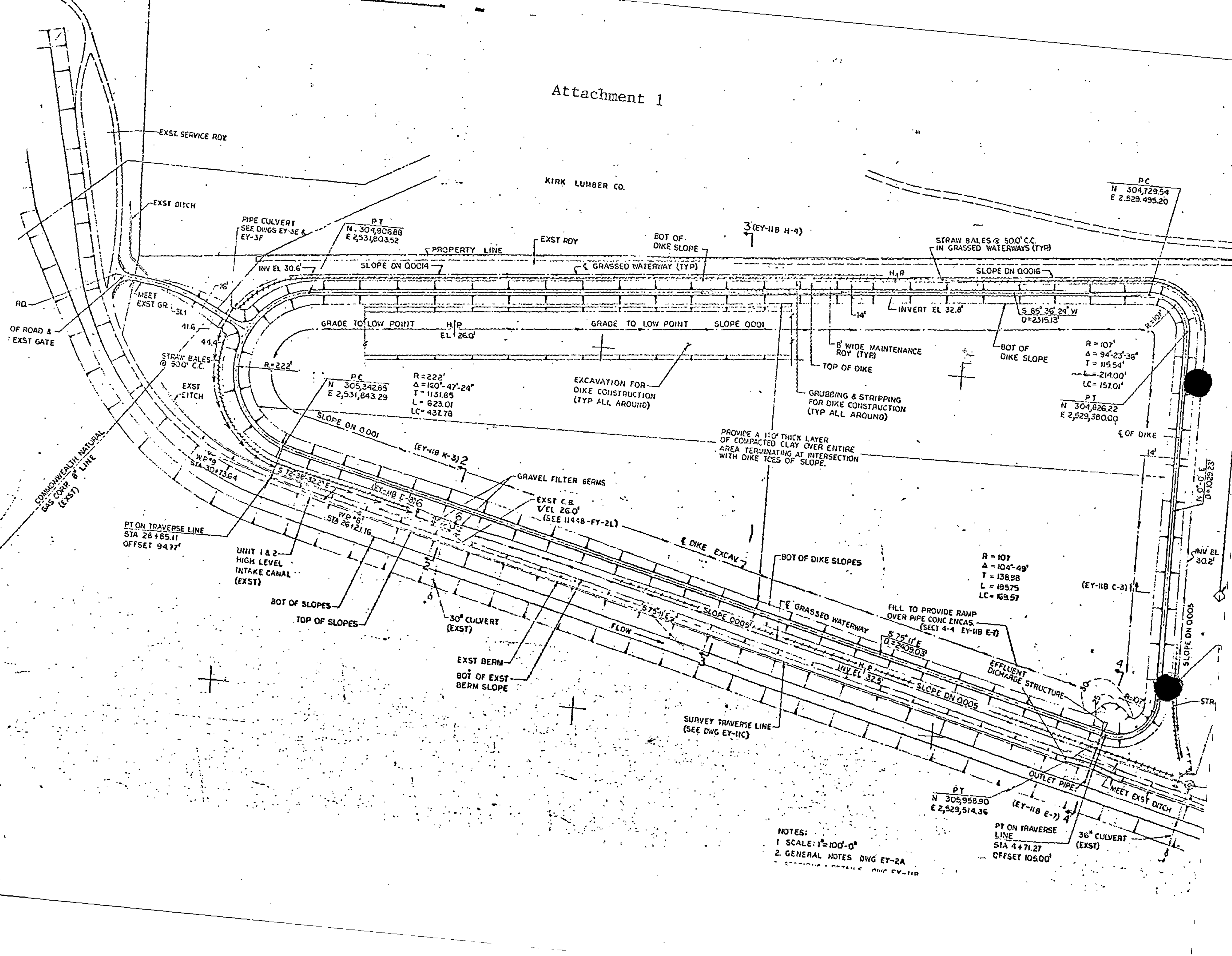
9. ANSI/ANS 6.1.1 Neutron and Gamma-ray Flux-to-dose Rate Factors, 1977.

10. Radiological Health Handbook, January 1970, U. S. Department of Health Education and Welfare, PHS.

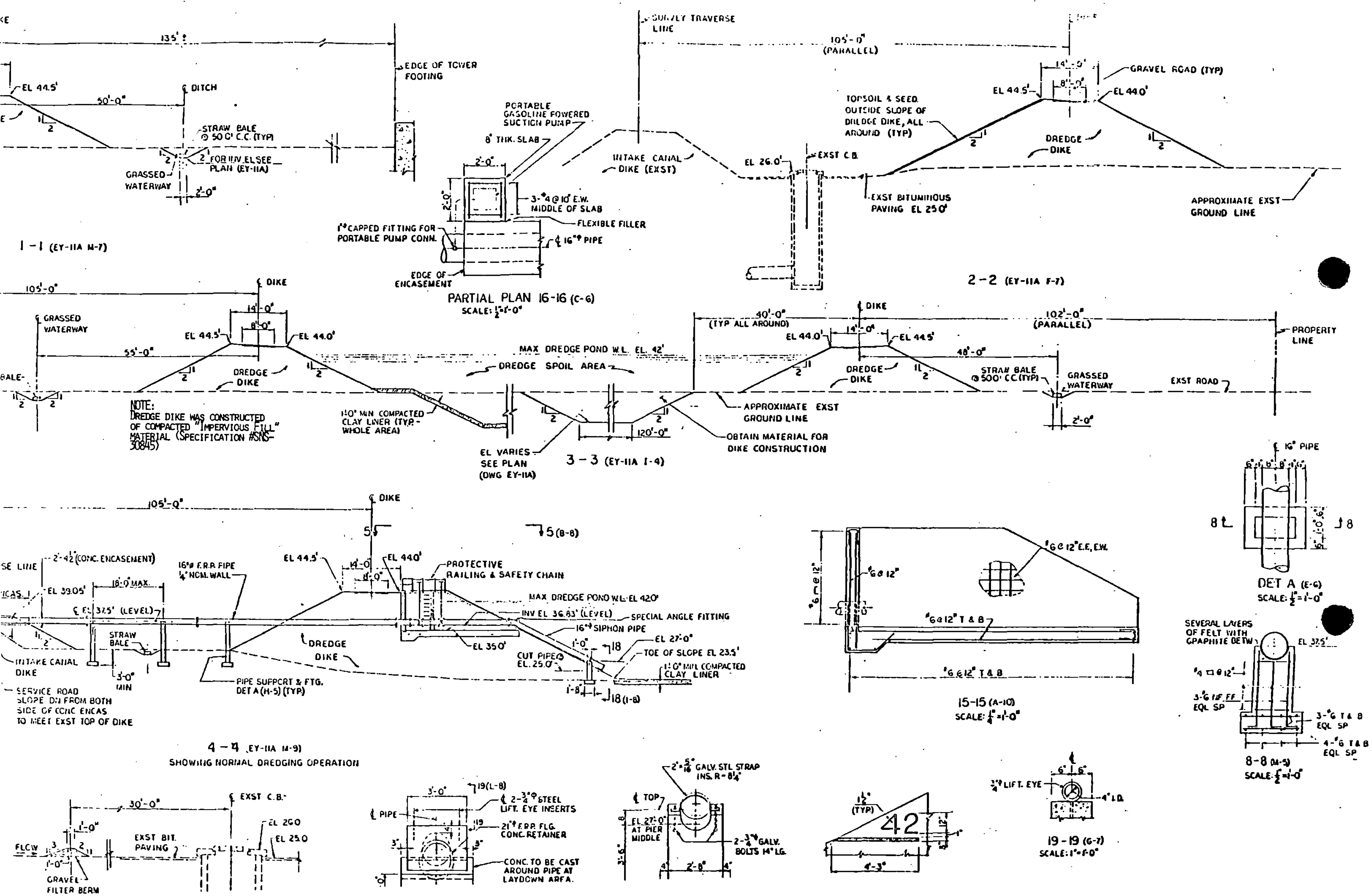
11. Code of Federal Regulations, Part 10CFR20.302.

12. NUREG 1101, Vol. 1, Onsite Disposal of Radioactive Waste, March, 1986.

Attachment 1



ATTACHMENT 1



ATTACHMENT 2

A. PERCENT UNRESTRICTED AREA MPC CALCULATIONS - INSTANTANEOUS RELEASE

I. Problem

Determine the unrestricted area (10CFR20.106) liquid effluent percent MPC for the release of all contaminated soil activity disposed in the dredge spoils pond.

II. Assumptions

1) Dredge spoils pond releases into the high-level intake canal, through the station, to the discharge canal, to the James River.

2) Sampling program results provide average isotopic concentrations of contaminated soil.

3) Two of the eight circulating water pumps are running. The capacity of each water pump is 2.00E+05 gallons per minute.

4) There is an instantaneous release of activity (i.e., 1 minute).

5) 10,000 yd^3 of soil to be disposed in the dredge pond.

III. Calculations

A. Average specific activity from all soil samples.

Isotope	Specific Activity (μCi/g)
Co-60	1.56E-06
Cs-134	5.26E-07
Cs-137	2.38E-06
Mn-54	2.68E-09

B. Density of soil and sand ρ = 2.2g/cc

C. Number of cm^3 of contaminated soil $= 10{,}000\ yd^3 \times 27\ \frac{ft^3}{yd^3} \times 28.32\ \frac{1}{ft^3} \times 1000\ \frac{cc}{1}$

Number of cm^3 of contaminated soil = 7.65E+09 cc

D. Total activity in 10,000 yd^3:

Isotope	Activity (μCi/g)	x	2.2 (g/cc)	x	7.65E+09 (cc)	=	μCi
Co-60	1.56E-06	x	2.2	x	7.65E+09	=	2.63E+04
Cs-134	5.26E-07	x	2.2	x	7.65E+09	=	8.85E+03
Cs-137	2.38E-06	x	2.2	x	7.65E+09	=	4.01E+04
Mn-54	2.68E-09	x	2.2	x	7.65E+09	=	4.51E+01

E. Concentration in dredge spoils pond

Total volume of pond = 2700 ft x 600 ft x 1 ft = 1.62E+06 ft^3

Total gallons = 1.62E+06 ft^3 x 7.481 $\frac{gal}{ft^3}$ = 1.21E+07 gal

Total cc = 1.21E+07 gal x 3.79 $\frac{1}{gal}$ x 1000 $\frac{cc}{1}$ = 4.58E+10 cc

Isotope	μCi	÷	4.58E+10 (cc)	=	μCi/cc
Co-60	2.63E+04	÷	4.58E+10	=	5.73E-07
Cs-134	8.85E+03	÷	4.58E+10	=	1.93E-07
Cs-137	4.01E+04	÷	4.58E+10	=	8.74E-07
Mn-54	4.51E+01	÷	4.58E+10	=	9.83E-10

F. Dilution Factor

$$\text{Dilution factor} = \frac{1.21E+07}{1.21E+07 + (2 \times 2.00E+05)}$$

Dilution factor = 0.968

G. Concentration in discharge canal

Isotope	Dredge Spoils Pond Concentration (μCi/cc)	x	Dilution Factor	=	Discharge Canal Concentration (μCi/cc)
Co-60	5.73E-07	x	0.968	=	5.55E-07
Cs-134	1.93E-07	x	0.968	=	1.87E-07
Cs-137	8.74E-07	x	0.968	=	8.46E-07
Mn-54	9.83E-10	x	0.968	=	9.52E-10

H. Percent unrestricted area MPC

Isotope	Concentration μCi/cc	÷	MPC (μCi/cc)		=	Conc./MPC
Co-60	5.55E-07	÷	3E-05		=	1.85E-02
Cs-134	1.87E-07	÷	9E-06		=	2.08E-02
Cs-137	8.46E-07	÷	2E-05		=	4.23E-02
Mn-54	9.52E-10	÷	1E-04		=	9.52E-06
				Σ	=	8.16E-02

Percent of unrestricted area MPC = 8.16

B. PERCENT UNRESTRICTED AREA MPC CALCULATION - DREDGING OPERATION

I. Problem

Determine the unrestricted area (10CFR20.106) liquid effluent percent MPC for the release of contaminated soil activity disposed in the dredge spoils pond during dredging operations.

II. Assumptions

1) Dredging operation takes 5 weeks, 7 days per week, 20 hours per day.

2) Dredging flow rate from pond is 1.20E+04 gallons per minute.

3) Total activity (μCi) of radionuclides in dredge spoils pond determined in A.III.D is valid.

4) Two of the eight circulating water pumps are running. The capacity of each pump is 2.00E+05 gallons per minute.

5) Dredge spoils pond releases into the high-level intake canal, through the station, to the discharge canal, to the James River.

6) Release through the effluent discharge structure is at maximum water elevation in pond (Drawing #12313-EY-11B-1, #1213-EY-11A-1).

NOTE: Assumptions #1 and #2 are based on the first 2 dredgings of the spoils pond. Information was provided by Surry, E&C.

III. Calculations

A. Total volume of water in pond.

Volume of pond, ft^3 = 2700 ft x 600 ft x 18.5 ft,
where 2700 ft = length of pond,
600 ft = width of pond
18.5 ft = maximum dredge pond elevation - min. elevation of slope toe
= 42.0 ft. - 23.5 ft.

Total gallons = $3.00E+07\ ft^3 \times 7.481 \frac{gal}{ft^3} = 2.24E+08\ gal$

Total cc = $2.24E+08\ gal \times 3.79 \frac{1}{gal} \times 1000 \frac{cc}{1} = 8.49E+11$

B. Concentration based on 10,000 yd^3 of disposed soil.

Isotope	Total Activity (μCi)	÷	8.49E+11(cc)	=	μCi/cc
Co-60	2.63E+04	÷	8.49E+11	=	3.10E-08
Cs-134	8.85E+03	÷	8.49E+11	=	1.04E-08
Cs-137	4.01E+04	÷	8.49E+11	=	4.72E-08
Mn-54	4.51E+01	÷	8.49E+11	=	5.31E-11

C. Dilution factor

$$\text{Dilution factor} = \frac{1.20E+04}{1.20E+04 + (2 \times 2.00E+05)}$$

Dilution factor = 2.91E-02

D. Percent unrestricted area MPC

Isotope	Concentration µCi/cc	x	Dilution Factor	÷	MPC	=	Concentration MPC
Co-60	3.10E-08	x	2.91E-02	÷	3.0E-05	=	3.01E-05
Cs-134	1.04E-08	x	2.91E-02	÷	9.0E-06	=	3.36E-05
Cs-137	4.73E-08	x	2.91E-02	÷	2.0E-05	=	6.88E-05
Mn-54	5.32E-11	x	2.91E-02	÷	1.0E-04	=	1.55E-08
					Σ	=	1.33E-04

Percent of unrestricted area MPC = 1.33E-02

C. LIQUID EFFLUENT DOSE CALCULATIONS - DREDGING OPERATION

I. Problem

Determine the dose commitment to the member(s) of the general public from radioactive material in liquid effluents released from the dredge spoils pond during dredging operation.

II. Assumptions

1) Radioactive material is only released during dredging operations.

2) Dredging operation takes 5 weeks, 7 days per week, 20 hours per day. The pond is designed to contain material for one future dredging.

3) Dredging flow rate from pond is 1.20E+04 gallons per minute (4.54E+07 cc/min).

4) Total activity (μCi) of radionuclides in dredge spoils pond determined in A.III.D is valid.

5) Two of the eight circulating water pumps are running. The capacity of each pump is 2.00E+05 gallons per minute.

6) Dredge spoils pond releases into the high-level intake canal, through the station, to the discharge canal, to the James River.

7) Release through effluent discharge structure is at maximum water elevation in pond (Drawing #12313-EY-11B-1, #1213-EY-11A-1).

III. Calculations

A. Total volume of water in pond.

Volume cc = 8.49E+11 cc from B.III.A.

B. Total activity released from pond during dredging operation.

$$A_i = A_{oi}\,(1 - e^{-4.54E+07t/8.49E+11})$$

where

A_i = Total activity, in μCi of isotope i, released from pond at time t.

A_{oi} = Total activity, in μCi of isotope i, originally in pond.

t = Total time, in minutes, of dredging operation.

$$t = 5 \text{ weeks} \times 7 \frac{\text{days}}{\text{week}} \times 20 \frac{\text{hours}}{\text{day}} \times 60 \frac{\text{min}}{\text{hour}} = 4.2E{+}04 \text{ min}$$

$$(1 - e^{-4.54E+07 \times 4.2E+04/8.49E+11}) = 0.89$$

Isotope	A_{oi}	x	0.89	=	A_i
Co-60	2.63E+04	x	0.89	=	2.34E+04
Cs-134	8.85E+03	x	0.89	=	7.88E+03
Cs-137	4.01E+04	x	0.89	=	3.57E+04
Mn-54	4.51E+01	x	0.89	=	4.01E+01

C. $D = tFM\sum_i A_i \, DF_i$

where: D = Dose commitment to the total body or critical organ from liquid effluents for the time period t, in mrem.

t = The length of the time period over which C_i and F are averaged for all liquid releases, hours.

m = The mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless, 0.2 from Appendix 11A, Surry UFSAR.

F = The inverse of the total dilution volume for the time period t, cc^{-1}.

A_i = The total activity, μCi of isotope i, released from pond.

DF_i = The site related ingestion dose commitment factor to the total body or GI-LLI of an adult from ODCM Table 4.0, mrem/hr per μCi/cc.

$$t = 5 \text{ weeks} \times 7 \frac{\text{days}}{\text{week}} \times 20 \frac{\text{hours}}{\text{day}} = 7.00{+}02 \text{ hours}$$

m = 0.2

$$F = 1/(2 \times 2.0E{+}05 \frac{\text{gal}}{\text{min}} \times 63.09 \frac{\text{cc-min}}{\text{gal-sec}} \times 2.52E{+}06 \text{ sec})$$

$$F = 1.57E{-}14 \text{ cc}^{-1}$$

D. Total Body Dose

Isotope	A_i (μCi)	x	DF_i $\frac{(mrem/hr)}{\mu Ci/cc}$	=	$\frac{mrem-cc}{hr}$
Co-60	2.34E+04	x	3.82E+03	=	8.94E+07
Cs-134	7.88E+03	x	1.33E+04	=	1.05E+08
Cs-137	3.57E+04	x	7.85E+03	=	2.80E+08
Mn-54	4.01E+01	x	1.35E+03	=	5.41E+04
			Σ	=	4.75E+08

$$D(\text{Total Body}) = 7.00E+02\ (hr) \times 1.57E-14 (cc^{-1}) \times 4.75E+08 \left(\frac{mrem-cc}{hr}\right)$$

D(Total Body) = 5.22E-03 mrem

E. GI-LLI Dose

Isotope	A_i (μCi)	x	DF_i $\frac{(mrem/hr)}{\mu Ci/cc}$	=	$\frac{mrem-cc}{hr}$
Co-60	2.34E+04	x	3.25E+04	=	7.61E+08
Cs-134	7.88E+03	x	2.85E+02	=	2.25E+06
Cs-137	3.57E+04	x	2.32E+02	=	8.28E+06
Mn-54	4.01E+01	x	2.16E+04	=	8.66E+05
			Σ	=	7.72E+08

$$D(\text{GI-LLI}) = 7.00E+02\ (hr) \times 1.57E-14 (cc^{-1}) \times 7.72E+08 \left(\frac{mrem-cc}{hr}\right)$$

D(GI-LLI) = 8.48E-03 mrem

D. INHALATION OF RESUSPENDED RADIONUCLIDES IN AIR

I. Problem

Determine the total body and critical organ dose to the member(s) of the general public and the Company worker from inhalation of radionuclides resuspended in air.

II. Assumptions

1) All contaminated soil activity is deposited on the surface of the dredge spoils pond.

2) The entire dredge spoils pond surface area is used for the disposal of the contaminated soil.

3) Reg. Guide 1.109 assumptions are valid.

4) The resuspension factor for moderate activity conditions from LA-4558-MS-LASL, Surface Contamination Decision Levels, 1.00E-05 m^{-1}, is valid.

5) Calculations pertain to the adult total body and teen for critical organ (lung).

6) The member of the general public is estimated to occupy the vicinity of the dredge spoils pond approximately one month throughout the year and the Company worker is estimated to occupy the dredge spoils pond approximately 2000 hours throughout the year.

III. Calculations

A. Total surface area of dredge spoils pond:

2700 ft x 600 ft = 1.62E+06 ft^2
1.62E+06 ft^2 x 9.29E-02 $\frac{m^2}{ft^2}$ = 1.51E+05 m^2

B. Concentration in Air

Nuclide	Activity (μCi)	÷	Surface Area (m^2)	=	Surface Contamination (μCi/m^2)	x	Resuspension Factor (m^{-1})	=	Concentration in Air μCi/m^3
Co-60	2.63E+04	÷	1.51E+05	=	1.74E-01	x	1.00E-05	=	1.74E-06
Cs-134	8.85E+03	÷	1.51E+05	=	5.86E-02	x	1.00E-05	=	5.86E-07
Cs-137	4.01E+04	÷	1.51E+05	=	2.66E-01	x	1.00E-05	=	2.66E-06
Mn-54	4.51E+01	÷	1.51E+05	=	2.99E-04	x	1.00E-05	=	2.99E-09

C. Total Body and Critical Organ Dose Equation

$$\dot{D} = \Sigma C_i \times BR \times DF \times CF$$

where:

$\dot{D}$ = The total body or critical organ (lung) annual dose, mrem.

C_i = Concentration of radionuclide, $\mu Ci/m^3$

BR = Breathing rate of a teen or adult, 8.00E+03m^3/yr,R.G.1.109.

DF = Inhalation total body dose factor for an adult or inhalation lung dose factor for a teen, mrem/pCi,R.G.1.109.

CF = Conversion factor, 1.00E+06 pCi/μCi.

D. Total Body Annual Dose to an Adult.

Nuclide	Ci ($\mu Ci/m^3$)	x	BR (m^3/yr)	x	DF (mrem/pCi)	x	CF (pCi/μCi)	=	$\dot{D}$ (mrem/yr)
Co-60	1.74E-06	x	8.00E+03	x	1.85E-06	x	1.00E+06	=	2.58E-02
Cs-134	5.86E-07	x	8.00E+03	x	9.10E-05	x	1.00E+06	=	4.27E-01
Cs-137	2.66E-06	x	8.00E+03	x	5.35E-05	x	1.00E+06	=	1.14E+00
Mn-54	2.99E-09	x	8.00E+03	x	7.87E-07	x	1.00E+06	=	1.88E-05
							Σ	=	1.59

Member of general public: Annual dose for 744 hours occupancy = 1.35E-01 mrem.

Company worker: Annual dose for 2000 hours occupancy = 3.63E-01 mrem.

E. Critical Organ (Lung) Annual Dose to a Teen

Nuclide	Ci ($\mu Ci/m^3$)	x	BR (m^3/yr)	x	DF (mrem/pCi)	x	CF (mrem/μCi)	=	$\dot{D}$ (mrem/yr)
Co-60	1.74E-06	x	8.00E+03	x	1.09E-03	x	1.00E+06	=	1.52E+01
Cs-134	5.86E-07	x	8.00E+03	x	1.83E-05	x	1.00E+06	=	8.58E-02
Cs-137	2.66E-06	x	8.00E+03	x	1.51E-05	x	1.00E+06	=	3.21E-01
Mn-54	2.99E-09	x	8.00E+03	x	2.48E-04	x	1.00E+06	=	5.93E-03
							Σ	=	1.56E+01

Member of general public: Annual dose for 744 hours occupancy = 1.33E+00 mrem.

Company worker: Annual dose for 2000 hours occupancy = 3.56E+00 mrem.

E. DOSE FROM EXTERNAL IRRADIATION FROM RADIONUCLIDES DEPOSITED ON GROUND SURFACE

I. Problem

Determine the annual dose to the member(s) of the general public and the Company worker from external radiation due to radionuclides deposited onto the ground surface.

II. Assumptions

1) All contaminated soil activity is deposited onto the surface of the dredge spoils pond.

2) The dredge spoils pond is a volume slab source of infinite extent having a finite thickness with self-absorption (61 cm).

3) The gamma flux is uniform throughout the volume source.

4) The equation for calculating the gamma flux for a thick slab of infinite extent with self-absorption contained in Reactor Shielding Design Manual, T. Rockwell III, is valid.

5) The density of soil is 2.2 g/cc.

6) The member(s) of the general public is estimated to occupy the vicinity of the dredge spoils pond approximately one month throughout the year and the Company worker is estimated to occupy the dredge spoils pond approximately 2000 hours throughout the year.

III. Calculations

A. From sample results, the following average isotopic concentrations were determined:

Isotope		Concentration (μCi/cc)
Co-60		1.56E-06
Cs-134		5.26E-07
Cs-137		2.38E-06
Mn-54		2.68E-09
	Σ =	4.47E-06

B. $\emptyset = \frac{Sv}{2\mu_s} [E_2(b_3)]$, where

$\emptyset$ = gamma flux, photons/cc-sec.

Sv = source strength, cc^{-1} sec^{-1}

μ_s = linear absorption coefficient, cm^{-1}

$E_2(b_3)$ = integral exponential function equal to 5.0E-04 for b = 3 to 10, Rockwell graph, p. 374 Rockwell Manual.

$b_3 = \mu_s \times h$, where h is the amount of soil providing self-absorption, equal to 61 cm.

1. From NBS Handbook No. 29, the interpolated value of μ_s for 1.33 MeV gamma photons is 9.2E-02 cm^{-1}.

2. $b_3 = \mu s \times h$

   $b_3 = 9.2E{-}02\ cm^{-1} \times 61\ cm$

   $b_3 = 5.61$

3. Sv = 4.47E-06μCi/cc x 3.7E+04 dps/μCi

   Sv = 1.65E-01 photons/cc-sec

4. $$\emptyset = \frac{Sv}{2\mu_s}[E_2(b_3)]$$

   $$\emptyset = \frac{1.65\ E{-}01\ \text{photons/cc-sec}}{2 \times 9.2E{-}02cm^{-1}}(5.0E{-}04)$$

   $\emptyset = 4.48E{-}04\ \text{photons}/cm^2\text{-sec}$

5. From ANSI 6.1.1., the gamma ray flux to dose rate conversion factor for 1.4 MeV gamma photons is 2.51E-06 rem/hr per photon/cm^2-sec. The 1.4 MeV energy is more conservative than the actual isotopic energies.

6. Dose Rate (mrem/hr) = 2.51E-06 x 4.48E-04

   = 1.12E-09 rem/hr

   = 1.12E-06 mrem/hr

Member(s) of the general public: Annual dose for 744 hours (one month) occupancy = 8.33E-04 mrem

Company worker: Annual dose for 2000 hours occupancy = 2.24E-03 mrem.