DRAFT

WASH-1538

ENVIRONMENTAL STATEMENT
WASTE
MANAGEMENT OPERATIONS

Hanford Reservation
Richland, Washington

VOLUME 2
APPENDIXES

SEPTEMBER 1974

MASTER

UNITED STATES ATOMIC ENERGY COMMISSION

DRAFT

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DRAFT

ENVIRONMENTAL STATEMENT

WASTE MANAGEMENT OPERATIONS

HANFORD RESERVATION
RICHLAND, WASHINGTON

VOLUME 2
(NUMBER 2 OF 3)

APPENDICES

SEPTEMBER 1974

U.S. ATOMIC ENERGY COMMISSION

MASTER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This document is
PUBLICLY RELEASABLE

B. Amy Schaefer
Authorizing Official

Date: 5-23-07

DRAFT

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DM

VOLUME 1 CONTENTS

	<u>Page</u>
FOREWORD	i
I SUMMARY.	I-1
I.1 INTRODUCTION	I-1
I.2 BACKGROUND	I-1
I.2.1 Description of Site	I-1
I.2.2 Anticipated Benefits	I-3
I.2.3 Characterization of the Existing Environment	I-3
I.3 ENVIRONMENTAL IMPACT.	I-5
I.3.1 Environmental Effects of Routine Operation of Plant Facilities	I-5
I.3.2 Postulated Waste Management Accidents	I-7
I.4 UNAVOIDABLE ADVERSE EFFECTS	I-7
I.5 ALTERNATIVES	I-8
I.6 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY	I-9
I.7 RELATIONSHIP OF PROPOSED ACTION TO LAND USE PLANS, POLICIES, AND CONTROLS	I-10
I.8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES	I-11
I.9 COST-BENEFIT ANALYSIS	I-11
II BACKGROUND	II.1-1
II.1 Detailed Description of Hanford Site	II.1-1
II.1.1 Plant and Waste Management Facilities	II.1-1
II.1.1.1 External Appearances	II.1-1
II.1.1.1.1 Introduction	II.1-1
II.1.1.1.2 100 Areas	II.1-7
II.1.1.1.3 200 Areas	II.1-17
II.1.1.1.4 300 Area	II.1-50
II.1.1.1.5 400 Area	II.1-52
II.1.1.1.6 600 Areas	II.1-53
II.1.1.2 Waste Management Facilities, Processes and Equipment	II.1-55

CONTENTS (Continued)

	<u>Page</u>
II.1.1.2.1 100 Areas	II.1-55
II.1.1.2.2 200 Areas	II.1-61
II.1.1.2.3 300 Area	II.1-107
II.1.1.2.4 Waste Management Facilities and Activities Planned and Under Construction FY-1973 - FY-1975 .	II.1-115
II.1.1.3 Plant Water Usage	II.1-124
II.1.1.4 Waste Inventories	II.1-126
II.1.1.4.1 Contained Solids and Liquids.	II.1-126
II.1.1.4.2 Liquid Discharges to Soil.	II.1-128
II.1.1.4.3 Radionuclides Stored Beneath Selected 200 Area Cribs	II.1-129
II.1.1.4.4 Inventory in the Saturated Groundwater	II.1-130
II.1.1.4.5 Unplanned Releases	II.1-138
II.1.1.5 Waste Handling System and Operating Experience - Radioactive	II.1-140
II.1.1.5.1 Gaseous Radioactive Material Releases.	II.1-140
II.1.1.5.2 Liquid Radioactive Material Releases to Columbia River	II.1-141
II.1.1.6 Waste Handling Systems and Operating Experience Nonradioactive	II.1-142
II.1.1.6.1 Nonradioactive Gaseous Releases	II.1-142
II.1.1.6.2 Nonradioactive Liquid Disposal	II.1-146
II.1.1.6.3 Nonradioactive Solid Waste Disposal	II.1-157
II.1.1.6.4 Sanitary Sewage and Industrial Waste (Future Plans)	II.1-158
II.1.2 Environmental Measurements and Monitoring Programs	II.1-160
II.1.2.1 Operational Programs - Radiological	II.1-160
II.1.2.2 Operational Programs - Ecological	II.1-166
II.1.2.2.1 Aquatic Ecology	II.1-167
II.1.2.2.2 Terrestrial Ecology.	II.1-169
II.1.2.2.3 Hydrology	II.1-172
II.1.2.2.4 Meteorology	II.1-174
II.1 REFERENCES.	II.1-181

CONTENTS (Continued)

	<u>Page</u>
II.2 ANTICIPATED BENEFITS	II.2-1
II.3 CHARACTERIZATION OF THE EXISTING ENVIRONMENT	II.3-1
II.3.1 Plant Location	II.3-1
II.3.2 Regional Demography	II.3-1
II.3.3 Land Use.	II.3-3
II.3.4 Water Use	II.3-12
II.3.5 Historical and Archeological Sites and Natural Landmarks	II.3-13
II.3.6 Geology	II.3-14
II.3.7 Seismology	II.3-20
II.3.8 Hydrology	II.3-25
II.3.8.1 Surface Water	II.3-25
II.3.8.1.1 Columbia River	II.3-25
II.3.8.1.2 Yakima River	II.3-31
II.3.8.1.3 Ponds and Ditches	II.3-31
II.3.8.2 Groundwater	II.3-34
II.3.8.2.1 Background and Geological Summary	II.3-34
II.3.8.2.2 The Unconfined Aquifer.	II.3-35
II.3.8.2.3 The Confined Aquifers	II.3-43
II.3.8.2.4 Aquifers North and East of the Columbia River	II.3-51
II.3.9 Meteorology	II.3-53
II.3.9.1 General Climate.	II.3-53
II.3.9.2 Diffusion Climatology.	II.3-58
II.3.10 Aquatic Ecology	II.3-66
II.3.10.1 The Columbia River	II.3-66
II.3.10.1.1 Phytoplankton	II.3-66
II.3.10.1.2 Periphyton	II.3-68
II.3.10.1.3 Macrophytes	II.3-68
II.3.10.1.4 Zooplankton	II.3-68

CONTENTS (Continued)

	<u>Page</u>
II.3.10.1.5 Benthos	II.3-68
II.3.10.1.6 Fish	II.3-69
II.3.10.2 100-N Overflow Trench	II.3-70
II.3.10.3 200-Area Ponds and Ditches.	II.3-70
II.3.10.4 300 Area Waste Ponds.	II.3-72
II.3.10.5 Rattlesnake Springs	II.3-72
II.3.10.5.1 Phytoplankton and Periphyton	II.3-72
II.3.10.5.2 Macrophytes	II.3-72
II.3.10.5.3 Invertebrates	II.3-73
II.3.10.6 Other Springs on the ALE Site.	II.3-73
II.3.11 Terrestrial Ecology	II.3-73
II.3.11.1 Climatic Influences	II.3-73
II.3.11.2 Vegetation	II.3-74
II.3.11.3 Mammals	II.3-89
II.3.11.4 Birds.	II.3-90
II.3.11.5 Snakes and Lizards	II.3-91
II.3.11.6 Insects	II.3-91
II.3.11.7 Rare or Threatened Species.	II.3-93
II.3.11.8 Primary Productivity.	II.3-94
II.3.11.9 Mineral Uptake and Cycling.	II.3-94
II.3.11.10 Animal Populations	II.3-96
II.3.11.11 Food Webs	II.3-97
II.3.11.11.1 Transfers to Man	II.3-97
II.3.11.11.2 Food Webs in a Steppe Ecosystem	II.3-98
II.3.11.12 Ecological Research Results and Availability	II.3-98
II.3.12 Natural Radiation Background and Fallout Radioactivity	II.3-100
II.3.12.1 Direct Radiation	II.3-101
II.3.12.2 Air	II.3-101

CONTENTS (Continued)

	<u>Page</u>
II.3.12.3 Columbia River.	II.3-105
II.3.12.4 Groundwater.	II.3-106
II.3.12.5 Vegetation	II.3-106
II.3.12.6 Sediments	II.3-106
II.3.12.7 Miscellaneous Foodstuffs	II.3-106
II.3.13 Radiological Status of the Hanford Site and Environment	II.3-106
II.3.13.1 Columbia River.	II.3-107
II.3.13.1.1 Columbia River Bed--Contamination Studies . . .	II.3-115
II.3.13.1.2 Radioactivity in Drinking Water	II.3-116
II.3.13.2 Ditches and Ponds	II.3-116
II.3.13.3 Airborne Radioactivity	II.3-116
II.3.13.4 Soil and Vegetation	II.3-123
II.3.13.5 Biota	II.3-127
II.3.13.6 Foodstuffs	II.3-127
II.3.13.7 Direct Radiation	II.3-127
II.3 REFERENCES.	II.3-139
III ENVIRONMENTAL IMPACT.	III.1-1
III.1 ENVIRONMENTAL EFFECTS OF ROUTINE OPERATION OF PLANT FACILITIES	III.1-1
III.1.1 Radiological Impact on Man	III.1-1
III.1.1.1 Pathways of Exposure	III.1-1
III.1.1.2.1 Impact of Liquid Releases	III.1-6
III.1.1.2.2 Impact of Gaseous Releases	III.1-17
III.1.1.2.3 Direct Radiation	III.1-28
III.1.1.2.4 Transportation of Radioactive Materials. . . .	III.1-29
III.1.1.2.5 Dose to Population from All Sources	III.1-29
III.1.1.2.6 Maximum Health Effects	III.1-32
III.1.2 Radiological Impact on Biota Other than Man. . . .	III.1-37
III.1.2.1 Terrestrial.	III.1-37
III.1.2.2 Aquatic	III.1-40

CONTENTS (Continued)

	<u>Page</u>
III.1.2.2.1 Columbia River	III.1-40
III.1.2.2.2 200 Areas Ponds and Ditches.	III.1-48
III.1.2.2.3 Radiation Dose to Aquatic Organisms	III.1-52
III.1.3 Nonradiological Effects on Ecological Systems	III.1-54
III.1.3.1 Effects on Terrestrial Ecological Systems.	III.1-54
III.1.3.2 Effects on Aquatic Ecological Systems	III.1-55
III.1.3.2.1 Effects of Intake Structures on Aquatic Ecological Systems.	III.1-56
III.1.3.2.2 Effects on Aquatic Ecosystems of Dredging or Shoreline Disturbance.	III.1-57
III.1.3.2.3 Thermal and Chemical Effects on Aquatic Ecosystems	III.1-57
III.1.4 Effects on Land Use.	III.1-68
III.1.5 Effects on the Atmosphere.	III.1-68
III.1.6 Effects on Water Use	III.1-70
III.1.6.1 Effects of Surface Water and Groundwater Withdrawals.	III.1-70
III.1.6.2 Effects on Water Quality for Other Uses	III.1-71
III.1 REFERENCES	III.1-74
III.2 WASTE MANAGEMENT ACCIDENTS	III.2-1
III.2.1 Introduction	III.2-1
III.2.2 Leakage of High-Level Liquid Waste from Storage Tanks	III.2-2
III.2.2.1 Leak Detection Capability	III.2-2
III.2.2.2 Description of the 106-T Leak.	III.2-3
III.2.2.3 Postulated 800,000 Gallon Tank Leak.	III.2-4
III.2.2.3.1 Calculated Source Term for the 800,000 Gallon Leak	III.2-4
III.2.2.3.2 Calculated Radiological Impact on Man from 800,000 Gallon Leak.	III.2-12
III.2.3 Tank Gas Release Releases	III.2-14
III.2.3.1 High-Heat Waste Tanks	III.2-14

CONTENTS (Continued)

	<u>Page</u>
III.2.3.1.1 Normal Releases	III.2-14
III.2.3.1.2 Filter Failure	III.2-15
III.2.3.1.3 Seal Failure in Exhaust Piping	III.2-15
III.2.3.1.4 Solution Rollover (Bumping)	III.2-15
III.2.3.2 Low-Heat Waste Tanks	III.2-16
III.2.4 Salt Cake Storage Tank Dome Failure.	III.2-17
III.2.4.1 Source Term of Dome Failure.	III.2-17
III.2.4.2 Calculated Radiation Doses for Postulated Dome Failure Accident.	III.2-18
III.2.5 Postulated Liquid Waste Transfer Accidents	III.2-21
III.2.5.1 Source Term for Liquid Waste Transfer Accident	III.2-23
III.2.5.2 Calculated Radiological Impact on Man	III.2-26
III.2.6 Filter Failure in B Plant	III.2-27
III.2.6.1 Calculated Source Term for Filter Failure in B Plant	III.2-29
III.2.6.2 Calculated Radiological Impact on Man	III.2-31
III.2.7 Liquid Waste Shipments Accidents.	III.2-32
III.2.7.1 Leakage from an Overfilled Rail Tank Car	III.2-32
III.2.7.1.1 Probability of Event	III.2-33
III.2.7.1.2 Calculated Source Term for Leakage from an Overfilled Rail Tank Car	III.2-33
III.2.7.1.3 Calculated Radiological Impact On Man	III.2-36
III.2.7.2 Rail Tank Car Transport Accident	III.2-37
III.2.7.2.1 Calculated Source Term for Rail Tank Car Transport Accident	III.2-37
III.2.7.2.2 Calculated Radiological Impact On Man.	III.2-39
III.2.8 Solid Waste Transfer and Storage Operation Accidents	III.2-39
III.2.8.1 Fire from Vehicle Accident	III.2-39
III.2.8.1.1 Calculated Source Term for Fire from Vehicle Accident	III.2-40
III.2.8.1.2 Calculated Radiological Impact on Man.	III.2-41

CONTENTS (Continued)

	<u>Page</u>
III.2.8.2 Fire in Solid Waste Burial Trench.	III.2-42
III.2.8.2.1 Calculated Source Term for Fire in Solid Waste Burial Trench.	III.2-44
III.2.8.2.2 Postulated Radiological Impact on Man	III.2-45
III.2.9 Range Fire on Contaminated Land	III.2-46
III.2.9.1 Calculated Source Term for Range Fire on Contaminated Land	III.2-47
III.2.9.2 Calculated Radiological Impact on Man	III.2-49
III.2.10 Criticality at Ground Disposal Sites	III.2-50
III.2.11 Effects of Natural Forces	III.2-54
III.2.11.1 Effect of Natural Forces on Radioactivity Stored in the Ground	III.2-54
III.2.11.2 Capability of Facilities to Resist Natural Forces	III.2-55
III.2.11.2.1 Designs for Seismic Activity	III.2-55
III.2.11.2.2 Designs for Winds	III.2-61
III.2.11.3 Columbia River Floods	III.2-64
III.2.11.3.1 Calculated Source Term for Columbia River Flood	III.2-69
III.2.11.3.2 Calculated Radiological Impact on Man	III.2-70
III.2 REFERENCES	III.2-73
IV UNAVOIDABLE ADVERSE EFFECTS	IV-1
IV REFERENCES.	IV-8
V ALTERNATIVES	V-1
V.1 INTRODUCTION.	V-1
V.2 ALTERNATIVES TO HIGH-LEVEL WASTE TREATMENT.	V-4
V.2.1 Continue Present Program	V-4
V.2.1.1 Replace All Single-Wall Tanks.	V-7
V.2.1.2 Replace Some Single-Wall Tanks	V-8
V.2.1.3 Final Solidification.	V-9
V.2.1.3.1 Material Addition for Residual Liquids	V-9
V.2.1.3.2 Further Evaporation for Residual Liquids	V-10
V.2.2 Shutdown of N Reactor	V-11

CONTENTS (Continued)

	<u>Page</u>
V.2.3 Shutdown of Purex	V-12
V.2.3.1 Shutdown of Purex After Processing Current Inventory	V-12
V.2.3.2 Shutdown of Purex Immediately	V-13
V.2.3.2.1 Ship Fuel Offsite.	V-13
V.2.3.2.2 Store Irradiated Fuel	V-14
V.2.4 Discontinue Solidification to Salt Cake.	V-15
V.2.4.1 Construct New Double-Wall Tanks.	V-16
V.2.4.2 Calcine Waste.	V-17
V.2.4.3 High Temperature Melt Formations	V-19
V.2.4.4 Insoluble Formation.	V-20
V.2.5 Ultimate Disposal	V-21
V.3 OTHER RADIOACTIVE LIQUID WASTE	V-23
V.3.1 Current Program	V-23
V.3.2 Liquid Waste Treatment Alternatives	V-27
V.3.2.1 100 Areas	V-27
V.3.2.2 200 Areas	V-28
V.3.2.2.1 5 Million Dollar Effluent Treatment Plan	V-30
V.3.2.2.2 50 Million Dollar Effluent Treatment Plan.	V-30
V.4 GASEOUS EFFLUENTS.	V-36
V.4.1 Current Program.	V-36
V.4.2 Gaseous Waste Treatment Alternatives.	V-39
V.5 SOLID RADIOACTIVE WASTE.	V-42
V.5.1 Current Practice	V-42
V.5.2 Solid Waste Treatment Alternatives	V-42
V.6 NONRADIOACTIVE WASTE.	V-47
V.6.1 Chemical Releases to the Columbia River.	V-47
V.6.2 Chemical Releases to the Land	V-49
V.6.3 Chemicals Released to the Air	V-50
V.6.4 Chemical Waste Stored in Special Repositories.	V-52

CONTENTS (Continued)

	<u>Page</u>
V.6.5 Sanitary Waste.	V-54
V.6.6 Nonradioactive Solids Released to the Land	V-56
V.6.7 Other Environmental Pollutants	V-57
V.6.7.1 Heat to the Columbia River	V-57
V.6.7.2 Heat Released to Land.	V-58
V.6.7.3 Heat Released to the Air.	V-58
V.6.7.4 Odors	V-59
V.6.7.5 Noise	V-60
V REFERENCES	V-61
VI RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY	VI-1
VI.1 BACKGROUND	VI-1
VI.2 EFFECTS OF PROPOSED ACTIONS.	VI-3
VII RELATIONSHIP OF PROPOSED ACTION TO LAND USE PLANS, POLICIES, AND CONTROLS	VII-1
VIII IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES.	VIII-1
VIII.1 PERMANENT COMMITMENTS	VIII-1
VIII.2 TEMPORARY COMMITMENTS	VIII-1
IX COMPARISON OF COSTS AND BENEFITS.	IX-1
IX.1 EVALUATION OF BENEFITS FOR THE WASTE MANAGEMENT OPERATIONS.	IX-1
IX.1.1 Minimum Radiation Dose.	IX-1
IX.1.2 Minimum Chemical Pollution	IX-1
IX.1.3 Increased Technical Knowledge	IX-2
IX.1.4 Employment.	IX-2
IX.2 EVALUATION OF COSTS FOR THE WASTE MANAGEMENT OPERATIONS	IX-2
IX.2.1 Capital Cost	IX-2
IX.2.2 Operating Costs	IX-2
IX.2.3 Land Use	IX-2
IX.3 COST-BENEFIT ANALYSIS.	IX-4

VOLUME 2 CONTENTS

APPENDIX

	<u>Page</u>
II.1-A DETAIL MAP OF THE HANFORD RESERVATION	II.1-A-1
II.1-B 100 AREA FACILITIES	II.1-B-1
Part 1 100 Area Maps	II.1-B-3
Part 2 Waste Management Facilities, Cribs and Burial Grounds	II.1-B-11
Part 3 Estimated Radioactive Material Inventories	II.1-B-25
Part 4 100 Areas, Radioactive Material Releases--1972	II.1-B-29
Part 5 100 Areas Unplanned Releases	II.1-B-33
II.1-C 200 AREA FACILITIES	II.1-C-1
Part 1 200 Area Maps	II.1-C-3
Part 2 Waste Management Facilities Tanks, Cribs, Ponds, and Burial Grounds	II.1-C-7
Part 3 Details of 200 East Area Facilities and Operations	II.1-C-21
Part 4 Details of 200 West Area Facilities and Operations	II.1-C-57
Part 5 Radioisotopes Stored Beneath Selected 200 Area Cribs	II.1-C-81
Part 6 Estimated Inventories 200 Area Facilities	II.1-C-101
Part 7 200 Area Gaseous Radioactive Material Releases	II.1-C-109
Part 8 200 Areas, Unplanned Releases	II.1-C-125
II.1-D LIQUID WASTE STREAMS TO THE COLUMBIA RIVER	II.1-D-1
II.1-E 300 AREA FACILITIES	II.1-E-1
Part 1 300 Area Maps	II.1-E-3
Part 2 Waste Management Facilities Storage and Disposal Sites.	II.1-E-7
Part 3 Estimated Radioactive Liquid Waste Inventory - 300 Area	II.1-E-13
Part 4 300 Area, Radioactive Material Releases, 1972	II.1-E-17

CONTENTS (Continued)

APPENDIX

	<u>Page</u>
Part 5 300 Area Unplanned Releases.	II.1-E-25
II.1-F PROCESS CHEMICAL INVENTORY AND CONSUMPTION . . .	II.1-F-1
II.1-G STANDARDS APPLICABLE TO HANFORD WASTE MANAGEMENT OPERATIONS	II.1-G-1
Part 1 Regional Air Quality Standards.	II.1-G-3
Part 2 State Water Quality Standards	II.1-G-5
II.3-A DEMOGRAPHIC AND ARCHAEOLOGICAL DATA	II.3-A-1
Part 1 Population Projections with Geographical Distributions Within 50-Mile Radius	II.3-A-3
Part 2 Estimated Water Usage for 50 Miles Downstream from the 100-N Area	II.3-A-17
Part 3 Archaeological Sites and Description.	II.3-A-23
II.3-B HANFORD GEOLOGY DATA	II.3-B-1
Part 1 Hanford Geology Data	II.3-B-3
II.3-B.1 Geomorphology	II.3-B-4
II.3-B.2 Soils	II.3-B-8
II.3-B.3 The Basement Rocks	II.3-B-10
II.3-B.4 The Columbia River Group	II.3-B-11
II.3-B.5 The Ellensburg Formation	II.3-B-14
II.3-B.6 Anticlinal Uplift and Faulting	II.3-B-16
II.3-B.7 The Ringold Formation	II.3-B-23
II.3-B.8 The Palouse Soils	II.3-B-26
II.3-B.9 The Glacial Lake Missoula Flood Deposits	II.3-B-27
II.3-B.10 Volcanic Ash Deposits	II.3-B-30
Part 2 Geological Studies of the Hanford Site	II.3-B-37
II.3-C SEISMOLOGY	II.3-C-1
II.3-C.1 General	II.3-C-1
II.3-C.2 The Olympic-Wallowa Lineament	II.3-C-7
II.3-C.3 The Saddle Mountains	II.3-C-9

CONTENTS (Continued)

APPENDIX

	<u>Page</u>
II.3-C.4 Other Structures	II.3-C-10
II.3-C.5 The Effects of Earthquakes	II.3-C-12
II.3-C.5.1 Differential Compaction	II.3-C-13
II.3-C.5.2 Liquefaction	II.3-C-14
II.3-C.5.3 Landslides	II.3-C-15
II.3-C.6 Maximum Anticipated Earthquake	II.3-C-16
II.3-C.7 Summary and Conclusions	II.3-C-19
II.3-D HYDROLOGY	II.3-D-1
II.3-D.1 Surface Waters	II.3-D-1
II.3-D.1.1 The Columbia River	II.3-D-1
II.3-D.1.1.1 Physical and Hydraulic Characteristics	II.3-D-1
II.3-D.1.1.2 Temperatures	II.3-D-4
II.3-D.1.1.3 Chemical	II.3-D-7
II.3-D.1.1.4 Columbia River Sediments	II.3-D-12
II.3-D.1.2 The Yakima River	II.3-D-14
II.3-D.1.3 Ponds	II.3-D-14
II.3-D.2 Groundwater	II.3-D-22
II.3-D.2.1 Background and Geological Summary	II.3-D-22
II.3-D.2.2 The Unconfined Aquifer.	II.3-D-29
II.3-D.2.2.1 Hydraulic Characteristics	II.3-D-34
II.3-D.2.2.2 Groundwater Quality	II.3-D-44
II.3-D.2.3 The Confined Aquifers	II.3-D-65
II.3-D.2.4 Aquifers Across the Columbia River.	II.3-D-72
II.3-E METEOROLOGY	II.3-E-1
II.3-E.1 General Climatology	II.3-E-1
II.3-E.2 Temperature	II.3-E-1
II.3-E.3 Humidity	II.3-E-8
II.3-E.4 Wind	II.3-E-10
II.3-E.4.1 Strong Winds	II.3-E-31
II.3-E.4.2 Tornadoes	II.3-E-36

CONTENTS (Continued)

APPENDIX

	<u>Page</u>
II.3-E.4.3 Dust Devils	II.3-E-40
II.3-E.4.4 Hurricanes	II.3-E-42
II.3-E.5 Severe Weather and Miscellaneous Phenomena	II.3-E-43
II.3-E.5.1 Thunderstorms	II.3-E-43
II.3-E.5.2 Hail	II.3-E-44
II.3-E.5.3 Lightning	II.3-E-45
II.3-E.5.4 Glaze	II.3-E-46
II.3-E.5.5 Fog	II.3-E-46
II.3-E.5.6 Air Pollution Potential	II.3-E-47
II.3-E.5.7 Sky Cover and Solar Radiation	II.3-E-49
II.3-E.5.8 Precipitation	II.3-E-52
II.3-F ECOLOGY	II.3-F-1
Part 1 Aquatic Ecology	II.3-F-4
II.3-F.1 The Columbia River.	II.3-F-4
II.3-F.1.1 Phytoplankton	II.3-F-6
II.3-F.1.2 Periphyton	II.3-F-7
II.3-F.1.3 Macrophytes	II.3-F-10
II.3-F.1.4 Zooplankton	II.3-F-10
II.3-F.1.5 Benthos.	II.3-F-10
II.3-F.1.6 Fish	II.3-F-11
II.3-F.2 100-N Dispersal Ditch.	II.3-F-13
II.3-F.3 200 Area Ponds and Ditches	II.3-F-14
II.3-F.4 300 Area Waste Ponds	II.3-F-17
II.3-F.5 Rattlesnake Springs	II.3-F-17
II.3-F.5.1 Phytoplankton and Periphyton.	II.3-F-19
II.3-F.5.2 Macrophytes	II.3-F-19
II.3-F.5.3 Invertebrates.	II.3-F-19
II.3-F.6 Other Springs on the ALE Site	II.3-F-19
Part 2 Columbia River Biota	II.3-F-23

CONTENTS (Continued)

APPENDIX

	<u>Page</u>
II.3-G TERRESTRIAL ECOLOGY, PART 1	II.3-G-3
II.3-G.1 Climatic Influences	II.3-G-3
II.3-G.2 Soil	II.3-G-7
II.3-G.2.1 Description and Classification of Hanford Reservation Soils	II.3-G-9
II.3-G.2.1.1 Soil Descriptions	II.3-G-10
II.3-G.2.1.2 Soil Classification	II.3-G-14
II.3-G.3 Vegetation	II.3-G-20
II.3-G.3.1 Primary Plant Descriptions	II.3-G-20
II.3-G.3.2 Pattern of Secondary Plant Succession	II.3-G-34
II.3-G.4 Mammals	II.3-G-37
II.3-G.5 Birds	II.3-G-38
II.3-G.6 Snakes and Lizards	II.3-G-40
II.3-G.7 Insects	II.3-G-41
II.3-G.8 Rare or Threatened Species	II.3-G-44
II.3-G.9 Fragile or Restricted Microhabitats	II.3-G-45
II.3-G.10 Pest Animal Species	II.3-G-48
II.3-G.11 Plants	II.3-G-48
II.3-G.11.1 Primary Productivity	II.3-G-48
II.3-G.11.2 Mineral Uptake	II.3-G-54
II.3-G.12 Litter Decay and Mineral Cycling	II.3-G-56
II.3-G.13 Animal Populations	II.3-G-57
II.3-G.14 Food Webs	II.3-G-59
II.3-G.14.1 Transfers to Man	II.3-G-59
II.3-G.14.2 Food Webs in Steppe Ecosystem	II.3-G-62
II.3-G.15 Ecological Research Results and Availability	II.3-G-68
Part 2 Vascular Taxa of the Hanford Reservation	II.3-G-73
Part 3 Vertebrate Taxa of the Hanford Reservation	II.3-G-79
Part 4 Insects of the Hanford Reservation	II.3-G-85
Part 5 Shrub-Steppe Biota on the Hanford Reservation	II.3-G-93

CONTENTS (Continued)

APPENDIX

	<u>Page</u>
III-A MODELS AND COMPUTER CODES FOR EVALUATING ENVIRONMENTAL RADIATION DOSES	III-A-1
Part 1 Program ARRRG, CRITR and GRONK.	III-A-3
III-A.1 Introduction	III-A-3
III-A.2 Pathways of Exposure	III-A-4
III-A.3 Dose to Man--Basic Considerations	III-A-7
III-A.3.1 Concentrations of Nuclides in Environmental Media, C_{ip}	III-A-7
III-A.3.2 Usages, U_p	III-A-8
III-A.3.3 Dose Factors, D_{ipr}	III-A-8
III-A.4 Dose to Man--Liquid Pathways	III-A-11
III-A.4.1 Drinking Water	III-A-11
III-A.4.2 Aquatic Foods	III-A-11
III-A.4.3 Shoreline Deposits	III-A-12
III-A.4.4 Swimming and Boating	III-A-14
III-A.5 Dose To Man--Gaseous Pathways	III-A-15
III-A.5.1 Air Submersion	III-A-15
III-A.5.2 Thyroid Doses From Radioiodine	III-A-17
III-A.6 Dose to Organisms Other Than Man	III-A-22
III-A.6.1 Internal Doses Via Liquid Pathways	III-A-23
III-A.6.2 Other Doses to Aquatic and Terrestrial Animals	III-A-25
III-A.7 Computer Programs ARRRG, CRITR and GRONK.	III-A-27
III-A.7.1 Introduction	III-A-27
III-A.7.2 Program ARRRG	III-A-32
III-A.7.3 Program CRITR	III-A-45
III-A.7.4 Program GRONK	III-A-60
III-A.7.5 Mixing Ratios and Reconcentration Formula	III-A-71
III-A.7.6 Treatment of Parent-Daughter Nuclide Pairs	III-A-91

CONTENTS (Continued)

APPENDIX

	<u>Page</u>
III-A PART 1 REFERENCES.	III-A-93
III-A Part 2 Program FOOD	III-A-97
III-A.1 Introduction	III-A-98
III-A.2 Irrigated Vegetation.	III-A-98
III-A.3 Animal Products	III-A-101
III-A PART 2 REFERENCES.	III-A-106
III-B DESCRIPTION OF MATHEMATICAL MODELS USED IN DOSE CALCULATIONS.	III-B-1
III-B.1 Atmospheric Dispersion Models.	III-B-1
III-B.1.1 Accidental Release.	III-B-2
III-B.1.2 Chronic Release.	III-B-4
III-B.2 Total Body Tissue Dose from Gamma Radiation	III-B-8
III-B.3 Inhalation Dose Models	III-B-11
III-B.3.1 ILM.	III-B-11
III-B.3.2 TGLM	III-B-12
III-B.4 Population Doses	III-B-24
III-B REFERENCES.	III-B-26
III-C ACCIDENT ESTIMATION TECHNIQUES	III-C-1
III-C.1 Calculation of Doses From Atmospheric Releases	III-C-1
III-C.2 Liquid Release Calculation.	III-C-2
III-C REFERENCES	III-C-5
III-D RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK	III-D-1
III-E AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND	III-E-1
III-E REFERENCES	III-E-3
III-F TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE	III-F-1
GLOSSARY	G-1
LIST OF ELEMENTS	

VOLUME 1 FIGURES

	<u>Page</u>
II.1-1 MAP OF HANFORD RESERVATION.	II.1-5
II.1-2 RADIOACTIVE WASTE MANAGEMENT OPERATIONS AT HANFORD	II.1-6
II.1-3 B/C REACTOR AREA	II.1-8
II.1-4 K REACTOR AREA	II.1-10
II.1-5 N REACTOR AREA WITH WPPSS GENERATING PLANT TO LEFT. .	II.1-12
II.1-6 D/DR REACTOR AREA.	II.1-13
II.1-7 H REACTOR AREA	II.1-15
II.1-8 100-F REACTOR AREA	II.1-16
II.1-9 200-E AREA WITH 200-W AREA AND 100 B/C REACTOR AREA IN BACKGROUND.	II.1-18
II.1-10 200-W AREA WITH 100 B/C AREA IN BACKGROUND	II.1-19
II.1-11 PUREX PROCESS SCHEMATIC	II.1-21
II.1-12 200-E AREA PUREX PLANT.	II.1-22
II.1-13 200-E AREA B PLANT	II.1-23
II.1-14 200-E AREA CRITICAL MASS LABORATORY AND SEMIWORKS. .	II.1-25
II.1-15 200-W AREA U PLANT	II.1-27
II.1-16 UO_3 PLANT PROCESS SCHEMATIC	II.1-28
II.1-17 200-W AREA REDOX (S) PLANT	II.1-29
II.1-18 200-W AREA T PLANT	II.1-31
II.1-19 200-W AREA Z-PLANT	II.1-32
II.1-20 PLUTONIUM RECOVERY AND FINISHING OPERATIONS . . .	II.1-34
II.1-21 200-E AREA TANK FARMS	II.1-36
II.1-22 200-E AREA TANK FARMS BY, BX AND B.	II.1-37
II.1-23 200-EAST AREA TANK FARM FACILITIES.	II.1-38
II.1-24 200-W AREA TANK FARMS SX AND S	II.1-39
II.1-25 200 WEST AREA TANK FARM FACILITIES.	II.1-40
II.1-26 216-B-3 POND	II.1-42
II.1-27 GABLE MOUNTAIN POND.	II.1-43
II.1-28 WEST LAKE	II.1-44
II.1-29 200-E AREA BURIAL GROUNDS 218-E-10, 5A, 5, 2, 9 AND 4	II.1-45

FIGURES (Continued)

	<u>Page</u>
II.1-30 216-S-16 POND.	II.1-46
II.1-31 200-W AREA BURIAL GROUNDS 218-W-24, 3 AND 3A . . .	II.1-47
II.1-32 218-E-12-B BURIAL GROUND	II.1-49
II.1-33 300 AREA	II.1-51
II.1-34 100-N LIQUID WASTE SYSTEMS	II.1-56
II.1-35(a) 200 AREAS WASTE OUTPUT - 1972	II.1-62
II.1-35(b) 200 AREAS WASTE OUTPUT - 1972	II.1-63
II.1-36 WASTE FRACTIONIZATION FLOWSHEET.	II.1-66
II.1-37 CESIUM CHLORIDE ENCAPSULATION PROCESS FLOW DIAGRAM .	II.1-68
II.1-38 STRONTIUM FLUORIDE ENCAPSULATION PROCESS FLOW DIAGRAM	II.1-69
II.1-39 TYPICAL STORAGE TANK FOR NONBOILING WASTE	II.1-73
II.1-40 CHARACTERISTICS OF WASTE USED FOR DESIGN ON NONBOILING WASTE TANKS.	II.1-74
II.1-41 CHARACTERISTICS OF WASTE USED FOR DESIGN OF BOILING WASTE TANKS.	II.1-75
II.1-42 TYPICAL HIGH-LEVEL BOILING WASTE STORAGE FACILITY. .	II.1-76
II.1-43 TYPICAL CONTROL AND SAFETY FEATURES FOR HIGH-LEVEL BOILING RADIOACTIVE WASTE STORAGE . . .	II.1-77
II.1-44 DOUBLE-WALL BOILING WASTE TANK	II.1-79
II.1-45 IN-TANK SOLIDIFICATION-1 SCHEMATIC.	II.1-81
II.1-46 IN-TANK SOLIDIFICATION-2 SCHEMATIC.	II.1-82
II.1-47 242-T EVAPORATOR SCHEMATIC	II.1-83
II.1-48 242-S VACUUM EVAPORATOR-CRYSTALLIZER	II.1-84
II.1-49 242-S BOTTOMS TANK SYSTEM	II.1-85
II.1-50 TYPICAL CRIB FOR AQUEOUS WASTE	II.1-89
II.1-51 SCHEMATIC OF TYPICAL CRIB FOR INTERMEDIATE- LEVEL WASTES	II.1-91
II.1-52 APPROXIMATE SORPTION PATTERNS FOR TYPICAL HANFORD DISPOSAL CRIB	II.1-92
II.1-53 SCHEMATIC VIEW OF TYPICAL POND RECEIVING LOW-LEVEL AQUEOUS WASTE	II.1-96

FIGURES (Continued)

	<u>Page</u>
II.1-54 SOLID WASTE BURIAL TRENCHES	II.1-98
II.1-55 CONCRETE LINES V-TRENCH USED FOR RETRIEVABLE TRANSURANIC WASTE STORAGE	II.1-100
II.1-56 THE TRANSURANIC SLAB	II.1-101
II.1-57 SOLID WASTE BURIAL CAISSONS	II.1-102
II.1-58 TUNNEL FOR STORAGE OF RADIOACTIVE EQUIPMENT.	II.1-104
II.1-59 SCHEMATIC OF VENTILATION OF TYPICAL SEPARATIONS PLANT	II.1-105
II.1-60 CONTAMINATED LIQUID WASTE COLLECTION SYSTEM.	II.1-108
II.1-61 RETENTION WASTE SYSTEM	II.1-109
II.1-62 300 AREA NORMALLY UNCONTAMINATED WASTE SYSTEM	II.1-110
II.1-63 340 AND 340A BUILDING INTERMEDIATE-LEVEL WASTE STORAGE TANK	II.1-111
II.1-64 300 AREA WASTE STORAGE AREAS.	II.1-116
II.1-65 B/C CRIBS	II.1-123
II.1-66 AVERAGE GROSS BETA (AS ^{106}Ru) CONCENTRATIONS, JULY-DECEMBER 1972	II.1-131
II.1-67 AVERAGE TRITIUM (^3H) CONCENTRATIONS, JULY- DECEMBER 1972	II.1-132
II.1-68 AVERAGE NITRATE ION (NO_3^-) CONCENTRATIONS JULY-DECEMBER 1972	II.1-133
II.1-69 300 AREA SANITARY SEWER SYSTEM	II.1-147
II.1-70 PROCESS SEWERS AND RETENTION PONDS.	II.1-151
II.1-71 HANFORD METEOROLOGICAL SENSOR FACILITIES.	II.1-175
II.3-1 THE HANFORD SITE	II.3-2
II.3-2 1970 U.S. CENSUS POPULATIONS OF COMMUNITIES IN THE HANFORD SITE VICINITY	II.3-4
II.3-3 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1970 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION	II.3-5
II.3-4 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1970 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA	II.3-6

FIGURES (Continued)

	<u>Page</u>
II.3-5 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1970 POPULATION WITHIN A 50-MILE RADIUS OF THE 300 AREA	II.3-7
II.3-6 HANFORD SITE LAND USE	II.3-9
II.3-7 NUMBER AND LOCATION OF KNOWN ARCHEOLOGICAL SITES WITHIN A 50-MILE RADIUS OF HANFORD METEOROLOGICAL STATION	II.3-15
II.3-8 SEISMIC RISK MAP	II.3-21
II.3-9 EARTHQUAKE ZONES OF WASHINGTON	II.3-23
II.3-10 SURFACE WATER AREAS ON HANFORD SITE	II.3-26
II.3-11 COLUMBIA RIVER BASIN	II.3-27
II.3-12 1972 MONTHLY AVERAGE TEMPERATURE COMPARISON FOR FOR PRIEST RAPIDS DAM AND RICHLAND.	II.3-29
II.3-13 HANFORD RESERVATION WELL LOCATION MAP.	II.3-33
II.3-14 HANFORD RESERVATION WATER TABLE MAP	II.3-36
II.3-15 HANFORD RESERVATION WATER TABLE MAP Hindcast	II.3-39
II.3-16 WELL HYDROGRAPHS.	II.3-40
II.3-17 HANFORD RESERVATION WATER TABLE MAP WITH STREAMLINES.	II.3-42
II.3-18 AVERAGE NITRATE (NO_3^-) CONCENTRATIONS	II.3-44
II.3-19 GROUNDWATER TEMPERATURES AT THE SURFACE OF THE UNCONFINED AQUIFER	II.3-45
II.3-20 AVERAGE GROSS BETA (AS ^{106}Ru) CONCENTRATIONS	II.3-46
II.3-21 AVERAGE TRITIUM (^3H) CONCENTRATIONS	II.3-47
II.3-22 PASCO BASIN UPPERMOST CONFINED AQUIFER POTENTIAL MAP.	II.3-49
II.3-23 410 FOOT TOWER AT THE HANFORD METEOROLOGICAL STATION.	II.3-54
II.3-24 WIND ROSES AS A FUNCTION OF STABILITY AND WIND SPEED AT HMS BASED ON WINDS AT 200 FT AND AIR TEMPERATURE STABILITY DEFINED BETWEEN 3 FT AND 200 FT FOR THE PERIOD OF 1955 THROUGH 1970	II.3-60

FIGURES (Continued)

		<u>Page</u>
II.3-25	WIND ROSES AS A FUNCTION OF STABILITY AT N AREA BASED ON WINDS AT 200 FT AND AIR TEMPERATURES BETWEEN 3 FT AND 200 FT FOR THE PERIOD OF JANUARY 29, 1970 TO JANUARY 28, 1971	II.3-61
II.3-26	WIND ROSE FOR THE FFTF SITE	II.3-63
II.3-27	WIND ROSE FOR THE WNP-2 SITE	II.3-64
II.3-28	SURFACE WIND ROSES FOR VARIOUS LOCATIONS ON AND SURROUNDING THE HANFORD SITE	II.3-65
II.3-29	FOOD WEB IN THE COLUMBIA RIVER	II.3-67
II.3-30	FOOD WEB IN GABLE MOUNTAIN POND AND U POND	II.3-71
II.3-31	DISTRIBUTION OF VEGETATION TYPES ON THE HANFORD RESERVATION	II.3-75
II.3-32	SAGEBRUSH/BLEEDBUSH WHEATGRASS COMMUNITY.	II.3-76
II.3-33	SAGEBRUSH/BLEEDBUSH WHEATGRASS COMMUNITY.	II.3-77
II.3-34	SAGEBRUSH/CHEATGRASS COMMUNITY	II.3-78
II.3-35	SAGEBRUSH/SANDBERG'S BLUEGRASS COMMUNITY.	II.3-79
II.3-36	SAGEBRUSH-BITTERBRUSH/CHEATGRASS COMMUNITY	II.3-80
II.3-37	GREASEWOOD/CHEATGRASS-SALTGRASS COMMUNITY	II.3-81
II.3-38	WINTERFAT/SANDBERG'S BLUEGRASS COMMUNITY.	II.3-82
II.3-39	THYME BUCKWHEAT/SANDBERG'S BLUEGRASS COMMUNITY.	II.3-83
II.3-40	CHEATGRASS-TUMBLE MUSTARD COMMUNITY	II.3-84
II.3-41	WILLOW COMMUNITY.	II.3-85
II.3-42	LOCATION AND DIRECTION OF VIEW FOR PLANT COMMUNITY PHOTOGRAPHS	II.3-86
II.3-43	FOOD WEB CENTERED ON CHEATGRASS.	II.3-99
II.3-44a	RADIONUCLIDE CONCENTRATION IN SURFACE AIR AT RICHLAND, WASHINGTON	II.3-103
II.3-44b	RADIONUCLIDE CONCENTRATION IN SURFACE AIR AT RICHLAND, WASHINGTON	II.3-104
III.2-1	SORPTION OF RADIONUCLIDES IN SOIL BENEATH WASTE TANK.	III.2-8
III.2-2	SORPTION OF ⁹⁰ Sr BENEATH WASTE TANK	III.2-9
III.2-3	SORPTION OF ¹³⁷ Cs BENEATH WASTE TANK	III.2-10

FIGURES (Continued)

	<u>Page</u>
III.2-4 SORPTION OF ^{125}Sb BENEATH WASTE TANK	III.2-11
III.2-5 MAP OF FLOOD POTENTIAL.	III.2-68
V-1 5 MILLION DOLLAR EFFLUENT TREATMENT ALTERNATIVE.	V-31
V-2 50 MILLION DOLLAR EFFLUENT TREATMENT ALTERNATIVE	V-35

VOLUME 1 TABLES

	<u>Page</u>
II.1-1 SUMMARY - REACTOR STATUS.	II.1-7
II.1-2 PREVIOUSLY UTILIZED ACREAGE OF THE 600 AREA . . .	II.1-54
II.1-3 RADIOACTIVE WASTE SOURCES	II.1-64
II.1-4 WASTE STORAGE TANKS	II.1-72
II.1-5 VENTILATION FILTERS	II.1-106
II.1-6 PLANT WATER USE.	II.1-125
II.1-7 HIGHEST GROSS BETA, Co-60, Ru-106, Sr-90, Cs-137, AND GROSS ALPHA CONCENTRATIONS IN THE GROUNDWATER UNDER THE AREAS LISTED BY DISPOSAL SITE	II.1-135
II.1-8 SOURCES AND EMISSIONS OF NONRADIOACTIVE POLLUTANTS TO THE ATMOSPHERE CY-1972	II.1-143
II.1-9 SEWAGE DISPOSAL TO GROUND	II.1-146
II.1-10 SEWAGE DISPOSAL TO GROUND	II.1-148
II.1-11 DIRECT DISPOSAL TO THE COLUMBIA RIVER	II.1-149
II.1-12 1301-N CRIB - 1972	II.1-149
II.1-13 NONRADIOACTIVE CHEMICALS RELEASED	II.1-152
II.1-14 DISPOSAL OF USED OIL.	II.1-153
II.1-15 ROUTINE ENVIRONMENTAL SURVEILLANCE SCHEDULE CY-1973	II.1-162
II.1-16 INSTRUMENT HEIGHT LOCATIONS	II.1-174
II.1-17 SENSOR HEIGHTS WITH RESPECT TO BASE	II.1-178
II.3-1 ESTIMATED PERCENT OF ACREAGE BY CROP IN THE IRRIGATED AREA WITHIN 50 MILES OF THE 100-N AREA 1962-1968.	II.3-11
II.3-2 AVERAGE CHEMICAL CONCENTRATIONS IN THE COLUMBIA RIVER AT PRIEST RAPIDS DAM, OCTOBER 1971 TO SEPTEMBER 1972	II.3-30
II.3-3 (Table Appears in Appendix II.3-D-11)	
II.3-4 TRITIUM IN HANFORD WELLS TAPPING THE CONFINED AQUIFER ABOVE THE BASALT	II.3-52
II.3-5 AVERAGES AND EXTREMES OF CLIMATIC ELEMENTS AT HANFORD	II.3-55

TABLES (Continued)

	<u>Page</u>
II.3-6 HANFORD ATMOSPHERIC DISPERSION MODEL DEFINITION OF STABILITIES	II.3-62
II.3-7 CONCENTRATIONS OF RADIONUCLIDES IN SURFACE AIR AT RICHLAND, WASHINGTON, 1972	II.3-102
II.3-8 CONCENTRATIONS OF RADIONUCLIDES IN COLUMBIA RIVER WATER UPSTREAM FROM HANFORD, 1972	II.3-105
II.3-9 RADIOACTIVITY CONCENTRATIONS IN VEGETATION NEAR HANFORD - 1972	II.3-108
II.3-10 RADIOACTIVITY IN SOILS NEAR HANFORD AND IN THE COLUMBIA RIVER UPSTREAM FROM HANFORD - 1972	II.3-109
II.3-11 RADIOACTIVITY IN GAMEBIRDS AND FOOD ANIMALS NEAR HANFORD, 1972	II.3-110
II.3-12 RADIOACTIVITY IN LOCAL MILK AND EGGS, 1972	II.3-110
II.3-13 CONCENTRATIONS OF RADIONUCLIDES IN COLUMBIA RIVER WATER FOR 1972	II.3-112
II.3-14 ANNUAL AVERAGE TRANSPORT RATES OF SELECTED RADIONUCLIDES IN THE COLUMBIA RIVER AT RICHLAND AND AT BONNEVILLE DAM, 1972	II.3-113
II.3-15 ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN COLUMBIA RIVER AT McNARY DAM--1972	II.3-113
II.3-16 CONCENTRATIONS OF SEVERAL RADIONUCLIDES IN RICHLAND DRINKING WATER - 1972	II.3-117
II.3-17 GAMMA ACTIVITY IN WASTE WATER SAMPLES - 1972	II.3-118
II.3-18 RADIOACTIVITY IN AIR AT HANFORD ONSITE LOCATIONS - 1972	II.3-119
II.3-19 ANNUAL AVERAGE CONCENTRATIONS OF SELECTED RADIONUCLIDES IN AIR HANFORD ONSITE LOCATIONS - 1972	II.3-120
II.3-20 RADIOACTIVITY IN AIR AT HANFORD OFFSITE LOCATIONS - 1972	II.3-121
II.3-21 AVERAGE CONCENTRATIONS OF SELECTED RADIONUCLIDES IN AIR, QUARTERLY AVERAGES - 1972.	II.3-122
II.3-22 CONCENTRATIONS OF RADIONUCLIDES IN SOIL SAMPLES--1972	II.3-124
II.3-23 CONCENTRATIONS OF RADIONUCLIDES IN VEGETATION-1972	II.3-126

TABLES (Continued)

	<u>Page</u>
II.3-24 CONCENTRATIONS OF SEVERAL RADIONUCLIDES IN SMALL ANIMALS	II.3-128
II.3-25 AVERAGE RADIONUCLIDE CONCENTRATIONS IN MUSCLE OF GAMEBIRDS - 1972	II.3-130
II.3-26 CONCENTRATION OF SEVERAL RADIONUCLIDES HANFORD DEER AND COYOTE--1972	II.3-131
II.3-27 AVERAGE RADIONUCLIDE CONCENTRATIONS IN MUSCLE GAMEBIRDS, FISH, AND SHELLFISH--1972	II.3-132
II.3-28 RADIONUCLIDE CONCENTRATIONS IN LOCALLY PURCHASED MILK AND FOOD--1972	II.3-133
II.3-29 AVERAGE EXTERNAL GAMMA EXPOSURE RATES	II.3-134
II.3-30 DOSE RATES FROM MONTHLY SHORELINE SURVEYS FOR 1972	II.3-136
II.3-31 AVERAGE EXPOSURE RATES BELOW THE SURFACE OF THE COLUMBIA RIVER--1972	II.3-138
III.1-1 POTENTIAL PATHWAYS OF RADIATION EXPOSURE TO MAN FROM OPERATION OF THE NUCLEAR FACILITIES AT HANFORD	III.1-3
III.1-2 RADIONUCLIDES RELEASED TO THE COLUMBIA RIVER WITH LIQUID ELEMENTS AT 100-N IN 1972	III.1-7
III.1-3 RADIONUCLIDES RELEASED TO THE COLUMBIA RIVER WITH LIQUID EFFLUENTS AT 100-F IN 1972	III.1-8
III.1-4 RADIONUCLIDES RELEASED TO THE COLUMBIA RIVER WITH LIQUID EFFLUENTS AT 300 AREA IN 1972.	III.1-9
III.1-5 BIOACCUMULATION FACTORS FOR RADIONUCLIDES IN FRESH WATER ORGANISMS	III.1-10
III.1-6 REMOVAL OF RADIONUCLIDES BY WATER TREATMENT SYSTEMS AT RICHLAND AND PASCO, WASHINGTON	III.1-13
III.1-7 ESTIMATED MAXIMUM DOSE TO AN INDIVIDUAL FROM THE EFFLUENTS RELEASED AT THE HANFORD PROJECT IN 1972	III.1-14
III.1-8 RADIONUCLIDES RELEASED WITH GASEOUS EFFLUENTS AT 100-N AREA IN 1972	III.1-18
III.1-9 RADIONUCLIDES RELEASED WITH GASEOUS EFFLUENTS AT THE 200 AREAS IN 1972	III.1-18

TABLES (Continued)

	<u>Page</u>
III.1-10 RADIONUCLIDES RELEASED WITH GASEOUS EFFLUENTS AT 300 AREA IN 1972	III.1-19
III.1-11 ESTIMATED CUMULATIVE POPULATION, CUMULATIVE ANNUAL DOSE AND AVERAGE ANNUAL DOSE IN CIRCULAR AREAS AROUND THE HANFORD METEOROLOGY STATION FROM GASEOUS EFFLUENTS RELEASED FROM ALL FACILITIES IN 1972	III.1-22
III.1-12 SUMMARY OF ESTIMATED POPULATION DOSES RECEIVED AS A RESULT OF THE HANFORD OPERATIONS IN 1972 . .	III.1-23
III.1-13 MAXIMUM RADIATION DOSE TO AN INDIVIDUAL FROM INHALATION OF PLUTONIUM RELEASED AT THE 200 AREAS IN 1972	III.1-25
III.1-14 CONVERSION FACTORS	III.1-33
III.1-15 MAXIMUM NUMBER OF HEALTH EFFECTS FOR 1972 ENVIRONMENTAL DOSE LEVELS.	III.1-34
III.1-16 AVERAGE RADIONUCLIDE CONCENTRATIONS IN MUSCLES OF WATERFOWL	III.1-39
III.1-17 COMPARISON OF CONCENTRATIONS OF GAMMA EMITTING RADIONUCLIDES IN COLUMBIA RIVER ORGANISMS 1957-67.	III.1-42
III.1-18 COMPARATIVE RADIONUCLIDE CONCENTRATIONS - 200 AREAS SURFACE WATERS	III.1-49
III.1-19 CONCENTRATION OF RADIONUCLIDE IN GABLE MOUNTAIN POND BIOTA - 1972	III.1-50
III.1-20 ESTIMATED RADIATION DOSES TO AQUATIC ORGANISMS AND WATERFOWL FROM LIQUID RELEASES AT THE HANFORD PROJECT - 1972.	III.1-53
III.1-21 HANFORD INTAKE STRUCTURES DRAWING FROM THE COLUMBIA RIVER	III.1-56
III.1-22 DISCHARGE LINES TO COLUMBIA RIVER	III.1-58
III.1-23 TOTAL DIRECT CHEMICAL DISCHARGE TO COLUMBIA RIVER PER YEAR	III.1-59
III.1-24 CHEMICAL CONCENTRATIONS AT 100-N AREA, AUGUST 1972	III.1-63
III.1-25 300 AREA SPRING DISCHARGE.	III.1-64
III.1-26 SOUTH POND - INPUT CHEMICAL CONCENTRATION . . .	III.1-67

TABLES (Continued)

	<u>Page</u>
III.1-27 POLLUTANT RELEASES TO THE ATMOSPHERE FROM POWER HOUSE STACKS	III.1-68
III.1-28 AIR QUALITY MEASUREMENTS ANNUAL AVERAGES - 1972	III.1-69
III.1-29 TEMPERATURE OF COLUMBIA RIVER WATER IN 1972.	III.1-71
III.1-30 COLUMBIA RIVER CHEMICAL ANALYSES FOR 1972	III.1-72
III.1-31 COLUMBIA RIVER BIOLOGICAL ANALYSES FOR 1972.	III.1-72
III.2-1 SOURCE TERM FOR THE POSTULATED WASTE TANK LEAK TO GROUND.	III.2-13
III.2-2 RADIATION DOSE FROM POSTULATED 800,000 GALLON TANK LEAK	III.2-13
III.2-3 SOURCE TERM FOR POSTULATED DOME FAILURE	III.2-19
III.2-4 RADIATION DOSES FOR POSTULATED DOME FAILURE	III.2-20
III.2-5 SOURCE TERM FOR POSTULATED SURFACE SPILL OF NEUTRALIZED 5 YEAR OLD WASTE	III.2-25
III.2-6 DOSES IN REM FROM POSTULATED TRANSFER LINE LEAKAGE OF 100,000 GALLONS OF WASTE.	III.2-26
III.2-7 ESTIMATED INVENTORY OF RADIONUCLIDES ON B PLANT FILTERS	III.2-29
III.2-8 SOURCE TERM FOR POSTULATED B PLANT FILTER FIRE	III.2-30
III.2-9 RADIATION DOSE FOR CESIUM AND STRONTIUM PROCESSING POSTULATED FILTER FAILURE	III.2-31
III.2-10 RADIONUCLIDE CONTENTS OF A TYPICAL TANK CAR SHIPMENT FROM 300 AREA.	III.2-34
III.2-11 SOURCE TERM FOR POSTULATED RELEASE FROM LEAKING TANK CAR.	III.2-35
III.2-12 RADIATION DOSE FROM A POSTULATED LEAKING RAIL TANK CAR SHIPMENT.	III.2-36
III.2-13 SOURCE TERM FOR POSTULATED TANK CAR DERAILMENT AND RUPTURE.	III.2-38
III.2-14 RADIATION DOSE FROM A POSTULATED RAIL TANK CAR TRANSPORT ACCIDENT	III.2-39
III.2-15 SOURCE TERMS FOR POSTULATED SOLID WASTE FIRE DURING TRANSPORTATION	III.2-41
III.2-16 RADIATION DOSE FROM POSTULATED FIRE ACCOMPANYING A WASTE VEHICLE ACCIDENT	III.2-42

TABLES (Continued)

	<u>Page</u>
III.2-17 CHARACTERISTICS OF DRY WASTE BURIED ON AN AVERAGE DAY	III.2-43
III.2-18 CHARACTERISTICS OF THE MAXIMUM VOLUME OF DRY WASTE BURIED ON ANY DAY	III.2-43
III.2-19 SOURCE TERM FOR POSTULATED SOLID WASTE FIRE IN BURIAL GROUND	III.2-45
III.2-20 RADIATION DOSE FROM POSTULATED FIRE IN SOLID WASTE BURIAL TRENCH.	III.2-45
III.2-21 POSTULATED DISTRIBUTION OF ¹³⁷ Cs IN AVERAGE SQUARE METER PLOT	III.2-47
III.2-22 SOURCE TERM FOR POSTULATED RANGE FIRE ON B/C CRIB CONTROLLED AREA	III.2-48
III.2-23 SOURCE TERM FOR POSTULATED WIND DISPERSAL OF REMAINING ACTIVITY FOLLOWING A FIRE IN THE B/C CRIB CONTROLLED AREA	III.2-49
III.2-24 RADIATION DOSE DUE TO POSTULATED FIRE ON CONTROLLED AREA	III.2-49
III.2-25 RADIATION DOSE DUE TO POSTULATED WIND DISPERSAL AFTER FIRE ON CONTROLLED AREA	III.2-50
III.2-26 ESTIMATED INVENTORIES OF PLUTONIUM IN DISPOSAL SITES CONTAINING MORE THAN 1 KILOGRAM OF PLUTONIUM	III.2-51
III.2-27 NATURAL FORCE DESIGNS WASTE MANAGEMENT FACILITIES.	III.2-56
III.2-28 PREDICTED AND MEASURED PEAK DISCHARGES OF THE COLUMBIA RIVER AT THE DALLES, OREGON	III.2-67
III.2-29 STORED RADIONUCLIDE QUANTITIES ($T_{1/2} > 1$ yr) AND TOXIC CHEMICALS INUNDATED BY THE PEAK FLOW OF THE PROBABLE MAXIMUM FLOOD OF THE COLUMBIA RIVER AND THEIR CONCENTRATIONS IF MIXED WITH 1 DAY'S RIVER FLOW AT THE PMF PEAK.	III.2-71
III.2-30 RADIATION DOSE FROM POSTULATED COLUMBIA RIVER FLOOD	III.2-72
IV-1 ESTIMATED MAXIMUM DOSE TO AN INDIVIDUAL FROM THE EFFLUENTS RELEASED AT THE HANFORD PROJECT IN 1972	IV-3
IV-2 SUMMARY OF ESTIMATED POPULATION DOSES RECEIVED AS A RESULT OF THE OPERATION OF THE HANFORD PROJECT IN 1972	IV-4

TABLES (Continued)

	<u>Page</u>
IV-3 MAXIMUM NUMBER OF HEALTH EFFECTS FOR 1972 ENVIRONMENTAL DOSE LEVELS	IV-5
V-1 HIGH-LEVEL WASTE ALTERNATIVES	V-3
V-2 LIQUID EFFLUENT WASTE ALTERNATIVES	V-3
V-3 WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED OR UNDER CONSTRUCTION, FY-1973 THROUGH FY-1975	V-5
V-4 WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975	V-24
V-5 DESCRIPTION OF WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975.	V-25
V-6 RELEASES TO CRIBS	V-32
V-7 GASEOUS RADIOACTIVE WASTE RELEASED TO THE AIR.	V-37
V-8 WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975	V-37
V-9 DESCRIPTION OF WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975	V-38
V-10 SOLID RADIOACTIVE WASTE RELEASES TO THE GROUND	V-43
V-11 CHEMICAL RELEASES TO THE COLUMBIA RIVER	V-48
V-12 CHEMICAL RELEASES TO THE LAND.	V-50
V-13 MAJOR CHEMICAL RELEASES TO THE AIR IN 1972	V-51
V-14 SANITARY WASTE FLOWS TO SEPTIC TANKS	V-55
V-15 TYPICAL HEAT RELEASES TO THE AIR AT HANFORD	V-59
IX-1 WASTE MANAGEMENT FACILITIES AND ACTIVITIES PLANNED AND UNDER CONSTRUCTION FY-1973 THROUGH FY-1975	IX-3
IX-2 DEDICATED WASTE MANAGEMENT LANDS.	IX-5
IX-3 COST-BENEFIT SUMMARY.	IX-7

VOLUME 2 FIGURES

	<u>Page</u>
II.1-A-1 USAEC HANFORD RESERVATION DETAIL MAP	II.1-A-1
II.1-B-1 B AREA MAP.	II.1-B-4
II.1-B-2 K AREA MAP.	II.1-B-5
II.1-B-3 N AREA MAP.	II.1-B-6
II.1-B-4 D AREA MAP.	II.1-B-7
II.1-B-5 H AREA MAP.	II.1-B-8
II.1-B-6 F AREA MAP.	II.1-B-9
II.1-C-1 DETAILED MAP OF 200 EAST AREA	II.1-C-4
II.1-C-2 DETAILED MAP OF 200 WEST AREA	II.1-C-5
II.1-C-3 TYPICAL PROCESS SOLUTION TRANSFERS 200 EAST AREA N-FUELS PROCESSING	II.1-C-24
II.1-C-4 TYPICAL PROCESS SOLUTION TRANSFERS 200 EAST AREA - PAS PROCESSING	II.1-C-25
II.1-C-5 PUREX PLANT INPUT-OUTPUT DIAGRAM OPERATING-N-FUELS	II.1-C-26
II.1-C-6 PUREX PLANT INPUT-OUTPUT DIAGRAM STAND BY	II.1-C-27
II.1-C-7 ACTIVE WASTE TRANSFER LINES 202-A FACILITY PUREX PLANT	II.1-C-28
II.1-C-8 WASTE FRACTIONIZATION - B PLANT PROCESS INPUT- OUTPUT DIAGRAM (OPERATING)	II.1-C-31
II.1-C-9 WASTE FRACTIONIZATION - B PLANT PROCESS INPUT- OUTPUT (STAND BY) DIAGRAM	II.1-C-32
II.1-C-10 ENCAPSULATION-225-B INPUT-OUTPUT DIAGRAM	II.1-C-33
II.1-C-11 ACTIVE WASTE TRANSFER LINES 221-B FACILITY AND 225-B ENCAPSULATION FACILITY	II.1-C-34
II.1-C-12 ACTIVE WASTE TRANSFER LINES 244-AR VAULT FACILITY TRANSFERS OF TANK FARM SUPERNATANTS	II.1-C-38
II.1-C-13 ACTIVE WASTE TRANSFER LINES 244-AR VAULT FACILITY SLUDGE SLUICING	II.1-C-39
II.1-C-14 244-AR VAULT INPUT-OUTPUT DIAGRAM CAW PROCESSING	II.1-C-44
II.1-C-15 244-AR VAULT INPUT-OUTPUT DIAGRAM PAS PROCESSING	II.1-C-45

FIGURES (Continued)

	<u>Page</u>
II.1-C-16 244-AR VAULT INPUT-OUTPUT DIAGRAM STAND BY . . .	II.1-C-46
II.1-C-17 ACTIVE WASTE TRANSFER LINES A, AX AND AY TANK FARM PROCESS CONDENSATES AND COOLING WATER . . .	II.1-C-47
II.1-C-18 ITS NO. 1 AND ITS NO. 2 ACTIVE WASTE LINES INTERFARM TRANSFERS	II.1-C-50
II.1-C-19 ITS NO. 1 AND ITS NO. 2 WASTE COOLING WASTE COOLING WATER PROCESS CONDENSATES AND DRAINS . . .	II.1-C-51
II.1-C-20 TYPICAL PROCESS SOLUTION TRANSFERS, 200 WEST AREA	II.1-C-60
II.1-C-21 200-E AND 200-W TRANSFER LINES	II.1-C-61
II.1-C-22 "Z" PLANT INPUT-OUTPUT DIAGRAM OPERATING. . . .	II.1-C-62
II.1-C-23 "Z" PLANT INPUT-OUTPUT DIAGRAM STAND BY	II.1-C-63
II.1-C-24 Z PLANT.	II.1-C-64
II.1-C-25 UO ₃ PLANT INPUT-OUTPUT DIAGRAM OPERATING. . . .	II.1-C-66
II.1-C-26 UO ₃ PLANT INPUT-OUTPUT DIAGRAM STAND BY	II.1-C-67
II.1-C-27 UO ₃ PLANT AND U PLANT FACILITIES	II.1-C-68
II.1-C-28 REDOX PLANT AND 222-S LABORATORY	II.1-C-70
II.1-C-29 T PLANT, LAUNDRY AND MASK STATION	II.1-C-72
II.1-C-30 T FARM AND EVAPORATOR LINES	II.1-C-74
II.1-C-31 S, SX AND U FARMS AND EVAPORATOR ACTIVE WASTE LINES	II.1-C-75
II.1-C-32 242-S EVAPORATOR ACTIVE WASTE LINES	II.1-C-78
II.1-C-33 RADIONUCLIDE DISTRIBUTION BENEATH THE 216-S 1 AND 2 CRIB SITE FROM 1956 AND 1966 FIELD EVALUATION DATA	II.1-C-84
II.1-C-34 ¹³⁷ Cs AND ⁹⁰ Sr CONCENTRATIONS PROFILES IN SEDIMENTS UNDERLYING THE 216-S 1 AND 2 CRIBS, 1966.	II.1-C-86
II.1-C-35 LOGS FROM MONITORING WELLS AT THE 216-S 1 AND 2 CRIB SITE	II.1-C-88
II.1-C-36 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E33-2A	II.1-C-92
II.1-C-37 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E24-1A	II.1-C-93

FIGURES (Continued)

	<u>Page</u>
II.1-C-38 RADIOISOTOPE CONCENTRATIONS AS A FUNCTION OF DEPTH, WELL E13-3A (¹³⁷ Cs and ⁹⁰ Sr)	II.1-C-94
II.1-C-39 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E13-3A (¹³⁷ Sb and ¹⁰⁶ Ru)	II.1-C-95
II.1-C-40 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL W22-13A (¹³⁷ Cs AND ¹⁰⁶ Ru).	II.1-C-97
II.1-C-41 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL W22-13A (⁹⁰ Sr)	II.1-C-98
II.1-C-42 200 EAST TANK FARMS.	II.1-C-136
II.1-C-43 200 WEST AREA TANK FARMS	II.1-C-137
II.1-D-1 EXISTING DISCHARGES INTO COLUMBIA RIVER	II.1-D-1
II.1-D-2 INLET SCREEN WASH WATER, 100-B AREA	II.1-D-5
II.1-D-3 PROCESS DRAIN, 100-B AREA.	II.1-D-6
II.1-D-4 INLET SCREEN WASH WATER, 100-K AREA	II.1-D-7
II.1-D-5 PROCESS DRAIN, 100-K AREA.	II.1-D-8
II.1-D-6 WATER STORAGE TANK FARM OVERFLOW, 100-N AREA	II.1-D-9
II.1-D-7 OVERFLOW AND FLOOR DRAIN DISCHARGE, 100-N AREA	II.1-D-10
II.1-D-8 INLET SCREEN WASH WATER, 100-N AREA	II.1-D-11
II.1-D-9 TURBINE CONDENSER COOLING WATER, 100-N AREA.	II.1-D-12
II.1-D-10 DUMP CONDENSER COOLING WATER, 100-N AREA.	II.1-D-13
II.1-D-11 INLET SCREEN WASH WATER, 100-D AREA	II.1-D-14
II.1-D-12 RESEARCH FACILITY AND BACKWASH DRAIN, 100-D AREA	II.1-D-15
II.1-D-13 331 BUILDING OUTFALL STRUCTURE	II.1-D-16
II.1-D-14 FILTER PLANT OUTFALL STRUCTURE	II.1-D-17
II.1-D-15 309 BUILDING OUTFALL STRUCTURE	II.1-D-18
II.1-E-1 300 AREA MAPS.	II.1-E-4
II.3-A-1 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION	II.3-A-4

FIGURES (Continued)

		Page
II.3-A-2	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION	II.3-A-5
II.3-A-3	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION	II.3-A-6
II.3-A-4	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION	II.3-A-7
II.3-A-5	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA.	II.3-A-8
II.3-A-6	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA.	II.3-A-9
II.3-A-7	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA.	II.3-A-10
II.3-A-8	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA.	II.3-A-11
II.3-A-9	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION WITHIN A 50-MILE RADIUS OF THE 300-N AREA.	II.3-A-12
II.3-A-10	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION WITHIN A 50-MILE RADIUS OF THE 300-N AREA.	II.3-A-13
II.3-A-11	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION WITHIN A 50-MILE RADIUS OF THE 300-N AREA.	II.3-A-14
II.3-A-12	ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION WITHIN A 50-MILE RADIUS OF THE 300 AREA	II.3-A-15
II.3-B-1	REGIONAL GEOLOGIC MAP	II.3-B-5
II.3-B-2	GEOLOGIC CROSS SECTIONS OF COLUMBIA RIVER BASALT PLATEAU	II.3-B-12
II.3-B-3	MAP OF THE BASALT SURFACE IN THE PASCO BASIN, IDENTIFYING MAJOR STRUCTURES	II.3-B-22

FIGURES (Continued)

	<u>Page</u>
II.3-B-4 THE SURFACE OF THE RINGOLD FORMATION IN THE PASCO BASIN	II.3-B-24
II.3-B-5 OUTLINE MAP OF HANFORD RESERVATION AND PERIPHERAL SITES SHOWING THE SITES AND AREAS STUDIED AND AVAILABLE REPORTS ISSUED . . .	II.3-B-38
II.3-C-1 SEISMIC RISK MAP.	II.3-C-3
II.3-D-1 COLUMBIA RIVER BASIN	II.3-D-2
II.3-D-2 FLOW VARIATION FOR 1972	II.3-D-3
II.3-D-3 HISTORICAL MONTHLY AVERAGE TEMPERATURE COMPARISON FOR PRIEST RAPIDS DAM AND RICHLAND	II.3-D-6
II.3-D-4 1972 MONTHLY AVERAGE TEMPERATURE COMPARISON FOR PRIEST RAPIDS DAM AND RICHLAND.	II.3-D-6
II.3-D-5 PARTICLE SIZE DATA FOR EIGHT OF THE RESERVOIRS OF THE COLUMBIA RIVER	II.3-D-15
II.3-D-6 PONDS ON THE HANFORD SITE.	II.3-D-21
II.3-D-7 HANFORD RESERVATION WELL LOCATION MAP.	II.3-D-25
II.3-D-8 SATURATION AS A FUNCTION OF CAPILLARY PRESSURE	II.3-D-27
II.3-D-9 RELATIVE HYDRAULIC CONDUCTIVITY AS A FUNCTION OF CAPILLARY PRESSURE	II.3-D-27
II.3-D-10 RELATIONSHIP BETWEEN WATER STORAGE PROPERTIES AND MEDIAN GRAIN SIZE OF ALLUVIUM FROM LARGE VALLEYS	II.3-D-28
II.3-D-11 HANFORD RESERVATION UNCONFINED AQUIFER BOTTOM MAP FOR SIMULATION MODEL	II.3-D-30
II.3-D-12 HANFORD RESERVATION WATER TABLE MAP - JULY 1972	II.3-D-32
II.3-D-13 HYDRAULIC CONDUCTIVITY DISTRIBUTION OF THE HANFORD UNCONFINED GROUNDWATER AQUIFER	II.3-D-35
II.3-D-14 WATER TABLE MAP - JANUARY 1944 HINDCAST	II.3-D-39
II.3-D-15 WELL HYDROGRAPHS.	II.3-D-40
II.3-D-16 WATER TABLE MAP WITH STREAMLINES AND TRAVEL TIMES	II.3-D-42

FIGURES (Continued)

		Page
II.3-D-17	AVERAGE NITRATE (NO_3^-) CONCENTRATIONS JULY-DECEMBER 1972	II.3-D-46
II.3-D-18	TEMPERATURE DISTRIBUTION AT THE WATER TABLE (January 1974)	II.3-D-48
II.3-D-19	WATER TABLE MAP FOR JULY 1972 WITH STREAMLINES AND TRAVEL TIME RANGE ESTIMATES FROM SELECTED LIQUID WASTE DISPOSAL SITES	II.3-D-55
II.3-D-20	AVERAGE GROSS BETA (^{106}Ru) CONCENTRATIONS JULY-DECEMBER 1972	II.3-D-57
II.3-D-21	AVERAGE TRITIUM (^3H) CONCENTRATIONS JULY-DECEMBER 1972	II.3-D-58
II.3-D-22	HYDRAULIC POTENTIAL DISTRIBUTION OF THE UPPERMOST CONFINED AQUIFER - 1970	II.3-D-66
II.3-D-23	WELL HYDROGRAPHS FOR THE CONFINED AQUIFER	II.3-D-68
II.3-D-24	WELL HYDROGRAPHS FOR THE CONFINED AQUIFER	II.3-D-69
II.3-E-1	ANNUAL VARIATION OF NORMAL AND EXTREME DAILY MAXIMUM AND MINIMUM TEMPERATURES AT HMS	II.3-E-5
II.3-E-2	PROBABILITIES OF HIGH TEMPERATURES BASED ON THE HIGH TEMPERATURE DURING EACH OF 57 SUMMERS OF RECORD AT HANFORD: 1912-1969	II.3-E-6
II.3-E-3	PROBABILITY OF LOW TEMPERATURES BASED ON LOWEST TEMPERATURE DURING EACH OF 58 WINTERS AT HANFORD: 1912-13 to 1969-70.	II.3-E-7
II.3-E-4	EXAMPLE OF EFFECT OF CHINOOK, OBSERVED HOURLY TEMPERATURES AT HANFORD, JANUARY 6-7, 1949	II.3-E-9
II.3-E-5	JANUARY, JULY, AND HOURLY AVERAGES OF DRY BULB AND WET BULB TEMPERATURE, RELATIVE HUMIDITY AND DEW POINT TEMPERATURE AT HMS, 1957-1970	II.3-E-11
II.3-E-6	HMS MEAN RELATIVE HUMIDITY AT 1300 PST IN JULY, EACH YEAR FROM 1946 to 1970	II.3-E-14
II.3-E-7	WIND ROSES AS A FUNCTION OF STABILITY AND FOR ALL STABILITIES OF HMS BASED ON WINDS AT 200 FT AND AIR TEMPERATURE STABILITIES BETWEEN 3 FT AND 200 FT FOR THE PERIOD 1955 THROUGH 1970	II.3-E-16
II.3-E-8	WIND ROSES AS A FUNCTION OF STABILITY AND FOR ALL STABILITIES AT HANFORD-1 BASED ON WINDS AT 200 FT AND AIR TEMPERATURE BETWEEN 3 FT AND 200 FT FOR THE PERIOD JANUARY 29, 1970 TO JANUARY 28, 1971	II.3-E-22

FIGURES (Continued)

		<u>Page</u>
II.3-E-9	MONTHLY AVERAGE WIND ROSES FOR THE WNP-2 SITE BASED ON 1 YEAR OF DATA TAKEN AT 23 FEET. . . .	II.3-E-24
II.3-E-10	MONTHLY AVERAGE WIND ROSES FOR THE HMS BASED ON 1 YEAR OF DATA TAKEN AT 50 FEET. . . .	II.3-E-25
II.3-E-11	MONTHLY AVERAGE WIND ROSES FOR HMS BASED ON 50 FEET WIND DATA, 1955-1970. . . .	II.3-E-26
II.3-E-12	SURFACE WIND ROSES FOR VARIOUS LOCATIONS ON AND SURROUNDING THE HANFORD SITE BASED ON FIVE-YEAR AVERAGES (1952-1956)	II.3-E-28
II.3-E-13	SEASONAL AND ANNUAL WIND ROSES FROM PIBAL AND TOWER DATA. . . .	II.3-E-29
II.3-E-14	WIND ROSES AT 15 METERS FOR 0100 PST, 1300 PST AND 24 HOUR AVERAGE. . . .	II.3-E-30
II.3-E-15	PEAK WIND GUST RETURN PROBABILITY DIAGRAM . . .	II.3-E-33
II.3-E-16	DISTRIBUTION OF CHARACTERIZED TORNADOES IN 20-YEAR PERIOD, 1950-1969. . . .	II.3-E-39
II.3-E-17	SEASONAL MAXIMUM PERSISTENCE OF STAGNATION, 1947-48 THROUGH 1961-62	II.3-E-50
II.3-E-18	AVERAGE MONTHLY PRECIPITATION AMOUNTS BASED ON THE PERIOD 1912-1970	II.3-E-54
II.3-E-19	RETURN PERIODS OF RAINFALL INTENSITY AND DURATION :	II.3-E-57
II.3-E-20	TOTAL ANNUAL PRECIPITATION PROBABILITY DIAGRAM. .	II.3-E-58
II.3-E-21	GREATEST DEPTH OF SNOW ON GROUND DURING 24 OF 25 WINTERS OF RECORD AT HANFORD 1946-47 THROUGH 1969-70	II.3-E-60
II.3-E-22	HMS TOTAL ANNUAL PRECIPITATION (1913-1970) AND 10 AND 15 YEAR MOVING AVERAGES. . . .	II.3-E-61
II.3-F-1	FOOD-WEB OF COLUMBIA RIVER	II.3-F-5
II.3-F-2	SEASONAL FLUCTUATION OF PLANKTON BIOMASS. . . .	II.3-F-8
II.3-F-3	SEASONAL FLUCTUATION OF NET PRODUCTION RATE OF PERIPHYTON	II.3-F-9
II.3-F-4	FOOD-WEB OF GABLE MOUNTAIN POND AND U POND . . .	II.3-F-15
II.3-G-1	RELATIVE DEPARTURE OF TEMPERATURE, PRECIPITATION AND SOIL WATER FROM THEIR RESPECTIVE ANNUAL AVERAGES	II.3-G-4

FIGURES (Continued)

		<u>Page</u>
II.3-G-2	AVERAGE "BIOYEAR" (OCTOBER THROUGH MARCH) PRECIPITATION AS A FUNCTION OF ELEVATION ON THE ARID LANDS ECOLOGY RESERVE	II.3-G-6
II.3-G-3	SOIL MAP OF THE HANFORD PROJECT IN BENTON COUNTY WASHINGTON	II.3-G-9
II.3-G-4	DISTRIBUTION OF VEGETATION TYPES ON THE HANFORD RESERVATION.	II.3-G-21
II.3-G-5	SAGEBRUSH/BUEBUNCH WHEATGRASS COMMUNITY	II.3-G-22
II.3-G-6	ARID LANDS ECOLOGY RESERVE	II.3-G-23
II.3-G-7	SAGEBRUSH/BUEBUNCH WHEATGRASS COMMUNITY.	II.3-G-24
II.3-G-8	SAGEBRUSH/CHEATGRASS COMMUNITY	II.3-G-25
II.3-G-9	SAGEBRUSH/SANDBERG'S BLUEGRASS COMMUNITY.	II.3-G-26
II.3-G-10	SAGEBRUSH-BITTERBRUSH/CHEATGRASS COMMUNITY	II.3-G-28
II.3-G-11	GREASEWOOD/CHEATGRASS-SALTGRASS COMMUNITY	II.3-G-30
II.3-G-12	WINTERFAT/SANDBERG'S BLUEGRASS COMMUNITY	II.3-G-31
II.3-G-13	THYME BUCKWHEAT/SANDBERG'S BLUEGRASS COMMUNITY.	II.3-G-32
II.3-G-14	CHEATGRASS-TUMBLE MUSTARD COMMUNITY	II.3-G-33
II.3-G-15	LOCATION AND DIRECTION OF VIEW FOR PLANT COMMUNITY PHOTOGRAPHS	II.3-G-35
II.3-G-16	WILLOW COMMUNITY.	II.3-G-36
II.3-G-17	DISTRIBUTION OF ROOT MATERIAL WITH DEPTH IN PERENNIAL AND ANNUAL GRASS COMMUNITIES	II.3-G-53
II.3-G-18	RATE OF WEIGHT LOSS IN LITTER BAGS OF LEAVES AND STEMS OF CHEATGRASS, SAGEBRUSH AND BLUEBUNCH WHEATGRASS	II.3-G-57
II.3-G-19	NUMBER OF NESTS AND NUMBER OF EGGS PER NEST FOR CANADA GEESE NESTING ON ISLANDS IN THE COLUMBIA RIVER, HANFORD RESERVATION	II.3-G-60
II.3-G-20	POPULATION FLUCTUATIONS OF THE POCKET MOUSE, <u>PEROGNATHUS PARVUS</u> , IN A SAGEBRUSH/CHEATGRASS COMMUNITY	II.3-G-60
II.3-G-21	FOOD WEB CENTERED ON CHEATGRASS	II.3-G-63

FIGURES (Continued)

	<u>Page</u>
II.3-G-22 FOOD WEB CENTERED ON CHUKAR PARTRIDGE.	II.3-G-64
II.3-G-23 FOOD WEB CENTERED ON GRASSHOPPER	II.3-G-66
II.3-G-24 FOOD WEB CENTERED ON FUNGI	II.3-G-67
III-A-1 RECONCENTRATION IN REACTOR EFFLUENT DUE TO RECYCLING THROUGH A COOLING POND	III-A-90
III-B-1 RATIO OF DEPTH DOSE TO SURFACE DOSE AS A FUNCTION BETA ENERGY SPECTRA	III-B-10
III-B-2 SCHEMATIC DIAGRAM OF ICRP TASK GROUP LUNG MODEL	III-B-13
III-F-1 RANGE FIRES ON HANFORD SITE	III-F-3

VOLUME 2 TABLES

	<u>Page</u>
II.1-B-1 WASTE MANAGEMENT FACILITIES, B AREA CRIBS AND BURIAL GROUNDS	II.1-B-12
II.1-B-2 WASTE MANAGEMENT FACILITIES, D AREA CRIBS AND BURIAL GROUNDS	II.1-B-15
II.1-B-3 WASTE MANAGEMENT FACILITIES, F AREA CRIBS AND BURIAL GROUNDS	II.1-B-18
II.1-B-4 WASTE MANAGEMENT FACILITIES, H AREA CRIBS AND BURIAL GROUNDS	II.1-B-20
II.1-B-5 WASTE MANAGEMENT FACILITIES, K AREA CRIBS AND BURIAL GROUNDS	II.1-B-22
II.1-B-6 WASTE MANAGEMENT FACILITIES, N AREA CRIBS AND BURIAL GROUNDS	II.1-B-23
II.1-B-7 ESTIMATED INVENTORIES IN REACTOR FACILITIES THROUGH 1972	II.1-B-26
II.1-B-8 100 AREAS APPROXIMATE INVENTORIES CRIBS AND BURIAL GROUNDS THROUGH 1972	II.1-B-27
II.1-B-9 ESTIMATED INPUT TO THE 100-N AREA CRIB THROUGH 1972	II.1-B-28
II.1-B-10 100-N RADIOACTIVE MATERIAL RELEASES TO THE COLUMBIA RIVER-1972	II.1-B-30
II.1-B-11 GASEOUS RADIOACTIVE MATERIAL RELEASE-1972	II.1-B-31
II.1-B-12 100 AREAS UNPLANNED RELEASES	II.1-B-34
II.1-C-1 200 EAST AREA TANK FARMS AND FACILITIES	II.1-C-8
II.1-C-2 200 WEST AREA TANK FARMS AND FACILITIES	II.1-C-11
II.1-C-3 200 EAST AREA LIQUID WASTE DISPOSAL SITES	II.1-C-13
II.1-C-4 WEST AREA LIQUID WASTE DISPOSAL SITES	II.1-C-16
II.1-C-5 200 EAST AREA DRY RADIOACTIVE WASTE BURIAL GROUNDS	II.1-C-18
II.1-C-6 200 WEST AREA DRY RADIOACTIVE WASTE BURIAL GROUNDS	II.1-C-19
II.1-C-7 PUREX PLANT ACTIVE WASTE TRANSFER LINES.	II.1-C-29
II.1-C-8 B PLANT ACTIVE WASTE TRANSFER LINES	II.1-C-35

TABLES (Continued)

	<u>Page</u>
II.1-C-9 ACTIVE TANK FARM SUPERNATANT TRANSFER LINES . .	II.1-C-40
II.1-C-10 ACTIVE 244-AR VAULT SLUDGE TRANSFER LINES . . .	II.1-C-42
II.1-C-11 TANK FARMS A, AX AND AY: ACTIVE WASTE TRANSFER LINES FOR PROCESS CONDENSATES AND COOLING WATER	II.1-C-48
II.1-C-12 ITS NO. 1 AND 2 ACTIVE INTERFARM WASTE TRANSFER LINES	II.1-C-52
II.1-C-13 ITS NO. 1 AND 2 ACTIVE WASTE TRANSFER LINES FOR PROCESS CONDENSATES AND COOLING WATER . . .	II.1-C-54
II.1-C-14 Z PLANT ACTIVE WASTE TRANSFER LINES	II.1-C-65
II.1-C-15 U PLANT AND UO ₃ PLANT ACTIVE WASTE TRANSFER LINES	II.1-C-69
II.1-C-16 222S-REDOX PLANT ACTIVE WASTE TRANSFER LINES . .	II.1-C-71
II.1-C-17 T PLANT, LAUNDRY AND MASK STATION ACTIVE WASTE LINES	II.1-C-73
II.1-C-18 EVAPORATOR AND TANK FARM ACTIVE WASTE LINES . .	II.1-C-76
II.1-C-19 242-S EVAPORATOR AND ASSOCIATED TANK FARM WASTE TRANSFER LINES	II.1-C-79
II.1-C-20 WASTE FACILITY EXPLORATORY WELLS	II.1-C-90
II.1-C-21 TANK WASTE INVENTORY SUMMARY 1968-1980 (IN MILLIONS OF GALLONS)	II.1-C-102
II.1-C-22 ESTIMATED INVENTORY AND CHARACTERISTICS OF SOLIDS STORED IN TANKS - YEAR 1980	II.1-C-103
II.1-C-23 ESTIMATED INVENTORIES RADIOACTIVE LIQUID WASTE TO GROUND 200 AREAS	II.1-C-105
II.1-C-24 ESTIMATED DECAYED STATUS OF SOLID WASTE BURIAL GROUNDS IN THE 200 AREAS THROUGH 1972 . .	II.1-C-107
II.1-C-25 PUREX EQUIPMENT STORAGE TUNNELS INVENTORY- SEPTEMBER 30, 1973	II.1-C-108
II.1-C-26 SUMMARY OF RADIONUCLIDES IN GASEOUS WASTE DISCHARGED FROM 200 AREA FACILITIES DURING 1972	II.1-C-110
II.1-C-27 200 AREAS, UNPLANNED RELEASES	II.1-C-126
II.1-D-1 DESCRIPTION OF DISCHARGES	II.1-D-2
II.1-E-1 TABLE OF STORAGE AND DISPOSAL SITES 300 AREA	II.1-E-8

TABLES (Continued)

	<u>Page</u>
II.1-E-2 TABLE OF STORAGE AND DISPOSAL SITES SITES ANCILLARY TO THE 300 AREA	II.1-E-11
II.1-E-3 ESTIMATED RADIOACTIVE LIQUID WASTE INVENTORY - 300 AREA	II.1-E-14
II.1-E-4 SUMMARY OF RADIOACTIVE GASEOUS WASTE DISCHARGED FROM 300 AREA FACILITIES DURING 1972	II.1-E-18
II.1-E-5 ESTIMATED RADIOACTIVE LIQUID RELEASES-1972 . . .	II.1-E-23
II.1-E-6 300 AREA UNPLANNED RELEASE	II.1-E-26
II.1-F-1 PROCESS CHEMICAL INVENTORY - 200 AREAS . . .	II.1-F-1
II.1-F-2 B PLANT CHEMICAL CONSUMPTION	II.1-F-7
II.1-F-3 ENCAPSULATION PLANT - Chemical Consumption . .	II.1-F-8
II.1-F-4 CHEMICAL CONSUMPTION FOR TANK FARMS	II.1-F-8
II.1-F-5 PUREX PLANT CHEMICAL CONSUMPTION	II.1-F-9
II.1-F-6 CHEMICAL CONSUMPTION FOR Pu RECLAMATION AND Pu FINISHING (Z PLANT)	II.1-F-10
II.1-F-7 POWER AND WATER CHEMICAL CONSUMPTION	II.1-F-11
II.1-F-8 FUEL FABRICATION PROCESS CHEMICALS (300 AREA). .	II.1-F-11
II.1-F-9 SANITARY AND PROCESS WATER TREATMENT CHEMICALS (100 AND 300 AREAS)	II.1-F-11
II.1-F-10 PROCESS CHEMICAL CONSUMPTION-1972	II.1-F-12
II.3.B-1 GEOLOGICAL HISTORY OF PASCO BASIN	II.3-B-7
II.3-B-2 TIME AND GEOLOGIC EVENTS, PLIOCENE TO HALOCENE EPOCHS, PASCO BASIN	II.3-B-31
II.3-C-1 APPROXIMATE RELATION CONNECTING EARTHQUAKE INTENSITY WITH ACCELERATION	II.3-C-2
II.3-D-1 MONTHLY AVERAGE TEMPERATURE (°C) AT PRIEST RAPIDS DAM	II.3-D-5
II.3-D-2 MONTHLY AVERAGE TEMPERATURES (°C) AT RICHLAND	II.3-D-5
II.3-D-3 CHEMICAL ANALYSES AT PRIEST RAPIDS DAM WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972	II.3-D-8

TABLES (Continued)

	<u>Page</u>
II.3-D-4 COLUMBIA RIVER CHEMICAL CHARACTERISTICS (1963)	II.3-D-11
II.3-D-5 COLUMBIA RIVER BIOLOGICAL ANALYSES FOR 1972 . .	II.3-D-13
II.3-D-6 PARTICLE-SIZE DISTRIBUTIONS OF UNDISPERSED AND DISPERSED SEDIMENTS FROM COLUMBIA RIVER SIZE CLASSES	II.3-D-16
II.3-D-7 MINERAL COMPOSITION OF BOTTOM SEDIMENTS FROM COLUMBIA RIVER RESERVOIRS	II.3-D-17
II.3-D-8 CHEMICAL COMPOSITION IN BOTTOM SEDIMENTS FROM COLUMBIA RIVER RESERVOIRS	II.3-D-18
II.3-D-9 YAKIMA RIVER CHEMICAL ANALYSES, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972, AT KIONA, WASHINGTON	II.3-D-19
II.3-D-10 TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972 OF YAKIMA RIVER AT KIONA, WASHINGTON	II.3-D-20
II.3-D-11 MAJOR GEOLOGIC UNITS IN THE HANFORD REGION AND THEIR WATER-BEARING PROPERTIES	II.3-D-23
II.3-D-12 AVERAGE FIELD HYDRAULIC CONDUCTIVITY (FT/DAY) MEASUREMENTS	II.3-D-37
II.3-D-13 MEASURED GROUNDWATER FLOW VELOCITIES	II.3-D-44
II.3-D-14 AVERAGE ION CONCENTRATIONS FOR ALL WELLS MEASURED (mg/liter)	II.3-D-45
II.3-D-15 1301-N CRIB INPUT RADIONUCLIDE DATA AND RIVERBANK SPRINGS DATA, 1973	II.3-D-52
II.3-D-16 CHEMICAL CONCENTRATIONS AT 100-N AREA, AUGUST 1972	II.3-D-53
II.3-D-17 TRAVEL TIME RANGES FOR GROUNDWATER UNDER SELECTED LIQUID WASTE DISPOSAL FACILITIES (JULY 1972 WATER TABLE)	II.3-D-56
II.3-D-18 AVERAGE CHEMICAL CONCENTRATIONS FOR THE FIRST QUARTER 1972	II.3-D-61
II.3-D-19 BIOLOGICAL MEASUREMENTS OF SAMPLES COLLECTED FROM THE 300 AREA LEACHING TRENCH AND ITS ASSOCIATED RIVER SHORELINE SEEPAGE AREA - 1972	II.3-D-63

TABLES (Continued)

	<u>Page</u>
II.3-D-20	CONFINED AQUIFER PUMP TEST RESULTS II.3-D-70
II.3-D-21	TRITIUM IN HANFORD WELLS TAPPING THE CONFINED AQUIFER II.3-D-73
II.3-D-22	CHEMICAL ANALYSES OF GROUNDWATER SAMPLES FROM WELLS DRAWING WATER PRINCIPALLY FROM BASALT UNDER THE HANFORD RESERVATION (Physical Data). . II.3-D-75
II.3-E-1	AVERAGES AND EXTREMES OF CLIMATIC ELEMENTS AT HANFORD (BASED ON ALL AVAILABLE RECORDS TO AND INCLUDING THE YEAR 1970) II.3-E-2
II.3-E-2	MONTHLY AND ANNUAL FREQUENCY OF OCCURRENCE (%) OF WET BULB VALUES (°F) PERIOD OF RECORD AT HMS, 1957-70 (TOTAL OBSERVATIONS: 122,712) . . II.3-E-12
II.3-E-3	WNP-2 SITE MONTHLY AND ANNUAL FREQUENCY OF OCCURRENCE (%) OF WET BULB VALUES II.3-E-13
II.3-E-4	HMS COMPOSITE REPORT (1955 THROUGH 1970) OF PERCENTAGE FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT 200-FT LEVEL VERSUS ATMOSPHERIC STABILITY II.3-E-17
II.3-E-5	HANFORD STABILITY DEFINITION AND COMPARISON WITH PASQUILL CLASSES AS DEFINED IN USAEC REGULATORY GUIDE 1.23 II.3-E-23
II.3-E-6	HIGH WIND STATISTICS AT HMS - HIGHEST AVERAGE MONTHLY WIND SPEED AND PEAK GUSTS . . . II.3-E-32
II.3-E-7	EXAMPLE OF AN EXTREME HIGH WIND OCCURRENCE, DATA RECORDED BY THE AEC (BATTELLE) NETWORK OF WIND SENSORS ON JANUARY 11, 1972 II.3-E-34
II.3-E-8	EXAMPLE OF EXTREME HIGH WIND OCCURRENCE, WIND OBSERVATIONS ON OR NEAR THE HANFORD RESERVATION FOR JANUARY 11, 1972 II.3-E-35
II.3-E-9	SELECTED RATTLESNAKE MOUNTAIN WIND OBSERVATIONS II.3-E-37
II.3-E-10	TORNADO HISTORY WITHIN 100 MILES OF HMS II.3-E-38
II.3-E-11	AVERAGE NUMBER OF DAYS OF FOG AT HMS II.3-E-47
II.3-E-12	TOTAL DURATION AND MAXIMUM PERSISTENCE OF FOG AT THE HMS TABULATED IN HOURS FOR THE PERIOD 1945-70 II.3-E-48

TABLES (Continued)

		<u>Page</u>
II.3-E-13	HMS MONTHLY AND HOURLY SKY COVER AVERAGES STATISTICS ON CLEAR, PARTLY CLOUDY, AND CLOUDY DAYS	II.3-E-51
II.3-E-14	HMS AVERAGE HOURLY AND DAILY SOLRAD TOTALS (LANGLEYS) BASED ON THE PERIOD 1957-70 . . .	II.3-E-53
II.3-E-15	PROBABLE DURATION OF VARIOUS PRECIPITATION INTENSITIES AT HANFORD FOR 500-YEAR STORM . . .	II.3-E-55
II.3-E-16	AVERAGE RETURN PERIOD (R) AND EXISTING RECORD (ER) FOR VARIOUS PRECIPITATION AMOUNTS AND INTENSITY DURING SPECIFIED TIME PERIODS AT HANFORD	II.3-E-56
II.3-F-1	NUMBER OF SPAWNING FALL CHINOOK SALMON AT HANFORD, 1947-1973	II.3-F-12
II.3-F-2	MAJOR TAXA IDENTIFIED IN GABLE MOUNTAIN POND AND U POND	II.3-F-16
II.3-F-3	CHEMICAL ANALYSIS, RATTLESNAKE SPRINGS, 1962-1963	II.3-F-18
II.3-F-4	MAJOR ALGAE TAXA IN RATTLESNAKE SPRINGS . . .	II.3-F-20
II.3-F-5	MAJOR TAXA IDENTIFIED IN RATTLESNAKE SPRINGS . .	II.3-F-20
II.3-G-1	CLASSIFICATION OF SOIL SERIES OF BENTON COUNTY AREA	II.3-G-15
II.3-G-2	APPROXIMATE CLASSIFICATION OF HANFORD SOILS IN ENGINEERING CATEGORIES	II.3-G-16
II.3-G-3	SOIL CAPABILITY CLASSIFICATION	II.3-G-18
II.3-G-4	PRODUCTIVITY ESTIMATES FOR VARIOUS ECOSYSTEMS. .	II.3-G-49
II.3-G-5	PRODUCTIVITY OF OLD-FIELD (CHEATGRASS- TUMBLE MUSTARD) COMMUNITIES, 1969-1973 . . .	II.3-G-51
II.3-G-6	PRODUCTIVITY OF A SAGEBRUSH-BLUEBUNCH WHEATGRASS COMMUNITY	II.3-G-51
II.3-G-7	SPECIES DIVERSITY IN CHEATGRASS AND SAGEBRUSH/ GRASS COMMUNITIES	II.3-G-52
II.3-G-8	HEATS OF COMBUSTION OF SEVERAL SPECIES ON THE HANFORD RESERVATION	II.3-G-54
II.3-G-9	MINERAL ELEMENTS IN CHEATGRASS AND BLUEBUNCH WHEATGRASS	II.3-G-55

TABLES (Continued)

		<u>Page</u>
II.3-G-10	ACCUMULATION OF MINERALS IN DESERT SHRUB FOLIAGE	II.3-G-55
II.3-G-11	COYOTE SIGHTINGS BY AERIAL PATROL	II.3-G-58
II.3-G-12	SMALL MAMMALS TRAPPED IN A SAGEBRUSH/CHEATGRASS COMMUNITY, 1972	II.3-G-61
III-A-1	PATHWAYS OF EXPOSURE TO MAN	III-A-5
III-A-2	PATHWAYS OF EXPOSURE TO ORGANISMS OTHER THAN MAN	III-A-6
III-A-3	RECOMMENDED ADULT VALUES FOR U _p TO BE USED IN LIEU OF SITE-SPECIFIC DATA ^p	III-A-9
III-A-4	SHORE WIDTH FACTORS FOR USE IN EQUATIONS 5 AND 6	III-A-14
III-A-5	METABOLIC PARAMETERS USED IN THE THYROID DOSE FACTORS	III-A-18
III-A-6	FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE TO THYROID DOSE VIA MILK	III-A-19
III-A-7	FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINES TO THYROID DOSE VIA MILK	III-A-20
III-A-8	FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE TO THYROID DOSE VIA LEAFY VEGETABLES	III-A-21
III-A-9	RECOMMENDED PARAMETERS FOR ORGANISMS OTHER THAN MAN TO BE USED IN LIEU OF SITE-SPECIFIC DATA	III-A-26
III-A-10	PROGRAMS FOR CALCULATING RADIATION DOSES	III-A-28
III-A-11	DATA FILES UTILIZED BY THE DOSE CALCULATION PROGRAMS	III-A-30
III-A-12	INDEX TO PROGRAM DESCRIPTIONS AND LISTINGS	III-A-31
III-A-13	NUCLIDE MASTER LIST	III-A-33
III-A-14	NUCLIDE RELEASE WORKSHEET	III-A-40
III-A-15	TELETYPE PRINTOUT FOR SAMPLE ARRRG RUN	III-A-43
III-A-16	ARRRG INPUT WORKSHEET	III-A-44

TABLES (Continued)

	<u>Page</u>
III-A-17 HIGH SPEED PRINTER OUTPUT FOR SAMPLE ARRRRG RUN	III-A-46
III-A-18 FILE CRITEN	III-A-55
III-A-19 TELETYPE PRINTOUT FOR SAMPLE CRITR RUN	III-A-57
III-A-20 GRONK INPUT WORKSHEET	III-A-62
III-A-21 RULES FOR FORMATION FOR FILE GXXXX	III-A-63
III-A-22 FILE TONIC	III-A-67
III-A-23 TELETYPE PRINTOUT FOR SAMPLE GRONK RUN	III-A-68
III-A-24 HIGH-SPEED PRINTER OUTPUT FOR SAMPLE GRONK RUN	III-A-72
III-A-25 ANIMAL CONSUMPTION RATES	III-A-102
III-A-26 PLANT CONCENTRATION FACTORS AND ANIMAL PRODUCT TRANSFER COEFFICIENTS	III-A-103
III-A-27 FOOD INPUT WORKSHEET	III-A-104
III-B-1 VALUES OF METEOROLOGICAL PARAMETERS FOR THE HANFORD MODEL	III-B-3
III-B-2 NUMERICAL VALUES OF ATMOSPHERIC DISPERSION PARAMETERS FOR NEUTRAL AND UNSTABLE ATMOSPHERES	III-B-5
III-B-3 VALUES OF σ_y FOR PASQUILL STABILITY CATEGORIES .	III-B-6
III-B-4 VALUES OF σ_z FOR PASQUILL STABILITY CATEGORIES .	III-B-7
III-B-5 VALUES OF THE CLEARANCE PARAMETERS FOR THE TASK GROUP LUNG MODEL	III-B-15
III-D-1 WEIGHT INVENTORY BY NUCLIDE, GRAMS	III-D-5
III-D-2 RADIOACTIVITY BY NUCLIDE, CURIES	III-D-17
III-D-3 THERMAL POWER BY NUCLIDE, WATTS	III-D-25
III-F-1 SIZE AND DATE OF FIRES ON THE HANFORD RESERVATION 1964 THROUGH 1973	III-F-2

APPENDIX II.1-A

DETAIL MAP OF THE HANFORD RESERVATION

FIGURE II.1-A-1 USAEC HANFORD RESERVATION DETAIL MAP.
Enlarged sections appear on the fol-
lowing pages.

a

FIGURE II.1-A-1a

FIGURE II.1-A-1b

FIGURE II.1-A-1c

R27E
R28E
370

FIGURE II.1-A-1d

FIGURE II.1-A-1e

FIGURE II.1-A-1g

FIGURE II.1-A-1i

FIGURE II.1-A-1j

FIGURE II.1-A-1k

II.1-A-14

FIGURE II.1-A-1m

n

522100.63 ?

526070.97

531785.22

52371.06

2280.000

CITY OF RICHLAND

RIFLE RANGE

300 AREA

DISPOSAL PIT

EXXON NUCLEAR

BATTELLE PROPERTY

PORT OF BENTON PROPERTY

1A JONES

1100 AREA

240

10 RICHLAND

CONTAMINATED AND NON-RADIOACTIVE (BIOLOGICAL)

PORT DIST. RR. BASE

IN SECTION 14, T10N, R28E
PPAL EASEMENT ONLY
R.R. EASEMENT ONLY
PIPELINE EASEMENT ONLY

FIGURE II.1-A-1n

FIGURE II.1-A-10

p

LEGEND

TOWNSHIP OR RANGE LINE	_____
SECTION LINE, KNOWN AND UNKNOWN	_____
SECTION CORNER LOCATED	+
SECTION NUMBER	32
TOWNSHIP AND RANGE NUMBER	T12N R28E
UTM COORDINATE SYSTEM ZONE 11	5170000mN
WASHINGTON STATE LAND COORDINATE	410.000
HANFORD LAND COORDINATE	N16658.76 W15746.14
BENCH MARK	△
U.S. RESERVATION BOUNDARY	_____
LEASED PROPERTY LINE	_____
U.S. BUREAU OF RECLAMATION LAND	U.S.B.R.
FENCE, ARID LANDS ECOLOGY RESERVE	—x—
FENCE, HANFORD PROJECT	—x—
FENCE, AREAS 100, 200, 300, ETC.	—/—
CONTROLLED ACCESS GATE	G
RAILROAD, 1 AND 2 TRACK	—+—
WATER MAIN, EXPORT WATER	EW
BURIED PROCESS PIPING CONTAMINATED	△
DRAINAGE DITCH, CONTAMINATED	△ DITCH
DRAINAGE DITCH	DITCH
INTERMITTENT STREAM	—~—
WATER WELL	.WW
LAKE OR POND	—
RIVER AND DAM	—
RIVER MILEAGE	248.5
BUILDING	■
BURIAL GROUND, CONTAMINATED	△
ROAD, STATE	240
ROAD, PAVED FOUR LANE	=====
ROAD, PAVED TWO LANE	=====
ROAD, GRAVEL	=====
ROAD, DIRT UNIMPROVED	=====
POWER TRANSMISSION LINE OR EASEMENT	—•—
BONNEVILLE POWER ADMINISTRATION	BPA
BENTON COUNTY P.U.D.	BC PUD
PACIFIC POWER & LIGHT	PP&L
TELEPHONE LINE	—T—
TELEPHONE LINE, BURIED	—T—
WEATHER STATION - AUTOMATIC	△

FIGURE II.1-A-1p

APPENDIX II.1-B

100 AREA FACILITIES

APPENDIX II.1-B

100 AREA FACILITIES

	<u>Page</u>
Part 1 100 Area Maps	II.1-B-3
Part 2 Waste Management Facilities, Cribs and Burial Grounds	II.1-B-11
Part 3 Estimated Radioactive Material Inventories	II.1-B-25
Part 4 100 Areas, Radioactive Material Releases - 1972	II.1-B-29
Part 5 100 Areas Unplanned Releases	II.1-B-33

APPENDIX II.1-B, PART 1

100 Area Maps

[illegible]

REVISÉ AUGUST 1973

II.1-B-5

FIGURE II.1-B-2 K AREA MAP

II.1-B-6

FIGURE II.1-B-3 N AREA MAP

II.1-B-7

FIGURE II.1-B-4 D AREA MAP

II.1-B-8

FIGURE II.1-B-5 H AREA MAP

FIGURE II.1-B-6 F AREA MAP

APPENDIX II.1-B, PART 2
Waste Management Facilities,
Cribs and Burial Grounds

TABLE II.1-B-1

WASTE MANAGEMENT FACILITIES, B AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
118-C-1 (105-C Burial Ground)	N67316.00/W80005.48 N67316.00/W79748.48 N67249.63/W79494.48 N66920.00/W79494.48 N66920.00/W80005.48	Disposal of miscellaneous radioac- tive solid waste from 105-C Building.	1953	1969
118-B-1 (105-B Burial Ground)	1100 ft west of 182-C (reservoir and pump house)	Disposal of miscellaneous radioactive solid waste Also received 100-N Area waste.	1944	1974
118-B-2 (Construction Burial Ground No. 1)	350 ft directly east of the 105-B Building. Approx. 30' x 60'	Used for the disposal of dry waste from the 107-B basin repairs and for waste from 115-B alterations.	1954	1956
118-B-3 (Construction Burial Ground No. 2)	East of the other con- struction burial trench.	Disposal of waste from efflu- ent line modifications.	1956	1960
118-B-4 (105-B Dummy Storage Burial Ground)	Approx. 200' east of 103-B	Six storage tanks were installed below ground for fuel spacer disposal.	1956	1968
118-B-5 (Ball 3X Burial Ground)	150' east of 115-B (gas recirculation)	Received irradiated material such as thimbles and step plugs removed from Reactor during the ball 3X work in 1953.	January 1953	1953

II.1-B-12

TABLE II.1-B-1 (contd)

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
118-B-6 (108-B Solid Waste Burial Ground)	350 ft NW of 105-B Reactor	Two concrete pipes 18 ft long and 6 ft in diameter placed ver- tically in the ground for the disposal of dry tritium waste	1950	1953
116-B-1 (107-B Liquid Waste Disposal Trench)	Approx. 200 directly east of the 107-B basin.	Received effluent water from the B reactor during outages due to a ruptured fuel element.	1950	1968
116-B-2 (105-B Storage Basin Trench)	250' NE of 105-B	This trench was dug after a fuel element was accidentally cut in half in the storage basin. The basin was cleaned by draining the water into this trench.	1946	1946
116-B-3 (105-B Pluto Crib)	100' east of 105-B	Received water from isolated tubes containing ruptured fuel elements.	1951	1956
116-B-4 (105-B Dummy Decon- tamination Disposal Crib)	Approx. 50' south of 105-B Crib	Disposal of radioactive waste from decontamination of process dummies and poison which was done on the wash pad.	1957	1968
116-B-5 (108-B Crib)	200' north of 1713-C (solvent storage)	Disposal of liquid tritium waste Only waste of less than 1 μ Ci/cc of tritium was discharged to this crib.	1950	1968
116-B-6 (111-B Cribs (2))	Immediately north and south of the 111-B Building	Received radioactive waste from the 111-B Building	1951	1968
116-B-7 (1904B1 Outfall Structure)	Approx. 600' west of the 1904-B-2 outfall struc- ture identified below.	Currently used for disposal of water plant treatment waste water.	1944	In Use

II.1-B-13

TABLE II.1-B-1 (contd)

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
116-B-8 (1904-B2 Outfall Structure)	300' north of 107-B retention basin's NE corner.	Received and discharged reactor coolant effluent to the Columbia River.	1944	1968
116-C-1 (107-C Liquid Waste Disposal Trench)	1000 ft east of the 107-B retention basin	Received effluent water from the reactor during outages due to a ruptured fuel element.	1952	1968
116-C-2 (105-C Pluto Crib)	275 ft east of the NE corner of 105-C	Received contaminated waste from the dummy decontamination done on the wash pad and water from the 105-C metal examining facilities.	1952	1956
116-C-3 (105-C Chemical Waste Tanks)	300 ft NE of 105-C	Two 27,000 gallon tanks received caustic waste from dejacketing and acid waste from extruding of irradiated fuel elements in the metal examination facility.	1964	1969
116-C-4 (1904-C Outfall Structure)	Approx. 900' east of the 1904-B-2 structure identified previously as 116-B-8.	Received and discharged reactor coolant effluent to the Columbia River.	November 1952	1969
107-B (107-B Retention Basin)	N71660/W80560 N71660/W80090 N71430/W80560 N71430/W80090	Retained coolant effluent water from B Reactor for radioactive decay prior to release to the Columbia River.	1944	1968
107-C (107-C Retention Basins)	Center pts. at: N71045/W79970 N71045/W80320	Retained coolant effluent water from C Reactor for radioactive decay prior to release to the Columbia River.	1952	1969

II.1-B-14

TABLE II.1-B-2

WASTE MANAGEMENT FACILITIES, D AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
118-D-1 (100-D Burial Ground No. 1)	N90380.0/W53205.0 N90380.0/W52755.0 N90005.0/W52755.0 N90005.0/W53205.0	Contains irradiated dummies, thimbles, rods, gunbarrels and other contaminated solid waste	August 1944	1967
118-D-2 (100-D Burial Ground No. 2)	N90582/W55652.00 N90582.00/W55295.00 N89493.00/W55295.00 N89500.W55652.00	Contains miscellaneous con- taminated solid waste Starting in April 1966, 100-N Area solid waste was also buried here	1949	1970
118-D-3 (100-D Burial Ground No. 3)	N91222.61/W52543.30 N91346.35/W52543.13 N91461.09/W52377.65 N91473.66/W51950.73 N91317.73/W51725.01 N91323.05/W51435.73 N91264.50/W51430.74 N91262.57/W51998.27 N91224.19/W52099.07	Miscellaneous contaminated solid wastes and irradiated dummies, splines, rods, thimbles, and gunbarrels. Also used for disposal of 100-N Area solid waste	1956	1973
118-D-4 (Construction Burial Ground)	600' x 200' burial area which starts approx. 200 ft east of 115-D (gas recirculation)	Several trenches used for disposal of contaminated material removed from the reactor building.	1953	1967
118-D-5 (Ball 3X Burial)	100 ft south of 105-DR	Thimbles removed from the 105-DR Reactor during the ball 3X work in 1954 were buried in this trench.	1954	1954
118-DR-1 (105-DR Gas Loop Burial Ground)	600 ft south of 105-DR	Irradiated metal assembly from the 105-DR gas loop was buried here.	1963	1964
116-D-1 (105-D Storage Basin Trench)	100 ft east of 105-D	Received contaminated sludge from the 105-D storage basin.	1947	1967

II.1-B-15

TABLE II.1-B-2 (contd)

<u>Site Designation</u> Current (Past)	<u>Location</u>	<u>Function</u>	<u>Service Dates</u>	
			<u>In Service</u>	<u>Removed From Service</u>
116-D-2 (105-D Pluto Crib)	100 ft east of 115-D (gas recirculation)	Received water from isolated reactor tubes contain ruptured fuel elements.	1950	1956
116-D-3 (108-D Crib No. 1)	Directly east of 108-D (Technical Development Laboratory)	Used for low level fission pro- duct waste from a contaminated maintenance shop and cask decon- tamination.	1951	1967
116-D-4 (108-D Crib No. 2)	100 ft east of 108-D	Used for contaminated waste from maintenance shop and technical laboratory.	1956	1967
116-D-5 (1904-D Outfall Structure)	Approx. 400 ft west of the 107-D retention basin.	Received reactor coolant water from the 107-D retention basin. In-service to receive waste from the area process sewer.	1944	In Use
116-DR-1 (107-DR Liquid Waste Disposal Trench No. 1)	100 ft east of 107-DR basin's NE corner	Received effluent water from the 105-D or 105-DR reactor when either had a ruptured fuel element.	1950	1967
116-DR-2 (107-DR Liquid Waste Disposal Trench No. 2)	Directly southeast of 107-DR liquid waste disposal Trench No. 1	A second trench for disposal of effluent from D and DR systems during outages caused by a ruptured fuel element.	1955	1967
116-DR-3 (105-DR Storage Basin Trench)	150 ft east of 117-DR (filter building)	Contaminated sludge removed from 105-DR basin in 1955 was buried here.	1955	1955
116-DR-4 (105-DR Pluto Crib)	40 ft NE of 105-DR storage basin trench described above	Received water from isolated tubes containing ruptured fuel elements in 105-DR.	1950	1956
116-DR-5 (1904-DR Outfall Structure)	Approx. location N94651/W53657	Received and discharged reactor coolant effluent to the Columbia River.	1950	1965

TABLE II.1-B-2 (contd)

<u>Site Designation</u> Current (Past)	<u>Location</u>	<u>Function</u>	<u>Service Dates</u>	
			<u>In Service</u>	<u>Removed From Service</u>
107-DR (107-DR Retention Basin)	Approx.: N94680/W52516 N94680/W52219 N94058/W52219 N94058/W52516	Retained reactor coolant effluent water from DR Reactor for radioactive decay prior to release.	1950	1964
107-D (107-D Retention Basin)	N94685/W53250 N94685/W52780 N94455/W52780 N94455/W53250	Retained reactor coolant effluent water from D Reactor for radioactive decay prior to release.	1944	1967

II.1-B-17

TABLE II.1-B-3

WASTE MANAGEMENT FACILITIES, F AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
118-F-1 (Burial Ground No. 1 Solid Waste Burial Ground No. 2, and Minor Construction Burial Ground No. 2)	N78071.90/W32200.00 N78178.34/W31800.00 N78178.34/W31600.00 N77671.09/W31600.00 N77671.09/W32200.00	Miscellaneous Radioactive Solid Waste Disposal	1954	1965
118-F-2 (Burial Ground No. 2 Solid Waste Burial Ground No. 1)	N78990.99/W32787.00 N78985.45/W32461.78 N78626.50/W32469.82 N78623.33/W32796.01	Miscellaneous Radioactive Solid Waste Disposal	1945	1965
118-F-3 (Burial Ground No. 3 M.C. Burial Ground No. 1)	N78839.56/W31274.03 N78812.17/W31232.21 N788749.49/W31273.27 N78663.54/W31267.57 N78660.24/W31317.46 N78762.87.W31324.26	Received irradiated waste such as thimbles and step-plugs removed from the 105-F pile dur- ing the ball 3X work in 1952.	1952	1952
118-F-4 (115-F Pit)	200 ft south of the 115-F Building	Received silica gel from a dryer room.	1949	1949
118-F-5 (PNL Sawdust Repository)	N78980 N79020 W28990 W27900 N78600 N78690 W27780 W28380	Low-level activity Sawdust from animal pens	1954	In Use
118-F-6 (PNL Solid Waste Burial Ground)	N77780 W31948 N77390 W31720	Animal and laboratory waste	1965	February 1973
116-F-1 (Lewis Canal)	Natural ditch to the west and then north of 105-F (H-1-15244)	Liquid waste from 105-F and 190-F Bldgs, and decontamina- tion waste from 189-F Building	1953	1965
116-F-2 (107-F Liquid Waste Disposal Trench)	150 ft SE of 107-F Basins SE corner	Disposal of coolant effluent water containing rupture debris.	1950	1965

II.1-B-18

TABLE II.1-B-3 (contd)

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
116-F-3 (105-F Storage Basin Trench)	130 ft south of 105-F	Received effluent from fuel element rupture. In 1951, sludge from the 105-F storage basin was put in the trench.	1949	1951
116-F-4 (105-F Pluto Crib)	100 ft west of the 105-F storage basin trench described above	Disposal of coolant water from process tubes containing rup- tured fuel elements.	1950	1956
116-F-5 (Ball Washer Crib)	250 ft SW of 105-F	Waste from decontamination of boron-steel balls.	1953	1953
116-F-6 (1608-F Liquid Waste Disposal Trench)	50 ft SW of the 105-F storage basin trench described above	Disposal of outage effluent water.	1952	1965
116-F-7 (117-F Crib)	Approx. 200 ft south of the ball washer crib (116-F-5)	Drainage from confinement system's filter seal pits.	1960	1965
116-F-8 (1904-F Outfall Structure)	Approx. 850 ft north of 107-F retention basin	Received and discharged reactor coolant effluent to the Columbia River	1945	1965
107-F (107-F Retention Basin)	N79967.0/W29130.0 N79967.0/W28900.0 N79500.0/W28900.0 N79500.0/W29130.0	Retained coolant effluent water from F Reactor for radioactive decay prior to release to the Columbia River.	1945	1965
116-F-9 (PNL Animal Waste Leach Trench)	N80140 N80110 W28880 W28910 N79860 N79840 W28610 W28640	Receives washdown from animal pens	1963	In Use

TABLE II.1-B-4

WASTE MANAGEMENT FACILITIES, H AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
118-H-1 (110-H Burial Ground No. 1)	N94185.11/W40650.34 N94175.44/W39954.21 N93835.44/W39956.31 N93835.44/W40680.19	Contains dummy elements, process tubing, and miscellaneous solid waste	1949	1965
118-H-2 (100-H Burial Ground No. 2 H-1 loop burial area)	N95318.05/W41129.53 N95313.50/W40983.24 N95267.72/W40984.59 N95266.68/W41127.99	Received stainless steel tube removed from the reactor in 1955. During the deactivation of H plant, it was used for disposal of a small amount of contaminated pipe.	1955	1965
118-H-3 (Construction Burial Ground)	Approx. 800 ft south of 105-H Building's SE corner	Received sections of contaminated 16" pipe used as chutes for removal of thimbles from 105-H.	1953	1957
118-H-4 (Ball 3X Burial Ground)	100 ft directly west of 105-H	Irradiated material such as VSR thimbles and guides from 105-H was buried in this trench.	1953	1965
118-H-5 (105-H Thimble Pit)	100 ft directly north of the 1608-H crib (see 1608-H crib's location under 116-H-	A thimble assembly from the "B" experimental hole, 105-H, was buried here.	1953	1953
116-H-1 (107-H Liquid Waste Disposal Trench)	Approx. 350 ft south of the 107-H retention basin	Disposal of coolant effluent from ruptures. Also received water pumped from the 107-H basin during deactivation of the basin.	1952	May 1965
116-H-2 (1608-H Crib and Trench)	Directly south of 105-H and just outside of the cyclone fence which surround the reactor building	Received reactor liquid effluent during the Ball 3X project.	1953	1965

II.1-B-20

TABLE II.1-B-4 (Contd)

<u>Site Designation</u> Current (Past)	<u>Location</u>	<u>Function</u>	<u>Service Dates</u>	
			<u>In Service</u>	<u>Removed From Service</u>
116-H-3 (105-H Dummy Decon- tamination French Drain - Also known as Perf Decontamina- tion Drain)	200 ft southeast of 105-H	Received the spent acid and rinse water from the 105-H dummy decontami- nation facility.	1950	1965
116-H-4 (105-H Pluto Crib)	Just off the 105-H Build- ing's southwest corner	Disposal of effluent from tubes containing ruptured fuel elements.	1950	1952
116-H-5 (1904-H Outfall Structure)	N96258.97/W38545.56 N96278.97/W38502.56 N96240.0/W38479.76 N96215.0/W38523.06	Received and discharged reactor coolant effluent to the Columbia River.	1949	1965
107-H (107-H Retention Basin)	N96000.0/W38740.0 N96000.0/W38466 N95368/W38466 N95368/W38740.0	Retained coolant effluent water from H Reactor for radioactive decay prior to release to the Columbia River.	1949	1965
116-H-6 (183-Basin)	Center Pts. At N96030/W39020	Receives the liquid waste from the 300 Area Duels Fabrication Facility for solar evaporation and recovery of metals.	1973	In Use

II.1-B-21

TABLE II.1-B-5

WASTE MANAGEMENT FACILITIES, K AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates	
			In Service	Removed From Service
118-K (K Burial Ground)	NK5229.50/WK3930 NK5229.50/WK3651.50 NK5142.20/WK3580 NK5032.20/WK3380.75 NK4235.00/WK3379.50 NK4235.00/WK3830	Radioactive solid waste from K and N Reactors were buried here.	1955	December 1973
116-K-1 (100-K Crib)	Approx. 200' outside of the perimeter fence's north corner	Received reactor coolant water from 107-K retention basins.	1955	1971
116-K-2 (100-K "Mile Long" Trench)	Starts approx. 450' outside of the peri- meter fence's north corner	Received reactor coolant water from the 107-K retention basins.	1955	1971
116-K-3 (190S-K Outfall Structure)	Center of NK5650/WK5036	Received and discharged reactor coolant water from the 107-K retention basins, to the Columbia River.	1955	In Use
116-KE-1 (115-KE Crib)	200 ft east of 1713-KE (maintenance building)	Condensate and other waste water from the reactor gas purification system.	1955	1970
116-KE-2 (1706-KER Crib)	180 ft west of 1706-KE building	Waste from the cleanup columns in the 1706-KER loop.	1957	1964
116-KW-1 (115-KW Crib)	Approx. 230' east of 105-KW	Condensate and other waste water from the reactor gas purifi- cation system.	1955	1971
107-KE (107-KE Retention Basins [3])	Center points: NK5356.99/WK4268.02 NK5328.50/WK4536.51 NK5300.00/WK4805.00	Retained coolant effluent water from KE Reactor for radioactive decay prior to release to the Columbia River.	1955	1971
107-KW (107-KW Retention Basins [3])	Center points: NK5245/WK6190 NK5245/WK6460 NK5245/WK6730	Retained coolant effluent water from KW Reactor for radioactive decay prior to release to the Columbia River.	1955	1970

II.1-B-22

TABLE II.1-B-6
WASTE MANAGEMENT FACILITIES, N AREA CRIBS AND BURIAL GROUNDS

<u>Site Designation</u> Current (Past)	<u>Location</u>	<u>Function</u>	<u>Service Dates</u>	
			<u>In Service</u>	<u>Removed From Service</u>
116-N-1 (1301-N Crib and Trench)	<u>Crib</u> WN5982/NN7004 WN5982/NN7300 WN5856/NN7300 WN5856/NN7004	Radioactive effluent streams from 105 and 109-N	Crib 1964	In Use
	<u>Trench</u> 1600' northeast extension of the above crib		Trench 1965	In Use
116-N-2 (1310-N Waste Storage Area)	Center point at WN5985/NN6775	Collecting tank for N Reactor primary piping decontamination wastes.	1964	In Use
118-N (100-N Area Silos [3])	Area just outside of 105-N Building's NW corner.	Storage of N Reactor fuel spacer elements	1963 (one) 1967 (two)	In Use

APPENDIX II.1-B, PART 3

Estimated Radioactive Material Inventories

TABLE II.1-B-7

ESTIMATED INVENTORIES IN REACTOR FACILITIES THROUGH 1972

<u>100-B</u>	Inventory - (Curies)
2 Reactor Blocks	13,000 (^{60}Co)
2 Metal Storage Basins	20 (^{90}Sr , ^{137}Cs , ^{239}Pu)
3 107 Basins and Soil	150 (^{152}Eu , ^{239}Pu)
<u>100-D</u>	
2 Reactor Blocks	8,500 (^{60}Co)
2 Metal Storage Basins	20 (^{90}Sr , ^{137}Cs , ^{239}Pu)
2 107 Basins and Soil	100 (^{152}Eu , ^{239}Pu)
<u>100-F</u>	
1 Reactor Block	4,300 (^{60}Co)
1 Metal Storage Basin	10 (^{90}Sr , ^{137}Cs , ^{239}Pu)
1 107 Basin and Soil	50 (^{152}Eu , ^{239}Pu)
<u>100-H</u>	
1 Reactor Block	4,300 (^{60}Co)
1 Metal Storage Basin	10 (^{90}Sr , ^{137}Cs , ^{239}Pu)
1 107 Basin and Soil	50 (^{152}Eu , ^{239}Pu)
<u>100-K</u>	
2 Reactor Blocks	26,000 (^{60}Co)
2 Metal Storage Basins	100 (^{90}Sr , ^{137}Cs , ^{239}Pu)
6 107 Basins and Soil	300 (^{152}Eu , ^{239}Pu)
<u>100-N</u>	
1 Reactor Block	18,000 (^{60}Co)
Spacer Storage	150,000 (^{59}Fe)
	2,000 (^{60}Co)
TOTAL (Ci)	160 (^{90}Sr , ^{137}Cs , ^{239}Pu)
	650 (^{152}Eu , ^{239}Pu)
	76,100 (^{60}Co)
	150,000 (^{59}Fe)

NOTE: ^{14}C data in the reactors and reactor systems are insufficient to quantify at this time.

TABLE II.1-B-8

100 AREAS APPROXIMATE INVENTORIES
CRIBS AND BURIAL GROUNDS THROUGH 1972 (a)

Location	Radioactive Inventory	
	Half-Life <1 Year, Ci	Half-Life >1 Year, Ci
<u>100-B</u>		
Solid Waste (Production)	3,500 (⁵⁴ Mn, ⁹⁵ Zr)	3,500 (⁶⁰ Co)
<u>100-D</u>		
Solid Waste (Production)		4,000 (⁶⁰ Co)
<u>100-F</u>		
Solid Waste (Production)		1,900 (⁶⁰ Co)
Solid Waste (Research)		15 (⁹⁰ Sr)
Sawdust Repository (Research)		15 (⁹⁰ Sr) 0.3 (²³⁹ Pu)
Animal Waste Leaching Trench (Research)		4 (⁹⁰ Sr) 0.08 (²³⁹ Pu)
<u>100-H</u>		
Solid Waste (Production)		3,500 (⁶⁰ Co)
<u>100-K</u>		
Solid Waste (Production)	1,000 (⁶⁵ Zn)	13,000 (⁶⁰ Co)
TOTAL		
	⁶⁰ Co	25,900
	⁹⁰ Sr	34
	²³⁹ Pu	0.38
	⁶⁵ Zn	1,000
	⁵⁴ Mn, ⁹⁵ Zn	3,500

(a) Except for 100 N Area Crib.

TABLE II.1-B-9
ESTIMATED INPUT TO THE 100-N AREA CRIB
Through 1972

	Crib Inventory, <u>Ci</u>
^{32}P	15
^{51}Cr	40
^{54}Mn	800
^{58}Co	14
^{59}Fe	80
^{60}Co	2000
^{89}Sr	10
^{90}Sr	50
^{95}Zr	150
^{99}Mo	20
^{106}Ru	80
^{131}I	6
^{134}Cs	90
^{137}Cs	350
^{140}Ba	<u>20</u>
TOTAL	3725

APPENDIX II.1-B, PART 4

100 Areas, Radioactive Material Releases--1972

TABLE II.1-B-10

100-N RADIOACTIVE MATERIAL RELEASES TO THE COLUMBIA RIVER--1972

Via 102 inch Discharge Line ^(a)

Gross Volume	Nuclide	Curies	Conc. (μ Ci/ml)
3.7×10^{11} l	$^{140}\text{BaLa}$	10	2.7×10^{-8}
	^{58}Co	2	5.4×10^{-9}
	^{60}Co	20	5.4×10^{-8}
	^{51}Cr	20	5.4×10^{-8}
	^{134}Cs	0.5	1.4×10^{-9}
	^{137}Cs	5	1.4×10^{-8}
	^{59}Fe	10	2.7×10^{-8}
	^{131}I	40	1.1×10^{-7}
	^{54}Mn	40	1.1×10^{-7}
	^{56}Mn	600	1.6×10^{-6}
	^{99}Mo	20	5.4×10^{-8}
	^{24}Na	500	1.4×10^{-6}
	^{239}Np	90	2.4×10^{-7}
	^{124}Sb	0.8	2.2×10^{-9}
	$^{95}\text{ZrNb}$	8	2.2×10^{-8}
	^{103}Ru	0.4	1.1×10^{-9}
	^{106}Ru	4	1.1×10^{-8}
	^{133}Xe	10	2.7×10^{-8}

Via Seepage Springs on Riverbank

2.8×10^9 l	$^{140}\text{BaLa}$	0.5	1.8×10^{-7}
	^{60}Co	0.01	3.6×10^{-9}
	^{51}Cr	5.3	1.9×10^{-6}
	^{137}Cs	0.05	1.8×10^{-8}
	^3H	7000	2.5×10^{-3}
	^{131}I	1.9	6.8×10^{-7}
	^{99}Mo	1.1	3.9×10^{-7}
	^{89}Sr	0.05	1.8×10^{-8}
	^{90}Sr	0.95	3.4×10^{-7}

(a) Significant reduction of the activity in this stream is expected following the post-1972 rerouting of radioactive liquid waste streams feeding into the 102 inch discharge line.

TABLE II.1-B-11

GASEOUS RADIOACTIVE MATERIAL RELEASE--1972

N Reactor Plant

	^{41}Ar	^3H	^{131}I	^{133}I
Volume $1.9 \times 10^{15} \text{ ml}$				
Total Release (Ci)	1×10^5	2.7×10^1	1.3×10^{-2}	0.5
Avg. Release Rate (Ci/day)	274	0.07	3.6×10^{-5}	1.4×10^{-3}
Avg. Concentration ($\mu\text{Ci/ml}$)	5.2×10^{-5}	1.4×10^{-8}	6.8×10^{-12}	2.6×10^{-10}

Plutonium Inhalation Laboratory--144-F

	Total Alpha ^(a)	Total Beta ^(b)
Volume $2.4 \times 0.09 \text{ (ft}^3\text{)}$		
Ave. Concentration ($\mu\text{Ci/ml}$)	$<5.4 \times 10^{-15}$	$<6.6 \times 10^{-14}$
Ave. Release Rate ($\mu\text{Ci/wk}$)	<0.007	<0.087
Max. Release Rate ($\mu\text{Ci/wk}$)	<0.029	<0.132
Total Release (μCi)	<0.372	<4.54

- (a) Analyzed as though alpha activity were due entirely to ^{239}Pu .
 (b) Analyzed as though beta activity were due entirely to ^{90}Sr .

APPENDIX II.1-B, PART 5
100 Areas Unplanned Releases

TABLE II.1-B-12

100 AREAS UNPLANNED RELEASES

<u>DATE</u>	<u>BLDG.</u>	<u>DESCRIPTION</u>	<u>ISOTOPE & AMOUNT</u>
6-27-72	1310-N	Radioactive chemical waste handling facility piping leak. Approx. 90,000 gallons of radioactive wastes discharged to ground.	35 Ci, of which 26 Ci were ^{60}Co .
3-13-71	141-C 100-F	The main sewer lines from 141-C to 141-N Bldgs. became plugged and spread contamination on the ground. Area 20' x 40' x 40' 8000-20,000 c/m ~. Area stabilized with clean gravel cover.	~ 0.005 Ci ^{90}Sr
5-23-68	105-KE	Release to river. 2000 Ci mixed activation products.	2000 Ci mixed F.P.
2-11-66	105-KW	Fuel element failure, releasing 600 curies of I-131 to river.	600 Ci ^{131}I
1-17-64	107-F	High wind spread particulate contamination out of 107-F basin while it was dry for repairs. Particles to 80,000 c/m. Particles with > 5000 c/m removed.	Mixed activation products
7-11-63	107-KW	Northeast wind spread particulate contamination out of KW Basins while they were dry for repairs. Particles from 1000-8000 c/m. No contamination detected off project. Involved area controlled as radiation zone, contaminants seated by water flush and decayed.	Mixed activation products
6-7-63	107-KE	Wind spread particulate contamination out of KE Basins which were nearly dry due to extended reactor shutdown. Maximum particle inside limited area fence was 300 mrads/hr. Maximum outside fence was 20,000 c/m. No contamination detected off project. Particles > 5000 c/m recovered.	Mixed activation products
4-29-59	105-KW	During discharge, a small fraction of a ruptured fuel element burned and particulate contamination was released to the atmosphere via the ventilation stack. Widely dispersed particulates detected on Wahluke Slope. Five particles ranged from 3000 to 60,000 cpm. Control monitoring plots established to determine migration of low activity particles; those particles > 5000 c/m recovered.	1.3 Ci mixed F.P.

TABLE II.1-B-12 (Continued)

DATE	BLDG.	DESCRIPTION	ISOTOPE & AMOUNT
12-6-57	107-C	Wind spread particulate contamination from C Basin which was dry for repair. General contamination of 3000 to 6000 c/m in a fan shape area to the east and southeast with a maximum of 65 mrad/hr. Area posted as Radiation Zone, seasonal rains fixed contaminant in soil.	Mixed activation products
9-27-57	105-C	Ruptured fuel element burned for 10-min at reactor discharge face. No deposition of radioactivity was found on the ground outside 105-C exclusion area although an estimated 4 Ci of filterable gross beta activity was emitted from 105-C stack.	4 Ci F.P.
4-23-57	107-C	Wind spread particulate contamination from C Basin which was dry for repair work. Ground contamination of 5000 to 80,000 c/m extended in a fan shape east. A later wind shifted the contamination to the northeast with readings up to 5000 c/m on May 2, 3 and 6. Area flushed repeatedly with water to immobilize particulates.	Mixed activation products
2-21-57	107-D	Wind spread particulates contamination out of 107-D Basin while it was dry for repair work. Maximum contamination was 40 mrad/hr with 0-8 particles per 100 ft ² inside 100-D area fences. No significant contamination was found outside 100-D Area or on Wahluke slope. Particles > 5000 c/m recovered.	Mixed activation products
9-17-56	105-C	A fuel element burned for 6 minutes at the reactor discharge face resulting in stack emission of particulates. Contamination levels on ground were 5000 to 30,000 c/m. Maximum particle 350 mrad/hr. Area involved was decontaminated.	²³⁹ Np and mixed F.P.
5-15-56	107-H	Swallows used mud from 107-H liquid waste trench for nest building. The contaminated mud was being dropped around the 100-H water towers and at scattered locations over the flight path to White Bluffs across the Columbia River. Concentrations ranged from 0-6 particles per 100 ft ² with a maximum reading of 150 mrad/hr. Nests removed at the building sites, waste trench exposed mud covered with clean gravel.	

TABLE II.1-B-12 (Continued)

DATE	BLDG.	DESCRIPTION	ISOTOPE & AMOUNT
11-1-55	105-H	Ruptured fuel element burned briefly during discharge resulting in a stack emission and discharge of 1000-2000Ci of mixed fission products to the basins. Ground level contamination was up to 12 particles per 100 ft ² ranging from 1000 to 10,000 c/m and a maximum level of 700 mrad/hr. The contamination spread south over about seven square miles. Contaminated soil removed and disposed of to burial trench.	0.8 Ci Barium, Rare Earths, Yttrium
5-23-55	107-F	Water overflowed 107-F Basin after baffles broke loose and plugged the outlet. General contamination around the basin and along a narrow path to the river ranged from 20,000 to 60,000 c/m with a maximum of 350 mrad/hr. Baffle boards carried into the river read 14 mrad/hr. Area covered with clean soil.	Mixed activation products
5-3-55	105-H	Removal of two ruptured fuel elements from the reactor resulted in release of particulate radioactivity with concentrations as high as 20 particles per 100 ft ² in the north-east corner of 100-H Area. Six particles were detected in 10,000 ft ² along the Wahluke Slope road. Particles were removed as located.	0.1 Ci gross Beta
3-26-54	107-C	Ground level contamination occurred while 107-C Basin was empty for repair. Particulate contamination up to 50 mrad/hr covered 20% of 100-B Area. No particles above 10 mrad/hr were found outside 100-B Area. Roadways were water flushed and the concentrated activity was removed to the burial ground.	50% Rare Earths 5% ¹⁰³ , ¹⁰⁶ _{Ru} Traces of Sr, U, Pu
2-25-54	107-B	A break in 107-B Basin flooded an area around the basin with water reading up to 13 mrad/hr. Beta radioactivity of the mud was 10 ⁻⁴ to 10 ⁻² μ Ci/gm. Contamination was confined to the vicinity of the basin. The area involved was covered with clean gravel.	Mixed activation products
12-4-51	P-11	Fire occurred in contaminated waste storage area of a remotely located research facility. Fire spread to chemical laboratory and exhaust filters. Contamination was confined to immediate vicinity of laboratory. Contaminated soil surfaces were covered with sand.	$\sim$ 0.7 Ci Pu

APPENDIX II.1-C

200 AREA FACILITIES

APPENDIX II.1-C

200 AREA FACILITIES

	<u>Page</u>
Part 1 200 Area Maps	II.1-C-3
Part 2 Waste Management Facilities Tanks, Cribs, Ponds, and Burial Grounds	II.1-C-7
Part 3 Details of 200 East Area Facilities and Operations	II.1-C-21
Part 4 Details of 200 West Area Facilities and Operations	II.1-C-57
Part 5 Radioisotopes Stored Beneath Selected 200 Area Cribs	II.1-C-81
Part 6 Estimated Inventories 200 Area Facilities	II.1-C-101
Part 7 200 Area Gaseous Radioactive Material Release	II.1-C-109
Part 8 200 Areas, Unplanned Releases	II.1-C-125

APPENDIX II.1-C, PART 1

200 Area Maps

FIGURE II.1-C-1 DETAILED MAP OF 200 EAST AREA

REVISÉ 3-5-73

II.1-C-5

FIGURE II.1-C-2 DETAILED MAP OF 200 WEST AREA

APPENDIX II.1-C, PART 2

Waste Management Facilities

Tanks, Cribs, Ponds, and Burial Grounds

TABLE II.1-C-1

200 EAST AREA TANK FARMS AND FACILITIES

Number	Description
<u>A - Tank Farm Facilities</u>	
241-A	6 Tanks: 10^6 gal each
241-AX	4 Tanks: 10^6 gal each
241-AY	2 Tanks: 10^6 gal each
241-AZ	2 tanks: 10^6 gal each; one complete, one under construction
241-A-201	Emergency Cooling Water Storage Tank
241-A-271	Control House
241-A-401	Condenser House
241-A-431	Ventilation House (Standby)
241-A-701	Compressor House
241-A-702	Fan House
241-AX-801-A	AX Farm Control House North
241-AX-801-B	AX Farm Control House South
241-AX-801-C	AX Farm Control House (Diverter House)
241-AY-801	AY Farm Instrument House
2707-AX	Change House
241-A-152	Diversion Box
241-A-153	Transfer Box
	Other structures include Ion Exchange Column, Cooling Tower, Contact Condensers, Isolation Jumper Pit, Emergency Water Well
241-AX-151,152	Diverter Stations
241-AZ-151	Diverter Stations
241-AY-152	Sluice Transfer Box
241-AZ-152	Sluice Transfer Box
241-AY-151	Pump Out Pit
241-A-501	Condensate Valve Pit
241-AX-501	Condensate Valve Pit
241-AY-501	Condensate Valve Pit
241-AZ-501	Condensate Valve Pit
241-A-417	Condensate Receiver and Pump Pit

TABLE II.1-C-1

(Continued)

Number	Description
<u>"AR Vault" Facilities</u>	
244-AR	Current Acid Waste Storage and Sludge Processing Vault
2707-AR	Change House
2714-AR	General Storage
2802-AR	Steam Distribution Piping
2901-AR	Water Storage Piping
2904-AR	Process Sewer System
291-AR	Exhaust Air Filter, Stack and Plenum
2708-AR	Laundry Storage
244-AR-701	Emergency Generator Bldg.
<u>"B" Tank Farm Facilities</u>	
241-B	12 Tanks: 533,000 gal each 4 Tanks: 55,000 gal each
241-BX	12 Tanks: 533,000 gal each
241-BY	12 Tanks: 758,000 gal each
241-BR, BXR, BYR	Waste Metal Recovery Facilities
241-B-701	Compressor House
241-BY-254	ITS No. 2 Control and Compressor House
241-BY-301	ITS No. 1 Control House
241-BY-302	ITS No. 1 Compressor House
2707-BY	Change House
242-B	Aerosol Release, Corrosion Test Facility
252-BY	Substation (13.8 kW)
244-BXR	Waste Disposal Vault (Underground)
<u>Diversion Boxes</u>	
241-B-151,152,153	
242-B-152	
241-B-252	
241-BR-152	
241-BX-153,155	
241-BXR-151,152,153	
241-BYR-152,153,154	

TABLE II.1-C-1

(Continued)

Number	Description
<u>"C" Tank Farm Facilities</u>	
241-C	12 Tanks: 533,000 gal each 4 Tanks: 55,000 gal each
241-CR-271	Control House and Office
241-C-801	Cesium Load-Out Building
291-CR	Stack and Filter
244-CR	Waste Disposal Vault (Underground)
241-C-151,152,252	Diversion Boxes
241-CR-151,152,153	

TABLE II.1-C-2

200 WEST AREA TANK FARMS AND FACILITIES

Number	Description
<u>"S" Tank Farm Facilities</u>	
241-S	12 Tanks: 758,000 gal each
241-SX	15 Tanks: 10 ⁶ gal each
241-SX-281	Emergency Cooling Water Pump House
241-SX-401	Condenser House (North)
241-SX-402	Condenser House (South)
241-SX-701	Compressor House
241-SX-271	Control House
2707-SX	Change House
242-S	Evaporator Building
2901-SX	Water Storage Tank
2902-SX	Water Storage Tank
242-S-702	Ventilation Turbine
242-S-272	Maintenance Shop
241-S-151	Diversion Box
241-SX-151,152	Diversion Box
<u>"T" Tank Farm Facility</u>	
241-T	12 Tanks: 533,000 gal each 4 Tanks: 55,000 gal each
241-TX	18 Tanks: 758,000 gal each
241-TY	6 Tanks: 758,000 gal each
241-T-601	Chemical Makeup
241-TR, TXR	Waste Metal Recovery Facilities
242-T	Waste Evaporator
244-TXR	Waste Disposal Vault (Underground)
241-T-701	Compressor House
242-TA	Vault
241-T-151 thru 153	Diversion Boxes
242-T-151,152	Diversion Boxes
241-TX-153 thru 155	Diversion Boxes
241-TY-153	Diversion Boxes
241-TR-152,153	Diversion Boxes
241-TXR-151 thru 153	Diversion Boxes

TABLE II.1-C-2

(Continued)

Number	Description
<u>"U" Tank Farm Facilities</u>	
241-U	12 Tanks: 530,000 gal each 4 Tanks: 55,000 gal each
241-UR	Waste Metal Recovery Facilities
271-U-271	U Farm Control House
244-UR	Waste Disposal Vault
241-U-701	Compressor House
241-U-151 thru 153,252	Diversion Boxes
241-UR-151 thru 154	Diversion Boxes
241-UX-154	Diversion Boxes
241-WR	Thorium Nitrate Storage Vault

TABLE II.1-C-3

200 EAST AREA LIQUID WASTE DISPOSAL SITES
(Cribs, Ponds, Ditches, Trenches, Pits, French Drains, etc.)

Type of Construction	Number	Description	Bottom Area ft ²	Use Dates		Status
				From	To	
PUREX PLANT - 244 SR Vault, A, AX, AY Tank Farms						
C	216-A-1	Startup Waste	900	11/55	12/55	Terminated
C	216-A-2	Organic Waste	400	5/56	1/63	Terminated - Replaced by A-31
C	216-A-3	203-A Silica Gel Waste	400	3/56	1/73	Inactive
C	216-A-4	Laboratory and Stack Drain	400	12/55	12/58	Terminated - Replaced by A-21
C	216-A-5	Process Condensate	1,225	11/55	11/61	Inactive - Replaced by A-10
C	216-A-6	Steam Condensate	10,000	11/55	1/70	Inactive
C	216-A-7	Catch Tank Pump Pit Drain	100	11/55	-	Active
C	216-A-8	Tank Farm Condenser Effluent	17,600	11/55	-	Active
C	216-A-9	Fractionator Condenser Effluent and N Reactor Decontamination Waste	8,400	3/56	8/69	Terminated
C	216-A-10	Process Condensate	12,375	11/61	-	Active
FD	216-A-11	Trap Pit No. 1 Drain (French Dr)	30 in. diam	11/55	-	Active
FD	216-A-12	Trap Pit No. 3 Drain (French Dr)	30 in. diam	11/55	-	Active
FD	216-A-13	Air Sample Vacuum Pump Seal Drain (French Dr)	2 ft diam	11/55	-	Terminated
FD	216-A-14	Vacuum Cleaner Pit Drain (French Dr)	30 in. diam	11/55	1/73	Inactive
FD	216-A-15	Prop. Sampler Pit No. 5 Drain (French Dr)	2 ft diam	11/55	-	Active
FD	216-A-16	241-A Deentrainment Floor (Drain)	4 ft diam	1/56	3/69	Inactive
FD	216-A-17	Overflow from A-16	4 ft diam	1/56	3/69	Inactive
C	216-A-18	Startup Waste	6,400	11/55	12/55	Terminated
C	216-A-19	Startup Waste	625	11/55	12/55	Terminated
C	216-A-20	Startup Waste	625	11/55	12/55	Terminated
C	216-A-21	NH ₃ Scrubber and Stack Drainage	960	10/57	6/65	Terminated
FD	216-A-22	203-A Con. and Floor Drain	6 ft diam	11/55	1/73	Inactive
FD	216-A-23A	241-A Fan House Drain	42 in. diam	1957	3/69	Inactive
FD	216-A-23B	Overflow from A-23A	42 in. diam	1957	3/69	Inactive
C	216-A-24	Tank Farm Condenser Effluent	28,000	5/58	1/66	Inactive
Pd	216-A-25	Cooling Water (Gable Mt. Pond)	71 acres	12/57	-	Active
FD	216-A-26A	Fan Control Room Drain	3 ft diam	3/59	7/65	Terminated
FD	216-A-26B	291 Fan House Drain	4 ft diam	3/59	6/73	Terminated
C	216-A-27	Lab, Scrubber and Stack Drain	2,000	6/65	7/70	Inactive
FD	216-A-28	203-A Floor Drainage	10 ft diam	12/58	11/67	Terminated
D	216-A-29	Cooling Water and Chemical Waste Ditch	39,000	11/55	-	Active
C	216-A-30	Steam Condensate	14,000	1/61	-	Active
C	216-A-31	Organic Waste	700	1/63	1/65	Inactive
C	216-A-32	E. Crane Maint. Plat. Floor Drain	560	1/59	-	Active
FD	216-A-33	291-A Stack Exhaust Fans Bearing Cooling Water	6 ft diam	11/55	7/64	Terminated
D	216-A-34	241-A Condensate Cooling Water	12,300	11/55	12/57	Terminated
FD	216-A-35	Vacuum Pump Seal Water	6 ft diam	12/63	1/66	Terminated
C	216-A-36A	Ammonia Scrubber Waste	1,100	9/65	3/66	Terminated
C	216-A-36B	Ammonia Scrubber Waste	5,500	3/66	9/72	Inactive
C	216-A-37	Steam Condensate	7,000	Not Used	-	Inactive
C	216-A-38	Process Condensate	7,800	Not Used	-	Inactive
C	216-A-39	241-AX-801 Building Drain	360	6/66	6/71	Inactive
T	216-A-40	244-AR Vault Cooling Water - Emergency Diversion	8,000	1/68	-	Inactive ^(a)
C	216-A-41	216-A-13 Stack Drainage	100	1/68	-	Active

^(a) No diversion through CY-1973

TABLE II.1-C-3 (Continued)

Type of Construction	Number	Description	Bottom Area ft ²	Use Dates		Status
				From	To	
B PLANT						
C	216-B-1	Not Built				
D	216-B-2	Cooling Water and Chemical Sewer Ditch	24,570	4/45	-	Active
D	216-B-2-1 (-2E)	Cooling Water, Chemical Sewer Ditch	19,980	3/70	11/70	Terminated
D	216-B-2-2 (-2W)	Cooling Water, Chemical Sewer Ditch	14,200	3/70	5/70	Terminated
Pd	216-B-3	Cooling Water and Chemical Sewer Ditch	46 acres	4/45	-	Active
RW	216-B-4	292-B Floor Drainage	8 in. diam	4/45	12/49	Terminated
RW	216-B-5	224-B and 5-6 Waste	8 in. diam	4/45	10/47	Terminated
RW	216-B-6	222-B Waste	8 in. diam	4/45	12/49	Terminated
C	216-B-7A	224-B Waste and 5-6 Cell Drain	196	9/46	5/67	Terminated
C	216-B-7B	224-B Waste	196	10/46	5/67	Terminated
C	216-B-8	224-B, 5-6 and 2nd Cycle Waste	1,344	1945	1952	Terminated
C	216-B-9	5-6 and 2nd Cycle Waste	864	8/48	7/51	Terminated
C	216-B-10A	292-B Floor Drainage	196	12/49	-	Active 1967
C	216-B-10B	221-BE Decon. Waste	196	6/69	10/73	Inactive
RW	216-B-11A&B	242-5 Condensate	4 ft diam	12/51	12/54	Terminated
C	216-B-12	U and B Plant Process Condensate	8,000	11/52	11/73	Inactive
ED	216-B-13	291-B Stack Drainage	4 ft diam	4/45	-	Active
C	216-B-14	U Plant Scavenged Waste	1,600	1/56	2/56	Terminated
C	216-B-15	U Plant Scavenged Waste	1,600	4/56	12/57	Terminated
C	216-B-16	U Plant Scavenged Waste	1,600	4/56	8/56	Terminated
C	216-B-17	Tank Farm Scavenged Waste	1,600	1/56	1/56	Terminated
C	216-B-18	U Plant Scavenged Waste	1,600	3/56	4/56	Terminated
C	216-B-19	U Plant and Tank Farm Scavenged Waste	1,600	2/57	10/57	Terminated
T	216-B-20	U Plant and Tank Farm Scavenged Waste	5,000	8/56	9/56	Terminated - Backfilled
T	216-B-21	U Plant and Tank Farm Scavenged Waste	5,000	9/56	10/56	Terminated - Backfilled
T	216-B-22	U Plant and Tank Farm Scavenged Waste	5,000	10/56	10/56	Terminated - Backfilled
T	216-B-23	U Plant and Tank Farm Scavenged Waste	5,000	10/56	10/56	Terminated - Backfilled
T	216-B-24	U Plant Scavenged Waste	5,000	10/56	11/56	Terminated - Backfilled
T	216-B-25	U Plant Scavenged Waste	5,000	11/56	12/56	Terminated - Backfilled
T	216-B-26	U Plant Scavenged Waste	5,000	12/56	2/57	Terminated - Backfilled
T	216-B-27	U Plant Scavenged Waste	5,000	2/57	4/57	Terminated - Backfilled
T	216-B-28	U Plant and Tank Farm Scavenged Waste	5,000	4/57	6/57	Terminated - Backfilled
T	216-B-29	U Plant Scavenged Waste	5,000	6/57	7/57	Terminated - Backfilled
T	216-B-30	U Plant and Tank Farm Scavenged Waste	5,000	7/57	7/57	Terminated - Backfilled
T	216-B-31	U Plant and Tank Farm Scavenged Waste	5,000	7/57	8/57	Terminated - Backfilled
T	216-B-32	U Plant and Tank Farm Scavenged Waste	5,000	8/57	9/57	Terminated - Backfilled
T	216-B-33	U Plant and Tank Farm Scavenged Waste	5,000	9/57	10/57	Terminated - Backfilled
T	216-B-34	U Plant and Tank Farm Scavenged Waste	5,000	10/57	10/57	Terminated - Backfilled
T	216-B-35	1st Cycle Supernatant - 221-B	2,520	2/54	3/54	Terminated - Backfilled
T	216-B-36	1st Cycle Supernatant - 221-B	2,520	3/54	4/54	Terminated - Backfilled
T	216-B-37	Evaporator Bottoms - 242-B	2,520	8/54	8/54	Terminated - Backfilled
T	216-B-38	1st Cycle Supernatant - 221-B	2,520	7/54	7/54	Terminated - Backfilled
T	216-B-39	1st Cycle Supernatant - 221-B	2,520	12/53	11/54	Terminated - Backfilled
T	216-B-40	1st Cycle Supernatant - 221-B	2,520	4/54	7/54	Terminated - Backfilled
T	216-B-41	1st Cycle Supernatant - 221-B	2,520	11/54	11/54	Terminated - Backfilled
T	216-B-42	U Plant Scavenged Waste	2,520	2/55	3/55	Terminated - Backfilled
C	216-B-43	U Plant Scavenged Waste	900	11/54	11/54	Terminated
C	216-B-44	U Plant Scavenged Waste	900	12/54	3/55	Terminated
C	216-B-45	U Plant Scavenged Waste	900	4/55	6/55	Terminated
C	216-B-46	U Plant Scavenged Waste	900	9/55	12/55	Terminated

TABLE II.1-C-3 (Continued)

Type of Construction	Number	Description	Bottom Area ft ²	Use Dates		Status
				From	To	
C	216-B-47	U Plant Scavenged Waste	900	9/55	9/55	Terminated
C	216-B-48	U Plant Scavenged Waste	900	11/55	7/57	Terminated
C	216-B-49	U Plant Scavenged Waste	900	11/55	12/55	Terminated
C	216-B-50	ITS No. 1 Condensate	900	1/65	-	Active
FD	216-B-51	Pipe Line Drain BC Crib	5 ft diam	1/56	1/58	Terminated
T	216-B-52	Tank Farm Scavenged Waste	5,800	12/57	1/58	Terminated - Backfilled
T	216-B-53A	HLO Waste From 300 Area	600	10/65	11/65	Terminated - Backfilled
T	216-B-53B	HLO Waste From 300 Area	1,500	11/62	3/63	Terminated - Backfilled
T	216-B-54	HLO Waste From 300 Area	2,000	3/63	10/65	Terminated - Backfilled
C	216-B-55	B Plant Steam Condensate	7,500	9/67	-	Active
C	216-B-56	B Plant Organic Waste	700	Never Used		
C	216-B-57	ITS No. 2 Condensates	3,000	12/67	-	Active
T	216-B-58	300 Area Waste	2,000	11/65	6/67	Terminated - Backfilled
T	216-B-59	B Plant Cooling Water Diversion (Emergency)	8,000	12/67	-	Inactive*
C	216-B-60	Cell Drain Cleanout	8 ft diam	11/67	11/67	Terminated
C	216-B-61	ITS No. 1 Condensate	1,750	Not Used		Inactive
C	216-B-62	B Plant Process Condensate	5,000	11/73	-	Active
D	216-B-63	B Plant Chemical Sewer Ditch	5,000	3/70	-	Active

SEMIWORKS AND CRITICAL MASS LABORATORY

C	216-C-1	201-C Process Condensate and Waste	184	1/53	6/57	Terminated
RW	216-C-2	291-C Stack and Filter Drain	12 in. diam	1/53	-	Active
C	216-C-3	271-C Chemical Waste	500	1/53	3/54	Terminated
C	216-C-4	276-C Organic Waste	200	7/55	5/65	Inactive
C	216-C-5	201-C High Salt Waste	200	3/55	6/55	Inactive
C	216-C-6	241-CX Waste Storage Cond.	200	9/55	9/64	Terminated
C	216-C-7	290-E Critical Lab Waste	400	5/61	-	Active
FD	216-C-8	271-CR Ion-Exchange Waste	6 ft diam	6/62	6/65	Terminated
Pd	216-C-9	C-Area Cooling Water Pond	80,000	6/53	-	Active (209-E only)
C	216-C-10	Strontium Semiworks Process Condensate	160	11/64	10/69	Inactive

200 NORTH AREAS

Pd	216-N-1	212-N Basin Overflow Pond	50,000	9/44	6/52	Terminated - Backfilled
T	216-N-2	212-N Basin Cleanout Trench	500	3/47	4/47	Terminated - Backfilled
T	216-N-3	212-N Basin Cleanout Trench	500	5/52	6/52	Terminated - Backfilled
Pd	216-N-4	212-P Basin Overflow Pond	100,000	9/44	6/52	Terminated - Backfilled
T	216-N-5	212-R Basin Overflow Trench	1,200	5/52	6/52	Terminated - Backfilled
P	216-N-6	212-R Basin Overflow Pond	75,000	9/44	6/52	Terminated - Backfilled
T	216-N-7	212-R Basin Cleanout Trench	1,200	5/52	6/52	Terminated - Backfilled

C - crib D - ditch RW - reverse well
 Pd - pond T - trench
 Pt - pit FD - french drain

TABLE II.1-C-4

WEST AREA LIQUID WASTE DISPOSAL SITES (Crisbs, Ponds, Ditches, Trenches, Pits, French Drains, etc.)

Type of Construction	Number	Description	Bottom Area ft ²	Use Dates From To		Status
REDOX PLANT, 222 Laboratory, 242-S						
C	216-S-1	D-2 Process Condensate	1,800	1/52	1/56	Terminated - Replaced by S-7
C	216-S-2	Overflow from S-1	1,800	1/52	1/56	Terminated - Replaced by S-7
C	216-S-3	241-S TK 101 and 104 Condensate	100	8/53	8/56	Terminated
FD	216-S-4	241-S TK 101 and 104 Condensate	30 in. diam	8/53	8/56	Terminated
C	216-S-5	Steam Condensate - Cooling Water	44,100	3/54	3/57	Terminated - Replaced by S-6
C	216-S-6	Steam Condensate - Cooling Water	44,100	11/54	7/72	Inactive
C	216-S-7	D-2 Process Condensate	5,000	1/56	7/65	Terminated
T	216-S-8	Startup Waste	6,000	11/51	2/52	Terminated - Backfilled
C	216-S-9	D-2 Process Condensate	9,000	7/65	1/69	Terminated
D	216-S-10	Ditch to S-11 Pond	13,500	2/54	-	Active
Pd	216-S-10	202-S Chemical Waste Pond	5 acres	5/54	7/72	Inactive
Pd	216-S-11	202-S Chemical Sewer Pond	1/5 acres	5/54	-	Active
T	216-S-12	291-S Stack Wash Water	1,800	7/54	7/54	Terminated - Backfilled
C	216-S-13	Organic Waste and 204-S Sump Waste	1,300	1/52	7/72	Inactive
T	216-S-14	Organic Startup Waste	800	12/51	1/52	Terminated - Backfilled
Pd	216-S-15	241-S TK 110 Condensate	175	12/51	10/52	Terminated - Backfilled
D	216-S-16	Process Cooling Water Ditch	6,300	9/56	7/72	Inactive
Pd	216-S-16	Process Cooling Water Pond #2	31 acres	9/56	-	Active
Pd	216-S-17	Process Cooling Water Pond #1	17 acres	3/52	4/54	Terminated - Covered
T	216-S-18	Steam Cleaning Pit	1,500	10/54	10/54	Terminated - Backfilled
Pd	216-S-19	222-S Cooling Water (Pond)	3.5 acres	2/52	-	Active
C	216-S-20	222-S Waste	3,600	3/52	5/73	Inactive
C	216-S-21	241-SX Condensate	2,500	11/54	12/70	Inactive
C	216-S-22	293-S Caustic Scrubber Waste	350	10/57	6/67	Terminated
C	216-S-23	Process Condensate (D-2)	3,600	1/69	7/72	Inactive
C	216-S-25	242-S Process and Steam Condensate	5,750	10/73	-	Active
T PLANT, 242-T EVAPORATOR						
D	216-T-1	Steam Heater Condensate - Ditch	5,475	11/44	-	Active
RW	216-T-2	222-T Lab Waste	3 in. diam	1/45	5/50	Terminated
RW	216-T-3	224-T and 5-6 Waste	8 in. diam	6/45	8/45	Terminated
D	216-T-4	Cooling Water Ditch	6,800	11/44	-	Active
Pd	216-T-4	Cooling Water Pond	2.5 acres	11/44	-	Active
T	216-T-5	2nd Cycle and 112-T Waste	500	5/55	5/55	Terminated
C	216-T-6	224-T and 5-6 Waste	1,260	8/46	6/51	Terminated
C	216-T-7	224, 5-6, and 2nd Cycle Waste	26,200	4/48	11/55	Terminated
C	216-T-8	222-T Lab Waste	1,260	5/50	9/51	Terminated
T	216-T-9	Equip. Decontamination Waste (Trench)	500	2/51	3/54	Terminated - Backfilled
T	216-T-10	Equip. Decontamination Waste (Trench)	500	6/51	3/54	Terminated - Backfilled
T	216-T-11	Equip. Decontamination Waste (Trench)	500	6/51	3/54	Terminated - Backfilled
Pt	216-T-12	Retention Basin Sludge (Pit)	150	11/54	11/54	Terminated - Backfilled
Pt	216-T-13	Equipment Decontamination Pit	400	6/54	6/64	Terminated - Backfilled
T	216-T-14	1st Cycle Supernate Waste (221-T)	2,200	1/54	1/54	Terminated - Backfilled
T	216-T-15	1st Cycle Supernate Waste (221-T)	2,400	1/54	2/54	Terminated - Backfilled
T	216-T-16	1st Cycle Supernate Waste (221-T)	2,400	2/54	2/54	Terminated - Backfilled
T	216-T-17	1st Cycle Supernate Waste (221-T)	2,400	2/54	6/54	Terminated
Pt	216-T-18	Scavenged Waste Supernatant (221-T)	100	11/53	11/53	Terminated - Backfilled
C	216-T-19	242-T Process & Steam Condensate	33,200	9/51	-	Active
Pt	216-T-20	155 TX Catch Tank Waste (Pit)	100	11/52	11/52	Terminated - Backfilled
T	216-T-21	1st Cycle Supernate Waste (221-T)	2,400	6/54	8/54	Terminated - Backfilled
T	216-T-22	1st Cycle Supernate Waste (221-T)	2,400	7/54	8/54	Terminated - Backfilled
T	216-T-23	1st Cycle Supernate Waste (221-T)	2,400	7/54	8/54	Terminated - Backfilled
T	216-T-24	1st Cycle Supernate Waste (221-T)	2,400	8/54	8/54	Terminated - Backfilled
T	216-T-25	242-T Evaporator Bottoms	1,800	9/54	9/54	Terminated - Backfilled
C	216-T-26	Scavenged Waste Supernatant (221-T)	900	8/55	11/56	Terminated - Backfilled
C	216-T-27	300 Area LOB Waste	900	9/65	11/65	Terminated
C	216-T-28	221-T Decontamination Waste	900	2/60	12/66	Terminated
FD	216-T-29	Sand Filter Drains	5,280	3/49	3/64	Inactive

TABLE II.1-C-4 (Continued)

Type of Construction	Number	Description	Bottom Area ft ²	Use Dates		Status
				From	To	
FD	216-T-30	TK-154 Diversion Box Spill	14,400	7/53	7/53	Terminated - Covered
C	216-T-31	241-TX French Drain	36 in. diam	10/54	2/62	Terminated - Replaced
C	216-T-32	224 T Waste	950	11/46	5/52	Terminated
C	216-T-33	2706-W Building Waste	150	1/63	2/63	Terminated
C	216-T-34	300 Area Waste	6,000	5/66	3/67	Terminated
C	216-T-35	300 Area Waste	4,500	3/67	12/67	Inactive
C	216-T-36	221-T, 221-U Miscellaneous Waste	1,600	6/67	12/68	Inactive
U PLANT						
C	216-U-1	224-U Waste	196	3/52	6/67	Terminated
C	216-U-2	Overflow from U-1	196	3/52	6/67	Terminated
FD	216-U-3	241-U TK 110 Condensate	72 in diam	5/54	8/55	Terminated
RW	216-U-4, 4A, 4B	222-U Laboratory Waste	6, 36 and 36 in. diam	3/47	7/70	Terminated
T	216-U-5	Startup Waste - 221-U	400	3/52	3/52	Terminated - Backfilled
T	216-U-6	Startup Waste - 221-U	750	3/52	3/52	Terminated - Backfilled
FD	216-U-7	221-U Counting Box Floor Drainage	30 in. diam	3/52	6/57	Terminated
C	216-U-8	221-U, 224-U Process Condensate and 291-U Stack Drainage	8,000	6/52	4/60	Terminated - Replaced by U-12
D	216-U-9	Cooling Water and Chemical Waste Ditch (U-10 Pond Overflow)	19,800	3/52	4/54	Terminated - Backfilled
Pd	216-U-10	Cooling Water and Chemical Waste Pond	22 acres	7/44	--	Active
D	216-U-11	Overflow from U-10 Pond (Old Ditch)	9,000	11/44	7/55	Terminated - Backfilled
D	216-U-11	Overflow from U-10 Pond (New Ditch)	17,200	7/55	--	Active
C	216-U-12	224-U Process Condensate and 291-U-1 Stack Drainage	1,000	4/60	--	Active
T	216-U-13	241-UR Steam Cleaning Waste	8,000	3/52	3/56	Terminated - Backfilled
D	216-U-14	Laundry Ditch to U Pond	44,800	7/44		Active
Pt	216-U-15	Contaminated Solvent (Pit)	400	5/55	5/55	Terminated - Backfilled
Z PLANT						
D	216-Z-1	231-Z, 234-5 Cooling Water Ditch	17,000	12/44	3/59	Terminated - Backfilled
C	216-Z-1	D-6 Waste	196	6/49	4/69	Terminated
C	216-Z-1A	Overflow from Z-1, 2 and 3	26,000	6/49	3/59	Replaced by Z-12
		Reclamation Waste		6/64	4/69	Terminated
C	216-Z-2	D-6 Waste	196	6/49	6/52	Replaced by Z-3
		Reclamation Waste		6/52	5/66	Terminated
C	216-Z-3	D-6 Waste	350	6/52	3/59	Replaced by Z-12 - Terminated
Pt	216-Z-4	231-Z Lab Waste	100	6/45	6/45	Terminated - Backfilled
C	216-Z-5	231-Z Proc. Waste	1,120	6/45	2/47	Replaced by Z-7 Terminated
C	216-Z-6, 6A	231-Z Proc. Waste	300	6/45	6/45	Terminated
C	216-Z-7	231-Z Lab Waste**	1,400	2/47	2/67	Terminated
FD	216-Z-8	Recuplex Waste	36 in. diam	7/55	4/62	Terminated
C	216-Z-9	Recuplex CAW Waste	1,800	7/55	6/62	Terminated
RW	216-Z-10	231-Z Waste	6 in. diam	2/45	6/45	Replaced by Z-5 Terminated
D	216-Z-11E	Cooling Water Ditch	10,680	6/49	5/71	Terminated - Backfilled
C	216-Z-12	D-6 Waste	6,000	3/59	5/73	Inactive
FD	216-Z-13	234-5 Tunnel Drain	36 in. diam	6/49		Active
FD	216-Z-14	Evaporator Cond. Water	36 in. diam	6/49		Active
FD	216-Z-15	Evaporator Cond. Water	36 in. daim	6/49		Active
C	216-Z-16	231-Z (BNW) Process waste	1,800	3/68		Active
T	216-Z-17	231-Z Ditch	3,000	2/67	2/68	Terminated - Backfilled
C	216-Z-18	High Salt Waste	10,350*	4/69	5/73	Inactive
C	216-Z-19	234-5, 231-Z Cooling Water and Condensate	10,700	5/71		Active

* 5 cribs in parallel; two not used

** 2 cribs in parallel

C - crib

Pd - pond

Pt - pit

D - ditch

T - trench

FD - french drain

RW - reverse well

TABLE II.1-C-5

200 EAST AREA
DRY RADIOACTIVE WASTE BURIAL GROUNDS

<u>Number</u>	<u>Description</u>	<u>Burial Ground Designation</u>	<u>Status</u>
218-E-1	Dry Waste Burial Grounds	1	Inactive
218-E-2	Industrial Burial Grounds	2	Inactive
218-E-2A	Regulated Equipment Storage Site	2A	Inactive
218-E-4	Minor Construction Burial Grounds	4	Active
218-E-5	Industrial Burial Grounds	5	Inactive
218-E-5A	Industrial Burial Grounds	5A	Inactive
218-E-7	Vault (Behind 222-B)		Inactive
218-E-8	Construction Waste Burial Grounds		Inactive
218-E-9	Regulated Equipment Storage Site		Active
218-E-10	Industrial Waste Burial Grounds		Active
218-E-12A	Dry Waste Burial Grounds (North)	12	Active
218-E-12B	Dry Waste Burial Grounds (South)	12B	Active
218-E-13	Solid Waste Disposal Site (Contaminated Concrete)		Inactive
218-E-14	Failed Equipment Disposal Tunnel (Purex)	1	Inactive
218-E-15	Failed Equipment Disposal Tunnel (Purex)	2	Active

TABLE II.1-C-6

200 WEST AREA
DRY RADIOACTIVE WASTE BURIAL GROUNDS

<u>Number</u>	<u>Description</u>	<u>Burial Ground Designation</u>	<u>Status</u>
218-W-1	Dry Waste Burial Grounds	1	Inactive
218-W-1A	Industrial Waste Burial Grounds	1	Inactive
218-W-2	Dry Waste Burial Grounds	2	Inactive
218-W-2A	Industrial Burial Grounds	2	Active
218-W-3	Dry Waste Burial Grounds	3	Inactive
218-W-3A	Dry Waste Burial Grounds	3A	Active
218-W-4A	Dry Waste Burial Grounds	4A	Inactive
218-W-4B	Dry Waste Burial Grounds	4B	Active
218-W-4C	Dry Waste Burial Ground	4C	Active
218-W-7	Vault South of 222-S		Inactive
218-W-8	Vault South of 222-T		Inactive
218-W-9	Dry Waste Burial Grounds		Inactive
218-W-11	Regulated Equipment Storage Site		Active

APPENDIX II.1-C, PART 3

Details of 200 East Area Facilities and Operations

II.1-C Part 3 Details of 200 East Area Facilities and Operations

The flowchart of Figure II.1-C-3 depicts the transfer of waste generated in the Purex processing of N Reactor fuels. The fractionization of stored waste in B Plant requires the sluicing of tank farm sludges and the liquid waste transfers schematically depicted in Figure II.1-C-4.

Fuel Processing--Purex Plant

The irradiated fuel separation processes of Purex Plant yield waste streams which are routed to various processing and disposal sites. Figures II.1-C-5 and II.1-C-6 identify the waste streams produced by the Purex Plant and their destination, when Purex is both in operation and in standby status. Liquid waste lines emanating from the Purex Plant are shown in Figure II.1-C-7. They are described in Table II.1-C-7.

Waste Fractionization (B Plant), and Waste Encapsulation and Storage Facility (WESF)

The waste fractionization and encapsulation and storage activities of B Plant and WESF yield waste streams which are routed to various processing and disposal sites. Figures II.1-C-8 and II.1-C-9 identify the waste streams produced in B Plant and their destination, when B Plant is both in operation and in standby status. Figure II.1-C-10 identifies waste streams produced in the waste encapsulation storage facility.

Liquid waste lines emanating from B Plant and the WESF are shown in Figure II.1-C-11. They are described in Table II.1-C-8. Lines used in the transfer of stored waste for fractionization are shown in Figures II.1-C-12 and II.1-C-13, and are described in Tables II.1-C-9 and II.1-C-10. The 244-AR vault has an active role in waste processing and transfer operations. Input/output diagrams for vault activities are

shown in Figures II.1-C-14, II.1-C-15, and II.1-C-16 for processing current acid wastes and acidified sludge, and standby.

Boiling Waste Storage Facility Effluents

Liquid waste lines used to dispose of process condensate and condenser cooling water are shown in Figure II.1-C-17. They are described in Table II.1-C-11.

In-Tank Solidification - 200 East Area

Inter and intratank farm lines used for ITS processes in B, BX and BY tank farms are shown in Figures II.1-C-18 and II.1-C-19. The lines are described in Tables II.1-C-12 and II.1-C-13.

II.1-C-24

FIGURE II.1-C-3 TYPICAL PROCESS SOLUTION TRANSFERS 200 EAST AREA N-FUELS PROCESSING^(a)

II.1-C-25

FIGURE II.1-C-4 TYPICAL PROCESS SOLUTION TRANSFERS
200 EAST AREA - PAS PROCESSING^(a)

FIGURE II.1-C-5 PUREX PLANT INPUT-OUTPUT DIAGRAM
OPERATING-N-FUELS^(a)

FIGURE II.1-C-6 PUREX PLANT INPUT-OUTPUT DIAGRAM STAND BY

FIGURE II.1-C-7 ACTIVE WASTE TRANSFER LINES 202-A FACILITY PUREX PLANT

TABLE II.1-C-7

PUREX PLANT ACTIVE WASTE TRANSFER LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
1.	Current Acid Waste to B Plant via 244-AR Vault	3 in., Stainless Steel (schedule 10)	Not Required	Concrete	8 to 20	7 to 23
2.	High-Level Waste B Plant to AY and AZ Tanks via 244-AR Vault	3 in., Stainless Steel (schedule 10)	Not Required	Concrete; with Line #1	5 to 20	0 to 23
3.	Process Condensate to 216-A-10 Crib	8 in., Stainless Steel (schedule 5)	Yes	No	25	11
4.	Steam Condensate to 216-A-30 Crib	16 in., Steel (schedule 40)	Not Required; Coated and wrapped	No	5 to 25	5 to 19
5.	NH ₃ Scrubber Waste to 216-A-36B Crib	6 in., Stainless Steel	Yes	No	11 to 21	9
6.	216-A-2 Catch Tank into Purex	4 in., Stainless Steel (schedule 10)	Yes	No	4 to 20	6 to 19
7.	Cooling Water to 216-A-25 (Gable Mt.) Pond	30 in., Steel (schedule 30); 30 in. extra-strength vitreous clay; 30 to 42 in. 14 gauge corrugated metal	Not Required	No	2 to 13	16

TABLE II.1-C-7

(Continued)

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
8.	Chemical Sewer to 216-B-3 Pond	12 in., Vitreous Clay	Not Required	Concrete; Partial	6 to 13	19
9.	Decladding Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
10.	Organic Wash Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
11.	Sump Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
12.	Lab. Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
13.	C Farm Tank 104 to 241-C-151 Diversion Box (nonboiling waste)	3 in., Stainless Steel (schedule 40)	Yes	No	2 to 12	3
14.	Nonboiling Waste, 241-C-151 to 241-B-154 Diversion Boxes	3 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 10	27
15.	Process Condensate Sample Pit to 216-A-5 Trench Drain	4 in., Stainless Steel (schedule 40)	Yes	No	34	20

FIGURE II.1-C-8 WASTE FRACTIONIZATION - B PLANT PROCESS INPUT-OUTPUT DIAGRAM (OPERATING)^(a)

FIGURE II.1-C-9 WASTE FRACTIONIZATION - B PLANT PROCESS INPUT-OUTPUT (STAND BY) DIAGRAM

FIGURE II.1-C-10 ENCAPSULATION-225-B INPUT-OUTPUT DIAGRAM

FIGURE II.1-C-11 ACTIVE WASTE TRANSFER LINES 221-B FACILITY AND 225-B ENCAPSULATION FACILITY

TABLE II.1-C-8

B PLANT ACTIVE WASTE TRANSFER LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
1.	Process Condensate Sample Tank to 216-B-12 Crib	4 in., Steel (schedule 40), and 4 in., Fiberglass	Not Required, coated and wrapped	No	3 to 13	5 to 8
2.	Steam Condensate Sample Tank to 216-B-55 Crib	6 in., Steel (schedule 40)	Not Required, coated and wrapped	No	4 to 9	8
3.	5 Lines: B Plant Condensates to Sample Tanks of #1 and #2	3 in., SS (sch. 40)-2 4 in., SS (sch. 40)-2 3 in., SS (sch. 10)-2	Yes	No	5	8
4.	2 Lines: High-level Wastes to and from 244-AR Vault (Purex Table #1 and #2)	3 in., Stainless Steel (schedule 10)	Not Required	Concrete	4 to 20	0 to 23
5.	Ion Exchange Waste: 241-BX-154 to 241-BX-155 Diversion Boxes	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Not Required	Concrete	8 to 12	26

TABLE II.1-C-8

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
6.	Ion Exchange Waste: 241-BX-155 to 241-BX-153 Div. Box, to BX Farm Tank 104	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No*	10 to 21	27
7.	Chemical Sewer to 216-B-63 Trench	6 to 15 in. Vitreous Clay; Acid Proof Joints	Not Required	No	5.5 to 15.5	1 to 25
8.	Cell 23 Bottoms to B Farm Tank 101 via 241-B-154 and 241-B-151 Diversion Boxes	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No*	5 to 22	24 to 27
9.	High-risk Cooling Water to 216-B-3 Pond via 207-B Retention Basin	6 in., Steel (sch. 40); 8 to 12 in., Steel (sch. 20); 14 in., Steel (sch. 10); 15 in., Extra Strength Vitrified Clay	Not Required, Coated and wrapped	No	4 to 14	7
10.	Low-risk Cooling Water to 216-B-3 Pond via 207-B Retention Basin	24 in., Cast Iron; 24 and 30 in., Vitreous Clay	Not Required	No	4 to 18	24

*To be replaced with encased line

TABLE II.1-C-8

(Continued)

<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
11. 2 Lines; 241-C-151 to 241-B-154 Diversion Boxes (Purex Table #14)	3 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 10	27
12. 241-B-154 to 241-B-152 to 241-BX-153 Diversion Boxes	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	10 to 14	27
13. 241-BX-153 and 241-BYR-152 Diversion Boxes to BX Farm Tank 103	3 in., Steel (sch. 40); 6 in., Steel (sch. 80)	Not Required; coated and wrapped	Concrete, Partial	3 to 10	7 to 22
14. Tank Farm Supernatant from 241-B-154 Diversion Box	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 12	24

FIGURE II.1-C-12 ACTIVE WASTE TRANSFER LINES 244-AR VAULT FACILITY TRANSFERS OF TANK FARM SUPERNATANTS

II.1-C-39

FIGURE II.1-C-13 ACTIVE WASTE TRANSFER LINES 244-AR VAULT FACILITY SLUDGE SLUICING

TABLE II.1-C-9

ACTIVE TANK FARM SUPERNATANT TRANSFER LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
1.	Sluicing Supernatant A Farm Tank 104 to 241-AY-151 Diversion Box	3 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 9	4
2.	Sluicing Sup., 241-AY-151 to AX Farm Tank 103	3 and 4 in., Steel (schedule 10)	Not Required	Concrete; Galvanized Corrugated 16 ga. metal	5 to 21	10 to 11
3.	Centrifuge Sup., A Farm Tank 101 to Tank 104	4 in., Steel (schedule 80)	Not Required; coated and wrapped	No	3 to 8	20
4.	AX Farm Tank 103 to 241-C-151 Diversion Box	3 in., Steel (schedule 40)	Yes	No*	5 to 11	6
5.	241-C-151 Diversion Box to C Farm Tank 105	3 in., 18-8 Columbian Stainless Steel; 3 in., SS (sch. 10)	Yes	No	2 to 13	3
6.	C Farm Tank 105 to 241-C-152 Diversion Box	3 in., Stainless Steel (schedule 40)	Yes	No	2 to 13	3

*To be replaced with encased lines

TABLE II.1-C-9

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
7.	241-C-152 Diversion Box to B Plant Via 241-B-154 Diversion Box	3 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 10	27
8.	Alternate Line; A Farm Tank 101 to C Farm Tank 105 via 241-C-151 Diversion Box	2 in., Steel (schedule 40)	Yes	No*	3 to 7.5	10

*
To be replaced with encased lines

TABLE II.1-C-10

ACTIVE 244-AR VAULT SLUDGE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	4 Lines: A Farm via 241-A-153 diversion box, and AX Farm via 241-AY-152 sluice transfer box	6 in., Steel (schedule 40)	Yes	No	4 to 14	7
2.	A Farm, from Tanks 102, 103, 106 to #1 Above	6 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 8.5	7
3.	AX Farm, from Tanks 101, 103, 104 to #1 Above	6 in., Steel (schedule 40)	Not Required; coated and wrapped	Concrete	2 to 3.5	<1
4.	Acidified Sludge to B Plant via 241-AX-151 Diverter Station and 244-CR Vault	3 and 4 in., Stainless (schedule 10); 2, 3 and 3.5 in., SS (schedule 40)	Partial	Concrete; Partial	4 to 19	7 to 23
5.	Sluicing Supernatant to A Farm Tank 104	3 and 4 in., Stainless (schedule 10)	Yes	Concrete; Partial*	5 to 17	7 to 10

* Direct burial portion of line will be replaced with encased line

TABLE II.1-C-10

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
6.	Centrifuge Waste, B Plant to A Farm Tank 101 via Vault and 241-AX-151 Diversion Box	3 to 4 in., Stainless (schedule 10) 3.5 in. Stainless	Partial	Concrete; Partial	4 to 20	0 to 23
7.	Cooling Water and Steam Condensate to 216-A-25 (Gable Mt.) Pond	2, 3 and 6 in. Steel; 12 in., Concrete	Not Required; coated and wrapped	No	5 to 16	7

FIGURE II.1-C-14 244-AR VAULT INPUT-OUTPUT DIAGRAM CAW PROCESSING (a)

FIGURE II.1-C-15 244-AR VAULT INPUT-OUTPUT DIAGRAM PAS PROCESSING (a)

FIGURE II.1-C-16 244-AR VAULT INPUT-OUTPUT DIAGRAM
STAND BY

II.1-C-47

FIGURE II.1-C-17 ACTIVE WASTE TRANSFER LINES A, AX AND AY TANK FARM PROCESS CONDENSATES AND COOLING WATER

TABLE II.1-C-11

TANK FARMS A, AX AND AY: ACTIVE WASTE TRANSFER
LINES FOR PROCESS CONDENSATES AND COOLING WATER

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Proc. Cond. from Condensers to Receiver and Pump Tank 241-A-TK-417	6 in., Steel (schedule 80)	Not required; coated and wrapped	no	14 to 16	16
2.	241-A-TK-417 to 241-AY-501 Valve Pit	2 and 3 in., Steel (schedule 40)	Not required; coated and wrapped	No	6 to 12	5 to 11
3.	241-AY-501 to AY Farm Tanks 101 and 102	2 in., Steel (schedule 40)	Not required; coated and wrapped	No	10 to 12	5
4.	241-AY-501 to AX Farm Tanks 101, 102, 103 and 104	2 and 4 in., SS (schedule 10)	Not required	Concrete	10 to 20	5 to 11
5.	241-A-TK-417 to Ion Exchange Column	2 in., Steel (schedule 40)	Not required; coated and wrapped	No	3 to 9	4
6.	241-A-TK-417 Overflow and Ion Exchange Column to Sampler Pit #2	2 in., Steel (sch. 40); 6 in. Steel (sch. 30)	Not required; coated and wrapped	No	3 to 16	4 to 15

TABLE II.1-C-11

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
7.	Cooling Water: Condensers to 216-A-25 (Gable Mt.) Pond	21 in., 16 gauge galvanized Corrugated (asphalt coated) metal	Not required; coated	Concrete under roadways	11 to 37	16
8.	Condensate; Sampler Pit #2 to 216-A-8 Crib	16 in., Steel (schedule 20)	Not required; coated and wrapped	Concrete under road	4 to 7	18

FIGURE II.1-C-18 ITS NO. 1 AND ITS NO. 2 ACTIVE WASTE LINES INTERFARM TRANSFERS

FIGURE II.1-C-19 ITS NO. 1 AND ITS NO. 2 WASTE COOLING WATER PROCESS CONDENSATES AND DRAINS

TABLE II.1-C-12

ITS NO. 1 AND 2 ACTIVE INTERFARM WASTE TRANSFER LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>(years)</u>
1.	BX Farm Tank 105 to BY Farm Tank 101 BX Farm Tanks 105 to 106, 110 to 111, BY Farm Tanks 101 to 104 (Project 641)	3 in., Steel (schedule 40)	Not required; insulated	No	3 to 9	5
2.	BY Farm Tanks 107 to 104 to 105 to 103 to 106 to 109 (Project 646)	3 in., Steel (schedule 40)	Not required; insulated	No	3 to 9	3
3.	B Farm Tank 109 to BX Farm Tank 105; BX Farm Tank 112 to BY Farm Tank 110; B Farm Tanks 112 to 108 to 102 to 103 to 106 to 109 to 108; BX Farm Tanks 110 to 108 to 106, 112 to 111 (Project 657)	3 in., Steel (schedule 40)	Not required; insulated	No	3 to 8	2
4.	Salt Well Liquid in B Farm; to Tank 102 from Tanks 101, 104, 107, 110	2 in., Steel (schedule 40)	Not required; insulated	No	4 to 6	1

TABLE II.1-C-12

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
5.	BY Farm Tanks 102 to 105; B Farm Tanks 101 to 105	3 in., Steel (schedule 40)	Not required; insulated	No	2 to 5	1
6.	BY Farm Tanks 108 to 109 to 112	3 in., Steel (schedule 40)	Not required; insulated	No	1.5 to 3	6
7.	BY Farm Tanks 111 to 110 to 107 to 108	3 in., Steel (schedule 40)	Not required; insulated	No	1 to 3.5	5
8.	BY Farm Tanks 102 to 111	3 in., Steel (schedule 40)	Not required; insulated	No	1 to 2	1
9.	BY Farm Tanks 112 to 111	1.5 in., Steel (schedule 40)	Not required; insulated	No	4	8
10.	BX Farm Tanks 108 to 109 (Phosphoric Acid Solidification Process Prototype)	2 in., Steel (schedule 40)	Not required; insulated	No	3	1

TABLE II.1-C-13

ITS NO. 1 AND 2 ACTIVE WASTE TRANSFER LINES FOR
PROCESS CONDENSATES AND COOLING WATER

Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1. Condensate from Tank Exhausters to BY Farm Tank 109; B Farm-2 Exhausters BX Farm-2 Exhausters BY Farm-1 Exhauster	1.5 and 2 in., Steel (schedule 40)	Not Required; coated and wrapped	No	2 to 6	2 to 7
2. Condensate from one BY Farm Exhauster and ITS #2 to Ion Exchange Unit	1 and 2 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 7	1 to 9
3. Condensate from ITS #1 to Ion Exchange Unit	2 in., Steel (schedule 40)	Not Required; insulated	No	Above Ground (5 feet)	6
4. ITS #1 Condenser Cooling to 216-B-3 Pond via 207-B Retention Basin	4 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 5	6
5. ITS #2 Condenser Cooling to 216-B-3 Pond via 241-BYR-154 Diversion Box	6 in., Steel (schedule 80 and schedule 40)	Not Required; coated and wrapped	Concrete; Partial	3	10

TABLE II.1-C-13

(Continued)

<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
6. Condensate Processed by Ion Exchange Unit to 216-B Cribs	2 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3	10

APPENDIX II.1-C, PART 4

Details of 200 West Area Facilities and Operations

II.1-C Part 4 Details of 200 West Area Facilities and Operations

The Typical Process Solution Transfers within 200 West Area are shown in Figure II.1-C-20. The interarea transfer line is shown in Figure II.1-C-21.

Plutonium Processing--Z Plant

Plutonium processing operations of Z Plant (including scrap reclamation, chemical conversion and finishing operations) produce waste streams which are routed to various processing and disposal sites. Figures II.1-C-22 and II.1-C-23 identify the waste streams produced by Z Plant and their destination when Z Plant is both in operation and standby status. Liquid waste lines emanating from Z Plant⁶ are shown in Figure II.1-C-24 and described in Table II.1-C-14.

Uranium Processing--UO₃ Plant

Calcining uranyl nitrate hexahydrate (UNH) solution to produce uranium trioxide (UO₃) produces waste streams which are routed to various processing and disposal sites. Figure II.1-C-25 and II.1-C-26 identify the waste streams produced by the UO₃ Plant (224 U) and their destination, when the plant is both in operation and in standby status. Liquid waste lines emanating from the UO₃ plant and the adjacent U Plant facilities are shown in Figure II.1-C-27 and described in Table II.1-C-15.

222-S Laboratory - REDOX

Laboratory operations yield waste streams of varying types which are routed to waste management facilities. Figure II.1-C-28 shows liquid waste lines emanating from the laboratory and their destination. The lines are described in Table II.1-C-16. Lines for unloading and transfer of liquid waste received from the 100 and 300 Areas are also shown and described in the above figure and table.

Decontamination--T Plant, Laundry and Mask Station

Active decontamination and laundry waste lines are shown in Figure II.1-C-29, and are described in Table II.1-C-17.

Evaporation/Solidification - 200 West Area

Tank farm operations, including waste solidification facilities 242-T and 242-S, produce waste streams which are routed to various processing and disposal sites. Figures II.1-C-30 and II.1-C-31 show the waste and transfer lines and are further described in Table II.1-C-18. Figure II.1-C-32 shows the details of the 242-S evaporator and associated tank farm waste transfer lines and are further described in Table II.1-C-19.

FIGURE II.1-C-20 TYPICAL PROCESS SOLUTION TRANSFERS,
200 WEST AREA

Material of Construction: 3 in. stainless tubing per ASTM
A-269-47 Type 347, 3.5 in. O.D.
0.120 in. wall

Cathodic Protection: Yes

Secondary Containment: Concrete encased

Buried Depth: 5.5 to 16 ft

Age: 23 yr

FIGURE II.1-C-21 200-E AND 200-W TRANSFER LINES

FIGURE II.1-C-22 "Z" PLANT INPUT-OUTPUT DIAGRAM OPERATING^(a)

II.1-C-63

FIGURE II.1-C-23 "Z" PLANT INPUT-OUTPUT DIAGRAM STAND BY

FIGURE II.1-C-24 Z PLANT

TABLE II.1-C-14

Z PLANT ACTIVE WASTE TRANSFER LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
1.	High Salt Waste from 234,5-Z to 242-TA Tank R-1	2 in., Stainless Steel (2)	Yes	Concrete	3.5 to 5	1
2.	234,5-Z Cooling Water, Condensate and Chemical Sewer to 216-Z-19 Ditch	15 in., Vitrified Clay (2)	No	No	3.5 to 6	12
3.	231-Z Cooling Water, Condensate and Chemical Sewer to 216-Z-19 Ditch	8 in., Vitrified Clay; 10 in., Wrought Iron	No	No	3.5 to 8	8
4.	231-Z Process Waste to 216-Z-16 Crib	3 in., Stainless Steel (3); 3 in. and 4 in., PVC	No	No	3.5 to 18	6

FIGURE II.1-C-25 UO₃ PLANT INPUT-OUTPUT DIAGRAM OPERATING(a)

II.1-C-67

FIGURE II.1-C-26 UO_3 PLANT INPUT-OUTPUT DIAGRAM STANDBY

II.1-C-68

FIGURE II.1-C-27 UO_3 PLANT AND U PLANT FACILITIES

TABLE II.1-C-15

U PLANT AND UO₃ PLANT ACTIVE WASTE TRANSFER LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age) (years)</u>
1.	Decontamination Solutions from 221-U to U Farm Tank 107 via Diversion Boxes 241-UX-154, 241-TX-155, 241-U-152 and 153 (Also for T Plant Waste)	3 in., Stainless Steel (11 gauge)	Partial	Concrete	8 to 18	25
2.	224-U Process Cooling Water to 216-U-14 Ditch via 207-U Retention Basins	24 in., Vitrified Clay	Not Required	No	6 to 17	20
3.	291-U Stack Drain to 241-UR-154 Diversion Box, to Tie-in from 224-U;	3.5 in., Stainless Steel (schedule 40)	Yes	Partial	4 to 8	20 to 22
4.	Also 224-U Process Condensate to Tie-in Point for 216-U-12 Crib Line					
3,4.	Tie Point (Above) to 216-U-12 Crib	6 in., Vitrified Clay	Not Required	No	4 to 19	14 to 20

FIGURE II.1-C-28 REDOX PLANT AND 222-S LABORATORY

TABLE II.1-C-16

222S-REDOX PLANT ACTIVE WASTE TRANSFER LINES

<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
1. Process Waste from 222-S Lab. to 240-S-151 Diversion Box via 219-S and 202-S Buildings (to U Farm as Above)	3 in., 11 gauge Stainless; 3 in., Steel (sch. 80)	Yes	Concrete	2.5 to 23	22
2. Railroad Tank Car Waste to U Farm Tank 107 via 204-S Tanks Pump and Diversion Boxes 240-S-152, 151 and 241-U-153	2 and 3 in. Stainless Steel (schedule 40); 3 in., Steel (sch. 80)	Yes	Yes	3 to 25	3 to 23
3. Waste Water from 222-S Lab. to 216-S-19 Pond via 207-L Retention Basins	8 in., Vitrified Clay	Not Required	No	3.5 to 12.5	22
4. Waste Water from 202-S and High Tank Overflow to 216-S-10 Pond	12 in., Vitrified Clay	Not Required	No	3.5 to 19	23
5. Stack Drain Line to the 202-S Bldg.	3 in., Stainless Steel (sch. 40)	Yes	Concrete	4 to 12	23

II.1-C-72

FIGURE II.1-C-29 T PLANT, LAUNDRY AND MASK STATION

TABLE II.1-C-17

T PLANT, LAUNDRY AND MASK STATION ACTIVE WASTE LINES

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
1.	Neutralized Decontamination Waste from 221-T to U Farm Tank 107 via Diversion Boxes 241-TX-154, 155 and 241-U-152, 153 (Also for U Plant Waste)	3 in., 11 gauge Stainless Steel	Partial	Concrete	8 to 18	25
2.	Waste Water from 2724-W Laundry and 2773-W Mask Cleaning to 216-U-14 Ditch	8 and 10 in. Vitreous Clay; 24, 36 and 42 in. Concrete	No	No	3.5	29
3.	Stack Condensate from 291-T	3.5 in., 11 gauge Stainless Steel	Yes	Concrete	4	30

II.1-C-74

FIGURE II.1-C-30 T FARM AND EVAPORATOR LINES

II.1-C-75

FIGURE II.1-C-31 S, SX AND U FARMS AND EVAPORATOR ACTIVE WASTE LINES

TABLE II.1-C-18

EVAPORATOR AND TANK FARM ACTIVE WASTE LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Cooling Water from 242-T Evaporator to 216-T-4 Pond via 207-T Retention Basins	4 in. Steel (schedule 40)	No	No	3 to 7	20
2.	Process Condensate from 242-T Evaporator to 216-T-14 Crib via 241-TX-153 Diversion Box	3.5 in. Stainless Steel; 3 in. Steel	Yes	No	3.5 to 18	18
3.	Cooling Water from 242-S Evaporator to 216-U Pond via 216-U-14 Ditch	24 in. Corrugated Metal, Zinc Coated	No	No	3.5 to 8	1
4.	Process Condensate from 242-S Evaporator to 216-S-25 Crib	4 in. Steel (schedule 40)	No	No	3.5 to 8	1
5.	Process Waste Transfer Between S and SX Farms Diversion Box 241-S-151 and U Farm Box 241-U-152	3 in. Stainless Steel (18-8 Columbian)	Yes	Concrete	7 to 20	20

TABLE II.1-C-18

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
6.	East Area Neutralized High-Level Waste to S and SX Farms for Evaporator Feed via Diversion Boxes 241-UR-154, 241-S-151 and 241-SX-151	3 in. Stainless Steel (2) (schedule 10)	No	Concrete	3 to 18	2
7.	242-S Evaporator Supernate Feed from 241-S-02A Pump Pit; Also Slurry Discharge to S Tank Farm	2 and 3 in. Steel (schedule 40)	No	No	3 to 4	1
8.	Condenser Cooling Water, SX Farm to 216-U-10 Pond	8 in. Steel (schedule 40)	No	No	3.5 to 5	19

II.1-C-78

FIGURE II.1-C-32 242-S EVAPORATOR ACTIVE WASTE LINES

TABLE II.1-C-19

242-S EVAPORATOR AND ASSOCIATED TANK FARM WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Slurry transfer line network from 242-S to Tanks 241-S-101 through 241-S-112 via valve pits 241-S-A, B, C & D.	2 in. Carbon Steel (schedule 40, Insulated)	No	No	3 to 4	1
2.	Supernate transfer line network from Tanks 241-S-101 through 241-S-112 to 242-S via valve pits 241-S-A, B, C & D.	3 in. Carbon Steel (schedule 40, Insulated)	No	No	3 to 4	1
3.	Emergency slurry dump transfer line from 242-S Evaporator to the 241-S-103 tank	10 in. Carbon Steel (schedule 40, Insulated)	No	No	7	1

II.1-C-79

TABLE II.1-C-19

(Continued)

	<u>Function</u>	<u>Description</u>	<u>Cathodic Protection</u>	<u>Secondary Containment</u>	<u>Buried Depth (feet)</u>	<u>Age (years)</u>
4.	Process condensate diversion transfer line from the 242-S Evaporator to the 241-S-103 Tank. Floor drain waste is also routed to the 241-S-103 tank via this line.	6 in. Carbon Steel (schedule 40, Insulated)	No	No	7	1
5.	Steam condensate diversion transfer line from 242-S to the 241-S-103 tank. Sump drainage from 242-S is also routed to the 241-S-103 tank via this line.	10 in. Carbon Steel (schedule 10, coated and wrapped)	No	No	7	1

APPENDIX II.1-C, PART 5
Radioisotopes Stored Beneath Selected 200 Area Cribs

II.1-C Part 5 Radioisotopes Stored Beneath Selected 200 Area Cribs

Field Study of 216-S 1 and 2 Crib Site

The most complete data regarding radionuclide migration in the vadose zone were obtained from the 216-S 1 and 2 crib site. This disposal facility consisted of two timbered cribs buried in an excavation 11 meters deep, 12 meters wide, and 30 meters long. Three monitoring wells were initially drilled through the bottom area of the excavation to a depth of 46 meters and terminated 18 meters above the regional water table.

This facility was in service from January 1952 until January 1956. During this 4-year period approximately 1.5×10^8 liters of waste liquid were discharged into the ground through the bottom area of the excavation. Contained in this liquid waste was an estimated 750,000 Ci of mixed fission products, including 3,000 Ci of ^{90}Sr and 2,000 Ci of ^{137}Cs . The crib was removed from service when the ^{137}Cs and ^{90}Sr concentrations in samples taken from the monitoring wells reached predetermined limits.

Field Evaluations Following Termination of the 216-S 1 and 2 Crib Site

Early in 1956, following the termination of discharges to the 216-S 1 and 2 crib site, an exploratory field study was undertaken to determine the spatial distribution of radionuclides in the underlying sediments. An evaluation of the field data and results from radiochemical analyses of the sediments cored from these wells was made.

Three of the shallow wells located at this site were deepened and six additional research wells were drilled through the contaminated sediments. A special well logging program was initiated to detect possible changes in the nuclide distribution pattern with time. Well logs showing profiles of gamma activity throughout the vadose zone were obtained with a scintillation counter probe. Later, a neutron probe was incorporated into this monitoring zone in each well.

In 1956, 10 years after the first field exploration at the 216-S 1 and 2 crib site, five additional wells were drilled to determine the extent of radionuclide redistribution. The logging data indicated that very little change had occurred around the periphery of the crib site, so the main attention was focused on the sediment column directly underlying the crib excavation.

Figure II.1-C-33 shows two diagrammatic cross sections and a plan view of the 216-S 1 and 2 crib site and the associated monitoring wells. The radionuclide distribution, determined at the time the crib site was removed from service in 1956, is indicated in the upper portion of Figure II.1-C-33 and the results of the 1966 evaluation are shown in the lower portion. The isoconcentration line, selected to delineate the shape of the ^{90}Sr and ^{137}Cs contamination patterns in these two cross sections, was arbitrarily chosen at 10^{-4} μCi per gram of sediment. A schematic log of the geology beneath this area and the position of the regional unconfined water table are shown in these cross sections.

The upper cross section depicts the 1956 results. The approximate degree of lateral spreading of liquids is indicated by the ^{106}Ru isoconcentration line at the 10^{-4} $\mu\text{Ci/g}$ value. Very little lateral spreading of the long-lived radionuclides had taken place, strontium and cesium being detected in only three of the wells (299-W22-11, -15, and -18) drilled adjacent to this crib site at distances up to 35 meters. The contamination pattern in the sediment column immediately beneath the excavated crib site was determined from the 46 meter depth downward by deepening the three original wells. Radiochemical analyses of sediment samples removed from the bottom of the wells showed both ^{90}Sr and ^{137}Cs present in concentrations above 10^{-4} $\mu\text{Ci/g}$. There was some doubt as to whether this activity resulted from radionuclide migration through the sediment column or from channeling of the liquid waste down well casings. From this investigation it was concluded that the bulk of the long-lived fission products were contained in the sediments underlying the crib excavation to a depth of about 15 meters.

FIGURE II.1-C-33 RADIONUCLIDE DISTRIBUTION BENEATH THE 216-S 1 AND 2 CRIB SITE FROM 1956 AND 1966 FIELD EVALUATION DATA

The lower cross section, depicting 1966 results, also shows the 10^{-4} $\mu\text{Ci/g}$ isoconcentration lines for ^{90}Sr and ^{137}Cs . By 1966, nearly all of the radionuclides with half lives of less than 1 year had decayed to concentrations below their routine analytical detection limits. Of the nuclides with half lives greater than 1 year, all were below the 10^{-4} $\mu\text{Ci/g}$ limit except where they were detected within the contaminated zones shown for strontium and cesium. Within these contaminated zones, the following maximum concentrations were noted: ^{60}Co 2×10^{-1} $\mu\text{Ci/g}$; ^{125}Sb 1×10^{-1} $\mu\text{Ci/g}$; and ^{106}Ru 9×10^{-4} $\mu\text{Ci/g}$. The concentration distribution of these nuclides followed the same general pattern as that observed for strontium and cesium.

Interpretation of Radionuclide Migration from the 216-S 1 and 2 Crib Studies

The data from these field investigations show that greater than 99.9% of the strontium and cesium curies discharged to this disposal site are contained within the first 5 to 10 meters below the bottom of the two cribs.

The lower cross section in Figure II.1-C-33 indicates that liquid waste, in draining through the sediment column, transports small yet measurable amounts of strontium and cesium downward from the zones of high concentration immediately below the cribs. The lenticular-shaped zones of strontium and cesium, designated A through E in this cross section, probably represent sedimentary interbeds with greater capacity for removing the radionuclides from the liquid waste. Figure II.1-C-34 shows the ^{137}Cs and ^{90}Sr concentration profiles in two wells drilled through the bottom area of the 216-S 1 and 2 crib site. The concentrations were determined from radiochemical analyses of the sediments cored during the drilling operation. These logarithmic graphs show that the bulk of the cesium activity is in a relatively narrow zone and that the strontium activity has built up on the sediments to concentrations above 10^{-1} $\mu\text{Ci/g}$ over a 15 meter vertical section. The letter designations on these two graphs indicate the positions of the lenticular zones shown in Figure II.1-C-33.

II.1-C-86

FIGURE II.1-C-34 ¹³⁷Cs AND ⁹⁰Sr CONCENTRATIONS PROFILES IN SEDIMENTS UNDERLYING THE 216-S 1 AND 2 CRIBS, 1966

There are two possible explanations for the higher strontium and cesium concentrations at the 46 meter depth (letter D in Figure II.1-C-33 and C-34). Perhaps liquid waste channels down the well casings to this depth, with lateral spreading taking place above the caliche horizon (CaCO_3) known to be present here. If bypassing down the well casings occurred, the contamination pattern shown in the lower cross section of Figure II.1-C-33 would actually represent the migration in two disposal sites, one on top of the other.

Zones A, B and C show the extent of migration from beneath the crib structures while zone E shows the migration from the liquid waste entering the ground at zone D. The other possibility is that the selectivity of the minerals in the sediments in this zone are significantly greater for strontium and cesium than those in the strata where the peak activities occur at positions A, B, and C. Experience at Hanford has shown that geologic strata underlying the Hanford Reservation have significantly different mineral contents. In the zone at the 46 meter depth beneath this disposal site a significant change does occur. The higher concentrations of CaCO_3 and mica in the sediments at this level could account for the strontium and cesium concentration levels measured there.

Crib Drainage

Data from the well logging program indicate that the waste liquid is draining from the vadose zone beneath this disposal site. Figure II.1-C-35 shows a plot of the gamma activity and moisture content in the ground beneath the 216-S 1 and 2 cribs between the 44 meter and 60 meter depths. A sediment log is also shown. In the 44 to 46 meter zone the sediments are predominantly sand and silt, with some gravel; below the 46 meter depth the materials are mostly coarser grained sands and gravels. The gamma profiles in this figure are for the years 1958, 1959, 1963 and 1966. The neutron logs presented are for the years 1965 and 1966. These were the only logging records available for this crib site. For convenience the neutron count rates were converted to percent moisture by volume.

Geologic Log

FIGURE II.1-C-35 LOGS FROM MONITORING WELLS AT THE 216-S 1 AND 2 CRIB SITE

II.1-C-88

Two distinct gamma peaks are shown on the 1958 profile, one at the 46 meter depth and one at the 52 meter depth. Each successive year the count rate decreased and the relative positions of the peaks moved progressively lower in the section (comparison of points 1 or 2 on the curves). The gamma data indicate that the activity recorded is predominantly ^{106}Ru , which has a 1 year half-life. This isotope is not appreciably exchanged on the sediments and provides some information on the rate of movement of the liquid through the sands and gravels.

The average rate of moisture movement downward during the period 1958 to 1959 was about 1.5 meters per year. From 1959 to 1963 the average rate dropped to about 0.9 meters per year, then from 1963 to 1966 the downward rate averaged 0.5 meters per year. Although these data are only approximate, they do show that the rates of movement appears to be decreasing with time, as would be expected. The reduction in moisture content from 1965 to 1966 amounted to about 1 percent by volume.

Less is known about other cribs on the Project. The exploratory wells drilled in 1966 and their relationships to given cribs are listed in Table II.1-C-20. The results of the drilling will be summarized here.

TABLE II.1-C-20

WASTE FACILITY EXPLORATORY WELLS

<u>Disposal Site Monitored</u>	<u>Well Number</u>	<u>Depth (feet)</u>
216-BY-1 Crib	299 E33-1A	146
216-BY-3 Crib	299 E33-2A	233
216-BY 2 & 3 Cribs	299 E33-3A	141
216-BY-4 Crib	299 E33-4A	230
216-A-5 Crib	299 E24-1A	320
216-BC-3 Crib	299 E13-3A	338
216-BC-7 Trench	299 E13-7A	100
216-BC-17 Trench	299 E13-14A	94
216-A-24 Crib	299 E26-4A	245
216-A-8 Crib	299 E25-6A	208
216-A-8 Crib	299 E25-5A	85
"B" Pond	699 43-42	154
Gable Mt. Pond	699 53-47	41
216-S-1 & 2 Cribs	299 W22-1A	202
216-S-1 & 2 Cribs	299 W22-3A	207
216-S-1 & 2 Cribs	299 W22-1B	206
216-S-1 & 2 Cribs	299 W22-11A	115
216-S-1 & 2 Cribs	299 W22-1C	206
216-S-7 Crib	299 W22-14A	212
216-S-7 Crib	299 W22-13A	212
216-T-28 Crib	299 W14-2A	205
216-S-9 Crib	299 W22-26A	216
216-S-9 Crib	299 W22-27A	215
216-Z-9 Crib	299 W15-83	100
216-Z-9 Crib	299 W15-94	95
216-Z-9 Crib	299 W15-94A	50
216-Z-12 Crib	299 W18-5A	212
216-Z-12 Crib	299 W18-5B	50
P-11 Crib	699 63-25A	50
Background	699 11-45A	100

216-BY-Cribs. The 216-BY crib site was selected for investigation because of 1) the large amount of radioactivity disposed, 2) the nature of the waste, and 3) the location of the cribs in the northern part of 200 East Area. The eight combined cribs received 3.4×10^7 liters of waste containing 4.1×10^5 gross beta Ci of U-Plant high salt scavenged waste. The waste contained 3300 Ci of ^{137}Cs and 12,900 Ci ^{90}Sr .

The highest ^{137}Cs and ^{90}Sr concentrations were detected in well 299-E33-2A. The highest concentration of ^{137}Cs was $28.7 \mu\text{Ci/g}$ at a depth of 100 feet beneath the crib (Figure II.1-C-36).

216-A-5 Cribs. The 216-A-5 crib received Purex process condensate from November 1955 to October 1961. Total disposal was 3460 gross beta Ci (mostly ruthenium). Total water disposed was 1.8×10^9 liters. Figure II.1-C-37 shows that in well 299-E24-1A, ^{137}Cs rapidly decreases from a concentration of $4.4 \times 10^{-3} \mu\text{Ci/g}$ at about 65 feet. Strontium-90 was below detection limit. Ruthenium-106 was plotted to show the soil concentration in relation to the ^{137}Cs .

216-B/C Cribs and Trenches. The 216-B/C cribs and trenches together received the greatest amount of radioactivity disposed at any one site on the Hanford Project (9.2×10^5 gross beta Ci) in 1.2×10^8 liters of tank farm and U Plant high salt scavenged waste. Of this volume, 6.01×10^5 Ci were disposed in 8×10^7 liters to trenches on a specific retention basis. Specific retention disposal relied on a long-term storage of the waste in the pore space of the soil above the water table. Disposal volumes were much less than the total pore volume of soil beneath the trenches.

Well 216-E13-3A was drilled to a depth of 339 feet at the east edge of the B/C-3 crib. Figures II.1-C-38 and C-39 show the ^{137}Cs , ^{90}Sr , ^{125}Sb , and ^{106}Ru concentrations as a function of depth detected in the well. Other wells drilled in the area of the B Cribs and trenches showed lesser amounts of ^{137}Cs and ^{90}Sr , except for 216-E13-14A where ^{137}Cs reached

FIGURE II.1-C-36 RADIOISOTOPE CONCENTRATION AS A
FUNCTION OF DEPTH, WELL E33-2A

FIGURE II.1-C-37 RADIOISOTOPE CONCENTRATION AS A
FUNCTION OF DEPTH, WELL E24-1A

FIGURE II.1-C-38 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E13-3A (^{137}Cs and ^{90}Sr)

FIGURE II.1-C-39 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E13-3A (^{125}Sb and ^{106}Ru)

0.22 $\mu\text{Ci/g}$ at 15 feet below the surface, dropping rapidly to background below 25 feet. Apparently the bulk of the long-lived radioisotopes are retained from 150 to 200 feet above the water table at the B/C location south of 200 East Area.

216-A-8 Crib. An estimated 1000 Ci of long-lived isotopes ^{137}Cs and ^{90}Sr were disposed at this crib. Two test wells were drilled near the inlet end of the crib. Only low levels of radioactive contamination were detected in the drilling samples. Cesium-137 concentrations were less than detection limits in both wells below 40 feet. Strontium-90 concentrations were less than $3 \times 10^{-4} \mu\text{Ci/g}$ at depths greater than 25 feet in both wells.

216-A-24 Crib. The waste disposed between May 1958 and December 1965 contained an estimated 519 Ci of ^{137}Cs and 80 Ci of ^{90}Sr . The highest ^{137}Cs concentration ($0.3 \mu\text{Ci/g}$) and ^{90}Sr concentration ($6.2 \times 10^{-3} \mu\text{Ci/g}$) occurred at 19 feet below the ground surface in a well drilled at the inlet end of the crib.

216-T-28 Crib. The 216-T-28 crib received a total of 41.5×10^6 liters of waste containing 5.77×10^4 gross beta Ci prior to the site investigation. A well drilled adjacent to the corner of this facility showed peak concentrations of $2.5 \times 10^{-3} \mu\text{Ci } ^{137}\text{Cs/g}$ of soil at 32 feet below the surface.

216-S-7 Cribs. This facility consisted of two 50-foot square timbered cribs operated in parallel. A replacement for the S-1 and 2 cribs, it received 3.8×10^8 liters and 2.82×10^5 gross beta Ci between January 1956 and July 1965. This waste contained approximately 3047 Ci of ^{90}Sr and 466 Ci of ^{137}Cs . A maximum ^{137}Cs concentration of $13.0 \mu\text{Ci/g}$ of soil and ^{106}Ru concentration of $18 \mu\text{Ci/g}$ of soil occurred at 21 feet below ground surface in a well drilled 25 feet from the center of the one of the cribs (Figure II.1-C-40). Strontium-90 concentration peaked at $2.7 \mu\text{Ci/g}$, also at 21 feet (Figure II.1-C-41). The isotopic

FIGURE II.1-C-40 RADIOISOTOPE CONCENTRATION AS A FUNCTION OF DEPTH, WELL W22-13A (^{137}Cs AND ^{106}Ru)

FIGURE II.1-C-41 RADIOISOTOPE CONCENTRATION AS A FUNCTION
 OF DEPTH, WELL W22-13A (${}^{90}\text{Sr}$)

concentrations dropped sharply and were less than detection limits below 150 feet. Results in a second well drilled adjacent to the other crib showed peak concentrations of ^{137}Cs at $1.5 \times 10^2 \mu\text{Ci/g}$ and ^{90}Sr of $5.8 \times 10^{-2} \mu\text{Ci/g}$ of soil. Concentrations of the isotopes beyond 150 feet beneath the surface were below detection limits.

216-S-9 Crib. The 216-S-9 crib facility was drilled after having received 2.7×10^7 liters of waste containing 9150 gross beta Ci. Two wells showed only a low level of ^{90}Sr ($\sim 1 \times 10^{-5} \mu\text{Ci/g}$) at 140 feet, with no long-lived isotopes detected below that level.

216-Z-9. 216-Z-12. Wells drilled adjacent to these facilities showed only slight alpha contamination in the soil sediments a short distance below the cribs.

Gable Mountain and B Plant Ponds. Although these wastewaters are normally uncontaminated, equipment malfunction has infrequently allowed some radiocontaminants to enter the ponds. A well drilled at the east end of B pond showed a very low ^{137}Cs concentration ($5 \times 10^{-6} \mu\text{Ci/g}$ of soil). A well drilled at the north side of Gable Mountain Pond showed no long-lived radioisotopes in the soil samples.

Inventory Estimates Above the Water Table

During 1971, the above data were used to define an empirical relationship from which the quantities of cesium and strontium in the lowermost 50 feet of the vadose zone were estimated. Forty-two cribs were identified where possible quantities of these long-lived radioisotopes might exist. The total inventory calculated for the lowest 50 feet of the vadose zone was about 2000 Ci of ruthenium and about 400 Ci of strontium plus cesium.

APPENDIX II.1-C, PART 6
Estimated Inventories 200 Area Facilities

TABLE II.1-C-21

TANK WASTE INVENTORY SUMMARY 1968-1980
(IN MILLIONS OF GALLONS)

WASTE STATUS
1968
(PEAK WASTE VOLUME)

NON-BOILING

15

EVAP. FEED 36
BOTTOMS LIQUID 8
INTERSTITIAL LIQUID 3

CURRENT
WASTE
STATUS 1972

NON-BOILING

WASTE STATUS
1976

NON-BOILING

EVAP. FEED 0
BOTTOMS LIQUID 6
INTERSTITIAL LIQUID 7

WASTE STATUS
1980

NON-BOILING

BOTTOMS LIQUID 1.5
INTERSTITIAL LIQUID 1

BOILING

TO BE PROCESSED
FOR Sr AND Cs REMOVAL

LIQUID 61
SOLID 16
TOTAL 77

BOILING

AGING 1

TO BE SLUICED
FOR Sr AND Cs
REMOVAL

LIQUID 48
SOLID 22
TOTAL 70

BOILING

AGING 1

0 GALLONS
TO BE SLUICED

LIQUID 14
SOLID 37
TOTAL 51

BOILING

AGING <1

0 GALLONS
TO BE SLUICED

LIQUID 3
SOLID 47
TOTAL 50

II.1-C-102

TABLE II.1-C-22

ESTIMATED INVENTORY AND CHARACTERISTICS OF
SOLIDS STORED IN TANKS - YEAR 1980

	<u>Salt Cake</u>	<u>High Heat Sludge (SX Farms)</u>	<u>Other Sludges</u>
Gallons (Millions)	38	0.6	8
Number of Tanks	73	7	72
Radionuclides (Ci/gal)			
^{137}Cs	0.6	5.0	0.3
^{90}Si	3×10^{-2}	50	2
^{239}Pu	4×10^{-4}	4×10^{-3}	6×10^{-4}
Average Composition (wt%)			
	<u>In Tank Solidi- fied Waste</u>	<u>Neutral- ized Acid Waste</u>	
Chemical			
NaNO_3	80	20	45
NaNO_2	4	1	7
NaOH	10	1	5
NaAlO_2	1	2	20
Na_2CO_3	2	1	10
			75
			4
			1
			-
			-

TABLE II.1-C-22

(Continued)

	<u>In Tank Solidi- fied Waste</u>	<u>Neutral- ized Acid Waste</u>	<u>High Heat Sludge (SX Farms)</u>	<u>Other Sludges</u>
Other				
(Fe, SO ₄ , PO ₄)	1	25	3	18
Water of Hydration	2	50	10	2
Bulk Density (g/cc)	1.8	1.8	2.0	2.0

II.1-C-104

TABLE II.1-C-23

ESTIMATED INVENTORIES RADIOACTIVE LIQUID WASTE
TO GROUND 200 AREAS

Decayed Through 1972 (From Startup)		200 East			
	Units	To Ponds and Ditches	To Cribs	To Specific Retention Sites	Total
Volume	(l)	.257 + 12*	.159 + 11	.103 + 09	.273 + 12
Pu	(gm)	<.660 + 03	.105 + 05	.437 + 03	.116 + 05
Beta	(ci)	.626 + 04	.624 + 05	.401 + 05	.109 + 06
⁹⁰ Sr	(ci)	.143 + 04	.147 + 05	.796 + 04	.241 + 05
¹⁰⁶ Ru	(ci)	<.332 + 02	.230 + 04	.297 + 03	.263 + 04
¹³⁷ Cs	(ci)	.428 + 03	.778 + 04	.109 + 05	.191 + 05
⁶⁰ Co	(ci)	<.345 + 02	<.129 + 03	.175 + 02	<.181 + 03
U	(kgm)	<.958 + 03	.277 + 05	.467 + 05	.754 + 05
²³³ U	(gm)	<.987 + 03	.479 + 03		<.967 + 03
Decayed Through 1972 (From Startup)		200 West			
Volume	(l)	.215 + 12	.114 + 11	.825 + 08	.226 + 12
Pu	(gm)	.850 + 04	.815 + 05	.881 + 05	.178 + 06
Beta	(ci)	.449 + 03	.259 + 05	.210 + 05	.474 + 05
⁹⁰ Sr	(ci)	<.120 + 03	.644 + 04	.150 + 03	.671 + 04
¹⁰⁶ Ru	(ci)	<.153 + 01	.887 + 02	.157 + 01	.918 + 02
¹³⁷ Cs	(ci)	<.891 + 02	.520 + 04	.108 + 05	.161 + 05
⁶⁰ Co	(ci)	<.741 + 01	<.285 + 02	.255 + 01	<.382 + 02
U	(kgm)	<.558 + 04	.361 + 05	.130 + 04	.429 + 05
²³³ U	(gm)				
Decayed Through 1972 (From Startup)		Total 200E + 200 W			
Volume	(l)	.12 + 12	.72 + 10	.185 + 09	.499 + 12
Pu	(gm)	.916 + 04	.920 + 05	.885 + 05	.190 + 06
Beta	(ci)	.671 + 04	.883 + 05	.611 + 05	.156 + 06

* .257 + 12 = .257 x 10¹²

TABLE II.1-C-23

(Continued)

	<u>Units</u>	<u>To Ponds and Ditches</u>	<u>To Cribs</u>	<u>To Specific Retention Sites</u>	<u>Total</u>
⁹⁰ Sr	(ci)	.155 + 04	.211 + 05	.811 + 04	.308 + 05
¹⁰⁶ Ru	(ci)	<.347 + 02	.239 + 04	.299 + 03	.272 + 04
¹³⁷ Cs	(ci)	.517 + 03	.130 + 05	.217 + 05	.352 + 05
⁶⁰ Co	(ci)	<.417 + 02	<.153 + 03	.201 + 02	<.219 + 03
U	(kgm)	<.653 + 04	.638 + 05	.480 + 05	.118 + 06
²³³ U	(gm)	<.489 + 03	.479 + 03		<.967 + 03

TABLE II.1-C-24

ESTIMATED DECAYED STATUS OF SOLID WASTE BURIAL GROUNDS
IN THE 200 AREAS THROUGH 1972

BURIAL GROUND	VOLUME (CUBIC FEET)	URANIUM (GRAMS)	PLUTONIUM (GRAMS)	TOTAL (CURIES)	⁹⁰ Sr (CURIES)	¹³⁷ Cs (CURIES)	¹⁰⁶ Ru (CURIES)	
200 EAST AREA								
DRY WASTE NO. 001	1.07x10 ⁵	4.00x10 ⁵	9.00x10 ²	4.64x10 ⁰	1.12x10 ⁰	1.24x10 ⁰	9.07x10 ⁻⁷	
DRY WASTE NO. 12A	5.39x10 ⁵	9.90x10 ⁵	8.93x10 ³	6.77x10 ¹	1.41x10 ¹	1.53x10 ¹	3.01x10 ⁻¹	
DRY WASTE NO. 12B	2.59x10 ⁵	7.00x10 ³	1.27x10 ³	1.71x10 ³	1.54x10 ²	1.66x10 ²	6.34x10 ¹	
MINOR CONSTRUCTION NO. 4	5.60x10 ⁴	1.00x10 ³	1.00x10 ¹	5.41x10 ⁻¹	1.29x10 ⁻¹	1.42x10 ⁻¹	2.44x10 ⁻⁶	
CONSTRUCTION (NO NUMBER)	8.00x10 ⁴	2.00x10 ³	2.00x10 ¹	5.98x10 ⁻¹	1.41x10 ⁻¹	1.54x10 ⁻¹	2.90x10 ⁻⁵	
222 VAULTS	6.00x10 ³	1.00x10 ³	1.00x10 ⁰	2.82x10 ¹	6.79x10 ⁰	7.51x10 ⁰	6.09x10 ⁻⁶	
INDUSTRIAL WASTE NO. 002	3.19x10 ⁵	3.00x10 ⁵	8.00x10 ²	1.21x10 ³	2.92x10 ²	3.22x10 ²	5.87x10 ⁻⁴	
INDUSTRIAL WASTE NO. 005	1.12x10 ⁵	1.20x10 ⁵	6.20x10 ²	4.08x10 ²	9.75x10 ¹	1.07x10 ²	2.44x10 ⁻³	
INDUSTRIAL WASTE NO. 05A	2.18x10 ⁵	1.20x10 ⁵	1.38x10 ³	9.68x10 ²	2.29x10 ²	2.50x10 ²	3.46x10 ⁻²	
INDUSTRIAL WASTE NO. 010	5.31x10 ⁵	8.01x10 ⁵	4.93x10 ³	5.26x10 ⁴	4.33x10 ³	4.65x10 ³	1.96x10 ³	
TOTAL 200-E	2.23x10 ⁶	2.74x10 ⁶	1.89x10 ⁴	5.70x10 ⁴	5.12x10 ³	5.52x10 ³	2.03x10 ³	
BURIAL GROUND	VOLUME (CUBIC FEET)	URANIUM (GRAMS)	PLUTONIUM (GRAMS)	TOTAL (CURIES)	⁹⁰ Sr (CURIES)	¹⁰⁶ Ru (CURIES)	¹³⁷ Cs (CURIES)	OTHER RADIOACTIVE (CURIES)
200 WEST AREA								
DRY WASTE NO. 001	2.53x10 ⁵	7.00x10 ⁵	9.40x10 ⁴	9.29x10 ⁰	2.23x10 ⁰	2.17x10 ⁻⁶	2.47x10 ⁰	
DRY WASTE NO. 002	2.91x10 ⁵	1.40x10 ⁶	1.26x10 ⁵	2.70x10 ¹	6.45x10 ⁰	1.41x10 ⁻⁴	7.08x10 ⁰	
DRY WASTE NO. 003	3.85x10 ⁵	7.00x10 ⁷	6.80x10 ⁴	5.39x10 ¹	1.27x10 ¹	3.23x10 ⁻³	1.39x10 ¹	
222-T VAULTS	2.40x10 ³	3.00x10 ²	3.00x10 ⁻¹	3.64x10 ¹	8.75x10 ⁰	8.86x10 ⁻⁶	9.69x10 ⁰	
222-S VAULTS	5.60x10 ³	7.00x10 ²	7.00x10 ⁻¹	2.28x10 ²	5.42x10 ¹	5.65x10 ⁻³	5.94x10 ¹	
INDUSTRIAL WASTE NO. 001	4.84x10 ⁵	9.00x10 ⁵	2.00x10 ³	2.32x10 ³	5.58x10 ²	1.29x10 ⁻³	6.17x10 ²	
INDUSTRIAL WASTE NO. 002	6.69x10 ⁵	2.00x10 ⁶	6.10x10 ³	1.62x10 ⁴	3.44x10 ³	9.55x10 ¹	3.75x10 ³	
DRY WASTE NO. 03A	1.79x10 ⁵	8.60x10 ⁶	3.92x10 ³	1.41x10 ⁵	2.66x10 ²	1.01x10 ²	2.93x10 ²	1.38x10 ⁵
DRY WASTE NO. 04A	6.25x10 ⁵	5.00x10 ⁸	3.54x10 ⁴	2.55x10 ²	4.98x10 ¹	1.97x10 ⁰	5.39x10 ¹	
DRY WASTE NO. 04B	2.97x10 ⁵	4.18x10 ⁶	1.53x10 ⁴	1.97x10 ⁵	3.12x10 ²	8.65x10 ¹	3.35x10 ²	1.94x10 ⁵
CAISSON - NO. 1	2.25x10 ²	1.54x10 ⁵	4.73x10 ²	1.02x10 ²	1.47x10 ¹	2.37x10 ⁰	1.59x10 ¹	
CAISSON - NO. 2	8.00x10 ⁰		<5.00x10 ⁻¹	2.76x10 ⁰	3.65x10 ⁻¹	7.65x10 ⁻²	3.92x10 ⁻¹	
CAISSON - NO. 3	1.86x10 ²	1.00x10 ⁵	4.74x10 ²	2.63x10 ³	3.38x10 ²	7.58x10 ¹	3.63x10 ²	
CAISSON - NO. 4	5.40x10 ¹	4.86x10 ⁴	7.30x10 ²	1.10x10 ⁴	1.06x10 ³	4.34x10 ²	1.14x10 ³	
CAISSON - ALPHA 1	2.01x10 ²	4.07x10 ⁴	1.45x10 ³	3.60x10 ⁴	6.58x10 ²	3.71x10 ²	7.05x10 ²	1.37x10 ⁴
TOTAL 200-W	3.19x10 ⁶	5.88x10 ⁸	3.54x10 ⁵	4.07x10 ⁵	6.78x10 ³	1.17x10 ³	7.36x10 ³	3.46x10 ⁵
TOTAL 200 AREAS	5.42x10 ⁶	5.91x10 ⁸	3.73x10 ⁵	4.64x10 ⁵	1.19x10 ⁴	3.20x10 ³	1.29x10 ⁴	3.46x10 ⁵

TABLE II.1-C-25
PUREX EQUIPMENT STORAGE TUNNELS
INVENTORY--SEPTEMBER 30, 1973

	<u>Tunnel No. 1</u>	<u>Tunnel No. 2</u>	<u>Total</u>
Volume, ft ³	20,000	19,000	39,000
Total MFP, Ci	5,600	24,000	29,600
⁹⁰ Sr, Ci	1,300	40	1,340
¹⁰⁶ Ru, Ci	1	7	8
¹³⁷ Cs, Ci	1,400	40	1,440
⁶⁰ Co, Ci	--	15,000	15,000
²³⁹ Pu, g	--	<500	<500

NOTE: Curies shown are decayed to September 30, 1973

APPENDIX II.1-C, PART 7
200 Area Gaseous Radioactive Material Releases

TABLE II.1-C-26

SUMMARY OF RADIONUCLIDES IN GASEOUS WASTE
DISCHARGED FROM 200 AREA FACILITIES DURING 1972291-A-1
Purex Process

	Alpha*	Beta	¹³¹ I
Volume 6.32×10^{10} (ft ³)			
Total Release (Ci)	3.05×10^{-3}	0.444	0.206
Avg. Release Rate (Ci/day)	8.35×10^{-6}	1.22×10^{-3}	7.54×10^{-4}
Max. Release Rate (Ci/day)	4.13×10^{-5}	2.29×10^{-3}	1.59×10^{-3}
Avg. Concentration (μ Ci/cc)	1.70×10^{-12}	2.48×10^{-10}	1.15×10^{-10}

*As Pu

296-A-1
Purex N and Q Cells
and PR Room

Volume 3.69×10^9 (ft ³)		
Total Release (Ci)	1.24×10^{-3}	3.87×10^{-3}
Avg. Release Rate (Ci/day)	3.39×10^{-6}	1.06×10^{-5}
Max. Release Rate (Ci/day)	1.63×10^{-5}	2.47×10^{-5}
Avg. Concentration (μ Ci/cc)	1.56×10^{-13}	3.70×10^{-11}

*As Pu

296-A-2
Purex West Sample
Gallery Hoods

Volume 2.27×10^9 (ft ³)		
Total Release (Ci)	3.06×10^{-6}	1.84×10^{-4}
Avg. Release Rate (Ci/day)	8.37×10^{-9}	5.03×10^{-7}
Max. Release Rate (Ci/day)	3.68×10^{-8}	9.19×10^{-7}
Avg. Concentration (μ Ci/cc)	4.76×10^{-14}	2.86×10^{-11}

*As Pu

296-A-3
Purex East Sample
Gallery Hoods

Volume 2.37×10^9 (ft ³)		
Total Release (Ci)	2.91×10^{-6}	3.79×10^{-5}
Avg. Release Rate (Ci/day)	7.97×10^{-9}	1.04×10^{-7}
Max. Release Rate (Ci/day)	7.23×10^{-8}	3.26×10^{-7}
Avg. Concentration (μ Ci/cc)	4.34×10^{-14}	5.65×10^{-13}

*As Pu

TABLE II.1-C-26

(Continued)

296-A-5
Purex Lab Hoods and
Glove Boxes

	Alpha*	Beta	¹³¹ I
Volume 1.32×10^{10} (ft ³)			
Total Release (Ci)	1.79×10^{-5}	3.05×10^{-4}	
Avg. Release Rate (Ci/day)	4.90×10^{-8}	8.35×10^{-7}	
Max. Release Rate (Ci/day)	1.22×10^{-7}	1.34×10^{-6}	
Avg. Concentration (μCi/cc)	4.79×10^{-14}	8.16×10^{-13}	

*As Pu

296-A-6
Purex East Sample
Gallery and U Cell

Volume 6.85×10^9 (ft ³)			
Total Release (Ci)	6.09×10^{-6}	2.29×10^{-3}	
Avg. Release Rate (Ci/day)	1.67×10^{-8}	6.27×10^{-6}	
Max. Release Rate (Ci/day)	6.94×10^{-8}	3.35×10^{-5}	
Avg. Concentration (μCi/cc)	3.14×10^{-14}	1.18×10^{-11}	

*As Pu

296-A-7
Purex West Sample
Gallery and R Cell

Volume 1.05×10^{10} (ft ³)			
Total Release (Ci)	2.93×10^{-5}	0.142	
Avg. Release Rate (Ci/day)	8.02×10^{-8}	3.89×10^{-4}	
Max. Release Rate (Ci/day)	2.84×10^{-7}	4.06×10^{-3}	
Avg. Concentration (μCi/cc)	9.85×10^{-14}	4.78×10^{-12}	

*As Pu

296-A-8
Purex P & O Gallery
(White Room)

Volume 8.96×10^9 (ft ³)			
Total Release (Ci)	5.07×10^{-6}	3.95×10^{-4}	
Avg. Release Rate (Ci/day)	1.39×10^{-8}	1.08×10^{-6}	
Max. Release Rate (Ci/day)	7.26×10^{-8}	1.05×10^{-5}	
Avg. Concentration (μCi/cc)	2.00×10^{-14}	1.56×10^{-12}	

*As Pu

TABLE II.1-C-26

(Continued)

296-A-10
Purex Burial Tunnel
No. 2

	Alpha*	Beta	¹³¹ I
Volume 5.16×10^9 (ft ³)			
Total Release (Ci)	2.76×10^{-5}	4.10×10^{-4}	
Avg. Release Rate (Ci/day)	7.56×10^{-8}	1.12×10^{-6}	
Max. Release Rate (Ci/day)	8.13×10^{-7}	7.17×10^{-6}	
Avg. Concentration (μCi/cc)	1.89×10^{-13}	2.81×10^{-12}	

*As Pu

296-A-12
AR Vault Vessel Vent

Volume 1.74×10^8 (ft ³)			
Total Release (Ci)	3.27×10^{-7}	1.40×10^{-4}	2.29×10^{-3}
Avg. Release Rate (Ci/day)	8.95×10^{-10}	3.83×10^{-7}	7.54×10^{-6}
Max. Release Rate (Ci/day)	1.73×10^{-9}	2.18×10^{-6}	3.87×10^{-5}
Avg. Concentration (μCi/cc)	6.64×10^{-14}	2.84×10^{-11}	4.65×10^{-10}

*As Pu

296-A-13
AR Vault and Cell

Volume 1.08×10^{10} (ft ³)			
Total Release (Ci)	1.64×10^{-5}	2.54×10^{-3}	2.42×10^{-3}
Avg. Release Rate (Ci/day)	4.48×10^{-8}	6.96×10^{-6}	7.95×10^{-6}
Max. Release Rate (Ci/day)	8.10×10^{-8}	4.58×10^{-5}	3.87×10^{-5}
Avg. Concentration (μCi/cc)	5.36×10^{-14}	8.30×10^{-12}	7.91×10^{-12}

*As Pu

296-A-14
293-A Bldg.

Volume 3.16×10^9 (ft ³)			
Total Release (Ci)	2.79×10^{-6}	3.16×10^{-5}	
Avg. Release Rate (Ci/day)	7.63×10^{-9}	8.67×10^{-8}	
Max. Release Rate (Ci/day)	7.32×10^{-8}	5.55×10^{-7}	
Avg. Concentration (μCi/cc)	3.12×10^{-14}	3.53×10^{-13}	

*As Pu

TABLE II.1-C-26

(Continued)

296-A-17
241-A, AX and AY
Tank Farm Vent

	Alpha*	Beta	¹³¹ I
Volume 2.64×10^9 (ft ³)			
Total Release (Ci)	4.75×10^{-6}	3.34×10^{-4}	
Avg. Release Rate (Ci/day)	1.30×10^{-8}	9.16×10^{-7}	
Max. Release Rate (Ci/day)	9.57×10^{-8}	4.97×10^{-6}	
Avg. Concentration (μCi/cc)	6.35×10^{-14}	4.47×10^{-13}	

*As Pu

296-A-18
101-AY Tank Annulus

Volume 1.26×10^9 (ft ³)			
Total Release (Ci)	1.21×10^{-7}	4.33×10^{-6}	
Avg. Release Rate (Ci/day)	3.30×10^{-10}	1.19×10^{-8}	
Max. Release Rate (Ci/day)	5.10×10^{-10}	2.28×10^{-8}	
Avg. Concentration (μCi/cc)	3.39×10^{-15}	1.21×10^{-13}	

*As Pu

296-A-19
102-AY Tank Annulus

Volume 1.26×10^9 (ft ³)			
Total Release (Ci)	2.42×10^{-7}	1.10×10^{-5}	
Avg. Release Rate (Ci/day)	6.63×10^{-10}	3.01×10^{-8}	
Max. Release Rate (Ci/day)	2.36×10^{-9}	1.95×10^{-7}	
Avg. Concentration (μCi/cc)	6.78×10^{-15}	3.08×10^{-13}	

*As Pu

291-B-1
B Plant Process

Volume 2.90×10^{10} (ft ³)			
Total Release (Ci)	4.05×10^{-5}	0.158	
Avg. Release Rate (Ci/day)	1.11×10^{-7}	4.34×10^{-4}	
Max. Release Rate (Ci/day)	1.68×10^{-7}	2.12×10^{-3}	
Avg. Concentration (μCi/cc)	4.93×10^{-14}	1.92×10^{-10}	

*As Pu

TABLE II.1-C-26

(Continued)

296-B-2
ITS No. 1

	Alpha*	Beta	¹³¹ I
Volume 1.84×10^9 (ft ³)			
Total Release (Ci)	4.14×10^{-6}	1.26×10^{-2}	
Avg. Release Rate (Ci/day)	1.13×10^{-8}	3.46×10^{-5}	
Max. Release Rate (Ci/day)	1.72×10^{-8}	2.60×10^{-4}	
Avg. Concentration (μCi/cc)	7.94×10^{-14}	3.07×10^{-10}	

*As Pu

296-B-3
ITS No. 2

Volume 2.11×10^8 (ft ³)			
Total Release (Ci)	8.28×10^{-7}	6.25×10^{-3}	
Avg. Release Rate (Ci/day)	2.27×10^{-9}	1.71×10^{-5}	
Max. Release Rate (Ci/day)	1.35×10^{-8}	8.42×10^{-5}	
Avg. Concentration (μCi/cc)	1.39×10^{-13}	1.05×10^{-11}	

*As Pu

291-C-1
Semiworks Process
and Cells

Volume 1.05×10^{10} (ft ³)			
Total Release (Ci)	6.73×10^{-6}	1.60×10^{-3}	
Avg. Release Rate (Ci/day)	1.84×10^{-8}	4.39×10^{-6}	
Max. Release Rate (Ci/day)	3.97×10^{-8}	3.19×10^{-5}	
Avg. Concentration (μCi/cc)	2.26×10^{-14}	5.38×10^{-12}	

*As Pu

296-C-2
Semiworks A and C
Sample Galleries

Volume 4.22×10^9 (ft ³)			
Total Release (Ci)	5.94×10^{-7}	1.25×10^{-5}	
Avg. Release Rate (Ci/day)	1.63×10^{-9}	3.41×10^{-8}	
Max. Release Rate (Ci/day)	4.70×10^{-9}	9.83×10^{-8}	
Avg. Concentration (μCi/cc)	4.97×10^{-15}	1.05×10^{-13}	

*As Pu

TABLE II.1-C-26

(Continued)

296-C-5
CR Vault Cell and
Vessel Vent

	Alpha*	Beta	¹³¹ I
Volume 1.84×10^9 (ft ³)			
Total Release (Ci)	1.94×10^{-6}	1.75×10^{-4}	
Avg. Release Rate (Ci/day)	5.32×10^{-9}	4.78×10^{-7}	
Max. Release Rate (Ci/day)	1.40×10^{-8}	4.23×10^{-6}	
Avg. Concentration (μCi/cc)	3.72×10^{-14}	3.36×10^{-12}	

*As Pu

296-P-1 (296-B-11)
BX Tank Farm

Volume 3.69×10^9 (ft ³)			
Total Release (Ci)	1.65×10^{-7}	1.56×10^{-5}	
Avg. Release Rate (Ci/day)	4.51×10^{-10}	4.27×10^{-8}	
Max. Release Rate (Ci/day)	7.81×10^{-10}	3.31×10^{-7}	
Avg. Concentration (μCi/cc)	1.58×10^{-15}	1.49×10^{-13}	

*As Pu

296-P-2 (296-B-9)
ITS Bottoms Tanks

Volume 2.59×10^9 (ft ³)			
Total Release (Ci)	3.52×10^{-6}	5.20×10^{-4}	
Avg. Release Rate (Ci/day)	9.64×10^{-9}	1.43×10^{-6}	
Max. Release Rate (Ci/day)	2.73×10^{-8}	6.12×10^{-6}	
Avg. Concentration (μCi/cc)	4.80×10^{-14}	7.09×10^{-12}	

*As Pu

296-P-3 (296-B-6)
ITS Bottoms Tanks

Volume 3.69×10^9 (ft ³)			
Total Release (Ci)	4.53×10^{-6}	1.89×10^{-3}	
Avg. Release Rate (Ci/day)	1.24×10^{-8}	5.18×10^{-6}	
Max. Release Rate (Ci/day)	1.99×10^{-8}	3.10×10^{-5}	
Avg. Concentration (μCi/cc)	4.33×10^{-14}	1.89×10^{-11}	

*As Pu

TABLE II.1-C-26

(Continued)

296-P-4 (296-B-8)
ITS Bottoms Tanks

	Alpha*	Beta	¹³¹ I
Volume 7.91×10^7 (ft ³)			
Total Release (Ci)	4.70×10^{-8}	1.88×10^{-5}	
Avg. Release Rate (Ci/day)	1.29×10^{-10}	5.16×10^{-8}	
Max. Release Rate (Ci/day)	3.10×10^{-10}	3.16×10^{-7}	
Avg. Concentration (μCi/cc)	2.10×10^{-14}	8.39×10^{-12}	

*As Pu

296-P-5 (296-C-6)
Tanks 105 and
106-C

Volume 6.78×10^7 (ft ³)			
Total Release (Ci)	7.59×10^{-7}	3.86×10^{-5}	
Avg. Release Rate (Ci/day)	2.25×10^{-9}	1.15×10^{-7}	
Max. Release Rate (Ci/day)	9.40×10^{-9}	4.42×10^{-7}	
Avg. Concentration (μCi/cc)	3.59×10^{-13}	2.01×10^{-11}	

*As Pu

296-P-8 (296-T-4)
242-TX Evaporator
Bottoms Tanks

Volume 3.16×10^9 (ft ³)			
Total Release (Ci)	4.26×10^{-6}	1.39×10^{-4}	
Avg. Release Rate (Ci/day)	1.75×10^{-8}	5.72×10^{-7}	
Max. Release Rate (Ci/day)	2.55×10^{-8}	1.44×10^{-6}	
Avg. Concentration (μCi/cc)	4.76×10^{-14}	1.55×10^{-13}	

*As Pu

296-P-10 (296-T-10)
242-TX Evaporator
Bottoms Tanks

Volume 3.69×10^9 (ft ³)			
Total Release (Ci)	4.71×10^{-6}	1.16×10^{-3}	
Avg. Release Rate (Ci/day)	1.29×10^{-8}	3.17×10^{-6}	
Max. Release Rate (Ci/day)	3.29×10^{-8}	1.30×10^{-5}	
Avg. Concentration (μCi/cc)	4.51×10^{-14}	1.11×10^{-11}	

*As Pu

TABLE II.1-C-26

(Continued)

296-P-11 (296-T-9)
242-TX Evaporator
Bottoms Tanks

	Alpha*	Beta	¹³¹ I
Volume 7.91×10^7 (ft ³)			
Total Release (Ci)	9.33×10^{-8}	1.78×10^{-5}	
Avg. Release Rate (Ci/day)	2.56×10^{-10}	4.88×10^{-8}	
Max. Release Rate (Ci/day)	4.87×10^{-10}	1.28×10^{-7}	
Avg. Concentration (μCi/cc)	4.16×10^{-14}	7.95×10^{-12}	

*As Pu

296-P-12 (296-T-11)
242-TX Evaporator
Bottoms Tanks

Volume 3.69×10^9 (ft ³)			
Total Release (Ci)	6.20×10^{-6}	5.52×10^{-4}	
Avg. Release Rate (Ci/day)	1.70×10^{-8}	1.51×10^{-6}	
Max. Release Rate (Ci/day)	4.51×10^{-8}	5.73×10^{-6}	
Avg. Concentration (μCi/cc)	5.93×10^{-14}	5.28×10^{-12}	

*As Pu

291 -S-1
Redox Process Vessels

Volume 2.06×10^{10} (ft ³)			
Total Release (Ci)	5.40×10^{-5}	8.83×10^{-4}	
Avg. Release Rate (Ci/day)	1.48×10^{-7}	2.42×10^{-6}	
Max. Release Rate (Ci/day)	2.33×10^{-7}	4.40×10^{-6}	
Avg. Concentration (μCi/cc)	9.26×10^{-14}	1.51×10^{-12}	

*As Pu

296-S-1
Redox South Sample
Gallery

Volume 1.84×10^9 (ft ³)			
Total Release (Ci)	6.69×10^{-7}	1.01×10^{-5}	
Avg. Release Rate (Ci/day)	1.83×10^{-9}	2.75×10^{-8}	
Max. Release Rate (Ci/day)	7.50×10^{-9}	8.90×10^{-8}	
Avg. Concentration (μCi/cc)	1.28×10^{-14}	1.94×10^{-13}	

*As Pu

TABLE II.1-C-26

(Continued)

296-S-2
Redox North Sample
Gallery and Hoods

	Alpha*	Beta	¹³¹ I
Volume 1.84×10^9 (ft ³)			
Total Release (Ci)	2.79×10^{-7}	9.78×10^{-5}	
Avg. Release Rate (Ci/day)	7.63×10^{-10}	2.68×10^{-7}	
Max. Release Rate (Ci/day)	1.28×10^{-9}	2.98×10^{-6}	
Avg. Concentration (μCi/cc)	5.35×10^{-15}	1.88×10^{-12}	

*As Pu

296-S-4
Redox Regulated Shop
and Tool Room and SWP Lobby

Volume 1.16×10^9 (ft ³)		
Total Release (Ci)	6.54×10^{-7}	3.72×10^{-5}
Avg. Release Rate (Ci/day)	1.79×10^{-9}	1.02×10^{-7}
Max. Release Rate (Ci/day)	4.16×10^{-9}	2.17×10^{-7}
Avg. Concentration (μCi/cc)	1.99×10^{-14}	1.13×10^{-12}

*As Pu

296-S-5
Redox Product
Removal Cage

Volume 9.49×10^8 (ft ³)		
Total Release (Ci)	8.00×10^{-7}	5.87×10^{-6}
Avg. Release Rate (Ci/day)	2.64×10^{-9}	1.94×10^{-8}
Max. Release Rate (Ci/day)	4.99×10^{-9}	3.61×10^{-8}
Avg. Concentration (μCi/cc)	2.98×10^{-14}	2.18×10^{-13}

*As Pu

296-S-6
Redox Silo Sample
Gallery

Volume 5.53×10^9 (ft ³)		
Total Release (Ci)	4.41×10^{-6}	1.57×10^{-4}
Avg. Release Rate (Ci/day)	1.21×10^{-8}	4.29×10^{-7}
Max. Release Rate (Ci/day)	4.83×10^{-8}	2.77×10^{-6}
Avg. Concentration (μCi/cc)	2.82×10^{-14}	1.00×10^{-12}

*As Pu

TABLE II.1-C-26

(Continued)

296-S-7 Redox Product (233-S) Process Vessels and Greenhouse			
	Alpha*	Beta	¹³¹ I
Volume 4.06×10^9 (ft ³)			
Total Release (Ci)	4.86×10^{-5}	2.36×10^{-4}	
Avg. Release Rate (Ci/day)	1.33×10^{-7}	6.47×10^{-7}	
Max. Release Rate (Ci/day)	3.99×10^{-7}	3.97×10^{-6}	
Avg. Concentration (μCi/cc)	4.23×10^{-13}	2.05×10^{-12}	
*As Pu			
296-S-13 222-S Laboratory			
Volume 3.64×10^{10} (ft ³)			
Total Release (Ci)	4.95×10^{-5}	3.52×10^{-2}	
Avg. Release Rate (Ci/day)	1.36×10^{-7}	9.64×10^{-5}	
Max. Release Rate (Ci/day)	5.26×10^{-7}	6.19×10^{-4}	
Avg. Concentration (μCi/cc)	4.80×10^{-14}	3.41×10^{-11}	
*As Pu			
296-S-14 241-SX Tank Farm Vent			
Volume 3.16×10^8 (ft ³)			
Total Release (Ci)	4.10×10^{-6}	4.31×10^{-3}	
Avg. Release Rate (Ci/day)	1.12×10^{-8}	1.18×10^{-5}	
Max. Release Rate (Ci/day)	8.08×10^{-8}	3.85×10^{-5}	
Avg. Concentration (μCi/cc)	4.58×10^{-13}	4.82×10^{-10}	
*As Pu			
296-S-15 241-SX Sludge Cooling			
Volume 5.27×10^9 (ft ³)			
Total Release (Ci)	1.22×10^{-5}	1.37×10^{-4}	
Avg. Release Rate (Ci/day)	3.35×10^{-8}	3.75×10^{-7}	
Max. Release Rate (Ci/day)	1.37×10^{-7}	1.27×10^{-6}	
Avg. Concentration (μCi/cc)	8.17×10^{-14}	9.18×10^{-13}	
*As Pu			

TABLE II.1-C-26
(Continued)

296-S-16
222 S Lab Waste Tanks
and Vault

	Alpha*	Beta	¹³¹ I
Volume 5.96×10^7 (ft ³)			
Total Release (Ci)	1.01×10^{-6}	9.28×10^{-5}	
Avg. Release Rate (Ci/day)	3.29×10^{-9}	3.03×10^{-7}	
Max. Release Rate (Ci/day)	8.45×10^{-9}	8.65×10^{-7}	
Avg. Concentration (μCi/cc)	5.98×10^{-13}	5.50×10^{-11}	

*As Pu

291-T-1
T Plant

Volume 2.11×10^{10} (ft ³)		
Total Release (Ci)	2.50×10^{-4}	3.67×10^{-2}
Avg. Release Rate (Ci/day)	6.86×10^{-7}	1.01×10^{-4}
Max. Release Rate (Ci/day)	3.32×10^{-6}	4.52×10^{-4}
Avg. Concentration (μCi/cc)	4.18×10^{-13}	6.14×10^{-11}

*As Pu

296-T-1
242-T Evaporator Hot
Cells

Volume 4.22×10^8 (ft ³)		
Total Release (Ci)	1.01×10^{-6}	3.45×10^{-3}
Avg. Release Rate (Ci/day)	2.77×10^{-9}	9.46×10^{-6}
Max. Release Rate (Ci/day)	6.87×10^{-9}	3.09×10^{-5}
Avg. Concentration (μCi/cc)	8.45×10^{-14}	2.89×10^{-10}

*As Pu

296-T-2
242-T Evaporator
Cold Cells

Volume 4.48×10^8 (ft ³)		
Total Release (Ci)	1.09×10^{-6}	1.81×10^{-4}
Avg. Release Rate (Ci/day)	3.00×10^{-9}	4.96×10^{-7}
Max. Release Rate (Ci/day)	8.19×10^{-9}	1.32×10^{-6}
Avg. Concentration (μCi/cc)	8.59×10^{-14}	1.43×10^{-11}

*As Pu

TABLE II.1-C-26

(Continued)

296-T-3
242-T Evaporator
Vessel Vent

	Alpha*	Beta	¹³¹ I
Volume 1.05×10^8 (ft ³)			
Total Release (Ci)	7.29×10^{-7}	1.17×10^{-3}	
Avg. Release Rate (Ci/day)	2.00×10^{-9}	3.21×10^{-6}	
Max. Release Rate (Ci/day)	1.49×10^{-8}	1.21×10^{-5}	
Avg. Concentration (μ Ci/cc)	2.45×10^{-13}	3.93×10^{-10}	

*As Pu

296-T-13
T Plant

Volume 1.43×10^{10} (ft ³)			
Total Release (Ci)	1.14×10^{-5}	4.39×10^{-4}	
Avg. Release Rate (Ci/day)	6.17×10^{-8}	2.39×10^{-6}	
Max. Release Rate (Ci/day)	1.06×10^{-7}	5.16×10^{-6}	
Avg. Concentration (μ Ci/cc)	2.81×10^{-14}	1.08×10^{-12}	

*As Pu

291-U-1
U Plant

Volume 7.38×10^9 (ft ³)			
Total Release (Ci)	1.29×10^{-5}	1.05×10^{-3}	
Avg. Release Rate (Ci/day)	3.52×10^{-8}	2.87×10^{-6}	
Max. Release Rate (Ci/day)	8.87×10^{-8}	5.32×10^{-6}	
Avg. Concentration (μ Ci/cc)	6.17×10^{-14}	5.02×10^{-12}	

*As Pu

296-U-2
Uranium Oxide 224-UA
Filters

Volume 3.81×10^8 (ft ³)			
Total Release (Ci)	8.14×10^{-5}	2.44×10^{-4}	
Avg. Release Rate (Ci/day)	5.76×10^{-7}	1.81×10^{-6}	
Max. Release Rate (Ci/day)	1.36×10^{-6}	3.94×10^{-6}	
Avg. Concentration (μ Ci/cc)	7.54×10^{-12}	2.26×10^{-11}	

*As U

TABLE II.1-C-26

(Continued)

296-U-4 Uranium Oxide Nitric Acid Absorber Off-gas			
	Alpha*	Beta	^{131}I
Volume 7.66×10^8 (ft ³)			
Total Release (Ci)	7.26×10^{-6}	5.08×10^{-3}	
Avg. Release Rate (Ci/day)	2.40×10^{-8}	1.68×10^{-5}	
Max. Release Rate (Ci/day)	6.71×10^{-8}	4.84×10^{-5}	
Avg. Concentration ($\mu\text{Ci/cc}$)	3.35×10^{-13}	2.34×10^{-10}	
*As U			
296-U-5 Uranium Oxide 224-U F Cell			
Volume 2.29×10^8 (ft ³)			
Total Release (Ci)	1.91×10^{-6}	7.38×10^{-4}	
Avg. Release Rate (Ci/day)	6.99×10^{-9}	2.70×10^{-6}	
Max. Release Rate (Ci/day)	1.12×10^{-8}	4.29×10^{-6}	
Avg. Concentration ($\mu\text{Ci/cc}$)	2.95×10^{-13}	1.14×10^{-10}	
*As U			
296-U-10 271-U PU Storage			
Volume 5.32×10^9 (ft ³)			
Total Release (Ci)	4.10×10^{-7}	7.35×10^{-6}	
Avg. Release Rate (Ci/day)	3.36×10^{-9}	6.02×10^{-8}	
Max. Release Rate (Ci/day)	2.12×10^{-9}	5.93×10^{-8}	
Avg. Concentration ($\mu\text{Ci/cc}$)	2.72×10^{-15}	4.88×10^{-14}	
*As Pu			
291-Z-1 ZPlant Process and Ventilation			
Volume 1.26×10^{11} (ft ³)			
Total Release (Ci)	2.93×10^{-4}	1.97×10^{-3}	
Avg. Release Rate (Ci/day)	8.02×10^{-7}	5.39×10^{-6}	
Max. Release Rate (Ci/day)	2.52×10^{-6}	2.11×10^{-5}	
Avg. Concentration ($\mu\text{Ci/cc}$)	8.21×10^{-14}	5.52×10^{-13}	
*As Pu			

TABLE II.1-C-26

(Continued)

296-Z-3

241-Z Vault

	Alpha*	Beta	¹³¹ I
Volume 1.32×10^{10} (ft ³)			
Total Release (Ci)	3.55×10^{-6}	4.89×10^{-6}	
Avg. Release Rate (Ci/day)	1.66×10^{-8}	2.28×10^{-8}	
Max. Release Rate (Ci/day)	1.93×10^{-8}	2.40×10^{-8}	
Avg. Concentration (μ Ci/cc)	9.50×10^{-15}	1.31×10^{-14}	

*As Pu

209-E

Critical Mass Lab

Volume 1.21×10^9 (ft³)

Total Release (Ci)	$<1.56 \times 10^{-7}$
Avg. Release Rate (Ci/wk)	$<0.03 \times 10^{-7}$
Max. Release Rate (Ci/wk)	$<0.19 \times 10^{-7}$
Avg. Concentration (μ Ci/cc)	$<7.8 \times 10^{-15}$

*As Pu

231-Z

Plutonium Metallurgy Lab

Volume 5.19×10^9 (ft³)

Total Release (Ci)	1.27×10^{-5}
Avg. Release Rate (Ci/wk)	2.45×10^{-7}
Max. Release Rate (Ci/day)	2.08×10^{-6}
Avg. Concentration (μ Ci/cc)	8.5×10^{-14}

*As Pu

APPENDIX II.1-C, PART 8
200 Areas, Unplanned Releases

TABLE II.1-C-27

200 AREAS, UNPLANNED RELEASES

Date	Location	Description	Isotopes and Amount
11-73	241-S Tank Farm 102-S Tank	Approximately 8,660 gallons of radioactive waste solution was pumped out of a 12-inch riser on to the adjacent ground and covered an area approximately 50 x 200 feet. This was caused by an unplanned blockage in the riser. The spill area was immediately covered with a temporary layer of earth to provide shielding and prevent airborne contamination. Final cleanup operations excavated all of the contaminated soil for subsequent disposal in a designated contaminated burial trench.	1,020 Ci ¹³⁷ Cs 1 Ci ¹³⁴ Cs 1 Ci ⁶⁰ Co
8-72	221-B, R-13 Utility Pit	Excavation of an unencased line (from Tank 18-1, 221-B Building to 154-BX diversion box) near the utility pit at R-13 disclosed a process waste leak. Radiation measurements taken at bottom of the pit read 15 rad/hr within 2 in. of the source.	Approx. 15 Ci ¹³⁷ Cs
2-72	224-T Building southeast side	During remodeling of 224-T Building for Pu storage, gross alpha contamination was found in soil on back side of building. The 224-T Building was originally constructed with vent lines from process tanks entering tile piping at ground level to rear of building. The jointed tile piping went to a common tile header which fed into 221-T Building cells. During the years of process operation, alpha-laden moisture seeped through pipe joints and grossly contaminated the subsoil. Excavations of area showed soil contamination below the surface of an area 50 ft long by 12 ft wide by 12 ft deep. A total of 139 drums of soil were removed from the zone containing approximately 72 g of plutonium. The zone is marked for underground contamination which remains below the header pipe. (It is believed a similar contaminated condition exists behind 224-B Building in 200-East Area.)	Approx. 10 g ²³⁹ Pu

TABLE II.1-C-27

(Continued)

Date	Location	Description	Isotopes and Amount
4-71	216-Z-18 waste line near 236-Z	<p>The 216-Z-18 crib line from 234-5 complex broke at location approximately 6 ft south and 12 ft west of southwest corner of 236-Z Building.</p> <p>An excavation 25 ft long by 6 ft wide by 7 ft deep uncovered gross alpha contamination in soil to greater than 6 million dis/min/100 cm² of surface. Approximately one hundred 55-gal barrels of contaminated soil were removed and buried in 200-W Area Pu "storage for recovery" burial ground. Much contamination still remains under 6 ft of clean soil.</p>	<p>Approx. 10 g ²³⁹Pu</p>
3-71	Near southwest corner of 241-C Tank Farm	<p>Process transfer line No. 812 from AR Vault to 241-C Tank Farm was found leaking near southwest corner of that farm. At that location the line is 8 ft deep. Contaminated soil zone was estimated at 1300 ft³. Test wells driven into the ground indicated the contamination did not extend below a depth of 20 ft.</p>	<p>Approx. 25,000 Ci ¹³⁷Cs</p>
3-22-70	221-B to 216-B-3 (B Pond)	<p>Decontamination of operating gallery, following process solution flow reversal from storage vessel.</p>	<p>50 Ci ⁹⁰Sr</p>
11-69	Near 241-C-152 diversion box. Liquid radioactive waste transfer line break	<p>A leak in the line from Tank 105-C to B Plant was found December 19, 1969. Volume which leaked to ground was estimated at 2600 gal. The contaminated soil was covered with clean gravel.</p>	<p>11,300 Ci ¹³⁷Cs 260 Ci ¹⁴⁴Ce 130 Ci ¹⁰⁶Ru 260 Ci ⁹⁵ZrNb 100 Ci ¹³⁴Cs</p>

TABLE II.1-C-27

(Continued)

Date	Location	Description	Isotopes and Amount
10-69	Near 241-CR-151 diversion box. Liquid radioactive waste transfer line break	A leak in the line from Purex Plant to 102-C tank was found October 19, 1969. Volume which leaked to ground was estimated at 36,000 gal. Contamination was covered with clean gravel.	360 Ci ^{90}Sr 720 Ci ^{137}Cs 360 Ci ^{144}Ce 1,080 Ci $^{95}\text{ZrNb}$ 1,080 Ci ^{103}Ru
1-69	233-S	Plutonium-contaminated water backed up in 233-S Filter House drain line and overflowed into a low spot in the ground directly north of 233-S Filter House. An area of 150 yd ² was affected. Twenty-eight yards of clean gravel were spread over the spill.	Approx. 0.1 g ^{239}Pu
9-68	153-TX diversion box	Ground and road contamination along Camden Av. and adjacent ground surfaces resulted from two plumes of airborne contamination that floated northeast and southeast from 153-TX diversion box depositing ^{90}Sr over an area running 250 yd north and south along Camden and extending from 75 to 100 yd east of Camden. Particles up to 700 mrad/hr were found. Road contamination was covered with a new tar mat, sides of roads were "fixed" with tar, and the field to the east of Camden Av. was turned under to cover the particulate material.	Approx. 1 Ci ^{90}Sr

II.1-C-128

TABLE II.1-C-27

(Continued)

Date	Location	Description	Isotopes and Amount
1-68	Near 241-B-153	A leak in the transfer line from 9-2 tank in 221-B Plant to the 110-B underground storage tank was found near 241-B-153 diversion box on January 4, 1968. The volume which leaked to the ground was estimated at 5400 gal. The contaminated ground was covered with clean gravel.	4,780 Ci ¹⁴⁴ Ce 340 Ci ¹⁰⁶ Ru 850 Ci ⁹⁵ ZrNb
5-66	23rd and Camden Ave.	Liquid waste solution spilled from a broken underground line on southeast corner of 23rd and Camden Ave. The liquid surfaced and ran across the road to west side. All ground surface contamination was removed to a depth of 3 ft and buried in the 200-W burial grounds. The remaining radioactivity was covered to ground level with 3 ft of clean soil.	Approx. 10 Ci Fission Products
9-30-60	202-A	During jumper testing on 241-A-151 Diversion Box, contamination was spread downwind to the south and outside the 200-E Area perimeter fence, a distance of about 1 mile. Radiation levels near the diversion box were 1 to 3 rad/hr, and just outside the exclusion area fence, general contamination was up to 3000 counts/min. Particulate contamination was about 50 particles per 100 ft ² just outside the exclusion area and dropped to less than 5 particles per 100 ft ² 1 mile south of the diversion box. Ground surface contamination was removed or stabilized.	Approx. 0.1 Ci

TABLE II.1-C-27

(Continued)

Date	Location	Description	Isotopes and Amount
Early 1960	B-C Cribs outer area	Early in 1960 animal burrows were observed in residue salts in bottom of B-C liquid waste trenches. Radioactive feces from coyotes and rabbits were subsequently spread over surrounding sagebrush-covered desert land to east, south and west of trenches. The bulk of radioactivity remaining is fixed in rabbit droppings scattered over approximately 4 square miles of ground surface.	7 Ci ^{137}Cs 30 Ci ^{90}Sr
3-57	221-U Building	Reclaimed acid spilled onto ground at northeast end of 221-U Building, contaminating an area 65 ft by 90 ft. The spill was covered with 3 in. of sand and gravel.	Approx. 1 Ci Fission Products
10-55	Near 241-BX-153 and 241-BX-155 Ground Contamination	A spill that occurred during pressure testing of lines and jumpers in the 155-BX diversion box caused ground contamination to a maximum dose rate of 22.6 rad/hr at surface. Affected area is approximately 200 ft ² . It was covered with clean soil.	Approx. 10 Ci Fission Products
1954-55	241-B-153	Contamination spread associated with work being done in the 153-B diversion box during 1954 and 1955 caused a general buildup of contamination. An area 50 ft by 100 ft is marked as a radiation zone. The contamination was covered with clean gravel.	Approx. 1 Ci Fission Products

TABLE II.1-C-27

(Continued)

Date	Location	Description	Isotopes and Amount
1954	241-B-152	An incident which occurred during the spring of 1954 while performing diversion box work contaminated an area approximately 50 ft ² . A portion of the contamination was removed and buried. The remainder was covered with several inches of clean fill dirt.	Approx. 1 Ci Fission Products
1954	Leak in process line from 105-TX to 118-TX	Leakage of first cycle waste was discovered in 1954 with maximum dose rates of 4.5 R/hr observed at 4 ft above surface of spill. An area approximately 100 ft by 125 ft was covered with soil.	Approx. 10 Ci Fission Products
1954	216-S-207 Redox retention basin	Basin became highly contaminated from coil leaks in 202-S Building. Its use was discontinued in 1954. Basin concrete surfaces were subsequently covered with soil.	Approx. 10 Ci Fission Products
1-2-54	Redox	During Ru oxidation and scrubbing operations, the caustic recirculation system was not functioning properly and about 260 Ci of radio-Ru were released to the environs via the ventilation stack. The wind was blowing strong in a general northeasterly direction and particulate radio-Ru was deposited on vegetation and roads extending beyond the Hanford perimeter. Individual high radiation measurements of particles were: 7.5 rad/hr near the Redox stack, 400 mrad/hr on the road northeast of the stack, 100 mrad/hr down to 50 mrad/hr between 200-W and 200-E Area and diminishing to 20 mrad/hr northeast of the 200-E Area.	Approx. 195Ci 103Ru 65Ci 106Ru

TABLE II.1-C-27
(Continued)

Date	Location	Description	Isotopes and Amount
1953 to 1955	216-S-4 Culvert pipes (cooling water well)	241-S Tank Farm, 101 and 104 tank condensate and cooling water was piped from 241-S Tank Farm into two metal culvert pipes placed on end to a depth of 20 ft. Radioactivity accumulated at bottom of pipes.	Approx. 1 Ci Fission Products
6-53	216-U-7 221-U Vessel vent blower pit French drain	An estimated 300 lb of uranium (UNH solution) overflowed into the 221-U Building vessel vent blower pit and then to ground through the French drain. (This is in the established radiation zone on southeast of 221-U Building near R-3 entrance.)	13.6 kg uranium
6-53	242-B to 207-B Waste Line	Five leaks in the line were discovered in June 1953. No determination of activity below ground surface was made at that date. The area was covered with about 2 in. of clean soil.	Approx. 10 Ci Fission Products
3-53	241-ER-151 Catch tank leak	About 1700 gal of contaminated acid was lost to ground through a leaking catch tank. No ground surface contamination was detected.	Approx. 10 Ci Fission Products
1951 to 1952	216-S-15 (110-S tank condenser cooling waste)	A maximum dose rate of 10 rad/hr was observed at the surface of the receiving pond east of 241-S Tank Farm. It was covered with 2 ft of dirt.	Approx. 1 Ci Fission Products

TABLE II.1-C-27

(Continued)

Date	Location	Description	Isotopes and Amount
1951 to 1952	241-B-151	The area around the diversion box was contaminated as a result of diversion box work in the fall of 1951 and again in the summer of 1952. Most of the contamination was removed. That remaining was covered with approximately 1 ft of clean soil.	Approx. 10 Ci Fission Products
1947	221-T, R-19 Waste line leak	A leak in underground metal waste line at southeast corner of 221-T Building in the spring of 1947 resulted in spread of an unknown amount of activity to ground. A maximum dose rate of 20 R/hr was detected. The area was subsequently covered with several feet of gravel.	Approx. 10 Ci Fission Products
1946	221-B, R-3 Line leak	A leak during 1946 from an underground metal waste line south of 221-B Building resulted in spread of an unknown quantity of activity to an area 100 ft wide by 500 ft in length. A portion of the ground above the leak caved in but was subsequently backfilled with several feet of clean gravel. During subsequent construction activity the major portion of the radioactivity was excavated and removed to 200-E Dry Waste Burial Garden.	Approx. 10 Ci Fission Products
1946	241-B-154 Ground Contamination	Metal waste solution was spread over the ground around the diversion box as a result of work associated with replacement of a leaky jumper in the box in 1946. The contamination was covered with approximately 1 ft of clean soil.	Approx. 1 Ci Fission Products

Waste Storage Tank Leaks. Eighteen tank leaks have occurred through 1973. The number of each affected tank, the year of occurrence, the estimated volume of leakage in gallons, and the associated ^{137}Cs are shown below.

The letter(s) after the number of each tank indicates their location by storage area, e.g, the letter "U" is the "U" tank farm, the letters "SX" mean the "SX" tank farm, etc. The tank farms can be found on the maps attached as Figures II.1-C-42 and II.1-C-43.

The columns next to the list of eighteen tanks include the estimated volume of leakage from each tank and the associated ^{137}Cs in curies. ^{137}Cs leakage can be used to estimate the maximum amount of other radio-nuclides leaked.

	<u>Tank</u>	<u>Year Leaked</u>	<u>Estimated Vol. of Leakage (Gallons)</u>	<u>Associated ^{137}Cs (1000 Ci)</u>	<u>Status</u>
1.	104-U	1958	55,000	0.09	Diatomite added - Tank Isolated
2.	113-SX	1958	15,000	8	Diatomite added - Tank Isolated
3.	106-TY	1959	20,000	2	Diatomite added - Tank Isolated
4.	101-U	1959	30,000	23	Isolated
5.	105-TY	1960	35,000	4	Isolated
6.	108-SX	1962	2,400	17	Sludge Air Cooling
7.	105-A	1963	<5,000	--	Pumped to Residual Liquid Heel
8.	107-SX	1964	<5,000	--	Sludge Air Cooling
9.	109-SX	1965	<5,000	--	Sludge Air Cooling
10.	115-SX	1965	50,000	40	Sludge Air Cooling
11.	112-SX	1969	30,000	45	Sludge Air Cooling

	<u>Tank</u>	<u>Year Leaked</u>	<u>Estimated Vol. of Leakage (Gallons)</u>	<u>Associated ¹³⁷Cs (1000 Ci)</u>	<u>Status</u>
12.	102-BX	1971	70,000	51	Diatomite added - Tank Isolated
13.	108-BY	1972	<5,000	--	Salt Well Pumping - Isolation in Progress
14.	103-BY	1973	<5,000	--	Salt Well and Isolation Program
15.	106-T	1973	115,000	40	Pumped to Residual Liquid Heel
16.	103-TY	1973	3,000	0.7	Salt Well Pumping - Isolation Initiated
17.	111-SX	1974	<2,000	2.4	Pumped to Residual Liquid Heel
18.	108-BX	1974	2,500	0.5	Pumped to Residual Liquid Heel

FIGURE II.1-C-42 200 EAST TANK FARMS

II.1-C-137

FIGURE II.1-C-43 200 WEST AREA TANK FARMS

APPENDIX II.1-D

LIQUID WASTE STREAMS TO THE COLUMBIA RIVER

REV. APRIL 1972

FIGURE II.1-D-1 EXISTING DISCHARGES INTO COLUMBIA RIVER

TABLE II.1-D-1

DESCRIPTION OF DISCHARGES

Area	Discharge ^(a) No.	Description
100-B/C	001	<u>Inlet Screen Wash Water and Fish Return</u> The 100-B river pumphouse serves 100-B Area, the chemical processing facilities (200 Areas) and other minor facilities totaling about 19 million gpd. Discharge line permit .001 covers untreated water used to dislodge and backflush material entrained on the river pump inlet screens (Figure II.1-D-2).
100-B/C	002	<u>Process Drain</u> Leakage and waste water from pumping operations in the 182-B building and overflow from the 183-B Basin raw water storage facility in 100-B Area are released to the river directly. These facilities are used in transporting water from river pumping structure to the 200 Areas (Figure II.1-D-3).
100-K	003	<u>Inlet Screen Wash Water and Fish Return</u> Untreated river water used to dislodge and backflush material entrained on the river pump inlet screens on the pumping structure serving 100-K Areas is released directly to the river (Figure II.1-D-4).
100-K	004	<u>Process Drain</u> Treated cooling water used for compressors and pumps and overflow drains from the filter basin are released directly to the river (Figure II.1-D-5).
100-N	005	<u>Water Storage Tank Farm Overflow</u> A 36-in. line containing the overflow from the 182-N tank empties into a concrete chute (see Figure II.1-D-6). This discharge is a part of the approximately 200,000 gpm pumped by the 100-N river pumping facilities. It amounts to about 500 gpm of overflow from filtered and raw water storage tanks in the 182-N tank farm. A small amount of steam from the medium pressure steam system is included.
100-N	006	<u>Overflow and Floor Drain Discharge</u> Figure II.1-D-7 shows the discharge point from the 182-N building consisting of filtered water overflow and

(a) Application for EPA discharge permit number is 071-0YC-3-000099 covering 14 discharges.

TABLE II.1-D-1 (Continued)

Area	Discharge ^(a) No.	Description
		waste from floor drains into a 12-in. steel pipe to the river bank. This is also part of the 200,000 gpm pumped by the 100-N river pumping facilities.
100-N	007	<u>Inlet Screen Wash Water and Fish Return</u> This discharge consists of untreated water used to dislodge and back flush material entrained on river pump inlet screens. The entrained material consists only of solid matter present in untreated Columbia River water (Figure II.1-D-8).
100-N	008	<u>Turbine Condenser Cooling Water</u> This process waste discharge is a part of the approximate 200,000 gpm pumped by the 100-N river pumping facilities. It consists of drive and generator turbine condenser cooling water and graphite cooling water discharged via a 66-in. line and concrete flume to the river bank (Figure II.1-D-9). During normal reactor operating periods the flows are about 65,000 gpm.
100-N	009	<u>Dump Condenser Cooling Water</u> This waste consists primarily of steam condenser cooling water discharged via a 102 in. line to the Columbia river channel (Figure II.1-D-10).
100-D/DR	010	<u>Inlet Screen Wash Water and Fish Return</u> Untreated water used to dislodge and backflush material entrained on the river pump inlet screens is returned to the river. The entrained material consists only of solid matter present in untreated Columbia River water. The pumping plant serves sanitary needs and process water to research facilities located in the 100-D Area (Figure II.1-D-11).
100-D/DR	011	<u>Research Facility and Backwash Drain</u> Treated process water used in 189-D and 183-D as coolant and wash water and in hydraulic test loops is returned to the river. The test loops are part of a research and development facility in support of N Reactor and other interests. Radioactive materials are not included in the test loops (Figure II.1-D-12).

(a) Application for EPA discharge permit number is 071-0YC-3-000099 covering 14 discharges.

TABLE II.1-D-1 (Continued)

Area	Discharge ^(a) No.	Description
300	012	<u>331 Fish Pond Effluent</u> This stream results from an AEC research effort in which experimental stocks of fish and other aquatic organisms are maintained in fresh or treated Columbia River water. Experiments involve the addition of small amounts of chemical or temperature increments. This discharge includes only raw water which is not chemically treated (Figure II.1-D-13).
300	013	<u>Filter Backwash</u> This stream, which results from the normal operation of the water treatment plant filter backwash, carries water treatment chemicals as well as silt back to the river. The small water treatment plant is a conventional design. Aluminum sulfate is added to river water, a proprietary polyacrylamide called "Separan" is added as a filter aid, and the water is chlorinated. The finished water is used for sanitary and process needs in the 300 Area (Figure II.1-D-14).
300	014	<u>309 Drains</u> This stream involves cooling water from air conditioning chillers and floor drains from the south basement service area in the 309 Building. The water is initially from the 300 Area drinking water system and no chemicals or other pollutants are added (Figure II.1-D-15).

(a) Application for EPA discharge permit number is 071-OYC-3-000099 covering 14 discharges.

FIGURE II.1-D-2 INLET SCREEN WASH WATER, 100-B AREA

FIGURE II.1-D-3 PROCESS DRAIN, 100-B AREA

FIGURE II.1-D-4 INLET SCREEN WASH WATER, 100-K AREA

REV. APRIL 1972
APPLICATION FOR EPA
DISCHARGE NO. 004

FIGURE II.1-D-5 PROCESS DRAIN, 100-K AREA

FIGURE II.1-D-6 WATER STORAGE TANK FARM OVERFLOW, 100-N AREA

REV. APRIL 1972
APPLICATION FOR EPA
DISCHARGE NO. 006

FIGURE II.1-D-7 OVERFLOW AND FLOOR DRAIN DISCHARGE, 100-N AREA

FIGURE II.1-D-8 INLET SCREEN WASH WATER, 100-N AREA

FIGURE II.1-D-9 TURBINE CONDENSER COOLING WATER, 100-N AREA

REV. APRIL 1972
APPLICATION FOR EPA
DISCHARGE NO. 009
102 INCH LINE 109N

FIGURE II.1-D-10 DUMP CONDENSER COOLING WATER, 100-N AREA

REV. APRIL 1972
APPLICATION FOR EPA
DISCHARGE NO. 010

FIGURE II.1-D-11 INLET SCREEN WASH WATER, 100-D AREA

REV. APRIL 1972
APPLICATION FOR EPA
DISCHARGE NO. 011

FIGURE II.1-D-12 RESEARCH FACILITY AND BACKWASH DRAIN, 100-D AREA

FIGURE II.1-D-13 331 BUILDING OUTFALL STRUCTURE

II.1-D-17

FIGURE II.1-D-14 FILTER PLANT OUTFALL STRUCTURE

FIGURE II.1-D-15 309 BUILDING OUTFALL STRUCTURE

APPENDIX II.1-E
300 AREA FACILITIES

APPENDIX II.1-E
300 AREA FACILITIES

	<u>Page</u>
Part 1 300 Area Maps	II.1-E-3
Part 2 Waste Management Facilities Storage and Disposal Sites	II.1-E-7
Part 3 Estimated Radioactive Liquid Waste Inventory - 300 Area	II.1-E-13
Part 4 300 Area, Radioactive Material Releases, 1972	II.1-E-17
Part 5 300 Area Unplanned Releases	II.1-E-25

APPENDIX II.1-E, PART 1

300 Area Maps

II.1-E-4

FIGURE II.1-E-1 300 AREA MAPS

BUILDINGS AND DESCRIPTIONS

BUILDING NUMBER	DESCRIPTION	BUILDING NUMBER	DESCRIPTION	BUILDING NUMBER	DESCRIPTION
301	EQUIPMENT STORAGE	326	PHYSICS AND METALLURGY BUILDING	3701-L	BADGE HOUSE - SOUTH
303-A	PRODUCT STORAGE BUILDING	327	RADIOMETALLURGY BUILDING	3701-N	BADGE HOUSE - NORTH
303-B	PRODUCT STORAGE BUILDING	328	ENGINEERING SERVICES AND SAFETY	3701-Z	BADGE HOUSE - CONSTRUCTION
303-C	FISSILE MATERIAL STORAGE BUILDING	328-A	TECHNICAL SHOPS ANNEX	3702	OFFICE BUILDING
303-E	ESSENTIAL MATERIAL STORAGE BUILDING	329	BIOPHYSICS LABORATORY	3703	OFFICE BUILDING
303-F	CHEMICAL STORAGE & DISPERSAL BUILDING	330	STRESS RUPTURE TEST FACILITY	3704	STORAGE
303-G	ESSENTIAL MATERIAL STORAGE BUILDING	331	LIFE SCIENCE LABORATORY - I	3705	PHOTOGRAPHY BUILDING
303-J	MATERIAL STORAGE BUILDING	331-A	VIROLOGY LABORATORY	3706	OFFICES AND SERVICES
303-K	DECONTAMINATION AND BATTERY CHARGE BUILDING	331-B	INHALATION FACILITY	3706-A	VENTILATION EQUIPMENT BUILDING FOR 3706
303-L	OXIDE BURNING BUILDING	333	N-FUELS MANUFACTURING BUILDING	3707-A	ENGINEERING
304	FUELS ENGINEERING LABORATORY	334	CHEMICAL HANDLING BUILDING	3707-B	UTILITY OPERATIONS BUILDING
305	TEST REACTOR	335	SODIUM TESTING FACILITY	3707-C	NONDESTRUCTIVE TESTING
305-A	OFFICE AND SHOP	336	SODIUM TESTING FACILITY	3707-D	STORAGE
305-B	EXPERIMENTAL TEST REACTOR BUILDING	337	HIGH TEMPERATURE SODIUM FACILITY	3707-E	STORAGE
306	METAL FABRICATION DEVELOPMENT	338	LMFBR MOCK-UP AND MAINTENANCE	3707-F	PERSONNEL SURVEY BUILDING
307	RETENTION BASIN	340	RETENTION AND NEUTRALIZATION BUILDING	3707-G	URANIUM OXIDE CHANGE HOUSE
307-D	EFFLUENT HOLDUP TANK	340-A	MAINTENANCE STORAGE	3708	FISSILE MATERIAL STORAGE
308	PLUTONIUM LABORATORY	340-B	RAILROAD LOAD-OUT STATION	3709	PAINT SHOP
308-E	EMERGENCY STORAGE ANNEX	351	SUBSTATION	3709-A	FIRE STATION
309	PRTR OFFICES AND SHOPS	351-B	METER, TESTING & SWITCHGEAR FACILITY	3710	OIL AND GREASE STORAGE
310	PRTR CONDENSER BUILDING	352	SUBSTATION - 2.4KV	3710-A	OIL AND GAS STORAGE
311	ACID, CAUSTIC AND METHANOL TANK FARM	352-A	SUBSTATION - 115KV	3711	STORAGE (CONSTRUCTION)
312	RIVER PUMP HOUSE	352-C	SUBSTATION - 2.4KV	3712	FUEL MATERIAL STORAGE
313	FUELS MANUFACTURING BUILDING	352-D	2400 VOLT SWITCHGEAR BUILDING	3713	CARPENTER AND PAINT SHOP
314	ENGINEERING DEVELOPMENT LABORATORY	352-E	SWITCH STATION EAST SIDE	3714	ORGANIC CHEMISTRY LABORATORY
314-A	GAS BONDING AUTOCLAVE PIT	366	FUEL OIL BUNKER	3715	FUEL MATERIAL STORAGE
315	WATER FILTER PLANT	382	PUMP HOUSE	3716	METALLURGICAL DEVELOPMENT FACILITY
318	HIGH TEMPERATURE LATTICE TEST REACTOR	382-A	WATER RESERVOIR - 200,000 GAL.	3717	SHEETMETAL SHOP AND OFFICE BUILDING
318-A	DETECTOR BUILDING	382-B	WATER RESERVOIR - 225,000 GAL.	3717-B	STANDARDS LABORATORY
318-B	HTLTR STACK	384	POWERHOUSE	3717-C	SODIUM MAINTENANCE FACILITY
318-C	HTLTR FILTER	3106	HELIUM STORAGE TANKS	3718	PLANT OPERATIONS SERVICES BUILDING
320	LOW LEVEL RADIOCHEMISTRY BUILDING	3503-A	ELECTRICAL CABLE PIT NO. 2	3718-A	LABORATORY EQUIPMENT POOL
321	ENGINEERING DEVELOPMENT LABORATORY	3503-B	ELECTRICAL CABLE PIT NO. 3	3718-B	LABORATORY EQUIPMENT POOL
323	METALS CREEP LABORATORY	3506-A	TELEPHONE EXCHANGE FACILITY	3718-C	LABORATORY EQUIPMENT POOL
324	CHEMICAL ENGINEERING LABORATORY	3607	SEPTIC TANK	3718-D	LABORATORY STORAGE BUILDING (308)
324-A	STACK GAS SAMPLING BUILDING	3614-A	COLUMBIA RIVER MONITORING STATION	3718-E	STORAGE BUILDING (324)
324-B	EXHAUST STACK	3621-B	EMERGENCY GENERATOR	3718-F	SODIUM MAINTENANCE BUILDING
325	RADIOCHEMISTRY BUILDING	3621-C	EMERGENCY GENERATOR CONTROL ROOM	3718-M	SODIUM TANK STORAGE FACILITY
325-A	CESIUM RECOVERY FACILITY	3621-D	EMERGENCY POWER GENERATING STATION NO. 3	3718-N	CRAFT SUPPORT SHOP
325-B	SHIELDED LABORATORY ANNEX	3622	LABORATORY VIEWPOINT SHELTER		
325-C	FLORINE GAS STORAGE	3701-A	GATE HOUSE - WEST		
325-D	MAINTENANCE SHOP

FIGURE II.1-E-1 (Continued)

APPENDIX II.1-E, PART 2

Waste Management Facilities Storage and Disposal Sites

TABLE II.1-E-1

TABLE OF STORAGE AND DISPOSAL SITES
300 AREA

<u>Grounds</u>	<u>Size Acres</u>	<u>Description</u>	<u>Terminated Service In Year</u>	<u>Depth to Water Table (ft)</u>	<u>Monitored by Well Number</u>
1	1.1	200 ft long trenches 15 ft wide by 8 ft deep on N-S axis and some 20 ft wide by 15 ft deep on E-W axis. Covered with 4 ft layer of clean dirt, and marked in 1961. Markers 3-61-51 through 3-61-90. Contains all 300 Area solid radioactive waste generated from 1945-1956, including uranium, plutonium, and fission products.	1956	41	399-1-2
2	1.7+	Pits 150 ft long by 51 ft wide by 15 ft deep. Covered with clean soil and marked in 1961. Markers 3-61-1 through 3-61-50. Contains uranium contaminated equipment and material.	1961	41	399-1-2
3	1.3+	An expansion to the west of No. 2 with similar contents and deactivation procedures.	1961	41	399-1-2

TABLE II.1-E-1 (Continued)

Grounds	Size Acres	Description	Terminated Service In Year	Depth to Water Table (ft)	Monitored by Well Number
4	2.9+	Elongated pits containing uranium contaminated miscellaneous materials from 300 Area manufacturing facilities. Filled and covered with clean dirt. Marked in 1961 with markers 3-61-137 through 3-61-189.	1961	33	--
5	1.2+	Elongated pits to 15 ft deep containing uranium contaminated trash. Covered, filled with 4 ft of clean dirt. Marked in 1962, 3-62-1 through 3-62-38.	1962	38	
6	--	No longer exists. Wastes moved to other sites. Contained solid uranium waste from 6 mo in 1944. Filled with clean dirt.	1944	--	
7	~16.7	Two drive-in trenches and a V-shaped pit, containing materials primarily from 300 Area fuel manufacturing process contaminated slightly with uranium or thorium. Backfilled and covered with clean dirt.	1971	52	399-8-2

TABLE II.1-E-1 (Continued)

Grounds	Size Acres	Description	Terminated Service In Year	Depth to Water Table (ft)	Monitored by Well Number
8	~1.4	Long trenches filled with low level uranium bearing waste from fuel manufacturing areas filled and covered with clean dirt and a parking lot (North). Marked in 1961, 3-61-91 through 136.	Prior	52	--
300 West	0.1	A long trench filled with drums of uranium contaminated organic solvent from the 321 Building in 1955 and 1956. Terminated and marked in 1963, 3-63-1 through 18.	1956	55	--
Contaminated Equipment Storage Area		All equipment removed. Ground slightly contaminated.			

II.1-E-10

TABLE II.1-E-2

TABLE OF STORAGE AND DISPOSAL SITES
SITES ANCILLARY TO THE 300 AREA

Site or Building No.	Size Acres	Description	Service	Depth To Water Table (ft)
300 North	6.1	Located about 4 miles northwest of 300 Area. Terminated. Broad spectrum of low-to high-level solid radioactive waste, primarily fission products and plutonium. Cartoned low-level waste was buried in trenches; medium to high-level waste in caissons or buried pipe facilities.	1953-63	65
300 North	<1	A stainless steel tank with an open bottom, about 150 ft southeast of the 300 North burial ground, into which was dumped uranium contaminated liquid waste from the 321 Building.	1948-56	65
300 Wye	8.6	Located about 7-1/3 miles north of the 300 Area. Retired--filled and marked. Broad spectrum of low-to high-level solid radioactive waste, primarily fission products and plutonium. Cartoned low-level waste was buried in trenches; medium to high-level waste in caissons or buried pipe facilities.	1962-67	45

II.1-E-11

APPENDIX II.1-E, PART 3

Estimated Radioactive Liquid Waste Inventory - 300 Area

TABLE II.1-E-3

ESTIMATED RADIOACTIVE LIQUID WASTE INVENTORY - 300 AREA

340 STORAGE
75,000 GAL CAPACITY

Routine Analyses - Average Concentration
 (Ci/m³)

	<u>Filtrate</u>	<u>Solids^(a)</u>
Total Beta ^(b)	7.16	42.5
Total Alpha ^(c)	0.011	0.033
⁶⁰ Co	<0.006 ^(d)	<0.046 ^(d)
⁹⁰ Sr	0.304	0.364
¹⁰⁶ Ru-Rh	0.042 ^(d)	0.399
¹³⁷ Cs	0.321	0.038

-
- (a) Solids concentrations in units per cubic meter of liquid.
 (b) Total beta calculated as a hypothetical, nonvolatile nuclide emitting a beta particle of energy 0.3 MeV.
 (c) Total alpha is calculated as ²³⁹Pu.
 (d) "Less Than" is used when the results were below detection levels.
 (e) The number in parenthesis indicates the number of values reported and averaged. Blanks indicate no value reported.

340 STORAGE (Continued)

Nuclides Detected in One or More Samples Concentration (Ci/m ³)		
	<u>Filtrate^(e)</u>	<u>Solids^{(a)(e)}</u>
¹²⁵ Sb	0.006(1)	0.013(3)
¹³⁴ Cs	0.017(10)	0.003(2)
¹⁵² Eu		0.0003(1)
¹⁵⁴ Eu	0.053(2)	0.003(4)
¹⁵⁵ Eu	0.095(3)	0.042(5)
²⁴¹ Am		0.0003(2)

The concentration of all nonradioactive chemical compounds is shown below:

Nonradioactive Analyses Average	
pH	11.5
Nonvolatile Residue	2650 g/m ³
Uranium Filtrate	30.7 g/m ³
Solids ^(a)	1.22 g/m ³

APPENDIX II.1-E, PART 4

300 Area, Radioactive Material Releases, 1972

TABLE II.1-E-4

SUMMARY OF RADIOACTIVE GASEOUS WASTE DISCHARGED FROM
300 AREA FACILITIES DURING 1972

METAL FABRICATION DEVELOPMENT - 306-W

Roof No. 1 - Thorium Storage Room

	<u>Alpha</u>	<u>Beta</u>
Volume 1×10^{13} (cc)		
Ave. Concentration	$<1.14 \times 10^{-14}$ $\mu\text{Ci/cc}$	$<1.2 \times 10^{-13}$ $\mu\text{Ci/cc}$
Ave. Release Rate	<0.001 $\mu\text{Ci/wk}$	<0.024 $\mu\text{Ci/wk}$
Max. Release	<0.011 $\mu\text{Ci/wk}$	<0.051 $\mu\text{Ci/wk}$
Total Release	<0.052 μCi	<1.24 μCi

METAL FABRICATION DEVELOPMENT - 306-W

Roof No. 2 - Bag Filter Exhaust

	<u>Alpha</u>	<u>Beta</u>
Volume 2×10^{14} (cc)		
Ave. Concentration	$<1.2 \times 10^{-14}$ $\mu\text{Ci/cc}$	$<1.8 \times 10^{-13}$ $\mu\text{Ci/cc}$
Ave. Release Rate	<0.046 $\mu\text{Ci/wk}$	<0.728 $\mu\text{Ci/wk}$
Max. Release	<0.170 $\mu\text{Ci/wk}$	<2.349 $\mu\text{Ci/wk}$
Total Release	<2.392 μCi	<37.856 μCi

METAL FABRICATION DEVELOPMENT - 306-W

	<u>Alpha</u>	<u>Beta</u>
Volume 1×10^{14} (cc)		
Ave. Concentration	$<3.24 \times 10^{-14}$ $\mu\text{Ci/cc}$	$<2.59 \times 10^{-13}$ $\mu\text{Ci/cc}$
Ave. Release Rate	<0.065 $\mu\text{Ci/wk}$	<0.526 $\mu\text{Ci/wk}$
Max. Release Rate	<0.425 $\mu\text{Ci/wk}$	<1.77 $\mu\text{Ci/wk}$
Total Release	<3.39 μCi	<27.3 μCi

306-W METAL FABRICATION DEVELOPMENT

URANIUM POWDER LABORATORIES NO. 158 AND NO. 159

	<u>Alpha</u>	<u>Beta</u>
Volume 3.1×10^{13} (cc)		
Ave. Concentration	$<5.0 \times 10^{-15} \mu\text{Ci/cc}$	$<3.6 \times 10^{-14} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.003 \mu\text{Ci/wk}$	$<0.02 \mu\text{Ci/wk}$
Max. Release Rate	$<0.02 \mu\text{Ci/wk}$	$<0.08 \mu\text{Ci/wk}$
Total Release	$<0.156 \mu\text{Ci}$	$<1.1 \mu\text{Ci}$

BIOPHYSICS LABORATORY - 329

	<u>Alpha</u>	<u>Beta</u>
Volume 4×10^{14} (cc)		
Ave. Concentration	$<0.35 \times 10^{-14} \mu\text{Ci/cc}$	$<2.22 \times 10^{-14} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.29 \mu\text{Ci/wk}$	$<0.186 \mu\text{Ci/wk}$
Max. Release Rate	$<0.38 \mu\text{Ci/wk}$	$<0.529 \mu\text{Ci/wk}$
Total Release	$<1.49 \mu\text{Ci}$	$<9.67 \mu\text{Ci}$

LIFE SCIENCE BUILDING - 331

	<u>"D" Stack, Alpha^(a)</u>	<u>"S" Stack, Alpha^(a)</u>
Volume	1.7×10^8	5.6×10^8
Ave. Concentration	$<3.10 \times 10^{-10} \text{pCi/cc}$	$<1.92 \times 10^{-10} \text{pCi/cc}$
Ave. Release Rate	$<0.003 \mu\text{Ci/wk}$	$<0.002 \mu\text{Ci/wk}$
Max. Release Rate	$<0.011 \mu\text{Ci/wk}$	$<0.024 \mu\text{Ci/wk}$
Total Release	$<0.052 \mu\text{Ci}$	$<0.107 \mu\text{Ci}$

(a) As plutonium.

FISSILE MATERIAL STORAGE - 3708

	Alpha
Volume 4×10^{13} (cc)	
Ave. Concentration	$<4.4 \times 10^{-15} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.0048 \mu\text{Ci/wk}$
Max. Release Rate	$<0.008 \mu\text{Ci/wk}$
Total Release	$<0.166 \mu\text{Ci}$
Facility put into service	May 1, 1972.

308 FUELS LABORATORY

	Alpha
Volume 3.3×10^{14} (cc)	
Ave. Concentration	$<4.5 \times 10^{-15} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.03 \mu\text{Ci/wk}$
Max. Release Rate	$<0.03 \mu\text{Ci/wk}$
Total Release	$<1.5 \mu\text{Ci}$

324 CHEMISTRY AND MATERIALS ENGINEERING LABORATORY

	Alpha	Beta
Volume 1×10^{15} (cc)		
Ave. Concentration	$<3.1 \times 10^{-14} \mu\text{Ci/cc}$	$<7.9 \times 10^{-14} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.38 \mu\text{Ci/wk}$	$<2.5 \mu\text{Ci/wk}$
Max. Release Rate	$<0.4 \mu\text{Ci/wk}$	$<3.2 \mu\text{Ci/wk}$
Total Release	$<20.2 \mu\text{Ci}$	$<136.9 \mu\text{Ci}$

	Iodine-131
Ave. Concentration	$<7.8 \times 10^{-13} \mu\text{Ci/cc}$
Ave. Release Rate	$<26.0 \mu\text{Ci/wk}$
Max. Release Rate	$<48.0 \mu\text{Ci/wk}$
Total Release	$<1383.0 \mu\text{Ci/wk}$

325 RADIOCHEMISTRY LABORATORY

	Alpha	Beta
Volume 2×10^{15} (cc)		
Ave. Concentration	7.8×10^{-15} $\mu\text{Ci/cc}$	1.2×10^{-12} $\mu\text{Ci/cc}$
Ave. Release Rate	<0.22 $\mu\text{Ci/wk}$	52 $\mu\text{Ci/wk}$
Max. Release Rate	0.93 $\mu\text{Ci/wk}$	910 $\mu\text{Ci/wk}$
Total Release ^(a)	<11.9 μCi	2756 μCi

	Iodine-131
Ave. Concentration	$<1.3 \times 10^{-12}$ $\mu\text{Ci/cc}$
Ave. Release Rate	28 $\mu\text{Ci/wk}$
Max. Release Rate	380 $\mu\text{Ci/wk}$
Total Release ^(a)	<1493 μCi

(a) 1 Ci Radon release on September 25, 1972.

325-B RADIOCHEMISTRY LABORATORY ANNEX

	Alpha	Beta
Volume 1×10^{14} (cc)		
Ave. Concentration	$<5.4 \times 10^{-15}$ $\mu\text{Ci/cc}$	1.85×10^{-13} $\mu\text{Ci/cc}$
Ave. Release Rate	<0.008 $\mu\text{Ci/wk}$	<0.3 $\mu\text{Ci/wk}$
Max. Release Rate	0.02 $\mu\text{Ci/wk}$	10.0 $\mu\text{Ci/wk}$
Total Release ^(a)	<0.44 μCi	<16.4 μCi

	Iodine-131
Ave. Concentration	1.1×10^{-11} $\mu\text{Ci/cc}$
Ave. Release Rate	19.0 $\mu\text{Ci/wk}$
Max. Release Rate	310.0 $\mu\text{Ci/wk}$
Total Release ^(a)	1004 μCi

(a) 1 Ci Radon release on July 26, 1972.

326 PHYSICS AND METALLURGY

	Alpha	Beta
Volume 1×10^{15} (cc)		
Ave. Concentration	$<8.3 \times 10^{-15} \mu\text{Ci/cc}$	$5.6 \times 10^{-14} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.34 \mu\text{Ci/wk}$	$1.0 \mu\text{Ci/wk}$
Max. Release Rate	$0.67 \mu\text{Ci/wk}$	$2.9 \mu\text{Ci/wk}$
Total Release	$<17.7 \mu\text{Ci}$	$54.8 \mu\text{Ci}$

327 RADIOMETALLURGY LABORATORY

	Alpha (a)	Beta (b)
Volume 1×10^{15} (cc)		
Ave. Concentration	$5.6 \times 10^{-15} \mu\text{Ci/cc}$	$<3.4 \times 10^{-14} \mu\text{Ci/cc}$
Ave. Release Rate	$<0.1 \mu\text{Ci/wk}$	$<0.66 \mu\text{Ci/wk}$
Max. Release Rate	$0.34 \mu\text{Ci/wk}$	$0.84 \mu\text{Ci/wk}$
Total Release	$<5.5 \mu\text{Ci}$	$<33.8 \mu\text{Ci}$

	Iodine-131
Ave. Concentration	$7.6 \times 10^{-12} \mu\text{Ci/cc}$
Ave. Release Rate	$159.7 \mu\text{Ci/wk}$
Max. Release Rate	$3000 \mu\text{Ci/wk}$
Total Release	$8145 \mu\text{Ci}$

- (a) Alpha activity was presumed to have the same plutonium composition as the fuel being examined: 88.3% ^{239}Pu , 10.3% ^{240}Pu , 1.3% ^{241}Pu and 0.1% ^{242}Pu . In this mixture 95% of the alpha particles emitted come from ^{241}Pu .
- (b) Beta emitters were not identified. There were larger amounts of fission products than activation products in samples being examined.

340 TANK VENT

	Alpha	Beta
Volume 5×10^{12} (cc)		
Ave. Concentration	$<4.3 \times 10^{-13}$ $\mu\text{Ci/cc}$	6.7×10^{-11} $\mu\text{Ci/cc}$
Ave. Release Rate	<0.012 $\mu\text{Ci/wk}$	5.0 $\mu\text{Ci/wk}$
Max. Release Rate	0.41 $\mu\text{Ci/wk}$	220.0 $\mu\text{Ci/wk}$
Total Release	<0.60 μCi	290 μCi

	Iodine-131
Ave. Concentration	1.4×10^{-10} $\mu\text{Ci/cc}$
Ave. Release Rate	15.5 $\mu\text{Ci/wk}$
Max. Release Rate	370.0 $\mu\text{Ci/wk}$
Total Release	775.8 μCi

TABLE II.1-E-5

ESTIMATED RADIOACTIVE LIQUID RELEASES-1972^(a)

	Uranium ^(b)	Total Alpha	Total Beta
Average Flow Rate	2.9×10^6 gal/day		
Total Discharge	525 kg 0.4 Ci	0.38 Ci	0.48 Ci
Average Concentration	131 $\mu\text{g/liter}$	96×10^{-9} $\mu\text{Ci/ml}$	121×10^{-9} $\mu\text{Ci/ml}$

(a) The 300 Area South Pond was used for 5 days in 1972.

(b) Analysis of accumulated solids indicated 0.977% ^{235}U . On this basis the specific activity was determined to be 8.4×10^{-7} Ci/g.

APPENDIX II.1-E, PART 5
300 Area Unplanned Releases

TABLE II.1-E-6
300 AREA UNPLANNED RELEASE

Date	Building	Description	Isotope and Amount
1-7-70	307,340	A leak was discovered in the transfer line from retention basins to crib waste system. Crib waste backed up and the bottom half of a short carbon steel transition piece was eroded away and contaminated waste leaked to the soil about 5 feet below grade.	840 Ci Shortlived F.P. 10 Ci ⁹⁰ Sr 10 Ci ¹³⁷ Cs
6-7-69	325-B	Stack release from 325-B. (¹³¹ I) Sample showed additional emission ~3 mCi. Alpha and total beta release low and normal.	0.6 Ci ¹³¹ I
6-13-67	325	Nonstandard release of ¹⁴⁷ Pm from 325 Bldg. 0.71 Ci to 300 Area pond. 0.1 Ci to atm via 325 stack.	0.85 Ci ¹⁴⁷ Pm
5-09-67	327	Release of iodine resulted from examination of irradiated reactor fuel.	0.11 Ci ¹³¹ I
5-09-66	325	Daily check of stack filters detected 144-141Ce had been released.	0.6 Ci ¹⁴⁴⁻¹⁴¹ Ce
3-23-67 thru 4-18-67	300 Area Stacks 325 Stacks	¹³¹ I releases in excessive amounts from 300 Area stacks.	0.2 Ci ¹³¹ I
5-03-67	327	Release of iodine during the sectioning off of PRTR fuels.	0.1 Ci ¹³¹ I
9-29-65	309 Bldg.	Failure of reactor coolant tube caused high radiation limits inside reactor and containment vessel.	

II.1-E-26

TABLE II.1-E-6

(Continued)

<u>Date</u>	<u>Building</u>	<u>Description</u>	<u>Isotope and Amount</u>
No significant releases 1958-1964 per G. E. Backman, HW 84619.			
8-16-55	300 North Burial Grounds	Fire caused particulates to be spread out to 1500 ft in a northeast direction. Particle frequencies ranged from 0.5 to 4 per 100 ft ² . Instrument readings of 35,000 to 80,000 counts/min. Isolated 4.5 rad/hr.	Mixed
2-17-54	Burial Ground	Fire occurred in 300 Area solid waste burial ground. Small area east of and up to 20 ft from BG fence contained widely scattered contamination from 2000 counts/min to 100 mrad/hr	Mixed

II.1-E-27

APPENDIX II.1-F

PROCESS CHEMICAL INVENTORY AND CONSUMPTION

TABLE II.1-F-1

PROCESS CHEMICAL INVENTORY - 200 AREAS

<u>Chemical Compound</u>	<u>How Stored</u>	<u>Where Stored</u>	<u>How Used</u>	<u>How Disposed</u>	<u>Typical Inventory</u>
Aluminum Nitrate - Nonahydrate	Bulk Tank	202-A Bldg. 234-5 Bldg.	Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank	30,000 lb
Ammonium Fluoride Ammonium Nitrate	Bulk Tank	202-A Bldg.	Process Chemical	Underground Storage Tank	100,000 lb
Ammonia (Anhydrous)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	45,000 lb
Carbon Tetrachloride	Drum	234-5 Bldg.	Process Chemical	Underground Storage Tank	20,000 lb
Carbon Dioxide	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	30,000 lb
Citric Acid	100 lb. Bag	275-EA Warehouse 271-B Bldg. 271-T Bldg.	Process Chemical Process Chemical Cleaning Agent	To User Facility Underground Storage Tank Underground Storage Tank	2,700 lb
Cadmium Nitrate	55 gal Drum	275-EA Warehouse	Neutron Poison Neutron Poison	Z-9 Crib Underground Storage Tank	15,000 lb
Dibutyl Butyl Phosphonate	55 gal Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	11,000 lb
Di2 Ethyl Hexyl Phosphoric Acid	55 gal Drum	275-EA Warehouse 271-B Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	10,000 lb
Ferric Nitrate	Fiber Drum	275-EA Warehouse 202-A Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	6,000 lb
Ferrous Sulfamate	Fiber Drum	275-EA Warehouse 202-A Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	5,000 lb
Magniflox 581C	55 gal Drum	275-EA Warehouse 244-AR Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	10,000 lb
Hydrogen Fluoride	Cylinder	234-5 Bldg.	Process Chemical	Underground Storage Tank	10,000 lb
Hydroxyacetic Acid	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	200,000 lb

TABLE II.1-F-1 (Continued)

Chemical Compound	How Stored	Where Stored	How Used	How Disposed	Typical Inventory
Hydrogen Peroxide	Aluminum Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	1,500 lb
Calcium	Drum	234-5 Bldg.	Process Chemical	Underground Storage Tank	1,500 lb
Magnesium Oxide	Drum	234-5 Bldg.	Process Chemical	Underground Storage Tank	3,000 lb
Liquid Nitrogen	Bulk Tank	234-5 Bldg.	Process Chemical	Atmosphere	150,000 ft ³
Hydrochloric Acid	Bottle	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	1,000 lb
Hydroxylamine Sulfate	Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	20,000 lb
Lead Nitrate ^(b)	Wooden Keg (polylined)	275-EA Warehouse	Process Chemical	To User Facility	5,000 lb
Mercuric Nitrate	Ice Cream Carton (poly- lined)	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	350 lb
Tetra Sodium Ethy- lene Diamine Tetra Acetate (EDTA)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	250,000 lb
Nitrilotriacetic Acid (b)	55 gal Drum	275-EA Warehouse	Process Chemical	To User Facility	3,000 lb
Trisodium Hydroxy- ethyl Ethylene Diamine Triace- tate (HEDTA)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	400,000 lb
Normal Paraffin Hydrocarbon	Bulk Tank	202-A Bldg. 271-B Bldg.	Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank	200,000 lb
Nitric Acid	Bulk Tank Bulk Tank	202-A Bldg. 234-5 Bldg.	Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank	200,000 lb

TABLE II.1-F-1 (Continued)

Chemical Compound	How Stored	Where Stored	How Used	How Disposed	Typical Inventory
Nitric Acid (contd)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	
	Bulk Tank	244-AR Bldg.	Process Chemical	Underground Storage Tank	
	Bulk Tank	271-T Bldg.	Cleaning Agent	Underground Storage Tank	
	Bulk Tank	211-U Bldg.	Process Chemical	Underground Storage Tank	
Oxalic Acid	Fiber Drum (polylined)	275-EA Warehouse	Process Chemical	To User Facility	15,000 lb
		271-B Bldg.	Process Chemical	Underground Storage Tank	
		234-5 Bldg.	Process Chemical	Underground Storage Tank	
Pentasodium Diethylene Triamine Penta-acetate (b) (DTPA)	55 gal Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	1,200 lb
Phosphotungstic Acid	Steel Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	2,500 lb
Phosphoric Acid	Bulk Tank (polylined)	241-BX Tank Farm	Process Chemical	To User Facility	15,000 lb
	Fiber Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	
Potassium Hydroxide	Bulk Tank	202-A Bldg.	Process Chemical	Underground Storage Tank	35,000 lb
Potassium Permanganate	Steel Pail (polylined)	275-EA Warehouse	Process Chemical	To User Facility	8,000 lb
		234-5 Bldg.	Process Chemical	Underground Storage Tank	
		271-T Bldg.	Cleaning Agent	Underground Storage Tank	
		284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment	Sanitary Water Sanitary Water	
Potassium Per- sulfate (b)	100 lb. Bag	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	4,000 lb
Silver Nitrate ^(b)	Ice Cream Carton (poly- lined)	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	1,000 lb
Sodium Bisulfate	Fiber Drum (polylined)	275-EA Warehouse	Process Chemical	To User Facility	125,000 lb
		271-T Bldg.	Cleaning Agent	Underground Storage Tank	

TABLE II.1-F-1 (Continued)

<u>Chemical Compound</u>	<u>How Stored</u>	<u>Where Stored</u>	<u>How Used</u>	<u>How Disposed</u>	<u>Typical Inventory</u>
Soda Ash	100 lb Bag	275-EA Warehouse 202-A Bldg. 271-B Bldg. 271-T Bldg.	Process Chemical Process Chemical Process Chemical Cleaning Agent	To User Facility Underground Storage Tank Underground Storage Tank Underground Storage Tank	250,000 lb
Sodium Chloride	100 lb Bag	284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment	Seepage Pond Seepage Pond	150,000 lb
Sodium Fluoride	100 lb Bag	275-EA Warehouse	Process Chemical	Underground Storage Tank	500 lb
Sodium Fluoride (Reagent Grade)	200 lb Fiber Drum	275-EA Warehouse	Process Chemical	To User Facility	1,000 lb
Sodium Gluconate	50 lb Bag	275-EA Warehouse 271-B Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	100,000 lb
Sodium Hydroxide.	Bulk Tank	202-A Bldg. 271-B Bldg. 234-5 Bldg. 244-AR Bldg. 271-T Bldg.	Process Chemical Process Chemical Process Chemical Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank	300,000 lb
Sodium Nitrate	100 lb Bag	275-EA Warehouse 234-5 Bldg.	Process Chemical	To User Facility Underground Storage Tank	50,000 lb
Sodium Nitrite	100 lb Bag Fiber Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	50,000 lb
Sodium Sulfate	100 lb Bag	275-EA Warehouse 271-B Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	75,000 lb
Sugar	100 lb Bag	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	5,000 lb
Sulfanic Acid	50 lb Bag	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	4,300 lb

TABLE II.1-F-1 (Continued)

<u>Chemical Compound</u>	<u>How Stored</u>	<u>Where Stored</u>	<u>How Used</u>	<u>How Disposed</u>	<u>Typical Inventory</u>
Sulfuric Acid	Bulk Tank	202-A Bldg. 211-U Bldg.	Water Treatment Process Chemical	Seepage Pond In Product	100,000 lb
Hydrazine	Steel Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical	To User Facility Underground Storage Tank	10,000 lb
Tartaric Acid	Burlap Sack	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	20,000 lb
Tributyl Phosphate	Bulk Tank 55 gal Drum	202-A Bldg. 234-5 Bldg. 271-B Bldg. 275-EA Warehouse	Process Chemical Process Chemical Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank Underground Storage Tank To User Facility	25,000 lb
Turco 4306B	Fiber Drum (polylined)	275-EA Warehouse	Cleaning Agent	To User Facility Underground Storage Tank	12,000 lb
Turco 4518	55 gal Drum (polylined)	275-EA Warehouse 271-T Bldg.	Cleaning Agent Cleaning Agent	To User Facility Underground Storage Tank	6,000 lb
Turco 4512-A	55 gal Drum	275-EA Warehouse 271-T Bldg.	Cleaning Agent Cleaning Agent	To User Facility Underground Storage Tank	200 gal
Aluminum Sulfate	100 lb Sack	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility Seepage Pond Seepage Pond	80,000 lb
Chlorine	Cylinder	284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment	Sanitary Water Sanitary Water	20,000 lb
Disodium Phosphate	100 lb Sack	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility Seepage Pond Seepage Pond	2,500 lb
Octafilm	Fiber Drum	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility French Drains and Crips	15,000 lb

TABLE II.1-F-1 (Continued)

<u>Chemical Compound</u>	<u>How Stored</u>	<u>Where Stored</u>	<u>How Used</u>	<u>How Disposed</u>	<u>Typical Inventory</u>
Sodium Sulfite	100 lb Sack	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility Seepage Pond Seepage Pond	5,000 lb
Corregen	55 gal Drum	275-EA Warehouse 284-E Bldg.	Water Treatment	To User Facility French Drains and Cribs	5,000 lb
Age1	Fiber Drum	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility French Drains and Cribs	15,000 lb

TABLE II.1-F-2

B PLANT CHEMICAL CONSUMPTION

Chemical	Consumption (lb/yr)	
	PAS + PSS(a)	CAW(b)
Ammonia	600,000	- -
Carbon Dioxide	700,000	- -
Citric Acid		300,000
Di(2-Ethylhexyl) Phosphoric Acid (D2EHPA)	25,000	10,000
Hydroxyacetic Acid	300,000	250,000
Tetra Sodium Ethylene Diamine Tetra Acetate (EDTA)	1,500,000	- -
Tri Sodium Hydroxyethyl Ethylene Diamine Triacetate (HEDTA)	2,000,000	15,000
Normal Paraffin Hydrocarbon (NPH)	85,000	30,000
Nitric Acid	1,500,000	1,000,000
Oxalic Acid	4,000	3,000
Phosphotungstic Acid (PTA)	- -	22,000
Sodium Carbonate (Soda Ash)	100,000	650,000
Sodium Glucomate	100,000	70,000
Sodium Hydroxide (Caustic)	1,800,000	1,600,000
Sodium Sulfate	50,000	40,000
Sulfuric Acid	3,000	2,000
Tributyl Phosphate (TBP)	15,000	6,000

(a) SX Operating 70% of time - 200,000 gal sludge per year

(b) SX Operating 50% of time - 250,000 gal CAW per year (from 1,000
T/YR N Reactor fuels)

TABLE II.1-F-3

ENCAPSULATION PLANT
Chemical Consumption

Hydrochloric Acid (12M solution)	945 liters/year
Sodium fluoride (Solid)	1,000 pounds/year
Sodium Hydroxide (Solid)	900 pounds/year
(Liquid)	700 liters/year

TABLE II.1-F-4

CHEMICAL CONSUMPTION FOR TANK FARMS

<u>Chemical</u>		<u>Quantity/Yr</u>
Nitric Acid 57%	Now	1,000,000 lb
	Future	3-10 million lb
Magnifloc 581C		15,000 lb
Sodium Hydroxide		120,000 lb
Turco 4518		1,300 lb
Fabrifilm		55
Sodium Nitrate		100,000 lb
Phosphoric Acid		2-3 million lb/yr during 1976, 77, 78, 79
or		or
Kaolin Clay		10-15 million lb/yr during 1976, 77, 78, 79

TABLE II.1-F-5

PUREX PLANT CHEMICAL CONSUMPTION

Chemical	lb/yr (a)	N Fuels lb/ton
Aluminum Nitrate (ANN)	275,000	272
Ammonium Fluoride - Ammonium Nitrate (AFAN)	700,000	668
Ferric Nitrate	750	
Ferrous Sulfamate	20,000	20.4
Normal Paraffin Hydrocarbon (NPH)	16,000	16.4
Nitric Acid (HNO_3)	900,000	907
Oxalic Acid	20,000	
Potassium Hydroxide (KOH)	160,000	160
Potassium Permanganate	2,000	2.0
Sodium Carbonate (Soda Ash)	10,000	9.9
Sodium Hydroxide (Caustic)	650,000	647
Sodium Nitrite	15,000	13.6
Sugar	30,000	26.5
Sulfamic Acid	5,000	5.4
Sulfuric Acid	25,000	24.5
Hydrazine	4,000	3.3
Tartaric Acid	6,000	
Tributyl Phosphate (TBP)	100,000	
Hydroxylamine Nitrate	20,000	5 gal
Potassium Fluoride	25,000	
Cadmium Nitrate	5,000	

(a) Assumes 1,000 T/Yr of N Reactor fuels

TABLE II.1-F-6

CHEMICAL CONSUMPTION FOR
Pu RECLAMATION AND Pu FINISHING (Z PLANT)

Chemical	Quantity/Yr
Aluminum Nitrate Nonahydrate ^(a)	450,000 lb
Carbon Tetrachloride ^(a)	11,000 gal
Ca metal ^(b)	1,500 lb
Magnesium Oxide ^(b)	2,000 lb
RS-6 Crucible ^(b)	700 ea
Dibutyl Butyl Phosphonate ^(a)	3,520 lb
Hydrogen Fluoride ^(b)	10,000 lb
Hydrogen Peroxide ^(b)	1,000 lb
Hydroxylamine Sulfate ^(a)	20,000 lb
Mercuric Nitrate ^(a)	100 lb
Nitric Acid 57% ^(b)	350,000 lb
Liquid Nitrogen ^(b)	5,500,000 ft ³
Oxalic Acid ^(a)	8,000 lb
Potassium Permanganate ^(a)	300 lb
Soda Ash ^(a)	200 lb
Caustic ^(a)	200,000 lb
Sodium Nitrate ^(a)	8,000 lb
Sodium Nitrite ^(a)	800 lb
Hydrazine - Scarox ^(a)	2,500 lb
Tributyl Phosphate ^(a)	8,000 lb

(a) Pu Reclamation

(b) Pu Finishing

TABLE II.1-F-7

POWER AND WATER CHEMICAL CONSUMPTION

<u>Chemical</u>	<u>lb/yr</u>
Aluminum Sulfate	90,000
Chlorine	9,000
Disodium Phosphate	6,000
Filming Amine (Octafilm)	24,000
Salt	500,000
Sodium Sulfite	14,000
AGEL	15,000
Potassium Permanganate	2,500
Corregen	8,000

TABLE II.1-F-8

FUEL FABRICATION PROCESS CHEMICALS
(300 AREA)

<u>Chemical</u>	<u>Typical Inventory Gallons</u>
Nitric Acid	10,000
Sulfuric Acid	6,000
Sodium Hydroxide	20,000
Trichlorethylene	10,000

TABLE II.1-F-9

SANITARY AND PROCESS WATER TREATMENT CHEMICALS
(100 AND 300 AREAS)

<u>Chemical</u>	<u>Typical Inventory Gallons</u>
Aluminum Sulfate	16,000
Sulfuric Acid	30,000
Ammonium Hydroxide	8,000
Hydrazine	1,700
Morpholine	900
Sodium Dichromate	150
Chlorine (Liquid)	1 ton Cylinders

TABLE II.1-F-10

PROCESS CHEMICAL CONSUMPTION-1972

		<u>100-B</u>	<u>100-D</u>	<u>100-K</u>	<u>100-N</u>	<u>300</u>	<u>Total</u>
Aluminum Nitrate	Lbs					24,200	24,200
Aluminum Sulfate	Lbs	83,980	40,138	336,632	325,107	24,480	840,337
Ammonium Bifluoride	Lbs					24,200	24,200
Bauxite	Lbs			220,120			220,120
Calcium Carbonate (Lime)	Lbs					200,000	200,000
Chlorine	Lbs	22,500	10,200	74,675	28,000	6,000	141,375
Hydrazine	Lbs				18,470		18,470
Hydrofluoric Acid	Lbs					2,400	2,400
Methanol	Lbs					2,586	2,586
Morpholine	Lbs				4,140		4,140
Nitric Acid	Lbs					517,104	517,104
Oxalic Acid	Lbs					900	900
Polyacrylamide	Lbs	150	150	4,500	1,150	300	6,250
Salt (Rock)	Lbs			3,700			3,700
Sodium Dichromate	Lbs			30,450	9,000		39,450
Sodium Hydroxide	Lbs				542,350	249,563	791,913
Sodium Nitrate	Lbs					16,800	16,800
Sulfuric Acid	Lbs			1849,003	1219,492	44,426	3112,921
Trichlorethylene	Lbs					66,150	66,150
Copper	Lbs					13,800	13,800
Ammonium Hydroxide	Gals				33,027		33,027

APPENDIX II.1-G

STANDARDS APPLICABLE TO HANFORD WASTE MANAGEMENT OPERATIONS

APPENDIX II.1-G

STANDARDS APPLICABLE TO HANFORD WASTE MANAGEMENT OPERATIONS

	<u>Page</u>
Part 1 Regional Air Quality Standards	II.1-G-3
Part 2 State Water Quality Standards	II.1-G-5

APPENDIX II.1-G, PART 1

Regional Air Quality Standards

1. Sulfur dioxide: 24-hour average: 0.10 ppm
Annual Average: 0.02 ppm

Ref: Washington State Department of Ecology
Sulfur Oxide Standards, Chapter 18-56, April 1970.

2. Nitrogen dioxide: Annual arithmetic mean $100 \mu\text{g}/\text{m}^3$; 24 hour average - not to exceed $250 \mu\text{g}/\text{m}^3$ more than once per year.

Ref: Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 50, "National Primary and Secondary Ambient Air Quality Standards," January 1971.

3. Suspended particulates: Annual mean - concentration not to exceed $60 \mu\text{g}/\text{m}^3$ of air (less background east of the Cascades).

Ref: Washington State Department of Ecology
Suspended Particulate Standards, Chapter 18-40, April 1970.

APPENDIX II.1-G, PART 2

Extracts from State of Washington Department of Ecology
Water Quality Standards, June 1973

WAC 173-201-030 -----GENERAL WATER USE AND CRITERIA CLASSES. The following criteria shall be applicable to the various classes of water in the State of Washington:

- (2) Class A (Excellent).
 - (a) General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.
 - (b) Characteristic uses. Characteristic uses shall include, but are not limited to, the following:
 - (i) Water supply (domestic, industrial, agricultural).
 - (ii) Wildlife habitat, stock watering.
 - (iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing and boating).
 - (iv) Commerce and navigation.
 - (v) Fish and shellfish reproduction, rearing and harvest.
 - (c) Water quality criteria.
 - (i) Total coliform organisms shall not exceed median value of 240 (fresh water) with less than 20% of samples exceeding 1,000 when associated with any fecal sources or 70 (marine water) with less than 10% of samples exceeding 230 when associated with any fecal sources.
 - (ii) Dissolved oxygen shall exceed 8.0 mg/l (fresh water) or 6.0 mg/l (marine water).
 - (iii) Total dissolved gas - the concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.
 - (iv) Temperature - water temperatures shall not exceed 65° F. (fresh water) or 61° F. (marine water) due in part to measurable (0.5° F.) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 90/(T-19)$ (fresh water) or $t = 40/(T-35)$ (marine water); for purposes hereof "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.
 - (v) pH shall be within the range of 6.5 to 8.5 (fresh water) or 7.0 to 8.5 (marine water) with an induced variation of less than 0.25 units.
 - (vi) Turbidity shall not exceed 5 JTU over natural conditions.
 - (vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

- - - - -

WAC 173-201-040 -----GENERAL CONSIDERATIONS. The following general guidelines shall be applicable to the water quality criteria and classifications set forth in WAC 173-201-020 through WAC 173-201-080 hereof:

(3) Except for the aesthetic values and acute biological shock conditions the water quality criteria herein established shall not apply:

(a) Within immediate mixing zones of a very limited size adjacent to or surrounding a wastewater discharge;

(b) In the case of total dissolved gas, when the stream flow exceeds the 10-year, 7-day average flood;

(c) In a manner contrary to the applicable conditions of a valid discharge permit.

(4) The total area and/or volume of a receiving water assigned to a mixing zone shall be as described in a valid discharge permit and limited to that which will: (a) not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem; (b) not diminish other beneficial uses disproportionately.

(5) The criteria established in WAC 173-201-030 through WAC 173-201-050 for any of the various classifications of this regulation may be modified by the director for limited periods when receiving waters fall below their assigned water quality criteria due to natural causes or if in the opinion of the director the protection of the overall public interest and welfare requires such modification.

(6) Except where the director determines that overriding considerations of the public interest will be served, wherever receiving waters of a classified area are of a higher quality than the criteria assigned for said area, the existing water quality shall constitute water quality criteria.

(7) Whenever the natural conditions are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.

(8) Due consideration will be given to the precision and accuracy of the sampling and analytical methods used in the application of the criteria.

(9) The analytical testing methods for these criteria shall be in accordance with the most recent editions of Standard Methods for the Examination of Water and Waste Water, and Methods for Chemical Analysis of Water and Wastes (EPA 16020), and other or superceding methods published or approved by the department following consultation with adjacent states and concurrence of the Environmental Protection Agency.

(10) Deleterious concentrations of radioactive materials for all classes shall be as determined by the lowest practicable concentration

attainable and in no case exceed: (a) 1/3 of the values listed in WAC 402-24-220 (Column 2, Table II, Appendix A, Rules and Regulations for Radiation Protection), or (b) the 1962 U.S. Public Health Service Drinking Water Standards as revised, or (c) the Radiation Protection Guides for maximum exposure of critical human organs recommended by the former Federal Radiation Council in the case of foodstuffs harvested from waters for human consumption.

(11) Deleterious concentrations of toxic, or other nonradioactive materials shall be as determined by the department in consideration of the Report of the National Technical Advisory Committee on Water Quality Criteria, 1968, and as revised, and/or other relevant information.

WAC 173-201-050 -----CHARACTERISTIC USES TO BE PROTECTED. The following is a noninclusive list of uses to be protected by the various classifications in fresh and marine waters:

USES	WATERCOURSE CLASSIFICATION
	<u>A</u>
FISHERIES	
Salmonid	
Migration	F M
Rearing	F M
Spawning	F
Warm Water Game Fish	
Rearing	F
Spawning	F
Other Food Fish	F M
Commercial Fishing	F M
Shellfish	M
WILDLIFE	F M
RECREATION	
Water Contact	F M
Boating and Fishing	F M
Environmental	
Aesthetics	F M
WATER SUPPLY	
Domestic	F
Industrial	F M
Agricultural	F
NAVIGATION	F M
LOG STORAGE AND RAFTING	F M
HYDRO-POWER	F

NEW WAC 173-201-080 -----SPECIFIC CLASSIFICATIONS. Various specific waters of the State of Washington are classified as follows:

Class A (24) Columbia River from Washington-Oregon border (river mile 309) to Grand Coulee Dam (river mile 595). Special condition from Washington-Oregon border (river mile 309) to Priest Rapids Dam (river mile 397). Temperature - water temperature shall not exceed 68°F due in part to measurable (0.5°F) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 110/(T-15)$; for purposes hereof, "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

APPENDIX II.3-A

DEMOGRAPHIC AND ARCHAEOLOGICAL DATA

APPENDIX II.3-A, PART 1

Population Projections with Geographical
Distributions Within 50-Mile Radius of

- Hanford Meteorological Station
- 100-N Area
- 300 Area

FIGURE II.3-A-1 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

FIGURE II.3-A-2 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

FIGURE II.3-A-3 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981
POPULATION WITHIN A 50-MILE RADIUS OF THE
HANFORD METEOROLOGICAL STATION

FIGURE II.3-A-4 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

FIGURE II.3-A-5 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973
POPULATION WITHIN A 50-MILE RADIUS OF THE
100-N AREA

FIGURE II.3-A-6 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977
POPULATION WITHIN A 50-MILE RADIUS OF THE
100-N AREA

FIGURE II.3-A-7 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA

FIGURE II.3-A-8 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION WITHIN A 50-MILE RADIUS OF THE 100-N AREA

FIGURE II.3-A-9 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION WITHIN A 50-MILE RADIUS OF THE 300-N AREA

FIGURE II.3-A-10 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977
POPULATION WITHIN A 50-MILE RADIUS OF THE
300-N AREA

FIGURE II.3-A-11 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION WITHIN A 50-MILE RADIUS OF THE 300-N AREA

FIGURE II.3-A-12 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION WITHIN A 50-MILE RADIUS OF THE 300 AREA

APPENDIX II.3-A, PART 2

Estimated Water Usage for 50 Miles
Downstream from the 100-N Area
(1970)

APPENDIX II.3-A, PART 2

ESTIMATED WATER USAGE FOR 50 MILES DOWNSTREAM FROM THE 100-N AREA (1970)

User	Annual Quantity in Acre-ft	Source (a)	Use (b)
USBR	20	G	D
Bailie	200	S	I
Lloyd	240	S	I
AEC	4,500	S	C
AEC	4,380	S	C
AEC	4,500	S	C
Herman	16	G	I,D
Skidmore	6	G	I
City of Richland	67,242	S	I,D,M,C
City of Richland	6,400	G	D,M,C
Battelle	880	S	I
University of Washington	1,250	S	I
Sloat	2	S	I
State	9	G	D
Pasco	51	S	C
Petty	96	S	I
Ketchersid	332	S	I
Rogers	1,419	G	C
Clark	53	G	I,D
Jacobsen	24	G	I,D
County, Franklin	18,300	S	I
Smith	10	G	D
Mocear	226	G	I,D
Stout	60	G	I
Driver	3	G	I,D
Young	18	G	I,D
Harris	12	G	I,D
Maxson	120	G	I,D
Grove	11	G	I,D
Columbia Basin College	171	G	I
Kahlen	50	G	I,D
Wirth	50	G	I,D

- (a) G = Well, S = Surface
 (b) I = Irrigation, D = Domestic,
 M = Municipal, C = Commercial

APPENDIX II.3-A-1 PART 2

(Continued)

User	Annual Quantity in Acre-ft	Source ^(a)	Use ^(b)
Collier Carbon	113	G	C
Allied	3	S	C
Henchel	3	S	I
Mullen	96	G	I
Lanning	136	G	I
Pride	24	G	D
Gustafson	60	G	I
Laird	80	G	I
Seidle	100	G	I
Howard	80	G	I
Rush	300	G	I
Blair	137	G	D
Lampon	7	G	I
Blair	140	G	I
Valdez	28	G	I
School	184	G	I, D
Slocumb	7	G	I, D
Eggers	100	G	I
Tink	50	G	D
Chevron	13,040	G	C
Phillips	323	S	C
Rick	11	G	I, D
Blair	40	G	I, D
Sandvik	293	G	C
Calhoun	45	G	I, D
Tomas	376	G	I, D
Carnahan	34	G	I
Bennett	60	G	I
Phillips	158	G	I
MacRoberts	26	G	I
Brown	94	G	I, D
USCE	24	G	I, D
Kennewick	5,600	G	M
Kennewick	9,600	G	M
State	1,693	G	I, D
Dietrick	72	G	I
USDI	115	G	C
Bumgarner	8	C	D
Hospital	20	G	I, D
Pasco	7,000	S	M
Pasco	209	G	M
Columbia	2,588	G	I

APPENDIX II.3-A-1 PART 2

(Continued)

User	Annual Quantity in Acre-ft	Source (a)	Use (b)
Collins	12	G	I,D
Olsen	130	G	I,D
Copeland	65	G	I,D
Kloppenstein	150	G	I,D
Clancy	70	G	I,D
Briston	23	G	I
Johnson	50	G	I
Stromme	90	G	I,D
Stromme	40	G	I
County, Franklin	18,300	S	I
Philip	12	G	I,D
Philip	12	G	I,D
Kuffel	8	G	I,D
Olson	7	G	I,D
Rogers	2,838	G	C
Rogers	490	G	C
Washington State	3,349	G	I,D
Columbia	915	G	I
Pasco	300	G	I,D
NPRY	108	G	C
Sea. Hard.	116	G	I,D,C
Close	8	G	I,D
Mudd	8	G	I
Fanning	32	G	I,D
Frontier	127	G	I,D,C
Columbia	845	G	I
Columbia	839	G	I
Columbia	719	G	I
Livestock	120	G	I
Kennewick	3,200	G	C
Atwood	60	G	I,D
Franklin	38	G	I,D
Beauchamp	80	G	I,D
Thomas	18	G	I
Mount	19	G	I
Laird	72	G	I
Mensing	16	G	I
Freeman	48	G	I
Corn	46	G	I,D
Gregg	36	G	I
USCE	50	G	I,D
Gen. Chem.	32	G	C

APPENDIX II.3-A-1 PART 2

(Continued)

<u>User</u>	<u>Annual Quantity in Acre-ft</u>	<u>Source (a)</u>	<u>Use (b)</u>
Richards	82	G	I
Columbia	2,588	G	I
Burnham	40	G	I
USFWS	684	G	I
Umbarger	320	G	I,D
Port of Walla Walla	52	G	C
Benninghaven	<u>950</u>	G	I,D
TOTAL	<u>191,920</u>

APPENDIX II.3-A, PART 3
Archaeological Sites and Description

APPENDIX II.3-A, PART 3

ARCHAEOLOGICAL SITES AND DESCRIPTION

A number of archaeological sites in the Hanford Reservation area have been identified^{1,2} and are described in the following table. Identification numbers were assigned by the Archaeological Research Center, Washington State University, Pullman, Washington. AEC procedures assure protection of any antiquities or historic sites as required by the Antiquities Act of 1906 (16USC 431-433) and the Historic Sites, Buildings and Antiquities Act of 1935 (16USC 461-467).

45BN105

This is a possible housepit site located on a sheltered bench 1.0 miles north of the old North Richland townsite. (SW 1/4 of the SE 1/4 of Sec. 11, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock along the riverbank and may include as many as four or five housepits on the beach above the bank. The site is about 200 ft long and 150 ft wide.

Artifacts encountered include cobble tools and hopper mortar.

45BN106

This is an open camp site located immediately to the southeast of the 300 Area along the riverbank. (Center of Sec. 11, T.10N., R.22E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. It is about 400 ft long and 150 ft wide.

Artifacts encountered include stemmed projectile points, cobble tools, and hopper mortars.

45BN145

This is an ethnographically reported camp site located on the south bank of the Columbia opposite a large island upstream from Locke Island. (NW 1/4 of Sec. 12, T.14N., R.26E., W.M.).

The site consists of three or four mat lodge depressions on a gravel bar close to water's edge. Much camp rock and many flakes are scattered around the encampment. The site was reportedly last occupied about 1915.

45BN145 (contd)

Artifacts encountered include cobble tools, hopper mortars, a chipped stone knife, corner-notched projectile points, and a grooved net weight.

45BN162

This is an open camp site located along the riverbank at the 300 Area. (SE 1/4 of the SW 1/4 of Sec. 11, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. It is about 600 ft long and 150 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, grooved net weights, hopper mortars, a glass trade bead, and a military button.

45BN163

This is a possible housepit site located on the west bank of the Columbia just opposite the lower end of the island immediately upstream from the 300 area. (E 1/2 of the NW 1/4 of Sec. 2, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, shell. Several hearth areas are exposed in the bank and there are five or six oval-shaped depressions strung in a line on the bench above the bank, suggesting housepits. The site is about 400 ft long and 100 ft wide.

Artifacts encountered include cobble tools, hopper mortars, and a faceted blue-glass trade bead.

45BN164

This is an open camp site located on the southern end of the island just upstream from the 300 Area. (Center of Sec. 2, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. It is about 250 ft long and 200 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, and corner-notched projectile points.

45BN165

This site is a fishing station located on the west bank of the Columbia about 1.0 miles north of the 300 Area. (NE 1/4 of the SW 1/4 of Sec. 35, T.11N., R.28E., W.M.).

The site consists of concentrations of cobble tools and notched pebble sinkers. It is about 125 ft long and 30 ft wide.

45BN166

This is an open camp site located on the west bank of the Columbia about 1.7 miles north of the 300 Area. (SW 1/4 of the SE 1/4 of Sec. 26, and the W 1/2 of the NE 1/4 of Sec. 35, T.11N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock. Several hearth areas are eroding out of the bank. The site is about 300 ft long and 75 ft wide.

Artifacts encountered include cobble tools and a grooved net weight.

45BN167

This is an open camp site located on the west bank of the Columbia about 2.1 miles north of the 300 Area. (SW 1/4 of the NE 1/4 of Sec. 26, T.11N., R.28E., W.M.).

The site consists of concentrations of camp rock, flakes, and shell. Hearth areas are eroding out of the bank and it is possible that there are some filled-in housepits on the bench above the bank. The site is about 350 ft long and 100 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, hopper mortars, a contracted-stemmed projectile point, and a blue-glass trade bead.

45BN168

This is a housepit site located about 100 yd south of the lower end of Wooded Island on the west bank of the Columbia, or approximately 2.4 miles north of the 300 Area. (NW 1/4 of the NE 1/4 of Sec. 26, T.11N., R.28E., W.M.).

The site consists of four or five housepit depressions on a bench overlooking the river. It is about 100 ft long and 50 ft wide.

No artifacts were encountered.

45BN169

This is a housepit site located on a bench on the west bank of the Columbia about 0.3 miles northeast of the Benton Substation. (NW 1/4 of the NE 1/4 of Sec. 11, T.11N., R.28E., W.M.).

The site consists of 8 to 10 housepits and shows scattered concentrations of camp rock, flakes, and shell at the base of the riverbank. It is 200 ft long and 150 ft wide.

No artifacts were encountered.

45BN170

This is an open camp site located at Rattlesnake Springs, which lies at the terminus of Yakima Ridge. (SE 1/4 of Sec. 20, T.12N., R.25E., W.M.).

The site consists of scattered concentrations of camp rock and flakes. It is severely eroded by wind deflation and is superimposed upon geological units which contain at least three volcanic ashes. It is about 600 ft long and 400 ft wide. Historically, this is the site of the Perkins Massacre which took place on or about July 10, 1878.

No artifacts were encountered.

45BN171

This is an open camp site located about 0.2 miles east of Rattlesnake Springs on the north bank of Dry Creek. (Center of the SW 1/4 of Sec. 21, T.12N., R.25E., W.M.).

The site consists of small quantities of camp rock and scattered flakes. It has been severely eroded by wind deflation. The site is about 300 ft long and 150 ft wide.

Two leaf-shaped points were encountered.

45BN172

This is an open camp site located about 0.25 miles from the mouth of the Snively Canyon on the east side of the road. (NW 1/4 of the SW 1/4 of Sec. 5, T.11N., R.25E., W.M.).

The site consists of scattered camp rock and flakes. It is about 150 ft long and equally wide.

Artifacts encountered include a corner-notched projectile point.

45BN173

This is an open camp site located at the Snively Ranch. (NE 1/4 of the SW 1/4 of Sec. 8, T.11N., R.25E., W.M.).

The site consists of a few flakes, bone fragments, and some firecracked rock exposed in a bank to the southwest of the ranch house about 30 ft. It is about 50 ft long and 30 ft wide.

Artifacts encountered include a pestle and a piece of worked antler.

45BN174

This is an open camp site located on the western side of West Lake, just south of the western terminus of Gable Mountain. (SW 1/4 of the NE 1/4 of Sec. 22, T.13N., R.26E., W.M.).

The site consists of a concentration of camp rock and flakes. It has been severely eroded by wind deflation. The site is about 75 ft long and 50 ft wide.

Artifacts encountered include corner-notched and contracted-stemmed points, and a bifacially flaked cobble tool.

45BN175

This is an open camp site located at a spring close to the summit of Rattlesnake Mountain. (SE 1/4 of the SW 1/4 of Sec. 30, T.11N., R.26E., W.M.).

The site consists of scattered flakes on a rather rocky surface with a small amount of fill. The site has been largely destroyed by construction of a pumphouse and bulldozing for a road and transmission line. It is about 50 ft long and 30 ft wide.

Artifacts encountered include small stemmed and corner-notched projectile points.

45BN176

This is an ethnographically reported camp site located about 0.2 miles east of 100-H Area. (NW 1/4 of SW 1/4 of Sec. 17, T.14N., R.27E., W.M.).

45BN176 (Continued)

The site consists of three or four mat lodge depressions on a gravel bar and a cache of belongings in an adjacent bank. Much camp rock and few flakes are scattered around the encampment. The site was last occupied about 1942.

No artifacts were encountered.

45BN178

This is an open camp site located on the west bank of the 100-F Area slough in a sand dune. (NE 1/4 of the NE 1/4 of Sec. 4, T.13N., R.27E., W.M.).

The site consists of scattered concentrations of camp rock and flakes. It is about 400 ft long and 300 ft wide. Artifacts encountered include a corner-notched projectile point.

45FR266

This is a historic site located on the east bank of the Columbia opposite East White Bluffs townsite. (E 1/2 of Sec. 29, T.14N., R.27E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. In addition, the site is of historic interest because of a small log house which was reportedly built in the 1850's and used as a blacksmith shop. The site is about 2000 ft long 500 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, pestles, small corner-notched points, glass trade beads, and a clam shell disc bead.

45GR325

This site is a flaking floor located on the Wahluke Slope above the White Bluffs and south of State Highway 24. (N 1/2 of the NW 1/4 of Sec. 6, T.14N., R.26E., W.M.).

The site consists of scattered cores and chipping detritus. These have been exposed by wind deflation on the tops and sides of small knolls along Northern Pacific Railway right-of-way.

Artifacts encountered include cores and corner-notched projectile points.

Archaeological Localities

Gable Butte Locality

The Gable Butte locality lies a short ways to the south of 100-B and 100-K Areas. It includes area in Sections 13 and 14, T.13N., R.25E., and Sections 18, 19, and 20, T.13N., R.26E., W.M.

Several flakes and rock piles were found along the top of the ridge at the western end of the locality.

Corner-notched projectile points were encountered from this locality.

Gable Mountain Locality

The Gable Mountain Locality lies to the northeast of 200-E Area. It includes area in Sections 13, 14, 15, 22, 23, 24, T.13N., R.26E., and Sections 18, 19, 20, and 21, T.13N., R.27E., W.M.

Relander (1956:306) reports that this locality was one of the principal places where Indian boys and girls were sent on their spirit quests.

A corner-notched projectile point was encountered.

The Shifting Dunes Locality

The Shifting Dunes locality lies along the west bank of the Columbia opposite Ringold Flat and the lower end of Savage Island. It includes area in Sections 8, 9, 15, 16, 17, 18, 19, 20, 21, 22, 23, 26, 27, and 28, T.12N., R.28E., W.M.

This locality evidently contains numerous small camp sites that have been deflated by wind erosion and then buried by the shifting sands.

Corner- and basal-notched projectile points were encountered.

II.3-A REFERENCES

1. D. G. Rice, "Archaeological Reconnaissance-Ben Franklin Reservoir Area, 1968," Laboratory of Anthropology, Washington State University, Pullman, WA, 1968.
2. D. G. Rice, "Archaeological Reconnaissance-Hanford Atomic Works," Washington State University, Pullman, WA, 1968.

APPENDIX II.3-B
HANFORD GEOLOGY DATA

APPENDIX II.3-B
HANFORD GEOLOGY DATA

	<u>Page</u>
Part 1 Hanford Geology Data	II.3-B-4
Part 2 Geological Studies of the Hanford Site	II.3-B-37

APPENDIX II.3-B, PART 1

Hanford Geology Data

II.3-B Part 1 Hanford Geology Data

II.3-B.1 Geomorphology

Eastern Washington is dominated by the Columbia Basin geologic province. The Basin encompasses about 50,000 square miles of southeastern Washington and adjacent parts of Idaho and Oregon (Figure II.3-B-1). It is underlain by the vast field of flood lavas of the Columbia River Basalt Group. Today those lavas and the ground surface generally dip radially inward toward the Pasco Basin, the physiographic low of the larger Columbia Basin.

The Columbia, Snake, Yakima and Walla Walla rivers reflect the regional gradients, drain centripetally and join within a few miles of each other within the Pasco Basin, the slightly off-centered low point of the Columbia Basin. To the south the Columbia River exits from the Pasco Basin through Wallula Gap at an altitude of about 340 feet, then flows westward through an ever-deepening gorge until it exits from the region through the Cascade Range.

The AEC Hanford Reservation overlies the structural low point of the Pasco Basin. The Hanford Reservation is bounded to the southwest, west and north by large anticlinal ridges that trend eastward from the Cascade Range, enter the Pasco Basin and die out within its confines. The Reservation is bounded to the east by the Columbia River and the steep and imposing, west-facing White Bluffs of the Ringold Formation. Beyond them the gently rising basaltic lava flows lead into the Palouse country of eastern Washington. To the southeast the Reservation is bounded by the confluence of the Yakima and Columbia Rivers and by the City of Richland.

The Hanford Reservation lies on the low-lying, partly dissected and modified alluvial plain of the Columbia River within the central part

FIGURE II.3-B-1 REGIONAL GEOLOGIC MAP

of the Pasco Basin. Altitudes on that plain range from a low of about 345 feet in the southeastern part of the Reservation to a high of about 800 feet in the northwest corner. Beyond the plains, the bordering White Bluffs rise to a maximum altitude of 980 feet above sea level and the anticlinal ridges to the west rise to a maximum altitude of 3,586 feet atop the crest of the Rattlesnake Hills.

The Hanford alluvial plain contains a mix of aggradational and degradational features that reflect part of the complex geological history and development (Table II.3-B-1) of the Pasco Basin, especially during the latter part of the Pleistocene and the entire Holocene epoch (approximately the last 100,000 years). The discontinuous plain, as originally formed about 18,000 to 20,000 years ago and significantly modified about 12,000 years ago, sloped from a high of perhaps 700 to 800 feet above sea level in the northwest, to about 100 feet lower in the southeast. Subsequent to the deposition of the basin fill sediments, the Columbia River shifted generally northeastward as it adjusted its base level and its grade. Estimates of its lateral rates of shift range up to a foot per year. Today relic channels, some attributable to the last flood, cross the northeast part of the reservation. In the process of eastward shifting concomitant with downcutting, several benches or terraces related to the floods were further modified. They are best displayed in the southern part of the reservation south of the Hanford Wye road junction. There the uppermost terrace lies at an altitude of 500 to 540 feet, while the lower terrace is 100 feet lower (400 to 440 feet), with the escarpment of boundary between the two paralleling the Columbia River and about 4 to 5 miles from the river.

Subsequent to the river shift, wind action simultaneously established two sets of dunes that now cross both terraces indiscriminately. The first set forms a belt that extends from the junction of Cold and Dry Creek valleys to a point halfway to the Yakima Horn, thence east-northeastward immediately north of the Hanford Wye road junction to the Columbia River. There they form a belt 4 miles wide immediately

TABLE II.3.B-1

GEOLOGICAL HISTORY OF PASCO BASIN

ERA	SYSTEM	SERIES	GEOLOGIC UNIT	MATERIAL
CENOZOIC	QUATERNARY	HOLOCENE	DUNES AND EOLIAN SEDIMENTS (0-40 FEET THICK)	SANDS, INCREASINGLY FINER AND QUARTZ-RICH TO THE NORTHEAST
			ALLUVIUM, COLLUVIUM, LANDSLIDES (0-100 FEET THICK)	UNSORTED RUBBLE AND DEBRIS, LOCALLY INTERFINGER WITH RINGOLD FORMATION AND PASCO GRAVELS
			PASCO GRAVELS AND THE TOUCHET BEDS (0-400 FEET THICK)	SANDS AND GRAVELS OCCURRING AS GLACIAL FLOOD DEPOSITS. COMMONLY ROUGHLY GRADED. UNCONSOLIDATED BUT HIGHLY COMPACT.
		PLEISTOCENE	PALOUSE SOILS (0-30 FEET THICK)	WIND-TRANSPORTED AND DEPOSITED SILT, LOCALLY WEATHERED TO CLAY
			RINGOLD	WELL-BEDDED FLUVIAL AND FLOOD-PLAIN SILTS, SANDS AND GRAVEL. POORLY SORTED, COMPACT BUT VARIABLY CEMENTED. BASAL PORTION LARGELY SILT AND CLAY OF HIGHLY VARIABLE THICKNESS. REMAINDER OF FORMATION IS INTERBEDDED GRAVEL, SAND AND SILT. GENTLY DEFORMED.
	TERTIARY	PLIOCENE	FORMATION (0-1200 FEET THICK)	VOLCANICLASTIC ROCKS AND THEIR WEATHERING PRODUCTS, LARGELY CLAYS. GRADES INTO AND INTERFINGERS WITH RINGOLD FORMATION SEDIMENTS.
			ELLENSBURG (20-200 FEET THICK)	
			FORMATION	
		MIOCENE	YAKIMA BASALT FORMATION (PROB. 2500 FEET THICK)	BASALTIC LAVAS WITH INTERBEDDED STREAM SEDIMENTS IN UPPER PART, LOCALLY FOLDED AND FAULTED.
		OLIGOCENE	PICTURE GORGE FORMATION EQUIVALENT (?) (PROB. 1500 FEET THICK)	BASALTIC LAVAS
		EOCENE	?	BASALTIC LAVAS POSSIBLY COMPARABLE TO THE TEANAWAY BASALTS
		PALEOCENE	?	PROBABLY SANDSTONES COMPARABLE TO THE SWAUK AND ROSLYN FORMATIONS
MESOZOIC			ROCKS OF UNCERTAIN AGE, TYPE AND STRUCTURE	PROBABLY METASEDIMENTS AND METAVOLCANICS INTRUDED BY GRANITIC ROCKS

COLUMBIA RIVER BASALT GROUP
PROB. 12,000 FT THICK

south of the Hanford townsite to a point opposite Ringold on the east bank of the Columbia River. They evidently originated in Cold Creek Valley by deflation of the valley and wind transport of the sands to the east-northeast.

The second group of dunes focuses on the area between the Yakima Horn and North Richland, with the dunes dying out to the northwest and southeast. The dunes trend northeastward. Their eastward convergence with the more northerly belt indicates a somewhat different direction of the prevailing winds at different localities. To a large extent this is topographic control, or the presence of wind gaps and anti-clinal ridges in the wind's path.

Both sets of dunes evidently developed in the dry and warm climate of the Altithermal period, and have in part stabilized as a result of subsequent climatic changes. Both sets attest to some eastward migration of the Columbia River and to the lack of its presence on the Hanford Reservation in the time since dune emplacement. Otherwise the dunes would have been breached.

The eastward shift of the Columbia River evidently is continuing in the northern reaches of the Reservation. Thus, the northern reaches of the White Bluffs (north of the Hanford townsite) are being actively undercut. Landslides of up to 1 million cubic yards have occurred and will recur as the bluffs are oversteepened. The addition of large volumes of irrigation waste waters from the Columbia Basin Irrigation Project to ground near the crest of the Bluffs increases the potential of such slides.

II.3-B.2 Soils

Eastern Washington, in the rain-shadow of the Cascade Mountains, evidently has experienced a continuously semi-arid to arid climate for nearly 12,000 years. Most of the Hanford Reservation is underlain by generally coarse-grained sediments¹ deposited by several glacial floods. The surficial sediments generally were ineffectually weathered

and only locally show the A, B and C soil horizons developing from the regolith, or the organic matter to distinguish true soils from their parent materials. Consequently, a working definition of most Hanford soils includes the materials within the root zone of the native perennial plants. This is a variable depth value depending on the plant species.

All the materials overlying basalt bedrock have at least some physical properties that generally are identified with soils in an engineering sense. That concept corresponds to the pedologist's or geologist's definition of regolith. Most of those materials also have geologic properties such as formation identity, stratigraphic continuity, weak to moderate induration and coherence, and a physical origin that permits their description in geologic terms.

Most of the Hanford Reservation is underlain by sediments laid down by the glacial Lake Missoula floods, particularly of 18,000 to 20,000 years ago, and about 12,000 years ago. Those sediments, at or near the ground surface, range from coarse boulder and cobble gravel in the extreme northern reaches of the Hanford Reservation to sandy cobble to granule gravels in the central part of the Reservation to coarse sands in the southern part. Adjacent to the Yakima and Rattlesnake Hills the sediments grade into silts and fine sands. The distribution reflects the velocity of the flood waters depositing the sediments: the greatest velocities where the floods debouched from the Columbia River gorge upstream from Hanford; less where the flood waters spread out in the Pasco Basin; and least in the lee of ridges and with the shallow waters adjacent to the bordering mountain masses.

As a result of the semi-arid to arid environment that prevailed for at least 12,000 years, the entire Reservation was blanketed by at least a thin veneer of wind-blown (eolian) sediments. These were derived largely from the flood deposits, most of it locally, but some from as far as the lower Yakima and Columbia River valleys upwind (southwest) of the Hanford Reservation. The eolian sediments thus

range from very fine sands and silts that in some places blanket coarse gravels and basalt bedrock, to coarse sands that were moved only short distances and can scarcely be distinguished from the parent materials.

Generally, true soil profiles developed only where fine-grained and poorly drained sediments prevail, as in Cold Creek Valley. There, under the prevailing conditions, weathering is more effective than elsewhere and true A, B and C horizons develop from the regolith.

The eolian sediments not only variably blanket the Hanford Reservation from negligible thicknesses to 50 feet or more, in the case of live dunes, but the eolian silts locally have sifted into the fluvial sands and gravels to depths up to 5 feet. This decreases the ground's infiltration capacity. When that condition combines with frozen ground, local runoff occurs.

Numerous dunes and dune features prevail on site. Incorporation of the Mount Mazama ash bed in some now stabilized dunes indicates a period of dune formation 6000 to 7000 years ago during the Altithermal period. Subsequent climatic changes are indicated that stabilized the dunes. South of the Hanford townsite, and elsewhere where the vegetal cover was destroyed in road cuts or burned areas, active dune movement is again underway.

II.3-B.3 The Basement Rocks

The basement rocks, those underlying the basaltic lava flows, are of uncertain composition. Certain rock types can be projected from the margins of the Columbia Basin, 100 to 150 miles away, and certain prebasalt rocks can be logically inferred from the known general geologic history of the region. On these bases, and from data from the Basalt Explorer Well near Odessa, Washington, sandstones and shales comparable to the Swauk Formation of the Blewett and Swauk Pass areas of Washington may lie beneath the region. Beneath them are probably granitic rocks

comparable to those in Okanogan Highlands, the Snoqualmie Pass area of the Cascade range, the Moscow Basin, Idaho, the base of the Basalt Explorer Well, and parts of the core of the Blue Mountains, Oregon.² Granite rocks there were intruded into largely Paleozoic and early Mesozoic metavolcanic and metasedimentary rocks whose equivalents perhaps occur beneath the Pasco Basin. Alternatively, a still thicker basalt section is possible.

II.3-B.4 The Columbia River Group

The Columbia Basalt Plateau is one of the world's greatest continental accumulations of basaltic lava flows. The total area covered is estimated at 250,000 to 300,000 square miles and comprises more than 100,000 cubic miles of lava. In the Columbia Basin, 50,000 square miles in extent, probably more than 60,000 cubic miles of lava have accumulated (Figure II.3-B-2).

The northern part of the Columbia Basin centers around the Pasco Basin, the topographic and structural low point of the Columbia Plateau area. In 1957 and 1958, the Standard Oil Company of California drilled an exploratory and stratigraphic test well (Rattlesnake No.1) in the Pasco Basin to a depth of 10,655 ft, still in basalt. The well was reopened and relogged in 1968.³ Current estimates are that the sequence is at least 12,000 feet thick. Other data indicate a probably orderly accumulation of more than 100 basalt flows, emitted concomitantly with the subsidence of the basin. If the oldest flows are Eocene in age as has been suggested, roughly 50 million years were available for emission of the complete sequence up to the about 8 million years age of the youngest flow. An average rate of emission then is roughly one flow per 500,000 years.

No other comparably deep wells have been drilled within the Pasco Basin or its periphery. Within the Pasco Basin four deep wells and core holes were drilled to depths of 5661, 3540, 5002 and 4766 feet.⁴ Above

FIGURE II.3-B-2. GEOLOGIC CROSS SECTIONS OF COLUMBIA RIVER BASALT PLATEAU

those depths, the data on the nature and character of the basalt sequence increase rapidly. This is the result of available outcrops and many wells drilled for geologic information, and for water supply purposes.

The basalt sequence tentatively is divided into a series of possible formational units. The divisions are based on: 1) identified, evidently significant, changes in the chemistry of the basalts, 2) estimated ages based upon floral assemblages from pollen in coal beds in the Rattlesnake No. 1 well and 3) two initial potassium-argon age dates on basalts.⁶ The very limited data can result in numerous interpretations of which Figure II.3-B-2⁶ is one. Unpublished and largely unavailable data will, when evaluated, result in increasing detail and a corresponding improvement in the interpretation.

The sources of extrusion of the early flows are unknown. All appear to be the plateau type of basalt, emitted from fissures by quiet extrusions.⁴ Various dike swarms are known that may have been sources, but none are demonstrated as sources of the early flows. One possibility is the Teanaway dike swarm in the Mount Stuart area, Washington.

Within the upper 1000 feet of the sequence, sufficient data are available to indicate that most of the flows in the western part of the plateau were moving between north and west when emplaced.⁵ Progressively upward in the section, the evidence increasingly indicates that dike swarms in extreme northeastern Oregon were the vents for some of the flows. One vent for one or more flows lies in easternmost Washington, another, feeding at least the youngest recognized flow, is at Ice Harbor Dam on the lower Snake River.⁴

The presence of that many sources suggests that more may be present, perhaps buried by later flows beneath the Pasco Basin.

The later basalt flows generally advanced northwestward across the Pasco Basin. They pinch out in an offlap relationship to the plateau margins, the effect of the continuing subsidence and resulting opposed gradient. Many flows divided into flow units, whereby separate tongues, gushes or spurts of lava emerged from the main flow.

II.3-B.5 The Ellensburg Formation

Within the upper part of the basalt sequence, sedimentary materials are increasingly important upward, beginning with the Vantage sandstone. These include tuffs and tuffaceous sediments of many kinds, in part now altered to clays. Virtually every basalt flow above the Vantage sandstone horizon is capped, at one site or another, by stream-deposited sediments. Their extent and thickness generally increase upward in the section. The lower beds tend toward rock types common to the Okanogan Highlands, southern British Columbia and the north Cascades. The upper beds show an increasing preponderance of volcanic debris referred to as the Ellensburg Formation.

About 15 million years ago, the ancestral Columbia River was crossing central Washington, laying down trains of gravels, sands, silts and clays comparable to today's Columbia River sediments. As the basalt flows advanced upon the river, they forced it westward toward Yakima. As the basin subsided, the river returned by gravity to the basin center, leaving its sediment trains as a mark of its earlier courses. East of the current course, river sediments are virtually nonexistent between basalt flows, attesting to the shifting only westward from the current basin center.⁶

In addition to the interbasalt sediments, the basalt flows themselves record the river's presence. Pillow basalts, palagonite and pillow-palagonite complexes at the bases of flows identify the former presence of water into which the flows advanced. Oftentimes they contain features indicating the direction of flow movement. In many instances the complexes with or without sedimentary interbeds are important and confined, sometimes artesian, aquifers.

Continuing subsidence resulted in maximum thickness of the basalt sequence and accumulation of the greatest number of flows in the Pasco Basin. The Pasco Basin low probably centered southwest of its current position, at least late in flow emplacement. This is suggested by isopach maps of various members. Numerous thin beds of coal in the Rattlesnake No. 1 well, but not in other deep wells in comparable amounts, indicates a poorly drained area that may have been the basin low point for extended periods.

Anticlinal uplift began in the latter stages of flow emplacement. In some sites, near the Cascades, it may have been nearly 15 million years ago, roughly the time when the ancestral Columbia River first appeared in south-central Washington. Probably the ancestral Columbia River's appearance coincided with the beginning of uplift of the north Cascades which likely diverted the river from its westerly course north of the Pasco Basin.

Anticlinal uplift, together with basining, locked the ancestral Columbia River into the Pasco Basin once the ridges rose high enough that they were no longer periodically buried. The last few of the basalt flows and intervening interbeds clearly show thinning over the ridges and thickening in the valleys and pinchout where topographic highs were great enough.

Uplift progressed roughly from north to south with Umtanum Ridge and the Yakima Range rising first (or fastest) in the Pasco Basin, then the Saddle Mountains, Rattlesnake Hills, and the Horse Heaven Hills. The ancestral Columbia River, flowing southwestward from its locked-in position in the Pasco Basin across the Horse Heaven Hills, was diverted to the structural low that now is Wallula Gap.

The combined uplift of the Horse Heaven Hills and Rattlesnake Hills probably caused the shift of the early Pasco Basin low point from the lower Yakima Valley to its current position.

The last four of the basalt flows (two Ice Harbor, the Elephant Mountain and Ward Gap are currently recognized) are progressively smaller and more restricted to the current basin center. The last one and probably two were emitted near Ice Harbor Dam, about 20 miles southeast of the nearest part of the Hanford Reservation. Only one of them barely reaches the Hanford Reservation, it is recognized in few wells to date.⁷

The progressive decrease in indicated lateral extent (and probably volume as well) of the last four flows suggests depletion of a lava source. Comparable events must have occurred earlier, with an interval of some millions of years, prior to new flow emission.

II.3-B.6 Anticlinal Uplift and Faulting

Creation of the anticlines was dominantly by uplift, probably relating from long-term basining. Some faults may have developed as an early phase, but folding is a predominant reaction, with renewal of fault movement as an alternative. Generally the stresses that developed in deformation were relieved by slippage along the many joints and bedding planes, oftentimes on clay-rich sediments of the Ellensburg

Formation, which thereby give the impression of fault gouge and major faults.⁸ Folding of the basalt sequence with no superincumbent cover also resulted in sinuous fold axes at the ground surface, in some sites en echelon fold axes. At other sites cross folds complicate the structures. In all instances the divergence from single, well-defined, regular axes can be attributed to differing responses to folding of the variably-jointed, highly-layered basalt sequence. The sinuosity and en echelon nature of the fold axes and the presence of cross folds have led investigators to assume the presence of cross faults with strike slip offset up to one-third of a mile. This situation prevailed at Gable Butte and Gable Mountain on the Hanford Reservation.⁹ To date, strike-slip faults of any magnitude yet have not been demonstrated in the Pasco Basin.

The dominant type of faulting is normal faulting, in some instances developing into graben-like structures as inferred in the Badger Canyon area and as occurs in parts of the Saddle Mountains. Thrust faults locally are significant, especially where folding has been intense. In some instances antithetic faulting developed, with portions of the uplifted anticlines downdropped.

Numerous faults are hypothesized on various bases, including topographic expression,¹⁰ and aerial photointerpretation.⁹ The most important one postulated is that along the Olympic-Wallowa Lineament, particularly the Rattlesnake-Wallula-Milton-Freewater segment and the Rattlesnake-Wallula segment.¹¹ Some persons have attributed gross amounts of strike-slip movement to the hypothesized Lineament fault, analogous to the San Andreas fault, but without citing specific evidence for the fault or its offset. Neither the Oregon geologic map (1969)¹² nor the Oregon gravity map¹³ acknowledge or submit evidence in support of such a fault in Oregon.

Numerous signs of at least local faults are present along the various named segments of the Olympic-Wallowa Lineament. The maximum inferred

stratigraphic offset on a postulated fault is 300 feet in the Badger Canyon area,¹⁴ compared to a maximum of about 1500 feet of total stratigraphic offset by combined folding and faulting along the same segment. This fault offset thus is less than a major part of the total offset, a situation generally prevalent in south-central Washington. In the same general area, 500 feet of stratigraphic offset, as determined from drilled wells, may be largely fault offset. In some sites along the Olympic-Wallowa Lineament, faults are spatially removed from the fold axes, hence are "primary" in origin. However, all faults are associated with the anticlinal ridges and in some instances pass longitudinally into folds. Because of their relatively minor surface offset, the faults are "secondary" in importance to folds although locally "primary" in origin.

The Rattlesnake Hills to Wallula Gap structure is an alignment of discontinuous elongate domes or doubly terminated anticlines with only local signs of faulting, and none in several summit excavations. The structures between the domes, where visible or otherwise determined from the records of wells, are a sequence of flat-lying flows with no direct evidence for significant fault offset.

At the Yakima River water gap at the southeast end of the Rattlesnake Hills no folding or faulting is present. Northwestward along the north face of the Rattlesnake Hills anticline folding again becomes prominent, without identification of prominent faults or recent fault movement.¹⁵

The small amount of clearly demonstrable surface faulting, the minimal visible offset (compared to Basin and Range structures) and the 10 to 15 million years for the structures to develop indicate an overall low rate of diastrophism. Continuing activity is suggested, however, by apparent tilting of recent (12,000 years old) sediments at two widely separated sites,^{8,16} reported cracking of the ground near Walla Walla during the Milton-Freewater earthquake of 1936 along lines paralleling the

Horse Heaven Hills, and possible antithetic faulting of Ellensburg Formation beds and clastic dikes west of Prosser in the Horse Heaven Hills.

The faults along the Lineament evidently are associated with the Horse Heaven Hills anticline and similar structures rather than a major northwest trending transcurrent feature. A major Olympic-Wallula Lineament, if present as a structure, is not and has not been tectonically active since Miocene time, except possibly where its strike coincides with the strike of other structures (the Horse Heaven Hills). This is suggested by the uplift of the Blue Mountains, the Cascade Range, and the Yakima and Umtanum Ridges across the trend of the Lineament. None of those features show yet-identified evidence of fault offset attributable to movement along that Lineament, and especially the gross strike-slip offset required for a major transcurrent feature.

The Rattlesnake Hills, the most prominent anticlinal ridge in south-central Washington, consist of two main segments. The first is the east-west trending segment that extends from the southwest corner of the Hanford Reservation to and beyond the Union Gap where it becomes Ahtanum Ridge. The second segment extends from the Yakima River water gap north of Benton City northwestward to the southwest corner of the Hanford Reservation. There it overlaps the east-west segment at the site of the Standard Oil Company of California Rattlesnake No. 1 well.¹⁶

Both anticlines are asymmetrical, with the steeper face on the northerly side. Much of the total range remains to be studied, but work at intervals along it has yet to disclose evidence of major faults. Indeed the structure appears to be a sequence of overlapping, in part en echelon, anticlinal folds. The site of overlap of the two segments resulted in the near symmetry of the ridge such that the Rattlesnake No. 1 well penetrated probably a full 10,000 feet of stratigraphic section, rather than passing, with depth, into the north limb of the anticline.

Various persons have attempted to explain the trend change and the termination of the Yakima and Umtanum Ridges to the north. Commonly this has been by north-trending faults. One version passes through Gable Butte, a second along the east end at Yakima and Umtanum Ridges. Evidence has to date been solely topographic but permissive of faults, not demanding of them.

The Yakima Ridge, instead of sharply terminating against a north-south trending fault, consists of two anticlinal ridges that plunge eastward beneath the surficial cover. The structures can be and have been traced by well drilling at intervals and by seismic, gravity and magnetometric methods. The data suggest that the structures are comparable to those of the Rattlesnake Hills continuation from the Yakima River water gap to the Horse Heaven Hills--a sequence of doubly terminated anticlines or elongate domes. Maximum relief is about 300 feet above the regional slope from the Rattlesnake Hills to the basin low.

The southernmost anticline reappears at the ground surface at the Prosser barricade, then as a line of gently folded, evidently nonfaulted buttes that extend to and beyond West Richland as the "Horn Rapids Lineament." These buttes evidently die out southeastward beneath the Kennewick Highlands. The more northerly of the two anticlines evidently dies out beneath the Hanford Reservation although it has been considered to cross the Columbia River as a continuous low, broad warp south of the Fast Flux Test Facility Site. Much of the basis for the southern continuation of the low anticline was a well which did not certainly penetrate to basalt. A geophysical seismic line contra-indicated the interpretation of the well log.

Umtanum Ridge, and its continuations in Gable Butte, Gable Mountain and several isolated outcrops, represents a classic case of offset, en echelon anticlinal folds oblique to the main axis of uplift. Gable Mountain consists of two anticlines, reversely asymmetrical so that opposite ends of the mountain are bounded by steep faces on opposing sides. Early workers⁹

inferred a strike slip fault with offset of about two-thirds of a mile to account for the two axes. However, proponents of the concept did not explain the absence of the fault in the Rattlesnake Hills or White Bluffs where it should appear if the offset were valid. Instead, a low angle thrust fault(s) with less than 100 feet of offset occurs at the point of overlap of the two axes¹¹ and dies out in bedding plane shearing on both the north and south flanks of the mountain. The fault trace is covered by undisturbed flood deposits dated at more than 40,000 years old by ¹⁴C methods.

The Saddle Mountains are one of the most studied anticlinal ridges in central Washington. They are significant because important faults bound the mountain to the north in its western reaches.

The last discernable surface movement on the Saddle Mountain fault predates loesses dated by ¹⁴C assays on organic matter to be 12,000 years old.¹¹

The dominant surface faults that have been identified in the Pasco Basin trend roughly east-west, parallel to and within the anticlinal ridges. Bordering the Pasco Basin to east and west, however, are two monoclinal folds with the downfolded side toward the Basin. The westernmost of these is the Hog Ranch axis, roughly 10 miles west of the Hanford Reservation. The easternmost is the Jackass Mountain axis that lies roughly 10 miles east of the Columbia River. Along each axis the basalt flows warp gently downward toward the Basin center. These folds generally parallel the north-south structures in the Okanogan Highlands, and in the Cascade Range. (Figure II.3-B-3)

FIGURE II.3-B-3. MAP OF THE BASALT SURFACE IN THE PASCO BASIN, IDENTIFYING MAJOR STRUCTURES

II.3-B.7 The Ringold Formation

The Ringold Formation (Figure II.3-B-4) was deposited in response to a flattening of the gradient of the Columbia River and consequent deposition of the sediments it carried. Previously, basining was accompanied by basalt flow extrusion into the topographically and structurally low areas. Cessation of emission of flows about 8 million years ago permitted the deposition of a continuous sequence of sediments. Initially these were blends of up-river rock types derived from the north Cascades and the Okanogan Highlands with volcanic debris, largely of andesitic composition, from the central and southern Cascades. These latter sediments were contributed to the Pasco Basin by an ancestral Yakima and related rivers. With time, the composition of the sediments being deposited in the Pasco Basin became more and more that of the Okanogan rock types.

The beginning of anticlinal uplift, especially to the west and slightly prior to the emission of the latest basalt flows, locked the Columbia River into the Pasco Basin and halted its east-west migration. Somewhat later, uplift of the Horse Heaven Hills resulted in a continuously rising base level for the river and continued deposition of sediment.¹⁹ Today the Ringold Formation is recognized only upstream of the Horse Heaven Hills, reflecting the control of deposition by those Hills.

The Ringold Formation arbitrarily has been divided at the type locality into a lower blue clays member, a gravel or conglomerate member, and an upper sand-silt member. The division is unrealistic for the Basin as a whole, however. Sands, silts, clays and gravels are interbedded and interlayered throughout the basin in a manner indicating a nearly continuous stream flow and continuous fluvial deposition. Even the

**FIGURE II.3-B-4. THE SURFACE OF THE RINGOLD FORMATION
IN THE PASCO BASIN**

lowermost silts and clays actually occur as a sequence of beds in different stratigraphic positions largely linked together to form a semi-continuous blanket over the basalts in the basin center. Only locally do they suggest true lake deposits. Moreover, they lap out (were never deposited) and in at least one case evidently were eroded from a basalt high. Hence local interconnection between the higher unconfined and the low confined ground waters is present. The ancestral Columbia River, based on its gravel and silt-clay distribution, generally has centered over the basin's low point. Its floodplains extended eastward and lapped upon the basaltic plains that rise to the east and northeast.

Uplift of the controlling Horse Heaven Hills continued at a pace permitting the deposition of gravel in the main stream areas. Ultimately when the river level in the Pasco Basin reached an altitude that is now 1000 feet above sea level, the Columbia River was able to maintain its channel through the structural low at Wallula Gap as rapidly as the hills rose. A lowering of base level ultimately began and is continuing today.

The age of the Ringold Formation is critical to assessing the timing of tectonic activity (anticlinal uplift and faulting) that in turn resulted in deposition of the formation. The maximum age is that of the youngest lava flows (8 million years). The youngest inferred age is "middle to possibly late Pleistocene time"¹⁰ or within the last about several hundred thousand years for the uppermost beds. The latter age is invalid because of numerous lines of direct and indirect evidence, including stratigraphic, structural, sequential geologic, and paleontologic data. The official position of the U.S. Geological Survey now is that the formation is Pliocene and Pleistocene in age.¹¹ Probably the uppermost beds are about 1 million years old.

That tectonic deformation has continued to the current time is evidenced by warping in the Ringold Formation stratigraphic section, decreasingly so upward, and low angle tilting of the later Touchet Beds in key sites.^{8,16}

The resulting dips in the Ringold Formation beneath the plant site are low, a maximum of about 3°. The deformation has locally raised the silts and clays of the lower part of the Ringold Formation to and above the groundwater table. Groundwater flow accordingly is around these groundwater barriers in paths that confirm the presence and effectiveness of the silt-clay barriers.²¹

Stabilized water levels of the Columbia River and the presence of bordering floodplains are suggested by at least two thick beds of caliche (calcium carbonate). One caps the crest of the White Bluffs at an altitude of 900 to 1000 feet, the other lies beneath the west part of the Hanford Reservation where it caps the eroded surface of the Ringold Formation at an altitude of about 500 to 600 feet.

Adjacent to the anticlinal mountain ridges that surround the Pasco Basin, wells have disclosed coarse fanglomerates that in part inter-finger with classical Ringold Formation sediments and in part overlie them.¹⁶ The fanglomerates also pass upward into current-day alluvial fans that debouch from canyons penetrating the ridges. They attest to the fact that the Ringold Formation sediments were deposited largely subsequent to anticlinal uplift. They also suggest that the Rattlesnake Hills, in order to shed debris by early Ringold Formation time, must have risen earlier than the Horse Heaven Hills. This also is suggested by other data.

II.3-B.8 The Palouse Soils

An eolian silt (loess), in part altered to clay, and fine sand overlie part of the eroded surface of the Ringold Formation and the caliche bed beneath the western part of the Hanford Reservation.²² It is considered to be the equivalent of the Palouse soils (loesses) of

eastern Washington and westernmost Idaho. It indicates a climate comparable to that of today, with effective wind transport and deposition of sediment.

The most significant eolian sediments lie at depths of roughly 100 feet, or from 100 to 200 feet above the groundwater table. They thus have no effect upon the groundwaters in the zone of saturation but are important in controlling the downward and lateral movement of waste waters and radioisotopes above the groundwater table.

II.3-B.9 The Glacial Lake Missoula Flood Deposits

The Palouse soils, the Ringold Formation, and locally even the basalts and the interbedded Ellensburg Formation sediments were locally eroded and truncated by a sequence of gigantic floods. These emanated from the Clark Fork Valley near Missoula, Montana, and resulted from the catastrophic release of ice-dammed glacial Lake Missoula. Smaller floods resulted from the sudden drainage of smaller, similarly glacier-dammed streams.

The earliest floods recognized in the Pasco Basin occurred at least 50,000 years ago and may be up to 100,000 years old. A ^{14}C age date on conifer bark from a less-than-oldest flood deposit on Gable Mountain provided an age of more than 40,000 years.¹¹ A subsequent flood of far greater magnitude appears to correlate with one in easternmost Washington dated at 18,000 to 20,000 years.²³ A still later large-scale flood is dated at about 12,000 years old on the basis of the presence of the presumed Glacier Peak ash within the uppermost beds of the deposit.¹⁶

The floods scoured the then-existing land surface, the Palouse Formation, and caliche from part of the surface of the Ringold Formation and deeply gouged the Ringold Formation.²³ A network of buried river channels, closely resembling the Channeled Scabland in form, now cross the central to northeastern part of the Hanford Reservation.

Where basalt lies close to or above the current ground surface, it too was eroded. Gable Butte, in the direct path of the flood waters coming

down the Columbia River, was stripped and the anticlines breached and eroded. Gable Mountain, farther east, was less exposed and less eroded. Its west end, however, pointed into the current, was extensively eroded especially on the steeply-dipping south limb of the anticline. Eastward, progressively less erosion occurred until at the extreme east end a giant bar was deposited which extended toward the Hanford townsite.

Beneath 200-East area and immediately to the north an anticline subsidiary to Gable Butte was subjected to erosion. The upwarped Ringold Formation silts and clays, the underlying sediments of the Ellensburg Formation, and locally some of the latest basalt flows were stripped away. An erosional window was created. Of significance is the fact that the erosional window provides a site where exchange of water between the confined and unconfined aquifers (separated by the Ringold Formation silt and clay beds) can occur.

The depth of erosion was sufficient that the groundwater table today throughout much of the Reservation lies within those channels. Elsewhere it commonly lies just below the Ringold Formation surface. Consequently the routes of fastest movement of groundwater and any contaminants will be in those glacial flood channels, which are filled with permeable gravels.²¹

At least two floods momentarily rose to considerable heights in the Pasco Basin when the inflow to the Basin considerably exceeded the drainage ability of Wallula Gap. The maximum height reached was about 1200 feet above sea level (roughly 800 feet above the lowest land surface at Hanford), evidently by the earlier of the two major floods. The latter flood, possibly comparable in magnitude to the first, evidently rose only to about 900 feet altitude. This may have been because Wallula Gap was reamed out by the earlier flood so that it more readily

transmitted the floodwaters. Alternatively, the latter flood may have been less catastrophic, with the flood waters more spread out in time and with a lower flood crest.

The deposits of those two floods are locally distinguishable by character. Each tends to be graded, with boulder and cobble gravels in many sites forming the base of each deposit. Higher sediments in each sequence reflect the flood impoundment, with consequently finer materials deposited where currents lessened. The deposits of the earlier flood commonly include larger blocks of rock, are less well sorted, and exhibit more chaotic flood bedding.

Both floods lasted a few weeks, during which time an estimated 500 cubic miles of water passed downstream.²⁴ Maximum flow rates reached 9.5 to possibly 14 cubic miles per hour.²⁵ Ice-rafted erratics and thin silt deposits occur up to 1200 feet above sea level, but a 700 to 800 foot altitude appears to have been the maximum for basin-fill deposits. In turn this suggests that the flood crest above that altitude and to the 900 and 1200 foot altitudes was of short duration.

In addition to the vertical grading to finer sediments, a lateral grading also occurs. Boulder gravels lie within the flood deposits along the Columbia where it exits from the gorge upstream from the Hanford Reservation and decrease in amount downstream. Southwestward, progressively farther from the main stream flood, the sediments are prevailingly finer grained (grading to cobble, pebble and granule gravels, then to very coarse to fine sands; these are referred to as the Pasco Gravels). Adjacent to the flanking hills, beneath Dry and Cold Creek Valleys, and up the Yakima, Walla Walla and locally the Snake Rivers, the sediments are silts and fine sands known as the Touchet Beds. These beds also occur as thin blankets up to the maximum altitudes of the floods.

The Touchet Beds show evidence of quiet and shallow-water deposition with abundant rhythmic and ripple-marked bedding. Clastic dikes are characteristic within the Touchet Beds, locally within the Pasco Gravels,

and less commonly in the Ringold Formation, the basalt flows and Ellensburg Formation beds. Their origin is controversial. They are related in time and probably in origin to the floods.^{26,27}

The floods had additional impact. Many scarps were formed by the flood waters, and many landslides must have been induced in the basalts and the Ringold Formation by the rapidly changing lake levels (Table II.3-B-2). Persons unfamiliar with the total effect and height of the floods have concluded that some of those features reflect fault movement and earthquake activity, respectively. Subsequent weathering in central Washington's dry environment in the last 12,000 years has had minimal impact so that the flood-formed scarps and landslides appear to indicate a greater magnitude and frequency of historically recent tectonic activity than is warranted.

II.3-B.10 Volcanic Ash Deposits

Three and possibly four vitric tuff (volcanic ash) beds are known in the Pasco Basin where they occur in late Pleistocene and Holocene deposits and have at least tentatively been identified as to source.¹⁶

The oldest ash is associated with the last glacial Lake Missoula flood deposit. It is a bifurcated bed with layers about a half-inch thick.¹⁶ Traditionally, it is considered to have been erupted from Glacier Peak, in the north Cascades, about 12,000 years ago. Some evidence now suggests that the lower bed of the two may have been from an eruption of Mt. St. Helens, nearly simultaneously with that of Glacier Peak. The ash beds are significant in that they lie within the uppermost part of the flood deposits to an altitude of 850 to 900 feet and above that in eolian sediments. The beds thus identify the deposits of the latest flood and the height of the flood.

The most certainly identified ash bed in the Pasco Basin is that emanating from Mt. Mazama (Crater Lake, Oregon) about 6600 years ago. It is normally about 6 inches thick. It lies within stream-deposited sands

TABLE II.3-B-2. Time and Geologic Events, Pliocene to Holocene Epochs, Pasco Basin

EPOCH	AGE YRS BP	GEOLOGIC UNITS	GEOLOGIC AND RELATED EVENTS	CLIMATIC TRENDS
HOLOCENE	MODERN	LANDSLIDES	IRRIGATION-INDUCED LANDSLIDING	COOLER, MOISTER
		ASH DEPOSITS	ERUPTION OF MT. ST. HELENS	
	4,000	PALOUSE SOILS AND DUNES	DEFLATION OF COLD CREEK VALLEY, DUNE CREATION. MINIMAL MASS WASTING	
			COLUMBIA RIVER AT LOW FLOW RATE	
	6,600	MAZAMA ASH BED	ERUPTION OF MT. MAZAMA	<u>ALTITHERMAL PERIOD</u>
	8,000	EOLIAN SEDIMENTS		
			EXTINCTION OF MANY LARGE MAMMALS EARLY MAN KNOWN IN BASIN	
	10,000	TOUCHET BEDS LANDSLIDES	FLOODS TO AT LEAST 850 FEET ALTITUDE EXTENSIVE LANDSLIDING	
		GLACIER PEAK ASH BED	ERUPTION OF GLACIER PEAK EARLY MAN KNOWN AT MARMES ROCKSHELTER	PLUVIAL CLIMATE BECOMING WARMER AND DRIER
	12,000			
PLEISTOCENE		FLOOD DEPOSITS	CONTINUED ANTICLINAL UPLIFT AND BASINING. FLOODS. DOMINANTLY GRAZING ANIMALS IN REGION	
	18 - 20,000	TOUCHET BEDS AND PASCO GRAVELS	CATASTROPHIC FLOODS FROM GLACIAL LAKE MISSOULA, POSSIBLY TO 1250 FEET ALTITUDE. EXTENSIVE EROSION, LANDSLIDING, SEDIMENT DEPOSITION	
		FLOOD DEPOSITS	FLOODS FROM GLACIAL LAKE MISSOULA AND LAKES TO THE WEST	ONSET OF THE ICE AGE WITH COOL CLIMATE AND AT LEAST LOCALLY INCREASED MOISTURE.
	50,000	EARLY FLOOD DEPOSITS	GLACIAL LAKE MISSOULA FLOODS	REVERSALS IN INTER-GLACIAL PERIODS
		FANGLOMERATES	PLANING OF THE RINGOLD FORMATION	
	1-2 MILLION			
PLIOCENE		EARLY PALOUSE SOILS	CONTINUED ANTICLINAL UPLIFT AND BASINING	
		RINGOLD FORMATION AND ASSOCIATED FANGLOMERATES	DOMINANTLY BROWSING ANIMALS IN THE REGION	
	8 MILLION	THE YOUNGEST BASALT FLOWS (POMONA, ELEPHANT MOUNTAIN AND WARD GAP)	TERMINATION OF THE BASALT FLOODS BEGINNING OF ANTICLINAL UPLIFT AND INCREASING VOLCANIC ACTIVITY IN THE CASCADE RANGE	DRYING AND COOLING

below an altitude of about 450 feet, and within eolian sediments above that altitude. It marks the course of the Columbia River 6000 to 7000 years ago.²⁸

Mt. Mazama erupted in the midst of the Altithermal period which was characterized by a warm, dry climate and low flow of the Columbia River. The ash bed identified geologic formations created in that period, including sand dunes.

The youngest ash bed currently is known only at Rattlesnake Springs. It is believed to correlate with an eruption of Mount St. Helens about 3200 years B.P. (Before Present).

II.3-B PART 1 REFERENCES

1. B. F. Hajek, Soil Survey Hanford Project in Benton County, Washington, BNWL-243, Battelle, Pacific Northwest Laboratories, Richland, WA, April 1966.
2. Bates McKee, Cascadia, the Geologic Evolution of the Pacific Northwest, McGraw-Hill Book Company, 1972.
3. J. R. Raymond, and D. D. Tillson, Evaluation of a Thick Basalt Sequence in South-Central Washington, BNWL-776, Battelle, Pacific Northwest Laboratories, Richland, WA, 1968.
4. R. K. Ledgerwood, D. J. Brown, A. C. Waters and C. W. Meyers, Identification of Basalt Flows in the Pasco Basin, ARH-2768, March 1973.
5. Hans-Ulrich Schmincke, "Flow Directions in Columbia River Basalt Flows and Palcocurrents of Interbedded Sedimentary Rocks, South-Central Washington," Geologischen Rundschau, Band 56, p. 992-1020, 1967.
6. R. E. Brown, "Some Suggested Rates of Deformation of the Basalts in the Pasco Basin, and Their Implications," in Proc. of the Columbia River Basalt Symposium, Northwest Scientific Assoc., Cheney, Washington, March 21-23, 1969.
7. John A. Blume and Associates, Engineers, Subsurface Geologic Investigations for the FFTF Project in Pasco Basin, JABE-WADCO-07, October 1971.
8. R. E. Brown, A Study of Reported Faulting in the Pasco Basin, BNWL-662, Battelle, Pacific Northwest Laboratories, Richland, WA, January 1968.
9. F. O. Jones, and R. J. Deacon, Geology and Tectonic History of the Hanford Area and Its Relation to the Geology and Tectonic History of the State of Washington and the Active Seismic Zones of Western Washington and Western Montana, DUN-1410, June 15, 1966.
10. J. W. Skehan, A Continental-Oceanic Crustal Boundary in the Pacific Northwest, AFCRL-65-904, December 20, 1965.
11. J. W. Bingham, C. J. Londquist and E. H. Baltz, "Geologic Investigation of Faulting in the Hanford Region," Washington, U. S. Geol. Survey Openfile Report, 1970.

II.3-B PART 1 REFERENCES (Continued)

12. G. W. Walker, and P. B. King, "Geologic Map of Oregon," U. S. Geol. Survey Misc. Geol. Invest. Map I-595, 1969.
13. J. V. Thiruvathukal, J. W. Ber, Jr. and D. F. Heinrichs, "Regional Gravity of Oregon," Geol. Soc. America Bull., vol. 81, no. 3, p. 725-738, March 1970.
14. John A. Blume and Associates, Engineers, Supplementary Geologic Investigations for Seismic Evaluation of the FFTF Site Near Richland, Washington, JABE-WADCO-04, February 1971.
15. W. H. Price, The Rattlesnake Ridge Project - A Progress Report, ARH-2657, October 30, 1972.
16. R. E. Brown, Interrelationships of Geologic Formations and Processes Affecting Ecology as Exposed at Rattlesnake Springs, Hanford Project, BNWL-B-29, May 1970.
17. A. A. Hammer, "Rattlesnake Hills Gas Field, Benton County, Washington," Am. Assoc. Petrol Geol. Bull., vol. 18, p. 847-859, 1934.
18. R. C. Newcomb, Storage of Ground Water Behind Subsurface Dams in the Columbia River Basalt, Washington, Oregon and Idaho, U.S. Geol. Survey Prof. Paper 383-A, 1961.
19. R. E. Brown and M. W. McConiga, "Some Contributions to the Stratigraphy and Indicated Deformation of the Ringold Formation," Northwest Sci., vol. 34, no. 2, p. 43-54, 1960.
20. R. C. Newcomb, "Ringold Formation of Pleistocene Age in Type Locality, the White Bluffs, Washington," Am. Jour. Sci., vol. 256, p. 328-340, 1958.
21. R. E. Brown, "The Use of Geophysics and Geochemistry to Confirm Geological Interpretations at the Hanford Works of the Atomic Energy Commission, USA," Proc. XXI International Geol. Cong., Copenhagen, Denmark, 1960.
22. D. J. Brown, An Eolian Deposit Beneath 200-West Area, HW-67549, December 6, 1960.
23. R. E. Brown, An Introduction to the Surface of the Ringold Formation Beneath the Hanford Works Area, HW-66289, August 1, 1960.
24. J. T. Pardee, "Unusual Currents in Glacial Lake Missoula, Montana," Geol. Soc. America Bull., vol. 53, p. 1569-1600, 1942.

II.3-B PART 1 REFERENCES (Continued)

25. V. R. Baker, Paleohydrology and Sedimentology of Lake Missoula Flooding in Eastern Washington, Geol. Soc. America Spec. Paper 144, 1973.
26. D. J. Brown and R. E. Brown, Touchet Clastic Dikes in the Ringold Formation, HW-SA-2851, Dec. 3, 1962.
27. WPPSS Hanford No. 2, 1100 MW Nuclear Power Plant, Preliminary Safety Analysis Report, vol. 1, 1972.
28. R. E. Brown, "Volcanic Ash Beds in the Pasco Basin," Abst. Proc. 1971 Meeting Northwest Scientific Association, Moscow, Idaho, April 16-17, 1971.

APPENDIX II.3-B, Part 2
GEOLOGICAL STUDIES OF THE HANFORD SITE

FIGURE II.3-B-5. OUTLINE MAP OF HANFORD RESERVATION AND PERIPHERAL SITES SHOWING THE SITES AND AREAS STUDIED AND AVAILABLE REPORTS ISSUED

II.3-B PART 2 REFERENCES

1. Bensen, D.W., J.L. Nelson and G.J. Alkire. Chemical and Physical Properties of 100 Area Soils, HW-76181, Oct. 10, 1963.
2. Bingham, J.W. and M.J. Grolier. Ground Water Resources of the Columbia Basin Irrigation Project, Washington, U.S. Geol. Survey open-file report 1965.
3. Bingham, J.W., C.J. Lundquist and E.H. Baltz. Geologic Investigation of Faulting in the Hanford Region, Washington, U.S. Geol. Survey open-file report 1970.
4. John A. Blume and Associates, Engineers. Supplementary Geologic Investigations for Seismic Evaluation of the FFTF Site Near Richland, Washington, JABE-WADCO-04, Feb. 1971.
5. John A. Blume and Associates, Engineers. Subsurface Geologic Investigations for the FFTF Project in Pasco Basin, JABE-WADCO-07, Oct. 1971.
6. Bretz, J.H. "The Lake Missoula Floods and the Channeled Scabland". Jour. Geology, v. 77, no. 5, Sept. 1969.
7. Bretz, J.H. Washington's Channeled Scabland, Washington Div. Mines and Geology Bull. 45, April 15, 1959.
8. Brown, D.J. and P.P. Rowe. 100-N Area Aquifer Evaluation, HW-67326, Nov. 4, 1960.
9. Brown, D.J. An Eolian Deposit Beneath 200-West Area, HW-67549, Dec. 6, 1960.
10. Brown, D.J. Subsurface Geology of the Hanford Separations Areas, HW-61780, Oct. 1, 1959.
11. Brown, D.J. Geology Underlying 200-Area Tank Farms, HW-67729, Dec. 22, 1960.
12. Brown, D.J. Geology Underlying the 241-AX Tank Farm, HW-79805, Dec. 20, 1963.
13. Brown, D.J. Geology Underlying Hanford Reactor Areas, HW-69571, March 1, 1962.
14. Brown, R.E. and D.J. Brown. "The Surface of the Basalt Series in the Pasco Basin, Washington". Geol. Soc. Oregon Country, Geological News Letter, v. 25, no. 4, April 1959.
15. Brown, R.E. An Introduction to the Surface of the Ringold Formation Beneath the Hanford Works Area, HW-66289, Aug. 1, 1960.
16. Brown, R.E. and M.W. McConiga. "Some Contributions to the Stratigraphy and Indicated Deformation of the Ringold Formation". Northwest Sci., v. 34, no. 2, p. 43-54, 1960.
17. Brown, R.E. and J.R. Raymond. Geophysical Seismic Evaluation Study at Hanford, BNWL-47, Dec. 1964.
18. Brown, R.E. Some Suggested Rates of Deformation of the Basalts in the Pasco Basin, and Their Implications, in Proc. of the Columbia River Basalt Symposium, Northwest Scientific Assoc., Cheney, Washington, March 21-23, 1969.
19. Brown, R.E. The Geology of the Pasco Basin, BNWL-947, 1969 (unpublished).
20. Brown, R.E. Interrelationships of Geologic Formations and Processes Affecting Ecology as Exposed at Rattlesnake Springs, Hanford Project, BNWL-B-29, May 1970.
21. Grolier, M.J. Geology of Part of the Big Bend Area, in the Columbia Plateau, Washington. PhD dissertation, The Johns Hopkins Univ., Baltimore, Maryland, 1965.
22. Grolier, M.J. and J.W. Bingham. Geologic Map and Sections of Parts of Grant, Adams and Franklin Counties, Washington, U.S. Geol. Survey Misc. Geologic Invest. Map I-589, 1971.
23. Gustafson, E.F. The Ringold Formation: Age and a New Vertebrate Faunal List, Univ. of Washington M.S. Thesis, 1973.
24. Daly, M.R. "A Geological Report on the Rattlesnake Hills Field, Washington". Northwest Oil and Gas World, v. 6, no's. 3, 4, 5, 1936.
25. Hale, S. and M. Hurwitz. "Rattlesnake Hills Gas Field", Northwest Oil and Gas World, v. 2, no's. 5, 6, 7, 8, 9, 1931.
26. Hammer, A.A. "Rattlesnake Hills Gas Field, Benton County, Washington". Amer. Assoc. Petr. Geol. Bull. 18, p. 847-859, 1934.
27. Gilkeson, R.A. Washington Soils and Related Physiography-Columbia Basin Irrigation Project, Washington Agricultural Experiment Stations, State College of Washington, Stations Circular 327, April 1958.
28. Glover, S.L. Clays and Shales of Washington, Washington Div. Geology Bull. 24, 1941.
29. Hajek, B.F. Soil Survey Hanford Project in Benton County, Washington, BNWL-243, April 1966.
30. Jones, F.O. and R.J. Deacon. Geology and Tectonic History of the Hanford Area and Its Relation to the Geology and Tectonic History of the State of Washington and the Active Seismic Zones of Western Washington and Western Montana, DUN-1410, June 15, 1966.
31. LaSala, A.M. and G.C. Doty. Preliminary Evaluation of Hydrologic Factors Related to Radioactive Waste Storage in Basaltic Rocks at the Hanford Reservation, Washington, U.S. Geol. Survey open-file report 1971.
32. LaSala, A.M., C.C. Doty and F.P. Pearson, Jr. A Preliminary Evaluation of Regional Ground-Water Flow in South Central Washington, U.S. Geol. Survey open-file report, Jan. 1973.
33. Ledgerwood, R.K., D.J. Brown, A.C. Waters and C.W. Meyers. Identification of Yakima Basalt Flows in the Pasco Basin, ARH-2768, March 1973.
34. McHenry, J.R. Properties of Soils of the Hanford Project, HW-53218, Nov. 15, 1957.
35. McKnight, E.T. The White Bluffs Formation of the Columbia, Univ. of Washington thesis (unpublished) 1923.
36. Moodie, C.D., R. Okazaki, H.W. Smith and J.A. Kittrick. "A Note on the Clay Mineralogy of Four Samples from the Ringold Formation, Northwest Sci., v. 40, no. 2, p. 43-45, May 1966.
37. Roedder, E.W. Report on Twelve Samples of Sediments from the Hanford Site, U.S. Geol. Survey letter report, Feb. 13, 1957.
38. Merriam, J.C. and J.P. Riwald. Age of Strata Referred to the Ellensburg Formation in the White Bluffs of the Columbia River, California Univ. Dep't. Geol. Sci. Bull. v. 10, no. 15, p. 255-256, April 14, 1917.
39. Newcomb, R.C., J.R. Strand and J. Frank. Geology and Groundwater Characteristics of the Hanford Reservation, Atomic Energy Commission, Washington, U.S. Geol. Survey WP 8, interim rept. no. 2, Dec. 1953. Also U.S. Geol. Survey Prof. Paper 717, 1972.
40. Newcomb, R.C. Ringold Formation of Pleistocene Age, in Type locality, the White Bluffs, Washington, Am. Jour. Sci., v. 256, p. 328-340, May 1958.
41. Newman, K.R. Palynology of Interflow Sediments from Standard Oil Company of California Rattlesnake Hills No. 1 Well, Benton County, Washington.
42. Proc. 2nd Columbia River Basalt Symposium, Northwest Scientific Assoc., Cheney, Washington, March 21-23, 1969.
43. Parker, G.G. and A.M. Piper. Geologic and Hydrologic Features of the Richland Area, Washington, Relevant to the Disposal of Waste at the Hanford Directed Operations of the Atomic Energy Commission, U.S. Geol. Survey W.P. 7 (GEH 15, 045), July 1949.
44. Peterson, D.E. and R.E. Brown. Gravity Anomalies and Geologic Structures of the Central Part of the Columbia River Basalt Plateau, BNWL-SA-912, Aug. 1966.
45. Piper, A.M. Adequacy of Public Water Supply in the Hanford Barracks and Richland Village Areas of the Hanford Engineer Works (Project 9536) Hanford, Washington, U.S. Geol. Survey report GEH-20490, May 3, 1944.
46. Price, W.H. The Rattlesnake Ridge Project - A Progress Report, ARH-2657, Oct. 30, 1972.
47. Raymond, J.R. and C.A. Ratcliffe. A Test of the Refraction Seismic Method on the Hanford Project, HW-61796, Sept. 1959.
48. Raymond, J.R. The Magnetic Method of Geophysical Exploration on the Hanford Project, HW-57309, Sept. 1958.
49. Raymond, J.R. and V.L. McGhan. Results of an Airborne Magnetometer Survey of the Hanford Project, HW-78924, Sept. 12, 1963.
50. Raymond, J.R. and D.D. Tillson. Evaluation of a Thick Basalt Sequence in South-Central Washington, BNWL-776, 1968.
51. Shade, F.H. RDA-DC-6 Test Borings at Coyote Rapids Site, HDC-2564, April 14, 1952.
52. Shannon, W.L. Effect of Ben Franklin Dam on Structure Foundations, Hanford Atomic Products Operation, Richland, Washington, Shannon and Wilson, Seattle, Washington, June 13, 1958.
53. Strand, J.R. and D.H. Hart. Preliminary Report on the Aquifer Test in the 100-K Area, AEC Hanford Reservation, Washington, U.S. Geol. Survey typewritten report, Oct. 1952.
54. Strand, J.R. and J. Hough. Age of the Ringold Formation, Northwest Sci. v. 26, no. 4, p. 152-154, Nov. 1952.
55. Tillson, D.D. Analysis of Crustal Changes in the Columbia Plateau Area from Contemporary Leveling and Triangulation Measurement, BNWL-CC-2174, Feb. 12, 1970.
56. Udine, G. HAPSO Soil Information, HW-50239, Oct. 4, 1956 and unpublished supplement, July 11, 1961.
57. Walters, K.L. and M.J. Grolier. Geology and Ground Water Resources of the Columbia Basin Irrigation Project Area, Washington, Washington Dep't. Conservation, Div. Water Resources, Water Supply Bull. 8, 1960.
58. Washington Public Power Supply System. Preliminary Safety Analysis Report Hanford No. 2, 1100 MW Nuclear Power Plant, v. 1 and 6, 1972.
59. Washington Public Power Supply System. Preliminary Safety Analysis Report Nuclear Project No. 1, 1300 MW Nuclear Power Plant, v. 1 and 2, 1973.

APPENDIX II.3-C

SEISMOLOGY

II.3-C SEISMOLOGY

II.3-C.1 General

Eastern Washington is in a region of low to moderate seismicity that lies between the western Washington and western Montana zones of considerably greater seismicity.^{1,2} On the basis of the damage that has occurred since 1840, the U.S. Coast and Geodetic Survey (ESSA) designated eastern Washington as Zone 2 seismic probability, implying the potential for moderate damage from earthquakes. Periodic revisions since 1948, the date of the first issuance of the risk map, and up to 1969, resulted in no changes in the potential for eastern Washington although other parts of the country were upgraded in the damage potential (Table II.3-C-1). Currently western Washington and western Montana are in Zone 3 category, implying the risk of considerable damage. The categories are incorporated in the Uniform Building Code.

The seismic risk maps are based upon the worst damage that has been experienced, mostly on poorly consolidated and saturated sediments that are the most responsive to earthquakes. Hence a pessimistic damage potential is indicated for sites utilizing less earthquake-responsive ground. In compensation, the maps consider only about 100 years of historical record, during which a low density of population may have resulted in no record of some minor quakes and certainly no damage. The true earthquake potential then may be somewhat higher than suggested by the Seismic Risk Map (Figure II.3-C-1). The upgrading in potential seismic damage in part may reflect increased population density and increased use of seismically responsive ground, and in some sites an actual increase with time in earthquake frequency and magnitude. Other methods of assessment clearly are required.

Movement on surface faults often is associated with earthquakes. However, many earthquakes occur without surface faulting and some faults move (creep) without significant earthquake activity. The presence of major faults or sharp folds subject to faulting are validly considered as evidence of possible past earthquake activity, possible future activity and possible epicenters.

TABLE II.3-C-1

APPROXIMATE RELATION CONNECTING EARTHQUAKE
INTENSITY WITH ACCELERATION

ROSSI-FOREL INTENSITY SCALE (1883)	MODIFIED-MERCALLI INTENSITY SCALE (1931), WOOD AND NEUMANN	GROUND ACCELERATION α
COL 1	COL 2	COL 3
	I Detected only by sensitive instruments	$\frac{\text{cm}}{\text{sec}^2}$ $\frac{\alpha}{g}$
I The shock felt only by experienced observer under very favorable conditions	II Felt by a few persons at rest, especially on upper floors; delicate suspended objects may swing	2
II Felt by a few people at rest; recorded by several seismographs	III Felt noticeably indoors, but not always recognized as a quake; standing autos rock slightly; vibration like passing truck	3 4 5 .005g
III Felt by several people at rest; strong enough for the duration or direction to be appreciable	IV Felt indoors by many, outdoors by a few; at night some awoken; dishes, windows, doors disturbed; motor cars rock noticeably	6 7 8 9 10 .01g
IV Felt by several people in motion; disturbance of movable objects, cracking of floors	V Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	20 30
V Felt generally by everyone; disturbances of furniture, ringing of some bells	VI Felt by all; many frightened and run outdoors; falling plaster and chimneys; damage small	40 50 .05g 60 70 80 90 100 .1g
VI General awakening of those asleep, ringing of bells, swinging chandeliers, startled people run outdoors	VII Everybody runs outdoors; damage to buildings varies, depending on quality of construction; noticed by drivers of autos	200 300 400 500 .5g 600 700 800 900 1g 1000
VII Overthrow of movable objects, fall of plaster, ringing of bells, panic with great damage to buildings	VIII Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	2000 3000 4000 5000 5g 6000
VIII Fall of chimneys; cracks in walls of buildings	IX Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	
IX Partial or total destruction of some buildings	X Most masonry and frame structures destroyed; ground cracked; rails bent; landslides	
X Great disasters, ruins; disturbance of strata, fissures, rockfalls, landslides; etc.	XI New structures remain standing; bridges destroyed; fissures in ground; pipes broken; landslides; rails bent	
	XII Damage total; waves seen on ground surface; lines of sight and level distorted; objects thrown up into air

RICHTER SCALE

II.3-C-3

FIGURE II.3-C-1 SEISMIC RISK MAP

The Pasco Basin is a broad, shallow topographic and structural depression. It was evidently formed by long-term subsidence during which the vast volume of basaltic lava flows were emitted, probably from about 60 million years to 8 million years ago. Presumably the subsidence was slow and essentially continuous at an average rate of about 1 foot per 5000 years.³ Various lines of evidence suggest appreciable variations from that rate, as can be expected.

Late in the stage of basalt flow emission, about 15 million years ago, anticlinal uplift began. The anticlines superficially resemble the fault-block structures of the seismically more active Basin and Range country of Southeastern Oregon, eastern California, Nevada and western Utah. Indeed at one time (early in the 1900's), the anticlines in eastern Washington were considered equivalent to the more southerly fault block structures and large faults were assumed present.⁴

A seismic comparability thus seemed warranted and was applied by some parties. However, the Zone 3 designation for the Basin and Range region and the Zone 2 designation for eastern Washington, on the basis of more than 100 years of record, imply significantly different environments. This, together with geologic information earlier discussed, is more realistic than assuming that the magnitude of earthquakes in eastern Washington will be equal to those in the Basin and Range country but with lower frequency. Separate and distinct appraisals of the potential are needed.

Both regions, as in fact all the western United States, developed largely in response to global-wide forces associated with plate tectonics (continental drift). This specifically involves the relative motion of the Pacific and North American plates, the precise effects of which are still largely obscure though undeniably present.

Progressively northward from San Francisco, the oceanic structures reflect the increasing dominance of the generally east-west trending transform faults associated with sea-floor spreading and global tectonics. The change is similar to the change in trend from the north-south features of

California and Nevada through the transition zone of the Blue Mountains and the Snake River Plains to the east-west and Northwest-southeast-trending structures of eastern Washington.

The Basin and Range Province formed from uplift in Mesozoic and Cenozoic time of the Cordilleran geosynclinal deposits during the Nevadan and Laramide Revolutions. East-west tensional forces in late Cenozoic time (the Cascadian-Alpine Revolution) caused a breakup of the early Rocky Mountain arch and the development of normal, high-angle faults. Accompanying this was the rotation of fault blocks about horizontal axes parallel to the faults. Strike-slip faults also were prominent. Igneous activity then occurred.⁵

The Columbia Basin formed by subsidence in Cenozoic time, accompanying and probably directly related to the emission of flood basalts from beneath the region. In late Cenozoic time (within the last 15 million years), the anticlinal ridges began to rise. Evidence suggests a north to south progression of uplift, a greater rate to the north, or both.

If the eastern Washington structures are analogous to the Basin and Range structures, they should show comparable effects of compression and tension. The Washington anticlines tend to be asymmetrical with the steep face to the north, containing some thrust faults commonly dipping south. This implies north-south compression. The abundance of high-angle reverse faults and reversal of asymmetry, however, suggest a strong component of vertical uplift. The Horse Heaven Hills, a tilted and uplifted plateau, is one classic example.

Faulting was, and still is, the dominant means of stratigraphic offset in the Basin and Range country throughout its development. The faulting in eastern Washington appears to be an early response, followed by folding, once the belts of deformation were established. Possibly compression in part is related to subsidence of the Basin, in which the uppermost flows in a probably 12,000 feet sequence would be under compression and the lowermost flows in that section would be under tension.

Subsequently, the major deformation was uplift and folding with little evidence of major compressional or tensional forces and little evidence of recent fault offset. This contrasts with the Basin and Range Province. The major episode of faulting tends to be in early Ringold Formation time (the Pliocene epoch).⁶

Deformation certainly can be continuing since energy release will occur as stress accumulates. Commonly, as noted by many workers, the stress is released by minor slippage on the many joints in the basalts and on often clay-rich interbeds between basalt flows. Distinct faults commonly are limited in lateral extent, possibly in depth, and in offset because they pass into bedding plane shear zones and splay out into joints.

A wide distribution of centers of minor energy release (epicenters) can be expected. This is the situation to date, rather than that the recorded micro-earthquakes cluster along linear zones coincident with the anticlinal ridges and the mapped and hypothesized faults.

Sparse earthquake data and a yet-inadequate understanding of the geologic features of the region preclude a finite tectonic model of eastern Washington. Various models can be applied to infer a comparability of seismicity. However, as with the Basin and Range analogy, differences in the geology are likely to be gross and evident enough that the validity of the comparison suffers.

A model has been proposed⁷ that appears to explain the orientation of the gross tectonic features of the North American Cordillera (the main mountain region of the continent). Although simplistic and idealized, it offers a potential for a better understanding of the tectonic features one to another. Once the nature of the features is better understood through regional studies, their relationships to each other can better be assessed through the Wise or updated and modified models for a more meaningful seismicity determination.

II.3-C.2 The Olympic-Wallowa Lineament

An Olympic-Wallowa (topographic) lineament⁸ was cited as a possible major crustal rupture. Faults definitely are present at several locations along its strike, and the feature must represent, at least in some segments, an underlying or basement rock feature.

However, the Olympic-Wallowa lineament is not a sharply defined or continuous structure. It is part of a broad zone that is not generally recognized, which in turn appears related to a statewide grain or pattern. Along the west edge of the Hanford Reservation, the anticlines and synclines change their trends from east and west to northwest-southeast. The change occurs along a generally north-south line marking an increase in the eastward rate of plunge of the structures. The trend change occurs in the Horse Heaven Hills, the Rattlesnake Hills, the subsurface continuation of the Yakima Ridge anticlines, and in the Gable Butte and Gable Mountain structures, particularly in their subsurface extensions.

Possibly, in the process of maximum subsidence of the Pasco Basin, between the Hog Ranch and Jackass Mountain monoclinal flexures the effect of pre-existing structures was felt. Throughout the Cascade Range drainage patterns reflect a northwest-southeast trend that is identified as the remnants of an Oligocene-age Calkins Range. Evidence of that range also is present in the Willapa Hills of southwestern Washington, the Olympic Peninsula, and the San Juan Islands.

The origin of the Calkins Range and/or the northwest-southeast trending segments of eastern Washington's anticlines is certainly obscure and can only be postulated. Evidence indicates a clear-cut superposition of several periods of deformation and consequent structures one upon another which compounds the problems of an evaluation of the seismic hazard.

Geologic evidence suggests that the Horse Heaven Hills may be a more important geologic and tectonic feature, hence potentially a more significant earthquake-generator, than the Olympic-Wallowa topographic lineament and its hypothesized structure of uncertain significance. The Horse Heaven Hills are:

- a structure continuous from the Blue Mountains to the Cascade Range, and with appreciable relief throughout its course. (The Olympic-Wallowa Lineament is discontinuous, interrupted by other structures, and locally of no relief.)
- a structure with continuously large total stratigraphic offset and inferred local dip-slip fault offset of 300 feet. Fault offset on the lineament is more than about 200 feet.⁶
- a structure with several sites of tentatively recent fault offset. One is six to seven miles west of Milton-Freewater; one is near Warm Springs six to eight miles east of the Columbia River. A third site is about four miles west of Prosser where clastic dikes, filled with Touchet Beds sediments, have cut and offset Ellensburg Formation Beds about 20 feet. The age of the fault offset is probably 12,000 years. The offset in the first two instances could be on either the lineament or the Horse Heaven Hills structures.
- the locale of the Milton-Freewater earthquake of 1936, and the Umatilla quake of 1893. Seven other earthquakes were noted and recorded by the Blue Mountain Observatory, and epicenters were identified in the northern reaches of the Blue Mountains or in the Horse Heaven Hills.⁴ The Blue Mountain structures cross the lineament and have not been affected by it;⁹ the Horse Heaven Hills show evidence of recent uplift, away from the lineament. Hence both ranges show evidence of tectonic activity more recent than structures on the Olympic-Wallowa Lineament.

Shortened, more realistic versions of the Olympic-Wallowa zone were proposed along which faulting was demonstrated and which conceivably could be the epicenters of earthquakes.¹ The Rattlesnake-Wallula topographic lineament is one such.⁶ Faulting locally terminates at the Yakima River water gap (the southeast end of the Rattlesnake Hills) without clear-cut evidence of its continuation farther northwestward. On the assumption

that a significant fault or structure capable of faulting exists there and can generate earthquakes, the site is considered to be the possible epicenter for the maximum credible earthquake in the Pasco Basin.

The Rattlesnake-Wallula lineament then can be explained as an offshoot structure of the Horse Heaven Hills rather than as the major or dominant feature. The potential of an earthquake at this site is appreciably remote.

II.3-C.3 The Saddle Mountains

The second likeliest epicentral location for earthquakes is considered to be the Saddle Mountains, bordering the Pasco Basin on the north. It is more remote from most Hanford facilities than the Rattlesnake-Wallula lineament, except for the northernmost part of the Reservation. This is especially true if the Rattlesnake Hills, the projection of that lineament, should be considered capable of surface faulting. Hence the Saddle Mountains are of lesser concern to the whole of the Reservation.

The mapped and hypothesized faults along the north face of the Saddle Mountains die out eastward with the diminution of the Saddle Mountains and have not been hypothesized east of about Corfu. The faults have been traced west of the Columbia River about 15 miles.¹⁰

Studies in 1965¹ emphasized the significance of the Saddle Mountains faults and considered that the Corfu quake of 1918 occurred along that fault, caused numerous landslides and that a fault scarp had formed in recent times. The U.S. Geological Survey demonstrated however that the site reputed to show offset was an area of block glide, resulting probably from the effect of the glacial Lake Missoula floods 12,000 or more years ago.⁶ The larger landslides, moreover, in most instances appear to have been caused by the same floods,¹⁰ not the Corfu quake, and recent surveys have suggested that such slides as resulted from that quake were minimal. The Survey's conclusion was that no movement on the fault has occurred in at least 12,000 years. This was determined by ¹⁴C dating of organic matter in eolian silts that lay undisturbed across the fault trace.

Much of the concern for the Saddle Mountains faults relates to the Corfu earthquake of November 1, 1918. Based on the location of the sole reporter of the quake, it occurred at or even east of the east end of the surface trace of the faults. The epicentral location is uncertain because only one person initially reported it and the quake was uninstrumented. Subsequently the quake was, for uncertain reasons, translocated to the northernmost part of the Hanford Reservation. Because earthquakes commonly occur along faults, a major eastwest fault was hypothesized through the translocated epicenter in the Wahluke Syncline. As indicated earlier, all major faults in the region appear associated with anticlinal folds and have their greatest offset in the areas of maximum total relief. Hence, the epicenter in a major syncline appears unrealistic. Because of the uncertain location, similar to the uncertain extent of faulting along the Rattlesnake-Wallula lineament, the epicenter was conservatively assumed to have been beneath the Hanford Reservation.

Recently studies¹² confirmed the presence of faults in the Saddle Mountains, offset comparable to that determined by the Geological Survey, and an absence of evidence indicating recent movement.

II.3-C.4 Other Structures

Study of the Manastash Ridge--Hanson Creek anticline, between the Saddle Mountains and Umtanum Ridge and west of the Pasco Basin, disclosed a typical situation there.¹² The anticline is asymmetrical with the steep dip to the north, the anticlinal axis is sinuous, and one or more high angle reverse faults border the north side of the anticline. They emphasize the spatial relationship between the close folding and faulting. Stratigraphic offset on the faults is estimated at 500 feet in the east end of the structure and about 800 feet on the west end of the structure.

The anticline can be projected to the east side of the Columbia River where evidence tentatively indicates the fault is also present. The sinuosity of the anticlinal axis and the fault make projection farther east difficult. The structure evidently dies out eastward, similar to the structures to the north and south, and cannot be recognized within

20 miles of the WPPSS steam generating plant. This emphasizes the probable absence of a significant fault in the Wahluke Syncline along which the translocated Corfu quake could have originated.

Additional work in Umtanum Ridge confirmed previous conclusions. The Ridge is an asymmetrical anticline with the steep face to the north; locally the north limb is overturned. The anticlinal axis is sinuous. A high-angle reverse fault borders the north face. Erosion by the glacial Lake Missoula floods removed much of the north limb of the structure so that the fault is generally exposed and traceable only for a short distance to the east from the Priest Rapids Dam site. The fault can be projected to within about 12 miles of the WPPSS steam generating plant. There it evidently dies out and is superseded by the sequence of generally northwest-southeast-trending en echelon anticlines and synclines of the Gable Butte-Gable Mountain complex. A north-south trending thrust fault(s) is present in Gable Mountain but have not moved in more than 40,000 years.⁶ Normal or high-angle reverse faults may trend west-northwest along the north face of Gable Mountain and Gable Butte and the dissected anticline two miles west of 100-B Area. If so, they must be less than a few miles long because of the position and trend of the anticlines relative to the total uplift.

Stratigraphic offset on the Umtanum Fault is uncertain but is estimated at 500 to 1300 feet, with the south side upraised. The fault thus is a high-angle reverse fault. Since the Pasco Gravels which overlie the fault show no signs of offset, the last movement, as in the Saddle Mountains, was probably at least 12,000 years ago and may be more than 40,000 years ago, as dated at Gable Mountain, the eastward continuation of Umtanum Ridge. The main period of movement on the fault probably was during Ringold Formation time and the initial uplift of the anticlinal ridges. If the Umtanum Ridge structure was the first in the Basin to rise, the age of the initial period of faulting could exceed 10 million years.

The faults in the northern part of the Pasco Basin are considered inactive on the basis of lack of topographic expression, lack of evidence of move-

ment within the last 35,000 years or multiple movement in the last 500,000 years, and no relationship to a known active fault. Other than the Corfu quake, which is of uncertain epicentral location, magnitude and intensity, no macro earthquakes associated with known faults have occurred.

The faults bordering the Horse Heaven Hills, including those that lie along the various versions of the Olympic-Wallowa Lineament, apparently are the sites for potentially active surface faults in the Pasco Basin. Logically then, they are the sites for the maximum credible earthquake in the Pasco Basin.

II.3-C.5 The Effects of Earthquakes

The most significant single consideration in earthquake engineering is the nature of the foundation materials, as alluded to in the discussion on the seismic risk map. This is important from 1) the standpoint of rupture of the ground beneath a facility by propagation of fault movement, 2) vibration of the ground, and 3) differential compaction, liquefaction and landsliding.

Ground rupture occurs directly above a fault when movement along that fault propagates to the ground surface. In some instances ground rupture occurs at short distances from the fault plane. These risks can be prevented by avoiding faults by appropriate distances. Because all significant and especially active faults are associated at least spatially with the anticlinal ridges, avoidance of the anticlines is desirable and usually sufficient protection.

Ground vibration is the dominant concern in earthquake engineering, because facilities many tens of miles from the epicenter may be damaged or destroyed and because it is difficult to precisely determine the expected ground motion. Neuman states that local geological factors can spread the range of observed intensities over at least four grades, each grade representing ground motions that have double the amplitudes found in the next lowest grade. This means an eightfold range in amplitudes over a four-grade range of MM intensity.¹³ Local confirmation of this is suggested by several events as noted. Other factors are not yet adequately understood and may contribute to the differences:

- Prosser has one of the higher seismic foundation factors in the area, as indicated by the Milton-Freewater earthquake of 1936,¹³ the Olympia earthquake of 1949, and the Horse Heaven Hills quake of July 26, 1965. In those instances, Prosser responded more than Hanford or other adjoining areas.
- Records of reactor area and building response have shown different responses of the same area and buildings to roughly comparable quakes, and different responses of different areas and buildings within those areas to the same quake.

The precise response of the ground to the full spectrum of waves is a complex function that can best be answered only by the repeated observation of events. In some instances, especially with the short period waves, alluvium may damp out the ground motion. Thus, a prevailing period of vibration of 0.2 sec for short period waves in Hanford sediments poses little problem. However, longer period waves may be amplified, especially if the wave period coincides with as yet inadequately identified natural long periods of vibration of the geologic formations. The possibility of selective frequency effects thus requires that the dynamic properties of the structures be considered when assessing the effect of local geology.¹⁵

II.3-C.5.1 Differential Compaction

Differential compaction is common in unconsolidated alluvium and was a major cause of damage during the Prince William Sound (Anchorage) earthquake of 1964. The sediments at Hanford have a high degree of natural compaction. The Ringold Formation sediments at one time filled the Basin to an altitude of about 1000 feet (the crest of the White Bluffs), but have been eroded in part from the Hanford Reservation. They have been irregularly covered subsequently by later sediments, the Pasco Gravels. Hence, at one time 200 to 600 feet more sediments existed as a static load than now are present over the topmost Ringold Formation beds, a factor in their compaction. The beds, too, are low in permeability, owing to their age, the resulting cementation and opportunity for compaction subsequent to deposition.

Those factors and the relatively high seismic (P) wave velocity of about 6000 to 12,000 ft/sec confirm the compaction.

The Pasco Gravels and their fine-grained equivalent, the Touchet Beds, were laid down by the glacial Lake Missoula floods. The gravels that underlie all but the basin margins commonly are open-work or semiopen-work gravels with high permeabilities. Seismic (P) wave velocities are consistently low, about 2000 ft/sec. However, their load-bearing capacity without undue settlement is high, generally in excess of 6000 lb/ft² even for materials directly at the ground surface. Commonly 10,000 to 12,000 lb/ft² are measured.¹² That high load-bearing capacity of the flood deposits is attributed to the point-to-point contact between cobbles and pebbles and the subsequent interstitial filling by finer-grained sediments as the flood-water velocities slackened. Loads hence are supported on columns of cobbles and pebbles.

The Ringold Formation generally is saturated and the Pasco Gravels commonly are dry except locally and normally for only a few tens of feet of depth at the base of the gravel. Consequently the opportunity for reworking and compaction is minimal. Even where large quantities of water pass to ground and where vibrational and differential loading occur on undisturbed ground, settlement has been negligible. Differential compaction on undisturbed ground is of minimal concern.

II.3-C.5.2 Liquefaction

Due to the prevailing dry environment and as long as the potentially liquefiable sediments remain confined, the likelihood of liquefaction of Hanford sediments is very remote.

The sediments lying at and near the ground surface (the Pasco Gravels and uppermost Ringold Formation beds) to depths of 110 feet were compared to the range of gradation of liquefiable soils.¹² If saturated and if a face were free toward which they could move, a few samples found were sufficiently fine grained and clean to be potentially liquefiable. Most materials had a high relative density (were compact), a coarse grain size and good size gradations. The silts and clays that lie below the groundwater table were of high plasticity, but "are also insensitive and exhibit high shear strength in excess of 3 to 5 tons per square foot."¹² This is, in part, the result of deposition in a calcium-rich environment, some resulting cementation, compaction under high load, and maintenance of the calcium-rich environment for millions of years. The deposited clays were not changed to forms liable to liquefaction in a chemically changed environment.

Some sands in the Ringold Formation are clean, uncemented and well sorted. Upon penetration by wells (a face to which to flow), the sand rises in the wells. This is not liquefaction in the sense of rearrangement of particles to occupy a lesser volume; it is controlled by appropriate confinement of the sand.

II.3-C.5.3 Landslides

Many landslides are present in the region and have been attributed to earthquake activity, as earlier noted. They are, however, but permissive evidence of earthquakes and more commonly result from excess water in the ground. A classic case is that of the slides along the north face of the Saddle Mountains, attributed by some persons to earthquakes, especially the Corfu quake. In view of the findings in recent

years, the indications are that most of the features are related to the glacial Lake Missoula flood of about 12,000 years ago, not historically recent quakes. Water primarily decreases the shear strength of the clay-rich beds, which together with the pore pressure gradient at the draining face and the weight of the water, permit oftentimes minor earthquakes to trigger the slides. In the case of floods, the erosive action on the toes of slopes also is important.

Existing natural slopes on the Reservation were determined to be stable; only those slopes on the enclosing anticlinal ridges, Gable Mountain, Wahluke Slope and the White Bluffs are steep enough for concern. Of these, the White Bluffs pose the greatest concern because of 1) the clay-rich nature of some beds above river level and within the Ringold Formation, 2) discharge of large quantities of irrigation water to ground atop the bluffs, 3) gentle dips of the Ringold beds toward the Columbia River, and 4) the eastward shifting of the Columbia River and its undercutting of the bluffs. Slides of a million or more cubic yards have occurred within the last about 12,000 years; consequently, more are expected. It is not visualized that the river will be impounded. Rather, it likely would only be diverted to the more westward channel in the areas where slides are most likely.

II.3-C-6 Maximum Anticipated Earthquake

The Corfu earthquake (Modified Mercalli intensity IV to V) probably caused the maximum historical ground motion on the Hanford Reservation. The Milton-Freewater earthquake of 1936 and the Umatilla earthquake of 1893 were of higher intensity at their epicenters but sufficiently remote to result in less ground motion at Hanford. If the Corfu earthquake is assumed to be a full MM-V and with its epicenter on the Hanford Reservation,¹ rather than on the Saddle Mountains, the ground acceleration would have been three percent of gravity (3% g). This is roughly equivalent to a Richter magnitude 5 earthquake (Table II.3-C-1).

It is assumed that faults or structures capable of surface faulting are present along the Olympic-Wallowa lineament and its shorter, more realistic versions, it could also be assumed that an earthquake comparable to the Milton-Freewater quake could occur at the northwest end of the zone of identified faulting, at the southeast end of the Rattlesnake Hills. The Rattlesnake-Wallula zone of faulting ends at the Yakima River, however, to that neither surface-faulting nor recent offset is present. Migration of activity and offset along a fault can and does occur. The fact that it has not yet occurred in spite of the more than 10 million years of tectonic deformation suggests an extremely low probability that it might ever occur.

If, however, such an improbable MM-VII quake were to occur along that zone at its nearest approach to Hanford, the acceleration at the epicenter would be about 15% g. This is fully consistent with zone requirements of the Seismic Probability Map, for a building on firm alluvium and not near a great fault, as follows:

Zone 3	33% g
Zone 2	16% g
Zone 1	8% g
Zone 0	4% g

At a distance of 15 miles from the epicenter, the average distance to Hanford sites from the postulated epicenter, the acceleration would be reduced to 6%¹⁷ -13% g,¹² with a probable corresponding increase in the duration of the quake.¹³

A summary of the conclusions of various authorities in seismology as to the maximum anticipated earthquake is as follows:

Frank Neumann ¹³	MM-VII in total basin
Capt. R. A. Earle ¹¹ (USC&GS)	MM-IV maximum historically recorded in the Pasco Basin

Holmes & Narver ¹⁵	MM-VIII (25% g) maximum credible earthquake
N. H. Rasmussen ²	Magnitude 5.8
R. H. Jahns ¹⁶	Magnitude 5.5
G. W. Housner	Magnitude 5.5
John A. Blume Assoc. ¹⁷	Magnitude 6.8, MM-VIII maximum credible earthquake (conservative)

All authorities have concurred in the 25% g acceleration level for the Safe Shutdown Earthquake (formerly the Design Basis Earthquake). This is consistent with the vibratory acceleration associated with an intensity MM-VIII quake, larger than any known east of the Cascades in Oregon or Washington. An MM-VIII quake is consistent with the full-fledged Zone 3 of the Seismic Probability Map, not the Zone 2 recognized since 1949 by that map.

In March 1969, the U.S. Geological Survey established an array of six high sensitivity seismometers on and around the Hanford Reservation. The purpose was to attempt to determine the macroseismic characteristics of the region through recording of the microearthquakes. By October 1971, 24 stations were operating. Of the more than 1000 microearthquakes recorded, very few have occurred south of the Hanford Reservation, especially along the Olympic-Wallowa lineament or its abbreviated versions. This is "moderate by comparison with the microearthquake activity of seismically active regions of California and Nevada where similar monitoring studies have been made."⁶

By far, the bulk of the microearthquakes have occurred in the eastern to northern part of the Pasco Basin, from Wooded Island to the east end of the Wahluke Slope. Few quakes in that group are sufficiently close to mapped or postulated faults or sharp folds to be directly related to them. Some events further east appear related to blasting by contractors (to the Corps of Engineers) on railroad relocations for Snake River dams. Some others may have resulted from construction work (by Burlington-Northern, Inc.) on roadbeds across Wahluke Slope. Others may have

occurred because of near-surface crustal loading by irrigation water. If the Pasco Basin is slowly deforming, then the addition of several hundred feet of water, as indicated by rising water tables,¹⁸ could impose stresses above and beyond those naturally imposed. The abundance of microearthquakes in and near the Columbia Basin Irrigation Project suggests such a cause.

Large numbers of microearthquakes have occurred near the north-south trending Jackass Mountain monoclinal flexure, where the basalt flows turn downward toward the Pasco Basin center. Folding could result in the release of many small amounts of energy along joints and bedding planes in an essentially random pattern.

Only one earthquake of the more than 1000 recorded has exceeded the Richter magnitude 4 quake necessary for good analysis. That quake occurred December 19, 1973. The epicenter lay two to three miles north of Corfu and the magnitude was between 4 and 4.25. The quake occurred north and east of the surface trace of the Saddle Mountains fault and not near any other postulated fault.

The second largest quake recorded by the U.S. Geological Survey was a magnitude 3.2 quake that occurred on October 25, 1971. Its epicenter was beneath the central part of Wahluke Slope, close to the north bank of the Columbia River, and within the Wahluke syncline. Its focal depth was 3 km. A fault plane solution indicates thrust faulting resulting from north-south compression, probably the result of regional deformation.

No other quakes of sufficient magnitude to permit focal plane solutions have been recorded by the U.S. Geological Survey in the five years of operation at Hanford.

III.3-C-7 Summary and Conclusions

Eastern Washington lies in a region characterized by few earthquakes of damaging or potentially damaging intensity. No clear-cut relationships of epicenters to specific surface faults or structures capable of faulting is yet recognized. The suggested low rate of tectonic deformation for

probably more than 10 million years does not indicate cause for concern. Much of the stress resulting from the continuing low rate of tectonic deformation appears to be dissipated from random epicenters along joints and bedding planes.

On the assumption that a very low probability MM-VII quake (magnitude 5.5) were to occur at the northwest end of the Rattlesnake-Wallula fault zone, ground acceleration of 13% g could be expected beneath most of the Reservation. A design basis of 25% g on the Hanford Reservation thereby allows for an MM-VIII intensity quake (magnitude up to 6.8) for an earthquake epicentered at the same site. No such quake has ever been recorded in eastern Oregon or Washington.

The siting of nuclear facilities over the synclinal troughs introduces the maximum distance from all hypothesized faults capable of earthquake generation. If, in addition, the Ringold Formation and Pasco Gravels are compact and undisturbed, the site is certain to pose few problems.

An appreciable-to-high degree of conservatism appears present by acceptance of the MM-VIII, magnitude 6.8 quake, and the resulting 25% g acceleration of the Safe Shutdown Earthquake (SSE).

II.3-C REFERENCES

1. F. O. Jones and R. J. Deacon, Geology and Tectonic History of the Hanford Area and Its Relation to the Geology and Tectonic History of the State of Washington and the Active Seismic Zones of Western Washington and Western Montana, DUN-1410, June 1966.
2. N. H. Rasmussen, Seismology Report on Washington, Idaho, Northern Oregon and Western Montana, and the Hanford Area, Washington, DUN-1409, May 1966.
3. R. E. Brown, "Some Suggested Rates of Deformation of the Basalts in the Pasco Basin, and Their Implications," in Proc. of the Columbia River Basalt Symposium, Northwest Scientific Assoc., Cheney, WA., March 1969.
4. R. E. Brown, A Study of Reported Faulting in the Pasco Basin, BNWL-662, Battelle, Pacific Northwest Laboratories, Richland, WA., January 1968.
5. B. McKee, Cascadia, the Geologic Evolution of the Pacific Northwest, McGraw-Hill Book Company, 1972.
6. J. W. Bingham, C. J. Londquist and E. H. Baltz, Geologic Investigation of Faulting in the Hanford Region, Washington, U.S. Geol. Survey Openfile Report, 1970.
7. D. A. Wise, "An Outrageous Hypothesis for the Tectonic Pattern of the North American Cordillera," Geological Society of America Bulletin, vol. 74, no. 3, pp. 357-362, March 1963.
8. J. W. Skehan, A Continental-Oceanic Crustal Boundary in the Pacific Northwest, AFCRL-65-904, December 1965.
9. G. W. Walker and P. B. King, Geologic Map of Oregon, U.S. Geol. Survey Misc. Geol. Invest. Map I-595, 1969.
10. M. J. Groljer, Geology of Part of the Big Bend Area, in the Columbia Plateau, Washington, Ph.D. dissertation, The Johns Hopkins Univ., Baltimore, Md., 1965.
11. N. F. Fifer, Earthquake Studies of the Hanford Area, DUN-3625, February 1968.
12. WPPSS Nuclear Project no. 1, 1300 MW Nuclear Power Plant, Preliminary Safety Analysis Report, vol. 2, DOCKET-50397, 1973.
13. F. Neumann, Seismological Investigations at the Hanford Area 1958-1959, HW-63832, November 1959.

II.3-C REFERENCES (Continued)

14. (not used)
15. Lockheed Aircraft-Holmes and Narver, Nuclear Reactors and Earthquakes, TID 7024, August 1963.
16. R. H. Jahns, Geologic Factors Relating to Engineering Seismology in the Hanford Area, Washington, DUN-3100, October 1967.
17. John A. Blume and Associates, Engineers, A Summary Report, Seismic Evaluation and Development of Ground Acceleration and Response Spectra for FFTF Site, JABE-WADCO-03, February 1971.
18. K. L. Walters, and M. J. Grolier, Geology and Ground Water Resources of the Columbia Basin, Irrigation Project Area, Washington, Washington Dept. Conservation, Div. Water Resources, Water Supply Bull. no. 8, 1960.

APPENDIX II.3-D

HYDROLOGY

II.3-D HYDROLOGY

II.3-D.1 Surface Waters

II.3-D.1.1 The Columbia River

II.3-D.1.1.1 Physical and Hydraulic Characteristics

The river reach from Priest Rapids Dam (river mile 397) to the head (approximately river mile 351) of the reservoir behind McNary Dam is the last free-flowing reach of the Columbia River within the United States (Figure II.3-D-1). The main channel is braided around the island reaches and submerged rock ledges and gravel bars causing repeated pooling and channeling. The riverbed material is mobile and dependent on river velocities; it is typically sand, gravel, and rocks up to 8 inches in diameter. Small fractions of silts and clays are associated with the sands in areas of low-velocity deposition, becoming more dominant approaching the upstream face of each river dam.^{1,2,3}

The Columbia River in this reach has widely varying flows, not only from the annual flood flow, but also due to daily regulation by the power-producing Priest Rapids Dam just upstream. Flow rates during the late summer, fall and winter will vary from a low of 36,000 cfs (cubic feet per second) to as much as 160,000 cfs each day. During the spring runoff, peak flow rates from 160,000 cfs to 650,000 cfs have been observed. A maximum discharge of 692,000 cfs was recorded on June 12, 1948 while the minimum discharge of 4120 cfs was recorded on February 10, 1932. Continuous flow data in the vicinity of Hanford is available from the gauging station maintained just below Priest Rapids Dam. Data⁴ from **this** station and its predecessor near Rock Island Dam show a 55 year average flow of 120,800 cfs but during low flow periods daily flow rates may average around 80,000 cfs or less. The flow variation for 1972 is given in Figure II.3-D-2; the mean annual flow rate was 159,500 cfs.

FIGURE II.3-D-1 COLUMBIA RIVER BASIN

FIGURE II.3-D-2 FLOW VARIATION FOR 1972

River cross sections have been determined for a number of flow rates.⁴ The river width normally varies between 400 and 600 yards, depending upon the flow rate and location. The depth at the deepest part of the measured cross sections varies from approximately 10 to 40 feet and averages about 25 feet. However, the hourly variations in releases from Priest Rapids Dam can cause elevation changes during the day of as much as 10 feet upstream of Coyote Rapids and 3 to 5 feet downstream as far as Hanford. River stage measurements as a function of flow rate have been made at numerous points along the river in conjunction with reactor design and operation.^{5,6,7,8,9}

Velocity measurements in the river have been made at selected locations, usually in conjunction with temperature and radioactivity surveys, and have included both surface velocity and velocity as a function of depth. Surface and vertical velocity profiles have been drawn from these measurements.^{5,7} The maximum velocities measured vary from less than 3 feet

per second (fps) to over 11 fps, depending upon the river cross section and flow rate.

Travel times in the river have been measured by a number of different methods. Early work used radioactive tracers present in the reactor effluent and float methods.^{8,10,11} Later studies with dye injection have confirmed these early measurements. River flow rates, elevations, and travel times in the reservoir behind McNary Dam are strongly influenced by reregulation of river flows at McNary Dam, as well as at Ice Harbor Dam on the Snake River.

(Additional reference material for Physical and Hydraulic Characteristics may be found in References 12, 13 and 14.)

II.3-D.1.1.2 Temperatures

River temperatures have been measured at a number of locations both above and below the Hanford Reservation for many years with varying detail, methods, and instrumentation. The increase in dam construction and the interest in the effects of operation of the Hanford reactors gave rise to additional temperature monitoring stations for measuring temperatures along the river. It became apparent in this work that the measurements were not always accurate enough to properly and consistently characterize downstream temperatures. Hence, starting in 1965 and lasting through 1970, special efforts were made to ensure that the measured temperatures accurately represented the temperatures of the fully mixed river.^{12,13,15,16,17,18}

Tables II.3-D-1 and II.3-D-2 give the monthly average temperatures below Priest Rapids Dam and at Richland, respectively, for 1961 through 1972. Figure II.3-D-3 shows a historical comparison of temperatures at Priest Rapids Dam and Richland. Figure II.3-D-4 contains the 1972 temperature profile for measurements taken at Priest Rapids Dam and at Richland.

Analysis of the temperature trends recorded with the above data shows that dam construction on the Columbia has delayed the annual peak

TABLE II.3-D-1

MONTHLY AVERAGE TEMPERATURE (°C)
AT PRIEST RAPIDS DAM

Year	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
1960												
1961	5.4	4.7	4.7	7.4	10.4	13.7	17.3	18.9	17.8	14.9	10.4	6.6
1962	4.1	3.6	3.6	6.5	10.0	13.7	16.1	17.4	17.1	14.8	11.9	8.9
1963	5.3	3.8	4.6	6.5	10.4	14.0	16.6	18.4	18.3	16.3	11.9	7.7
1964	5.5	4.6	4.7	7.2	9.7	12.8	15.3	17.1	16.3	14.6	10.8	6.3
1965	4.4	3.3	4.1	6.6	10.0	13.3	16.1	18.4	17.3	15.3	11.9	7.8
1966	4.8	4.1	4.5	7.8	10.6	12.4	15.3	17.5	17.5	14.6	11.6	8.4
1967	5.9	5.7	5.0	6.8	10.1	13.3	16.1	18.5	18.2	15.4	11.3	7.2
1968	4.6	3.3	4.6	7.1	11.1	13.4	16.1	17.5	17.2	14.2	10.9	6.8
1969	2.4	1.5	3.4	7.2	10.8	14.6	17.1	18.2	17.7	14.8	11.5	7.6
1970	4.3	4.1	4.8	6.8	10.9	14.8	18.0	19.2	17.5	15.2	10.6	6.2
1971	4.0	3.5	3.6	6.6	10.7	12.6	15.3	18.4	17.2	15.2	11.3	6.8
1972	3.6	1.9	4.0	7.2	10.6	12.9	15.2	17.3	16.8	15.4	11.3	7.3

TABLE II.3-D-2

MONTHLY AVERAGE TEMPERATURES (°C)
AT RICHLAND

Year	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
1965	6.1	5.4	6.3	9.1	11.0	14.2	17.3	19.8	18.5	16.4	12.6	8.4
1966	5.9	6.2	6.8	10.3	12.1	13.5	16.2	18.8	19.4	15.6	12.6	9.5
1967	7.4	7.0	6.6	8.8	12.0	13.9	17.0	20.2	19.4	16.1	12.0	7.8
1968	5.7	5.0	6.0	8.8	12.8	14.3	17.0	18.7	18.3	15.0	11.4	7.4
1969	2.7	1.9	4.3	8.0	11.4	15.3	17.9	19.3	18.6	15.2	11.7	8.0
1970	5.3	4.9	5.7	7.9	11.7	15.4	19.0	19.9	17.5	14.9	10.6	5.9
1971	4.2	3.4	3.8	7.0	11.1	12.9	16.4	19.5	17.8	15.0	10.7	6.2
1972	3.3	2.2	3.7	7.0	11.0	13.3	15.5	18.1	16.9	14.0	10.5	6.1
1973	3.2	3.0	4.7	7.8	12.9	15.6	18.3	19.6	18.3	15.0	9.9

FIGURE II.3-D-3 HISTORICAL MONTHLY AVERAGE TEMPERATURE COMPARISON FOR PRIEST RAPIDS DAM AND RICHLAND

FIGURE II.3-D-4 1972 MONTHLY AVERAGE TEMPERATURE COMPARISON FOR PRIEST RAPIDS DAM AND RICHLAND

temperature arrival dates in direct proportion to the increase in travel time due to the dam.^{12,17,18,19} The free flowing stretch of river along the Hanford reach responds more rapidly to thermal modification from both weather and industrial inputs than impounded regions. Hence, in this stretch of river, summer warming and winter cooling occur more rapidly. Studies have indicated that about 65% of the heat input to the Hanford reach of the river (Figure II.3-D-1) is dissipated by the time it reaches the Washington-Oregon border.¹⁸ The residual heat below McNary Dam from Hanford input for the 1965-1969 period was about equal to the effect the Snake River has on the Columbia River temperature. The temperature rise from natural heating along the Hanford stretch during the period of maximum natural heating in August and September is about 0.5 to 0.75°C.

II.3-D.1.1.3 Chemical

Chemical analyses are made annually on the Columbia River water at Priest Rapids Dam. This information is routinely published.²⁰ The chemical analyses for water year October 1971 to September 1972 are given in Table II.3-D-3.

TABLE II.3-D-3

CHEMICAL ANALYSES AT PRIEST RAPIDS DAM WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED CALCIUM (Ca) (MG/L)	DISSOLVED MAGNESIUM (Mg) (MG/L)	DISSOLVED SODIUM (Na) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO ₃) (MG/L)	ALKALINITY AS CaCO ₃ (MG/L)	DISSOLVED SULFATE (SO ₄) (MG/L)	DISSOLVED CHLORIDE (Cl) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)
OCTOBER											
11	1630	106000	19	4.2	2.2	1.0	74	61	12	1.5	0.12
18	1410	91600	19	4.2	2.4	3.1	73	60	13	2.0	0.13
NOVEMBER											
08	1410	101000	19	4.4	2.3	1.1	74	61	11	0.7	0.08
15	1300	104000	19	4.0	2.7	1.5	72	59	11	2.0	0.79
DECEMBER											
13	1515	146000	21	4.7	2.0	0.7	76	62	15	1.0	0.02
27	1340	132000	20	4.5	2.1	1.1	75	62	13	1.9	0.15
JANUARY											
24	1350	132000	21	4.9	2.3	0.8	79	65	14	1.1	0.12
FEBRUARY											
07	1335	107000	22	4.8	2.0	0.8	78	64	14	1.7	0.06
21	1350	135000	21	4.7	2.4	1.1	82	67	14	1.8	0.13
MARCH											
13	1410	172000	21	4.9	2.1	1.2	80	66	14	1.2	0.30
27	1430	151000	21	4.9	2.4	1.0	77	63	16	1.2	0.31
APRIL											
10	1440	215000	20	4.8	3.0	0.9	77	63	16	0.6	0.14
24	1325	136000	21	4.9	2.4	1.4	80	66	1.6	0.19	
MAY											
08	1425	175000	20	4.9	2.5	1.0	76	62	15	0.6	0.19
22	1340	314000	19	4.4	2.7	0.7	68	56	14	0.9	0.39
JUNE											
12	1410	404000	16	3.6	1.4	0.9	64	52	9.5	1.8	0.93
26	1435	410000	17	3.7	1.8	0.8	65	53	9.8	0.7	0.37
JULY											
10	1440	241000	17	3.6	1.3	0.7	56	46	16	1.0	0.84
24	1530	197000	18	3.8	1.6	0.8	64	52	8.6	1.0	0.16
AUGUST											
07	1500	180000	18	3.7	1.6	0.7	65	53	9.6	0.3	0.24
21	1440	144000	18	3.7	1.7	0.7	67	55	9.5	0.9	0.79
SEPTEMBER											
11	1410	131000	19	3.9	2.4	0.7	69	57	9.8	1.3	0.11
25	1510	92000	18	4.2	1.9	9.0	70	57	11	0.6	0.13

II.3-D-8

TABLE II.3-D-3

(Continued)

DATE	DISSOLVED NITRITE (N) (MG/L)	AMMONIA NITROGEN (N) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	DISSOLVED ORTHO PHOSPHORUS (P) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180°C) (MG/L)	HARDNESS (Ca, Mg) (MG/L)	NON-CARBONATE HARDNESS (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	pH (UNITS)
OCTOBER										
11	0.000	0.05	0.11	0.010	0.030	82	65	4	160	7.8
18	0.000	0.06	0.07	0.010	0.020	98	65	5	140	7.8
NOVEMBER										
08	0.000	0.01	0.16	0.020	0.030	90	66	5	145	7.7
15	0.010	0.21	0.31	0.020	0.050	88	64	5	145	7.8
DECEMBER										
13	0.010	0.01	0.20	0.010	0.030	92	72	9	151	7.4
27	0.010	0.00	0.25	0.020	0.030	88	68	7	148	7.6
JANUARY										
24	0.000	0.03	0.45	0.030	90	73	8	156	7.8	
FEBRUARY										
07	0.010	0.01	0.04	0.030	0.040	78	75	11	171	7.6
21	0.000	0.05	0.18	0.030	0.040	112	72	5	165	7.8
MARCH										
13	0.010	0.05	0.32	0.030	0.060	152	73	7	158	6.5
27	0.010	0.07	1.5	0.010	0.070	136	73	9	158	7.8
APRIL										
10	0.010	0.03	0.14	0.020	0.050	154	70	7	156	8.0
24	0.010	0.05	0.05	0.010	0.060	130	73	7	159	8.0
MAY										
08	0.000	0.05	0.04	0.010	0.030	154	70	8	164	8.0
22	0.000	0.05	0.07	0.010	0.050	100	66	10	370	7.8
JUNE										
12	0.010	0.30	1.1	0.000	0.080	134	55	2	128	7.6
26	0.000	0.05	0.10	0.010	0.030	112	58	4	134	7.7
JULY										
10	0.000	0.18	0.15	0.010	0.030	112	57	11	150	7.6
24	0.010	0.02	0.22	0.000	0.020	70	61	8	135	8.1
AUGUST										
07	0.010	0.04	0.08	0.000	0.020	104	60	7	144	8.2
21	0.010	0.24	0.10	0.010	0.020	104	60	5	139	7.9
SEPTEMBER										
11	0.000	0.01	0.10	0.000	0.010	82	63	7	140	8.2
25	0.010	0.03	0.30	0.010	0.030	98	62	5	139	8.5

TABLE II.3-D-3

(Continued)

DATE	TEMPERATURE (DEG C)	COLOR (PLATINUM COBALT UNITS)	TURBIDITY (JTU)	DISSOLVED OXYGEN (MG/L)	IMMEDIATE COLIFORM (COL. PER 100 ML)	DISSOLVED CHROMIUM (Cr) (UG/L)	DISSOLVED COPPER (Cu) (UG/L)	DISSOLVED LEAD (Pb) (UG/L)	TOTAL MERCURY (Mg) (UG/L)	DISSOLVED ZINC (Zn) (UG/L)
OCTOBER										
11	17.9	9	4	9.9	100	-	-	-	---	--
18	15.1	26	2	10.0	2000	-	2	2	0.1	0
NOVEMBER										
08	10.5	12	2	10.8	>100	-	-	-	---	--
15	11.7	5	2	10.4	50	-	-	-	---	--
DECEMBER										
13	6.2	27	2	11.7	50	-	-	-	0.3	10
27	5.2	7	1	12.5	----	-	-	-	---	--
JANUARY										
24	3.0	8	2	13.2	----	0	1	2	1.1	20
FEBRUARY										
07	1.8	7	2	13.5	30	0	6	3	0.5	30
21	3.6	12	10	13.6	50	0	2	3	0.8	20
MARCH										
13	4.7	12	4	15.4	60	0	1	4	0.3	50
27	5.1	21	7	15.9	65	0	1	9	0.1	60
APRIL										
10	7.8	17	4	14.6	250	0	1	8	0.6	80
24	10.0	13	3	11.3	100	0	1	3	0.2	50
MAY										
08	9.4	12	4	13.3	130	0	1	5	0.0	40
22	11.7	21	9	13.8	400	0	1	5	0.3	50
JUNE										
12	13.1	33	29	13.0	400	0	9	76	5.3	40
26	13.6	16	5	12.8	200	0	2	6	0.7	50
JULY										
10	15.2	18	3	12.0	400	0	2	5	0.2	20
24	17.5	12	4	11.6	1300	0	2	5	0.8	20
AUGUST										
07	19.2	13	2	11.3	110	0	0	2	0.1	10
21	18.9	9	2	11.0	120	0	2	2	0.6	30
SEPTEMBER										
11	18.7	14	1	10.1	400	0	2	4	3.3	0
25	14.8	12	1	11.0	220	0	10	1	2.5	20

II.3-D-10

In addition, several other investigations have been carried out. One studied the effect of reactor effluent on the chemical quality of the river water by comparing analyses on river samples taken semimonthly at Vernita (upstream from reactors) and Hanford (downstream of reactors). Determinations made on each sample are shown below with the mean values for the year 1963 (Table II.3-D-4).

TABLE II.3-D-4
COLUMBIA RIVER CHEMICAL CHARACTERISTICS (1963)
(All values in ppm)

	<u>Ca</u>	<u>Mg</u>	<u>Cu</u>	<u>Fe</u>	<u>SO₄</u>	<u>Cl</u>	<u>PO</u>
Vernita	21	3.9	0.0035	0.057	11.9	0.34	0.067
Hanford	21	3.7	0.0034	0.050	12.0	0.35	0.052

	<u>M.O. Alk</u>	<u>Hardness</u>	<u>Total Diss. Solids</u>	<u>Diss. O₂</u>	<u>Cr^{+c}</u>
Vernita	63	69	86	10.8	<0.005
Hanford	63	69	84	10.8	0.015

Statistical comparison of the mean values, using a t-test on the differences between means, showed no significant differences at the 90% confidence level in any of the species other than hexavalent chromium, used in reactor cooling water treatment. Similar data plus Si, Na, K, Zn, B, Mn, NH₄, NO₃, and turbidity for samples taken at Vantage and 100-F Area during 1962 and 1963 also showed no significant differences.

Table II.D-5²² presents biological and chemical analyses on the Columbia River at Vernita and Richland for 1972. Reference 23 gives more complete data on a weekly basis.

II.3-D.1.1.4 Columbia River Sediments

From the reactors located on the Hanford Reservation to several miles below the Snake River mouth, bed sediments of the Columbia River are typically sand intermixed with gravel and rock as large as 8 inches in diameter. Streambeds of eddying areas in this relatively fast-water reach sometimes are deposits of sand. Sand, silt, and clay are deposited in slack-water areas behind McNary Dam. Between the upstream reach (which has a coarse-sediment bed) and the deposits of small-size sediments near McNary Dam, the streambed in deep channels is sand and in shallow areas is a mixture of sand, silt and some clay. Some sediment is present in the Bonneville reservoir. In general, the bed in most stretches of the river between the reservoirs either has been scoured to bedrock or has been covered with a thin deposit of coarse gravel.

Concentrations of suspended sediment carried by the Columbia River vary considerably throughout the year because of the seasonal contributions of tributaries. However, during all seasons the Snake River usually is the major contributor of suspended sediments. During slack water the dams along the Columbia and Snake Rivers normally interrupt the transport of suspended sediment as well as the bedload; during high water the sediment is resuspended. Thus, most of the suspended sediment is discharged to the Pacific Ocean during the late spring and early summer at the time of maximum water.³

Bedload sediment transport is appreciable only in the lower Columbia and the amount of sediment transported is probably small, perhaps on the order of 10% of the total sediment load exclusive of dissolved materials.²⁴

TABLE II.3-D-5
COLUMBIA RIVER BIOLOGICAL ANALYSES FOR 1972

	Coliform (N/100 ml)		Enterococci (N/100 ml)		BOD (ppm)	
	Vernita	Richland	Vernita	Richland	Vernita	Richland
# Samples	14	11	14	11	14	11
Max.	210.	460.	280.	88.	4.1	4.2
Min.	1.0	2.0	1.0	2.0	1.0	1.2
Avg.	49.	88.	37.	34.	2.6	2.9

COLUMBIA RIVER CHEMICAL ANALYSES FOR 1972

	Nitrate (NO ₃) (ppm)		pH		Turbidity (JTU)		Dissolved O ₂ (ppm)	
	45		6.5 to 8.5		5 + Bg		8.0 min.	
Water Quality Standard	Vernita	Richland	Vernita	300 Area	Vernita	300 Area	Vernita	300 Area
# Samples	51	52	47	224	48	219	34	181
Max.	1.3	1.0	9.2	9.4	28.	30.	13.6	14.7
Min.	*	0.14	7.4	7.2	0.6	0.05	4.0	8.1
Avg.	0.36	0.37	8.1	8.0	5.0	4.6	11.0	10.

* Less than the analytical limit of 0.1 ppm.

Figure II.3-D-5²⁴ and Table II.3-D-6 give particle size data for eight of the reservoirs of the Columbia River, based on 152 samples from near the center of the channel. The reservoirs of importance here are Priest Rapids, Ice Harbor, McNary, The Dalles, and Bonneville. Table II.3-D-7²⁴ shows the mineral composition of the sediment while Table II.3-D-8 shows the chemical composition.

II.3-D.1.2 The Yakima River

The Yakima River is a small river with flows of between 1,300 cfs and 20,000 cfs. This river partially borders the Hanford Reservation on the southern side. It is of minimal importance to the Hanford Reservation and its operation; i.e., no direct withdrawal or disposal is made to the Yakima River.

Continuous flow data⁴ in the vicinity of Hanford is available from a water stage recorder located at Kiona (approximately 20 miles west of Richland). Data from this station show a maximum flow of 67,000 cfs on December 23, 1933, and a minimum of 105 cfs on September 11, 1906. For 1972 the maximum and minimum flows were 20,200 cfs and 1,420 cfs respectively. The mean flow for 1972 was 6,700 cfs.

Water quality for the Yakima River at Kiona, Washington, is summarized by Tables II.3-D-9²⁰ and II.3-D-10. Table II.3-D-9 presents the chemical analyses and specific conductance while Table II.3-D-10 contains temperature data for 1972.

II.3-D.1.3 Ponds

The Hanford Reservation contains a number of man-made ditches and ponds which are used for the disposal of radioactive liquid wastes, other industrial wastes, and cooling waters from various processes. These sites, shown in Figure II.3-D-6 are listed in Appendixes II.1-B, C and E with detailed inventory data.

II.3-D-15

FIGURE II.3-D-5 PARTICLE SIZE DATA FOR EIGHT OF THE RESERVOIRS OF THE COLUMBIA RIVER

TABLE II.3-D-6

PARTICLE-SIZE DISTRIBUTIONS OF UNDISPERSED AND DISPERSED
SEDIMENTS FROM COLUMBIA RIVER SIZE CLASSES

Type of Analysis: A, not dispersed mechanically or chemically;
B, dispersed mechanically and chemically

(Size limits and range in microns)

Size Class Number and Limits	Location	Type of Analysis	Percent in Size Range				
			62-31	31-16	16-4	4-2	<2
8 (62-31)	Pasco	A	93.8	4.0	0.7	0.6	0.9
	McNary Dam	A	92.2	5.3	1.4	.1	1.0
	The Dalles	A	89.0	8.9	1.3	.1	.7
	Hood River	A	90.8	7.3	.5	.5	.9
	Hood River	B	86.4	9.5	1.4	1.1	1.6
	Bonneville Dam	A	92.8	5.2	1.3	.0	.7
	Vancouver	A	92.5	6.5	.6	.1	.3
	St. Helens	A	90.8	8.0	.8	.1	.3
8 (31-16)	McNary Dam	A	10.8	83.7	3.7	1.8	.0
	The Dalles	A	7.4	86.4	4.4	.5	1.3
	Hood River	A	9.8	84.1	5.5	.2	.4
	Bonneville Dam	A	12.3	82.7	3.6	.1	1.3
	Vancouver	A	8.7	85.4	5.2	.2	.5
	St. Helens	A	9.6	84.7	4.7	.3	.7
9 (16-4)	Pasco	A	.0	22.9	68.1	5.1	3.9
	McNary Dam	A	.0	11.0	84.6	1.1	3.5
	McNary Dam	B	.0	7.3	81.5	5.5	5.7
	The Dalles	A	.0	10.9	82.1	4.0	3.0
	Hood River	A	.0	.0	90.5	7.6	1.9
	Bonneville Dam	A	.5	9.1	85.1	2.5	2.8
	Vancouver	A	.0	8.8	83.7	3.9	3.6
	St. Helens	A	.0	5.1	87.4	.0	7.5
10 (4-2)	McNary Dam	A	.0	3.7	40.5	46.7	9.1
	McNary Dam	B	.0	.0	11.6	52.2	36.2
	The Dalles	A	.0	.0	24.3	60.4	15.3
	The Dalles	B	1.0	1.4	2.0	70.6	25.0
	Vancouver	A	.0	.0	32.0	56.3	11.7
11 (<2)	McNary Dam	A	.0	.0	.0	34.6	65.4
	McNary Dam	B	1.1	.2	13.8	10.3	74.6
	The Dalles	A	.0	.0	.0	30.1	69.9
	Hood River	A	.0	.0	.5	9.1	90.4
	Hood River	B	.0	.0	.7	10.1	89.2
	Vancouver	A	.0	.0	.5	19.7	79.8
	St. Helens	A	.0	.0	.0	6.1	93.9
	St. Helens	B	.0	.0	.1	7.9	92.0

TABLE II.3-D-7

MINERAL COMPOSITION OF BOTTOM SEDIMENTS FROM COLUMBIA RIVER RESERVOIRS

Bulk-Mineral Composition (in %) of Bottom Sediments from Columbia River Reservoirs
Determined Petrographically by Point-Counting Thin Sections. Approximately
250 grains counted per sample. x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids		Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
Quartz	29	9.0	29	9.3	34	9.0	41	6.5	37	10.4	45	5.2
Plagioclase	18	5.2	17	5.9	15	6.8	12	3.5	5	0.6	8	4.1
K-feldspar	10	4.3	13	6.6	12	5.1	11	2.7	12	9.9	11	3.9
Lithic fragments	35	12.5	32	20.4	29	11.9	21	10.9	28	9.3	16	7.5
Opaque minerals	4	4.5	5	2.9	4	3.2	13	5.3	15	2.7	3	1.5
Mafic minerals*	5	3.2	4	3.1	6	5.3	2	1.7	3	1.7	18	5.0
Number of Samples	19		6		15		12		3		19	

*Largely orthopyroxene (hypersthene), clinopyroxene (augite), hornblende, and biotite.

Heavy-Mineral (SG>3.17) Composition (in %) of Bottom Sediments from Columbia River Reservoirs
Determined Petrographically by Point-Counting Grain Mounts in Hyrax (n=1.67).
Approximately 250 grains counted per sample. x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids		Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
Orthopyroxene*	27	10.0	10	7.3	6	3.2	5	2.4	5	3.5	2	1.5
Clinopyroxene**	38	9.1	47	9.8	30	7.7	20	10.1	14	3.5	12	6.0
Hornblende	22	11.9	32	9.9	44	10.0	58	13.1	57	3.6	72	7.8
Epidote	2	2.9	1	0.8	2	1.8	3	3.1	3	1.7	1	1.3
Garnet	6	5.2	6	3.3	9	6.8	7	4.5	9	7.0	4	2.8
Sphene	1	1.0	2	1.0	3	1.1	5	1.9	9	2.4	5	2.3
Zircon	1	1.3	1	1.0	4	4.5	2	1.5	3	1.3	3	1.7
Apatite	1	0.8	1	0.8	1	1.0	1	0.7	0		1	0.3
Other	tr		tr		tr		tr		tr		tr	
Number of Samples	19		6		15		12		4		9	

*Largely hypersthene.

**Largely augite.

TABLE II.3-D-8

CHEMICAL COMPOSITION IN BOTTOM SEDIMENTS FROM COLUMBIA RIVER RESERVOIRS

Chemical Composition of Major-Element Oxides (in weight %) in Bottom Sediments from
Columbia River Reservoirs. Analysis by X-ray emission spectrography
(MnO and TiO₂ by optical emission spectrography). x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids		Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
SiO ₂	68.5	4.3	65.2	3.4	67.6	4.8	66.2	3.3	58.4	2.9	62.3	2.0
TiO ₂	0.8	0.2	0.8	0.1	0.8	0.2	0.7	0.2	0.8	0.1	1.1	0.1
Al ₂ O ₃	13.3	1.1	14.1	1.4	13.6	0.8	14.4	0.8	17.0	1.9	14.9	1.4
FeO as Fe ₂ O ₃	5.1	1.3	5.7	0.9	4.8	1.3	3.3	0.8	5.1	0.6	4.6	0.7
Fe ₂ O ₃	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.3	0.4
MnO	2.1	0.5	2.1	0.2	1.8	0.4	2.1	0.4	2.6	0.5	2.1	0.2
MgO	3.2	1.0	3.7	0.5	3.2	1.0	3.5	0.3	2.6	0.3	3.7	0.9
CaO	3.0	0.2	2.7	0.3	2.8	0.3	3.5	0.3	2.5	0.2	2.9	0.2
Na ₂ O	2.1	0.3	2.0	0.2	2.2	0.2	2.1	0.1	3.1	0.3	2.3	0.3
K ₂ O	nd		nd		nd		nd		nd		nd	
H ₂ O	nd		nd		nd		nd		nd		nd	
CO ₂	nd		nd		nd		nd		nd		nd	
Total	98.2		96.4		96.9		95.9		92.3		94.2	
Number of Samples	21		11		15		12		6		9	

Chemical Composition of Minor Elements (ppm) in Bottom Sediments from Columbia River Reservoirs.
Analysis by optical emission spectrography (E. Bingham, analyst). x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids		Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
B	29	<5	20	<10	30	10	30	<10	50	<10	30	<10
Ba	1720	430	1600	270	1410	330	860	60	970	190	860	90
Co	10	<10	10	<10	10	<10	10	<10	20	<10	20	<10
Cr	50	10	50	<10	50	20	40	10	40	10	30	<10
Cu	20	10	40	10	40	10	40	10	90	20	50	10
Ga	20	<10	20	<10	20	<10	20	<10	20	<10	20	<10
Ni	30	10	30	<10	30	<10	40	10	50	10	30	<10
Pb	20	<10	40	20	40	20	70	50	570	170	30	10
Sc	20	<10	20	<10	20	<10	20	<10	20	<10	30	<10
Sr	430	70	430	80	450	110	360	110	280	30	300	50
V	90	50	120	30	60	50	100	40	90	10	130	30
Y	40	<10	50	10	50	10	50	10	120	20	60	<10
Zr	150	40	180	40	190	50	190	40	180	30	280	90
Number of Samples	21		11		15		12		6		9	

TABLE II.3-D-9

YAKIMA RIVER CHEMICAL ANALYSES, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972, AT KIONA, WASHINGTON

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED CALCIUM (Ca) (MG/L)	DISSOLVED MAGNESIUM (Mg) (MG/L)	DISSOLVED SODIUM (Na) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO ₃) (MG/L)	ALKALINITY AS CaCO ₃ (MG/L)
OCTOBER								
05	1015	2320	29	11	20	2.9	160	131
19	0935	2820	27	10	17	3.3	151	124
NOVEMBER								
16	0940	2900	---	---	---	---	---	---
DECEMBER								
07	1055	2840	23	8.7	18	2.9	132	108
14	1105	2860	22	8.3	15	2.3	120	98
JANUARY								
10	1125	3080	19	8.0	14	2.9	114	94
FEBRUARY								
01	1105	4340	16	6.6	10	2.2	97	80
08	1115	4340	16	6.0	9.3	1.7	89	73
22	1315	7220	14	5.4	8.1	1.9	82	67
MARCH								
14	1120	17200	11	3.7	5.5	1.8	67	55
APRIL								
04	0915	17000	10	3.8	5.7	1.4	59	48
11	1055	15200	9.7	3.9	5.4	1.2	62	51
18	1125	11800	11	3.6	5.4	1.2	59	48
MAY								
10	1010	12800	12	4.1	5.9	1.4	66	54
23	1425	16100	12	4.2	5.9	1.3	64	52
JUNE								
13	1500	11600	13	4.2	6.8	1.5	72	59
27	1435	9450	13	4.4	6.9	1.4	73	60
JULY								
11	1715	2510	26	8.4	15	3.2	148	121
25	1540	1640	29	10	18	3.1	152	125
AUGUST								
08	1430	1470	30	11	20	3.7	167	137
22	1315	2320	26	9.7	17	3.3	150	123
SEPTEMBER								
12	1320	2280	27	10	18	2.9	140	122

TABLE II.3-D-10

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1971 TO SEPTEMBER
1972 OF YAKIMA RIVER AT KIONA, WASHINGTON

DAY	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1	11.5	6.0	6.0	3.5	0.0	4.5	8.5	9.0	15.0	18.5	24.5	18.5
2	13.0	6.0	6.0	2.0	0.0	4.5	8.5	10.0	16.5	18.0	20.5	18.5
3	15.0	6.5	6.0	0.5	0.0	1.0	7.0	10.0	16.5	18.5	21.0	19.0
4	14.0	8.5	5.0	1.0	0.0	2.0	7.0	11.5	16.0	18.5	21.0	19.0
5	15.0	6.5	4.5	1.0	0.0	6.0	8.5	15.0	14.5	19.0	21.0	19.0
6	15.0	5.5	4.5	1.5	0.5	4.5	8.5	13.5	18.0	20.0	21.0	17.0
7	14.5	6.0	4.0	2.0	0.5	4.5	8.0	14.5	20.5	20.0	21.5	18.5
8	14.5	5.5	1.5	1.0	1.0	4.5	8.0	12.0	16.5	19.0	22.0	16.5
9	15.0	5.5	3.0	1.0	0.5	4.5	7.0	11.5	17.0	19.5	26.0	16.0
10	15.0	7.0	3.0	0.0	1.0	7.0	6.0	10.0	15.5	18.0	22.0	16.5
11	15.0	7.0	5.0	3.5	1.5	7.0	7.0	11.0	14.5	16.5	25.0	15.0
12	14.0	8.5	0.0	4.0	4.0	8.0	8.5	12.0	13.5	18.0	20.5	15.0
13	11.5	6.0	0.5	3.0	4.0	7.0	6.0	15.0	14.0	19.5	21.0	14.5
14	12.0	9.5	0.0	1.5	3.5	7.0	9.5	----	14.5	20.5	20.0	15.0
15	11.5	6.0	2.0	0.5	4.0	6.5	9.0	14.0	16.5	20.5	20.0	16.0
16	11.5	8.0	3.0	0.0	4.5	7.0	9.5	12.0	16.0	19.5	19.5	16.0
17	7.0	6.5	4.0	2.0	4.5	5.5	6.5	11.0	15.5	20.0	17.0	17.0
18	9.0	6.0	4.5	3.0	4.0	6.0	9.0	10.0	15.5	20.0	18.5	16.0
19	10.0	6.0	4.0	3.5	4.0	9.5	8.0	10.5	15.5	19.5	18.0	14.5
20	9.5	7.0	4.0	5.5	5.0	8.0	10.0	13.5	16.0	19.0	18.5	13.5
21	9.5	5.0	4.5	5.0	4.5	5.0	8.5	13.5	16.0	18.0	18.5	14.0
22	10.0	6.0	4.5	5.5	4.5	8.5	7.0	11.5	16.5	19.5	21.5	12.0
23	10.5	6.0	4.5	4.0	4.5	6.5	9.5	11.0	14.5	21.0	19.0	11.5
24	10.0	6.0	4.5	3.0	4.5	6.5	8.0	11.5	14.0	20.0	----	12.0
25	10.0	6.0	4.5	1.6	4.0	6.0	9.0	11.0	14.0	19.0	19.5	10.5
26	9.0	---	3.5	0.0	4.5	6.0	8.5	11.5	15.5	20.5	20.0	----
27	9.0	6.0	1.5	0.0	6.0	6.5	9.5	14.0	15.0	20.5	21.0	10.5
28	7.0	7.0	1.0	0.0	7.0	5.5	10.0	15.0	16.0	20.5	21.0	10.5
29	6.0	6.5	1.5	0.5	5.5	6.5	10.0	16.5	17.0	25.0	21.0	11.0
30	6.0	6.5	1.0	-0.5	---	6.5	10.0	18.0	18.0	26.0	20.5	----
31	6.0	---	1.0	---	---	7.0	----	17.0	----	22.0	19.5	----
MONTH	11.0	6.5	3.5	1.0	3.0	6.0	8.5	12.5	16.0	20.0	20.5	15.0

FIGURE II.3-D-6 PONDS ON THE HANFORD SITE

In addition to these artificial ponds, one natural pond exists, West Lake, also shown in Figure II.3-D-6. The size of this pond is a direct function of the elevation of the groundwater in that area. The average size is about 10 acres. No routine chemical or temperature measurements are made of these disposal sites.

II.3-D.2 Groundwater

II.3-D.2.1 Background and Geological Summary

Hanford is located in an area of relatively low relief. Thus, most of the data on the underlying structure and stratigraphy were obtained from wells drilled in the area. During the past 30 years, over 1500 wells were drilled on the Reservation for various purposes:

- to provide water supply
- to provide quantitative data for evaluating the chemical and physical properties of the underlying material
- for measuring the hydrological characteristics of the various sediments
- for foundation engineering design
- for monitoring of waste disposal facilities
- for monitoring the radiological status of the groundwater.

Reference 25 is a compilation of the construction data for these wells. Figure II.3-D-7 shows locations of wells currently available for hydrological measurements.

As described in the section on geology, three principal rock types underlie the Hanford-Reservation--unconsolidated silts, sands, and gravels, semiconsolidated lake and stream sediments (Ringold Formation), and dense, hard basalt which forms the bedrock beneath the area. The lithologic character and water bearing properties of the several geologic units occurring in the Hanford area are summarized in Table II.3-D-11. In general, groundwater in the surficial sediments occurs under

TABLE II.3-D-11³⁵

MAJOR GEOLOGIC UNITS IN THE HANFORD REGION AND THEIR WATER-BEARING PROPERTIES

System	Series	Geologic Unit	Material	Water-Bearing Properties
Quaternary	Pleistocene	Fluviatile and glacio-fluviatile sediments and the Touchet Formation. (0-200 ft thick)	Sands and gravels occurring chiefly as glacial outwash. Unconsolidated, tending toward coarseness and angularity of grains, essentially free of fines.	Where below the water table, such deposits have very high permeability and are capable of storing vast amounts of water. Highest permeability value determined was 12,000 ft/day.
		Palouse Soil (0-40 ft thick)	Wind deposited silt.	Occurs everywhere above the water table.
		Ringold Formation (200-1,200 ft thick)	Well-bedded lacustrine silts and sands and local beds of clay and gravel. Poorly sorted, locally semi-consolidated or cemented. Generally divided into the lower "blue clay" portion which contains considerable sand and gravel, the middle conglomerate portion, and the upper silts and fine sand portion.	Has relatively low permeability; values range from 1 to 200 ft/day. Storage capacity correspondingly low. In very minor part, a few beds of gravel and sand are sufficiently clean that permeability is moderately large; on the other hand, some beds of silty clay or clay are essentially impermeable.
	Miocene and Pliocene	Columbia River basalt series (>10,000 ft thick)	Basaltic lavas with interbedded sedimentary rocks underlie the unconsolidated sediments.	Rocks are generally dense except for numerous shrinkage cracks, interflow scoria zones, and interbedded sediments. Permeability of rocks is small (e.g., 0.002 to 9 ft/day) but transmissivity of a thick section may be considerable (70 to 700 ft ² /day)
?	?	Rocks of unknown age, type, and structure.		?

II.3-D-23

FIGURE II.3-D-7 HANFORD RESERVATION WELL LOCATION MAP

unconfined or water table conditions, although there are locally confined zones caused by cemented deposits and clay lenses. Water in the basalt bedrock occurs mainly under confined conditions, although the hydraulic potential of the upper basalt aquifer is the same as that of the overlying unconfined aquifer in many places. In some areas the lower zone of the Ringold Formation is a confined aquifer which is separated from the unconfined aquifer by thick clay beds and which possesses a distinct hydraulic potential. Zones of "perched" water above the water table exist north of Gable Mountain where farm irrigation canals have caused significant recharge to the ground and in 200 West Area.

The rate of water movement in soil is of considerable importance in waste disposal and is influenced by the physical properties of soils in two ways. The size and structural arrangement of the soil particles determine the space configuration through which the water moves, and the interaction between the soil and the soil water gives rise to water-moving forces. In soils where pores are completely filled with water, the fluid is a single phase. Forces originating from gravity, including the pressure gradient, determine the flow.²⁶ Often in waste disposal (artificial recharge) the pores are not completely filled with water. Thus, the potential of the water depends not only on the position in the gravitational field but also upon the adsorptive forces associated with interfacial boundaries.

Where air partially fills the soil pores, with water occupying the remaining void space, a two phase flow takes place. As the percentage of water decreases, it occupies the position in the smaller and smaller capillaries that exist between soil particles, primarily because it is the wetting fluid. The measurement of the capillary forces versus the saturation can be plotted and a typical curve is shown in Figure II.3-D-8.

As a result of the decrease in water within the voids, hydraulic conductivity (the ability for the soil to transmit water) is also reduced. A typical plot would look like Figure II.3-D-9. As the curve on

FIGURE II.3-D-8 SATURATION
AS A FUNCTION OF CAPILLARY
PRESSURE

FIGURE II.3-D-9 RELATIVE
HYDRAULIC CONDUCTIVITY AS
A FUNCTION OF CAPILLARY
PRESSURE

Figure II.3-D-8 shows, the forces necessary to move the water must become larger as saturation decreases. If carried to a point where forces holding the water (surface tensions, etc.) are nearly balanced by forces (such as gravity) attempting to move the water, a saturation level, loosely termed the specific retention capacity of the soil, is reached. The amount of water retained for long periods of time is dependent on the characteristics of the soil. Figure II.3-D-10 shows a relationship between water storage properties and median grain size of the alluvial soils.

FIGURE II.3-D-10 RELATIONSHIP BETWEEN WATER STORAGE PROPERTIES AND MEDIAN GRAIN SIZE OF ALLUVIUM FROM LARGE VALLEYS²⁷

The amount of water retained in the capillaries at equilibrium is a function of 1) the physical and chemical nature of the porous media, 2) the position of the porous media in a gravitational field with respect to a free water surface, 3) temperature, 4) pressure, 5) relative humidity, and 6) direction of approach to equilibrium. Thus, theoretically, any porous medium at equilibrium, following drainage, has some capacity for water retention against vaporization and against gravitational attraction to a free water table.

Practically, measurement of the specific retention capacity of soils and sediments is difficult because under most conditions water movement in soil is exceedingly slow and equilibrium can be achieved only after extended periods of time. These equilibrium times are extremely long with respect to times available for human measurement.²⁸ Thus, reported specific retention capacities do not refer to equilibrium values, but to measured values at some nonequilibrium time when the rate of drainage becomes small.

II.3-D.2.2 The Unconfined Aquifer

This information on the hydrology and water quality of the unconfined aquifer beneath the Hanford Reservation is based on more than 20 years of study of this aquifer. The unconfined aquifer consists of both glaciofluvial sand and gravel deposits and the Ringold silts, clays, and gravels. These materials are very heterogeneous, and there are often greater lithologic differences within a given bed than there are between beds. The lateral boundaries of the unconfined aquifer consist of essentially impermeable areas where the basalt rises above the water table and hydraulic potential boundaries where a surface water body contacts the aquifer. The aquifer bottom is the basalt bedrock in some areas and silt/clay zones of the Ringold Formation in other areas. There are certain "erosional windows" where hydraulic communication between the unconfined and confined aquifers²⁹ is possible, but quantitative data on magnitudes and locations of interflow have not been obtained. It is clear, however, that the bottom of the unconfined aquifer is by no means a continuous surface. The present interpretation of the unconfined aquifer bottom used for simulation modeling purposes appears in Figure II.3-D-11. It can be compared to the contour maps of the Ringold Formation Surface and the basalt surface presented in Figures II.3-B-3 and II.3-B-4.

FIGURE II.3-D-11 HANFORD RESERVATION UNCONFINED AQUIFER BOTTOM MAP FOR SIMULATION MODEL

The impermeable boundaries are the Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge on the west and southwest sides of the Hanford Reservation (Map, Figure II.3-D-12). Gable Mountain and Gable Butte also impede the groundwater flow. Other small areas of basalt outcrop above the water table are also shown on this map. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids to Richland. The Columbia River forms a hydraulic potential boundary which is mainly a discharge boundary for the aquifer. However, the groundwater flow from 1 to 3 miles inland from the Columbia is affected by seasonal river stage fluctuations.^{30,31,32} This riverbank storage phenomenon has been reduced by increased control of the river flow by dams upstream of the Hanford Reservation. The volume of riverbank storage under the Hanford Reservation has been estimated to be from 2×10^9 cubic feet to 3.6×10^9 cubic feet for a typical year.^{30,33} Discharge of groundwater by evapotranspiration is considered negligible over the Hanford Reservation.³⁴

The major source of natural recharge is precipitation on Rattlesnake Hills, Yakima Ridge and Umtanum Ridge which outcrop to the south and west of the Reservation. The water percolates underground near the base of the highlands and moves into the Reservation area.³⁵ Flow from springs emerging on the flanks of these hills and ridges generally sinks into the ground within a mile of the sources.

The average flow of Cold Creek and other infiltration water in that section has been estimated at 72,000 cubic feet per day, of which perhaps half reaches the water table.³³ Estimated recharge from the Dry Creek and Rattlesnake Springs area average about 36,000 cubic feet per day over the year. Additional recharge may be caused by leakage upward from the confined aquifers along the western boundary of the Reservation. Recent irrigation developments in the Cold Creek Valley could substantially augment the natural recharge from this area.

FIGURE II.3-D-12 HANFORD RESERVATION WATER TABLE MAP - JULY 1972

The natural recharge due to precipitation over the lowlands of the Hanford Reservation is not measurable. A minor amount occurs where the water table is close to the land surface.³³ As described in the following Section II.3-E, the Hanford Reservation is in the rain shadow of the Cascade Mountains with average annual precipitation of 6.3 inches; the higher ridges receive about 12 inches per year. A maximum 24-hour precipitation of 1.91 inches and a maximum monthly precipitation of 3.08 inches have been recorded since 1912.³⁶ The primary return of rainfall to the atmosphere takes place almost immediately, before deep penetration can occur. Drying of the land surface by wind and low humidity air produces a gradient of water potential toward the surface. The evaporation potential during the summer months greatly exceeds total precipitation. Data on migration from natural precipitation in deep soils (below 30 feet) show movement rates of less than 1/2 inch per year at the one measurement site available.^{37,38,39}

The major artificial recharge of groundwater to the unconfined aquifer occurs near the 200 East and 200 West Areas. The large volumes of process water disposed to ponds at these sites have caused the formation of significant groundwater mounds (Figure II.3-D-12) in the water table since the start of Hanford operations. Other local groundwater mounds existed at each reactor site along the Columbia River. The mound at the still active 100-N Area is the only one of these remaining. A very minor recharge mound exists at the 300 Area.

Artificial recharge to or withdrawal from the unconfined aquifer is detailed in the water supply section. The points of significant withdrawals on site at the present time are at the FFTF site (400 Area) and at the Washington Nuclear Plant No. 2 reactor site under construction. These are temporary withdrawal points of large groundwater flows that affect the local groundwater flow patterns.

II.3-D.2.2.1 Hydraulic Characteristics

Characteristics of importance for the unconfined aquifer are the hydraulic conductivity, the storage coefficient and the effective porosity. The hydraulic conductivity relates the quantity of groundwater flow to the gradient of the hydraulic potential and the effective porosity gives the fraction of porous media volume that is available to transmit groundwater flow. The storage coefficient relates a change in the water table elevation to a change in the volume of water contained in the aquifer per unit of horizontal area. In the limit, the storage coefficient is equal to the effective porosity of the soil through which the water table moves. These parameters are functions of location in the aquifer and have highly heterogeneous distributions over the Hanford Reservation (Figure II.3-D-13).

In its most general form the hydraulic conductivity is a tensor accounting for anisotropic flow conditions. Under the assumption of isotropic flow this quantity reduces to a scalar. No studies to evaluate possible anisotropic flow conditions have been made on the Hanford Reservation. However, comparison of observed contamination plume movement with the direction of groundwater gradients indicates that anisotropy is not a significant flow parameter in the horizontal plane.

Qualitatively the hydraulic conductivity storage coefficient and effective porosity distributions are functions of the different geologic formations in the unconfined aquifer. The Ringold Formation is frequently divided into a lower clay zone, a middle conglomerate zone, and an upper silty zone, although marked lithologic changes occur both horizontally and vertically within these zones, precluding a precise definition. Incised in the Ringold Formation are ancestral Columbia River channels which are filled with more permeable glacio-fluvial sediments. Channels of highly permeable sediments have been identified extending eastward along the northern and southern flanks of

FIGURE II.3-D-13 HYDRAULIC CONDUCTIVITY DISTRIBUTION OF THE HANFORD UNCONFINED GROUNDWATER AQUIFER

Gable Mountain and southeastward from the 200 East Area to the Columbia River.³⁵ These permeable channels are reflected in the groundwater flow pattern of the region.

Quantitative measurements of the hydraulic conductivity have been made at locations over the Hanford Reservation using a variety of techniques.^{35,40} With these techniques, an average hydraulic conductivity over the saturated thickness of the unconfined aquifer was determined at each test site.

Field tests have included pump tests, specific capacity tests, tracer tests, cyclic fluctuations of the water level, and regional hydraulic gradient integrations. Excluding the clay zone, the values obtained for the Ringold Formation ranged between the moderate values of 6 to 200 feet per day. In sharp contrast are the very large hydraulic conductivities of glacio-fluviatile sediments--ranging from 1,200 to 12,000 feet per day. Higher values from specific capacity test data are to be regarded with caution due to the inherently low accuracy of this type of test. The Glacio-fluviatile sediments in general are about 100 times more permeable than the Ringold Formation. A summary of test results is given in Table II.3-D-12.^{35,40,41}

The effective porosity and storage coefficient are much more difficult to measure in the field. A properly designed pumping test can yield a value for the storage coefficient, but some type of tracer test or well logging procedure is necessary to obtain values of effective porosity over the saturated aquifer thickness. Values for the storage coefficient parameter ranging from 0.0008 to 0.2 have been estimated for the Hanford area from field tests but the quality of these values is poor. A typical range of storage coefficient values for unconsolidated sediments is 0.05 to 0.4. For the purposes of groundwater flow and radionuclide transport simulation modeling, the effective porosity over the saturated thickness of the aquifer is assumed to be equal to the storage coefficient.

TABLE II.3-D-12

AVERAGE FIELD HYDRAULIC CONDUCTIVITY (FT/DAY) MEASUREMENTS

<u>Tested</u>	<u>Pumping Tests</u>	<u>Specific Capacity Tests</u>	<u>Tracer Tests</u>	<u>Cyclic Fluctuations</u>	<u>Gradient Method</u>
Glacio- fluviatile	1,200-12,000	1,300-17,000	8,000	2,200-7,600	-
Glacio- fluviatile and Ringold	120-670	130-530	-	130-800	-
Ringold (includ- ing clays)	1-200	8-40	-	20-60	13-40

In conjunction with development of a computer model for simulating groundwater flow in the unconfined aquifer under the Hanford Reservation, the hydraulic conductivity distribution has been computed from a technique using the best of the available field measurements.^{42, 43} Figure II.3-D-13 shows the most recent version obtained for the hydraulic conductivity distribution. The heterogeneity of this aquifer parameter is obvious. Unfortunately, the techniques and necessary input data for the calculation of the corresponding storage coefficient distribution for the unconfined aquifer have not yet been developed. A typical storage coefficient of 0.10 has been assumed for the model simulation work. Effective porosity can be measured in the field using tracer or well-logging techniques, but only with difficulty. No field measurements have been made of this parameter at Hanford to date.

The present state of the unconfined groundwater aquifer is characterized by the contour map of the hydraulic potential (or the water table): The map for July 1972, which portrays conditions current at that time, is Figure II.3-D-12. The wells used in determining the water table surface are also shown. The accuracy of the contouring is directly related to the density of the measurement points and the local gradients.

The depth to the water table varies greatly from place to place, depending chiefly on local topography, and ranges from less than 1 to more than 300 feet below the land surface. Beneath most of the 200 Area disposal sites it averages about 250 feet. The current estimate of the maximum saturated thickness of the unconfined aquifer is about 230 feet.

From 1944 through 1972 the chemical processing plants have discharged to ground over 130 billion gallons (4×10^5 acre ft) of wastewater and cooling water. Such a large volume of water has had a profound effect on the regional water table. Figure II.3-D-14 shows the water table map before plant operations as interpreted from the earliest water level measurements. This hindcast was made in 1955. Water table maps have been prepared over the years. Reference 44 contains a representative selection for the 30 years of Hanford operation.

Two distinct groundwater mounds have been created from the large volume of process water disposal on the 200 Areas plateau. Their locations, elevations, and shapes at any given time have been functions of the recharge rates, both previous and current, and the local aquifer characteristics. The present pattern of groundwater movement is affected by the topography of the water table and the saddle or groundwater divide that lies to the north of 200 East Area.

The peak of the western mound is at about 480 feet above MSL, which represents a rise of about 85 feet from preoperation conditions. The eastern mound peak is at about 418 feet MSL, representing about a 28-ft rise. Historical well hydrographs (Figure II.3-D-15) show the development and fluctuation of these mounds with time at monitoring wells. Rising groundwater levels have been measured as far as 16 miles away from the recharge site (Figure II.3-D-15c).

The groundwater flow in the unconfined aquifer under the Hanford Reservation has been assumed to obey Darcy's Law with an isotropic but

FIGURE II.3-D-14 WATER TABLE MAP - JANUARY 1944 HINDCAST

FIGURE II.3-D-15 WELL HYDROGRAPHS

heterogeneous hydraulic conductivity. Furthermore, the flow has been observed to be primarily horizontal except in the immediate vicinity of recharge sites. This means that the groundwater velocity vector is perpendicular to the water table contour lines and points in the direction of higher to lower hydraulic potential (water-table elevation).⁴⁵ Therefore, for any groundwater potential map (water-table map), flow paths can be drawn illustrating the direction of groundwater movement at that specific time. These flow paths are also called instantaneous streamlines. A parcel of water will follow one of these streamlines only as long as the potential contours remain the same. A slowly changing water table configuration will cause that parcel of water to follow the slowly changing instantaneous streamline. Its resulting path from one point to another is called a pathline.

The groundwater potential contours change slowly enough that the instantaneous streamlines do not move significantly over a period of several years in most places. However, within 1 to 5 miles of the Columbia River the annual recharge and discharge of river bank storage occurs with a daily fluctuation in the immediate vicinity of the river's edge. Thus the streamlines are transient in this area. The other area of seasonal contour adjustment is the 200 East Area, where the groundwater saddle or divide is affected by the river bank storage phenomenon and periodic adjustments in recharge flow rates. The relative flatness of the water table in this area (a result of the rather high hydraulic conductivities of these sediments) makes it sensitive to changes in boundary and recharge conditions. Figure II.3-D-16 shows the July 1972 water table map with some instantaneous streamlines.

This figure illustrates groundwater movement from the areas of natural and artificial recharge down to the Columbia River to the East and North. The water table contours show the river bank recharge taking place during this month of high river flow. During the low water period from September to April the bank storage returns to the river.

**FIGURE II.3-D-16 WATER TABLE MAP WITH STREAMLINES
AND TRAVEL TIMES**

The previously mentioned groundwater saddle or divide under the 200 East Area makes both northward and southeastward transport from the 200 East and 200 West processing areas possible. Radioactive contaminants, upon reaching the water table, are convected in the direction of groundwater movement. Thus the infiltration site is of critical importance in evaluating the fate of any radioactive waste that enters the groundwater. Ultimately all groundwater in the unconfined aquifer beneath the 200 Areas plateau, except that which is lost to the atmosphere by evapotranspiration, flows into the Columbia River.

For historical completeness it should be noted that small groundwater mounds were formed under each of the reactor areas by leakage from the cooling system water lines and holding basins. Each of these mounds subsided within several months after shutdown of the nearby reactor. Only the small mound at 100-N Area remains (Figure II.3-D-16) from discharges to the 1301-N crib. A similar low and shifting groundwater mound was created and persists at the 300 Area from infiltration from the process waste ponds and sanitary leach trenches.

The velocity of groundwater flow through the aquifer is of major significance in evaluating the potential impact of these groundwater discharges. Again, assuming Darcian and essentially horizontal flow, groundwater velocities can be computed from the potential gradients and the aquifer properties (hydraulic conductivity and effective porosity).⁴⁶ For any given water table map, a set of flow vectors can be calculated that are valid for that particular configuration of the water table.

Groundwater mound formation has affected the flow rates as well as the flow directions in the unconfined aquifer. Some hydraulic gradients have been increased from 5 feet per mile to as much as 10 to 20 feet per mile,⁴⁷ increasing the local groundwater velocities several times over.

Tracer tests^{35, 48, 49} for field measurement of groundwater flow velocities have been conducted at four locations, as shown in Table II.3-D-13.

TABLE II.3-D-13

MEASURED GROUNDWATER FLOW VELOCITIES

<u>Well Number</u>	<u>Average Velocity ft/day</u>
699-62-43 D to -62-43 C	170
1301-N Crib to River Bank Spring	10.8
699-24-33 to -15-26	85
699-24-33 to -20-20	100

The actual velocity of a particle of convected tracer or radioactive waste may differ from these average velocities due to the multiplicity of microscale flow paths of different lengths through the porous media, sorption interactions of contaminants with the soils, chemical reactions, and radioactive decay.

II.3-D.2.2.2 Groundwater Quality

The chemical quality of the groundwater in the unconfined aquifer is monitored semiannually at seven locations in the 600 Area and one location in the 200 East Area. Sodium, calcium and sulfate ion concentrations and pH are measured. The 300 Area wells are analyzed for chromium and fluoride ions associated with fuel manufacturing operations. Finally, the nitrate ion, which is a waste product from the manufacturing and chemical separations operations, is monitored over the entire Hanford Reservation.

Values for the chemical ions other than nitrate are given in Table II.3-D-14. Included for comparison are values from early years of Hanford operation, assumed to represent antecedent conditions.

Semiannual maps of the nitrate ion concentration near the surface of the unconfined aquifer are published. References 50 and 51 contain the maps for 1972 showing the present status of the nitrate plumes. The map for the last 6 months of 1972 appears in Figure II.3-D-17.

The temperature of the groundwater in the unconfined aquifer has been measured on an intermittent basis. The most recent temperature logs of the wells were obtained in January 1974. Figure II.3-D-18 shows the temperature distribution at the surface of the unconfined aquifer in January 1974. The residual heat from the previous reactor operations is evident, as is the thermal plume emanating from the 200 Areas. Relatively warm surface water near the basalt outcrops indicates recharge to the unconfined aquifer from the lower confined zones. Several areas of temperature anomaly exist with values both above and below that expected for the local area. Vertical circulation within the various well bores probably accounts for many of these anomalies. Columbia River recharge effects on the temperature can be seen along the river boundary.

TABLE II.3-D-14

AVERAGE ION CONCENTRATIONS FOR ALL
WELLS MEASURED (mg/liter)

	<u>1972^{47,48}</u>	<u>1951-53³⁰</u>
Sodium	29	17
Calcium	35	35
Sulfate	62	31
pH	7.6	7.9
Chromium	0.0051	-
Fluoride	0.7	0.45

FIGURE II.3-D-17 AVERAGE NITRATE (NO_3^-) CONCENTRATIONS JULY-DECEMBER 1972 (Drinking Water Standard - 45 mg/l)

In general, the thermal plumes reflect the same patterns of groundwater movement as do the contamination plumes of Figures II.3-D-17, II.3-D-20 and II.3-D-21. However, movement of process water to the east from 200 West Area is more apparent from the thermal map than from the contamination map. The older gross beta maps do show more of this eastward-tending plume. Radioactive decay has caused most of the ruthenium, the prime beta emitter in this plume, to vanish.

It should be noted that reactor groundwater mounds contained water on the order of 70-90°C.⁵² The residual heat from these mounds can be seen in Figure II.3-D-18 under the northern part of the Reservation.

In an attempt to develop a practical tool for managing the groundwater basin, simulation techniques are being employed. Initially, simple graphical flow net analysis and analog models were tried. With the increase of capability and flexibility of the digital computer, the emphasis shifted in the early 60's to mathematical simulations. To date, models for describing groundwater and contaminant movement in the vadose zone and in the unconfined aquifer have been developed and tested against analytical solutions and limited field data. The testing provided confidence in the mathematical methods and the approach being used. Although the testing with field data has not been completed, the results continue to illustrate the complexity of groundwater system. Additional data and work are required to reduce the uncertainty in the model predictions.

FIGURE II.3-D-18 TEMPERATURE DISTRIBUTION AT THE WATER TABLE
(January 1974)

Thus, the models in their present form are useful in providing general insight in assessing the effects of potential accidents or waste management alternatives. Examples of model predictions are provided to give general insight into the nature of the groundwater flow system and the associated contaminant movement.

A program was initiated to develop the capability to predict transport of contaminants in Hanford sediments. The initial efforts were directed toward developing models to predict groundwater movement under steady conditions. These models were theoretically sound, but the output was less reliable than desired because the data input requirements could not be economically satisfied. Therefore, compromising assumptions were necessary in order to use the models. In addition, the models could not simulate transient conditions or waste transport, which are required to answer many of the pertinent problems associated with management of a groundwater basin.

In the later 60's, an intensive effort was initiated to develop a more refined model that would provide transient analysis of contaminant movement in support of waste management programs. Selection and development of the system of models was based on the economics of data input requirements, accuracy of results, and the practicality of application. In addition to the models, a man-machine interactive computer system was developed to provide an efficient means for utilizing the models and analyzing the results. The program goal was to produce a management and engineering tool for use in analysis, decisions and policy formulations relative to management of groundwater systems.

Radioactive liquid waste discharged to the ground percolates down through the sediments where most of the radionuclides are sorbed to the water table, then moves with the groundwater to the Columbia River which is the discharge boundary for the Hanford Reservation unconfined aquifer. Because of the combination of arid climate, permeable surficial material, and deep water table at Hanford, most of the radioactivity of the

liquid waste is sorbed on the sediments as the waste liquid (water) percolates down to the water table. Discharge facilities include monitoring of the groundwater adjacent to the disposal sites.

Some disposal of radioactive waste at Hanford has been made on the basis of specific retention, allowing only that liquid to be disposed of which would raise the moisture to a pre-determined water content percentage in an assumed underlying column of soil.⁵³ These soil columns were conservatively calculated by assuming that no lateral spreading would take place. Any layering or transition zones from coarse to fine or fine to coarse soils would cause significant lateral spreading of the moisture front, further reducing the moisture content and slowing the moisture movement.

Since specific retention disposal depends on limiting the total amount of water that percolates down to the water table, the fate of precipitation on the Hanford Reservation has become the subject of ongoing research. At the Hanford Meteorological Station, precipitation averages only 6.25 inches per year. The three months, November through January, contribute 42%, while the three months of July through September contribute less than 10%. Pan evaporation studies at nearby Prosser, Othello and Connell indicate that water loss from an open pan was greater than 50 inches during the 1971 growing season. Therefore, a large deficit in soil moisture exists during the period May through October each year. This tends to remove substantial amounts of water from the upper part of the soil.

A tritium tracer, believed to be from natural precipitation which has occurred since nuclear weapons testing began, can be identified in the soil moisture to a depth less than twenty feet on the 200 Area Plateau.⁵⁴ In related studies^{37,38,39} it was shown that the annual cyclic variation of temperature and water potential can be seen to die out at a depth of about 15 to 20 feet below the land surface. These observations indicate that precipitation does not penetrate more than 15 to 20 feet below the land surface and that there is little or no recharging of the water

table from surface precipitation. Thus, the potential for leaching of sorbed radionuclides from beneath cribs and trenches down to the water table is nil under present climate conditions.

100-N Area

The disposal of radioactive liquid waste to the 1301-N crib and trench is the source of groundwater contamination and resulting transport to the Columbia River. The normal flow rate is 0.33×10^6 ft³/day with the average radionuclide concentrations shown in Table II.3-D-15⁵⁶ and the representative chemical composition shown in Table II.3-D-16.

The discharged liquid waste seeps down to the water table, about 55 feet below the crib, and then moves toward the Columbia River; the minimum horizontal crib-to-river distance is about 800 feet. The most recent studies show minimum field-measured travel times from the crib to the riverbank springs to be 2 to 4 days.⁵⁷ An estimated 20% of the flow from this crib reaches the river along the shortest travel paths while the remainder flows to the river along flowpaths having estimated travel times of up to 20 years.

Computing the ratios of crib input to riverbank spring output concentrations gives values of 0.002 to 0.034 for those nuclides for which data were available. At the riverbank springs, ¹³¹I and ⁹⁰Sr were present in 1972 at average concentrations which exceed the Concentration Guides⁵⁸ for release of water soluble radionuclide compounds into the uncontrolled environment; the Concentration Guides are exceeded by factors of 1.15 for ⁹⁰Sr and 2 for ¹³¹I. In 1973, only ¹³¹I was above the Concentration Guide by a factor of 4.6. Dilution in the river quickly reduce these concentrations to well below the applicable Concentration Guides. All other radionuclide concentrations at the riverbank springs are below their respective Concentration Guides.

TABLE II.3-D-15
1301-N CRIB INPUT RADIONUCLIDE DATA AND
RIVERBANK SPRINGS DATA, 1973

Radio- nuclide	To the 1301-N Crib			Seepage from Crib to River via Springs		
	Average Concentration pCi/l	Peak Concentration pCi/l	Total Released Ci/yr	Average Concentration pCi/l	Peak Concentration pCi/l	Total Released Ci/yr
^3H	1.5×10^5	1.3×10^6	480	ND	1.7×10^6	480
^{51}Cr	5.0×10^4	4.4×10^5	160	4.0×10^2	3.6×10^3	0.5
^{54}Mn	1.6×10^5	1.1×10^6	500	7.0×10^1	2.4×10^3	0.1
^{58}Co	8.7×10^3	7.6×10^4	23	3.0×10^1	1.1×10^3	0.005
^{59}Fe	2.4×10^5	1.9×10^6	650	4.6×10^1	4.8×10^3	0.08
^{60}Co	1.1×10^5	1.4×10^6	320	2.9×10^2	7.3×10^3	0.5
^{90}Sr	4.9×10^3	1.5×10^4	16	1.7×10^2	8.4×10^2	0.3
$^{95}\text{ZrNb}$	9.6×10^4	5.9×10^5	410	3.2×10^1	2.3×10^3	0.04
^{99}Mo	1.6×10^5	1.8×10^6	1260	4.0×10^2	1.0×10^4	0.3
^{103}Ru	2.4×10^4	7.3×10^5	80	ND	ND	ND
^{106}Ru	5.6×10^4	8.0×10^5	190	ND	ND	ND
^{131}I	8.3×10^4	6.6×10^5	390	1.4×10^3	7.0×10^3	2
^{133}Xe	1.0×10^5	5.9×10^5	520	9.8×10^2	5.6×10^3	0.7
^{134}Cs	1.4×10^4	5.7×10^4	23	ND	ND	ND
^{137}Cs	1.5×10^4	4.2×10^4	46	2.5×10^1	1.9×10^2	0.05
$^{140}\text{BaLa}$	1.2×10^5	1.1×10^6	460	1.3×10^2	2.0×10^3	0.2

ND - No Data

The disposal of the nonradioactive chemicals is insignificant for all but chromium, which can be detected in the river downstream. Since 1972 the Cr discharges have been eliminated by recirculation of the stream containing the chromium. As shown in Table II.3-D-16, the concentrations of the other chemicals are near the ambient concentrations on the river.

TABLE II.3-D-16

CHEMICAL CONCENTRATIONS AT 100-N AREA, AUGUST 1972

	<u>Riverbank Springs (mg/l)</u>	<u>Ambient River Concentration (mg/l)</u>
Sulfate	5.5	4.5
Calcium	24.5	17.
Chromium	20.	0.1
Nitrate	2.7	0.1
Total Solids	123.	81.
Aluminum	50.	80.
Iron	25.	75.
Magnesium	3.	3.
Ammonia	<0.1	<0.1
Nitrite	<0.002	<0.002
Strontium	0.080	0.120

200 Area

There are two major ways that waste management operations in the 200 Areas affect the quality of the groundwater under the Hanford Reservation. One is the disposal of liquid waste to cribs and trenches. This is the source of the radionuclide inventory on the soil and in the groundwater described in Appendixes II.1-B, C and E. The other is the disposal of large volumes of process cooling water which has had a significant effect on the elevation of the groundwater table of the unconfined

aquifer. This, in turn, has given flowpaths and flowrates of the groundwater that differ significantly from the pre-Hanford Operations configurations. Figure II.3-D-19 shows flow paths and travel time estimates computed for the major cribs and trenches in the 200 Areas for July 1972 water table conditions. Table II.3-D-17 presents these values. These values were computed using the groundwater flow model system, discussed earlier, at its present state of development with the data available through March 1974. These groundwater travel times indicate the convective transport rates without allowance for sorption, chemical reaction, radioactive decay, or dispersion effects. The ranges of values reflect the uncertainties in the input data. In addition, slightly different starting points from around a given disposal site may produce different travel times due to the extreme heterogeneity of the hydraulic conductivity distribution. These travel times shown in Figure II.3-D-19 and Table II.3-D-17 do not include the time required for groundwater seepage from the disposal facility to the water table. These travel times are the groundwater flow times from beneath the waste disposal facilities to the Columbia River.

The sorbed contaminants, most fission products and all transuranic elements, travel at very much longer travel time than the groundwater flow times and many such contaminants will decay before they move more than a few thousand feet from the disposal site. Most of the sorbed contaminants will remain on the soil columns and not reach the water table at all.

The radiological status of the groundwater near the surface of the unconfined aquifer is monitored regularly⁵⁹ and reported semi-annually.^{50,51} The gross beta (calculated as ^{106}Ru) plumes and the tritium plumes are mapped in Figures II.3-D-20 and II.3-D-21 for the latter half of 1972.

TABLE II.3-D-17

TRAVEL TIME RANGES FOR GROUNDWATER UNDER SELECTED LIQUID
WASTE DISPOSAL FACILITIES (JULY 1972 WATER TABLE)

Facility Number 200 East Area (Cribs Unless Noted)	Travel Time Range(a) to Columbia River (Years)	Facility Number 200 West Area (Cribs Unless Noted)	Travel Time to Columbia River (Years)	Facility Number	Travel Time to Columbia River (Years)
216-A-6	18-32	216-T-34	70-700	216-U-3	80-900
-A-30		-T-35		-U-13	120-500
-A-1	19-32	-T-1	60-600	241-U Tanks	100-1000
-A-7		-T-8		216-U-1, 2	80-350
-A-8		-T-9		-U-15	70-600
-A-24		-T-10		-U-8	60-200
-A-2	17-30	-T-11		-U-12	
-A-4		-T 20 French Drain		216-S-5, 6	60-250
-A-5		-T-30		-S-10, 11	
-A-21		-T-33		-S-19	70-150
-A-27		216-T-4 Pond	90-900	-S-1, 2	70-150
-A-31		-T-12	80-900	-S-4	
-A-10	18-200	-T-14 to 17		-S-7 to 9	
-A-36B	18-65	-T-5	100-1100	-S-12, 13	
-A-9	18-32	-T-7		-S-15	
-A-40		-T-13		-S-20, 21	
241-A Tanks	18-35	-T-36		-S-23	
-AX Tanks		241-T Tanks	90-1100	-S-25	
-AY Tanks		-TX Tanks		241-S Tanks	65-150
-AZ Tanks		-TY Tanks		-SX Tanks	
-C Tanks		-T-18	80-850	216-U-4 to 7	60-200
216-BC Cribs	60-150	-T-26 to 28		-U-9, 10	
-B-12	15-60	-T-31 French Drain			
-B-62		-T-19	90-950		
-B-55	40-100	-T-21 to 24	120-1300		
-B-10A, B		-T-25			
-B-35 to 50	15-60	216-Z-1, 2	125-1600		
-B-57		-Z-3			
-B-61		-Z-12 to 15			
241-B Tanks	15-60	-Z-8, 9	110-1200		
-BX Tanks		-Z-11			
-BY Tanks		-Z-19			

(a) Computed with groundwater flow model at its present state of development and aquifer property data as of March 1974.

FIGURE II.3-D-20 AVERAGE GROSS BETA (^{106}Ru) CONCENTRATIONS
JULY-DECEMBER 1972 (Concentration Guide
10 pCi/ml)

FIGURE II.3-D-21 AVERAGE TRITIUM (^3H) CONCENTRATIONS
JULY-DECEMBER 1972 (Concentration
Guide 3000 pCi/ml)

300 Area

The disposals of liquid waste to ground in the 300 Area are in the form of discharges to the 300 North Process Pond, the sewage leach trench, the 384 ash pits, the 331 leach trench, (which was taken out of service at the end of 1973) and the 315 filter plant. However, only the 300 North Process pond and the sewage leach trench have significant flow rates which average $0.4 \times 10^6 \text{ ft}^3/\text{day}$ and $0.064 \times 10^6 \text{ ft}^3/\text{day}$, respectively.

With the exceptions of fluoride and nitrate ions, the input concentrations to the North Process Pond and the 331 leach trench are below the Concentration Guides for Drinking Water Limits for release to uncontrolled areas. The average fluoride and nitrate ion concentrations are 35 to 40% above their respective drinking water limits.

The minimum time required for seepage from the North Process pond to travel the minimum distance (about 250 feet) to the Columbia has been estimated at about 3 days. In view of the local groundwater potential surface configuration, about 70% of the seepage from this pond is assumed to move directly east to the river. Groundwater monitoring wells near the North Process Pond and the sanitary leach trenches are analyzed regularly for gross alpha and gross beta activity and nitrate, chromium, and fluoride ions concentration. Average concentrations shown by Well 399-1-1 (between the North Pond and the Columbia River) were factors of 2 to 4 below the input to the pond.⁵¹ Those from Well 399-1-3 (between the pond and the trench) were factors of 1.4 to 2 lower, except fluoride ion (which was the same), and nitrate ion, (which was a factor of 1.3 higher).

Riverbank seepage springs located about 1 mile north of the 300 Area and directly east of the South Process Pond or about 100 feet downstream of the sanitary leach trenches are sampled regularly. Historically, the South Process Pond has contributed to the flow of these springs. Except for a few days in 1972, the South Pond has been out of service since 1968.

These springs are not on the shortest flow path from the North Process Pond to the river; however, they are near to the shortest flow path from the sanitary leach trenches. Travel times of 6 to 7 days from the North Process Pond to the riverbank seepage springs were observed using the chromium ion as a tracer.⁶⁰ These springs also become submerged at higher river stages on a daily to weekly frequency; thus, dilution by river recharge greatly affects the discharge concentrations observed at this sampling location. For 1972, the yearly average nitrate ion concentrations for the North Process Pond and the riverbank spring were equal at 61 mg/liter. Complete chemical analyses of the spring samples were made through the first quarter of 1972. The first quarter averages are presented in Table II.3-D-18 along with corresponding groundwater concentrations. On this quarterly basis, significant concentration reductions for chloride ion, copper ion, and uranium appear in the groundwater reaching the riverbank spring downstream from the Process Pond. The fluoride and nitrates ion concentrations were reduced to below drinking water limits; a smaller concentration reduction is observed for sulfate and chromium ions. For comparison, samples of riverbank springs upstream of the 300 Area show a first quarter 1972 nitrate ion concentration of 0.55 mg/liter and fluoride ion concentration of 0.15 mg/liter.

The sulfate concentration is above the ambient river concentration shown in Table II.3-D-18; no other chemicals were measured at these springs. Dilution by riverbank recharge is assumed to be the major cause of the concentration reductions. Very little of the uranium is being retained by the soil.⁶⁰ Therefore, the 300 Area North Process Pond appears to be releasing nitrate ion to the Columbia River at an average annual concentration above the drinking water limit. However, dilution by riverbank recharge tends to reduce the concentration at the surfaces of seepage into the Columbia River. The potential exists that the groundwater entering the river may periodically exceed the drinking water limit for fluoride ion.

TABLE II.3-D-18

AVERAGE CHEMICAL CONCENTRATIONS FOR THE FIRST QUARTER 1972
(mg/l)

Element	North Pond Input	Riverbank Springs	Springs Range		Well 399-1-1	Well 399-1-3
			May 1971 Through	March 1972		
Cl ⁻	11	3.9	1.1	16		
Cu	3.4	<0.05	0.006	0.08		
Fe	0.14	0.016	0.002	0.15		
F ⁻	3.3	0.58	<0.05	1.8	0.66	1.9
NO ₃ ⁻	68	20	1.2	212	37	130
SO ₄ ⁻⁻	28	21	13	40		
Cr ⁺⁶	0.004	0.003	0.001	0.023		
pH	7.4	8.0	7.4	8.2		
U	0.047 pCi/ml	0.019 pCi/ml	0.016 pCi/ml	0.20 pCi/ml		

II.3-D-61

Measurements of the bacterial and biological water quality parameters are routinely taken from the 300 Area sanitary waste leaching trench, which is located about 400 feet from the Columbia River shoreline as well as from the seepage springs at the riverbank; Table II.3-D-19 shows the sample results for 1972. The coliform counts at the riverbank springs are within the Environmental Protection Agency standards for a public drinking water supply. Similarly, the BOD levels are well within the Environmental Protection Agency's discharge criteria for publicly-owned secondary treatment plants for a 30-day average. In view of the Columbia River water quality data presented in Table II.3-D-19, the 300 Area sanitary waste leach trench appears to have a negligible impact on the Columbia River.

In 1974, the chemical waste from reactor fuels fabrication will be collected and transported to the 100-H Area for evaporation in a concrete basin. This operational change could yield about an 80% reduction in the concentration of the following chemicals now going to the North Process Pond: chromium, copper, fluoride ion, nitrate ion, and uranium. This will bring all the chemical and radionuclide concentrations in the pond input stream to well below drinking water limits or Concentration Guides.

New trenches, which will be located about 1200 feet from the Columbia River, are planned to replace the North and South Process Ponds. The primary advantage will be to increase the minimum travel time of groundwater flow to the river, thus affording a greater chance for dilution and radioactive decay of the waste material entering this disposal facility. In view of the operational change previously described, only an accident situation would lead to significant concentrations of contaminants entering the new wastewater trenches.

TABLE II.3-D-19

BIOLOGICAL MEASUREMENTS OF SAMPLES COLLECTED FROM THE 300 AREA
LEACHING TRENCH AND ITS ASSOCIATED RIVER SHORELINE SEEPAGE AREA - 1972

300 Leaching Trench			
Date	Coliform N/100 ml	Enterococci N/100 ml	BOD mg/l
1/11	330,000	3,300	7.0
2/8	190,000	5,000	6.7
3/14	1,280,000	6,500	5.9
4/4	720,000	29,000	2.6
6/20	640,000	7,500	4.2
7/11	1,320,000	12,000	4.0
8/8	500,000	23,000	4.6
9/5	3,000,000	17,000	3.6
10/3	850,000	33,500	2.0
11/14	320,000	11,000	1.9
12/12	264,000	8,000	1.4
Average	855,818	14,164	4.0

River Shoreline Seepage Area			
Date	Coliform N/100 ml	Enterococci N/100 ml	BOD mg/l
1/11	23.	16.	3.4
2/8	2.	5.	1.2
3/14	7.	4.	3.1
4/4	6.	10.	3.4
6/20	105.	20.	4.0
7/11	250.	28.	4.0
8/8	60.	17.	2.8
8/22	130.	25.	1.2
9/5	30.	13.	0.45
9/19	98.	55.	1.9
10/3	25.	18.	1.6
10/24	115.	148.	1.6
11/14	6.	120.	1.4
12/12	8.	7.	1.8
Average	62.	35.	2.3

EPA Treatment
Plant Criteria

30.

(Federal Water Quality Standards for Public Water Supply)

Desirable <100.

Permissible <10000.

400 Area (FFTF)

The only waste discharge to ground at the Fast Flux Test Facility (FFTF) is a combination sanitary sewage and construction wastewater stream with an average rate of 2700 ft³/day. This should increase to about 4000 ft³/day in 1975 when the facility begins operation and the Radiation and Repair Engineering Facilities are constructed and operational. This discharge has an insignificant effect on the groundwater flow patterns and water quality. Under operating conditions, this discharge will be monitored to ensure that it is free of radioactivity.

600 Area and Other 100 Areas

Sanitary sewage leach trenches and tile fields are in operation at 100-B/C, 100-K, 100-D Areas with the maximum average discharge rate being 1300 ft³/day (K Area). Various other facilities in the 600 Area, including fire stations, road maintenance building, BNW Atmospheric Physics, etc., also have sanitary sewage discharges to leach trenches, with a maximum average rate of 400 ft³/day (Atmospheric Physics). The impact of these minor sources is negligible.

Sanitary waste in plant areas is generally treated by means of a septic tank and tile leach lines or leach trenches for disposal of the water. The volumes of these disposals are relatively small and penetration rate to the water table is generally measured in years. In the shallow soils, around lines buried 18 inches to 36 inches deep, aerobic bacterial action prevails with high biological purification. During summer months, large quantities of the disposal will be lost to the atmosphere by evaporation.

II.3-D.2.3 The Confined Aquifers

From the limited amount of research that has been done to date, it appears that there are a number of confined aquifers underneath the Hanford Reservation. Relatively impermeable confining beds commonly include the individual basalt flows, where they are continuous and greater than about 50 feet thick, and the silts and clays of the lower part of the Ringold Formation.²⁹ Within the basalt sequence groundwater is transmitted primarily in the interflow zones, either in sedimentary beds or in the scoria and breccia zones forming the tops and bottoms of the flows.^{61,62} Some of the basalt flows in the Pasco Basin have been eroded, particularly in the anticlinal ridges. In some locations the basalts are highly jointed and contain breccia, pillow and palagonite complexes through which groundwater can move. Consequently, hydraulic potential differences between water bearing zones in the upper part of the basalt sequence are small over hundreds of feet of depth. The lowermost Ringold Formation silts and clays are of variable thickness. Distinct hydraulic potential differences have been observed below the silts and clays and the unconfined aquifer.

About 90 wells on the Hanford Reservation have been drilled to basalt. Thus data on the confined aquifers in the basalt flows are scarce and much more data must be gathered to fully characterize the confined aquifers.

The recharge area that has been identified is from the Yakima River at Horn Rapids. The piezometric map in Figure II.3-D-22 suggests recharge from the upper Cold Creek Valley with flow toward a potential trough under the Columbia River. The Columbia Basin Irrigation Project to the northeast and east, and the Columbia River behind Priest Rapids and Wanapum dams to the northwest are recharge areas where basalt is exposed and where it is covered by unconsolidated deposits which are saturated perennially. There is a site of possible minor recharge adjacent to Gable Butte-Gable Mountain anticline near the center of the Reservation.

FIGURE II.3-D-22 HYDRAULIC POTENTIAL DISTRIBUTION OF THE UPPERMOST CONFINED AQUIFER - 1970

The piezometric or hydraulic potential map for the confined aquifer in Figure II.3-D-22 was based on measurements made in 1970. In general the hydraulic potential observed in the confined zones above the basalt is greater than in the overlying unconfined aquifer. The main exception is in the vicinity of the 200 Area recharge mounds which have raised the potential in the unconfined aquifer. At ARH-DC-1 there is a decrease in hydraulic potential at a depth of about 3600 feet.⁶² The lowest observed potential was 365 feet at a depth of 4000 feet. This head is higher than the normal 340-foot Lake Wallula pool elevation. The decrease in potential with depth indicated that there is a downward flow to the water bearing zone at 4000 feet. Groundwater flow in this aquifer is also to the southeast with possible discharge into the Columbia River somewhere below Lake Wallula. However, the flow rates are expected to be quite small due to the low transmissivity range of this water bearing zone. Data from the area of the Horse Heaven Hills indicates that groundwater below the 3600-foot depth must discharge to the Columbia River north of these hills. Groundwater in the lower confined aquifers does not appear to cross the major anticlinal divides that define the Pasco Basin.⁶²

Seven wells that penetrate the aquifer confined by the Ringold silts and clays showed a 1 to 2-foot head rise during the 1963-1964 period. All of these wells are adjacent to the Columbia River. Wells further from the river showed no significant rise in water level. Water level data from the U.S. Bureau of Reclamation show that water levels in the unconfined aquifer in Franklin County were rising rapidly, reflecting an increase in potential at recharge sites to the northeast of the Hanford Reservation. These data strongly suggest that the hydraulic potential rise was caused by recharge from the Columbia Basin Irrigation Project.²⁹ Water level trends in most of these wells continue upward, as shown in the hydrographs of Figures II.3-D-23 and II.3-D-24.

FIGURE II.3-D-23 WELL HYDROGRAPHS FOR THE CONFINED AQUIFER

In 1970 and 1971, 23 wells that penetrate the uppermost confined aquifer were pump tested and transmissivity values calculated. Valid data were obtained from 17 of the tests and are presented in Table II.3-D-20. Values of transmissivity range from 2.3 square feet per day to 2400 square feet per day. Corresponding hydraulic conductivities based on estimated aquifer thicknesses are less than 0.1 foot per day to about 15 feet per day.

FIGURE II.3-D-24 WELL HYDROGRAPHS FOR THE CONFINED AQUIFER

TABLE II.3-D-20

CONFINED AQUIFER PUMP TEST RESULTS

<u>Well Number</u>	<u>Transmissivity (ft²/day)</u>	<u>Hydraulic Conductivity (ft/day)</u>
199-B3-2	3.5	0.1
199-H4-2	2.3	<0.1
299-W11-2	100	0.1
399-5-2	6	<0.1
699-S18-E2	13	1.3
699-S11-E12	35	0.9
699-S6-E4-C	1500-2400	9-15
699-S1-7-B	1600-2200	10-14
699-10-E12	190-210	19-21
699-14-E6	470-760	7-11
699-14-38	400	130
699-20-E12	350	9
699-20-E5	430	1.2
699-24-1	87	0.9
699-28-40	4.8	0.3
699-34-88	24	0.1
699-84-35	4.3	0.4

Some data on the aquifer properties of the lower confined aquifers are available from the deep drilling project, Well ARH-DC-1.⁶² This well was drilled to a depth of 5661 feet and is located near Well 699-48-49 in Figure II.3-D-7. At this well the basalt at depths from 362 to 1200 feet deep had a transmissivity of about 695 square feet per day. A sedimentary unit which occurs in this zone from 830 to 936 feet has a transmissivity of about 355 square feet per day. A dense basalt zone from 960 to 1090 feet has a transmissivity of 0.2 square feet per day. There is one significant water bearing zone 10 feet thick occurring at 3230 feet with a transmissivity of about 68 square feet per day.

Corresponding hydraulic conductivities were computed by factoring out the aquifer thicknesses from the transmissivities. Values from 0.0016 to 0.029 feet per day were calculated. Five significant basalt flow contacts had high hydraulic conductivities on the order of 8.7 feet per day. The five zones are located at depths of 1200, 2050, 2600, 3200, and 4000 feet at Well ARH-DC-1.

Water bearing sedimentary interbeds are centered at 500, 650, and 900 feet in range in thickness from 25 to 100 feet. The bed at 900 feet, which is about 100 feet thick, consists of well sorted medium sand of moderate permeability. Its hydraulic conductivity is about 3.5 feet per day, making it the most productive aquifer penetrated by this well.

Only one measurement of the storage coefficient has been made in the confined aquifer above the basalt. The storage coefficient is the change in volume of water per unit horizontal area caused by a unit change in the potential head. For the confined aquifer, it reflects the compressibility of the water and the elastic properties of the porous matrix. The results at Well 699-14-E6 gave values ranging from 0.0005 to 0.0007 which are comparable to those measured in the Ringold Formation.²⁹

The water quality and radiological status of the groundwater in the confined aquifers have been measured with less detail and regularity than for the unconfined aquifer. The most extensive measurements have been for the tritium content.

Table II.3-D-21 gives the results of the most recent (1968-1970) tritium measurements and the volume pumped before sampling. The differing well structures make a representative sampling of confined aquifer water difficult. Most values are below the routine tritium detection limit for water samples from the unconfined aquifer (500-700 pCi/liter).

Table II.3-D-22⁶² gives the results of chemical analyses from wells that tap basalt aquifers under the Hanford Reservation. There is a decreasing trend with depth for calcium, magnesium, and sulfate and an increasing trend with depth for sodium and chloride, as observed in ARH-DC-1.

In conclusion, a major barrier to investigation of the confined aquifer under the Hanford Reservation is a lack of suitable well structures that are capable of yielding reliable hydraulic potential measurements and representative confined groundwater samples.

II.3-D.2.4 Aquifers Across the Columbia River

Very little data are available on the groundwater aquifers to the north and northeast of the Columbia River. This area has been leased to the State of Washington and the U.S. Bureau of Sport Fisheries and Wildlife and is no longer under direct jurisdiction of the AEC. There were about 35 wells at one time in this Wahluke Slope-White Bluffs area, of which 20 remain.⁶³ The confined basalt aquifers underlie this area, as under the present Hanford Reservation. The unconfined aquifer exists only under the parts of the Wahluke Slope between the higher bluffs and the Columbia River. The Ringold Formation and glaciofluvial sediments form this aquifer.

The Saddle Mountains form the northern boundary to the confined aquifers and are a potential recharge site due to basalt flow

TABLE II.3-D-21

TRITIUM IN HANFORD WELLS TAPPING THE CONFINED AQUIFER

<u>Well Number</u>	<u>Samples Results^(a) (pCi tritium/liter)</u>	<u>Volume Pumped Prior to Sampling (gallons)</u>
199-H4-2	600 ± 70 730	NM 95,000
299-W11-2-P	3,900 + 320 - 640	500
699-S11-E12A	610 ± 29	Flowing Well
699-2-33-P	<500	NM
699-10-E12-P	<500 1,500 ± 56 <500 <500	NM 1,600 700 700
699-14-E6-P	550 + 77 610 - 35	2,000 NM
699-14-38-P	640	NM
699-15-15A	540	NM
699-20-E12-P	<500	NM
699-20-E5-P	<500 <500	NM NM
699-24-1-P	760 <500	NM NM

(a) The Concentration Guide for public drinking water, as given in the AEC Manual Chapter 0524 Appendix, Table 2, is 3×10^6 picocuries per liter.

NM - Not Measured.

Detection limit 500 to 700 pCi/liter

outcropping. The Columbia River behind Priest Rapids and Wanapum Dams and the Columbia Basin Irrigation Project are other probably recharge areas. There is also recharge from surface runoff in coulees and ditches.⁶² The Columbia River forms the primary discharge boundary for the unconfined aquifer. Seasonal riverbank storage and discharge also takes place as it does on the Reservation side of the river.

The remaining sources of recharge to the unconfined aquifer are the irrigation wasteways and ponds that have been constructed since this land was released from AEC control. There are no observation wells monitored by the AEC to record the recharge effects of these ponds.

The water table elevations in the unconfined aquifer near the Columbia River range from 370 to 405 feet MSL at the four available observation wells. The hydraulic potentials in the wells that penetrate the confined aquifers average about 50 feet higher. These wells are perforated in several basalt aquifers, precluding representative potential measurements.⁵⁵

The limited amount of information available indicates that the groundwater in the unconfined aquifer across the Columbia River moves toward the river, discharging into it. There is some evidence to indicate that groundwater in the confined aquifer may be flowing under the present riverbed to a trough of low potential. This flow, mixed with confined aquifer groundwater from under the Hanford Reservation, then moves downstream (with some discharge into the Columbia River) and up through the unconfined aquifer, controlled by the hydraulic conductivity of the confining beds.

Water quality data for the groundwater across the Columbia River consist only of routine nitrate measurements for the confined aquifers, and some data given in Table II.3-D-22. No nitrate concentrations above the routine detection limit (0.5 mg/liter) have been observed. Analyses for gross alpha, gross beta, and tritium have been made. The

TABLE II.3-D-22

CHEMICAL ANALYSES OF GROUNDWATER SAMPLES FROM WELLS DRAWING
WATER PRINCIPALLY FROM BASALT UNDER THE HANFORD RESERVATION
(Physical Data)

NUMBER	ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	DEPTH OF CONTINUOUS UNPERFORATED CASING (FEET)	STATIC WATER LEVEL	
				DEPTH (FEET)	DATE
11/24-14N1	2860	407	----	220	1970
11/26-34R1 699-S18-51	1212	1000	739	802	1958
12/23-28Q1 ^(a)	2200	2	----	---	----
12/24-20N1	1060	1200	400	+92	1924
12/28-24N1	430	755	----	19	----
13/24-25E1 699-52-111	924	777	625	+36	11/28/51
13/25-30G1 699-53-103	836	1110	----	+172	11/28/51
13/26-35H1 ^(b) ARH-DC-1	572	5661	964	166	5/8/69
14/25-1D1 699-107-79	660	938	891	183	6/9/58
15/26-28Q1 699-114-60	770	892	860	317	9/1/53

(a) A DEVELOPED SPRING

(b) WELL ARH-DC-1. SAMPLE TAKEN FROM THE DEPTH INTERVAL OF 540-620 FEET DURING CONSTRUCTION OF THE WELL. WATER LEVEL GIVEN IS THAT FOR THE DEPTH INTERVAL OF 540-620 FEET MEASURED DURING CONSTRUCTION OF THE WELL.

TABLE II.3-D-22 (Continued)

HANFORD WELL NUMBER	DATE COLLECTED	TEMPERATURE (°C)	MILLIGRAMS PER LITER																				DISSOLVED SOLIDS										pH	COLOR
			SILICA (SiO ₂)	ALUMINUM (Al)	IRON (Fe)	MANGANESE (Mn)	CHROMIUM (Cr (TOTAL))	NICKEL (Ni)	COPPER (Cu)	LEAD (Pb)	ZINC (Zn)	CALCIUM (Ca)	MAGNESIUM (Mg)	STRONTIUM (Sr)	SODIUM (Na)	POTASSIUM (K)	LITHIUM (Li)	BICARBONATE (HCO ₃)	CARBONATE (CO ₃)	SULFATE (SO ₄)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO ₃)	ORTHOPHOSPHATE (PO ₄)	BORON (B)	CALCULATED	RESIDUE ON EVAPORATION AT 180°C	HARDNESS						
																												AS CaCO ₃	NONCARBONATE	SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C)				
11/24-14N1	11/13/70	15	45	0.00	0.03	0.02	0.03	0.05	0.05	0.1	0.20	18	8.3	0.05	12	4.5	0.02	109	0	15	4.2	0.4	0.0	0.09	0.02	161	---	79	0	219	7.5	0		
11/26-34R1 699-S18-51	11/19/70	24	75	0.35	0.05	0.02	0.03	----	0.05	0.1	0.01	1.0	0.0	0.05	122	15	0.02	154	15	0.0	81	8.5	0.2	0.01	0.49	400	408	3	0	597	8.8	0		
12/23-28Q1 ^(a)	9/21/70	15.4	36	0.02	0.02	0.02	0.03	----	----	----	0.8	18	7.9	----	9.0	1.8	----	93	0	11	5.1	0.4	4.1	0.18	0.06	139	146	78	2	201	7.2	0		
12/24-20N1	9/11/70	26	56	0.00	0.08	0.05	0.03	----	----	----	----	18	11	----	21	7.7	----	170	0	0.2	3.8	0.6	0.0	0.02	0.02	202	204	90	0	276	8.0	0		
12/28-24N1	9/15/70	19	56	0.14	0.05	0.10	0.03	----	----	----	----	3.7	0.7	----	94	11	----	170	8	29	29	4.2	0.0	0.13	0.09	324	329	12	0	468	8.7	0		
13/24-25E1 699-52-111	8/27/70	24.2	56	0.09	0.09	0.10	0.03	----	----	----	----	18	11	----	26	7.3	----	180	0	0.2	4.4	0.7	0.0	0.03	0.09	213	213	90	0	295	8.0	0		
13/25-30G1 699-53-103	8/27/70	26.9	56	0.08	0.07	0.05	0.03	----	----	----	----	16	8.9	----	30	8.6	----	175	0	0.0	4.4	0.7	0.0	0.03	0.11	211	220	77	0	287	8.1	0		
13/25-30G1	9/8/70	27	57	0.08	0.08	0.05	0.03	----	----	----	----	16	8.8	----	30	8.3	----	175	0	0.0	4.5	0.7	0.0	0.03	0.07	211	216	76	0	288	8.1	0		
13/26-35H1 ^(b) ARH-DC-1	5/8/69	----	46	0.1	0.10	0.00	0.00	----	----	----	----	2.1	0.3	----	79	7.8	----	199	10	0.0	4.2	1.0	0.1	0.11	0.06	249	252	6	0	344	8.6	0		
14/25-101 699-107-79	9/17/70	26.4	56	0.02	0.14	0.02	0.03	----	----	----	----	24	8.6	----	17	11	----	141	0	24	5.0	0.4	0.0	0.03	0.03	215	222	96	0	291	8.1	0		
15/26-28Q1 699-114-60	5/15/69	----	54	0.0	0.06	0.00	0.00	----	----	----	----	11	3.3	----	4.1	17	----	139	3	24	4.3	0.3	0.2	0.04	0.04	226	220	41	0	303	8.4	0		

^(a) A DEVELOPED SPRING^(b) WELL ARH-DC-1. SAMPLE TAKEN FROM THE DEPTH INTERVAL OF 540-620 FEET DURING CONSTRUCTION OF THE WELL.

measurements of radionuclide concentrations in the confined aquifers have also shown no detectable concentrations above the routine detection limits.

There are no available data on the aquifer properties for the aquifers across the Columbia River within previous AEC-controlled land.

II.3-D.3 Hanford Hydrology Program Reviews

The AEC and its contractors at Hanford make periodic program reviews of the Hanford site hydrology in order to direct and improve the work. A comprehensive review of the groundwater management and environmental monitoring programs at the Hanford Reservation was initiated in 1973 and is being managed by the responsible onsite contractor. The results obtained from this review are represented in several documents.^{64, 65, 66, 67} The review was under the direction of a hydrology consultant, Dr. Raul A. Deju.* A large number of recommendations have been made as a result of this review which will improve the Hanford Hydrology Program. None the less, no information has been found by the reviewers which indicate that a hazard through the groundwater pathway presently exists as a result of AEC waste operations at Hanford.

As a result of the review, improvements have been initiated in the groundwater management program. If the recommendations, changes, and improvements are completely implemented, it should be possible within a few years to achieve a better and more comprehensive understanding of the migration of groundwater and radionuclides at the Hanford Reservation. Special emphasis will be placed on improving existing monitoring structures as well as enhancing the data base to be used in the predictive models.

* Dr. Deju is currently an independent consultant in the area of geo-hydrology. Most recently, (through June 1974) he was affiliated with Wright State University, Dayton, Ohio. He is the author of several books and numerous papers in the area of hydrology, geo-hydrology, and geo-chemistry. In addition, he has considerable field experience in both U.S. and Mexico.

II.3-D REFERENCES

1. J. L. Glenn, Relations Among Radionuclide Content and Physical Chemical and Mineral Characteristics of Columbia River Sediments, U.S.G.S. Water Resource Diversion, Portland, OR, 1971.
2. J. L. Nelson and W. L. Haushild, Accumulation of Radionuclides in Bed Sediments of McNary Reservoir of the Columbia River, BNWL-SA-1730, Battelle, Pacific Northwest Laboratories, Richland, WA, March 25, 1968.
3. J. T. Whetler, J. C. Kelley and L. G. Hanson, "Characteristics of Columbia River Sediment and Sediment Transport", Journal of Sedimentary Petrology, Vol. 39, 3, pp. 1149-1166, September 1969.
4. Water Resources Data for Washington, Part 1, Surface Water Records 1972, U.S. Dept of Interior, Geological Survey, 1973.
5. J. K. Soldat, A Compilation of Basic Data Relating to the Columbia River, Section VIII-Dispersion of Reactor Effluent in the Columbia River, HW-69369, Hanford Atomic Products Operation, Richland, WA, 1962.
6. J. P. Corley, H. A. Kramer and J. K. Soldat, A Compilation of Basic Data Relating to the Columbia River, Sections I-VI, HW-69368, Hanford Atomic Products Operation, Richland, WA, 1961.
7. J. F. Honstead, Columbia River Survey 1951, 1952, 1953, HW-32506, Hanford Atomic Products Operation, Richland, WA, 1954.
8. J. K. Soldat, Columbia River Flow - Time Calculations, HW-58312(Rev) Hanford Atomic Products Operation, Richland, WA, 1962.
9. R. T. Jaske, Columbia River Hydrograph, BNWL-CC-1236, Battelle, Pacific Northwest Laboratories, Richland, WA, 1967.
10. J. L. Nelson, R. W. Perkins and W. L. Haushild, Determination of Columbia River Flow Times Using Radioactive Tracers Introduced by the Hanford Reactors, BN-SA-176, Battelle, Pacific Northwest Laboratories, Richland, WA, 1965.
11. J. L. Nelson, R. W. Perkins and W. L. Haushild, "Determination of Columbia Flow Times Using Radioactive Tracers Introduced by the Hanford Reactors", Water Resources Research, 1966.
12. R. T. Jaske and M. O. Synoground, Effect of Hanford Plant Operations on the Temperature of the Columbia River, 1964 to Present, BNWL-1345, Battelle, Pacific Northwest Laboratories, Richland, WA, 1970.

II.3-D REFERENCES (Continued)

13. R. T. Jaske and J. F. Goebel, A Study of the Effects of Dam Construction on Temperatures of the Columbia River, BNWL-SA-845, Battelle, Pacific Northwest Laboratories, Richland, WA.
14. H. T. Norton, The Turbulent Diffusion of River Contaminants, HW-49195, Hanford Atomic Products Operation, Richland, WA, 1957.
15. R. T. Jaske, An Evaluation of the Use of Selective Discharges from Lake Roosevelt to Cool the Columbia River, BNWL-208, Battelle, Pacific Northwest Laboratories, Richland, WA, 1966.
16. R. T. Jaske, Potential Thermal Effects of an Expanding Power Industry - Columbia River Basin, BNWL-1646, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
17. R. T. Jaske, Columbia River Temperature Trends - Fact and Fallacy, BNWL-SA-2536, Battelle, Pacific Northwest Laboratories, Richland, WA, 1969.
18. R. T. Jaske and D. G. Daniels, Simulation of the Effects of Hanford at the Washington-Oregon Border, BNWL-1344, Battelle, Pacific Northwest Laboratories, Richland, WA, 1970.
19. R. F. Foster and P. A. Olson, Water Temperatures for the Columbia River Above the Hanford Reactors, 1946 through December 1958, HW-60028, Hanford Atomic Products Operation, Richland, WA, 1959.
20. Water Resources Data for Washington, Part 2, Water Quality Records, 1972, U.S. Dept of Interior, Geological Survey, 1973.
21. (not used)
22. P. E. Bramson and J. P. Corley, Environmental Surveillance at Hanford for CY-1972, BNWL-1727, Battelle, Pacific Northwest Laboratories, Richland, WA, April 1973.
23. P. E. Bramson and J. P. Corley, Environmental Surveillance at Hanford for CY-1972 Data, BNWL-1727 ADD., Battelle, Pacific Northwest Laboratories, Richland, WA, May 1973.
24. D. W. Hubbell and J. L. Glenn, "Distribution of Radionuclides in Bottom Sediments of the Columbia River", Open File Report, U.S.G.S. 1971.

II.3-D REFERENCES (Continued)

25. K. L. Kipp, V. L. McGhan and D. W. Damschen, Hanford Wells, BNWL-1739, June 1973.
26. W. R. Gardner, "Mathematics of Isothermal Water Conduction in Unsaturated Soil," Water and Its Conduction in Soils, Highway Research Board Special Report 40, NAS Publication 629, 1958.
27. S. Davis and R. J. M. DeWiest, Hydrogeology, John Wiley, NY, 1966.
28. R. C. Routson, Effect of the Prior Disposal of Uncontaminated Solution on the Waste Retention Capacity of a Hanford Crib, BNWL-1163, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1969.
29. R. E. Brown and F. B. Steele, "A Study of the Uppermost Confined Aquifer in the Basalt Sequence," Unpublished Report, Draft Copy 1971.
30. D. D. Tillson, D. J. Brown and J. R. Raymond, River Water Ground-Water Relationship Along a Section of the Columbia River Valley, Meeting Preprint 823 ASCE Annual National Meeting on Water Resources Engineering, New Orleans, LA, February 3-7, 1969.
31. J. R. Raymond and D. J. Brown, Ground Water Exchange with Fluctuating Rivers, HW-SA-3198, September 13, 1963.
32. R. C. Newcomb and S. G. Brown, Evaluation of Bank Storage Along the Columbia River Between Richland and China Bar, Washington, Geological Survey Water-Supply Paper 1959-I, 1961.
33. R. C. Newcomb, J. R. Strand and F. J. Frank, "Geology and Groundwater Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission," Washington U.S. Geological Survey Professional Paper #717, 1972.
34. W. H. Bierschenk, Regional Hydrology at Hanford, 1957.
35. W. H. Bierschenk, Aquifer Characteristics and Ground Water Movement at Hanford, HW-60601, June 9, 1959.
36. W. A. Stone, D. E. Jenne and J. M. Thorp, Climatography of the Hanford Area, BNWL-1605, Battelle Pacific Northwest Laboratories, Richland, WA, June 1972.

II.3-D REFERENCES (Continued)

37. R. E. Isaacson, L. E. Brownell, R. W. Nelson and E. L. Roetman, Soil Moisture Transport in Arid Site Vadose Zones, ARH-SA-169, Atlantic Richfield Hanford Company, January 1974.
38. J. J. C. Hsieh, et al., Lysimeter Experiment, Description and Progress Report on Neutron Measurements, BNWL-1711, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
39. J. J. C. Hsieh, et al., A Study of Soil Water Potential and Temperature in Hanford Soils, BNWL-1712, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
40. W. H. Bierschenk, Hydraulic Characteristics of Hanford Aquifers, HW-48916, March 3, 1957.
41. K. L. Kipp and R. D. Mudd, Collection and Analysis of Pump Test Data for Transmissivity Values, BNWL-1709, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
42. K. L. Kipp and D. B. Cearlock, The Transmissivity Iterative Calculation Routine - Theory and Numerical Implementation, BNWL-1706, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
43. L. E. Addison, D. R. Friedrichs and K. L. Kipp, The Transmissivity Iterative Programs on the PDP-9 Computer - A Man-Machine Interactive System, BNWL-1707, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
44. K. L. Kipp and R. D. Mudd, Selected Water-Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973, BNWL-B-360, Battelle, Pacific Northwest Laboratories, Richland, WA.
45. J. Bear, D. Zaslavsky and D. Irmay, Physical Principles of Water Percolation and Seepage, UNESCO, Arid Zone Research 29, pp. 465, 1968.
46. S. W. Lohman, "Groundwater Hydraulics," U.S.G.S. Professional Paper #708, 1972.
47. W. H. Bierschenk and M. W. McConiga, Changes in the Hanford Water Table 1944-1957, HW-51277, July 9, 1957.
48. J. F. Honstead, M. W. McConiga and J. R. Raymond, Gable Mountain Groundwater Tests, HW-34532, January 21, 1955.

II.3-D REFERENCES (Continued)

49. J. R. Eliason, Field Evaluation of Ground Disposal of Reactor Effluent-1301-N Crib, BNWL-CC-1032, Battelle, Pacific Northwest Laboratories, Richland, WA, February 8, 1967.
50. K. L. Kipp, Radiological Status of the Groundwater Beneath the Hanford Project, January - June 1972, BNWL-1737, Battelle, Pacific Northwest Laboratories, Richland, WA, May 1973.
51. K. L. Kipp, Radiological Status of the Groundwater Beneath the Hanford Project, July - December 1972, BNWL-1752, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1973.
52. D. J. Brown, Status of the Ground Water Beneath Hanford Reactor Areas, January 1962 to January 1963, HW-77170, April 1963.
53. W. A. Haney, A History and Discussion of Specific Retention Disposal of Radioactive Liquid Wastes in the 200-Area, HW-54599, 1958.
54. J. D. Anderson, Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1972, ARH-2757, Part 3, April 9, 1973.
55. (not used)
56. T. Dabrowski, United Nuclear Industries Reactor and Fuel Production Facilities 1973 Environmental Release Report, UNI-158, March 1974.
57. W. S. Crews and D. D. Tillson, Analysis for Travel Time of I-131 from the 1301-N Crib to the Columbia River During July 1969, BNWL-CC-2326, Battelle, Pacific Northwest Laboratories, Richland, WA, December 1969.
58. "Standards for Radiation Protection," AEC Manual, Chapter 0524, with Appendix, USAEC, Washington, D.C., 1963, revised November 1968, and February 1969.
59. P. E. Bramson and J. P. Corley, Master Schedule - CY 1973, Hanford Environmental Surveillance Routine Program, BNWL-B-234, Battelle, Pacific Northwest Laboratories, Richland, WA, December 1972.
60. J. W. Loe, An Investigation of Effluent Control Standards and Practices, DUN-3155, September 1967.

II.3-D REFERENCES (Continued)

61. R. C. Newcomb, "Some Preliminary Notes on Ground Water in the Columbia River Basalt," Northwest Sciences, Vol. 33, 1, pp. 1-18, 1959.
62. A. M. LaSala, Jr., G. C. Doty and F. J. Pearson, A Preliminary Evaluation of Regional Groundwater Flow in South-Central Washington, U.S.G.S. Open File Report, January 1973.
63. K. L. Walters and M. J. Grolier, "Geology and Groundwater Resources of the Columbia Basin Project Area, Washington," Vol. I, Washington Division of Water Resources, Water Supply Bulletin No. 8, 1960.
64. R. A. Deju, "Review of the Hydrology Program and Overall Water Management at Hanford Project", November 1973.
65. R. A. Deju, "A Comprehensive Review of Mathematical Models Constructed to Describe the Hydrology of the Hanford Reservation," April 1974.
66. R. A. Deju, "The Hanford Field Testing Program", May 1974.
67. W. K. Summers and R. A. Deju, " A Preliminary Review of the Regional Hydrology of the Hanford Reservation", June 1974.

APPENDIX II.3-E

METEOROLOGY

II.3-E METEOROLOGY

II.3-E.1 General Climatology

For general climatological purposes, meteorological data from the Hanford Meteorology Station (HMS) may be considered as representative of the Hanford site. Much of the information, including figures and tables, used in the following sections was derived from "Climatography of the Hanford Area"¹ which is based mostly on continuous observations at the HMS since 1944. Local topographic features have some influence on prevailing wind directions observed onsite.

Air masses with source regions over the continent and over the Pacific Ocean reach this area and exert their influence. Summers are sunny, warm, and dry, with several hot days. In the winter, frequent changes in the weather are caused by Pacific storm systems carried eastward by prevailing winds and arctic air masses moving southward from Canada.

The Cascade Mountain Range to the west greatly affects the climate of the Hanford area. Hanford is in the rain shadow of these mountains, which results in relatively low rainfalls over the Hanford site. By serving as a source of cold air drainage the Cascade Mountains also have considerable influence on the wind and temperature regime at Hanford. This drainage (gravity) wind, plus topographic channeling, causes a considerable diurnal range of wind speeds during the summer at the HMS.

The HMS experiences high winds due to squall lines, frontal passages, strong pressure gradients and thunderstorms. This site has experienced only one observed tornado and has not been known to be affected by hurricanes.

Table II.3-E-1 is a summary of local climatological observations, including means and extremes.

II.3-E.2 Temperature

The average maximum temperatures in January and July are 36.7°F and 91.8°F, respectively. The average minimum temperatures for the same months are

TABLE II.3-E-1

AVERAGES AND EXTREMES OF CLIMATIC ELEMENTS AT HANFORD (BASED ON ALL AVAILABLE RECORDS TO AND INCLUDING THE YEAR 1970)

TEMPERATURE (°F)															DEGREE DAYS (BASE 65°F)					PRECIPITATION (INCHES)															EXTREME AVERAGES OR TOTALS AND YEAR OR SEASON OF OCCURRENCE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
1912-1970 AVERAGES					1912-1970 EXTREMES										1945-1970 TOTALS					1912-1970 TOTALS										1912-1970 TEMPERATURE AVERAGES (°F)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
					DAILY MAXIMUM					DAILY MINIMUM															SNOW, ICE PELLETS (SLEET)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
					RECORD HIGHEST					RECORD LOWEST					RECORD HIGHEST					RECORD LOWEST										MEAN MONTHLY					MAXIMUM MONTHLY					MINIMUM MONTHLY										MEAN MONTHLY					MAXIMUM MONTHLY					MINIMUM MONTHLY					MAX. IN 24 HOURS					MEAN MONTHLY					MAXIMUM MONTHLY					MAX. IN 24 HOURS					MAXIMUM DEPTH																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
					YEAR					YEAR					YEAR					YEAR										YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR					YEAR				

TABLE II.3-E-1 (Continued)

NUMBER OF DAYS

CLEAR 0.3 TENTH SKY COVER, SR TO SS)
GREATEST ANNUAL (1946-70) 141
LEAST ANNUAL (1946-70) 85 1966

CLOUDY 18-10 TENTH SKY COVER, SR TO SS)
GREATEST ANNUAL (1946-70) 181 1969+
LEAST ANNUAL (1946-70) 84 1949

THUNDERSTORMS

GREATEST ANNUAL (1946-70) 23 1948
LEAST ANNUAL (1946-70) 3 1949

HEAVY FOG (VIS. 1/4 MILE OR LESS)

GREATEST ANNUAL (1946-70) 42 1950-51
LEAST ANNUAL (1946-70) 9 1948-49

PRECIPITATION 0.10 INCH OR MORE

GREATEST ANNUAL (1946-70) 39 1950
LEAST ANNUAL (1946-70) 10 1965

SNOW 1.0 INCH OR MORE

GREATEST ANNUAL (1946-70) 15 1955-56
LEAST ANNUAL (1946-70) 0 1957-58

3 IN. OR MORE SNOW ON GROUND

GREATEST ANNUAL (1946-70) 40 1964-65
LEAST ANNUAL (1946-70) 0 1960-61+

PEAK GUST 40 MPH OR GREATER

GREATEST ANNUAL (1946-70) 41 1961
LEAST ANNUAL (1946-70) 13 1958

MAX. TEMPERATURE 90 OR ABOVE

GREATEST ANNUAL (1912-70) 85 1960+
LEAST ANNUAL (1912-70) 37 1954

MAX. TEMPERATURE 100 OR ABOVE

GREATEST ANNUAL (1912-70) 32 1962
LEAST ANNUAL (1912-70) 1 1954

MAX. TEMPERATURE 32 OR BELOW

GREATEST ANNUAL (1912-70) 53 1955-56
LEAST ANNUAL (1912-70) 1 1957-58

MIN. TEMPERATURE 32 OR BELOW

GREATEST ANNUAL (1912-70) 141 1916-17
LEAST ANNUAL (1912-70) 75 1957-58

MIN. TEMPERATURE 0 OR BELOW

GREATEST ANNUAL (1912-70) 18 1969-70
LEAST ANNUAL (1912-70) 0 1969-70+

NUMBER OF DAYS (1945-1970) (b)

	CLEAR				CLOUDY				THUNDERSTORMS				HEAVY FOG (VIS. 1/4 MI. OR LESS)				PRECIP. 0.10 INCH OR MORE				SNOW 1.0 INCH OR MORE			
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY
Jan.	4	13	1949	0	1955+	7	20	27	1969+	6	146	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb.	5	9	1968+	1	1969+	6	17	26	1958	10	1951+	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar.	7	12	1963	2	1961+	9	15	22	1968	7	148	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr.	7	12	1963	2	1961+	9	15	22	1968	7	148	0	0	0	0	0	0	0	0	0	0	0	0	0
May	8	14	1961	2	1963	10	16	23	1965	8	150	0	0	0	0	0	0	0	0	0	0	0	0	0
June	11	21	1961	3	1966	10	19	25	1952	0	186	0	0	0	0	0	0	0	0	0	0	0	0	0
July	21	27	1953	14	1955	7	3	8	1955	0	180+	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug.	19	24	1962	11	1965	8	4	13	1968	0	180+	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept.	15	21	1962	11	1965	8	4	13	1968	0	180+	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct.	10	16	1953	3	1959+	6	12	18	1954+	5	186+	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov.	5	10	1957	1	1965+	6	19	24	1965+	12	146	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec.	3	7	1954	0	1947	7	21	28	1962	14	146	0	0	0	0	0	0	0	0	0	0	0	0	0
Year	115	30	1955	0	1955+	100	150	28	1962	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0

NUMBER OF DAYS (1945-1970)

	3" OR MORE SNOW ON GND.				PEAK GUST 40 MPH OR GREATER				MAX. TEMP. 90 OR ABOVE				MAX. TEMP. 100 OR ABOVE				MAX. TEMP. 32 OR BELOW				MIN. TEMP. 32 OR BELOW				MIN. TEMP. 0 OR BELOW			
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY
Jan.	5	23	1969	0	1967+	3	9	1953	0	1957+	0	1957+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb.	3	16	1950	0	1970+	2	6	1961+	0	1970+	0	1970+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar.	0	0	0	0	0	3	9	1956	1	1965+	0	1965+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr.	0	0	0	0	0	3	6	1951	0	1961+	0	1961+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	2	6	1951	0	1961+	0	1961+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	2	4	1970+	0	1970+	0	1970+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	1	4	1962+	0	1969+	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug.	0	0	0	0	0	1	5	1951	0	1970+	0	1970+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept.	0	0	0	0	0	2	4	1951	0	1970+	0	1970+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct.	1	10	1955	0	1970+	2	8	1961+	0	1969+	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov.	2	14	1955	0	1969+	3	8	1961+	0	1969+	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec.	2	14	1955	0	1969+	3	8	1961+	0	1969+	0	1969+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year	11	23	1969	0	0	26	9	1953	0	0	0	0	13	16	1960+	0	0	0	0	0	0	0	0	0	0	0	0	0

REFERENCE NOTES

- (a) CALORIES/cm²
(b) SKY COVER AND PRECIPITATION OBSERVATIONS
NOT BEGUN UNTIL 1946
* LESS THAN 1/2
+ ALSO ON EARLIER YEARS
DIFFERENT ACC. CONTRADICTIONS.

LOCATION AND HISTORY

PRESENT LOCATION 25 MILES NW OF RICHLAND, WASHINGTON
LATITUDE 46° 34' N. LONGITUDE 119° 36' W. ELEVATION 733 FEET
OBSERVATIONS FROM 1912 TO 1946 WERE BY UNITED STATES
WEATHER BUREAU COOPERATIVE OBSERVERS AT A SITE ABOUT
10 MILES ENE OF PRESENT LOCATION. SINCE 1946 OBSERVATIONS
HAVE BEEN MAINTAINED ON A 24 HOUR A-DAY BASIS BY THREE
DIFFERENT ACC. CONTRADICTIONS.

22.1°F and 61.0°F, based on local records from 1912-1970. The daily temperature range is about 17°F in January and about 30°F in July. Mountain ranges shield the area from many of the arctic air surges and half of all winters are free of temperatures as low as 0°. However, six winters in 58 of record show a total of 16 days with temperatures -20°F or below, and in January-February 1950, there were four consecutive such days. Ten days of record occurred when even the maximum temperature failed to rise above zero. At the other extreme, in the winter of 1925-1926, the lowest temperature all season was +22°.

Although the minimum winter season temperatures have varied from -27° to +22°F, summer season maximum temperatures varied only from 100°F to 115°F. However, there is considerable variation in the frequency of such maxima. In 1954, for example, there was only one day with a maximum as high as 100°F. On the other hand, there were two summers (1938 and 1967) when the temperature went to 100°F or above for 11 consecutive days.

Although temperatures reach 90°F or above on an average of 56 days a year, there were only seven annual occurrences of overnight minima 70°F or above. The usual cool nights are a result of the gravity wind. Figure II.3-E-1 presents an annual graphical summary of the diurnal normals and extremes of air temperature.

By applying Gumbel's² theory of extreme values, the probability of occurrence of extreme values of highest and lowest temperatures was developed.³ These findings are presented in Figures II.3-E-2 and II.3-E-3. The figures show the expected frequency of climatological extremes already experienced at Hanford as well as the frequency with which still greater extremes can be expected. It is also possible to specify a period of time, which may be in centuries, and to estimate the magnitude of an extreme which can be expected within that period. The charts employ both normal and extreme probability theory. Because of limitations inherent in any theory which uses a brief history for projecting into the future, the charts should be considered as only "best estimates" based on the available array of data.

II.3-E-5

FIGURE II.3-E-1 ANNUAL VARIATION OF NORMAL⁽¹⁾ AND EXTREME⁽²⁾ DAILY MAXIMUM AND MINIMUM TEMPERATURES AT HMS⁽³⁾

II.3-E-6

FIGURE II.3-E-2 PROBABILITIES OF HIGH TEMPERATURES BASED ON THE HIGH TEMPERATURE DURING EACH OF 57 SUMMERS OF RECORD AT HANFORD: 1912-1969

II.3-E-7

FIGURE II.3-E-3 PROBABILITY OF LOW TEMPERATURES BASED ON LOWEST TEMPERATURE DURING EACH OF 58 WINTERS AT HANFORD: 1912-13 to 1969-70

A "chinook"⁴ is defined as a warm and dry west wind of the föhn type which occurs on the eastern side of the Rocky Mountains. Its arrival is usually sudden, with a consequent large temperature rise and rapid melting snow. During the winter months the Hanford area frequently experiences an identical phenomenon, the "chinook inversion." For example, on January 7, 1949, the temperature rose from 19° to 43° (24°) in one hour as the result of the passage of a warm front (Figure II.3.E-4). On November 24, 1970, the temperature rose 8° in 4 minutes, 15° within 15 minutes, and 22° within 30 minutes. In all, the temperature on November 24, 1970, rose from a morning low of 24° to a high of 60°. The high of the previous day was 25°.

Temperature records have been summarized for limited periods of time at various locations on the Hanford Reservation including the Wahluke Slope Station (6 year summary),¹ the Washington Nuclear Plant No. 1 (WNP-1) Area (1 year summary)⁶ and the Arid Lands Ecology Reserve.⁷

Climatologically speaking, there are no apparent significant temperature differences among the low-level sites although simultaneous temperature differences between low level sites on the order of 10 to 15 degrees have frequently been observed. The pattern of weekly and monthly maximum temperatures over the Arid Lands Ecology (ALE) Reserve presents essentially a uniform adiabatic lapse rate of temperature with increasing elevation. Local topography modifies this pattern, especially near the crest of the Rattlesnake Hills. Isotherms of minimum temperature indicate a well defined nocturnal temperature inversion reaching from 600 to 1000 feet above the valley floor. The intensity of the inversion appears to be dependent on season; months near September and March exhibit minimum temperatures near the top of the inversion 10 to 15°F warmer than those of the valley floor, whereas near June and December the difference is more nearly 5 to 10°F.

II.3-E.3 Humidity

Relative humidity averages 75.7 percent and 31.8 percent in January and July respectively, based on 15 recent years of record. The highest

FIGURE II.3-E-4 EXAMPLE OF EFFECT OF CHINOOK,
OBSERVED HOURLY TEMPERATURES AT HANFORD,
JANUARY 6-7, 1949

monthly average relative humidity was 89.9 percent in December 1963, and the lowest average was 21.9 percent in July 1959. Figure II.3-E-5 presents January, July and annual hourly averages of dry bulb and wet bulb temperature values at HMS. Table II.3-E-2 presents monthly and annual frequency of occurrence of wet bulb temperature values at HMS. The other location on Hanford for which such information is available is at the WNP-2 site, elevation 450 feet MSL, about 15 miles ESE of the HMS and within four miles of the Columbia River. A summary of the frequency of occurrence of wet bulb values by months for one year of data is given in Table II.3-E-3.

Relatively higher humidity values can be expected at locations near the Columbia River as the result of the increased availability of airborne water vapor evaporating from the river. Relative humidity values on the Wahluke Slope portion of the Hanford Reservation can be significantly higher as a result of agricultural irrigation operations conducted there. Relative humidity values can be expected to rise as one approaches the periphery of the Hanford area, again due to increased proximity to extensive agricultural irrigation operations.

Although the Southern Columbia Basin Irrigation District surrounding the Hanford area has increased to about 180,700 hectares during the past 23 years,⁸ no apparent increase in atmospheric moisture in terms of relative humidity has been detected at the HMS near the middle of the Hanford Reservation. Figure II.3-E-6 presents mean values of relative humidity for July as well as long-term running means.

II.3-E.4 Wind

In July, hourly average speeds range from a low of 5.2 mph from 9:00 to 10:00 a.m. to a high of 13.0 mph from 9:00 to 10:00 p.m. In contrast, the corresponding speeds for January are 5.5 and 6.3 mph.

Although the gravity wind occurs with regularity in summer at the HMS, it is never strong unless reinforced by frontal activity. In June, the month of highest average speed, there are fewer instances of hourly averages exceeding 31 mph than in December, the month of lowest average speed.

FIGURE II.3-E-5 JANUARY, JULY, AND HOURLY AVERAGES OF DRY BULB (D.B.) AND WET BULB (W.B.) TEMPERATURE, RELATIVE HUMIDITY (R.H.) AND DEW POINT TEMPERATURE (D.P.) AT HMS, 1957-1970

TABLE II. 3-E-2

MONTHLY AND ANNUAL FREQUENCY OF OCCURRENCE (%) OF WET BULB VALUES (°F)
PERIOD OF RECORD AT HMS, 1957-70 (TOTAL OBSERVATIONS: 122,712)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
75-79	0	0	0	0	0	0	0	0	0	0	0	0	0
70-74	0	0	0	0	0	0.06	0.38	0.14	0	0	0	0	0.05
65-69	0	0	0	0	0.64	4.61	10.72	7.90	1.46	0	0	0	2.13
60-64	0	0	0	0.30	4.59	17.85	30.44	27.50	12.32	0.94	0	0	7.89
55-59	0.05	0.01	0.30	2.39	16.10	30.74	32.18	35.01	26.21	7.94	0.16	0	12.66
50-54	0.48	1.30	2.90	10.60	28.32	30.13	20.34	22.02	31.29	17.07	2.47	0.21	13.97
45-49	2.15	6.00	12.59	26.40	27.14	13.82	5.22	6.62	18.71	29.19	11.68	7.28	13.50
40-44	8.30	18.41	27.31	32.80	16.68	2.65	0.69	0.75	7.54	25.89	23.91	9.57	14.49
35-39	15.77	26.62	28.24	19.85	5.39	0.14	0	0.05	1.85	12.93	25.33	20.96	13.00
30-34	23.60	26.24	16.86	6.55	1.08	0	0	0	0.62	5.19	19.87	30.69	10.82
25-29	20.60	13.69	8.69	1.07	0.07	0	0	0	0.01	0.74	10.58	19.57	6.23
20-24	11.41	4.66	1.99	0.05	0	0	0	0	0	0.11	3.93	9.72	2.66
15-19	7.03	1.50	0.88	0	0	0	0	0	0	0	1.64	3.47	1.22
10-14	4.23	1.26	0.25	0	0	0	0	0	0	0	0.34	1.64	0.64
05-09	3.21	0.23	0	0	0	0	0	0	0	0	0.11	0.53	0.34
00-04	1.71	0.05	0	0	0	0	0	0	0	0	0	0.44	0.19
-05/-01	0.82	0.02	0	0	0	0	0	0	0	0	0	0.41	0.11
-10/-06	0.32	0	0	0	0	0	0	0	0	0	0	0.37	0.06
-15/-11	0.16	0	0	0	0	0	0	0	0	0	0	0.13	0.03
-20/-16	0.13	0	0	0	0	0	0	0	0	0	0	0	0.01
L. T. -20	0.03	0	0	0	0	0	0	0	0	0	0	0	0

II.3-E-12

TABLE II.3-E-3

WNP-2 SITE MONTHLY AND ANNUAL FREQUENCY OF OCCURRENCE (%) OF WET BULB VALUES

	1972				1973								
	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	ANNUAL
AB 79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.27	0.06
70-74	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	14.38	10.35	2.37
65-69	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	10.28	21.24	19.22	4.82
60-64	8.19	0.40	0.00	0.00	0.00	0.00	0.00	0.00	7.39	16.94	24.73	23.25	6.74
55-59	17.22	5.24	0.00	0.00	0.00	0.00	0.00	1.11	15.32	24.17	21.64	24.33	9.09
50-54	25.14	12.63	1.11	0.81	0.00	0.15	0.54	10.97	21.10	22.78	11.83	13.71	10.06
UN 50	39.17	81.72	98.89	97.04	100.00	99.85	99.46	87.92	55.38	21.67	5.78	8.87	66.31

II.3-E-13

FIGURE II.3-E-6 HMS MEAN RELATIVE HUMIDITY (%) AT 1300 PST
IN JULY, EACH YEAR FROM 1946 TO 1970

It is also notable that, although channeling results in a prevailing WNW or northwest wind the year round, at the HMS the strongest speeds are from the southwest direction.

Periods of relatively low wind speed are also part of Hanford's wind regime. December, for example, has an average of ten days with a peak gust under 13 mph. By contrast, only once in seven years does June have even one such day.

Joint wind speed, direction, and stability data are available from two locations on site. The longest periods of data are from the Hanford Meteorological Station tower. Wind roses for each stability and for all stabilities combined based on 15 years of Hanford Meteorological Station data are given in Figure II.3-E-7. Included in these are groupings of the persistences by wind speeds for each direction. These are based on the annual joint distributions of stability (ΔT between the surface and 200 feet), wind speed (200 feet), and direction (200 feet) for the period 1955 through 1970.¹ These data are presented in Table II.3-E-4. Figure II.3-E-8 presents wind rose summaries based on one year of data from the meteorological tower at the N-reactor site. These data are available in tabular form (Reference 6). These two locations cover the winds in the northern and central sections of the Hanford site. The definition of stability used in Figures II.3-E-7 and II.3-E-8, as well as in the Hanford diffusion model, is given in Table II.3-E-5.

Wind data is also available for the WPN-2 site about 15 miles ESE of the HMS at an elevation of 450 feet MSL. Figure II.3-E-9 presents wind roses at the WPN-2 site for a 12-month period. Figure II.3-E-10 presents similar data for the HMS site for the same period. Figure II.3-E-11 presents average monthly wind roses for the HMS site over a 15-year period. A comparison of the 12-month HMS data with the 15-year HMS data indicates that winds during the short term were reasonably typical of distributions during the long term. Therefore it is reasonable to infer that the WPN-2 short-term winds are also typical of the

FIGURE II.3-E-7 WIND ROSES AS A FUNCTION OF STABILITY AND FOR ALL STABILITIES OF HMS BASED ON WINDS AT 200 FT AND AIR TEMPERATURE STABILITIES BETWEEN 3 FT and 200 FT FOR THE PERIOD 1955 THROUGH 1970 (the points of the rose represent the directions from which the winds come)

TABLE II.3-E-4

HMS COMPOSITE REPORT (1955 THROUGH 1970) OF PERCENTAGE FREQUENCY DISTRIBUTION OF WIND
SPEED AND WIND DIRECTION AT 200-FT LEVEL VERSUS ATMOSPHERIC STABILITY

(see text for stability definition)

		SEASON - SPRING																		
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.15	0.13	0.09	0.14	0.21	0.23	0.16	0.13	0.14	0.21	0.15	0.38	0.27	0.31	0.27	0.22	0.14	0.23	3.55
	MS	0.08	0.11	0.08	0.10	0.17	0.20	0.07	0.08	0.08	0.08	0.07	0.14	0.09	0.10	0.14	0.12	0.08	0.08	1.86
	N	0.10	0.20	0.11	0.14	0.20	0.19	0.07	0.07	0.06	0.07	0.03	0.12	0.06	0.13	0.18	0.22	0.15	0.07	2.15
	U	0.51	0.70	0.39	0.46	0.29	0.31	0.12	0.20	0.16	0.14	0.11	0.14	0.17	0.30	0.36	0.67	0.50	0.01	5.56
4 - 7	VS	0.15	0.13	0.12	0.15	0.18	0.30	0.20	0.24	0.20	0.35	0.52	0.93	0.99	0.92	0.53	0.34	0.01	0.	6.25
	MS	0.08	0.12	0.10	0.16	0.18	0.33	0.16	0.18	0.15	0.19	0.27	0.44	0.37	0.37	0.23	0.22	0.01	0.	3.57
	N	0.06	0.10	0.07	0.13	0.12	0.25	0.13	0.11	0.07	0.08	0.10	0.13	0.18	0.21	0.16	0.10	0.02	0.	2.02
	U	1.00	1.03	0.69	0.61	0.52	0.71	0.46	0.60	0.56	0.65	0.38	0.40	0.58	1.28	1.19	1.27	0.23	0.	12.15
8 -12	VS	0.11	0.15	0.14	0.10	0.08	0.13	0.22	0.14	0.14	0.24	0.61	1.29	2.06	1.54	0.51	0.22	0.	0.	7.67
	MS	0.11	0.10	0.04	0.06	0.07	0.20	0.21	0.18	0.28	0.37	0.58	1.13	1.45	0.98	0.25	0.14	0.	0.	6.15
	N	0.07	0.04	0.05	0.05	0.06	0.10	0.10	0.06	0.09	0.14	0.18	0.18	0.31	0.39	0.10	0.08	0.	0.	1.98
	U	0.55	0.44	0.19	0.14	0.12	0.26	0.23	0.25	0.55	0.80	0.72	0.43	0.77	1.52	0.56	0.55	0.00	0.	8.08
13-18	VS	0.06	0.04	0.04	0.04	0.00	0.05	0.17	0.03	0.02	0.07	0.34	0.50	1.20	1.34	0.15	0.11	0.	0.	4.16
	MS	0.09	0.07	0.02	0.03	0.02	0.09	0.16	0.12	0.26	0.58	1.12	1.75	3.43	1.89	0.14	0.12	0.	0.	9.89
	N	0.09	0.02	0.01	0.01	0.01	0.05	0.05	0.08	0.10	0.20	0.29	0.21	0.39	0.38	0.04	0.04	0.	0.	1.95
	U	0.41	0.21	0.05	0.02	0.01	0.03	0.08	0.11	0.37	0.84	1.00	0.41	0.88	1.17	0.12	0.22	0.	0.	5.90
19-24	VS	0.	0.00	0.00	0.01	0.	0.01	0.02	0.01	0.	0.01	0.04	0.02	0.06	0.20	0.01	0.	0.	0.	0.38
	MS	0.05	0.02	0.01	0.01	0.00	0.04	0.08	0.07	0.18	0.51	0.72	0.45	1.99	1.36	0.03	0.02	0.	0.	5.52
	N	0.02	0.02	0.01	0.	0.	0.01	0.02	0.07	0.10	0.19	0.20	0.08	0.30	0.35	0.01	0.01	0.	0.	1.41
	U	0.12	0.06	0.01	0.01	0.	0.	0.01	0.04	0.26	0.63	0.72	0.21	0.52	0.75	0.02	0.04	0.	0.	3.40
OVER 24	VS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.00	0.01	0.	0.00	0.	0.	0.	0.	0.	0.01
	MS	0.01	0.01	0.	0.	0.	0.	0.01	0.05	0.19	0.45	0.26	0.06	0.75	0.84	0.	0.01	0.	0.	2.62
	N	0.01	0.00	0.00	0.00	0.	0.	0.01	0.01	0.07	0.24	0.14	0.03	0.24	0.26	0.	0.	0.	0.	1.02
	U	0.02	0.03	0.02	0.	0.	0.	0.	0.02	0.17	0.84	0.59	0.14	0.33	0.56	0.01	0.01	0.	0.	2.73
TOTALS	VS	0.47	0.46	0.39	0.44	0.47	0.72	0.76	0.54	0.50	0.89	1.65	3.12	4.58	4.32	1.47	0.88	0.15	0.23	22.03
	MS	0.42	0.42	0.25	0.36	0.45	0.85	0.69	0.67	1.15	2.17	3.02	3.97	8.09	5.54	0.79	0.62	0.09	0.08	29.61
	N	0.35	0.38	0.24	0.33	0.39	0.61	0.37	0.40	0.48	0.91	0.95	0.75	1.48	1.72	0.48	0.45	0.17	0.07	10.54
	U	2.62	2.46	1.35	1.23	0.93	1.32	0.90	1.23	2.07	3.89	3.52	1.74	3.25	5.58	2.25	2.76	0.74	0.01	37.83

II.3-E-17

TABLE II.3-E-4 (Continued)

SEASON = SUMMER

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.08	0.07	0.06	0.06	0.06	0.10	0.05	0.08	0.05	0.10	0.13	0.18	0.16	0.16	0.08	0.12	0.06	0.10	1.68
	MS	0.05	0.04	0.04	0.05	0.08	0.12	0.04	0.07	0.04	0.05	0.06	0.12	0.09	0.11	0.04	0.07	0.06	0.05	1.16
	N	0.10	0.10	0.09	0.12	0.10	0.15	0.07	0.06	0.07	0.06	0.08	0.07	0.07	0.11	0.10	0.15	0.10	0.05	1.64
	U	0.42	0.65	0.28	0.37	0.36	0.37	0.18	0.31	0.16	0.32	0.21	0.24	0.18	0.35	0.37	0.57	0.93	0.02	6.28
4 - 7	VS	0.14	0.13	0.10	0.13	0.12	0.21	0.14	0.11	0.13	0.18	0.35	0.78	0.81	0.51	0.38	0.21	0.01	0.	4.45
	MS	0.08	0.08	0.06	0.10	0.16	0.19	0.07	0.10	0.07	0.17	0.22	0.40	0.27	0.22	0.13	0.05	0.01	0.	2.38
	N	0.09	0.07	0.08	0.08	0.16	0.21	0.08	0.09	0.07	0.10	0.09	0.17	0.16	0.22	0.15	0.12	0.03	0.	1.98
	U	1.58	1.55	0.88	1.08	0.89	1.16	0.76	0.98	0.92	1.11	0.84	0.88	0.85	1.66	1.47	1.79	0.87	0.	19.27
8 -12	VS	0.14	0.16	0.09	0.09	0.11	0.08	0.16	0.09	0.06	0.13	0.49	1.18	2.04	1.28	0.44	0.18	0.	0.	6.71
	MS	0.09	0.20	0.03	0.09	0.11	0.12	0.10	0.05	0.06	0.19	0.48	1.25	1.49	0.63	0.13	0.12	0.	0.	5.04
	N	0.05	0.03	0.05	0.04	0.05	0.06	0.04	0.02	0.04	0.08	0.15	0.18	0.30	0.29	0.05	0.03	0.	0.	1.46
	U	0.78	0.54	0.20	0.18	0.18	0.23	0.15	0.22	0.53	1.21	1.06	0.62	0.99	1.95	0.66	0.66	0.01	0.	10.17
13-18	VS	0.04	0.04	0.02	0.03	0.	0.02	0.08	0.01	0.01	0.02	0.11	0.30	1.36	1.44	0.15	0.03	0.	0.	3.65
	MS	0.06	0.05	0.04	0.04	0.01	0.03	0.05	0.03	0.07	0.18	0.62	1.47	4.79	2.03	0.13	0.05	0.	0.	9.64
	N	0.02	0.02	0.01	0.01	0.00	0.02	0.03	0.03	0.03	0.10	0.29	0.24	0.44	0.36	0.02	0.02	0.	0.	1.64
	U	0.24	0.16	0.06	0.04	0.02	0.05	0.05	0.04	0.18	0.87	1.04	0.37	0.97	1.69	0.10	0.13	0.	0.	6.02
19-24	VS	0.	0.01	0.00	0.	0.	0.	0.	0.	0.	0.01	0.	0.03	0.22	0.00	0.	0.	0.	0.	0.27
	MS	0.02	0.03	0.02	0.01	0.00	0.00	0.01	0.02	0.03	0.09	0.18	0.29	2.77	2.70	0.02	0.01	0.	0.	6.19
	N	0.01	0.03	0.01	0.00	0.	0.	0.	0.	0.02	0.07	0.16	0.07	0.51	0.58	0.01	0.00	0.	0.	1.47
	U	0.05	0.07	0.01	0.01	0.	0.	0.02	0.02	0.07	0.27	0.45	0.15	0.48	1.27	0.02	0.01	0.	0.	2.89
OVER 24	VS	0.	0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.00	0.	0.	0.	0.	0.	0.01
	MS	0.00	0.01	0.	0.	0.	0.00	0.00	0.00	0.01	0.03	0.03	0.02	1.02	1.63	0.00	0.	0.	0.	2.77
	N	0.00	0.01	0.	0.	0.	0.	0.01	0.01	0.01	0.03	0.08	0.02	0.49	0.79	0.00	0.	0.	0.	1.44
	U	0.	0.03	0.01	0.	0.	0.	0.	0.	0.03	0.15	0.24	0.07	0.26	1.02	0.01	0.	0.	0.	1.80
TOTALS	VS	0.40	0.40	0.27	0.31	0.29	0.40	0.42	0.29	0.25	0.44	1.09	2.45	4.39	3.61	1.06	0.53	0.06	0.10	16.77
	MS	0.30	0.31	0.19	0.27	0.37	0.46	0.27	0.27	0.27	0.70	1.58	3.54	10.44	7.33	0.46	0.30	0.07	0.05	27.19
	N	0.29	0.25	0.23	0.25	0.32	0.44	0.23	0.21	0.23	0.43	0.85	0.76	1.96	2.35	0.33	0.31	0.12	0.05	9.62
	U	3.08	3.00	1.45	1.67	1.45	1.81	1.15	1.57	1.88	3.94	3.83	2.32	3.73	7.93	2.63	3.17	1.81	0.02	46.42

II.3-E-18

TABLE II.3-E-4 (Continued)

SEASON - FALL

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR,	CALM	TOTAL
0 - 3	VS 0.31	0.31	0.25	0.32	0.43	0.60	0.34	0.35	0.32	0.31	0.31	0.55	0.54	0.66	0.63	0.52	0.30	0.87	7.91
	MS 0.20	0.21	0.19	0.27	0.38	0.54	0.23	0.20	0.12	0.12	0.18	0.17	0.23	0.37	0.29	0.39	0.15	0.60	4.84
	N 0.37	0.43	0.38	0.41	0.40	0.51	0.21	0.16	0.15	0.11	0.08	0.13	0.16	0.35	0.46	0.37	0.16	0.39	5.24
	U 0.71	0.97	0.57	0.63	0.48	0.31	0.14	0.11	0.06	0.13	0.09	0.11	0.15	0.31	0.53	0.70	0.36	0.08	6.42
4 - 7	VS 0.28	0.23	0.17	0.18	0.28	0.50	0.47	0.43	0.38	0.49	0.67	1.20	1.53	1.48	0.92	0.49	0.02	0.	9.73
	MS 0.19	0.12	0.16	0.15	0.27	0.44	0.29	0.17	0.19	0.20	0.19	0.33	0.51	0.70	0.47	0.32	0.01	0.	4.71
	N 0.13	0.13	0.06	0.12	0.25	0.31	0.13	0.09	0.07	0.08	0.08	0.13	0.21	0.54	0.36	0.15	0.01	0.	2.85
	U 0.88	0.74	0.46	0.48	0.60	0.52	0.23	0.18	0.25	0.24	0.21	0.17	0.36	0.94	1.23	1.22	0.08	0.	8.81
8 - 12	VS 0.17	0.08	0.06	0.06	0.04	0.17	0.31	0.11	0.13	0.32	0.68	1.50	2.49	2.37	0.77	0.27	0.	0.	9.55
	MS 0.10	0.05	0.03	0.03	0.10	0.23	0.27	0.16	0.22	0.43	0.48	0.76	1.26	1.45	0.41	0.13	0.	0.	6.10
	N 0.05	0.05	0.01	0.03	0.03	0.09	0.08	0.07	0.05	0.07	0.15	0.11	0.23	0.60	0.17	0.06	0.	0.	1.85
	U 0.45	0.26	0.05	0.03	0.05	0.11	0.04	0.08	0.17	0.28	0.35	0.20	0.32	1.11	0.56	0.44	0.00	0.	4.50
13-18	VS 0.06	0.03	0.01	0.02	0.00	0.05	0.10	0.03	0.02	0.08	0.25	0.43	1.54	1.93	0.21	0.04	0.	0.	4.79
	MS 0.09	0.05	0.00	0.02	0.01	0.09	0.15	0.18	0.31	0.63	0.87	0.97	2.18	1.85	0.17	0.12	0.	0.	7.70
	N 0.04	0.02	0.00	0.00	0.	0.04	0.04	0.07	0.09	0.14	0.21	0.11	0.26	0.37	0.09	0.05	0.	0.	1.55
	U 0.25	0.22	0.01	0.	0.	0.03	0.03	0.03	0.10	0.34	0.45	0.14	0.42	0.63	0.09	0.13	0.	0.	2.78
19-24	VS 0.	0.00	0.00	0.	0.	0.	0.01	0.01	0.01	0.01	0.04	0.03	0.09	0.19	0.	0.00	0.	0.	0.38
	MS 0.05	0.03	0.03	0.	0.00	0.01	0.05	0.18	0.27	0.57	0.54	0.24	0.99	1.04	0.03	0.02	0.	0.	4.04
	N 0.00	0.01	0.01	0.	0.	0.02	0.02	0.04	0.10	0.19	0.20	0.02	0.13	0.23	0.01	0.02	0.	0.	1.00
	U 0.04	0.03	0.01	0.	0.	0.	0.01	0.01	0.07	0.32	0.34	0.08	0.23	0.37	0.01	0.02	0.	0.	1.55
OVER 24	VS 0.	0.	0.	0.	0.	0.	0.	0.01	0.01	0.	0.00	0.	0.	0.	0.	0.	0.	0.	0.02
	MS 0.	0.01	0.	0.	0.	0.	0.02	0.08	0.30	0.43	0.21	0.07	0.31	0.40	0.01	0.	0.	0.	1.84
	N 0.01	0.01	0.00	0.	0.	0.	0.01	0.02	0.09	0.19	0.09	0.03	0.07	0.13	0.00	0.00	0.	0.	0.66
	U 0.01	0.05	0.01	0.	0.	0.	0.	0.01	0.09	0.39	0.24	0.07	0.09	0.21	0.01	0.	0.	0.	1.16
TOTALS	VS 0.83	0.66	0.49	0.58	0.76	1.32	1.22	0.94	0.87	1.21	1.95	3.70	6.18	6.63	2.52	1.32	0.32	0.87	32.38
	MS 0.63	0.46	0.40	0.46	0.76	1.32	1.02	0.98	1.40	2.38	2.48	2.53	5.49	5.82	1.37	0.97	0.16	0.60	29.24
	N 0.60	0.64	0.47	0.56	0.68	0.96	0.49	0.46	0.56	0.78	0.82	0.54	1.08	2.23	1.09	0.65	0.16	0.39	13.16
	U 2.34	2.17	1.10	1.14	1.13	0.97	0.45	0.42	0.75	1.71	1.69	0.77	1.57	3.56	2.43	2.50	0.44	0.08	25.23

II.3-E-19

TABLE II.3-E-4 (Continued)

SEASON - WINTER

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.29	0.35	0.23	0.30	0.36	0.58	0.39	0.37	0.27	0.30	0.31	0.48	0.41	0.61	0.50	0.54	0.35	0.73	7.36
	MS	0.38	0.36	0.34	0.42	0.69	0.82	0.48	0.39	0.24	0.24	0.20	0.40	0.46	0.66	0.64	0.59	0.23	1.30	8.83
	N	0.62	0.64	0.51	0.66	0.74	0.91	0.55	0.32	0.23	0.22	0.21	0.39	0.45	0.75	0.89	0.91	0.14	1.42	10.56
	U	0.30	0.25	0.20	0.15	0.12	0.07	0.03	0.05	0.04	0.03	0.01	0.06	0.08	0.14	0.22	0.23	0.05	0.06	2.08
4 - 7	VS	0.29	0.21	0.16	0.21	0.22	0.33	0.30	0.36	0.25	0.36	0.48	0.93	0.99	1.10	0.92	0.53	0.06	0.	7.70
	MS	0.33	0.29	0.22	0.21	0.26	0.47	0.31	0.23	0.20	0.27	0.27	0.53	0.84	1.42	1.08	0.65	0.03	0.	7.62
	N	0.20	0.21	0.18	0.16	0.23	0.28	0.23	0.09	0.07	0.14	0.16	0.23	0.53	1.23	0.66	0.34	0.00	0.	4.93
	U	0.31	0.25	0.16	0.12	0.10	0.09	0.04	0.03	0.05	0.02	0.02	0.09	0.12	0.64	0.55	0.41	0.01	0.	2.96
8 -12	VS	0.09	0.05	0.03	0.03	0.05	0.13	0.15	0.12	0.13	0.29	0.59	0.95	1.41	1.79	0.70	0.15	0.	0.	6.67
	MS	0.15	0.07	0.03	0.06	0.11	0.30	0.19	0.13	0.25	0.36	0.45	0.69	1.67	3.10	0.72	0.18	0.00	0.	8.45
	N	0.07	0.06	0.03	0.01	0.03	0.09	0.06	0.03	0.05	0.07	0.08	0.10	0.86	1.87	0.28	0.09	0.	0.	3.78
	U	0.14	0.08	0.03	0.01	0.01	0.02	0.01	0.02	0.08	0.04	0.10	0.07	0.28	1.07	0.29	0.14	0.	0.	2.40
13-18	VS	0.05	0.03	0.	0.00	0.	0.04	0.04	0.05	0.09	0.19	0.31	0.51	0.89	1.41	0.17	0.03	0.	0.	3.81
	MS	0.15	0.05	0.01	0.01	0.05	0.08	0.16	0.26	0.36	0.78	0.88	0.76	1.73	3.16	0.29	0.12	0.	0.	8.85
	N	0.07	0.01	0.00	0.01	0.01	0.02	0.02	0.03	0.07	0.14	0.15	0.08	0.67	1.21	0.08	0.06	0.	0.	2.62
	U	0.13	0.03	0.00	0.00	0.	0.	0.00	0.01	0.08	0.10	0.20	0.11	0.26	0.44	0.06	0.08	0.	0.	1.51
19-24	VS	0.	0.	0.	0.	0.	0.01	0.02	0.01	0.04	0.07	0.05	0.05	0.08	0.12	0.00	0.	0.	0.	0.45
	MS	0.04	0.03	0.	0.	0.01	0.03	0.10	0.18	0.36	0.96	0.56	0.35	0.44	0.70	0.05	0.03	0.	0.	3.85
	N	0.03	0.01	0.	0.00	0.01	0.	0.01	0.03	0.09	0.14	0.12	0.03	0.07	0.18	0.01	0.06	0.	0.	0.79
	U	0.03	0.04	0.01	0.	0.	0.00	0.00	0.01	0.04	0.13	0.14	0.03	0.06	0.14	0.00	0.03	0.	0.	0.67
OVER 24	VS	0.	0.	0.	0.	0.	0.00	0.01	0.01	0.04	0.04	0.01	0.01	0.	0.	0.	0.	0.	0.	0.12
	MS	0.02	0.00	0.	0.	0.	0.02	0.06	0.21	0.69	0.99	0.41	0.11	0.12	0.13	0.01	0.02	0.	0.	2.79
	N	0.03	0.02	0.	0.	0.	0.	0.01	0.03	0.14	0.23	0.05	0.02	0.01	0.02	0.	0.03	0.	0.	0.61
	U	0.04	0.00	0.	0.	0.	0.	0.	0.01	0.08	0.20	0.16	0.02	0.01	0.04	0.00	0.01	0.	0.	0.57
TOTALS	VS	0.72	0.63	0.42	0.55	0.63	1.10	0.91	0.92	0.81	1.26	1.75	2.92	3.79	5.03	2.30	1.25	0.41	0.73	26.12
	MS	1.07	0.81	0.59	0.70	1.12	1.73	1.30	1.39	2.10	3.61	2.77	2.85	5.26	9.17	2.77	1.59	0.26	1.30	40.39
	N	1.02	0.96	0.72	0.83	1.01	1.30	0.87	0.52	0.66	0.93	0.77	0.85	2.60	5.26	1.93	1.49	0.14	1.42	23.29
	U	0.95	0.66	0.41	0.29	0.23	0.18	0.08	0.13	0.36	0.53	0.64	0.34	0.80	2.46	1.13	0.91	0.06	0.06	10.20

II.3-E-20

TABLE II.3-E-4 (Continued)

		SEASON - ANNUAL																		
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.21	0.21	0.15	0.20	0.26	0.38	0.23	0.23	0.20	0.23	0.22	0.40	0.34	0.43	0.37	0.35	0.21	0.48	5.11
	MS	0.17	0.18	0.16	0.21	0.33	0.42	0.20	0.18	0.12	0.12	0.13	0.21	0.22	0.31	0.28	0.29	0.13	0.50	4.15
	N	0.30	0.34	0.27	0.33	0.36	0.44	0.22	0.15	0.13	0.11	0.10	0.18	0.18	0.33	0.41	0.41	0.13	0.48	4.87
	U	0.49	0.64	0.36	0.40	0.31	0.27	0.12	0.17	0.10	0.16	0.10	0.14	0.14	0.27	0.37	0.54	0.46	0.04	5.00
4 - 7	VS	0.21	0.18	0.14	0.17	0.20	0.33	0.28	0.28	0.24	0.35	0.50	0.96	1.08	1.00	0.69	0.39	0.02	0.	7.02
	MS	0.17	0.15	0.13	0.15	0.22	0.36	0.21	0.17	0.15	0.21	0.24	0.42	0.50	0.68	0.47	0.31	0.02	0.	4.56
	N	0.12	0.13	0.10	0.12	0.19	0.26	0.14	0.10	0.07	0.10	0.11	0.16	0.27	0.55	0.33	0.18	0.01	0.	2.94
	U	0.94	0.90	0.55	0.58	0.53	0.62	0.37	0.45	0.45	0.51	0.37	0.38	0.48	1.13	1.11	1.18	0.30	0.	10.84
8 -12	VS	0.13	0.11	0.08	0.07	0.07	0.13	0.21	0.11	0.12	0.24	0.59	1.23	2.00	1.74	0.60	0.20	0.	0.	7.65
	MS	0.11	0.08	0.03	0.06	0.10	0.21	0.19	0.13	0.20	0.34	0.50	0.96	1.47	1.53	0.38	0.14	0.00	0.	6.43
	N	0.06	0.04	0.03	0.03	0.04	0.09	0.07	0.04	0.06	0.09	0.14	0.14	0.42	0.78	0.15	0.06	0.	0.	2.25
	U	0.48	0.33	0.12	0.09	0.09	0.15	0.11	0.14	0.34	0.59	0.56	0.33	0.59	1.42	0.52	0.45	0.00	0.	6.31
13-18	VS	0.05	0.03	0.02	0.02	0.00	0.04	0.10	0.03	0.03	0.09	0.25	0.43	1.25	1.53	0.17	0.05	0.	0.	4.10
	MS	0.10	0.05	0.02	0.02	0.02	0.07	0.13	0.15	0.25	0.54	0.87	1.24	3.04	2.23	0.18	0.10	0.	0.	9.03
	N	0.05	0.01	0.01	0.01	0.00	0.03	0.04	0.05	0.07	0.14	0.24	0.16	0.44	0.58	0.06	0.04	0.	0.	1.94
	U	0.26	0.13	0.03	0.01	0.01	0.03	0.04	0.05	0.18	0.54	0.68	0.26	0.64	0.98	0.09	0.14	0.	0.	4.07
19-24	VS	0.	0.00	0.00	0.00	0.	0.00	0.01	0.01	0.01	0.02	0.04	0.02	0.06	0.18	0.00	0.00	0.	0.	0.37
	MS	0.04	0.03	0.01	0.00	0.00	0.02	0.06	0.11	0.21	0.53	0.50	0.33	1.55	1.45	0.03	0.02	0.	0.	4.91
	N	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.03	0.08	0.15	0.17	0.05	0.25	0.34	0.01	0.02	0.	0.	1.17
	U	0.06	0.05	0.01	0.00	0.	0.00	0.01	0.02	0.11	0.34	0.41	0.12	0.32	0.63	0.01	0.03	0.	0.	2.13
OVER 24	VS	0.	0.00	0.	0.	0.	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.	0.	0.	0.	0.	0.04
	MS	0.01	0.01	0.	0.	0.	0.01	0.02	0.08	0.30	0.47	0.22	0.06	0.55	0.76	0.00	0.01	0.	0.	2.50
	N	0.01	0.01	0.00	0.00	0.	0.	0.01	0.02	0.08	0.17	0.09	0.03	0.21	0.30	0.00	0.01	0.	0.	0.93
	U	0.02	0.03	0.01	0.	0.	0.	0.	0.01	0.09	0.40	0.31	0.08	0.17	0.46	0.01	0.00	0.	0.	1.57
TOTALS	VS	0.60	0.54	0.39	0.47	0.53	0.88	0.83	0.67	0.61	0.95	1.61	3.05	4.73	4.89	1.83	1.00	0.23	0.48	24.29
	MS	0.60	0.50	0.36	0.45	0.67	1.08	0.82	0.83	1.22	2.21	2.46	3.23	7.33	6.96	1.34	0.67	0.14	0.50	31.57
	N	0.56	0.55	0.42	0.49	0.60	0.82	0.49	0.40	0.48	0.76	0.85	0.72	1.78	2.88	0.95	0.72	0.15	0.48	14.11
	U	2.25	2.08	1.08	1.09	0.94	1.07	0.65	0.84	1.27	2.53	2.43	1.30	2.35	4.90	2.11	2.34	0.77	0.04	30.03

II.3-E-21

FIGURE II.3-E-8 WIND ROSES AS A FUNCTION OF STABILITY AND FOR ALL STABILITIES AT HANFORD-1 BASED ON WINDS AT 200 FT AND AIR TEMPERATURE BETWEEN 3 FT AND 200 FT FOR THE PERIOD JANUARY 29, 1970 TO JANUARY 28, 1971 (the points of the rose represent the directions from which the winds come)

TABLE II.3-E-5

HANFORD STABILITY DEFINITION AND COMPARISON
WITH PASQUILL CLASSES AS DEFINED IN USAEC
REGULATORY GUIDE 1.23

<u>Hanford Diffusion Model</u>		<u>Regulatory Guide 1.23</u>	
<u>Class</u>	<u>$\Delta T/\Delta z$ ($^{\circ}\text{F}/200 \text{ ft}$)</u>	<u>Pasquill Class</u>	<u>$\Delta T/\Delta z$ ($^{\circ}\text{F}/200 \text{ ft}$)</u>
Unstable	less than or equal to -1.5	A	less than -2.1
Neutral	-1.4 to -0.5	B	-2.1 to -1.9
		C	-1.9 to -1.6
		D	-1.6 to -0.6
Moderately Stable	-0.4 to 3.4	E	-0.6 to 1.6
		F	1.6 to 4.4
Very Stable	greater than or equal to 3.5	G	greater than 4.4

FIGURE II.3-E-9 MONTHLY AVERAGE WIND ROSES FOR THE WNP-2 SITE BASED ON 1 YEAR OF DATA TAKEN AT 23 FEET (the numbers in the centers are the percentages of calm [top number] and variable [bottom number] winds) (the points of the rose represent the directions from which the winds come)

FIGURE II.3-E-10 MONTHLY AVERAGE WIND ROSES FOR THE HMS BASED ON 1 YEAR OF DATA TAKEN AT 50 FEET (the numbers in the centers are the percentages of calm [top numbers] and variable [bottom number] winds) (the points of the rose represent the directions from which the winds come)

FIGURE II.3-E-11 MONTHLY AVERAGE WIND ROSES FOR HMS BASED ON 50 FEET WIND DATA, 1955-1970 (the numbers in the centers are the percentages of calm [top numbers] and variable [bottom number] winds) (the points of the rose represent the directions from which the winds come)

long term; likewise, apparent differences between the two sites indicated by the two short-term periods of record are probably authentic differences. The most outstanding difference appears to be the much more frequent occurrence of west and northwest wind directions at the HMS site. This can be attributed to the gravity of "drainage" wind which occurs regularly at the HMS during the nocturnal hours but not at the WNP-2 site.

Surface wind rose data based on an eight point compass have been compiled from the telemetering network of meteorological stations. A summary of these wind roses plotted on a map of the measurement site is given in Figure II.3-E-12. These sensors were located so that they would define local topographical effects on surface winds as well as the general surface flow of winds. The occurrence of the gravity or "drainage" wind can be seen at stations 1, 8, 12, 13, and 14. The high occurrence of winds along a southwest-northeast axis at Station 10 can be attributed to a local channeling by topography. At Station 15 again the high occurrence of southwest winds is due to local channeling. At Station 9, too, the northwest-southeast effect is due to channeling.

As material is transported and dispersed by the atmosphere, a portion of it may be carried or diffused to heights well above the surface boundary layer. For this reason, climatological information on the winds above the surface based sensors is valuable. The seasonal and annual wind rose plots for four levels up to 1500 m are shown in Figure II.3-E-13. The 15 m level wind roses were derived from the once daily observation taken at 1300 PST from the 15 m level on the Hanford tower. The other levels are based on pibal data for a period of 11 years derived from monthly summaries of wind direction and average speed for the 1300 PST observation. For comparison purposes, Figure II.3-E-14 shows the wind roses from this level for the observations taken at 0100 PST, 1300 PST and the composite for all 24 hours.

FIGURE II.3-E-12

SURFACE WIND ROSES FOR VARIOUS LOCATIONS ON AND SURROUNDING THE HANFORD SITE BASED ON FIVE-YEAR AVERAGES (1952-1956). SPEEDS ARE GIVEN IN MILES PER HOUR. (the points of the rose represent the directions from which the winds come)

FIGURE II.3-E-13 SEASONAL AND ANNUAL WIND ROSES FROM PIBAL
(1500, 1000, 500m) AND TOWER (15m) DATA

II.3-E.4.1 Strong Winds

The highest monthly wind speeds and peak gusts recorded at the HMS are tabulated in Table II.3-E-6. Figure II.3-E-15 indicates the return probability of any peak wind gust, again due to any cause. For example, a gust of 96 mph might be expected to occur once every 500 years.

At certain locations other than the HMS site, strong winds can be expected due to orographic channeling or to elevation effects. The U.S. Army Corps of Engineers made a limited three-year study¹⁰ of surface winds along the Columbia River from McNary Dam to Wallula, upstream 20 miles. Their findings represent what might be encountered elsewhere on the Columbia River in the vicinity of the Hanford area.

The Corps of Engineers recorded wind data demonstrates that moderate to strong surface winds tend to blow within and approximately parallel to the river channel, with the predominant wind movement from west to east. However, winds 10 to 30 degrees from the river alignment are not uncommon. Some evidence, including smoke trails, indicates that at times a core of higher speed wind occurs over the river. This wind core appears to change position slightly within short time periods. Aerial observations of smoke and dust suggest that in the more entrenched reaches of the Columbia River it may ride up on the steep outside slopes of river bends and possibly even develop reflection meanders downwind of entrenched bends. It is suspected that the low-level wind field undergoes vertical as well as horizontal compression and expansion. Under certain meteorological conditions the core of stronger mid-river wind appears to be nonexistent or very weak.

One period of notably strong winds occurred at Hanford on January 11, 1972.¹¹ The passage of an occluded front during the morning hours preceded strong gale force winds, with gusts exceeding hurricane force. Tables II.3-E-7 and 8 list various peak wind gusts recorded or observed on and in the immediate vicinity of the Hanford site and show the

TABLE II.3-E-6

HIGH WIND STATISTICS AT HMS - HIGHEST
AVERAGE MONTHLY WIND SPEED AND PEAK GUSTS

<u>Month</u>	<u>Highest Average</u>	<u>Year</u>	<u>Peak Gust</u>		
			<u>Speed</u>	<u>Dir</u>	<u>Year</u>
Jan	10.3 ^(a)	1972	80 ^(b)	S	1972
Feb	9.4	1961	63	SW	1965
Mar	10.7	1964	70	SW	1956
Apr	11.1	1959	60	WSW	1969
May	10.5	1965+	71	SSW	1948
June	10.7	1949	72	SW	1957
July	9.6	1963	55	WSW	1968
Aug	9.1	1946	66	SW	1961
Sept	9.2	1961	65	SSW	1953
Oct	9.1	1946	63	SSW	1950
Nov	7.9	1945	64	SSW	1949
Dec	8.3	1968	71	SW	1955
YEAR	8.3	1968+	72 ^(b)	SW	JUNE 1957

(a) The average speed for January 1972 was 10.3 MPH

(b) On January 11, 1972, a new all-time record peak gust of 80 MPH was established

FIGURE II.3-E-15 PEAK WIND GUST RETURN PROBABILITY DIAGRAM

TABLE II.3-E-7

EXAMPLE OF AN EXTREME HIGH WIND OCCURRENCE,
DATA RECORDED BY THE AEC (BATTELLE) NETWORK
OF WIND SENSORS ON JANUARY 11, 1972

Observation Site	Location (a)	Elevation (MSL-ft)	Height of Sensor Above Ground (ft)	Wind (mph)	Time (PST)
Hanford Met Tower	1	727	7	64	0345
Hanford Met Tower	1	727	50	80	0345
Hanford Met Tower	1	727	100	79	0835
Hanford Met Tower	1	727	150	--(b)	--(b)
Hanford Met Tower	1	727	200	84	0835
Hanford Met Tower	1	727	250	82	0837
Hanford Met Tower	1	727	300	84(c)	0835
Hanford Met Tower	1	727	400	84	0827
Rattlesnake Mountain	11.0 S	3568	10	150+(d)	0546-0924
Army Loop Road	7.5 ESE	555	50	60+(e)	0900-1700
Central Wahluke Slope ^(f)	12.0 NNW	660	23	32	0155
Yakima Barricade ^(f)	6.0 WNW	795	23	45	0455
Gable Mountain ^(f)	7.0 ENE	1100	23	41	0055
Wye Barricade ^(f)	11.5 SE	550	23	43	0055
Prosser Barricade ^(f)	14.5 SE	450	23	35	0055
Richland Barricade ^(f)	26.5 SE	390	23	33	0355
Rattlesnake Mountain ^(f)	11.0 S	3568	9	--(g)	--(g)
Eastern Wahluke Slope ^(f)	17.5 NE	800	23	34	0455
Ringold ^(f)	17.5 E	620	23	30	0355

(a) Distance (miles) and direction from the Hanford Meteorology Tower located at 46° 34'N latitude, 119° 36'W longitude, approximately 25 miles NW of Richland, Washington.

(b) Equipment malfunction.

(c) Interpolated value.

(d) Limit of recorder 150 mph, also visually observed.

(e) Temporary research equipment - limit of recorder 60 mph.

(f) Radio-Telemetered Automatic Weather Station - highest hourly integrated wind speed, not equipped with gust recorded.

(g) Power outage for telemetering equipment during periods of peak winds.

TABLE II.3-E-8

EXAMPLE OF EXTREME HIGH WIND OCCURRENCE,
WIND OBSERVATIONS ON OR NEAR THE HANFORD RESERVATION FOR JANUARY 11, 1972

Observation Site	Location ^(a)	Height of Sensor Above Ground (ft)	Type of Data Readout	Peak Wind (mph)	Time (PST)	Operating Agency	Remarks
FFTF	15.0 SE	13	Analog Tape	--	--	AEC(HEDL)	Recorder limit, 60 mph Equipment malfunction
FFTF	15.0 SE	25	Dial	65	A.M.	AEC(Bechtel)	Visual observation
N Reactor	8.0 NNE	200	Analog Tape	42	0830-0900	AEC(DUN)	Recorder not activated; visual observation
Richland Airport	22.0 SE	30	Strip Chart	74	0245	AEC(Battelle)	
Priest Rapids Dam	18.0 NW	30	Dial	100+	0700+	Grant County PUD	Visual observation; dial limit - 100 mph
Richland By-Pass Highway	24.0 SE	35	Dial	100+	A.M.	Teleprompter Cable TV Co.	Visual observation; dial limit - 100 mph
Tri-Cities Airport (Pasco)	30.0 SE	16	Dial	63	A.M.	Hughes Air west	Visual observation
KONA Radio (Pasco)	32.0 SE	30	Manometer	78	1000	KONA Radio	Visual observation
Columbia TV (Kennewick)	35.0 SE	40	Dial	100+	1200-1300	Columbia TV	Visual observation; dial limit - 100 mph

(a) Miles from Hanford Meteorology Station

patterns of the extreme winds that occurred at various locations on the site.

Perhaps the "windiest" site on the Hanford Reservation is the crest of Rattlesnake Mountain, at an elevation of 3568 feet MSL, about 11 miles south of the HMS. Wind data are regularly recorded at this site but are not available in summary form. Some selected wind observations are listed in Table II.3-E-9 to give some insight into wind characteristics on Rattlesnake Mountain. These winds are considerably reduced at the elevations of most of the Hanford site, as shown in Figure II.3-E-15 where the peak wind gust return probability is given for three elevations.

II.3-E.4.2 Tornadoes

Two funnel clouds and one small tornado (June 16, 1948) have been observed in 26 years (1945-70) at Hanford. However, the nearest reported tornado damage was at Yakima, about 45 miles west (April 30, 1957), and at Wallula Junction, about 50 miles southeast (June 26, 1958). No loss of life or extensive property damage was reported from any of the tornadoes observed in this region.¹²

On the average the state of Washington experiences less than one tornado each year.¹² Within a 100-mile radius of the HMS, only fourteen tornadoes have been reported since 1916.¹³ These tornadoes are listed in Table II.3-E-10. Of these fourteen recorded, only five were associated with any damage. An extensive survey of tornadoes in the three northwestern states (Washington, Oregon and Idaho) was completed in 1970.¹⁴ The results indicate that tornadoes in this area occur primarily in "alleys." The locations of these "alleys" are shown in Figure II.3-E-16, along with the locations of tornadoes recorded in the tri-state area during the 20-year period 1950-1969.

The tornado survey data was analyzed¹⁵ to determine the probability of a tornado striking the Exxon Nuclear Company, Inc. (formerly the Jersey

TABLE II.3-E-9

SELECTED RATTLESNAKE MOUNTAIN WIND OBSERVATIONS

<u>OCCURRENCE</u>	<u>AVERAGE SPEED (mph)</u>	<u>DURATION</u>	<u>PEAK GUSTS (mph)</u>
2-27-66	83	-	103
1-4-67	-	-	75
1-29-67	-	-	114
2-17-67	110	1/2 hr	136.5
10-3-67	97	3 hrs	129
3-22-69	100	1 1/4 hrs	-
3-22-69	120	1/4 hr	142.5
12-30-70	100	-	118.5
1-9-71	67	1 hr	96.5
1-24-71	-	-	117
2-10-71	-	-	120
12-4-71	60	-	72
12-5-71	45	-	63
12-8-71	-	-	87
1-11-72	120	3/4 hr	150+ limit of recorder

TABLE II.3-E-10

TORNADO HISTORY WITHIN 100 MILES OF HMS

DATE	LOCATION
June 26, 1916	Walla Walla, Washington
April 15, 1925	Condon, Oregon
September 2, 1936	Walla Walla, Washington
May 20, 1948	Yakima, Washington
May 29, 1948	Yakima, Washington
June 11, 1948	Ephrata, Washington
June 16, 1948	Hanford Reservation
May 9, 1956	Kennewick, Washington
April 12, 1957	Ione, Oregon
April 30, 1957	Yakima, Washington
May 6, 1957	Harrington, Washington
April 24, 1958	Walla Walla, Washington
June 26, 1958	Wallula Junction, Washington
March 14, 1966	Little Goose Dam, Washington

FIGURE II.3-E-16 DISTRIBUTION OF CHARACTERIZED TORNADOES IN 20-YEAR PERIOD, 1950-1969

Nuclear Company) fuel fabrication facility approximately 25 miles southeast of the HMS. The analysis indicates the probability of tornado occurrence in the vicinity of the site as six chances in a million during any given year or about one chance in four thousand during a 40-year plant life.

The maximum wind speed for the Hanford site is estimated as 175 mph.³² This agrees with the best estimate of 174 mph derived in the statistical tornado study made by Exxon Nuclear Company, Inc.¹⁵

II.3-E.4.3 Dust Devils

Dust devils are frequently observed phenomena on the Hanford Reservation, particularly during the summer months. No objectively determined observations, measurements, or summaries pertaining to dust devil characteristics at Hanford have been compiled. However, investigators utilizing specially instrumented grids and other techniques have determined various characteristics of dust devils in desert-type areas. Since the Hanford area is also a desert-type area, it is believed that Hanford dust devils would have some degree of similarity to these others.

The following definitions have been extracted verbatim from the Glossary of Meteorology,¹⁷ American Meteorological Society, 1959:

dust devil--A well-developed dust whirl; a small but vigorous whirlwind, usually of short duration, rendered visible by dust,

sand, and debris picked up from the ground. Diameters range from about 10 feet to greater than 100 feet; their average height is about 600 feet, but a few have been observed as high as several thousand feet. They have been observed to rotate anticyclonically as well as cyclonically. (Dust devils are best developed on a hot, calm afternoon with clear skies, in a dry region when intense surface heating causes a very steep lapse rate of temperature in the lower few hundred feet of the atmosphere.)

dust-devil effect--In atmospheric electricity, a rather sudden and short-lived change of the vertical component of the atmospheric electric field that accompanies passage of a dust devil near an instrument sensitive to the vertical gradient. Such changes may be either positive or negative and the charge is probably produced by triboelectrification.

The following has been extracted from a report by S. E. Logan,¹⁸ Lawrence Radiation Laboratory, 1969:

"Lifetimes vary from a few seconds to nearly 20 minutes, most lasting under two minutes.¹⁹ Ives²⁰ observed an exceptional example during construction of a large railroad embankment near Sonora: 'In midmorning, a large dust devil suddenly appeared at the end of the embankment, and removed therefrom approximately one cubic yard of sand per hour for four hours. Erosion was halted, and the dust devil broken up, by parking a bulldozer at the end of the fill.'

Dust devils depend directly on the availability of heated boundary-layer air and dissipate quickly if this fuel is removed. The dust columns tend to meander across the desert floor at the prevailing wind speed. However, observers¹⁹ have detected an apparent critical wind speed above which dust devil activity decreases, probably due to destruction of the heated boundary layer by increased vertical mixing and shearing of the vortices near the ground. The

vertical velocities near the ground can be appreciable; Ives²⁰ made an early estimate of these by measuring the terminal velocities of small animals sometimes lifted by dust devils."⁽¹⁾

However, more detailed measurements of dust devil velocity, pressure and temperature fields have been made. The results included tangential velocities approaching 15 m/sec, vertical velocities of ten m/sec (at seven feet), and maximum radial velocities of about five m/sec. Commonly, between the environment and the core there is a pressure drop in excess of two mb and a temperature increase of 4°C or more. Recent observation results have been developed into a quantitative dust devil model.^{21,22} Over 1119 dust devils were observed at close range during a study conducted in the Mojave Desert of Southern California.²³ Maximum horizontal wind speeds up to 34.2 km/hr and vertical wind speeds up to 7.2 km/hr were recorded. A 1947 investigation²⁰ reported velocities up to 180 km/hr. In a study conducted in the desert of the White Sands Missile Range in New Mexico,²⁴ wind speeds up to 32 knots and pressure drops of 2.2 mbs were reported.

It would appear reasonable to assume that Hanford dust devils have similar characteristics.

II.3-E.4.4 Hurricanes

This region is not known to have experienced any hurricanes.

(1) In his amusing account Ives notes that the kangaroo rat (terminal velocity ~25 mph) is "apparently unhurt after landing, although usually very angry," whereas a jackrabbit (terminal velocity ~35 mph) is "stunned and internally injured."

II.3-E.5 Severe Weather and Miscellaneous Phenomena

II.3-E.5.1 Thunderstorms

A thunderstorm day is one in which thunder is heard. If a thunderstorm begins in the late evening and lasts past midnight, it is counted as two thunderstorm days even though only one storm event has occurred. Similarly, should there be two or more distinct thunderstorms in a day--and this sometimes happens--it is counted as a single thunderstorm day.²⁵ Thunderstorms may occur during any month of the year in this area. Although the tabulation below shows zero for the months November through January, the summary period¹ ended in 1970 and a thunderstorm did occur on December 22, 1971. In Richland, about 25 miles southeast of the HMS, one occurred on January 18, 1953. However, the thunderstorm season essentially includes only the months April through September. Although the average is 11 days per year, the number has varied from 3 to 23. In June 1948 there were 8 thunderstorm days during the month, and this record was repeated in August 1953.

Although severe thunderstorms are rare,¹ lightning strikes have occasionally ignited grass fires which have burned thousands of acres of Hanford Reservation land and have resulted subsequently in considerable wind erosion of soil. The most notable of these occurrences were in August 1961, July 1963, July 1970, and August 1973.

THUNDERSTORM DAYS: 1945-1970¹

	<u>J</u>	<u>F</u>	<u>M</u>	<u>A</u>	<u>M</u>	<u>J</u>	<u>J</u>	<u>A</u>	<u>S</u>	<u>O</u>	<u>N</u>	<u>D</u>	<u>SUM</u>
Total	0	1	7	18	53	64	46	54	24	5	0	0	272
Average	0	#	1	1	2	3	2	2	1	#	0	0	12
% of Total	0	#	3	7	19	23	17	20	9	2	0	0	100

- less than 0.5

II.3-E.5.2 Hail

Hail was reported at the HMS on 14 days or 5% of the days when thunderstorms were reported¹ (see preceding discussion). The monthly distribution of days on which hail occurred is as follows:

	<u>J</u>	<u>F</u>	<u>M</u>	<u>A</u>	<u>M</u>	<u>J</u>	<u>J</u>	<u>A</u>	<u>S</u>	<u>O</u>	<u>N</u>	<u>D</u>	<u>TOTAL</u>
Number	0	1	1	4	2	1	2	2	1	0	0	0	14
% of Total	0	7	7	30	14	7	14	14	7	0	0	0	100

The hail ranged in size from 0.2 to 0.3 inch in all but two of the available reports. The exceptions were May 26, 1954, and July 1, 1955, when the size reported was 0.4 inch.

Precipitation was not measured during 1945 and 1946, years in which 26 thunderstorm days occurred. This left 246 such days during the period 1947-1970. The daily precipitation distribution during these days was as follows:

<u>Amount - Inches</u>	<u>Number of Cases</u>	<u>% of Total</u>
None or trace	110	45
0.01 - 0.10	87	35
0.11 - 0.25	29	12
0.26 - 0.50	15	6
>0.50	<u>5</u>	<u>2</u>
	246	100

The record for rainfall intensity during a thunderstorm is 0.55 inch in 20 minutes (1.65 inches per hour) on June 12, 1969. This storm included hailstones of 1/4 inch diameter. Blowing dust or dust was reported on 16 thunderstorm days and both hail and blowing dust or dust on 6 days.¹

Peak gust data are not available for the 50, 200, and 400-foot tower levels prior to 1952. The speed classification of peak gusts on the 185 thunderstorm days occurring during the period 1952-1970 is as follows:¹

<u>mph</u>	<u>Number of Cases</u>			<u>% of Total</u>		
	<u>50</u> (ft)	<u>200</u> (ft)	<u>400</u> (ft)	<u>50</u> (ft)	<u>200</u> (ft)	<u>400</u> (ft)
< 21	18	9	5	10	5	3
21 - 30	75	45	42	40	24	23
31 - 40	63	80	73	34	43	39
41 - 50	23	34	46	12	19	25
51 - 60	4	11	12	2	6	6
61 - 70	1	4	5	1	2	3
> 70	1	2	2	1	1	1
	<u>185</u>	<u>185</u>	<u>185</u>	<u>100</u>	<u>100</u>	<u>100</u>

II.3-E.5.3 Lightning

A technique for estimating lightning stroke frequency based on the commonly observed climatological statistic, thunderstorm days, has been developed.²⁶

The annual number of discharges N_{yh} to a structure is given by:

$$N_{yh} = \sigma_{yg} A_a F_T$$

where σ_{yg} is the frequency of ground strikes of lightning, A_a is the "attractive area" of a structure and F_T is a factor which accounts for the triggering effect of high structures on lightning. σ_{yg} is a function of thunderstorm frequency and the ratio of innocuous cloud-to-cloud strokes to the potentially damaging cloud-to-ground strikes. This latter ratio is a function of latitude. A_a is a function of the height of the structure being considered.^(a) F_T is considered negligible, i.e., 1.0 for structures less than 100 m in elevation.

(a) Cianos and Pierce point out that in the case of towers at the summits of sharply peaked mountains, the effective height is substantially greater than the actual height of the structure.

Use of this technique, resulted in the computation of an annual lightning strike frequency of 0.022, or one strike per 46 years, for a structure with dimensions of 30 x 35 m and a height of about 10 m with a thunderstorm-day frequency of 11 per year.¹ (This frequency could be somewhat less if there were obvious protrusions, such as taller structures or trees, in the vicinity. Such protrusions distort the surface of equal electrical potential gradients in the atmosphere and tend to attract lightning strikes.) A similar computation was made for the 122 m Hanford Meteorology Tower which resulted in an annual lightning strike frequency of 0.225, or one strike every 4.44 years. The "reasonableness" of this technique can be adjudged by the fact that three strikes on this tower have been confirmed during its 30-year existence (bearing in mind that all strikes may not have been observed).

II.3-E.5.4 Glaze

Glaze is a coating of ice, generally clear and smooth but with some air pockets. It is formed on exposed objects at temperatures below or slightly above 32°F by the freezing of super-cooled drizzle or raindrops. Glaze is denser, harder, and more transparent than either rime or hoarfrost.¹⁷ Although the record shows an average of 7 glaze days per year,¹ many of these cause little or no inconvenience to the public. Two outstanding exceptions occurred on February 11-12, 1954, and on November 23-24, 1970. There was serious disruption to area traffic in each instance, although there was no known damage to transmission lines. In each instance, rising temperatures soon melted the ice.

II.3-E.5.5 Fog

Although fog has been observed in every month of the year at HMS, it is essentially a seasonal phenomenon, with 95% of fog observed during the months November through February. Inclusion of March and October fog would increase this percentage to 99.7. Tables II.3-E-11 and II.3-E-12 summarize the statistics on fog occurrence at HMS.¹ Because of the higher availability of moisture in the vicinity of the Columbia River,

TABLE II.3-E-11

AVERAGE NUMBER OF DAYS OF FOG AT HMS

Based on all Available Data from 1945 to 1970													
	<u>J</u>	<u>F</u>	<u>M</u>	<u>A</u>	<u>M</u>	<u>J</u>	<u>J</u>	<u>A</u>	<u>S</u>	<u>O</u>	<u>N</u>	<u>D</u>	<u>Y</u>
Fog ^(a)	9	6	1	(c)	(c)	(c)	(c)	(c)	(c)	2	8	12	38
Fog, dense ^(b)	6	3	1	(c)	(c)	0	0	(c)	(c)	1	5	8	24

(a) All fog regardless of visibility

(b) Visibility 1/4 mile or less

(c) Less than 1/2 day

it can be anticipated that both the frequency and persistence of fog in that area would be somewhat greater than at the HMS.

No fog observations have been regularly recorded for the slopes and the crest of Rattlesnake Mountain. However, because of Rattlesnake's higher elevation, one would not expect any HMS fog statistics to be descriptive of fog events there. Frequent occurrences of a crest cloud^(a) on the Hanford Reservation have been observed. At other times it has often been noted that when most areas of the Hanford Reservation were experiencing fog and/or low stratus clouds, the crest of Rattlesnake Mountain was clear and above the fog.

II.3-E.5.6 Air Pollution Potential (APP)

Consideration of the general weather parameters indicates a significantly high average annual APP over southeastern Washington. The mean annual mixing depth²⁷ in this area is about 450 m and for July about 2000 m. A significantly high frequency of low-level inversion²⁸ in winter over this area is indicated on the order of 43% with bases below

(a) "A type of standing cloud which forms along a mountain ridge, either on the ridge or slightly above and to leeward of it, and remains in the same position relative to the ridge."²⁵

TABLE II.3-E-12

TOTAL DURATION^(a) AND MAXIMUM PERSISTENCE OF FOG AT THE
HMS TABULATED IN HOURS FOR THE PERIOD 1945-70

ALL FOG (VIZ 0-6 MILES)	AVG TOTAL DURATION	MAX TOTAL DURATION	YEAR	MIN TOTAL DURATION	YEAR	AVG DURATION PER DAY OF OCCURRENCE	MAX. PERSISTENCE ^(c)	YEAR
JAN	68.3	193.4	1965	0	1949	7.2	58.1	1955
FEB	36.4	206.2	1963	0	1967	6.2	58.0	1963
MAR	4.4	20.6	1951	0	1968+	3.1	12.2	1949
APR	0.3	2.8	1950	0	1970+	1.4	2.8	1950
MAY	0.3	2.7	1958	0	1970+	1.2	2.7	1958
JUNE	#	0.5	1948	0	1970+	0.5	0.5	1948
JULY	#	0.7	1966	0	1970+	0.7	0.7	1966
AUG	#	1.0	1959	0	1970+	1.0	0.7	1959
SEPT	0.3	5.5	1957	0	1970+	2.0	2.6	1957
OCT	7.6	63.6	1962	0	1970+	3.9	39.0	1962
NOV	55.4	148.0	1952	1.0	1960	6.8	65.4	1963
DEC	105.4	193.8	1947	6.5	1968	8.7	72.3	1947
Y	278.4	462.5 ^(a)	1964-65	147.7 ^(b)	1948-49	7.0	72.3	1947-48
DENSE FOG (VIZ 1/4 MI OR LESS)								
JAN	20.4	52.4	1955	0	1949	3.4	15.0	1953
FEB	12.7	86.7	1963	0	1967+	3.8	16.7	1963
MAR	1.8	7.8	1949	0	1968+	2.2	5.0	1961
APR	0.1	1.8	1955	0	1970+	1.8	0	----
MAY	0.1	1.6	1958	0	1970+	1.6	1.6	1958
JUNE	0	0	----	0	----	0	0	----
JULY	0	0	----	0	----	0	0	----
AUG	#	1.0	1959	0	1970+	1.0	0.7	1959
SEPT	0.1	3.2	1957	0	1970+	3.2	1.4	1957
OCT	3.1	35.2	1962	0	1970+	3.1	15.8	1962
NOV	21.1	71.4	1952	0	1960	4.1	20.6	1963
DEC	42.0	119.8	1947	1.3	1968	5.4	47.0	1957
Y	101.4	201.5 ^(a)	1962-63	47.3 ^(b)	1948-49	4.2	47.0	1957-58

(a) TOTAL DURATION DENOTES TOTAL NUMBER OF HOURS AND TENTHS OF HOURS IN WHICH FOG IS OBSERVED.

(b) DENOTES LESS THAN 0.05 HOUR

(c) DENOTES THE GREATEST NUMBER OF HOURS IN A SEASON

(d) DENOTES THE LEAST NUMBER OF HOURS IN A SEASON

(e) MAXIMUM PERSISTENCE OF DENSE FOG IS BASED ON THE PERIOD 1953-70

150 m. The occurrence of very stable and moderately stable conditions between the surface and 60 m in winter at the HMS is 66.5%.¹

Stagnation²⁹ is defined as "the persistence of a given volume of air over a region, permitting an abnormal buildup of pollutants from sources within the region." By defining stagnation as an uninterrupted period of daily average wind speed of 5.0 mph or less and/or a peak gust of 15 mph or less, a 15-year summary³ of stagnation periods covering the months November through February (1947-48 through 1961-62) was accomplished. The two most notable stagnation periods experienced during this time occurred in November and December, 1952. The first period was from November 15 to December 3 (19 days). Then, after 5 days of ventilation, stagnation set in again on December 9 and lasted through December 28 (20 days). Average wind speeds during the two periods were, respectively, 2.6 and 2.9 mph. Eleven days during the first period and eight during the second had peak gusts under 10 mph. One day during the first period and two during the second had average speeds less than 1.0 mph with peak "gusts" of 4 mph. There were 13 days of fog in each period.

Figure II.3-E-17 summarizes the preceding investigation. Examination of this figure reveals that although stagnation lasting for 20 days can be expected only one season in 20, a 10-day stagnation period can be expected every other season. Only one season in three will fail to produce a stagnation period of at least 8 days.

It can be noted that the major cause of air pollution in the area is dust occurring during windy periods. The most significant sources are cultivated fields in the surrounding area. Dust or blowing dust occurs on an average of 6 days per year.¹

II.3-E.5.7 Sky Cover and Solar Radiation

The number of clear, partly cloudy, and cloudy days at the HMS itemized in Table II.3-E-13 come from assigning each day to one of three categories in accordance with the following:¹

11.3-E-50

FIGURE II.3-E-17 SEASONAL MAXIMUM PERSISTENCE OF STAGNATION, 1947-48 THROUGH 1961-62

TABLE II.3-E-13

HMS MONTHLY AND HOURLY SKY COVER AVERAGES
STATISTICS ON CLEAR, PARTLY CLOUDY,
AND CLOUDY DAYS

HOUR (PST)	TABULAR VALUES BASED ON THE PERIOD 1957-70												
	J	F	M	A	M	J	J	A	S	O	N	D	Y
00	7.1	6.0	5.2	5.1	4.6	4.4	2.4	2.5	3.4	4.5	6.6	7.4	4.9
01	7.1	6.1	5.4	5.2	4.6	4.1	2.2	2.5	3.4	4.5	6.7	7.5	4.9
02	7.1	6.1	5.4	5.3	4.5	4.0	2.1	2.4	3.5	4.7	6.6	7.5	4.9
03	7.3	6.2	5.4	5.2	4.8	4.5	2.4	2.4	3.5	4.8	6.4	7.4	5.0
04	7.4	6.3	5.5	5.5	5.2	4.7	2.5	2.8	3.5	4.8	6.5	7.5	5.2
05	7.4	6.7	5.7	6.0	5.6	5.0	2.7	3.3	4.3	5.0	6.6	7.8	5.5
06	7.5	7.2	6.3	6.2	5.6	4.9	2.6	3.4	4.5	5.5	6.8	7.8	5.7
07	8.1	7.5	6.6	6.3	5.6	4.8	2.7	3.3	4.4	5.9	7.5	8.3	5.9
08	8.3	7.6	6.8	6.3	5.4	4.7	2.5	3.2	4.3	5.8	7.7	8.4	5.9
09	8.2	7.6	6.7	6.3	5.5	4.8	2.4	3.0	4.2	5.8	7.6	8.3	5.9
10	8.2	7.5	6.6	6.4	5.6	5.0	2.5	3.2	4.3	5.8	7.4	8.5	5.9
11	8.1	7.3	6.8	6.5	5.8	5.3	2.6	3.2	4.3	5.8	7.4	8.4	5.9
12	8.1	7.4	6.9	6.7	6.0	5.2	2.8	3.3	4.3	6.0	7.6	8.3	6.0
13	8.1	7.4	7.0	7.0	6.2	5.3	2.9	3.4	4.4	6.2	7.7	8.2	6.1
14	8.0	7.4	7.0	7.0	6.1	5.3	3.0	3.5	4.4	6.3	7.6	8.1	6.1
15	8.0	7.4	6.9	6.9	6.3	5.4	3.1	3.6	4.4	6.4	7.5	8.1	6.2
16	8.1	7.4	6.9	7.0	6.4	5.6	3.2	3.7	4.4	6.4	7.3	8.0	6.2
17	7.9	7.2	6.9	6.8	6.2	5.4	3.2	3.6	4.4	6.2	7.1	7.8	6.0
18	7.5	6.7	6.7	6.7	6.1	5.4	3.1	3.4	4.4	5.9	6.9	7.6	5.9
19	7.4	6.3	6.3	6.4	6.1	5.3	3.2	3.2	4.2	5.6	6.6	7.6	5.7
20	7.3	6.2	5.9	6.0	5.8	5.1	3.0	3.1	3.9	5.4	6.5	7.5	5.5
21	7.1	6.2	5.7	5.6	5.2	4.8	2.8	2.8	3.8	4.9	6.6	7.4	5.2
22	7.2	6.3	5.4	5.4	4.7	4.3	2.4	2.7	3.6	4.8	6.5	7.3	5.0
23	7.0	6.2	5.3	5.2	4.5	4.0	2.3	2.6	3.4	4.6	6.7	7.2	4.9
AVG	7.6	6.9	6.2	6.1	5.5	4.9	2.7	3.1	4.0	5.5	7.0	7.8	5.6

AVERAGE SKY COVER (SUNRISE TO SUNSET) AND NUMBER OF DAYS CLEAR, PARTLY CLOUDY AND CLOUDY
1946-70

MONTH	SKY COVER (SCALE 0-10)						NUMBER OF CLEAR DAYS				PARTLY CLOUDY DAYS	AVG	NUMBER OF CLOUDY DAYS			
	AVG	RECORD GREATEST	YEAR	RECORD LEAST	YEAR	AVG	RECORD GREATEST	YEAR	RECORD LEAST	YEAR			RECORD GREATEST	YEAR	RECORD LEAST	YEAR
JAN	7.8	9.0	1969	4.3	1949	3	13	1949	0	1955+	6	22	27	1969+	6	1949
FEB	7.4	8.9	1961	5.9	1964	5	9	1968+	1	1969+	5	18	26	1958	10	1951+
MAR	6.7	7.9	1950	4.9	1965	7	12	1965+	2	1961+	8	16	22	1968	7	1948
APR	6.4	8.1	1963	3.7	1951	6	18	1951	1	1963	10	14	21	1963	3	1949
MAY	5.8	7.7	1960	4.5	1949	8	14	1953	2	1960	11	12	19	1960	3	1949
JUNE	5.2	7.0	1950	2.8	1961	10	21	1961	3	1966	10	10	15	1957	0	1949
JULY	2.7	4.5	1955	0.9	1953	20	27	1953	14	1955	7	4	8	1955	0	1967+
AUG	3.3	5.9	1968	0.6	1955	19	30	1955	11	1968	7	5	13	1968	0	1969+
SEPT	4.1	6.1	1959	2.5	1950	15	21	1967	8	1969	7	8	13	1969	2	1952+
OCT	5.9	7.7	1950	3.9	1952	10	16	1953	3	1950+	7	14	18	1956+	3	1946
NOV	7.5	9.0	1965	6.2	1957	5	10	1957	1	1965+	5	20	24	1965+	12	1948
DEC	8.1	9.2	1962	6.8	1954	3	7	1954	0	1947	5	23	28	1962	14	1946
Y	5.9	6.4	1966	5.1	1949	111	134	1967	85	1966	88	166	181	1969+	151	1967

<u>Category</u>	<u>Average Sky Cover (Tenths from Sunrise to Sunset)</u>
Clear	0 - 3
Partly Cloudy	4 - 7
Cloudy	8 - 10

About 200 days annually are sunny days at Hanford (the sum of the number of clear days and partly cloudy days).

Table II.3-E-14 presents solar radiation data measured at the HMS.¹

II.3-E.5.8 Precipitation¹

At the Hanford Meteorology Station average annual precipitation is 6.25 inches. The 3 months November-through-January contribute 42% of this total, while the 3 months July-through-September contribute only 10%. There are only two occurrences per year of 24-hour amounts of 0.50 inch or more, while occurrences of 24-hour amounts of 1.00 inch or more number only four in the entire 25 years of record (1946-1970). One of these was the record storm of October 1-2, 1957, in which rainfall totaled 1.08 inches in 3 hours, 1.68 inches in 6 hours, and 1.88 inches in 12 hours. At the other extreme, there have been 81 consecutive days without measurable rain (June 22-September 10, 1967), 139 days with only 0.18 inch (June 22-November 7, 1967), and 172 days with only 0.32 inch (February 24-August 13, 1968).

About 45% of all precipitation during the months December-through February is in the form of snow. However, only one winter in eight can expect an accumulation of as much as 6 inches on the ground. The average seasonal number of such days is five, although the 1964-65 winter had 35, 32 of which were consecutive.

Figure II.3-E-18 presents HMS average monthly precipitation data. It can be seen that there is a maximum during the winter months with a secondary maximum occurring in June. Tables II.3-E-15 and II.3-E-16 and Figures II.3-E-19 and II.3-E-20 present various observed and

TABLE II.3-E-14

HMS AVERAGE HOURLY AND DAILY SOLRAD TOTALS (LANGLEYS)
BASED ON THE PERIOD 1957-70

HOUR BEGINNING (PST)	J	F	M	A	M	J	J	A	S	O	N	D	Y
04	0	0	0	T	1.1	2.4	1.3	0.1	0	0	0	0	0.4
05	0	0	T	2.4	8.5	11.5	9.8	4.3	0.7	T	0	0	3.1
06	0	0.1	2.8	11.9	20.9	24.9	23.3	16.0	8.2	2.1	0.1	0	9.2
07	0.4	3.0	12.4	25.4	35.0	39.4	38.7	30.3	21.2	10.8	2.9	0.4	18.4
08	4.8	11.1	24.0	38.6	47.8	52.1	53.1	44.6	34.8	22.2	9.8	4.2	29.0
09	11.7	19.8	35.3	49.4	58.0	61.4	63.5	55.5	45.7	31.6	17.0	9.7	38.3
10	17.8	27.8	43.6	56.7	64.2	67.6	71.1	63.0	53.4	38.3	22.0	14.5	45.0
11	21.4	32.4	48.7	58.7	67.2	70.5	74.7	66.0	56.0	41.2	24.0	17.3	48.1
12	21.9	33.1	48.2	57.7	63.7	69.2	73.8	66.1	55.6	39.8	23.0	17.3	47.5
13	18.8	30.0	43.9	52.0	59.7	63.8	69.0	62.7	50.3	33.8	18.9	14.5	43.0
14	13.6	24.1	36.9	45.1	52.8	56.3	61.7	53.5	40.9	24.9	13.0	9.2	36.0
15	6.8	15.6	26.4	34.1	42.1	46.2	50.7	42.2	29.4	14.8	5.6	3.4	26.5
16	1.3	6.0	14.6	22.1	29.4	34.1	37.6	29.0	16.4	5.0	0.6	0.1	16.4
17	0	0.6	4.3	10.4	17.3	21.4	23.1	15.2	5.1	0.4	0	0	8.2
18	0	0	0.1	2.2	6.2	9.8	9.8	4.3	0.4	T	0	0	2.8
19	0	0	0	0	0.7	2.6	1.7	0.2	0	0	0	0	0.4
SUM * ^(a)	118.5	203.6	341.2	466.7	574.6	633.2	662.9	553.0	418.1	265.1	136.9	90.6	372.3
AVG ^(b)	118	200	340	470	571	626	659	551	418	262	135	91	370
HM	135	238	388	526	634	698	700	613	457	299	180	116	385
YEAR	1962	1960	1965	1959+	1970	1960	1969+	1955	1961	1958	1957	1970	1957
LM	88	164	305	374	511	563	588	475	354	227	97	57	357
YEAR	1955	1954	1961	1963	1962	1953	1955	1968	1959	1956	1964	1969	1967

(a) AVERAGE DAILY TOTAL BASED ON THE PERIOD 1957-70

(b) AVERAGE DAILY TOTAL BASED ON THE PERIOD 1953-70

HM HIGHEST MONTHLY AND ANNUAL (1953-70)

LM LOWEST MONTHLY AND ANNUAL (1953-70)

+ ALSO IN EARLIER YEARS

T AN AMOUNT TOO SMALL TO MEASURE

II.3-E-54

FIGURE II.3-E-18 AVERAGE MONTHLY PRECIPITATION AMOUNTS
BASED ON THE PERIOD 1912-1970

TABLE II.3-E-15

PROBABLE DURATION OF VARIOUS PRECIPITATION
INTENSITIES AT HANFORD FOR 500-YEAR STORM

<u>Time Period</u>	<u>Amount (Inches)^(a)</u>	<u>Intensity (Inches per Hour)^(a)</u>
5 minutes	0.5	6.0
10 minutes	0.6	3.6
15 minutes	0.7	2.8
20 minutes	0.73	2.2
30 minutes	0.9	1.8
40 minutes	0.93	1.4
50 minutes	1.00	1.2
60 minutes	1.02	1.02
2 hours	1.22	0.61
3 hours	1.33	0.44
4 hours	1.52	0.38
5 hours	1.70	0.34
6 hours	1.98	0.33
8 hours	1.84	0.23
10 hours	1.96	0.196
12 hours	2.34	0.195
18 hours	2.52	0.14
24 hours	2.47	0.103
1 year	15.60	-

(a) Differences in values between tables and figures can be attributed to smoothing errors when graphing the lines.

TABLE II.3-E-16

AVERAGE RETURN PERIOD (R) AND EXISTING RECORD (ER) FOR VARIOUS PRECIPITATION
AMOUNTS AND INTENSITY DURING SPECIFIED TIME PERIODS AT HANFORD

(based on extreme value analysis of 1947-69 records)

R (YEARS)	AMOUNT (INCHES)							INTENSITY (INCHES PER HOUR)						
	TIME PERIOD							TIME PERIOD						
	20 MIN	60 MIN	2 HRS	3 HRS	6 HRS	12 HRS	24 HRS	20 MIN	60 MIN	2 HRS	3 HRS	6 HRS	12 HRS	24 HRS
2	0.16	0.26	0.30	0.36	0.48	0.62	0.72	0.49	0.26	0.15	0.12	0.08	0.052	0.030
5	0.24	0.40	0.48	0.55	0.77	0.95	1.06	0.72	0.40	0.24	0.18	0.13	0.079	0.044
10	0.37	0.50	0.59	0.67	0.96	1.17	1.28	1.1	0.50	0.30	0.22	0.16	0.098	0.053
25	0.47	0.62	0.74	0.83	1.21	1.45	1.56	1.4	0.62	0.37	0.28	0.20	0.121	0.065
50	0.53	0.72	0.85	0.96	1.40	1.66	1.77	1.6	0.72	0.42	0.32	0.23	0.138	0.074
100	0.60	0.81	0.96	1.07	1.59	1.87	1.99	1.8	0.81	0.48	0.36	0.27	0.156	0.083
250	0.68	0.93	1.11	1.22	1.82	2.13	2.26	2.0	0.93	0.55	0.41	0.30	0.177	0.094
500	0.73	1.02	1.22	1.33	2.00	2.34	2.47	2.2	1.02	0.61	0.44	0.33	0.195	0.103
1000	0.80	1.11	1.33	1.45	2.20	2.55	2.68	2.4	1.11	0.67	0.48	0.37	0.212	0.112
ER	*	0.59	0.88	1.08	1.68	1.88	1.91	*	0.59	0.44	0.36	0.28	0.157	0.080
		6/12	10/1	10/1	10/1-2	10/1-2	10/1-2		6/12	10/1	10/1	10/1-2	10/1-2	10/1-2
DATE	--	1969	1957	1957	1957	1957	1957	--	1969	1957	1957	1957	1957	1957

* NO RECORDS HAVE BEEN KEPT FOR TIME PERIODS OF LESS THAN 60 MINUTES. HOWEVER, THE RAIN GAGE CHART FOR 6-12-69 SHOWS THAT 0.55 INCH OCCURRED DURING A 20-MINUTE PERIOD FROM 1835 TO 1855 PST. AN ADDITIONAL 0.04 INCH OCCURRED BETWEEN 1855 AND 1910 TO ACCOUNT FOR THE RECORD 60-MINUTE AMOUNT OF 0.59 INCH.

TO USE THIS CHART, SELECT ANY DESIRED RAINFALL INTENSITY AND DURATION AND READ FROM THE DIAGONAL LINES THE EXPECTED FREQUENCY OF SUCH INTENSITY AND DURATION. FOR EXAMPLE, RAINFALL INTENSITY OF 1.3 INCHES PER HOUR FOR 10 MINUTES CAN BE EXPECTED TO OCCUR, ON AVERAGE, ONCE EVERY 5 YEARS (POINT A). HOWEVER, SUCH INTENSITY CAN BE EXPECTED FOR 30 MINUTES DURATION ONLY ABOUT ONCE IN 100 YEARS (POINT B). THE RETURN PERIOD FOR THIS INTENSITY FOR 60 MINUTES DURATION IS GREATER THAN 1000 YEARS (POINT C).

THERE ARE, OF COURSE, VARIATIONS IN USE OF THE CHART. SUPPOSE, FOR EXAMPLE, IT IS DESIRED TO FIND THE "100-YEAR STORM" FOR 60 MINUTES. THIS IS 0.8 INCH (POINT D).

FIGURE II.3-E-19 RETURN PERIODS OF RAINFALL INTENSITY AND DURATION
(based on the period 1947-69 at HMS)

II.3-E-58

FIGURE II.3-E-20 TOTAL ANNUAL PRECIPITATION PROBABILITY DIAGRAM

theoretical extreme values of precipitation amounts and intensities during specified time periods. Figure II.3-E-21 presents similar data for depth of snow. Examination of these tables and figures would indicate that a "500-year storm" for example, could have one or more of the following characteristics:

Greatest depth of snow on the ground in a 500-year period would be 30 inches.

These precipitation data are considered generally representative of the entire Hanford Reservation except for the ALE area on Rattlesnake Mountain where precipitation may range up to 10-15 inches as a result of orographic effects.³⁰

A study³¹ on climatic effects of irrigation, suggests a 25% increase in local precipitation can be attributed to irrigation in the Southern Columbia Basin Irrigation District. Another study⁸ indicates that these conclusions are at variance with most other research, where irrigation is shown to have a minimum influence at distances much beyond boundaries of even substantial (40,000-50,000 hectares) irrigated blocks. The latter study could find no statistically significant difference between rainfall at stations inside the Columbia Basin Project and at upstream reference stations. Figure II.3-E-22 presents HMS total annual precipitation and 10- and 15-year moving averages. It is clear that total annual precipitation at the HMS has generally decreased between 1950 and 1970, when the Columbia Basin irrigation operation grew from 2876 hectares to 180,732 hectares.⁸ This decrease tends to refute the conclusion that an increase in local precipitation can be attributed to irrigation.

FIGURE II.3-E-21 GREATEST DEPTH OF SNOW ON GROUND DURING 24 OF 25 WINTERS OF RECORD AT HANFORD 1946-47 THROUGH 1969-70

II.3-E-61

FIGURE II.3-E-22 HMS TOTAL ANNUAL PRECIPITATION (1913-1970)
AND 10 and 15 YEAR MOVING AVERAGES

II.3-E REFERENCES

1. W. A. Stone, et al., Climatology of the Hanford Area, BNWL-1605, Battelle, Pacific Northwest Laboratories, Richland, WA, June 1972.
2. E. J. Gumbel, Statistical Theory of Extreme Values and Some Practical Applications, U.S. Dept. of Commerce, National Bureau of Standards Applied Mathematics Series 33, February 1954.
3. D. E. Jenne, Frequency Analysis of Some Climatological Extremes at Hanford, HW-75445, General Electric, Hanford Atomic Products Operations, Richland, WA, April 1963.
4. D. H. McIntosh, (Ed.), Meteorological Glossary, Chemical Publishing Co., Inc., New York, NY, 5th Edition, 1972.
5. D. E. Jenne and R. E. Kerns, A Climatological Study of the Hanford Area, HW-57722, General Electric, Hanford Atomic Products Operation, Richland, WA, November 1959.
6. Preliminary Safety Analysis Report, WNP-1, Washington Public Power Supply System, Richland, WA, 1973.
7. W. T. Hinds and J. M. Thorp, Annual Summaries of Microclimatological Data from the Arid Lands Ecology Reserve: 1968 through 1970, BNWL-1629, November 1971, Battelle, Pacific Northwest Laboratories, Richland, WA, 1971.
8. W. B. Fowler and J. D. Helvey, Effect of Large-Scale Agricultural Irrigation on Local Climate in the Columbia Basin (Central Washington, U.S.A.), U.S. Dept. of Agriculture, Forest Hydrology Laboratory, Wenatchee, WA, 1973.
9. R. K. Woodruff, D. E. Jenne, C. L. Simpson and J. J. Fuquay, "A Meteorological Evaluation of the Effects of the Proposed Cooling Towers of Hanford Number Two "C" Site on Surrounding Areas," Report to Burns and Roe, Inc. Hempstead, NY, September, 1971.
10. Wind-Wave Investigation, Project Bulletin No. 2, John Day Lock and Dam, U.S. Army Engineer District, Corps of Engineers, December 1967.
11. The Hanford Wind Storm of January 11, 1972, BNWL-1640, Battelle, Pacific Northwest Laboratories, Richland, WA, February 1972.
12. L. V. Wolford, Tornado Occurrences in the United States, Technical Paper No. 20, Weather Bureau, U.S. Dept. of Commerce, 1960.

II.3-E REFERENCES (Continued)

13. H. G. Daubek, Tornado History and a Discussion of the Tornado Warning System, Battelle, Pacific Northwest Laboratories Report to Jersey Nuclear Company, Richland, WA, December 1970.
14. T. Fujita, Estimate of Maximum Wind Speed of Tornadoes in Three Northwestern States, SMRP Research Paper No. 92, University of Chicago, IL, December 1970, COM-71-00731
15. J. L. Jaech, Statistical Analysis of Tornado Data for the Three Northwestern States, Jersey Nuclear Company, Richland, WA, December 1970.
16. Preliminary Safety Analysis Report, Washington Nuclear Project No. 2, Washington Public Power Supply System, Richland, WA, February 1973.
17. Glossary of Meteorology, American Meteorological Society, Boston, MA, 1959.
18. S. E. Logan, A Simple Analytical Model for the Dust Devil, UCRL-50667, Lawrence Radiation Laboratory, University of California, Livermore, CA, May 1969.
19. P. C. Sinclair, A Quantitative Analysis of the Dust Devil, Ph.D. Thesis, University of Arizona, Tucson, AZ, 1966.
20. R. L. Ives, "Behavior of the Dust Devil," Bull. Am. Meteorol. Soc. 28, pp. 168-174, 1947.
21. P. C. Sinclair, "General Characteristics of Dust Devils," J. Appl. Meteorology 8, pp. 32-45, 1969.
22. P. C. Sinclair, "The Lower Structure of Dust Devils," J. of Atmos. Sci., 30, November 1973.
23. J. A. Ryan and J. J. Carroll, "Dust Devil Wind Velocities: Mature State," Journal of Geophysical Research, 75, pp. 531-541, January 1970.
24. R. L. Lamberth, "On the Measurement of Dust Devil Parameters," Bull. Am. Meteorol. Soc. 47, pp. 522-526, July 1966.
25. Federal Meteorological Handbook No. 1. Surface Observations, U.S. Government Printing Office, January 1970.

II.3-E REFERENCES (Continued)

26. N. Cianos and E. T. Pierce, A Ground-Lightning Environment for Engineering Usage, Technical Report 1, Stanford Research Institute, Stanford, CA, August 1972.
27. G. C. Holzworth, "Mixing Heights, Windspeeds and Potential for Urban Air Pollution Throughout the Contiguous United States," Environmental Protection Agency, AP-101, January 1972.
28. C. R. Hosler, "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, Vol. 89, pp. 319-339, September 1961.
29. R. E. Huschke, (Ed.), Glossary of Terms Frequently Used in Air Pollution, American Meteorological Society, Boston, MA, January 1968.
30. E. L. Phillips, Washington Climate (selected counties) (EM 3127), Washington State University, Pullman, WA, January 1970.
31. C. K. Stidd, Local Moisture and Precipitation, Reprint Series No. 45, Desert Research Institute, University of Nevada, Las Vegas, NV, August 1967.
32. Fast Flux Test Facility Environmental Statement, USAEC, WASH-1510, 1972.

APPENDIX II.3-F

AQUATIC ECOLOGY

APPENDIX II.3-F

AQUATIC ECOLOGY

	<u>Page</u>
Part 1 Aquatic Ecology	II.3-F-1
Part 2 Columbia River Biota	II.3-F-23

APPENDIX II.3-F, PART 1

Aquatic Ecology

II.3-F Part 1 Aquatic Ecology

The dominant aquatic ecosystem on the Hanford Project is the Columbia River. The fifth largest river in North America, it has a total length of 1214 miles from its origin in British Columbia to its entrance into the Pacific Ocean. Numerous dams have been built on the river; in the section within the United States, it is essentially a series of impoundments with the only free-flowing section occurring between Priest Rapids Dam and McNary Reservoir. No significant tributaries enter the stream in this section which is mostly contained within the Hanford Reservation. The entire river is exceptionally clean for a river of its size. The only other natural lotic ecosystem of any size on the Hanford Project is Rattlesnake Springs.

Several small lentic sites that are a result of waste discharge effluents are present within the Hanford Project. The largest of these is Gable Mountain Pond.

II.3-F.1 The Columbia River

The basic physical and chemical characteristics of the Columbia River were presented in previous sections of this report. References 1, 2, and 3 present additional nonbiological data as well as comprehensive evaluations of the ecological characteristics of the Columbia River, mainly in the Hanford to McNary Dam section.

Studies concerned with the various aquatic organisms in the Columbia River, relating mainly to influence of reactor operation, were conducted for over 25 years; a bibliography with abstracts of these investigations was recently published.⁴ The following paragraphs summarize the essential ecological characteristics of the major communities.

Figure II.3-F-1 is a simplified diagram of the food-web relationships in selected Columbia River biota and represents probable major energy pathways. The Columbia River presents a very complex ecosystem in terms

II.3-F-5

FIGURE II.3-F-1 FOOD WEB OF COLUMBIA RIVER

of trophic relationships due to its size, the number of man-made alterations, the diversity of the biota, and the size and diversity of its drainage basin.

Streams in general, especially smaller ones, depend greatly upon allochthonous input of organic matter to drive the energetics of the system. Large rivers, particularly the Columbia because it is a series of lentic reservoirs, contain a significant population of autochthonous primary producers (phytoplankton and periphyton) which contribute the basic energy needs. The dependence of the free-flowing Columbia River in the Hanford stretch upon an autochthonous food base is reflected by the faunal constituents, particularly the herbivores in the second trophic level. Filterfeeding insect larvae such as caddis fly larvae, Hydropsyche, and periphyton grazers such as limpets and some mayfly nymphs are typical forms present. Shredders and large detrital feeders (such as the large stonefly nymphs) which are typical of smaller streams are absent. The presence of large numbers of the herbivorous suckers also attests to the presence of a significant periphytic population. Carnivorous species are numerous, as would be expected in a system of this size.

II.3-F.1.1 Phytoplankton

Diatoms are the dominant algae in the Columbia River, usually representing over 90% of the population. The main genera include Fragilaria, Asterionella, Melosira, Tabellaria, and Synedra; lentic forms that originate in the impoundments behind the upstream dams are dominant in the Hanford section of the river. The phytoplankton also contain a number of species derived from the periphyton or sessile algae community. This is particularly true of the Columbia River in the Hanford area because of the fluctuating daily water levels. Periphytic algae exposed to the air for part of the day may dry up and then become detached and suspended in the water when the river level rises again. Peak biomass of net phytoplankton is about 2.0 g dry wt/m³ in May and winter values

are less than 0.1 g dry wt/m^3 .⁵ Figure II.3-F-2 illustrates the seasonal fluctuations in plankton biomass. A spring increase with a second pulse in late summer and autumn was observed in the Hanford section of the Columbia River in previous studies.^{6,7} The spring pulse is probably related to increasing light and warming of the water rather than to availability of nutrients. The coincident decrease of PO_4 and NO_3 , essential nutrients for algae growth, may be partially related to uptake by the increasing phytoplankton populations but is also highly influenced by the dilution of these nutrients by the increased flows due to high run-off at this time. The degree of dilution depends upon the concentration of these nutrients in the run-off waters. However, these nutrients do not decrease to concentrations limiting to algae growth at any time of the year. Green and blue-green algae occur mainly in the warmer months, but in substantially fewer numbers than the diatoms.

II.3-F.1.2 Periphyton

Periphytic communities develop on suitable solid substrates wherever sufficient light occurs for photosynthesis. Dominant diatom genera include Melosira and Gomphonema and in spring and summer luxuriant growths of the filamentous green algae Stigeoclonium and Ulothrix occur. Net Production Rate (NPR), as measured from 14 day colonization of artificial substrates, varied from $0.07 \text{ mg dry wt/cm}^2/\text{day}$ in August to less than $0.01 \text{ mg dry wt/cm}^2/\text{day}$ in December and January.⁸ Figure II.3-F-3 shows the seasonal pattern of NPR. This represents the 14 day growth on clean glass slides and not the increment on an established community. NPR was highly correlated with solar energy and chlorophyll a concentration on the slides during the two week exposure. The high correlation with chlorophyll a is consistent with the fact that closest relationships between pigment content and productivity are usually found only during periods of rapid growth. The colonization conditions obtained in these studies began from a bare surface, and after two weeks the communities were probably still in the log-growth phase. Correlations among biomass

FIGURE II.3-F-2 SEASONAL FLUCTUATION OF PLANKTON BIOMASS

FIGURE II.3-F-3 SEASONAL FLUCTUATION OF NET PRODUCTION RATE OF PERIPHYTON

measurements were highest between dry weight and ash weight, due mainly to the high population of diatoms with silica frustules.

II.3-F.1.3 Macrophytes

Emergent macrophytic vegetation is extremely sparse and is usually found in slackwater areas. Rushes (Juncus) and sedges (Carex) occur in flooded areas, particularly after high-water levels recede. These areas are located above 100-K, below 100-D; and in the sloughs between 100-H and 100-F, below 100-F, and near the old Hanford townsite.

II.3-F.1.4 Zooplankton

In the Hanford stretch of the Columbia River, zooplankton populations are generally sparse and associated with benthic deposits in slack water areas near the edge of the river; cladocerans are more abundant than copepods.⁹ Quantitative data showed a pronounced spring pulse of 260,000 organisms/ft². Alona rectangula, A. affinis, and Chydorus sphaericus predominate in spring, fall, and winter. Sida crystallina and Eurycercus lemellatus are most abundant in summer. Twenty four species of Cladocera and Copepoda have been identified in McNary Reservoir.¹⁰ This reservoir receives water from the Yakima, Snake, and Walla Walla Rivers as well as from the Columbia, all of which may contribute to the zooplankton population.

II.3-F.1.5 Benthos

Benthic biota consist of organisms which are either attached to or live closely associated with the substrate. Dominant organisms presently found in the free-flowing Columbia include insect larvae, sponges, molluscs, flatworms, leeches, crayfish, and oligochaetes. The daily fluctuating water levels, due to the manipulation of flow by an upstream hydroelectric dam, have destroyed a part of this fauna in the littoral zone. Near the old Hanford townsite, midge larvae (Chironomidae) and caddis fly larvae (Trichoptera) are the most numerous benthic organisms, averaging 121 and 208 organisms/ft², respectively.¹ Caddis fly larvae

and molluscs (Mollusca) are predominant in terms of biomass, averaging 2.24 and 1.23 g wet wt/ft², respectively. Total benthic organisms averaged 375/ft² and 3.59 g wet wt/ft² during 1951-52. These figures are approximations of these populations due to the difficulty in sampling all of the bottom in a large river such as the Columbia. Sampling was restricted to the shallow shoreline, and even there variations between replicate samples were sometimes greater than seasonal variations.

II.3-F.1.6 Fish

Thirty-nine species of fish have been identified in the Hanford area of the Columbia River.^{4,11} Of the many species of fish in the river, the anadromous salmon and steelhead trout are of greatest economic importance. The Hanford reach of the Columbia serves as a migration route to and from upstream spawning grounds for chinook, sockeye, and coho salmon and for steelhead trout. Both fall chinook salmon and steelhead trout also spawn in the Hanford section of the river. Population estimates of the locally spawning chinook salmon are made annually by means of aerial surveys and enumeration of the number of salmon nests (redds) in the section of river from Richland to Priest Rapids Dam (Table II.3-F-1). For the period 1947 to 1972 the average number of chinook salmon spawners was almost 9500 fish, with a range of 450 to 31,600.¹² Since 1962, the local fall chinook salmon spawning population represents 15 to 20% of the total fall chinook escapement to the river.¹³ This recent increase in relative importance of the Hanford section for chinook spawning may result from the destruction of other mainstem spawning grounds by river impoundments.

The chinook juveniles move through the Hanford section of the Columbia in two age classes, young-of-the-year and yearlings. The young-of-the-year in particular inhabit the areas near shore where they feed as they move downstream. They are present from late winter through midsummer, with greatest numbers in April, May, and June.

TABLE II.3-F-1

NUMBER OF SPAWNING FALL CHINOOK SALMON AT HANFORD, 1947-1973
(population estimate based on 7 fish per redd)

<u>Year</u>	<u>No. of Redds (a)</u>	<u>Population Estimate</u>
1947	240	1680
48	785	5500
49	330	2310
50	316	2210
51	314	2200
52	539	3770
53	149	1040
54	157	1100
55	64	490
56	92	640
57	872	6100
58	1485	10400
59	281	1970
60	295	2070
61	939	6570
62	1261	8830
63	1303	9120
64	1477	10300
65	1789	12500
66	3101	21700
67	3267	22900
68	3560	24900
69	4508	31600
70	3813	26700
71	3600	25200
72	876	6130
73	2965	20800

(a) Redd counts obtained by aerial surveys

Average annual steelhead spawning population estimates for the years 1962-1971 are about 10,000 fish.¹⁴ The annual estimated 1963-1968 sport catch in the section of river from Ringold, just downstream from the Hanford site boundary, to the mouth of the Snake River, a distance of about 30 miles, was approximately 2700 fish.

The shad, another anadromous species, may also spawn in the Hanford section of the river. Young-of-the-year of this fish are collected during the summer. The upstream range of the shad has increased since the mid 1950's, possibly as the result of increased impoundment of water in the lower and middle river. In 1956 fewer than ten adult shad ascended McNary Dam; in 1966 about 10,000 passed upstream. The whitefish are resident in the Hanford section of the river and support a winter sport fishery. During the period of maximum plutonium production reactor operation, upstream movement of whitefish and other resident species was demonstrated by the capture of fish containing greater than background levels of radionuclides at Priest Rapids Dam, upstream of the Hanford Reservation.

Other game species such as sturgeon, smallmouth bass, crappie, and sunfish are also fairly abundant in the Hanford section of the Columbia. These populations are enhanced by the prohibition of fishing and public access to most of the river within the Hanford Reservation.

Population estimates of resident coarse fishes (such as suckers) and minnows have not been made. The problems inherent in effectively sampling a river the size of the Columbia preclude definitive measurements. The above mentioned species constitute a large portion of the resident population; other common species include sculpin, dace, and sticklebacks.

II.3-F.2 100-N Disposal Trench

Liquid waste from the N-Reactor flows into a crib and the overflow from the crib goes into a 1600-ft long dispersal ditch. Water seeping from the trench eventually reaches the Columbia River.

No ecological studies have been performed on this disposal trench, although periphytic algae and associated microscopic organisms are probably present. Some insect larvae may also be present. The trench was occasionally used by migrating waterfowl until it was partly screened and backfilled to prevent their access.

II.3-F.3 200 Area Ponds and Ditches

A number of ponds and ditches in the vicinity of the 200-E and 200-W areas have received low-level aqueous waste. A total of 360 acres received waste, but only about 180 acres are in current use. Ecological studies have not been performed on the majority of the sites because they occur within exclusion areas and present no known radiological problems involving the biota. The ditches in general have sand substrates with a rapid rate of infiltration. Vegetation grows abundantly along the shores if not controlled.

Ecological studies have been in progress since June 1972 on Gable Mountain Pond and since July 1973 on U Pond. The shoreline vegetation around Gable Mountain Pond is predominately cattails and rushes; open sections are present near the inlet and at the northwest end where the overflow passes through a culvert in a dike. Figure II.3-F-4 represents the basic food-web present in both Gable Mountain Pond and U Pond. The biota is rich in terms of species diversity but additional work is needed to quantify the various populations. (Major taxa are shown in Table II.3-F-2.) Quantitative sampling is in progress on the 22 acre U Pond. The daily thermal regime of the pond is dependent primarily upon the incoming water and secondarily on atmospheric and solar heat. However, the range within which the pond fluctuates is influenced by seasonal changes in solar and atmospheric heat. Since primary productivity is closely related to seasonal changes in insolation and temperature, striking pulses occur during the warmer months when wind and cloud cover are minimal.

II.3-F-15

FIGURE II.3-F-4 FOOD WEB OF GABLE MOUNTAIN POND AND U POND

TABLE II.3-F-2

MAJOR TAXA IDENTIFIED IN GABLE MOUNTAIN POND AND U POND

Plants

Phylum Chlorophyta
Phylum Tracheophyta
 Family Typhacea
 Family Cyperacea
 Family Najadaceae
 Family Haloragidaceae

Animals

Phylum Mollusca
Phylum Annelida
Phylum Arthropoda
 Class Crustacea
 Order Diplostraca
 Order Calanoida
 Order Cyclopoida
 Order Amphipoda
 Class Insecta
 Order Coleoptera
 Order Diptera
 Order Hemiptera
 Order Odonata
 Order Ephemeroptera
Phylum Chordata
 Class Osteichthyes
 Order Holostei
 Family Cyprinidae

The pond supports a simple food-web based mainly on detritus and sedimented organic matter. Primary producers are mainly phytoplanktonic green algae (Chlorococcales) and several emergent vascular plants. Benthic detritivores and scavengers include chironomid larvae, oligochaetes, amphipods, and mayfly and beetle larvae. Goldfish, the only nektonic form, also scavenge the bottom. Dragonfly larvae and backswimmers constitute the only known carnivores in the pond. (Major taxa present are shown in Table II.3-F-2.)

II.3-F.4 300 Area Waste Ponds

These two ponds, totalling about 12 acres, receive low-level liquid waste generated in the 300 Area laboratories and reactor fuel canning complex.¹⁵ The south pond is dry now, but could receive water again since the north pond is approaching capacity. Since the waste contains concentrations of copper and uranium, a thick layer of copper hydroxide is on the bottom.

No ecological studies have been conducted on these ponds. Vascular plants grow down to the water's edge, but the pond proper is unsuitable for aquatic life. Ducks are occasionally observed on the ponds and leaching trench alongside.

II.3-F.5 Rattlesnake Springs

Rattlesnake Springs, located in the Arid Lands Ecology (ALE) Reserve, is a permanent spring which begins from ground seepage and is subsequently fed by small ground springs along its course. It flows for approximately 2 miles at approximately 0.43 cfs and disappears into the ground. The stream bottom is composed of sand and gravel, while rubble occurring in some areas. The biotic communities in the stream are subjected to periodic flash floods in winter, depending upon weather conditions. Despite these floods, the stream supports a diverse flora and fauna.

Table II.3-F-3 gives the mean concentrations of several chemical parameters; pH varies slightly around 8.0. No chemicals are present in detrimental concentrations to the biota.

TABLE II.3-F-3

CHEMICAL ANALYSIS, RATTLESNAKE SPRINGS, 1962-1963

	<u>ppm</u>
Ca	30
Mg	11
Na	16
K	3
Zn	0.004
B	0.024
Fe	0.08
Si	24
SO ₄	13 to 30
Cl	3
PO ₄	0.3
NO ₃	0.8
Total dissolved solids	220
MO alkalinity	132
Turbidity	1.2

II.3-F.5.1 Phytoplankton and Periphyton

Some 90 species of algae have been collected and identified at Rattlesnake Springs. Slightly over half of the species are diatoms, in summer green algae are the second most numerous group and are the dominant group in terms of biomass. Table II.3-F-4 shows the breakdown by major taxonomic groups.

II.3-F.5.2 Macrophytes

Cattails and sedges occur along the stream, especially where it is not shaded, but the overwhelmingly dominant macrophyte is water cress, Rorippa nasturtium-aquatica. This plant seasonally occupies from 2 to 85% of the total stream area.¹⁷

II.3-F.5.3 Invertebrates

Several groups of invertebrates occupy the stream, although the species diversity is highly dependent upon the size of the winter floods, if any, and the resulting physiognomy of the stream. No exhaustive taxonomic study has been made of the invertebrates. The major taxa are given in Table II.3-F-5.

II.3-F.6 Other Springs on the ALE Site

Approximately 14 other permanent and intermittent springs occur on the ALE site. No ecological studies have been made of these springs but qualitative collections were made for certain organisms. Algae was collected at a few sites¹⁶ and the crayfish, Pacifastacus leniculatus, was collected for laboratory experiments.

TABLE II.3-F-4

MAJOR ALGAE TAXA IN RATTLESNAKE SPRINGS

<u>Taxon</u>	<u>No. of Species</u>
Phylum Chlorophyta	
Sub-Division Chlorophyceae	22
Sub-Division Characeae	1
Phylum Euglenophyta	11
Phylum Chrysophyta	
Sub-Division Xanthophyceae	3
Sub-Division Chrysophyceae	46
Phylum Cyanophyta	
Sub-Division Myxophyceae	7

TABLE II.3-F-5

MAJOR TAXA IDENTIFIED IN RATTLESNAKE SPRINGS¹⁷

<u>Plants</u>	<u>Animals</u>
Phylum Chlorophyta	Phylum Mollusca
Sub-Division Chlorophyceae	Phylum Annelida
Sub-Division Characeae	Phylum Arthropoda
Phylum Euglenophyta	Class Crustacea
Phylum Chrysophyta	Order Ostracoda
Sub-Division Xanthophyceae	Order Diplostraca
Sub-Division Chrysophyceae	Order Calanoida
Phylum Cyanophyta	Order Cyclopoida
Sub-Division Myxophyceae	Order Amphipoda
Phylum Tracheophyta	Order Decapoda (not in Rattlesnake Springs)
Family Cruciferae	Class Insecta
Family Typhaceae	Order Coleoptera
Family Cyperaceae	Order Ephemeroptera
	Order Plecoptera
	Order Trichoptera
	Order Diptera
	Order Hemiptera
	Order Odonata

II.3-F PART 1 REFERENCES

1. G. G. Robeck, C. Henderson and R. C. Palange, Water Quality Studies on the Columbia River, PHS, R. A. Taft Sanitary Engin. Center, 1954.
2. J. J. Davis, D. G. Watson, and C. C. Palmiter, Radiobiological Studies of the Columbia River Through December 1955, HAP0, HW-36074, 1956.
3. D. G. Watson, C. E. Cushing, C. C. Coutant, and W. L. Templeton, Radioecological Studies on the Columbia River, Parts I and II, BNWL-1377, Battelle, Pacific Northwest Laboratories, Richland, WA, 1970.
4. C. D. Becker, Aquatic Bioenvironmental Studies in the Columbia River at Hanford 1945-1971, A Bibliography with Abstracts, BNWL-1734, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
5. C. E. Cushing, "Concentration and Transport of ^{32}P and ^{65}Zn by Columbia River Plankton," Limnol. Oceanogr., vol. 12, pp. 330-332, 1967.
6. R. W. Coopey, "Radioactive Plankton from the Columbia River," Trans. Amer. Microscop. Soc., vol. 72, pp. 315-327, 1953.
7. C. E. Cushing, "Plankton-Water Chemistry Cycles in the Columbia River," Hanford Biology Research Annual Report for 1963, HW-80500, p. 212-218, 1964.
8. C. E. Cushing, "Periphyton Productivity and Radionuclide Accumulation in the Columbia River, Washington, U.S.A.," Hydrobiologia, vol. 29, pp. 125-139, 1967.
9. R. W. Coopey, The Abundance of the Principal Crustacea of the Columbia River and the Radioactivity They Contain, HAP0, HW-25191, 1953.
10. J. F. Scarola, "Cladocera and Copepoda in McNary Reservoir, 1965-66," Northwest Sci., vol. 42, pp. 112-114, 1968.
11. K. E. Herde, One Year Study of Radioactivity in Columbia River Fish, HW-11344, Hanford Works, Richland, WA, 1948.
12. D. G. Watson, "Fall Chinook Salmon Population Census," Pacific Northwest Laboratory Annual Report for 1972 to the USAEC Division of Biomedical and Environmental Research, BNWL-1750, vol. 1, part 2, p. 6.16-6.17, 1973.

II.3-F PART 1 REFERENCES (Continued)

13. D. G. Watson, Fall Chinook Salmon Spawning in the Columbia River near Hanford 1947-1969, Battelle, Pacific Northwest Laboratories, BNWL-1515, 1970.
14. D. G. Watson, Estimate of Steelhead Trout Spawning in the Hanford Reach of the Columbia River, Contract No. DACW67-72-C-0100, Battelle, Pacific Northwest Laboratories, 1973.
15. USAEC, Hanford Radioactive Waste Management Plans, PWM-530, Rev. 1, 157 pp., 1973.
16. (not used)
17. E. G. Wolf and C. E. Cushing, "Productivity of Rattlesnake Springs," In: Pacific Northwest Laboratory Annual Report for 1971 to the USAEC Division of Biology and Medicine, Volume I Life Sciences, Part 2, Ecological Sciences, BNWL-1650, 1972.

APPENDIX II.3-F, PART 2

Columbia River Biota

II.3-F Part 2 Columbia River Biota^(a)

<u>Organism</u>	<u>Organism</u>
Phylum Chlorophyta	Phylum Chrysophyta (contd)
<u>Ulothrix zonata</u>	<u>Stephanodiscus astraea</u>
<u>Stigeoclonium lubricum</u>	<u>S. a. var. minuta</u>
<u>Cladophora crispata</u>	<u>S. niagarea</u>
<u>C. glomerata</u>	<u>Rhizosolenia eriensis</u>
<u>Zoochlorella parasitica</u>	<u>Tabellaria fenestrata</u>
<u>Chara Braunii Gmelin</u>	<u>Diatoma vulgare</u>
<u>C. vulgaris</u>	<u>Fragilaria crotonensis</u>
<u>Tetraspora sp.</u>	<u>F. harrisonii</u>
<u>Oedogonium sp.</u>	<u>F. construens</u>
<u>Spirogyra sp.</u>	<u>F. virescens</u>
<u>Plesdorina sp.</u>	<u>Asterionella formosa</u>
<u>Pediastrum sp.</u>	<u>Synedra ulna</u>
<u>Staurostrum sp.</u>	<u>S. u. var. danica</u>
<u>Coelastrum sp.</u>	<u>S. acus</u>
<u>Ankistrodesmus sp.</u>	<u>S. rumpens</u>
<u>Pandorina sp.</u>	<u>S. pulchella</u>
<u>Scenedesmus sp.</u>	<u>S. parasitica</u>
<u>Rhizoclonium fontanum</u>	<u>Cocconeis placentula</u>
Phylum Chrysophyta	<u>C. pediculus</u>
<u>Hydrurus foetidus</u>	<u>Frustulia rhomboides</u>
<u>Botrydium granulatum</u>	<u>F. vulgaris</u>
<u>Eunotia pectinalis</u>	<u>Nedium productum</u>
<u>Melosira granulata</u>	<u>Diploneis elliptica</u>
<u>M. varians</u>	<u>Navicula oblonga</u>
<u>Cyclotella bodanica</u>	<u>Cymbella prostrate</u>
<u>C. glomerata</u>	<u>C. turgida</u>
<u>C. melosiroides</u>	<u>C. leptoceros</u>

(a) Classification after - T. I. Storer, R. L. Usinger, R. C. Stebbins, J. W. Wybakken, General Zoology, Fifth edition, McGraw-Hill Book Co., New York, 1972.

Organism

Phylum Chrysophyta (contd)

C. naviculiformis
C. cistula
C. ventriocosa
C. tumida
Gomphonema parvulum
G. olivaceum
Epithemia turgida
Rhopalodia gibba
Nitzschia dissipata
N. palea
Ceratoneis sp.
Cymatopleura solea
C. elliptica
Suriella linearis

Phylum Cyanophyta

Aulosira implexa
Oscillatoria anquina
O. chalybea
O. limosa
O. proboscidea
O. princeps
O. splendida
O. tenuis
O. t. var. natans
Phormidium autumnale
P. favosum
P. inundatum
P. retzii

Organism

Phylum Cyanophyta (contd)

P. subfuscum
P. tenue
P. uncinatum
Lyngbya aerugineocaerulea
L. aestuarii
L. Diguei
L. versicolor
Symploca muscorum
Anabaena oscillarioides
Nostoc caeruleum
N. ellipsoforum
N. sphaericum
Aphanizomenon flos-aquae
Tolypothrix distorta
T. lanata
T. tenuis
Plectonema nostocorum
Amphithrix janthina
Calothrix parietana
Gloeotrichia echinulata
G. natans
Audouinella violacea

Phylum Pyrrophyta

Ceratium sp.

Phylum Tracheophyta

Family Najadaceae

Potamogeton sp.

Organism

Phylum Tracheophyta (contd)

Family Hydrocharitaceae

Anacharis sp.

Elodea sp.

Family Lemnaceae

Lemna sp.

Family Polygonaceae

Polygonum sp.

Family Ceratophyllaceae

Ceratophyllum demersum

Family Cyperaceae

Family Juncaceae

Animals

Phylum Protozoa

Acanthocystis sp.

Actinosphaerium sp.

Vorticella sp.

Epistylis sp.

Phylum Porifera

Spongilla lacustris

Phylum Coelenterata

Craspedacusta sowerbii

Hydra sp.

Organism

Phylum Platyhelminthes

Class Turbellaria

Dugesia dorocephala

Class Trematoda

Actinocleidus sp.

Urocleidus sp.

Dactylogyrus spp.

Gyrodactylus spp.

Phyllodistomum sp.

Lecithaster salmonis

Diplostomum sp.

Posthodiplostomum minimum

Brachyphallus crenatus

Neascus spp.

Allocreadium sp.

Crepidostomum farionis

Crepidostomum sp.

Octomacrum sp.

Cestrahelmins rivularis

Plagioporus spp.

Class Cestoidea

Corallobothrium fimbriatum

Proteocephalus ambloplitis

P. tychocheilus

P. salmonidicola

Phyllobothrium sp.

Caryophyllaeus sp.

Ligula intestinalis

Organism

Class Cestoidea (contd)

Diphylobothrium sp.
Bothriocephalus sp.
Schistocephalus solidus
Eubothrium salvelini

Phylum Aschelminthes

Class Rotifera

Dapidia sp.
Kellicotia sp.
Syncheata sp.
Notholca sp.
Polyarthra sp.
Trichocerca sp.
Keratella sp.

Class Nematoda

Rhabdochona sp.
Contracaecum sp.
Philonena onchorhynchi
Bulbodacnitis sp.
Metabronena sp.
Cystidicola sp.
Camallanus sp.

Phylum Acanthocephala

Neoechinorhynchus rutili
N. cristatus
Pomphorhynchus bulbocolli
Bulbodactnitis sp.

Organism

Phylum Bryozoa

Plumatella sp.
Pectinatella sp.

Phylum Mollusca

Class Gastropoda

Stagnicola nuttalliana
Physa nuttallii
Fluminicola nuttalliana
Fisherola nuttallii
Stagnicola apicina
Radix japonica
Gyraulis vermicularis
Parapholix effusa costata
P. e. neritoides
Lymnaea stagnalis
Lymnaea sp.
Planorbis sp.

Class Bivalvia

Anodonta nuttalliana
Corbicula fluminea
Margaritifera margaritifera
Pisidium columbianum
Anodonta compressum
Anodonta californiensis

Organism

Phylum Annelida

Class Oligochaeta

Xironogiton instabilis

Triannulata montana

Chaetogaster sp.

Class Hirudinea

Placobdella montifera

Illinobdella moorei

Erpobdella punctata

Theromyzon rude

Piscicola sp.

Helobdella stagnalis

Phylum Arthropoda

Class Arachnida

Hydracarina sp.

Aranedia sp.

Class Crustacea

Order Anostraca

Steptocephalus seali

Order Diplostraca

Leptodora kindtii

Diaphanosoma brachyurum

Alona rectangula

A. affinis

A. quadrangularis

A. costata

Organism

Order Diplostraca (contd)

Chydoris sphaericus

Pleuroxus denticularis

Sida crystallina

Eurecerus lemallatus

Camptocercus rectirostris

Daphnia galeata mendotae

Scapholebercis kingi

Ceriodaphnia pulchella

Bosmina sp.

B. longirostis

Illyocryptus sordidus

I. spinifer

Macrothrix laticornis

Monospilus dispar

Leydigia quadrangularis

Pleuroxus trigonellus

Order Calanoida

Canthocamptus sp.

C. staphylinoides

C. vernalis

C. bicuspidatus thomasi

Diaptomus sp.

D. ashlandi

Bryocamptus zschokkei

Order Cyclopoida

Cyclops sp.

Organism

Phylum Arthropoda (contd)

Order Amphipoda

Gammarus sp.

Order Decapoda

Pacifasticus (lenius-
culus) trowbridgii

Class Insecta

Order Coleoptera

Gyrinus sp.

Order Ephemeroptera

Paraleptophlebia
bicornuta

Baetis sp.

Ephoron album

Ephemerella yosemite

E. sp.

Hexagenia sp.

Stenonema sp.

Order Plecoptera

Arcynepteryx paralla

Pteronarcys californica

Isogenus sp.

Perlodes americana

Order Trichoptera

Glossosoma velona

Hydropsyche cockerelli

Hydropsyche sp.

Organism

Order Trichoptera (contd)

H. californica

Leptocella sp.

Limnophilus sp.

Hydroptila argosa

Brachycentrus occidentalis

Rhacophila coloradensis

Psychomyia flavida

Cheumatopsyche enomis

C. campyla

Leucotrichia pictipes

Arthripsodes annulicornis

Mystacides alafimbriata

Lepidostoma strophis

Order Lepidoptera

Argyractis angulatalis

Order Diptera

Tipulidae

Chironomidae

Simulium vittatum

Simulium sp.

Order Hemiptera

Notonecta sp.

Gerris sp.

Sigara sp.

Order Collembola

Family Hypogasturidae

Organism

Phylum Tardigrada

Macrobiotus sp.

Phylum Chordata

Class Cyclostomata

Entosphenus tridentatus

Pacific Lamprey

Lampetra richardsoni

Western Brook Lamprey

Class Osteichthyes

Acipenser transmontanus

White Sturgeon

Oncorhynchus tshawytscha

Chinook Salmon

O. nerka

Sockeye or Blueback Salmon

O. kisutch

Coho or Silver Salmon

Salmo gairdneri

Steelhead or Rainbow Trout

S. clarki

Cutthroat Trout

Salvelinus malma

Dolly Varden

Prosopium williamsoni

Mountain Whitefish

Alosa sapidissima

American Shad

Pantosteus platyrhynchus

Mountain Sucker

Catostomus columbianus

Bridgelip Sucker

Catostomus macrocheilus

Largescale Sucker

Cyprinus carpio

Carp

Tinca tinca

Tench

Richardsonius balteatus

Redside Shiner

Ptychocheilus oregonensis

Northern Squawfish

Acrocheilus alutaceus

Chiselmouth

Mylocheilus caurinus

Peamouth

Rhinichthys atratulus

Blacknose Dace

R. cataractae

Longnose Dace

R. osculus

Speckled Dace

Organism

Phylum Chordata (contd)

<u>Ictalurus nebulosus</u>	Brown Bullhead
<u>I. melas</u>	Black Bullhead
<u>I. punctatus</u>	Channel Catfish
<u>I. furcatus</u>	Blue Catfish
<u>Gasterosteus aculeatus</u>	Threespine Stickleback
<u>Perca falvenscens</u>	Yellow Perch
<u>Stizostedion vitreum</u>	Walleye
<u>Lepomis macrochirus</u>	Bluegill
<u>L. gibbosus</u>	Pumpkinseed
<u>Pomoxis annularis</u>	White Crappie
<u>P. nigromaculatus</u>	Black Crappie
<u>Micropterus salmoides</u>	Largemouth Bass
<u>M. dolomieu</u>	Smallmouth Bass
<u>Lota lota</u>	Burbot
<u>Cottus asper</u>	Prickly Sculpin
<u>C. beldingii</u>	Piute Sculpin
<u>C. perplexus</u>	Reticulate
<u>C. rhotheus</u>	Torrent Sculpin

APPENDIX II.3-G
TERRESTRIAL ECOLOGY

APPENDIX II.3-G-3

TERRESTRIAL ECOLOGY

	<u>Page</u>
Part 1 Terrestrial Ecology	II.3-G-3
Part 2 Vascular Taxa of the Hanford Reservation	II.3-G-73
Part 3 Vertebrate Taxa of the Hanford Reservation	II.3-G-79
Part 4 Insects of the Hanford Reservation	II.3-G-85
Part 5 Shrub-Steppe Biota on the Hanford Reservation	II.3-G-93

II.3-G Part 1 Terrestrial Ecology

II.3-G.1 Climatic Influences

The Hanford region is frequently referred to as a "steppe" because of its resemblance to the steppeland of central Asia. The region is called¹ a shrub-steppe to differentiate the area from true steppes with more grasses and fewer shrubs. However, other points of contrast between Hanford and steppes in general deserve comment because they are fundamental to the structure and function of the ecosystems in the region; these include the causes of aridity and the relationships between precipitation and temperature.

True steppes have some common characteristics: 1) little precipitation, with the maximum occurring in summer, and 2) wide daily and annual temperature ranges. The causes of aridity usually stem from a lack of storm tracks and a substantial fraction of the annual precipitation coming from summer thunderstorms. However, Hanford's aridity arises from its geographical location in the rain shadow of the Cascade Mountains. Lying in the path of frequent winter storm tracks, the Hanford region is visited by many winter storms that bring clouds but little water. Summer thunderstorms average fewer than 10 annually, compared with 30 or more observed in classic steppelands.² These differences have led climatologists to classify the Hanford region variously as a cool desert, a winter-wet cool steppe, or a mid-latitude desert.^{1,2}

The winter maximum of precipitation is graphically shown in Figure II.3-G-1, in terms of the deviation of precipitation from the average monthly amount if the total precipitation were evenly distributed throughout the year. Temperature deviations are likewise shown in terms of monthly deviations from the annual mean temperature. The regular, nearly sinusoidal pattern of the temperature deviations contrasts with the much less regular precipitation pattern. Precipitation is relatively high during the winter months (2 to 3 cm per month on the average). Although June exhibits a secondary maximum, the June precipitation

II.3-G-4

FIGURE II.3-G-1 RELATIVE DEPARTURE OF TEMPERATURE, PRECIPITATION AND SOIL WATER FROM THEIR RESPECTIVE ANNUAL AVERAGES

is too little and too late to be of substantial importance to the vegetation because the rains usually wet the soil only to a depth of 20 cm or so, well within the reach of evaporation by the high insolation intensities and warm soil temperatures of that season.³ Consequently, the only precipitation of importance to vegetation is that which is stored as soil water during the cool season.⁴

Typically, about half of the winter precipitation occurs as snow, but snow cover is usually short-lived and offers an undependable shield against cold and dessicating winter wind.⁵ Snow is not always a reservoir of water for later use; falling as it does in an arid zone, it may blanket bare, frozen soil. Subsequent warm winds (chinooks) will melt the snow but not the soil, causing rapid runoff of the entire snow inventory.⁶ This tendency is most pronounced at the higher elevations because they have enough relief to initiate runoff.

Rainfall in the Hanford region is clearly dependent upon elevation,⁷ increasing significantly in the high elevations of the Rattlesnake Hills (Figure II.3-G-2). The rate of increase with elevation is much more rapid at lower elevations than at the higher elevations and wind interacts with precipitation patterns to produce substantial accumulations (snow drifts) on lee slopes. These alterations in precipitation provide the impetus for relatively far-reaching changes in plant communities, especially in terms of species present.

The middle elevations of the Rattlesnake Hills are at the top of a persistently occurring night-time inversion of temperature over the Hanford Reservation, i.e., air temperatures at night are 2 to 10°C warmer at about 400 m elevation than at the valley floor.⁵ Consequently, the freeze-free season at midelevations is about 4 to 6 weeks longer than at either lower or higher elevations and the soils may not freeze so deeply. In early spring, when soil water is plentiful, this temperature difference can induce noticeable advancement of the flowering time of plant species growing at midelevations.

II.3-G-6

FIGURE II.3-G-2 AVERAGE "BIOYEAR" (OCTOBER THROUGH MARCH) PRECIPITATION AS A FUNCTION OF ELEVATION ON THE ARID LANDS ECOLOGY RESERVE

Wind speeds in the Hanford region are, on the average, moderate, because very strong winds are separated by lengthy periods of light winds. Winds are of substantial ecological importance because they erode mobile surfaces and increase evaporation at higher elevations. Erodible soils exist on the Reservation--indeed, much of its surface is mantled by previous wind-laid deposits. Sands are the only size range physically able to form dunes,⁸ but silts can be made airborne when disturbed by saltating ("jumping") sand grains. The shear stress of the wind at the earth's surface determines whether sufficient force exists to move sand grains; where vegetation exists, the shear stress is reduced sharply and erosion is minimized. However, if the vegetation is removed, by fire, construction, plowing, or other means, strong winds will erode sandy soils. Most of the soils in the Hanford region have a substantial sand fraction and are therefore more or less erodible by winds, especially at the lower elevations where vegetation is sparser and sandier soils exist.⁹

The Rattlesnake Hills are much higher than any surrounding terrain for many kilometers, and are therefore subject to nearly free-stream wind speeds. During the windy season, winter and spring, winds are relatively constant and strong on the ridgetops, leading to a vegetation type consisting largely of cushion-form plants and grasses. However, even at more moderate elevations and exposures, the tendency for higher wind speeds at higher elevations increases evaporation of water from plant and, especially, soil surfaces. The increased water loss may amount to a centimeter or two during the spring growing season.¹⁰ Because only 3 to 5 more centimeters of precipitation may be at the higher elevations (Figure II.3-G-2), wind reduces the biological importance of the extra precipitation by a substantial fraction. "Books about nature seldom mention wind; they are written behind stoves."¹¹

II.3-G.2 Soil

Soils play an indispensable role in the ecological distribution of plant and animal communities on the Hanford Reservation. Soils provide water

storage, essential nutrients, and physical support for plants, as well as a refuge for many kinds of animals from the rigors of wind and extreme temperature fluctuations in both summer and winter.

Soils of the Hanford Reservation differ markedly in their physical and chemical properties and productivity, the results of the unique set of soil-forming factors which brought these soils to their present state. These factors are: 1) the parent material from which the soils were formed; 2) the climate under which the soils were formed; 3) the relief, including both slope and exposure, of each site; 4) the vegetation growing on each site; and 5) the period in which factors 2, 3, and 4 above have operated.

Soils of the Hanford Reservation formed in five kinds of parent material, including recent alluvium, old alluvium (glacial outwash), windblown sand, lacustrine (lake-laid) deposits, and loess (wind-laid deposits). Basalt bedrock underlies all of these deposits. The minerology of the parent material is varied, resulting in part from weathering of local basalts and in part from weathering of igneous and metamorphic rocks to the north and east of the Hanford Reservation.

Relief affects soil formation through its influence upon precipitation, drainage, runoff, and normal and accelerated erosion. Vegetation affects soil formation by producing organic matter, which in turn influences water holding capacity, infiltration, fertility, and structure.

In this area, annual precipitation varies from 13 to 26 cm, so the organic matter in the soil also varies widely, as shown by the color of the soil. Where annual precipitation is 22 cm or less, the organic content of the surface soil is generally less than 1% and the soil is dark grayish brown when moist.¹² In contrast, where annual precipitation amounts to 22 to 30 cm, the organic content of the surface soil is 1 to 2% and the surface soil is generally very dark grayish brown when moist.

II.3-G.2.1 Description and Classification of Hanford Reservation Soils

The soils of the Hanford Reservation have been mapped, described, and classified.⁹ Physical and chemical characteristics of major soil series of the Hanford Reservation are also available.¹³

Soils which are alike in all characteristics except texture are grouped into soil series. If the texture class is added to the series, the soil unit is called a soil type. The soil type was the unit mapped in a recent survey;⁹ however, small areas of other soil types were included in the delineation. For these reasons the soil type, indicated on the map (Figure II.3-G-3) and described below, represents the predominant type

FIGURE II.3-G-3 SOIL MAP OF THE HANFORD PROJECT IN BENTON COUNTY WASHINGTON⁹

of soil in the delineation: in uniform areas, the type indicated is representative of the entire area enclosed; in the others, inclusions of other soils occur. In addition, because soil boundaries seldom change abruptly, transitional areas are included.

II.3-G.2.1.1 Soil Descriptions

Ritzville Silt Loam (Ri)

This mapping unit consists chiefly of dark colored silt loam soils which developed midway up the slopes of Rattlesnake Hills. These soils developed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. The surface, an 8 in. layer, is usually very dark grayish brown (10YR³/2)^(a) grading with depth to a dark grayish brown (10YR⁴/2) silt loam subsoil. Small areas of very fine sandy loam are included in addition to Warden, Lickskillet, and Scootney soils.

Ritzville soils are characteristically greater than 60 inches deep but in places bedrock may occur between 60 and 30 inches deep.

Rupert Sand (Rp)

This mapping unit represents one of the most extensive soils on the Hanford Project. The surface is a brown to grayish brown (10YR⁵/2) coarse sand, which grades to a dark grayish brown (10YR⁵/2) sand at about 36 inches. Rupert soils developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits which were mantled by wind-blown sand. Relief characteristically consists of hummocky terraces and dune-like ridges. This soil may be correlated to Quincy sand, which was not separated here.

Active sand dunes are present. Although some dune areas are separated, many small dunes, blow-outs, and associated small areas of Ephrata and Burbank soils are included.

(a) Munsell color designation indicating hue, chroma, and value.

Hezel Sand (He)

Hezel soils, similar to Rupert sands, are a laminated grayish brown (10YR⁵/2) strongly calcareous silt loam subsoil usually encountered within 40 inches of the surface. The surface soil is very dark brown (10YR³/3) and was formed in wind-blown sands which mantled lake-laid sediments. Areas of Rupert, Burbank, and blow-outs are included.

Koehler Sand (Kf)

Koehler soils are similar to the other sandy soils found on the Hanford Reservation. They developed in a wind-blown sand mantle. This soil differs from the other sands in that the sand mantles a lime-silica cemented layer "hardpan." The very dark grayish brown (10YR³/2) color of the surface layer is somewhat darker than Rupert. The calcareous subsoil is usually dark grayish brown (10YR⁴/2) at about 18 inches. Inclusions are of the Rupert and Burbank series.

Burbank Loamy Sand (Ba)

This is a dark-colored coarse-textured soil which is underlain by gravel. The surface is very dark grayish brown (10YR³/2), while the subsoil is dark grayish brown (10YR⁴/2). The surface soil is usually about 16 inches thick but can be 30 inches thick. The gravel content of the subsoil may range from 20 to 80 vol%. Areas of Ephrata and Rupert are included.

Kiona Silt Loam (Ki)

This soil occupies steep slopes and ridges. The surface soil is very dark grayish brown (10YR³/2) and about 4 inches thick. The dark brown (10YR⁴/3) subsoil contains basalt fragments 12 inches and larger in diameter. Many basalt fragments also are found in the surface layer and basalt rock outcrops are present. Normally this shallow stony soil occurs in association with Ritzville and Warden soils. Many areas of stony silt loam and very shallow Lithosols are included.

Warden Silt Loam (Wa)

This is a dark grayish brown soil ($10YR^{4/2}$) whose surface layer is usually 9 inches thick. The silt loam subsoil becomes strongly calcareous and lighter colored (grayish brown ($10YR^{5/2}$)) at about 20 inches. Granitic boulders are found in many areas. Usually this soil is greater than 60 inches deep. Associated soils and inclusions are of the Ritzville, Kiona, Esquatzel and Scootney series. At higher elevations (1200 feet), Warden soils grade to Ritzville silt loam.

Ephrata Sandy Loam (E1)

This is a dark colored medium-textured soil which is underlain by gravelly material which may continue for many feet. The surface is very dark grayish brown ($10YR^{3/2}$), while the subsoil is dark grayish brown ($10YR^{4/2}$). Since this soil is associated with the Burbank soil, many small areas were included in delineations of this soil type. The topography is generally level.

Ephrata Stony Loam (Eb)

This soil is similar to Ephrata sand loam. It differs in that many large hummocky ridges are present which are made up of debris released from the melting ice of glaciers. Areas between hummocks contain many boulders several feet in diameter. Ephrata sandy loam and Burbank loamy sand are associated and included.

Scootney Stony Silt Loam (Sc)

This soil developed along the north slope of the Rattlesnake Hills, usually confined to floors of narrow draws or small fan-shape areas where draws open onto plains. The soils are often severely eroded with numerous basaltic boulders and fragments being exposed. The surface soil is usually dark grayish brown ($10YR^{4/2}$) grading to grayish brown in the subsoil. Many small areas of Warden and Ritzville are included.

Pasco Silt Loam (P)

This is a poorly drained very dark grayish brown ($10YR^{3/2}$) soil formed in recent alluvial material. The subsoil is variable, consisting of stratified layers. Only small areas of this soil are found on the Hanford Project and they are located in low areas adjacent to the Columbia River. Areas of riverwash may be included.

Esquatzel Silt Loam (Qu)

This is a deep dark brown ($10YR^{3/3}$) soil formed in recent alluvium derived from loess and lake sediments. The subsoil grades to dark grayish brown ($10YR^{4/2}$) in many areas but color and texture of the subsoil is variable due to the stratified nature of the alluvial deposits. Esquatzel soils are associated with Ritzville and Warden and often seem to have developed from sediments eroded from these two series.

Riverwash (Rv)

These are wet, periodically flooded areas of sand gravel and boulder deposits which make up overflowed islands in the Columbia River and adjacent to the river.

Dune Sand (D)

This unit represents a miscellaneous land type which consists of hills or ridges of sand-sized particles drifted and piled up by wind and are either actively shifting or so recently fixed or stabilized that no soil horizons have developed. In places, recently blown-out land and areas of Rupert sand are included. Many small active dunes and accompanying blown-out areas are included with other soils, mostly Rupert, Hezel and less frequently Burbank.

Lickskillet Silt Loam (Ls)

This soil occupies the ridge tops of Rattlesnake Hills and slopes above the 2500-ft elevation. The soil is similar to the Kiona series except that the surface soils are a very dark brown ($10YR^{2/2}$ to $^{3/2}$).

Lickskillet soils are shallow over basalt bedrock. Numerous basalt fragments are present throughout the profile. Many areas of very stony silt loam and Ritzville soils are included.

II.3-G.2.1.2 Soil Classification

The correlation from the earlier Hanford soil survey⁹ into the present system appears in Table II.3-G-1. In addition to the correlations shown, many small areas of soil were included with surrounding or adjacent large bodies of soils.

Table II.3-G-2 lists the approximate higher category and engineering classification of soil types on the Hanford Project. The Unified and A.A.S.H.O. engineering classification systems are based on characteristics which influence engineering behavior of soil. Both systems are based mostly on grain size, plasticity, and load limits. Brief description of the engineering categories are given in the following outline:

A.A.S.H.O. (American Association of State Highway Officials)

- Group A-1. Typically this is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand, and a nonplastic or pebble plastic soil binder. This group also includes stone fragments, gravel, coarse sand, etc., without soil binder.
- Group A-2. This group comprises a wide variety of granular material which is at the border line between groups A-1 and A-3. It includes any material of which not more than 35% will pass through a No. 2 sieve and cannot be classified as A-1 or A-3 because of having fines, plasticity, or both in excess or limitation for these groups.
- Group A-3. This soil group is a fine beach sand or fine desert blow sand without silty or clayey fines or with a very small amount of nonplastic silt.
- Group A-4. Typically Group A-4 is a nonplastic or moderately plastic silty soil with more than 36% of the material passing

TABLE II.3-G-1
 CLASSIFICATION OF SOIL SERIES OF BENTON COUNTY AREA
 (Rasmussen, 1971)

Series	Current Classification			1938 Classification	
	Family	Subgroup	Order	Great Soil Group	Order
Ritzville silt loam	Coarse-silty, mixed, mesic	Calciorthidic Haploxerolls	Mollisol	Brown soils	Zonal
Rupert sand	--	--	--	--	--
Koehler sand	Sandy, mixed, mesic	Xerollic Durorthids	Aridisol	Regosols	Azonal
Hezel sand	Coarse-loamy, mixed, nonacid, mesic	Typic Torriorthents	Entisol	Regosols	Azonal
Burbank loamy sand	Mixed, mesic	Typic Torripsamments	Entisol	Regosols	Azonal
Ephrata sandy loam	--	--	--	--	--
Licksillet silt loam	Loamy-skeletal, mixed, mesic	Aridic Lithic Haploxerolls	Mollisol	Chestnut soils	Zonal
Ephrata stony loam	--	--	--	--	--
Kiona silt loam	Loamy-skeletal, mixed, mesic	Xerollic Camborthids	Aridisol	Brown soils	Zonal
Warden silt loam	Coarse-silty, mixed, mesic	Xerollic Camborthids	Aridisol	Sierozems	Zonal
Scootenev stony silty loam	Coarse-loamy, mixed, mesic	Xerollic Camborthids	Aridisol	Sierozems	Zonal
Pasco silt loam	Coarse-silty, mixed, mesic	Cumulic Haploxerolls	Mollisol	Alluvial soils	Azonal
Esquatzel silt loam	Coarse-silty, mixed, mesic	Torrifluventic Haploxerolls	Mollisol	Alluvial soils	Azonal
Riverwash	--	--	--	--	--
Dunesand	--	--	--	--	--

TABLE II.3-G-2
 APPROXIMATE CLASSIFICATION OF HANFORD SOILS
 IN ENGINEERING CATEGORIES⁹

Soil Type	Classification	
	Unified	A, A, S, H, O,
Ritzville silt loam	ML	A-4
Rupert sand	Surface SM Subsoil SP to SM	A-4
Hezel sand	Surface SM Subsoil ML	A-2 A-4
Koehler sand	SM	A-2
Burbank loamy sand	Surface SM Subsoil GM to GP	A-2 A-2 to A-4
Ephrata sandy loam	Surface SM to ML Subsoil ML	A-2 to A-4 A-4 to A-1
Lickskillet silt loam	ML to GM	A-4 to A-1
Kiona silt loam	GM	A-1
Warden silt loam	SM to ML	A-2 to A-4
Scootney stony silt	SM to ML	A-2 to A-4
Ephrata stony loam	Surface SM-ML Subsoil ML	A-2 to A-4 A-4 to A-1
Pasco silt loam	SM to ML	A-4
Esquatzel silt loam	SM to ML	A-4
Riverwash	GP	A-1
Dune sand	SP to SW	A-3

through a No. 200 sieve. The usual type of significant constituent material is silt.

Unified System

- Group ML. Group ML is predominately silty material and micaceous or diatomaceous soils. The soils usually are sandy silts, clayey silts, or inorganic silts with relatively low plasticity. Also included are loessial soils and rock flours.
- Groups GM to SM. These groups include gravels or sands which contain more than 12% fines that have little or no plasticity. Both well graded and poorly graded materials are included. Some dry strength may be provided by cementation of calcareous materials or iron oxides.
- Groups GP to SP. Poorly graded sands and gravels containing less than 5% of nonplastic fines constitute these groups. They may consist of uniform gravels, uniform sands, or nonuniform mixtures of very coarse material and very fine sand with intermediate sizes lacking.
- Groups GW to SW. These groups comprise well-graded sandy and gravelly soils which contain less than 5% of nonplastic fines passing through the No. 200 sieve. Fines which are present must not noticeably interfere with the free draining characteristics of this group.

Table II.3-G-3 gives the approximate land use capability classification of Hanford Project soils. This is a practical grouping of soils based on 1) limitations of soils for possible cropland and pasture use and 2) on the risk of damage when they are used. The classification shown is the broadest grouping; subclasses and units are lower groups within this system but are not included. Dryland and irrigated capability units are used because of the increased potential of the soil when irrigated. The capability units are the same when the same hazards exist in both cases.

TABLE II.3-G-3
SOIL CAPABILITY CLASSIFICATION

<u>Soil Type</u>	<u>Dryland</u>	<u>Irrigated</u>
Ritzville silt loam	III-VII	I-IV
Rupert sand	VII	IV
Koehler sand	VII	IV
Hezel sand	VII	IV
Burbank loamy sand	VII	IV
Ephrata sandy loam	VI	II-IV
Licksillet silt loam	VI & VII	---
Ephrata stony loam	VI	---
Kiona silt loam	VI	---
Warden silt loam	IV	I-IV
Scotney stony silty loam	VI	---
Pasco silt loam	IV	III
Esquatzel silt loam	III	I
Riverwash	VIII	---
Dunesand	VIII	---

The following are descriptions of capability classes:

- Class I. These soils have few limitations and have wide latitude for use. Soils classed in this group are deep, productive, easily worked, and nearly level. No wind or water erosion hazard exists.
- Class II. Soils in this group have moderate limitations in use and are subject to moderate risk of damage. These are good soils; however, some special conservation attention is necessary due to slopes, erosion, depth, drainage, or overflows.
- Class III. These soils are subject to severe limitations in use for cropland because of moderately steep slopes, severe erosion hazards (wind or water), inherently low fertility. Intensive conservation practices are needed to farm this class of soil safely.
- Class IV. This class consists of soils that have very severe permanent limitations or hazards for cropland use. These limitations may be caused by steep slopes, wind, or water erosion hazards, or a dry, arid climate.
- Class V. Soils in this class should be kept in permanent vegetation used for pasture or forestry. Cultivation is not feasible because of wetness or stoniness.
- Class VI. Class VI soils should be used for grazing and forestry and may have moderate hazards when in this use. These soils are steep, or shallow over bedrock and stony. Erosion susceptibility is high.
- Class VII. These soils can be used for grazing or forestry; however, the steep, eroded rough stony or very dry sandy condition causes severe permanent limitations to use.
- Class VIII. These soils are suitable only for wildlife, recreation, or watershed uses.

II.3-G.3 Vegetation

II.3-G.3.1 Primary Plant Descriptions

The vegetation mosaic of the Hanford Reservation consists of eight major kinds of shrub-steppe communities identified by the most conspicuous or most abundant plant species:

- Sagebrush/bluebunch wheatgrass
- Sagebrush/cheatgrass or Sagebrush/Sandberg's bluegrass
- Sagebrush-bitterbrush/cheatgrass
- Greasewood/cheatgrass-saltgrass
- Winterfat/Sandberg's bluegrass
- Thyme buckwheat/Sandberg's bluegrass
- Cheatgrass-tumble mustard
- Willow

Onsite locations where these several communities predominate are shown in Figure II.3-G-4.

On the Hanford Reservation, the sagebrush/bluebunch wheatgrass (Figure II.3-G-5) vegetation-type occupies extensive acreage in the Rattlesnake Hills, mostly confined to the ALE Reserve (Figure II.3-G-6). In the absence of fire, sagebrush is the most conspicuous plant, but perennial grasses (bluebunch wheatgrass and Sandberg's bluegrass) contribute most of the plant biomass. In the event of fire, sagebrush is killed but the perennial grasses are not (Figure II.3-G-7). Over time, sagebrush is expected to return to burned areas, but this is a slow process that probably does not occur during the average human lifetime. Bluebunch wheatgrass is the most important livestock forage plant on the Hanford Reservation.

The most broadly distributed vegetation-type on the Hanford Reservation is the sagebrush/cheatgrass (Figure II.3-G-8 and Figure II:3-G-9) or

FIGURE II.3-G-4 DISTRIBUTION OF VEGETATION
 TYPES ON THE HANFORD
 RESERVATION

FIGURE II.3-G-5 SAGEBRUSH/BUEBUNCH WHEATGRASS COMMUNITY. (The shrub is big sagebrush and the large bunchgrass is blue-bunch wheatgrass.)

II.3-G-23

FIGURE II.3-G-6 ARID LANDS ECOLOGY RESERVE

FIGURE II.3-G-7 SAGEBRUSH/BLUEBUNCH WHEATGRASS COMMUNITY. (Burned in 1957. The shrub in the foreground is rabbitbrush, a shrub that can sprout following fire damage; sagebrush is usually killed by fire.)

FIGURE II.3-G-8 SAGEBRUSH/CHEATGRASS COMMUNITY. (The shrub is big sagebrush, the dense grass understory is mostly cheatgrass, an alien weed introduced to the Pacific Northwest with the advent of livestock grazing and agriculture. These growths are prevalent on the low-elevations of the Hanford Reservation.)

FIGURE II.3-G-9 SAGEBRUSH/SANDBERG'S BLUEGRASS COMMUNITY. (The shrub is big sagebrush and the sparse understory grass is Sandberg's bluegrass.)

sagebrush/Sandberg's bluegrass association. This vegetation-type occurs as a broad zone between the sagebrush/bluebunch wheatgrass type and the sagebrush-bitterbrush/cheatgrass type. The sagebrush/cheatgrass type differs from the sagebrush/bluebunch wheatgrass principally in that wheatgrass is absent, but another important difference is that sagebrush plants also tend to be larger in size and provide more ground cover. Spiny hopsage and rabbitbrush may be intermingled with sagebrush shrubs. Fire can burn through this kind of vegetation, killing sagebrush, but hopsage and rabbitbrush survive burning, sending out new growth during the growing season following the fire. Recovery of this vegetation following fire is not as readily apparent as in the sagebrush/bluebunch wheatgrass bluegrass vegetation because large perennial grasses are scarce. The general paucity of herbaceous cover also tends to favor invasion by tumbleweed, with or without fire. The sagebrush/cheatgrass and sagebrush/Sandberg's bluegrass communities provide very limited forage for livestock or wildlife.

The sagebrush-bitterbrush/cheatgrass (Figure II.3-G-10) vegetation-type occupies the low elevations in the southeastern sector of the Hanford Reservation. This vegetation-type differs from the sagebrush/cheatgrass type by having bitterbrush intermingled among the sagebrush shrubs. Also, snow eriogonum, a small shrub, is often locally abundant. The sagebrush-bitterbrush/cheatgrass vegetation-type occupies the sandiest soil short of dunes. Fire is especially destructive in this vegetation-type because sagebrush and bitterbrush are both killed by burning and the sandy soil is especially susceptible to wind erosion when protective vegetation cover is destroyed. The colonization of sandy soils in an arid environment is a slow process, especially if large areas are burned and seed sources severely reduced. The most efficient early invader of burned areas in the sagebrush-bitterbrush/cheatgrass vegetation-type is tumbleweed. Bitterbrush is an important forage plant for mule deer, especially in fall and winter.

FIGURE II.3-G-10 SAGEBRUSH-BITTERBRUSH/CHEATGRASS COMMUNITY. (The light colored shrub is sagebrush and the dark colored shrub is bitterbrush. The understory is mostly cheatgrass.)

The greasewood/cheatgrass-saltgrass (Figure II.3-G-11) vegetation-type is restricted to a small area of about 100 acres in the vicinity of Rattlesnake Springs.¹⁴ This vegetation-type is important because the geographic distribution of greasewood is determined by the presence of a relatively shallow water table. Greasewood has an extensive root system and can extract water from a depth of 12 meters at Rattlesnake Springs, remaining succulent throughout the summer when other upland shrubs are dried from summer drought. Greasewood is known to be a salt accumulator.¹⁵ The greasewood/cheatgrass-saltgrass vegetation type provides little forage.

The winterfat/Sandberg's bluegrass (Figure II.3-G-12) vegetation-type occupies several thousand acres along the gentle lower slopes of the Rattlesnake Hills. For the most part, winterfat is restricted in geographic distribution to the ALE Reserve. In the years prior to government acquisition of the Hanford Reservation lands, the winterfat areas were used as winter pastures for sheep, because winterfat is a nutritious and palatable forage plant for livestock.

The thyme buckwheat/Sandberg's bluegrass (Figure II.3-G-13) vegetation-type occupies thin, stony soils along ridge crests in the Rattlesnake Hills and Gable Mountain areas. These communities have no potential for agricultural use other than to provide limited forage for livestock and wildlife, but they possess great aesthetic value because of the presence of many species with showy flowers. These species are of substantial botanical interest because of their floristic composition and morphological, physiological and genetic adaptations to living in a stressed environment.

The cheatgrass/tumble mustard (Figure II.3-G-14) vegetation-type occupies abandoned agricultural fields, especially in the 100 Areas and on the ALE Reserve. This vegetation-type is comprised mostly of alien annual plants, i.e., cheatgrass and annual mustards. It has over the past 30 years resisted invasion by native perennial grasses and shrubs

FIGURE II.3-G-11 GREASEWOOD/CHEATGRASS-SALTGRASS COMMUNITY. (The shrub clump in the foreground is greasewood, the understory grasses are a mixture of cheatgrass and saltgrass.)

FIGURE II.3-G-12 WINTERFAT/SANDBERG'S BLUEGRASS COMMUNITY. (The short-statured shrub in the foreground is winterfat.)

FIGURE II.3-G-13 THYME BUCKWHEAT/SANDBERG'S BLUEGRASS COMMUNITY.
(Appearing at high elevations on the ALE Reserve,
the low-growing cushion-like plants are thyme buck-
wheat.)

FIGURE II.3-G-14 CHEATGRASS-TUMBLE MUSTARD COMMUNITY. (This occupies a 30-yr old abandoned wheatfield at mid-elevation on the ALE Reserve.)

and colonization by tumbleweed. The ecological behavior of cheatgrass/tumble mustard communities has been studied on the ALE Reserve.^{3,4,16,17,18,19} Cheatgrass/tumble mustard communities in the absence of livestock grazing are effective in binding soil against wind and water erosion. (Figure II.3-G-15 shows photographic locations.)

Willow vegetation (Figure II.3-G-16) occurs along the banks of the Columbia River, waste ponds in the 200 Areas, abandoned agricultural irrigation ditches in the 100 Areas and along permanent spring courses in the Rattlesnake Hills. Although the amount of acreage occupied by willow communities is small, their value to wildlife is large.

Willows and associated deciduous trees, shrubs and herbaceous plants provide food and nest sites for game and song birds, summer forage, and cover for mule deer.

Miscellaneous vegetation-types occur throughout the Hanford Reservation. Of particular importance are deciduous trees around waste ponds,²⁰ abandoned homesteads, and abandoned military installations that provide nesting and resting sites for raptorial birds of prey. A current floristic list for the Hanford Reservation is provided in Part 2 of this Appendix.

Ecological aspects of waste management are important for some of the vegetation types, particularly the sagebrush/cheatgrass type (around the 200 and 300 Areas) and some cheatgrass/tumble mustard type (around the 100 Areas).

II.3-G.3.2 Pattern of Secondary Plant Succession

The historical pattern of plant succession in the steppe region of Washington has been altered during the past century by the introduction of annual weeds from the steppes of Eurasia. One of the most aggressive of these plants is cheatgrass. Cheatgrass is well adapted to the fall-winter precipitation regime of the area because its seeds are highly viable and seedling growth is more competitive than that of

FIGURE II.3-G-15 LOCATION AND DIRECTION OF VIEW FOR PLANT COMMUNITY PHOTOGRAPHS

FIGURE II.3-G-16 WILLOW COMMUNITY. (Located at Rattlesnake Springs
on the ALE Reserve.)

native perennial grasses. Abandoned agricultural fields 30 years old continue to be dominated by cheatgrass; apparently the competition for soil, water, and available essential mineral nutrients is sufficient to exclude other kinds of plants for long periods of time.

Tumbleweed, another exotic plant, has an effective method of seed dispersal. Tumbleweed is not as competitive as cheatgrass in most habitats, but it is the most successful colonizer of habitats where cheatgrass is suppressed by mechanical means or herbicides, or in soils with heterogeneous texture. In the absence of physical disturbance, cheatgrass and tumbleweed are not effective in invading pristine steppe communities. Nevertheless, cheatgrass and tumbleweed will become more important on the Hanford Reservation as soil is disturbed by construction and waste burial sites.

II.3-G.4 Mammals

The mule deer is the only big game mammal normally found on the Hanford Reservation, although a white-tail deer has been recorded.²¹ A single elk resided on the Reservation for a few months in 1971-72, probably a migrant from the Blue Mountains 70 miles to the east. Most of the mule deer on the Hanford Reservation occur along the Columbia River, with smaller concentrations near Gable Mountain and the 200 Area, at Rattlesnake Springs, and on the Snively Ranch area in the Rattlesnake Hills. Over the past years, 180 fawns (from near the Columbia River only) have been tagged and released. Tagged animals have been taken during the legal hunting season as far away as Prosser, Washington, along the Yakima River; Mattawa, Washington, in the Saddle Mountains; and near the Walla Walla River.²²

The cottontail rabbit is the only small game mammal, with small populations scattered throughout the Reservation area. The raccoon is probably the most abundant furbearing mammal on the Hanford Reservation, mostly confined to shoreline areas of the Columbia River and waste ponds in the 200 Areas. Beaver and muskrats occur in backwater

areas of the Columbia River, while muskrats are found in wasteponds and ditches in the 200 Areas. Mink occur along the Columbia River and weasels are scattered throughout the Hanford area. The coyote is abundant on the Hanford Reservation as compared to adjacent land areas, although no accurate estimate of population density has been made. The bobcat and badger are present on the Reservation, but in low numbers.

The jackrabbit is widely distributed on the Hanford Reservation; however, it is less abundant in the sagebrush/bluebunch wheatgrass vegetation than in the sagebrush/cheatgrass and sagebrush-bitterbrush/cheatgrass vegetation-types. The jackrabbit is an important food item for coyotes and raptors.

Porcupines are widely distributed over the Reservation area but are especially abundant along the Columbia River. Porcupines occur in the 200 Areas and in the canyons and valleys of the Rattlesnake Hills.

Small mammals are abundant on the Hanford Reservation and their population dynamics have been studied by mark and recapture techniques in the sagebrush/bluebunch wheatgrass²³ and sagebrush/cheatgrass vegetation²⁴ and in the sagebrush-bitterbrush/cheatgrass vegetation.²⁵ The Great Basin pocket mouse is the most abundant mammal on the Reservation. Deer mice and ground squirrels are locally abundant, as is the pocket gopher. Other small mammals are the harvest mouse, house mouse, Norway rat, mountain vole, sagebrush vole, grasshopper mouse, vagrant shrew, Merriam shrew, least chipmunk, and woodrat. The kangaroo rat is not found on the Hanford Reservation although it is common in the steppe region of Oregon. (A species list of the mammals and other vertebrates that occur on the Reservation is provided in Part 3 of this Appendix.)

II.3-G.5 Birds

The chukar partridge is the most important game bird on the Hanford Reservation. Most of the population is concentrated on the ALE Reserve,

especially the Rattlesnake Hills, but there are local populations in the Gable Mountain and White Bluffs area. Although introduced to Washington from Eurasia, the chukar is well adapted to the arid environment of the Hanford Reservation, feeding upon herbage, seeds and insects associated with dry rangeland.

Chinese ring-necked pheasants are present on the Hanford Reservation but in small numbers. Small groups are found along the Columbia River, generally upstream from the old Hanford townsite, Rattlesnake Springs and Snively Spring. The habitat is marginal for pheasants.

California quail are present as scattered local populations along the Columbia River, especially abandoned farmstead sites with residual orchard and shade trees, and around the waste ponds in the 200 Areas.

Mourning doves are migratory birds that nest throughout the Hanford Reservation area during the spring months. Most birds have migrated by October.

Sage grouse are present on the Hanford Reservation in small numbers. In recent years most sightings occurred in the Rattlesnake Hills on the ALE Reserve. Over the years the sage grouse population declined in southeastern Washington as pristine habitat was converted to dry-land wheat and irrigated agricultural fields.

The Canada goose is the most important of the nesting waterfowl on the Hanford Reservation; the nesting habitat is confined to islands in the free-flowing reach of the Columbia River.²⁶ The Columbia River also provides a resting sanctuary for migratory flocks of ducks and Canada geese. At peak migratory periods, 70,000 birds or more, mostly mallards, use the Hanford reach of the Columbia River. Ducks, geese, and other migrating birds also utilize waste ponds in the 200 Areas especially during fall migration.²⁷

Raptorial birds use the Hanford Reservation as a refugium from human intrusions, especially during the nesting season. Trees around

abandoned farms in the 100 Areas and around abandoned military installations provide nesting habitat for red-tailed hawks, Swainson's hawks, and great horned owls, while Prairie falcon nests are located on Gable Butte and along Umtanum Ridge.²⁸ The sparrow hawk is the most abundant of the raptorial birds and the marsh hawk nests on the Hanford Reservation (as does the burrowing owl), but the osprey is only an occasional visitor along the Columbia River. The golden eagle and the bald eagle are both winter visitors. The raptorial birds are of particular interest because their ancestral ranges are being steadily reduced by human encroachment. Relatively large areas of uninhabited land, such as the Hanford Reservation, provide a nesting and foraging ground for raptorial birds.

The steppe region of south-central Washington is not rich in bird species. A year-long survey of the birds observed on and adjacent to waste ponds in the 200 Area showed 116 species.²⁷ The annual Christmas bird census by the Lower Columbia Basin Audubon Society registers about 80 species. Many species are migratory waterfowl and shorebirds; only a few species nest in steppe vegetation. The most abundant birds in steppe vegetation are the western meadowlark and the horned lark.²⁹ The most abundant nesting birds in the riparian vegetation include, among others, magpies, crows, doves, some warblers, and waterfowl.

II.3-G.6 Snakes and Lizards

As compared to the southwestern United States desert areas, the herpetofauna of the Hanford Reservation, like south-central Washington in general, is sparse. The most abundant reptile in low elevation steppe vegetation is the side-blotched lizard. The horned lizard is not common and the sagebrush lizard is scarce. The most abundant snake is the gopher snake, but the yellow-bellied racer and the Pacific rattlesnake are common. The coachwhip snake and the desert night snake are seldom observed.

Snakes are an important food item for the Swainson's hawk. Most reptiles are rather widely distributed over the Hanford Reservation in small numbers, generally decreasing in numbers as elevation increases. The side-blotched lizard apparently does not occur at all at elevations above 400 meters.

II.3-G.7 Insects

Insects on the Hanford Reservation, as everywhere else, are dependent upon plants for their livelihood. However, the vegetation in an area does more than provide food supporting associated invertebrate food webs; it also serves to modify extreme fluctuations of environmental conditions, such as temperature, humidity, and wind speed. An understanding of the influence plants exert on an area makes it easier to grasp how vegetation determines the kinds and abundance of insects.

Two main phases of plant growth are on the Hanford Reservation; one occurs in the fall with the onset of winter rains. The ensuing burst of growth in some grasses lasts until cold weather precludes further growth. This is not a good time for insects, even though succulent plant material is available, because the onset of cold weather is frequently swift and unpredictable. An insect population emerging at this time would risk decimation by adverse conditions. The second period of rapid plant growth occurs in the spring, with the occurrence of warmer temperatures. This seems to be the period when insects are most abundant, their numbers reaching a peak in June and then declining as the plants become dormant in response to depletion of soil moisture. The months of July and August are another inhospitable time for insects--temperatures are high, humidity is low and few succulent plants are available. This does not mean that insects are not present; insects are always present, but at times in relatively small numbers.

A preliminary list of insect species known to inhabit this area is shown in Part 4 of this appendix. Although it is probably safe to

assume that the species which contribute significantly to insect abundance are contained in this list, this list will probably continue to be updated for several years as additional specimens are found. The following discussion will deal only with some of the important groups known to be present at the Hanford site--particularly, where certain kinds of insects are found and their role in ecosystems functioning.

Members of the order Homoptera are rather specialized plant eaters (herbivores). All members of this order have their mouth parts modified into a piercing beak and imbibe juices from the leaves, stems or roots of plants. Homoptera occur in relatively low numbers early in the season at Hanford and become more numerous as the season progresses, reaching a peak during the month of August. Leafhoppers (Cicadellidae), aphids (Aphididae) and plant hoppers (Fulgoridae) are all present, but members of the superfamily Coccidea are the most abundant. The Coccidea are primarily mealybug (Pseudococcidae), most of which occur in association with bluebunch wheatgrass, indicating that this grass may be a favored food source. Cicadas may periodically be conspicuously present in this area, primarily due to the buzzing "song" produced by the males. They may remain as larvae in the soil for several years, but the adult stage generally lasts only a few summer months.

The order Orthoptera contains the well known family Acrididae (grasshoppers) which are frequently very destructive members of grassland communities. The grasshopper possessing the greatest potential for outbreak in this area is the migratory grasshopper (Melanoplus sanguinipes). Under optimal environmental conditions, this species is able to increase from 100 female eggs to 8265 female eggs in one generation.³⁰ Localized concentrations have occurred at Hanford in the past¹⁹ and will probably continue to do so in the future. These concentrations appear to occur only in the cheatgrass/tumble mustard vegetation. Soil disturbance, resulting in an invasion of cheatgrass,

Russian thistle or goatsbeard, would provide an ideal area for the buildup of grasshopper populations.

The order Coleoptera (beetles) comprises the largest insect order and contains nearly 50 percent of all known insect species. A very diverse group, they inhabit nearly all conceivable types of habitat. Many are herbivores, some are predaceous, and others are scavengers, helping to break down organic residue for further decomposition--an important role in an arid ecosystem.

Some important predaceous beetle families in this area are the ground beetles (Carabidae), tiger beetles (Cicindelidae), checkered beetles (Cleridae) and ladybird beetles (Coccinellidae). The weevils (Curculionidae) are probably the most important group of plant eaters in this order. There are 16 species of darkling beetles known to occur in this area. Many species in this group function as scavengers--eating dead plant and animal matter. Two species of darkling beetle, Philolithus densicollis and Stenomorpha puncticollis, can be particularly abundant. These beetles emerge from the soil in the fall and spend the few months prior to cold weather feeding, mating, and depositing their eggs in the soil where immature beetles spend two years feeding and developing beneath the surface. These beetles have a "patchy" distribution, being very abundant in certain areas and much less abundant in other nearby locations. Philolithus does not occur in high elevation cheatgrass/tumble mustard vegetation, and is very much more abundant in native grasslands than in cheatgrass swards. Stenomorpha is somewhat less abundant than Philolithus, and less sensitive to vegetation type, but Stenomorpha does not occur at low elevations.

The order Hymenoptera (ants, wasps, bees) contain a great number of species that are either predators or parasites, as well as the plant pollinators essential for ensuring fertilization of many flowering plant species. The ants (Formicidae) are an important component of natural systems. Most are omnivores--taking both plant and animal

material as food. They also perform a "tilling" of the soil through colony construction. Some colonies have tunnels penetrating to depths exceeding 10 feet. Soil from colony construction is deposited on the surface and organic materials (food) are taken into the colony, thereby enriching the soil. Ants are not abundant on the Reservation, but they seem to occur in all vegetation-types.

Members of the family Sphecidae are solitary wasps. Most nest in burrows constructed in the ground and provision the young with prey. The Ichneumonidae are another important Hymenopteran family, attacking a great variety of insect hosts. Unlike the sphecids who paralyze and then drag their prey to a burrow, the Ichneumons are mostly internal parasites of immature stages of the host. Wasps are very mobile and occur in all vegetation-types.

The collembola (springtails) play a dual role, some members feeding on decomposing plant material, others feeding directly on living plant tissue. Collembola are very common in any mulch layer but are frequently overlooked, due to their tiny size. Collembola populations at Hanford peak in early May and are collected infrequently at other times. They appear to be associated with the crowns of bunchgrasses and with the litter layer that accumulates beneath sagebrush or cheatgrass. The most abundant collembola species belongs to the family Sminthuridae, sometimes called the globular springtails.

The distribution of the abundant plants and animals in the several vegetation-types, arranged in order of decreasing elevation, is given in Part 5 of this appendix. This listing demonstrates clearly that animals are more ubiquitous than plants.

II.3-G.8 Rare or Threatened Species

Allium robinsonii, a wild onion restricted to Columbia River gravel bars between Wenatchee and John Day Dam, can occur on the Hanford Reservation, the last stretch of free-running river. The rocky soils

on the ridge crests of the Rattlesnake Hills hold an endemic species of Balsamroot, Balsamorhiza rosea, but this species is locally abundant and not endangered at this time.

Reptiles and amphibians on the Reservation are restricted to a few wide-ranging species, none of which can be classified as rare, although the sagebrush lizard and the desert night snake are seldom seen at Hanford.

Mammals on the Reservation are not endangered at the species level, although their presence on the Reservation may be in very small numbers. Minks and bobcats are examples of low-density species.

Birds are a different matter. The Hanford Reservation provides a refugium for several rare, threatened or indeterminate species,³¹ all raptors. The prairie falcon (Falco mexicanus) nests in several regions on the Reservation, with the number of nesting pairs probably in the dozens (Olendorff, 1973). The American peregrine falcon (Falco peregrinatus anatum) apparently does not nest on the Reservation but in the neighboring regions, probably in small numbers.²⁸ Species lacking specific data to attest to their status but considered to be possibly in some danger (i.e., indeterminate) include the ferruginous hawk (Buteo regalis), which nests in several sites on the Reservation but in small numbers; the American osprey (Pandion haliaetus carolinensis), only a visitor; and the northern long-billed curlew (Numenius americanus parvus) and the western burrowing owl (Speotyto cunicularia hypugaea), both of which nest on the Reservation in small but significant numbers.

II.3-G.9 Fragile or Restricted Microhabitats

The principal example of a fragile microhabitat on the Hanford Reservation is the few hectares of thin rocky soils on exposed ridgetops supporting the thyme buckwheat/Sandberg's bluegrass vegetation-type. On the Hanford Reservation, only the ALE Reserve has any extensive examples of this habitat, and its extent has been relentlessly reduced by construction activities over the past decades. The aspect of this

vegetation-type is quite reminiscent of an alpine fell-field: small grasses, cushion-form forbs, and a great deal of bare rocky surface. Constant exposure to cold and dessicating winds without the protection of winter snows has pruned the vegetation toward cushion-form, even in normally erect species, a fact readily seen by comparing the stature of species common to rocky outcrops at lower elevations and ridgetops. An alpine cushion plant, Phlox hoodii, is as abundant in this community as on the alpine slopes of Mt. Hood. The slow growth characteristic of arid climates is accentuated in this habitat by poor water and mineral relations, so any area of disturbance is extremely slow to recover.

The Hanford Reservation encloses about 3000 hectares (12 square miles) of active sand dunes near the Columbia River about 8 kilometers south of the old White Bluffs townsite. Shifting, blowing sands in the dune areas combine a very porous substrate with placement in a most arid region to produce a very severe microhabitat populated by relatively few species. Colonizing species such as Psoralea lanceolata are rather common on the larger (hence slower-moving) dunes, but the smaller dunes only a meter or two high move so rapidly that colonization is much reduced. Scattered dunes of small stature exist in the lower elevations of the Hanford Reservation between the 200 Areas and the WYE Barricade; these dunes barely exceed a meter in height and may move hundreds of meters each year. Many of these small dunes were drowned under gravel at roadsides by maintenance crews to prevent them from inundating roads with sand. However, the large dunes near the river may be 15 or 20 meters high and move only a few meters each year, providing suitable footing for vigorous colonizing species. Although the dunes contain so much sand they cannot be rightly considered a restricted microhabitat, the dune's structural integrity and existence are sensitive to disturbance. For example, animal tracks over the crest of a Barchan (crescent) dune can split the dune into two smaller dunes which therefore travel faster than their larger neighbors, leading to overrunning and disappearance.⁸

Kettles and drumlins exist in small areas near the N Reactor (WPPSS Hanford No. 1) on the Reservation. These small mounds and depressions are very rocky, with little fine soil, and are covered with a low-growing vegetation comprised mostly of small annuals, such as cheatgrass, *Microsteris* and Sandberg's bluegrass. The improved water relations on north-facing exposures of these small mounds can cause notable differences in species presence and abundance.

The dispersal of aqueous effluents to the ground surface formed permanent ponds in the 200 Areas. Over the past quarter of a century, vegetation has changed in response to the change in soil moisture. Aquatic emergent species, i.e., cattail and bulrush, grow in most of the ponds. Shrub and tree willows are becoming well established along pond shores, as are mesic plants such as barnyard grass, reed canary grass, cudweed, white top, Russian knapweed, goldenrod, milkweed, and others. These plants often form dense stands that provide food and cover for wildlife and nesting places for song birds and raptors that were not present before the formation of the ponds.

A few tiny areas of essentially pristine low elevation shrub-steppe vegetation exist along north-facing slopes of ancient dune trails on and below the 200 Area plateaus. The undisturbed nature of these small areas is testified to by the complete absence of cheatgrass, which in general abounds in these lower elevations. The slightly more favorable microenvironments on north-facing slopes has allowed mosses and other bryophytes to maintain a nearly continuous soil cover, thus preventing wind erosion of the sandy soils (which would provide the disturbed soil surface favoring cheatgrass). In these small areas, the spaces between sagebrush individuals are carpeted almost completely with either bryophytes or bunches of Sandberg's bluegrass, and are annually attired in the full regalia of desert flowers, principally Phlox.

A few sites exist on north exposures at higher elevations that have a relatively deep wind-deposited soil supporting a grassland reminiscent of shortgrass prairie (true steppe) and very similar to the Palouse grasslands of southeastern Washington before agriculture embraced them. A steep north exposure provides improved water relations by capturing windblown snow and shielding the community from desiccating winds and intense sunshine. A dense grass cover with no interstices between grass clumps is the result, including an interspersion of a few specimens of shrubs typical of more mesic (gentler) habitats, such a snowberry.

The eastern shoreline of the Columbia River is marked by steep-walled banks of 100 meters or more in height. These banks are marked on topographic maps as "White Bluffs." Historically, these banks have provided nesting sites for thousands of pairs of breeding swallows (cliff swallows and bank swallows) and a few nests of the prairie falcon. Occasionally Canada geese have also built nests on narrow ledges. In recent years the bluffs have provided nest sites for flocks of feral rock doves (pigeons) and starlings.

II.3-G.10 Pest Animal Species

House mice (Mus musculus) and the Norway rat (Rattus norvegicus) are occasionally trapped away from buildings. House mice have been trapped in the riparian vegetation at Rattlesnake Springs and along the Columbia River.

Starlings occasionally occur in large flocks, especially in winter. A few nesting pairs have been observed in hollow trees at Rattlesnake Springs and Snively Ranch on the ALE Reserve.

II.3-G.11 Plants

II.3-G.11.1 Primary Productivity

Arid and semi-arid lands are not as biologically productive as humid or wet lands (Table II.3-6-4). Deserts produce on an annual basis less

TABLE II.3-G-4

PRODUCTIVITY ESTIMATES FOR VARIOUS ECOSYSTEMS

Ecosystem	Productivity	
	<u>gm m⁻² yr⁻¹</u>	<u>gm m⁻² day⁻¹</u>
Spartina salt marsh	3300	9.0
Pine plantation	3180	6.0
Deciduous forest	1560	3.0
Tall grass prairie	446	1.22
Short grass prairie	69	0.19
Desert	40	0.11

than 0.2 grams of herbage per square meter per day. The annual above-ground herbage production has been determined on the Hanford Reservation in cheatgrass and in shrub-grass communities. A summary of the peak live standing crop of three different cheatgrass communities on the ALE Reserve over the last 5 years is shown in Table II.3-G-5. Over the 5-yr period herbage yields ranged between 107 and 328 g/m².

Over the years cheatgrass communities have produced on an annual basis more herbage than sagebrush-grass communities. The productivity of pristine stands of sagebrush-bunchgrass is considered¹ to be about 100 g/m². On the ALE Reserve, production of herbage in a sagebrush-grass community has been somewhat more than that in recent years (Table II.3-G-6).

Pronounced differences in species diversity are observed between cheatgrass communities and the sagebrush-grass communities, demonstrated in Table II.3-G-7. Nine species of plants contribute to the herbage yield of cheatgrass communities, eight of which are annuals. About 20 species contribute to plant biomass in the sagebrush-grass community and most of these are perennials of several different life forms.

Although herbage production is the visible output of plant growth, a root system is also produced each year. A comparison of root biomass and distribution in the soil profile of cheatgrass and sagebrush-grass communities is shown in Figure II.3-G-17. Less than 25% of the root biomass in the cheatgrass community is deeper than 2 decimeters, compared to 50% for the sagebrush-grass community. The total biomass is also greater in the sagebrush-grass community compared to the cheatgrass community, i.e., 1200 versus 800 g/m². However, the root biomass data consist of a mixture of living and dead roots, because it is not practical to separate live roots from dead roots from soil cores.

TABLE II.3-G-5

PRODUCTIVITY OF OLD-FIELD (CHEATGRASS-TUMBLE MUSTARD)
COMMUNITIES, 1969-1973
(g/m²)

	Elevation in Meters	180	305	518
1969		328 $\pm$ 28	327 $\pm$ 26	226 $\pm$ 15
1970		165 $\pm$ 11	127 $\pm$ 8	208 $\pm$ 20
1971		Not Avail.	211 $\pm$ 11	263 $\pm$ 38
1972		Not Avail.	132 $\pm$ 7	107 $\pm$ 12
1973		Not Avail.	205 $\pm$ 15	226 $\pm$ 35
Average		246	200	206

TABLE II.3-G-6

PRODUCTIVITY OF A SAGEBRUSH-
BLUEBUNCH WHEATGRASS COMMUNITY
(g/m²)

<u>Year</u>	<u>Herbage</u>	<u>Sagebrush</u>	<u>Total</u>
1971	63 $\pm$ 4	53 $\pm$ 11	116 $\pm$ 15
1972	65 $\pm$ 14	55 $\pm$ 36	120 $\pm$ 50
1973	51 $\pm$ 5	42 $\pm$ 19	93 $\pm$ 24

TABLE II.3-G-7

SPECIES DIVERSITY IN CHEATGRASS
AND SAGEBRUSH/GRASS COMMUNITIES

<u>Cheatgrass Community</u>		<u>Sagebrush-grass Community</u>	
<u>Taxa</u>	<u>Life Form</u>	<u>Taxa</u>	<u>Life Form</u>
Cheatgrass	ANGR	Sagebrush	SH
Sandberg bluegrass	PEGR	Longleaf phlox	PEFO
Tumble mustard	ANFO	Fleabane	PEFO
Tansy mustard	ANFO	Bluebunch wheatgrass	PEGR
Jagged chickweed	ANFO	Sandberg bluegrass	PEGR
Filaree	ANFO	Needlegrass	PEGR
Spring draba	ANFO	Cusick's poa	PEGR
Lanceleaf microseris	PEFO	Cluster lily	PEFO
Yellow Salsify	PEFO	Sego lily	PEFO
		Six weeks fescue	ANGR
		Hawk's beard	PEFO
		Lupine	PEFO
		Locoweed	PEFO
		Spring draba	ANFO
		Pussy Toes	PEFO
		Daisy	PEFO
		Yarrow	PEFO
		Indian paintbrush	PEFO
		Plantago	ANFO
		Tansy mustard	ANFO

<u>CODING</u>	
ANGR	= Annual Grass
ANGO	= Annual Form
PEFO	= Perennial Forb
PEGR	= Perennial Grass
SH	= Shrub

II.3-G-53

FIGURE II.3-G-17 DISTRIBUTION OF ROOT MATERIAL WITH DEPTH
IN PERENNIAL AND ANNUAL GRASS COMMUNITIES

II.3-G.11.2 Mineral Uptake

Herbage provides a source of energy, protein and essential minerals for herbivorous animals, but the amount of energy available to consumers is quite variable. Table II.3-G-8 shows the average heats of combustion (total heat release, or caloric content) of cheatgrass, tumble mustard, bluebunch wheatgrass, Sandberg's bluegrass, and sagebrush leaves and flowers. The mustard has a significantly higher amount of energy bound up in its tissues than the other species, while the grasses have the least, typical of comparisons between broad-leaved plants and grasses. Although a crude measure of energy such as this does not measure usable energy, the relative contribution of the various species to digestible energy is probably similar.

However, the importance of plants to consumers involves much more than as a source of energy. Plants extract minerals from the soil solution for their own functioning, making these minerals available for consumer organisms. Of particular interest to radiation ecology is the amount of stable mineral elements that plants obtain from the soil in which they grow. The mineral elements present in cheatgrass and bluebunch wheatgrass are shown in Table II.3-G-9.

TABLE II.3-G-8

HEATS OF COMBUSTION OF SEVERAL SPECIES
ON THE HANFORD RESERVATION
Kilocalories gram⁻¹ (Dry Weight)

Species	<u>Cheat- grass</u>	<u>Tumble mustard</u>	<u>Wheat- grass</u>	<u>Blue- grass</u>	<u>Sagebrush Flowers and Leaves</u>
Heat of Combustion	3.8	6.1	3.9	4.2	4.8

TABLE II.3-G-9

MINERAL ELEMENTS IN CHEATGRASS
AND BLUEBUNCH WHEATGRASS

	<u>Cheatgrass</u>	<u>Bluebunch Wheatgrass</u>
N, %	1.7	0.92
P, %	0.25	0.15
K, %	1.6	0.67
Ca, %	0.60	0.32
Mg, %	0.18	0.08
S, %	0.25	0.11
Na, %	0.06	0.03
Zn, ppm	20	7.2
Cu, ppm	6	1.1
Fe, ppm	700	130
B, ppm	20	9.4
Mn, ppm	80	77

Some plants accumulate mineral elements to significant concentrations;¹⁵ the results of chemical analysis of greasewood and hopsage leaves growing in the same plant community are shown in Table II.3-G-10.

TABLE II.3-G-10

ACCUMULATION OF MINERALS IN
DESERT SHRUB FOLIAGE

	<u>Na</u> <u>%</u>	<u>K</u> <u>%</u>	<u>Ca</u> <u>%</u>	<u>Mg</u> <u>%</u>
Greasewood	12	2.5	1.5	0.5
Hopsage	0.6	11	1.9	1.6

II.3-G.12 Litter Decay and Mineral Cycling

Continuous maintenance of life requires that mineral nutrients currently bound up in plant and animal life eventually be returned to a common nutrient pool for use by succeeding generations. The rate of return is mostly governed by the activity of microflora and microfauna, organisms of decay which live on or in dead biotic material. The metabolic activity of these microbiota (measured by CO_2 evolution from the soil) is rather closely attuned to environmental conditions of temperature and moisture.³² High levels of both temperature and water induce high levels of soil CO_2 evolution, but the climate of the Hanford Reservation precludes such coincidence in general. Consequently, soil CO_2 evolution is usually low, implying relatively little microbiotic activity compared to a humid climate.

The rate of return of biotically fixed minerals is shown in Figure II.3-G-18 for cheatgrass in the cheatgrass/tumble mustard vegetation-type and for sagebrush leaves in the sagebrush/cheatgrass vegetation-type. Decomposition of the annual grass, cheatgrass, can be considered in three phases following its peak standing crop in May: first, the loss of seeds during summer; second, the transition from standing dead (with essentially no potential for decomposition) to flat litter in intimate contact with the soil biota; and third, the relatively slow continuous disappearance of the flat litter. Measurements of loss from litter bags over a 2-yr period indicated that phase III can be accurately considered an exponential process with a half-time of 6 ± 1 years. This is much slower than the 1 to 2-yr half-time noted for the perennial bluebunch wheatgrass. Similar measurements in the humid tall grass prairie of Missouri³³ also indicated a disappearance half-time of about 1.5 year for perennial grass litter in Missouri.

Sagebrush casts about 90% of its leaf biomass in early summer, presumably a period of relatively slow decomposition, but weight losses from litter bags are noted³⁴ (as shown in Figure II.3-G-18) implying a half-

FIGURE II.3-G-18 RATE OF WEIGHT LOSS IN LITTER BAGS OF LEAVES AND STEMS OF CHEATGRASS, SAGEBRUSH AND BLUEBUNCH WHEATGRASS

time of about 1 year, very much faster than cheatgrass leaves and stems. However, leaf and inflorescence litter, which is the annual portion of sagebrush biomass, comprises only about a half of 1% of the total standing crop. No detectable weight losses of bark, branches, and buried roots occurred even after 2-1/2 years,³⁴ indicating that minerals in these portions of the sagebrush community remain unavailable for a relatively very long time.

II.3-G.13 Animal Populations

Most of the animals on the Hanford Reservation are non-game species having no direct link to man through the food he eats. However, these animals provide food for predators. Some of the most abundant animals on the Hanford Reservation in terms of biomass (g/m^2) are darkling beetles, which can attain an estimated peak biomass of 2 gm m^{-2} (20 pounds per acre) in cheatgrass communities.³⁵ These beetles can

provide an important food supply for some predators in autumn when beetles are active on the soil surface for a few weeks.³⁶

Coyotes are wide-ranging animals that have the potential for wandering on and off the Hanford Reservation boundaries in search of food. Coyotes have disrupted the nesting of Canada geese on Columbia River islands.²⁶ No studies on the Hanford Reservation have been conducted to determine the population densities or movements of the coyote, but an aerial patrol is maintained for the ALE Reserve and casual coyote sightings are recorded. The number of coyotes seen from 1969-1973 are shown in Table II.3-G-11. There is no way to tell how many of these values represent repeated sightings of the same animals.

TABLE II.3-G-11

COYOTE SIGHTINGS BY AERIAL PATROL

Year	1969	1970	1971	1972	1973
Sightings	9	6	16	14	13

The relative freedom from "people use" has made the Hanford Reservation an attractive nesting refuge for large raptors. A scarcity of suitable places to build nests is one of the reasons for low density nesting populations of Swainson's and red-tailed hawks.²⁸ Marsh hawks, sparrow hawks, prairie falcons, burrowing owls and great-horned owls are known to nest on the Hanford Reservation. The golden eagle, bald eagle and osprey frequent the Hanford Reservation in winter as a foraging ground.

The mule deer and the Canada goose are the most important game species that use the Columbia River area as a breeding ground. Both rely heavily upon the relative security of the islands in the Columbia River as a sanctuary for rearing young. Over the past 4 years 180 mule deer fawns were tagged near the Columbia River and released; 17 tags have been returned from legal kills and road kills, etc., some from more than 4 miles from the tagging site.²²

A 21-yr history of Canada goose nesting on the islands is shown in Figure II.3-G-19. The recent decline in numbers was attributed to coyote predation during nesting.²⁶ Over the study period, Hanford's nesting geese had 97.4% fertility, equal to or better than areas that do not have operating nuclear reactors nor chemical separations facilities.

The Great Basin pocket mouse is, in terms of number per acre, the most abundant mammal on the Hanford Reservation. Studies using mark-release techniques show that pocket mice spend their entire lives in a small area. The number of mice in a 6.8 acre plot in a sagebrush-grass community varies considerably from year to year, as shown in Figure II.3-G-20. The relative numbers of various species in the community are shown in Table II.3-G-12.²³

II.3-G.14 Food Webs

Earlier pages have discussed briefly some aspects of the distribution of environmental factors on the Hanford Reservation, and the subsequent distribution of plants and animals. Another section was devoted to considering population numbers and fluctuations on the Reservation, as opposed to distribution in space. However, the dynamic interplay of the many organisms can best be grasped by considering the rates and routes of energy transfers between the species...the "fate and effects" of food in the ecosystem. Following is a synthesis of ecological transfers on the Hanford Reservation, based on a few representative organisms and interactions, beginning with potential transfers to man, then considering a non-anthropocentric ecosystem.

II.3-G.14.1 Transfers to Man

Historically, the unmodified steppe ecosystem of southern Washington provided relatively little food to man. Indian tribes relied mostly upon Columbia River fishes as a food base. Apparently, steppe vegetation did not support bison nor antelope herds. Cattle and sheep grazing

FIGURE II.3-G-19 NUMBER OF NESTS AND NUMBER OF EGGS PER NEST FOR CANADA GEESE NESTING ON ISLANDS IN THE COLUMBIA RIVER, HANFORD RESERVATION

FIGURE II.3-G-20 POPULATION FLUCTUATIONS OF THE POCKET MOUSE, PEROGNATHUS PARVUS, IN A SAGEBRUSH/CHEATGRASS COMMUNITY

TABLE II.3-G-12

SMALL MAMMALS TRAPPED IN A SAGEBRUSH/
CHEATGRASS COMMUNITY, 1972

<u>Month</u>	<u>Pocket Mouse</u>	<u>Deer Mouse</u>	<u>Ground Squirrel</u>	<u>Grasshopper Mouse</u>
Jan	0	5	0	1
Mar	33	11	12	3
Apr	48	7	38	1
May	41	2	20	0
June	44	2	3	1
July	35	0	0	0
Sept	30	1	0	1
Nov	2	0	0	2

provided a food base for man, but the most arid parts of the steppe region were not very productive, and overgrazing resulted in marked changes in floristic composition.

Irrigation is a practical way to modify steppe lands to agriculturally productive acreage. However, the unmodified steppe ecosystem at Hanford provides little food for man. Livestock grazing is not practiced; mule deer forage to some extent upon steppe vegetation, but rely mostly upon riparian vegetation for food and cover. Since deer are mobile animals, some animals that are born on the Reservation are harvested off the Reservation by hunters.²² The chukar partridge is the most abundant game bird that can subsist on the food and cover provided by unmodified steppe vegetation. Although chukar partridges are not hunted on the Reservation, hunting is common in the Rattlesnake Hills, Yakima Ridge and the Saddle Mountains.

Duck and goose hunting is a popular outdoor sport in Benton County, Washington, so ducks and geese are biota with potential contributions to food chains leading to man. Within the Hanford Reservation, a few ducks use cooling wastewater ponds to rear their young, but most of the utilization of ponds by waterfowl is during the fall migration period.²⁷ Hunting is not permitted on the Hanford Reservation on the plant side of the river, so this area serves as a refugium for ducks and geese during the hunting season. During the peak week of use of 1972, 1,100 ducks and geese were on Hanford ponds, and 70,000 on the Hanford reach of the Columbia River.

II.3-G.14.2 Food Webs in a Steppe Ecosystem

Figure II.3-G-21 demonstrates the motivation for discussing food webs rather than chains, because typically a consideration of "who eats whom" will result in many linked transfers rather than a simple linear cascade of matter and energy through the ecosystem. Similar webs could be constructed around each plant species on the Reservation. Figure II.3-G-21 shows a web of energy and nutrient transfers centering on cheatgrass. Although inadvertently introduced to the region, this grass is well adapted to the Hanford climate.³ Its success does not stem from a highly efficient capture of energy from the sun, but physiologically, it is geared for growth under the cool conditions concurrent with Hanford's wet season. Consequently, green cheatgrass appears (as seedlings) when few perennials are growing, making it desirable forage for a wide variety of animals, including mule deer, coyotes, and chukars. Mature cheatgrass seeds form important food sources for pocket mice and birds. The dead leaves and stems support a large number of microbiota, including mites, insects, nematodes and fungi.

Larger food items support larger consumers; Figure II.3-G-22 centers on chukar partridges, a bird with average adult biomass somewhat less than a kilogram. The chukar, in common with many birds, is opportunistic in its choice of diet, employing food items in their period of seasonal

FIGURE II.3-G-21 FOOD WEB CENTERED ON CHEATGRASS (Arrows indicate direction of energy and mass transfer)

FIGURE II.3-G-22 FOOD WEB CENTERED ON CHUKAR PARTRIDGE (Arrows indicate direction of energy and mass transfer)

abundance: both plant and animal matter come to its attention. Chukars support avian predators like the prairie falcon, and scavengers like the magpie, at differing points in its life cycle. Likewise, mammalian and reptilian predators take advantage of its immobile reproductive stages--brooding hens and her eggs.

Insect predators abound in an arthropod-size community, as indicated in Figure II.3-G-23, which centers on grasshopper. However, insect predators are not alone, because even large mammalian predators will consume grasshoppers when the insect is abundant. Some reptiles also consume grasshoppers, as do small mammals, and many carnivorous birds, including large raptors, depend upon insects for prey.

There are two common notes to be found in the preceding diagrams: 1) the edges of the webs involve the same top carnivores--coyotes, eagles, owls, and so on--and 2) all webs have a transfer into the microbiota, represented by the transfer to fungi. Figure II.3-G-24 diagrams a web centering upon fungi in general, not a particular fungal species. Microbiota are critical for continuous functioning of an ecosystem, but generally they are difficult to discuss with the same degree of concreteness as the larger organisms. This is because their small size is associated with high metabolic rate, so the individuals (and species) increase and decline very rapidly compared to the human norm of consciousness. Representative species of fungi are therefore not readily chosen.

Figure II.3-G-24 differs from the preceding diagrams in fundamental ways: 1) the transfers nearest to the fungal organism are **more** nearly a chain than those for macrobiota, 2) there are very many more dashed lines, indicating ignorance or uncertainty in many of the transfers, and 3) many members of the web are identified by family or superfamily rather than genus or species. These problems arise because this food web is extraordinarily difficult to study: the organisms are small, transient, hard to identify and difficult to observe in action.

FIGURE II.3-G-23 FOOD WEB CENTERED ON GRASSHOPPER (Arrows indicate direction of energy and mass transfer)

II.3-G-67

FIGURE II.3-G-24 FOOD WEB CENTERED ON FUNGI (Arrows indicate direction of energy and mass transfer)

II.3-G.15 Ecological Research Results and Availability

The preceeding pages summarized some aspects of the ecological systems of the Hanford Reservation; more could have been written based on the many years of research at Hanford. A current and complete bibliography of journal articles, annual reports, Battelle documents and other writings by the staff of the Ecosystems Department is available.³⁷ Many of the references in that bibliography devolve directly from ecological research on the Hanford Reservation.

Good bibliographies of (world-wide) publications concerning ecological aspects of radioactive waste management are available, both for radioactive wastes in general³⁸ and for transuranics³⁹ specifically.

II.3-G PART 1 REFERENCES

1. R. Daubenmire, Steppe Vegetation of Washington, Agricultural Expt. Stat., Pullman, WA, Tech. Bull. 62, 1970.
2. G. R. Rumney, Climatology and the World's Climates, The Macmillan Company, London, 1968.
3. W. T. Hinds, An Ecological Assessment of Energy and Carbon Pathways in Swards of Bromus tectorum L. on Contrasting Slope Exposures, BNWL-1822, Battelle, Pacific Northwest Laboratories, Richland, WA, 1974.
4. W. H. Rickard, J. F. Cline, and R. O. Gilbert, "Behavior of Winter Annuals as Influenced by Microtopography and Elevation," Northwest Sci., vol. 47, pp. 44-49, 1973.
5. W. T. Hinds, On the Ecological Importance of Drifting Snow, Abiotic Specialists Meeting, Desert Biome, IBP, BNWL-SA-3161, Battelle, Pacific Northwest Laboratories, Richland, WA, 1970.
6. R. D. Harr, Stream Characteristics at Rattlesnake Springs, BNWL-1550, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1971.
7. W. T. Hinds and J. M. Thorp, Biotic and Abiotic Characteristics of the Microclimatological Network on the Arid Lands Ecology Reserve, BNWL-SA-2733, Battelle, Pacific Northwest Laboratories, Richland, WA, 1969.
8. R. A. Bagnold, The Physics of Blown Sand and Desert Dunes, Methuen and Co., London, 1941.
9. B. F. Hajek, Soil Survey, Hanford Project in Benton County, WA, BNWL-243, Battelle, Pacific Northwest Laboratories, Richland, WA, 1966.
10. W. T. Hinds, Evaporation from Bare and Vegetated Lysimeters at Different Elevations, BNWL-1550, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1971.
11. Aldo Leopold, A Sand County Almanac, Oxford Press, 1949.
12. J. J. Rasmussen, Soil Survey Benton County Area, Washington, USDA-Soil Conservation Service, Washington, DC, 1971.

II.3-G PART 1 REFERENCES (Continued)

13. R. C. Routson, A Review of Studies of Soil-Waste Relationships on the Hanford Reservation from 1944 to 1967, BNWL-1464, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
14. R. D. Harr and K. R. Price, "Evapotranspiration from a Phreatophyte Community," Water Resources Res., vol. 8, pp. 1199-1203, 1972.
15. W. H. Rickard and R. F. Keough, "Soil-Plant Relationships of Two Steppe Desert Shrubs," Plant and Soil, vol. 29, pp. 205-212, 1968.
16. J. F. Cline and W. H. Rickard, "Herbage Yields in Relation to Soil Water and Assimilated Nitrogen," J. Range Manag., vol. 26, pp. 296-298, 1973.
17. W. H. Rickard, J. F. Cline, and R. O. Gilbert, Above Ground Productivity of Winter Annuals on Abandoned Cultivated Fields in 1970 and 1971, BNWL-1650, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
18. W. H. Rickard, J. F. Cline, and R. O. Gilbert, Comparison of Above-ground Productivity of Old Field and Pristine Vegetation on the ALE Reserve, BNWL-1650, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.
19. L. E. Rogers, Grasshopper Abundance in an Abandoned Cultivated Field, BNWL-1750, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
20. K. R. Price and W. H. Rickard, Vascular Plants of Waste Storage Sites in the 200 Areas of the Hanford Reservation, BNWL-1796, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
21. T. P. O'Farrell and J. D. Hedlund, "Whitetailed Deer, Odocoileus virginianus, in South-Central Washington," J. Mammal., vol. 53, pp. 907-909, 1972.
22. J. D. Hedlund, R. A. Gies, and T. P. O'Farrell, Tagging Hanford Deer, Odocoileus hemionus, BNWL-1750, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
23. T. P. O'Farrell and J. D. Hedlund, Distribution and Abundance of Small Mammals on Rattlesnake Mountain, BNWL-1650, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.

II.3-G PART 1 REFERENCES (Continued)

24. T. P. O'Farrell, J. D. Hedlund, and R. A. Gies, Population Dynamics of Pocket Mice, Perognathus parvus, on the ALE Reserve, BNWL-1750, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
25. R. K. Schreiber, "Bioenergetics of Rodents in the Northern Great Basin Desert," Ph.D. Dissertation, University of Idaho, Zoology Dept., 1973.
26. W. C. Hanson and L. E. Eberhardt, "A Columbia River Canada Goose Study," Wildl. Monogr., No. 28, 1971.
27. R. E. Fitzner and K. R. Price, The Use of Hanford Waste Ponds by Waterfowl and Other Birds, BNWL-1738, Battelle-Northwest, Richland, WA, 1973.
28. R. R. Olendorff, Raptorial Birds of the U.S. AEC Hanford Reservation, Southcentral Washington, BNWL-1790, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
29. J. A. Wiens, Avian Populations at the ALE Reserve. Final Report, Contract BCA-797, BNWL-SA-5063, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
30. R. E. Pfadt and D. S. Smith, "Net Productive Rate and Capacity for Increase of the Migratory Grasshopper, Melanoplus sanguinipes sanguinipes (F.)," Acrida, vol. 1, pp. 149-165, 1972.
31. U.S. Fish and Wildlife Services, Threatened Wildlife of the United States, Bureau of Sport Fisheries and Wildlife, Washington, DC, 1973.
32. R. E. Wildung, T. R. Garland, and R. L. Schmidt, Influence of Environmental Factors on the Respiration Rate of Grassland Soils--a Model, Tech. Report No. 212, Grassland Biome, Ecosystem Analysis Studies, U.S. International Biological Program, Colorado State University, Fort Collins, CO, 1973.
33. M. R. Koelling and C. L. Kucera, "Dry Matter Losses and Mineral Leaching in Bluestem Standing Crop and Litter," Ecology, vol. 46, pp. 529-532, 1965.
34. R. N. Mack, "Mineral Cycling in Artemisia tridentata," Unpublished Ph.D. dissertation, Washington State University, Dept. of Botany, 1971.

II.3-G PART 1 REFERENCES (Continued)

35. W. H. Rickard and R. L. Uhler, Ground Dwelling Beetles on Abandoned Agricultural Fields, BNWL-1050, vol. 1, part 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1969.
36. W. T. Hinds and W. H. Rickard, "Correlations Between Climatological Fluctuations and a Population of Philolithus densicollis (Horn) (Coleoptera: Tenebrionidae)," 1973.
37. J. L. Engstrom (editor), A Bibliography of Environmental Research: Ecosystems Dept., BNWL-SA-4655, Battelle, Pacific Northwest Laboratories, Richland, WA, 1973.
38. K. R. Price, A Critical Review of Biological Accumulation, Discrimination and Uptake of Radionuclides Important to Waste Management Practices, 1943-1971, BNWL-B-148, Battelle, Pacific Northwest Laboratories, Richland, WA, 1971.
39. K. R. Price, "A Review of Transuranic Elements in Soils, Plants and Animals," J. Environ. Qual., vol. 2, pp. 62-66, 1973.

APPENDIX II.3-G, PART 2

Vascular Taxa of the Hanford Reservation^(a)

- (a) C. L. Hitchcock, A. Cronquist, M. Ownbey, and J. W. Thompson, Vascular Plants of the Pacific Northwest, (five volumes), University of Washington Press Publications in Biology, vol. 17, Seattle, Washington, 1955-1969.

Equisetaceae			
<u>Equisetum arvense</u>	Horsetail	Nyctaginaceae	<u>Abronia mellifera</u>
Marsileaceae		Portulacaceae	<u>Lewisia rediviva</u>
<u>Marsilia vestita</u>	Clover-fern	<u>Talinum spinescens</u>	Bitterroot
Cupressaceae			Fameflower
<u>Juniperus scopulorum</u>	Rocky Mountain Juniper	Caryophyllaceae	
Salicaceae		<u>Arenaria</u> sp.	Sandwort
<u>Populus tremuloides</u>	Aspen	<u>Holosteum umbellatum</u>	Jagged Chickweed
<u>Populus trichocarpa</u>	Cottonwood	Panunculaceae	
<u>Salix amygdaloides</u>	Peach-leaf Willow	<u>Clematis ligusticifolia</u>	Virgins-bower
<u>Salix exigua</u>	Sandbar Willow	<u>Delphinium nuttallii</u>	Larkspur
Moraceae		<u>Ranunculus glaberrimus</u>	Buttercup
<u>Morus alba</u>	Mulberry	<u>Myosurus aristatus</u>	Mouse-tail
Ulmaceae		Cruciferae	
<u>Ulmus siberica</u>	Siberian Elm	<u>Arabis</u> sp.	Rockcress
Urticaceae		<u>Capsella bursa-pastoris</u>	Shepherd's Purse
<u>Urtica dioica</u>	Nettle	<u>Cardaria draba</u>	Whitetop
Santalaceae		<u>Chorispora tenella</u>	Blue Mustard
<u>Commandra umbellata</u>	Commandra	<u>Descurainia pinnata</u>	Tansymustard
Polygonaceae		<u>Draba verna</u>	Whitlow-grass
<u>Eriogonum sphaerocephalum</u>	Wild Buckwheat	<u>Erysimum asperum</u>	Wallflower
<u>Eriogonum heracleoides</u>	Wild Buckwheat	<u>Lepidium perfoliatum</u>	Pepperweed
<u>Eriogonum thymoides</u>	Wild Buckwheat	<u>Physaria oregana</u>	Twinpod
<u>Eriogonum microthecum</u>	Wild Buckwheat	<u>Rorippa nasturtium-aquaticum</u>	Water Cress
<u>Eriogonum niveum</u>	Wild Buckwheat	<u>Sisymbrium altissimum</u>	Tumblemustard
<u>Polygonum periscaria</u>	Smartweed	<u>Thelypodium laciniatum</u>	Thelypod
<u>Rumex venosus</u>	Dock	Capparidaceae	
Chenopodiaceae		<u>Cleome lutea</u>	Spiderflower
<u>Sarcobatus vermiculatus</u>	Greasewood	Saxifragaceae	
<u>Bassia hyssopifolia</u>	Bassia	<u>Lithophragma parviflora</u>	Fringecup
<u>Eurotia lanata</u>	Winterfat	<u>Lithophragma bulbifera</u>	Fringecup
<u>Coriospermum hyssopifolium</u>	Bugseed	Grossulariaceae	
<u>Chenopodium album</u>	Goosefoot	<u>Ribes aureum</u>	Golden Currant
<u>Grayia spinosa</u>	Hopsage	<u>Ribes niveum</u>	Gooseberry
<u>Salsola kali</u>	Tumbleweed	Hydrangeaceae	
		<u>Philadelphus lewisii</u>	Mockorange

Rosaceae

Amelanchier alnifolia
Amelanchier utahensis
Potentilla sp.
Prunus virginiana
Purshia tridentata
Rosa sp.

Serviceberry
Serviceberry
Cinquefoil
Chokecherry
Bitterbrush
Wild Rose

Leguminosae

Astragalus purshii
(Several species of difficult
taxonomic status)
Glycyrrhiza lepidota
Lupinus laxiflorus
Lupinus sulfureus
(Other species of uncertain
taxonomy)
Medicago sativa
Melilotus alba
Petalostemon purpureum
Psoralea lanceolata
Robinia pseudo-acacia
Swainsona salsula
Vicia americana

Milk Vetch
Licorice-root
Lupine
Lupine
Alfalfa
Sweet-clover
Prairie Clover
Scurf-pea
Black Locust
Swainsona
Vetch

Geraniaceae

Erodium cicutarium

Filaree

Linaceae

Linum perenne

Flax

Zygophyllaceae

Tribulus terrestris

Puncture-vine

Anacardiaceae

Rhus glabra
Rhus radicans

Sumac
Poison Ivy

Malvaceae

Sphaeralcea munroana

Globe-mallow

Hypericaceae

Hypericum perforatum

St. John's-wort

Loasaceae

Mentzelia laevicaulis
Mentzelia albicaulis

Blazing Star
Blazing Star

Cactaceae

Opuntia polyacantha

Prickly-pear

Onagraceae

Oenothera pallida

Pale Evening Primrose

Umbelliferae

Cymopterus terebinthinus
Lomatium macrocarpus
Lomatium grayi
Lomatium triternatum
(Others of uncertain
taxonomy)

Cymopterus
Desert Parsley
Desert Parsley
Desert Parsley

Primulaceae

Dodecatheon cusickii

Shooting Star

Asclepiadaceae

Asclepias speciosa

Milkweed

Polemoniaceae

Collomia grandiflora
Gilia sinuata
Gilia minutiflora
Leptodactylon pungens
Microsteris gracilis
Phlox longifolia
Phlox hoodii
Polemonium micranthum

Collomia
Gilia
Gilia
Leptodactylon
Microsteris
Phlox
Phlox
Polemonium

Hydrophyllaceae

Phacelia linearis

Phacelia

Boraginaceae

Amsinckia tessellata
Amsinckia lycopsoides
Cryptantha circumscissa
Cryptantha pterocarya
Heliotropium curassavicum
Lappula redowskii
Lithospermum ruderales

Tarweed
Tarweed
Cryptantha
Cryptantha
Heliotrope
Stickseed
Stoneseed

Verbenaceae

Verbena bracteata

Verbena

Labiatae

Agastache urticifolia
Marrubium vulgare
Mentha arvensis
Salvia dorrii

Scrophulariaceae

Castilleja lutescens
Collinsia parviflora
Mimulus guttatus
Penstemon acuminatus
Penstemon sp.
Verbascum thapsus
Veronica americana

Orobanchaceae

Orobanche grayana

Plantaginaceae

Plantago patagonica

Rubiaceae

Galium boreale

Caprifoliaceae

Sambucus cerulea
Symphoricarpos albus

Valerianaceae

Plectritis ciliosa

Compositae

Achillea millefolium
Antennaria dimorpha
Arctium sp.
Artemisia tridentata
Artemisia tripartita
Artemisia absinthium
Aster canescens
Balsamorhiza careyana
Balsamorhiza rosea
Centurea repens
Chaenactis douglasii

Horse-mint
Horehound
Mint
Purple Sage

Indian Paintbrush
Collinsia
Monkey-flower
Penstemon

Mullein
Speedwell

Broomrape

Plantain

Bedstraw

Elderberry
Snowberry

Plectritis

Yarrow
Pussy-toes
Burdock
Sagebrush
Three-tip Sage
Sage
Aster
Balsamroot
Balsamroot
Knapweed
False Yarrow

Compositae (Cont.)

Chrysopsis oregona
Chrysothamnus nauseosus
Chrysothamnus viscidiflorus
Chichorium intybus
Cisium vulgare
Coreopsis atkinsoniana
Crepis atrabarba
Erigeron filifolius
Erigeron linearis
(Others of uncertain taxonomy)
Eriophyllum lanatum
Gaillardia aristata
Graphalium chilense
Haplopappus stenophyllus
Helianthella uniflora
Helianthus annuus
Hymenopappus filifolius
Lactuca serriola
Layia glandulosa
Lygodesmia spinosa
Microseris laciniata
Senecio spp.
Solidago occidentalis
Stephanomeria sp.
Taraxacum officinale
Tetradymia canescens
Townsendia florifer
Tragopogon dubius
Xanthium strumarium

Liliaceae

Allium geyeri
Allium schoenoprasum
Allium acuminatum
Asparagus officinalis

Golden Aster
Rabbit-brush
Rabbit-brush
Chicory
Thistle
Tickseed
Hawksbeard
Fleabane
Fleabane

Eriophyllum
Gaillardia
Cudweed
Goldenweed
Little-Sunflower
Sunflower
Hymenopappus
Wild Lettuce
Layia
Skeletonweed
Microseris
Groundsel
Goldenrod
Wire Lettuce
Dandelion
Horse-brush
Daisy
Salsify
Cocklebur

Wild Onion
Wild Garlic
Wild Garlic
Asparagus

Liliaceae (Cont.)

<u>Brodiaea douglasii</u>	Cluster Lily
<u>Calochortus macrocarpus</u>	Sego Lily
<u>Fritillaria pudica</u>	Yellow Bell
<u>Smilicina stellata</u>	False Solomon's Seal
<u>Zigadenus elegans</u>	Death-camas

Juncaceae

<u>Juncus balticus</u>	Rush
<u>Juncus</u> spp.	

Cyperaceae

<u>Carex</u> spp.	Sedge
<u>Eleocharis palustris</u>	Spike-rush
<u>Scirpus acutus</u>	Bulrush
<u>Scirpus americanus</u>	Bulrush

Typhaceae

<u>Typha latifolia</u>	Cattail
------------------------	---------

Graminae

<u>Agropyron cristatum</u>	Crested Wheatgrass
<u>Agropyron spicatum</u>	Bluebunch Wheatgrass
<u>Agropyron dasystachyum</u>	Thickspike Wheatgrass
<u>Bromus tectorum</u>	Cheatgrass
<u>Echinochloa crusgalli</u>	Barnyard-grass
<u>Elymus cinereus</u>	Ryegrass
<u>Elymus triticoides</u>	Ryegrass
<u>Festuca idahoensis</u>	Idaho Fescue
<u>Festuca octoflora</u>	Six Week's Fescue
<u>Melica bulbosa</u>	Oniongrass
<u>Oryzopsis hymenoides</u>	Indian Ricegrass
<u>Phalaris arundinacea</u>	Canary Grass
<u>Poa sandbergii</u>	Sandberg Bluegrass
<u>Poa bulbosa</u>	Bulbous Poa
<u>Poa cusickii</u>	Cusick's Poa
<u>Secale cereale</u>	Rye
<u>Sitanion hystrix</u>	Squirreltail
<u>Sporobolus cryptandrus</u>	Sand Dropseed
<u>Stipa comata</u>	Needlegrass
<u>Stipa thurberiana</u>	Needlegrass

APPENDIX II.3-G, PART 3

Vertebrate Taxa of the Hanford Reservation

AMPHIBIANS¹

Pelobatidae	Toads and Frogs
<u>Scaphiopus intermountanus</u>	Great Basin Spadefoot
Bufonidae	
<u>Bufo boreas</u>	Western toad
Hylidae	
<u>Hyla regilla</u>	Pacific Treefrog
Ranidae	
<u>Rana pretiosa</u>	Spotted Frog
<u>R. pipiens</u>	Leopard Frog
<u>R. catesbeiana</u>	Bullfrog
Testunidae	
<u>Chrysemys picta</u>	Turtles
	Painted turtle

REPTILES¹

Iguanidae	Lizards
<u>Sceloporus graciosus</u>	Sagebrush lizard
<u>Uta stansburiana</u>	Side-blotched lizard
<u>Phrynosoma douglassi</u>	Short-horned lizard
Colubridae	Snakes
<u>Masticophis taeniatus</u>	Striped whipsnake
<u>Coluber constrictor</u>	Western yellow-bellied racer
<u>Pituophis melanoleucos</u>	Gopher snake
<u>Thamnophis elegans</u>	Garter snake
<u>Hypsiglena torquata</u>	Desert night snake
Viperidae	
<u>Crotalus viridis</u>	Pacific rattlesnake

BIRDS^{2,3}

Podicipidae	
<u>Podiceps auritus</u>	Horned Grebe
<u>Podiceps caspicus</u>	Eared Grebe
<u>Aechmophorus occidentalis</u>	Western Grebe
<u>Podilymbus podiceps</u>	Pied-billed Grebe
Pelicanidae	
<u>Pelecanus erythrorhynchos</u>	White Pelican
Ardeidae	
<u>Ardea herodias</u>	Great Blue Heron
<u>Nycticorax nycticorax</u>	Black-crowned Night Heron
<u>Botaurus lentiginosus</u>	American Bittern
Anatidae	
<u>Olor columbianus</u>	Whistling Swan
<u>Branta canadensis</u>	Canada Goose
<u>Anas platyrhynchos</u>	Mallard
<u>Anas strepera</u>	Gadwall
<u>Anas acuta</u>	Pintail
<u>Anas crecca carolinensis</u>	Green-winged Teal
<u>Anas discors</u>	Blue-winged Teal
<u>Anas cyanoptera</u>	Cinnamon Teal
<u>Anas americana</u>	American Wigeon
<u>Anas clypeata</u>	Shoveler
<u>Aythya americana</u>	Redhead Duck
<u>Aythya collaris</u>	Ring-necked Duck
<u>Aythya valisneria</u>	Canvasback
<u>Aythya affinis</u>	Lesser Scaup
<u>Bucephala clangula</u>	Common Goldeneye
<u>Bucephala islandica</u>	Barrows Goldeneye
<u>Bucephala albeola</u>	Bufflehead
<u>Clangula hyemalis</u>	Oldsquaw
<u>Oxyura jamaicensis</u>	Ruddy Duck

BIRDS (Continued)

Merginae	
<u>Lophodytes cucullatus</u>	Hooded Merganser
<u>Mergus merganser</u>	Common Merganser
Accipitridae	
<u>Buteo jamaicensis</u>	Red-tailed Hawk
<u>Buteo swainsoni</u>	Swainson's Hawk
<u>Buteo lagopus</u>	Rough-legged Hawk
<u>Buteo regalis</u>	Ferruginous Hawk
<u>Aquila chrysaetos</u>	Golden Eagle
<u>Haliaeetus leucocephalis</u>	Bald Eagle
<u>Circus cyaneus</u>	Marsh Hawk
Pandionidae	
<u>Pandion haliaetus</u>	Osprey
Falconidae	
<u>Falco mexicanus</u>	Prairie Falcon
<u>Falco sparverius</u>	Sparrow Hawk
Tetraonidae	
<u>Pedioecetes phasianellus</u>	Sharp-tailed Grouse
<u>Centrocercus urophasianus</u>	Sage Grouse
Phasianidae	
<u>Lophortyx californicus</u>	California Quail
<u>Phasianus colchicus</u>	Ring-necked Pheasant
<u>Alectoris chukar</u>	Chuckar Partridge
<u>Perdix perdix</u>	Gray (Hungarian) Partridge
Rallidae	
<u>Fulica americana</u>	American Coot
Charadriidae	
<u>Charadrius vociferus</u>	Killdeer
Scalopacidae	
<u>Capella gallinago</u>	Common Snipe
<u>Numerius americanus</u>	Long-billed Curlew
<u>Actitis macularia</u>	Spotted Sandpiper

BIRDS (Continued)

<u>Tringa melanoleucus</u>	Greater Yellowlegs
<u>Tringa flavipes</u>	Lesser Yellowlegs
<u>Calidris alpina</u>	Dunlin
<u>Calidris mauri</u>	Western Sandpiper
<u>Limnodromus griseus</u>	Long-billed Dowitcher
Recurvirostridae	
<u>Recurvirostra americana</u>	American Avocet
Phalaropidae	
<u>Steganopus tricolor</u>	Wilson Phalarope
<u>Lobipes lobatus</u>	Northern Phalarope
Laridae	
<u>Larus californicus</u>	California Gull
<u>Larus delawarensis</u>	Ring-billed Gull
Columbidae	
<u>Zenaida macroura</u>	Mourning Dove
<u>Columbia livia</u>	Rock Dove
Tytonidae	
<u>Tyto alba</u>	Barn Owl
Strigidae	
<u>Bubo virginianus</u>	Great Horned Owl
<u>Speotyto cunicularia</u>	Burrowing Owl
<u>Asio otus</u>	Longeared Owl
Caprimulgidae	
<u>Chordeiles minor</u>	Common Nighthawk
Alcedinidae	
<u>Megaceryle alcyon</u>	Belted Kingfisher
Picidae	
<u>Colaptes auratus cafer</u>	Red-shafted Flicker
<u>Dendrocopos pubescens</u>	Downy Woodpecker
Tyrannidae	
<u>Tyrannus tyrannus</u>	Eastern Kingbird
<u>Tyrannus verticalis</u>	Western Kingbird

BIRDS (Continued)

<u>Myiarchus cinerascens</u>	Ash-throated Flycatcher
<u>Sayornis saya</u>	Say's Phoebe
Alaudidae	
<u>Eremophila alpestris</u>	Horned Lark
Hirundinidae	
<u>Hirundo rustica</u>	Barn Swallow
<u>Petrochelidon pyrrhonota</u>	Cliff Swallow
Corvidae	
<u>Pica pica</u>	Black-billed Magpie
<u>Corvus corax</u>	Common Raven
<u>Corvus brachyrhynchos</u>	Common Crow
<u>Nucifraga columbiana</u>	Clark's Nutcracker
Sittidae	
<u>Sitta canadensis</u>	Red-breasted Nuthatch
Troglodytidae	
<u>Troglodytes troglodytes</u>	Winter Wren
<u>Telmatodytes palustris</u>	Long-billed Marsh Wren
<u>Catherpes mexicanus</u>	Canyon Wren
<u>Salpinctes obsoletus</u>	Rock Wren
Mimidae	
<u>Mimus polyglottos</u>	Mockingbird
<u>Oreoscoptes montanus</u>	Sage Thrasher
Turdidae	
<u>Turdus migratorius</u>	Robin
<u>Ixoreus naevius</u>	Varied Thrush
<u>Catharus guttatus</u>	Hermit Thrush
<u>Myadestes townsendi</u>	Townsend's Solitaire
Sylviidae	
<u>Regulus satrapa</u>	Golden-crowned Kinglet
<u>Regulus calendula</u>	Ruby-crowned Kinglet
Motacillidae	
<u>Anthus spinoletta</u>	Water Pipit

BIRDS (Continued)

Bombycillidae	
<u>Bombycilla cedrorum</u>	Cedar Waxwing
Laniidae	
<u>Lanius ludovicianus</u>	Loggerhead Shrike
Sturnidae	
<u>Sturnus vulgaris</u>	Starling
Virionidae	
<u>Vireo huttoni</u>	Hutton's Vireo
<u>Vireo olivaceus</u>	Red-eyed Vireo
<u>Vireo gilvus</u>	Warbling Vireo
Parulidae	
<u>Vermivora celata</u>	Orange-crowned Warbler
<u>Vermivora ruficapilla</u>	Nashville Warbler
<u>Dendroica petechia</u>	Yellow Warbler
<u>Dendroica coronata coronata</u>	Myrtle Warbler
<u>Dendroica coronata auduboni</u>	Audubon's Warbler
<u>Dendroica townsendi</u>	Townsend's Warbler
<u>Wilsonia pusilla</u>	Wilson's Warbler
Ploceidae	
<u>Passer domesticus</u>	House Sparrow
Icteridae	
<u>Sturnella neglecta</u>	Western Meadowlark
<u>Xanthocephalus xanthocephalus</u>	Yellow-headed Blackbird
<u>Agelaius phoeniceus</u>	Red-winged Blackbird
<u>Icterus galbula bullockii</u>	Bullock's Oriole
<u>Euphagus cyanocephalus</u>	Brewer's Blackbird
<u>Molothrus ater</u>	Brown-headed Cowbird
Thraupidae	
<u>Prianga ludoviciana</u>	Western Tanager
Fringillidae	
<u>Passerina amoena</u>	Lazuli Bunting
<u>Carpodacus mexicanus</u>	House Finch

BIRDS (Continued)

Spinus tristis
Pipilo erythrophthalmus
Ammodramus savannarum
Poocetes gramineus
Chondestes grammacus
Amphispiza belli
Junco hyemalis
Spizella breweri
Zonotrichia leucophrys
Zonotrichia atricapilla

MAMMALS*

Insectivora (Insect-eaters)

Sorex merriami

Chiroptera (Bats)^(a)

Myotis lucifugus
Lasionycteris noctivagans
Lasiurus cinereus

Carnivora (Flesh-eaters)

Procyon lotor
Mustela vison
Mustela frenata
Taxidea taxus
Mephitis mephitis
Canis latrans
Lynx rufus

Rodentia (Gnawing Mammals)

Eutamias minimus
Citellus townsendii
Thomomys talpoides
Perognathus parvus

American Goldfinch
 Rufous-sided Towhee
 Grasshopper Sparrow
 Vesper Sparrow
 Lark Sparrow
 Sage Sparrow
 Junco
 Brewer's Sparrow
 White-crowned Sparrow
 Golden-crowned Sparrow

Merriam Shrew

Little Brown Bat
 Silver-haired Bat
 Hoary Bat

Raccoon

Mink
 Long tailed Weasel
 Badger
 Striped Skunk
 Coyote
 Bobcat

Least Chipmunk
 Townsend's Ground Squirrel
 Northern Pocket Gopher
 Great Basin Pocket Mouse

MAMMALS (Continued)*

Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Onychomys leucogaster
Neotoma cinerea
Microtus montanus
Lagurus curtatus
Ondatra zibethicus
Mus musculus
Rattus norvegicus
Erethizon dorsatum

Lagomorpha (Hares and Rabbits)

Lepus californicus
Sylvilagus nuttallii

Artiodactyla (Even-toed Hoofed Mammals)

Odocoileus hemionus
Odocoileus virginianus
Cervus canadensis

Beaver
 Western Harvester Mouse
 Deer Mouse
 Northern Grasshopper Mouse
 Bushytail Woodrat
 Mountain Vole
 Sagebrush Vole
 Muskrat
 House Mouse
 Norway Rat
 Porcupine

Black-tailed Jack Rabbit
 Nuttall Cottontail Rabbit

Mule Deer
 Whitetailed Deer^(b)
 Elk^(c)

(a) Most bats are occasional visitors only.

(b) Resident but very low in number.

(c) Accidental.

II.3-G PART 3 REFERENCES

1. R. L. Stebbins, A field Guide to Western Reptiles and Amphibians, Houghton Mifflin Co., Boston, Mass., 1966.
2. R. T. Peterson, A Field Guide to Western Birds, Houghton Mifflin Co., Boston, Mass., 1969.
3. "Thirty-second Supplement to the American Ornithologists' Union checklist of North American Birds," *The Auk*, vol. 90, pp. 411-419, 1973.
4. W. H. Burt and R. P. Grossenheider, A Field Guide to the Mammals, Houghton Mifflin Co., Boston, Mass., 1964.

APPENDIX II.3-G, PART 4

Insects of the Hanford Reservation

COLEOPTERA^(a)

Anthicidae

Notoxus sp.

Buprestidae

Agrilus politus (Say)

Chrysobothris sp.

Carbidae

Agonum jejunum LeC.

Amara sp.

Calosoma luxatum Say

Carabus taedutus F.

Cymindis brevipennis Zimmerman

Harpalus sp.

Chrysomelidae

Disonycha alternata Illiger

Glyptoscelis artemisiae Blake

Monoxia grisea Blake

Pachybrachis abdominalis Say

Phyllotreta sp.

Cicindelidae

Cicindela oregona LeC.

Cicindela purpurea Ol.

Omus californicus Reiche

(a) Only those groups identified to at least generic level are included. Many important invertebrate families are awaiting specific determinations and were excluded from this list.

COLEOPTERA (continued)

Cleridae

Enoclerus eximius Mann.

Phyllobaenus sp.

Coccinellidae

Coccinella novemnotata Herbst

Hippodamia convergens Guerin

Hyperaspis elliptica Casey

Hyperaspis fastidiosa Casey

Hyperaspis quadrivittata LeC.

Hyperaspis vittigera LeC.

Scymnus intrusoides Hatch

Scymnus (Pullus) sp.

Curculionidae

Anthonomus sp.

Baris sp.

Cercopedius artemisiae Pierce

Cleonus trivittatus Say

Dyslobus alternatus Horn

Ophryastes cinerascens Pierce

Sitona californicus Fahr.

Stamoderes lanei Van Dyke

Tychius lineatus LeC.

Dermestidae

Dermestes caninus Germar

Histeridae

Saprinus sp.

Saprinus copei Horn

COLEOPTERA (continued)

Meloidae

Epicauta oregona Horn

Epicauta normalis Werner

Epicauta puncticollis Mann.

Lytta vulnerata cooperi LeC.

Zonitis vermiculatis schaeffer

Melyridae

Anthocomus antennatus Hopping

Anthocomus horni Fall

Collops hirtellus LeC.

Collops versatilis Fall

Mordellidae

Mordellistena aspersa Melsh.

Scarabaeidae

Aphodius distinctus Muller

Aphodius fossor L.

Aphodius granarius L.

Aphodius haemorrhoidalis L.

Aphodius hirsutus Brown

Aphodius washtucna Robinson

Coenonycha sp.

Cremastocheilus pugetanus Csy.

Diplotaxis subangulata LeC.

Diplotaxis tenebrosa Fall

Glaresis clypeata Van Dyke

Onthophagus nuchicornis L.

Paracotalpa granicollis Haldeman

Pleurophorus caesus Creutzer

COLEOPTERA (continued)

Silphidae

Necrophorus marginatus F.

Tenebrionidae

Blapstinus discolor HornBlapstinus substriatus ChampionConiontis lanei BoddyConiontis ovalis UlkeConiontis setosa CaseyConisattus nelsoni BoddyEleodes granulata LeC.Eleodes hispilabris imitabilis Blais.Eleodes humeralis LeC.Eleodes nigrina difformis Blais.Eleodes novoverrucula BoddyEleodes obscura SayEusattus muricatus LeC.Oxygonodera hispidula HornPhilolithus densicollis HornStenomorpha puncticollis LeC.

COLLEMBOLA

Isotomidae

Isotoma viridis Bourlet

Sminthuridae

Bourletiella hortensis Fitch

DIPTERA

Acroceridae

Eulonchus n. sp.

Anthomyiidae

Hylemya cinerella FallenHylemya neomexicana MallochScatophaga furcata SayScatophaga stercoraria L.

Apioceridae

Apiocera sp.

Asilidae

Ablautus colei WilcoxCyrtopogon sp.Cyrtopogon ablautoides MelanderDioctria sp.Efferia albibarbis MacquartEfferia benedicti BromleyEfferia coulei WilcoxEfferia harveyi HineLasiopogon chaetosus Cole and WilcoxLeptogaster sp.Lestomyia n. sp.Myelaphus sp.Nicocles utahensis BanksProctacanthus sp.Promachus sp.Scleropogon neglectus Bromley

DIPTERA (continued)

Asilidae (continued)

Stenopogon inquinatus LoewStenopogon martini BromleyTolmerus sp.

Bombyliidae

Conophorus obesulus LoewVilla sp.

Calliphoridae

Calliphora vicina R.-D.Phormia regina Meigen

Cecidomyiidae

Lestremia sp.

Ceratopogonidae

Culicoides crepuscularis Mall.

Chironomidae

Cricotopus sp.Tanytarsus sp.

Chloropidae

Hippelates pusio LoewMeromyza nigriventris MacquartOscinella carbonaria Lw.Thaumatomyia appropinqua Ad.Thaumatomyia glabra Mg.

Ephydriidae

Hydrellia griseola FallenPhilygria debilis Lw.Scatella stagnalis Fallen

DIPTERA (continued)

Milichiidae

Leptomotopa halteralis Coq.

Muscidae

Fannia sp.

Musca domestica L.

Schoenomyza dorsalis Loew

Mycetophilidae

Docosia sp.

Nemestrinidae

Neorhyncocephalus sackenii Williston

Otitidae

Ceroxys latiusculus Loew

Physiphora demandata F.

Sarcophagidae

Blaesoxipha falciformis Aldrich

Helicobia rapax Walker

Ravinia lherminieri R.D.

Sarcophaga sp.

Senotainia sp.

Taxigramma heteroneura Meigen

Scenopinidae

Brevitrichia sp.

Scenopinus whittakeri James

Sciaridae

Bradysia sp.

DIPTERA (continued)

Sepsidae

Sepsis neocynipsea Melander and Spuler

Stratiomyidae

Nemotelus sp.

Syrphidae

Eristalis tenax L.

Metasyrphus meadii Jones

Scaeva pyrastris L.

Syrphus opinator Osten Sacken

Syrphus torrus Osten Sacken

Tachinidae

Acemys sp.

Alophorella sp.

Catagoniopsis sp.

Euphorocera sp.

Exorista mella Wlk.

Gonia frontosa Say.

Ostracophyto aristalis Tns.

Peleteria sp.

Periscepsia cinerosa Coq.

Periscepsia helymus Wlk.

Procatharosia calva Coq.

Stomatomyia parvipalpis Wulp

Uclesia retracta Ald.

Tephritidae

Euaresta tapetis coquillett

Oxyna utahensis Quisenberry

DIPTERA (continued)

Therevidae

Psilocephala baccata Coquillett

Thereva sp.

Tipulidae

Tipula (Lunatipula) dorsimacula Walker

Trixoscelididae

Trixoscelis sp.

HEMIPTERA

Coreidae

Leptoglossus occidentalis Heidemann

Lygaeidae

Neosuris castanea Barber

Miridae

Stenodema vicinum Prov.

Reduviidae

Zelus sp.

Saldidae

Saldula sp.

HOMOPTERA

Cicadellidae

Aceratagallia sp.

Ballana sp.

Carsonus aridus Ball

Circulifer tenellus Baker

HOMOPTERA (continued)

Cicadellidae (continued)

Collandonus germinatus Van Duzee
Comellus sexvittatus Van Duzee
Dikraneura carneola Stål.
Empoasca neaspera Oman and Wheeler
Empoasca nigra Gillette and Baker
Errhomus n. sp.
Psammotettix sp.
Sorhoanus debilis Uhler
Texananus extremus Ball
Xerophloea peltata Uhler

Cicadidae

Okanagana utahensis Davis

Orthetidae

Orthetia sp.

Pseudococcidae

Trionymus winnemucae McKenzie

HYMENOPTERA

Aphididae

Lysiphlebus sp.

Argidae

Schizocerella pilicornis Holmgren

Braconidae

Agathis sp.
Apanteles sp.
Bracon gelechia Ashm.

HYMENOPTERA (continued)

Braconidae (continued)

Cremnops californicus Morr.
Microctonus sp.
Microplitis sp.
Orgilus strigosus Mues.

Bethylidae

Epyris cochise Evans

Ceraphronidae

Ceraphron sp.

Chrysididae

Ceratochrysis sp.
Chrysis sp.
Chrysura sp.

Encyrtidae

Copidosoma sp.

Eulophidae

Euderus sp.
Tetrastichus coeruleus Ashmead

Eumenidae

Pterochilus decorus Cresson
Pterochilus provancheri Huard
Stenodynerus sp.

Eurytomidae

Bruchophagus sp.
Harmolita sp.

HYMENOPTERA (continued)

Formicidae

Camponotus semitestaceus Emery
Camponotus vicinus Mayr
Formica manni Wheeler
Formica neogagates Emery
Formica subpolita camponoticeps Wheeler
Lasius crypticus Wilson
Lasius sitkaensis Pergande
Monomorium pharaonis L.
Myrmecocystus testaceus Emery
Pheidole californica oregonica Emery
Pheidole creightoni Gregg
Pogonomyrmex owyheei Cole
Solenopsis molesta validiuscula Emery
Tapinoma sessile Say

Ichneumonidae

Anomalus sp.
Campoletis sp.
Diphyus sp.
Diolazon laetatorius F.
Erigorgus sp.
Euryproctus sp.
Lissonota sp.
Meringopus dirus Prov.
Ophion sp.
Pterocormus sp.
Temelucha sp.

HYMENOPTERA (continued)

Mutillidae

Odontophotopsis sp.

Sphaerophthalma (Photopsis) sp.

Pompilidae

Aporinellus sp.

Episyrus snowi Vierock

Pompilus (Ammosphex) sp.

Priocnemis oregona Banks

Tachypompilus torridus unicolor Banks

Pteromalidae

Gastrancistrus aphidis Girault

Mesopolobus sp.

Scelionidae

Gryon sp.

Sphecidae

Ammophila aberti Haldeman

Ammophila azteca Cameron

Ammophila karenae Menke

Ammophila mcclayi Menki

Cerceris sp.

Pidalonia mexicana Saussure

Podalonia luctuosa Smith

Podalonia valida Cresson

Prionyx atratus Lepeletier

Sphecius grandis Say

Stictiella emarginata Cresson

Stizoides unicinctus Say

HYMENOPTERA (continued)

Sphecidae (continued)

Tachysphex sp.

Tachytes californicus Bohart

Tachytes distinctus Smith

Tiphiidae

Brachycistis sp.

Vespididae

Polistes fuscatus F.

Vespula pennsylvanica Saussure

ISOPTERA

Rhinotermitidae

Reticulitermes hesperus Banks

LEPIDOPTERA

Arctiidae

Apantesis sp.

Coleophoridae

Coleophora sp.

Gelechiidae

Aroga rigidae Clarke

Chionodes sp.

Noctuidae

Euxoa sp.

Feltia ducens Walker

Feltia herilis Grote

Feltia subgothica Haworth

LEPIDOPTERA (continued)

Noctuidae (continued)

Lacinipolia pensilis Grote

Nephelodes emmedonia Cramer

Rhynchagrotis sp.

Schinia sp.

Spaelotis clandestina Harris

Ufeus hulsti J. B. Smith

Pyralidae

Crambus attenuatus Grote

Crambus whitemerellus Klots

Saturniidae

Hemileuca hera Harris

Scythridae

Scythris sp.

Tischeriidae

Coptotricha sp.

NEUROPTERA

Arctiidae

Apantesis sp.

Chrysopidae

Chrysopa coloradensis Bks.

Chrysopa excepta Bks.

Eremochrysa tibialis Bks.

Myrmeleontidae

Paranthaclisis congener Hag.

NEUROPTERA (continued)

Raphidiidae

Agulla bicolor Alb.

ORTHOPTERA

Acrididae

Ageneotettix deorum Thomas

Amphitornus coloratus Thomas

Arphia pseudonietana Thomas

Aulocara ellioti Thomas

Circotettix undulatus Thomas

Conozoa wallula Scudder

Cratypedes neglectus Thomas

Dissosteira carolina L.

Melanoplus bivittatus Say

Melanoplus cinereus cinereus Scudder

Melanoplus sanguinipes sanguinipes F.

Oedaleonotus enigma Scudd.

Paropomala pallida Bruner

Psoloessa delicatula buckelli Rehn

Trimerotropis caeruleipennis Bruner

Trimerotropis fontana Thomas

Trimerotropis gracilis sordida Walker

Trimerotropis pallidipennis pallidipennis Burmeister

Trimerotropis sparsa Thomas

Xanthippus lateritius Sauss.

Gryllacrididae

Ceuthophilus vicinus Hubbell

ORTHOPTERA (continued)

Gryllidae

Gryllus sp.

Oecanthus argentinus Sauss.

Oecanthus quadripunctatus Beutenmuller

Mantidae

Litaneutria minor Scudd.

Tettigoniidae

Steiroxys sp.

PSOCOPTERA

Liposcelidae

Liposcelis sp.

TRICHOPTERA

Hydroptilidae

Hydroptila xera Ross

Hydroptychidae

Cheumatopsyche campyla Ross

APPENDIX II.3-G, PART 5

Shrub-Steppe Biota on the Hanford Reservation

Summary of the distribution of important shrub-steppe biota on the Hanford Reservation in relation to elevation and vegetation associations.

Decreasing elevation →							
Thyme Eriogonum	Sagebrush/ Bluebunch Wheatgrass	Sagebrush/ Sandberg Bluegrass	Winter Fat	Greasewood	Sagebrush- Bitterbrush	Sand Dune	Plant associations
X							<u>Plant taxa</u>
X							Eriogonum thymoides
X							Haplopappus stenophyllus
X							Balsamorhiza rosea
X							Phlox hoodii
X	X	X	X	X	X		Poa secunda
	X						Agropyron spicatum
	X						Stipa thurberiana
	X	X	X		X		Phlox longifolia
	X	X	X				Erigeron filifolius
	X	X	X		X		Artemisia tridentata
	X	X					Crepis atrabarba
	X	X	X		X		Calochortus macrocarpus
			X				Eurotia lanata
				X			Sarcobatus vermiculatus
				X			Distichlis stricta
					X		Purshia tridentata
						X	Rumex venosus
						X	Oenothera pallida
						X	Psoralea lanceolata
						X	Agropyron dasystachyum
						X	Coriospermum hyssopifolium
						X	Oryzopsis hymenoides
							<u>Birds</u>
X	X	X	X	X	X		Horned Lark
	X	X	X	X	X		Meadowlark
	X	X	X	X	X		Mourning Dove
	X	X	X	X	X		Sage Sparrow
	X	X	X	X	X		Loggerhead Shrike
							<u>Mammals</u>
X	X	X	X	X	X		Deer Mouse
X	X	X	X	X	X		Pocket Mouse
X	X	X	X	X	X		Grasshopper Mouse
	X	X	X	X	X		Jackrabbit
	X	X					Sagebrush Vole
X	X	X	X	X	X		Coyote
X	X	X	X	X	X		Mule Deer
							<u>Reptiles</u>
	X	X	X	X	X		Sideblotched Lizard
X	X	X	X	X	X		Horned Lizard
X	X	X	X	X	X		Gopher Snake
X	X	X	X	X	X		Rattlesnake
							<u>Insects</u>
X	X	X	X	X	X		Philolithus densicollis
X	X	X	X	X	X		Stenomorpha puncticollis
X	X	X	X	X	X		Eleodes hispilabris
X	X	X	X	X	X		Melanopus sanguinipes

APPENDIX III-A

MODELS AND COMPUTER CODES FOR EVALUATING
ENVIRONMENTAL RADIATION DOSES

APPENDIX III-A

MODELS AND COMPUTER CODES FOR EVALUATING
ENVIRONMENTAL RADIATION DOSES

	<u>Page</u>
Part 1 Program ARRRG, CRITR and GRONK (excerpted from BNWL-1754)	III-A-3
Part 2 Program FOOD	III-A-97

III-A Part 1 Programs ARRRG, CRITR and CRONK

III-A.1 Introduction

The methods used for computing environmental radiation doses and for evaluating radiological impact are presented in detail in this appendix. To meet current needs, a simplified model for calculation of radiation doses from radioactive effluents was developed and programmed into a conversational language, providing the fast turnaround time required. The new model is divided into four independent parts, each written as a separate program:

- ARRRG: calculates individual and population doses from liquid effluents
- CRITR: calculates internal radiation doses to four common classes of aquatic organisms and to organisms which consume them
- GRONK: calculates doses from gaseous effluents, to individuals and to the total population within 50 miles
- FOOD: calculates doses from consumption of food crops and animal products produced on irrigated farms

The model can be used to calculate radiation doses to the total body and selected organs of individuals and population groups, and to organisms other than man. It includes all air and liquid exposure pathways thought to be significant and for which a reasonable amount of supporting data is available. Internal doses to man are based on a 1-year radionuclide intake, assuming no prior accumulation in the body. The radionuclide content of ingested food is assumed to be at equilibrium with the environment.

Part 1 of this appendix discusses the models in detail and describes the programs ARRRG, CRITR, and GRONK. FOOD is described in Part 2. The question-and-answer format of these programs allows them to be used by nonprogrammers. Although the programs were originally intended

specifically for nuclear reactors, they are applicable to any nuclear facility which releases radioactive effluents to air or water.

III-A.2 Pathways of Exposure

The pathways of consequence by which man can be exposed to radiation from a nuclear facility can be grouped into those associated with gaseous effluents, those associated with liquid effluents, and those involving exposure to direct radiation from the facility or from transportation of radioactive materials to or from the facility. The exposure pathways are arranged by group in Table III-A-1. Calculations for each pathway are made for those selected organs which could potentially receive the highest radiation dose.^(a)

The pathways of consequence by which organisms other than man can be exposed to radiation from a nuclear facility are similar to those for man. Table III-A-2 is a more inclusive list of pathways of exposure to organisms other than man.

In this report, aquatic organisms are designated as "primary" organisms if a bioaccumulation factor for them was found in the literature. The bioaccumulation factor relates equilibrium concentration of a radionuclide in the organism to that in its water environment, including contributions from direct assimilation of nuclides from water and ingestion of food and water. "Secondary" aquatic and terrestrial organisms are those that feed upon primary organisms; their dose must be calculated from their diet.

(a) Table III-A-10 includes a list of these organs for each pathway.

TABLE III-A-1

PATHWAYS OF EXPOSURE TO MAN

<u>Pathways</u>	<u>Equation</u>	<u>Computer Program</u>
<u>Water Pathways</u>		
<u>External</u>		
Water immersion and water surface	7	ARRRG
Exposure to shoreline	6	ARRRG
<u>Internal</u>		
Ingestion of water	2	ARRRG
Ingestion of aquatic foods	3	ARRRG
Ingestion of irrigated food crops	--	FOOD(a)
Ingestion of products from animals fed irrigated foods	--	FOOD(a)
<u>Air Pathways</u>		
<u>External</u>		
Air submersion	8	GRONK
Exposure to deposited materials ^(b)	--	--
<u>Internal</u>		
Inhalation	8	GRONK
Transpiration of tritium oxide	8	--
Ingestion of food crops	8	GRONK
Ingestion of animal products	8	GRONK
<u>Direct Radiation Pathways</u>		
<u>External</u>		
Direct radiation from the facility	--	--
Exposure during transport of fuels and solid wastes ^(b)	(c)	--

(a) The program FOOD is included in Part 2 of this Appendix.

(b) Doses from these pathways are generally insignificant.

(c) Reference 1.

TABLE III-A-2

PATHWAYS OF EXPOSURE TO ORGANISMS OTHER THAN MAN

<u>Pathway and Organism Type</u>	<u>Equation</u>	<u>Computer Program</u>
<u>Water Pathways</u>		
<u>External</u>		
Water immersion and water surface (Primary, Secondary)(a)	7	ARRRG
Exposure to sediment or shoreline (Primary, Secondary)	6	ARRRG
<u>Internal</u>		
Ingestion of water and aquatic foods (Primary)	12	CRITR
Ingestion of water (Secondary)	2	ARRRG
Ingestion of primary aquatic foods (Secondary)	16	CRITR
<u>Air Pathways</u>		
<u>External</u>		
Air submersion (Secondary)	8	GRONK
Exposure to deposited materials (Secondary)(b)	--	--
<u>Internal</u>		
Inhalation (Secondary)(b)	8	GRONK
<u>Direct Radiation Pathways</u>		
<u>External</u>		
Direct radiation from the facility (Secondary)(b)	--	--

(a) Organism types exposed via the given pathway are listed in parentheses.

(b) Doses from these pathways are generally insignificant.

III-A.3 Dose to Man--Basic Considerations

The fundamental equation for calculation of radiation dose from the pathways described above is

$$R_{ipr} = C_{ip} U_p D_{ipr} \quad (1)$$

where

- R_{ipr} = dose rate to organ r from nuclide i via pathway p
- C_{ip} = concentration of nuclide i in the medium of pathway p
- U_p = usage: the exposure or intake rate associated with pathway p
- D_{ipr} = dose factor: a number specific to a given nuclide i, pathway p, and organ r which can be used to calculate radiation dose rate from exposure to a given radionuclide concentration or radionuclide intake

The three terms on the right of Equation 1 are discussed in the following subsections.

Equations tailored to each specific exposure pathway are derived from Equation 1. The principal difference between pathways is the manner in which the radionuclide concentrations are calculated.

III-A.3.1 Concentrations of Nuclides in Environmental Media, C_{ip}

Concentrations of nuclides in air, water, soil or food are calculated as intermediate steps in the computer programs described in Section III-A.7. Concentrations in water, in aquatic foods, and on shoreline sediment are calculated from the radionuclide release rates, the effluent flow rate, the mixing and dilution in the receiving waters, and bio-accumulation factors for aquatic foods. Concentrations in air and on vegetation from aerial deposition are generated from radionuclide release rates and from the equations for atmospheric dispersion given in Equations 8 and 9.

Concentrations of nuclides in irrigated farm produce are calculated from concentrations of radionuclides in the irrigation water, irrigation rate, facility lifetime (determines long-term soil buildup), and decay time between nuclide release and produce consumption.

III-A.3.2 Usages, U_p

Usage refers to duration of exposure to external sources of radiation and to intake rates of ingested water and food. For pathways other than air submersion, the usage depends on the specific situation. Since noble gases are the principal contributors to air submersion dose, the assumption is made that the air concentrations of radionuclides are essentially the same indoors as outdoors. Thus, no shielding and occupancy factors are applied, and 8766 hr/yr is used for the air submersion pathway.

In the absence of site-specific data, the authors employ the usages and exposure times in Table III-A-3 to calculate individual adult doses. For population dose calculations the usages of the average adult are multiplied by the size of the population.

III-A.3.3 Dose Factors, D_{ipr}

Equations for calculating internal dose factors were previously published.^{2,3} They were derived originally from those given by the International Commission on Radiological Protection⁴ for body burden and maximum permissible concentration. For this study, effective decay energies for the radionuclides are calculated from the ICRP model, which assumes all of the radionuclide is at the center of a spherical organ with an appropriate effective radius. Where data is lacking, metabolic parameters for the Standard Man are used for other ages as well. Internal dose factors have units of mrem/yr per pCi/yr intake via ingestion or inhalation, and represent the first year's dose from one year's intake. For calculating external dose factors from air submersion or water immersion, the penetrating power of the radiation emitted determines whether it contributes to skin dose only, or to both skin and total-body

TABLE III-A-3

RECOMMENDED ADULT VALUES FOR U_p TO BE USED IN LIEU OF SITE-SPECIFIC DATA

Pathway	Maximum Individual Adult	References	Average Adult	References
Air Submersion	8766 hr/yr	(3)	8766 hr/yr	(3)
Inhalation	7300 m ³ /yr	(4)	7300 m ³ /yr	(4)
Drinking Water	730 liter/yr	(3)	438 liter/yr	(4)
Local Seafood -fish	18 kg/yr	(-)	2.3 kg/yr	(6)
-crustacea	9 kg/yr	(-)	0.9 kg/yr	(6)
-molluscs	9 kg/yr	(-)	0.25 kg/yr	(6)
Local Fresh Water Fish	18 kg/yr	(-)	2.2 kg/yr	(6)
Holdup Time for Aquatic Foods	24 hr	(-)	24 hr	(-)
Aquatic Recreation:				
Ocean - shoreline activ.	500 hr/yr	(7)	4 hr/yr ^(a)	(3)
- swimming	100 hr/yr	(8)	1 hr/yr ^(a)	(3)
- boating	100 hr/yr	(8)	1 hr/yr ^(a)	(3)
River - shoreline activ.	500 hr/yr	(7)	2 hr/yr ^(b)	(3)
- swimming	100 hr/yr	(8)	4 hr/yr ^(b)	(3)
- boating	100 hr/yr	(8)	4 hr/yr ^(b)	(3)
Lake - shoreline activ.	500 hr/yr	(7)	1 hr/yr ^(a)	(3)
- swimming	100 hr/yr	(8)	2 hr/yr ^(a)	(3)
- boating	100 hr/yr	(8)	4 hr/yr ^(a)	(3)

(a) These are hours spent in the vicinity of the site. Other hours are spent in areas unaffected by the liquid effluent from the facility.

(b) These are hours spent downstream of the site. Other hours are spent upstream and at nearby lakes.

dose. Beta and gamma radiation which can penetrate 7×10^{-3} cm of tissue is considered to contribute to skin dose; that which can penetrate 5 cm of tissue is considered to contribute to total-body dose (and dose to internal organs). The dose factors for air submersion and water immersion are derived by assuming that the contaminated medium is an infinite volume compared to the range of the emitted radiations. Under this assumption the energy emitted per gram of medium equals the energy absorbed per gram of medium. Corrections must be applied for differences in energy absorption between tissue and air or water, physical geometry of the specific exposure situation and the conversion from MeV per disintegration per gram to rem. The resulting dose factors have units of mrem/hr per pCi/m³ of air or mrem/hr per pCi/liter of water.

Material deposited from the air or from irrigation water onto the ground represents a fairly large, nearly uniform, thin sheet of contamination. The factors for converting surface contamination in pCi/m² to gamma dose at 1 meter above a uniformly contaminated plane are described in References 2, 3 and 9. Dose factors for exposure to soil (or river sediment) have units of mrem/hr per pCi/m² of surface.

A set of dose factors for 45 radionuclides was calculated originally for the Year 2000 Model.³ These are recalculated using the latest available decay schemes¹⁰ for an expanded list of 136 nuclides.^(a)

(a) The revised list is given in Table III-A-13. An explanation of the terms "+D" and "D" appearing in this table is given in Section III-A.7.6.

III-A.4 Dose to Man--Liquid Pathways

III-A.4.1 Drinking Water

The dose rate from ingestion of water is calculated by

$$R_{pr} = 1119 \sum_{i=1}^{136} \frac{Q_i N_i}{F} M_p e^{-\lambda_i t_p} U_p D_{ipr} \quad (2)$$

where

R_{pr} = dose rate to organ r from all of the nuclides i via pathway p (mrem/yr)

N_i = reconcentration factor as defined in Section III-A.7.5

Q_i = release rate of nuclide i (Ci/yr)

F = flow rate of the liquid effluent (ft³/sec)

M_p = mixing ratio at the point of exposure (or the point of withdrawal of drinking water or the point of harvest of aquatic food) as defined in Section III-A.7.5

t_p = transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and ingestion of food or water (hr)

λ_i = radiological decay constant of nuclide i (hr⁻¹)

1119 = a constant which converts from (Ci/yr)/(ft³/sec) to pCi/liter

The terms $\frac{Q_i N_i}{F}$ in Equation 2 define the concentration of nuclide i in the effluent at the point of discharge. The expression $\frac{Q_i N_i}{F} M_p \exp(-\lambda_i t_p)$ yields the concentration at the time that the water is consumed. This latter concentration is the term C_{ip} in Equation 1.

III-A.4.2 Aquatic Foods

Concentrations of radionuclides in aquatic foods are directly related to the concentrations of the nuclides in water. Equilibrium ratios between the two concentrations, called bioaccumulation factors in this

report, were taken from References 11 and 12 and are listed in Table III-A-13. The equation for calculation of internal dose rate from consumption of aquatic food is

$$R_{pr} = 1119 \sum_{i=1}^{136} \frac{Q_i N_i}{F} M_p B_{ip} e^{-\lambda_i t_p} U_p D_{ipr} \quad (3)$$

where B_{ip} is the bioaccumulation factor for nuclide i via pathway p (pCi/kg per pCi/liter).

III-A.4.3 Shoreline Deposits

The calculation of sediment load, transport and concentrations of radio-nuclides associated with suspended and deposited materials is a complex problem. One approach to this problem was used in the Year 2000 Study.³ For the program ARRRG, a simplified scheme for obtaining an order of magnitude estimate of the concentration of shoreline sediments was developed. The concentration of nuclide i in the sediment can be estimated from

$$S_i = K \frac{A_i (1 - e^{-\lambda_i t_s})}{\lambda_i} \quad (4)$$

where

S_i = concentration of nuclide i in sediment (pCi/kg)

A_i = concentration of the nuclide i in the water adjacent to the sediment (pCi/liter)

K = assumed constant in units of liter/kg-d

t_s = total time the sediment is exposed to the contaminated water, nominally taken to be the operating lifetime of the facility (hr)

In the original evaluation of the equation, λ_i was chosen to be the radiological decay constant, although the true value should include an unknown "environmental" removal constant. If the presence of a radionuclide in water and sediment is controlled primarily by radioactive equilibrium with its parent nuclide, then the water concentration and half-life of the parent should be used in the equation.

The relationship was tested and the value of K derived from radionuclide concentrations measured in water and sediment samples collected over a period of several years in the Columbia River between Richland, Washington and the river mouth and in Tillamook Bay, Oregon, 75 km (47 miles) south of the river mouth.^{13,14} Since the primary use of the equation is to facilitate estimates of the exposure rate from gamma emitters one meter above the sediment, an effective surface contamination was devised. This surface contamination level was taken to be all of the nuclides contained within the top 2.5 cm (1 in.) of sediment.^(a) The dose contribution from the radionuclides below 2.5 cm in depth was ignored. The resulting equation is

$$S_i' = 100 \tau_i A_i W (1 - e^{-\lambda_i t_s}) \quad (5)$$

where

S_i' = "effective" surface contamination (pCi/m²)

τ_i = radiological half-life of nuclide i (d)

W = shore width factor (unitless)

Shore width factors were derived from data given in Figure 3.1(5) of Reference 15 and are summarized in Table III-A-4.

(a) Calculated by multiplying the concentration (pCi/kg) by a mass thickness (40 kg/m²).

TABLE III-A-4

SHORE WIDTH FACTORS FOR USE IN EQUATIONS 5 AND 6

<u>Exposure Situation</u>	<u>Shore Width Factor (W)</u>
Discharge canal bank	0.1
River shoreline	0.2
Lake shore	0.3
Nominal ocean site	0.5
Tidal basin	1.0
Organisms on surface or in burrow(a)	2.0

(a) Since the radionuclide concentration normally decreases with depth in the mud, the dose to a buried organism is probably no higher than that to one lying on the mud surface.

The combination of Equations 5 and 1 yields the equation below for calculation of radiation dose from exposure to shoreline sediments.

$$\begin{aligned}
 R_{pr} &= \sum_{i=1}^{136} S_i^! U_p D_{ipr} = 100 \sum_{i=1}^{136} \tau_i A_i W (1-e^{-\lambda_i t_s}) U_p D_{ipr} \\
 &= 111,900 \sum_{i=1}^{136} \tau_i \frac{Q_i N_i}{F} M_p e^{-\lambda_i t_p} W (1-e^{-\lambda_i t_s}) U_p D_{ipr} \quad (6)
 \end{aligned}$$

III-A.4.4 Swimming and Boating

The equation for calculation of external dose to the skin and total-body from swimming (water immersion) or boating (water surface) is

$$R_{pr} = 1119 \sum_{i=1}^{136} \frac{Q_i N_i}{F K_p} M_p e^{-\lambda_i t_p} U_p D_{ipr} \quad (7)$$

where K_p is a geometry correction factor equal to 1 for swimming and 2 for boating.

III-A.5 Dose To Man -- Gaseous Pathways

III-A.5.1 Air Submersion

The formulas used to calculate doses from air submersion are Equations 8 and 9 below (Ref. 16, p. 113).

$$R_{pr}(x, \theta, d) = \sum_{i=1}^{136} \bar{X}_i U_p D_{ipr} \quad (8)$$

where

$R_{pr}(x, \theta, d)$ = external dose rate from all of the nuclides i via pathway p to organ r of a person located a point x meters from the source in a direction d , averaged over a sector width of θ radians (mrem/yr)

U_p = 8766 hr/yr for air submersion

D_{ipr} = dose factor for nuclide i via pathway p to organ r based on a half-infinite cloud geometry and corrected for the fractional penetration of beta and gamma radiations to the depth of 7×10^{-3} cm for skin and 5 cm for total-body (mrem/hr per pCi/m³)

and

$$\bar{X}_i = \sum_{j=1}^{J'} \left(\frac{2}{\pi} \right)^{1/2} \frac{(0.01 f_j) 10^{12} Q_i'}{(\sigma_z)_j \bar{u}_j \theta x} \left[\exp\left(-\frac{h^2}{2(\sigma_z)_j^2}\right) \right] \left[\exp\left(-\frac{\lambda_i x}{\bar{u}_j}\right) \right] \quad (9)$$

where

$\bar{X}_i$ = annual average concentration (pCi/m³) of nuclide i at point (x,θ,d)

f_j = percent of time wind blows in direction d under meteorological condition J

10¹² = picocuries per curie

Q'_i = release rate of nuclide i (Ci/sec)

θ = sector width = 2π/n radians, where the number of sectors n is normally 16

x = downwind distance (meter)

$\bar{u}_j$ = average wind speed for meteorological condition J (meter/sec)

$\frac{x}{\bar{u}_j}$ = travel time of released material to point (x,θ,d) under meteorological condition J (sec)

λ_i = radiological decay constant for nuclide i (sec⁻¹)

h = height of effluent release (meter)

$(\sigma_z)_J$ = standard deviation of vertical dispersion under meteorological condition J (meter²)

J' = number of meteorological conditions ("stability classes")

The standard deviation of vertical dispersion may be derived for the Hanford (Fuguay-Simpson) four-stability-class method from equations given on pp. 141 and 392 of Reference 16, or from tables of σ_z versus x by Pasquill stability category on p. 409 of Reference 16. Both the Hanford and the Pasquill formats are programmed into GRONK since raw meteorology data may be given in either format, depending upon the particular system employed at the nuclear facility.

Equation 8 yields the yearly external dose to a person located at point (x,θ,d). The population dose in man-rem/yr is determined by multiplying this dose by the population located within the sector of the annulus of concern. Values of the dose at the point (x,θ,d) are assumed to apply to all individuals located in that sector.

III-A.5.2 Thyroid Doses from Radioiodine

Equation 8 may also be applied to the calculation of thyroid dose from airborne radioiodine. Pathways of importance are inhalation, ingestion of vegetation contaminated via radioiodine deposition on agricultural land, and ingestion of milk from cows which consume such vegetation. The program provides for calculation of thyroid doses to different ages, since the thyroid dose is usually greater to children than to adults.

A standard value for the usage parameter, U_p , is assumed for each of the above pathways and standard transfer factors between air, vegetation, cow, milk and humans are assumed. For ease of calculation, these standard values are multiplied into the thyroid dose factors to create a modified dose factor which converts air concentrations of radioiodine directly into dose rate. The user need only consider those parameters which alter the standard usages: grazing season, vegetation growing season and vegetation consumption rates.

Parameters used to derive the thyroid dose factors are derived from the food pathway model used in the Year 2000 Study³ and are listed in Table III-A-5. The dose factors obtained from these parameters are listed in Tables III-A-6, III-A-7 and III-A-8.

TABLE III-A-5

METABOLIC PARAMETERS USED IN THE THYROID DOSE FACTORS³

Parameter	1 yr	4 yr	14 yr	Adult
Fractional uptake via ingestion, f_w	0.3	0.3	0.3	0.3
Fractional uptake via inhalation, f_a	0.23	0.23	0.23	0.23
Biological half-life in thyroid (d) ^(a)	20	20	50	100
Thyroid mass (g)	2	5	15	20
Thyroid radius (cm)	1.4	2	2.7	3
Inhalation rate (m ³ /d)	5.6	7.0	13.5	20
Effective MeV per disintegration ^(b)				
¹²⁹ I	0.060	0.061	0.063	0.064
¹³⁰ I	0.388	0.427	0.472	0.490
¹³¹ I	0.206	0.213	0.221	0.224
¹³² I	0.581	0.624	0.673	0.693
¹³³ I	0.467	0.478	0.491	0.497
¹³⁴ I	0.779	0.838	0.906	0.934
¹³⁵ I	0.481	0.514	0.551	0.566

(a) From Reference 16-20

(b) Calculated from formulas of Reference 4, p.28, and decay schemes of Reference 9.

TABLE III-A-6

FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE
TO THYROID DOSE VIA INHALATION(a)

(mrem/yr per pCi/m³)

<u>Age</u>	<u>¹²⁹I</u>	<u>¹³⁰I</u>	<u>¹³¹I</u>	<u>¹³²I</u>	<u>¹³³I</u>	<u>¹³⁴I</u>	<u>¹³⁵I</u>
1 yr	5.74	2.88	12.5	0.835	5.51	0.424	2.00
4 yr	4.68	1.62	8.07	0.449	2.93	0.229	1.05
14 yr	6.94	1.17	6.76	0.311	2.03	0.158	0.750
Adult	34.3	1.57	10.6	0.414	2.70	0.209	0.985

(a) Organic and inorganic forms of radioiodine give the same dose via inhalation.
Factors include a breathing rate for ages 1 yr, 4 yr, 14 yr and adult of 5.6, 7.0, 13.5 and 30 m³/d, respectively.

TABLE III-A-7

FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINES
TO THYROID DOSE VIA MILK(a)

(mrem/yr per pCi/m³)

Age	¹²⁹ I	¹³⁰ I	¹³¹ I	¹³² I	¹³³ I	¹³⁴ I	¹³⁵ I
1 yr	3600	83.0	3620	4.58	262	0.911	31.2
4 yr	2170	34.5	1730	1.82	103	0.363	12.4
14 yr	669	10.4	497	0.524	28.4	0.104	3.53
Adult	3140	6.61	448	0.330	18.7	0.0655	2.28

(a) Factors include the following assumptions:

- Grazing season is 365 d/yr.
- Milk consumption is 1 liter/d for all ages.
- There is no decay between milking and consumption.
- Radioiodine is 100% inorganic (organic forms of radioiodine contribute insignificantly to dose via this pathway).
- Long-term accumulation in the soil is ignored for ¹²⁹I (adds ~1.4% in 1 yr or 42% in 30 yr).

TABLE III-A-8

FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE
TO THYROID DOSE VIA LEAFY VEGETABLES^(a)(mrem/yr per pCi/m³)

Age	¹²⁹ I	¹³⁰ I	¹³¹ I	¹³² I	¹³³ I	¹³⁴ I	¹³⁵ I
1 yr	0	0	0	0	0	0	0
4 yr	1720	21.4	1090	1.13	63.5	0.224	7.62
14 yr	1650	10.0	594	0.507	28.5	0.101	3.53
Adult	5190	8.53	589	0.428	24.1	0.0844	2.94

(a) Factors include the following assumptions:

- Vegetables are from home gardens.
- There is no decay between garden and table.
- Vegetables are exposed 3 months above ground to air.
- 25% of deposited material remains on vegetables (remainder on ground) with "environmental" half-life of 14 days.
- Radioiodine is 100% inorganic (organic forms of radioiodine contribute insignificantly to dose via this pathway).
- Long-term accumulation in the soil is ignored for ¹²⁹I (adds ~1.4% in 1 yr or 42% in 30 yr).
- Maximum individual vegetable consumption for ages 1 yr, 4 yr, 14 yr and adult are 0, 32, 54 and 72 kg/yr, respectively.

III-A.6 Dose To Organisms Other Than Man

Pathways of exposure associated with liquid effluents are generally the most significant contributors to radiation dose to organisms other than man, since aquatic organisms can concentrate radionuclides from their water environment either directly or via their food chains. For purposes of calculating equilibrium concentrations of radionuclides, organisms other than man are divided into two classifications: "primary organisms" which are aquatic and for which bioaccumulation factors are available, and "secondary organisms" which feed upon primary organisms.

Radionuclide concentrations for primary organisms can be calculated directly from the water concentrations and bioaccumulation factors. The primary organisms are fish, crustacea, molluscs and plants. Radionuclide concentrations for secondary organisms must be calculated from their diet of primary organisms. Representative secondary birds and mammals were selected such that each primary organism would be in the diet of at least one secondary organism. The predatory birds and mammals commonly selected are herons, raccoons, muskrats and plant-eating ducks.

III-A.6.1 Internal Doses Via Liquid Pathways

The total-body dose rate to an aquatic organism is

$$R_c = 0.0187 \sum_{i=1}^{136} b_{ic} \epsilon_{ic} \quad (10)$$

where R_c = dose rate to total body of organism c (mrad/yr)

ϵ_{ic} = effective absorbed energy in MeV per disintegration (dis) for nuclide i in organism c

b_{ic} = specific body burden of nuclide i in organism c (pCi/kg)

0.0187 = conversion factor calculated as follows:

$$\begin{aligned} & \left(3.7 \times 10^{-2} \frac{\text{dis}}{\text{sec-pCi}} \right) \left(3.156 \times 10^7 \frac{\text{sec}}{\text{yr}} \right) \left(1.6 \times 10^{-6} \frac{\text{erg}}{\text{MeV}} \right) \left(\frac{\text{kg-mrad}}{100 \text{ erg}} \right) \\ & = 0.0187 \frac{\text{dis-kg-mrad}}{\text{pCi-yr-MeV}} \end{aligned}$$

For a primary organism, b_{ic} is given by

$$b_{ic} = A_i B_{ic} = 1119 \frac{Q_i N_i}{F} M_p e^{-\lambda_i t_p} B_{ic} \quad (11)$$

where the symbols are as given in Sections III-A.4.1 and III-A.4.2.

Combining equations 10 and 11 yields

$$R_c = 20.93 \sum_{i=1}^{136} \frac{Q_i N_i}{F} M_p e^{-\lambda_i t_p} B_{ic} \epsilon_{ic} \quad (12)$$

The total-body dose factor, d'_{ik} , from nuclide i for a secondary organism k is¹

$$d'_{ik} = \frac{0.0021 (f_w)'_i \epsilon'_{ik} (1 - e^{-\lambda'_{Ei} t})}{\lambda'_{Ei} m'_k} \left(\frac{\text{mrad/yr}}{\text{pCi/yr intake}} \right) \quad (13)$$

where

- $(f_w)_i'$ = fraction of ingested nuclide i retained in secondary organism (unitless)
 m_k' = mass of secondary organism k (g)
 $\lambda_{Ei} = \lambda_i + \lambda_{Bi}'$ = effective decay constant of nuclide i in secondary organism (hr^{-1}), where
 λ_{Bi}' = biological removal constant of nuclide i in secondary organism (hr^{-1}),
 t = period of exposure (hr)
 ϵ_{ik}' = effective absorbed energy in MeV per disintegration for secondary organism k .

The parameters $(f_w)_i'$ and λ_{Ei}' are taken to be the same as those for Standard Man because data for other organisms are lacking. Since the dose factors tabulated for the ARRRG program include total-body dose factors for man, it is convenient to use an alternate formulation for Equation 13:

$$D'_{ik} = \frac{\epsilon_{ik}'}{m_k'} \frac{m_{\text{man}}' D'_{i,\text{man}}}{\epsilon_{i,\text{man}}} = \frac{\epsilon_{ik}'}{m_k'} \frac{70,000 D_{i,\text{man}}}{\epsilon_{i,\text{man}}} \quad (14)$$

where 70,000 g is the total body mass of the adult.

The radiation dose rate to the total body of the secondary organism expressed in the format of Equation 1 is

$$R'_i = 0.365 \sum_{j=1}^{136} b_{ic} P'_{ck} D'_{ik} \quad (15)$$

where P'_{ck} = consumption rate of primary organism c by secondary organism k (g/d)

$$0.365 = (\text{kg/g}) (\text{d/yr})$$

Substituting the values of b_{ic} and D'_{ik} from Equations 11 and 14, respectively, into Equation 15 yields

$$R_i' = 2.86 \times 10^7 \sum_{i=1}^{136} B_{ic} \frac{Q_i N_i}{F} M_p e^{-\lambda_i t_p} p_{ck} \frac{\epsilon_{ik}' D_{i,man}}{m_k' \epsilon_{i,man}} \quad (16)$$

where

$$2.86 \times 10^7 = (0.365) (1119) (70,000).$$

The values for ϵ and ϵ' are determined from the effective radius of the organism. Table III-A-18 tabulates ϵ for seven effective radii for organisms other than man and for the total body of man for each of the 136 nuclides. In the absence of site-specific data, the values of the parameters in Table III-A-9 may be used for Equation 16.

III-A.6.2 Other Doses to Aquatic and Terrestrial Animals

Primary and secondary organisms are also exposed via water immersion, water surface, bottom sediment and shoreline silt. Although these doses are usually relatively insignificant, they may be calculated using the methods of Section III-A.4 or by the program ARRRG. For shoreline exposure, a correction must be made for the difference in height of exposure between animals and men. For small organisms this correction factor is 2, and has been incorporated in the shore width factor of 2.0 in Table III-A-4.

Secondary organisms are exposed via air submersion, inhalation, and radiation from materials deposited by air. Air submersion doses are of possible significance, depending upon the particular nuclear facility involved, and may be calculated using the methods of Section III-A.5 or by the program GRONK. Exposure from inhalation and materials deposited by air are usually relatively insignificant. Inhalation doses cannot be calculated directly at this time, since the detailed behavior of inhaled radionuclides in animals is not yet known.

TABLE III-A-9

RECOMMENDED PARAMETERS FOR ORGANISMS OTHER THAN MAN
TO BE USED IN LIEU OF SITE-SPECIFIC DATA

Organism	Body Mass (kg)	Effective Radius (cm)	Source of Nuclide	Intake Rate (g/d)	Air	Annual Exposure (hr)		
						Sediment	Immer- sion	Water Surface
Primary								
Fish	(a)	2	Water	(a)	0	0-8766 ^(b)	8766	
Crustacea	(a)	2	Water	(a)	0	0-8766 ^(b)	8766	
Molluscs	(a)	2	Water	(a)	0	8766		8766
Algae	(a)	2	Water	(a)			8766	
Secondary								
Muskrat	1	6	Plant	100	$\frac{8766}{3}$	$\frac{8766}{3}$	$\frac{8766}{3}$	
Raccoon	12	14	Crustacea & Molluscs	200	8766	$\frac{8766}{4}$		
Heron	4.6	11	Fish	600	8766	$\frac{8766}{3}$		$\frac{8766}{3}$
Duck	1	5	Plant	100	8766	$\frac{8766}{2}$		$\frac{8766}{2}$

(a) Not required for calculation of doses to primary organisms.

(b) The hours spent in contact with the sediments are highly variable.

III-A.7 Computer Programs ARRRG, CRITR and GRONK

III-A.7.1 Introduction

Three programs are written in the Basic Computer language to implement the dose calculation models described. These programs are executed interactively at a conversational terminal and are designed to be used by personnel untrained in programming. The codes print informative messages if a user error is detected and allow the user the opportunity to correct the faulty information. The data files utilized and items calculated by each program are listed in Table III-A-10.

Each program produces a summary output at the teletype, with the user controlling the level of detail in the output. ARRRG and GRONK also create fully detailed output at a high-speed printer to serve as a permanent record of the run.

The programs obtain their information from three sources:

- (1) Parameters which are highly variable, such as human diets assumed for the particular locality, reactor coolant flow rate and release height, are entered directly at the time each case is run. This is accomplished by interactive questions to be answered by the operator, such as "cooling flow in cfs=?"
- (2) Parameters which are applicable only to a given facility are stored once within a file at the time the information is received from the applicant. This information is then automatically accessed each time a case is run for that facility. For ARRRG and CRITR, the liquid release rates for all facilities are stored on a single large file called REL. For GRONK, a file called Gxxxx, where xxxx stands for the first four letters of the reactor name, contains the radionuclide release rates, the population distribution out to 50 miles in 16 sectors and up to 10 annular rings, and meteorological tables

TABLE III-A-10

PROGRAMS FOR CALCULATING RADIATION DOSES

<u>Program</u>	<u>Data Files</u>	<u>Item Calculated, Equations Used</u>	<u>Organ Doses Calculated</u>
ARRRG	ARGIN REL	Individual and population doses from ingested water, Equation 2	Total body, GI-LLI, ^(a) thyroid, bone
		Individual and population doses from aquatic foods (fish, crustacea, molluscs, plants), Equation 3	Total body, GI-LLI, thyroid, bone
		Individual and population doses from sediment exposure (shoreline), Equation 6	Skin, total body ^(b)
		Individual and population doses from swimming and boating, Equation 7	Skin, total body
CRITR	ARGIN REL CRITEN	Internal doses to aquatic biota (fish, crustacea, molluscs, plants), Equation 12	Total body
		Internal doses to predators of aquatic biota, such as ducks, muskrats, raccoons and herons, Equation 16	Total body
GRONK	GIN TONIC Gxxxx	Annual average atmospheric dilution factors (Ci/m^3 per Ci/sec released) versus distance and direction from the source ($\bar{X}/Q'$), Equation 9	---
		Individual doses from exposure to half-infinite cloud of effluents, versus distance and direction from the source, Equation 8	Skin, total body
		Integrated man-rem doses to total population within 50 miles, Equation 8	Total body
		Doses to child and adult from inhalation, and consumption of milk and leafy vegetables, Equation 8	Thyroid

(a) GI-LLI means gastrointestinal tract-lower large intestine.

(b) For these pathways, the calculated total-body dose is listed under GI-LLI, thyroid and bone on the printout and is added into the total dose to these organs.

of joint frequency of wind speed and direction by stability class in either Hanford or Pasquill format or both.

- (3) Parameters which remain constant every time a program is run are stored in permanent data files and accessed by the program when needed.

Table III-A-11 describes all permanent files of type (2) and (3) and lists the programs which use them.

Discussions of ARRRG, CRITR and GRONK are located in Sections III-A.7.2, III-A.7.3 and III-A.7.4, respectively. Table III-A-12 is a guide to the contents of these sections.

Each program discussion includes a teletype printout for a typical run, with input typed by the user^(a) indicated by wavy underlines. Once the user has signed onto the system, he begins execution with the command RUN *name*, where *name* represents ARRRG, CRITR or GRONK. CRITR allows one case to be computed per execution; for additional cases the user enters the command RUN. ARRRG allows any number of cases with varying input to be computed for the specified reactor; to change reactors the user enters the command RUN. GRONK has no restrictions on changing reactors or on the number of cases per reactor.

Constants may be entered with or without a decimal point or in E format. If more than one constant is to be entered on a line, the values may be separated by either blanks or commas. Questions requiring yes-or-no answers may be answered with either Y, YES, N or NO. Titles and reactor names may be more than one word.

(a) Reactor data files and input parameters for the sample runs are intended only to demonstrate operation of the programs. These data files and input parameters are not necessarily those which would be used.

TABLE III-A-11

DATA FILES UTILIZED BY THE DOSE CALCULATION PROGRAMS

<u>File</u>	<u>Contents</u>
ARGIN	Decay constants; internal ingestion dose factors for total-body, GI-LLI, thyroid and bone; external dose factors for skin and total body for exposure to sediment and to water for 136 radionuclides; fresh and salt water bioaccumulation factors for fish, crustacea, molluscs and algae by element.
REL	Radionuclides released with liquid effluents (Ci/yr) for each facility under study.
CRITEN	List of effective absorbed energies per disintegration versus radius for 136 radionuclides.
GIN	Decay constants, external skin and total-body dose factors for air submersion for 136 radionuclides; child and adult thyroid dose factors for inhalation, milk and leafy vegetables.
TONIC	Constants used for the Pasquill meteorology calculation.
Gxxxx ^(a)	File for a particular facility containing radionuclides released with gaseous effluents (Ci/yr), population distribution out to 50 miles in 16 sectors and up to 10 annular rings, and meteorological data in tables of joint frequency of wind speed, direction and stability class in either Hanford or Pasquill format or both.

(a) Where xxxx represents the first four letters of the facility name.

TABLE III-A-12
INDEX TO PROGRAM DESCRIPTIONS AND LISTINGS

<u>Program Name</u>	<u>Program Description (Section)</u>	<u>Sample Conversational Session (Table)</u>	<u>Input Work Sheet (Table)</u>	<u>Sample High-Speed Printer Output (Table)</u>
ARRRG	III-A.7.2 III-A.7.5	III-A-15	III-A-16	III-A-17
CRITR	III-A.7.3 III-A.7.5	III-A-19	None	None
GRONK	III-A.7.4	III-A-22	III-A-20	III-A-23

The programs use a common master list of 136 radionuclides. Section III-A.7.6 details the method by which parent-daughter nuclide pairs are treated in the master list. Table III-A-13 is a compilation by nuclide of standard decay constants, bioaccumulation factors and dose factors used in the programs. The Nuclide Release Worksheet (Table III-A-14) is helpful in preparing the release rate input required for REL and Gxxxx files.

Copies of the programs and associated data files may be obtained upon request. These programs are written in the considerably enhanced version of Basic provided by Computer Sciences Corporation for their INFONET time-sharing network. The CSCX operating system is currently available only at the Richland, Washington INFONET installation; the CSTS operating system is in use at all other installations. ARRRG and GRONK are available in both CSDX and CSTS versions; the other programs and files are compatible with either system without change. The sample output reproduced here was created with the CSTS versions of ARRRG and GRONK. The CSCX output shows minor differences in format.

Warning to non-INFONET potential users: the authors studied the possibility of converting ARRRG, CRITR and GRONK to the IBM 360-370 series and to the CDC 6600 series and found that many of the features used in these programs are lacking in the Basic of these other computers. Thus, the authors concluded that these programs are not convertible into IBM and CDC Basic. Presumably, this conclusion would hold true for most other computers and time-sharing companies.

III-A.7.2 Program ARRRG

ARRRG (Aqueous Reactor Release Result Generator) calculates annual individual and population doses resulting from radionuclides released with liquid effluents. The calculation is performed using the equations of Section III-A.4 for doses received via any user-selected combination of eight exposure pathways:

TABLE III-A-13

NUCLIDE MASTER LIST

ISOTOPE	LAMBDA 1/SEC	LAMBDA 1/HOURS	SALT WATER CONCENTRATION FACTORS, LITER/KG				FRESH WATER CONCENTRATION FACTORS, LITER/KG			
			FISH	CRUS- TACEA	MOL- LUSCS	ALGAE	FISH	CRUS- TACEA	MOL- LUSCS	ALGAE
1 H-3	1.79E-04	6.43E-06	1	1	1	1	1	1	1	1
2 C-14	3.83E-12	1.38E-08	1	1	1	1	4600	9100	9100	4600
3 H-13	1.16E-03	4.16E-00	0	0	0	0	0	0	0	0
4 H-18	1.04E-04	3.75E-01	4	4	4	1	10	100	100	2
5 NA-22	3.44E-09	3.04E-05	1	1	1	1	100	200	200	500
6 NA-24	1.28E-05	4.62E-02	1	1	1	1	100	200	200	500
7 P-32	5.61E-07	2.02E-03	10000	10000	10000	10000	1,0000	20000	20000	500000
8 SR-39	6.17E-11	2.94E-07	1	1	1	1	1	1	1	1
9 SR-41	1.95E-04	3.79E-01	1	1	1	1	1	1	1	1
10 SC-46	9.56E-08	3.44E-04	100	300	300	1000	2	1000	1000	10000
11 CR-51	2.89E-07	1.04E-03	100	1000	1000	1000	20	2000	2000	4000
12 IN-54	2.65E-08	9.53E-05	3000	10000	50000	10000	400	90000	90000	10000
13 NH-50	7.47E-05	2.69E-01	3000	10000	50000	10000	400	90000	90000	10000
14 FE-55	6.44E-09	3.04E-05	1000	4000	20000	6000	100	3200	3200	1000
15 FE-59	1.78E-07	6.42E-04	1000	4000	20000	6000	100	3200	3200	1000
16 CO-57	2.97E-08	1.07E-04	100	10000	300	100	50	200	200	200
17 CO-58	1.12E-07	4.05E-04	100	10000	300	100	50	200	200	200
18 CO-60	4.17E-09	1.50E-05	100	10000	300	100	50	200	200	200
19 NI-63	2.39E-10	8.60E-07	500	100	100	100	100	100	100	50
20 NI-65	7.53E-05	2.71E-01	500	100	100	100	100	100	100	50
21 CU-64	1.51E-05	5.42E-02	1000	5000	5000	1000	50	400	400	2000
22 ZN-65	3.28E-08	1.18E-04	5000	5000	50000	1000	2000(a)	10000	10000	20000
23 ZN-69;+U	1.39E-05	5.02E-02	5000	5000	50000	1000	2000	10000	10000	20000
24 ZN-69	2.02E-04	7.29E-01	5000	5000	50000	1000	2000	10000	10000	20000
25 ZR-92	5.44E-06	1.96E-02	3	10	10	100	420	330	330	50
26 SR-93+D	6.03E-05	2.89E-01	3	10	10	100	420	330	330	50
27 SR-94	5.64E-04	1.31E-00	3	10	10	100	420	330	330	50
28 SR-95	3.86E-03	1.39E-01	3	10	10	100	420	330	330	50
29 KR-93M	1.04E-04	3.73E-01	1	1	1	1	1	1	1	1
30 KR-93M	4.39E-05	1.58E-01	1	1	1	1	1	1	1	1
31 KR-95	2.04E-09	7.35E-06	1	1	1	1	1	1	1	1
32 KR-97	1.52E-04	5.47E-01	1	1	1	1	1	1	1	1
33 KR-98	6.86E-05	2.47E-01	1	1	1	1	1	1	1	1
34 RB-96	4.31E-07	1.55E-03	30	50	10	10	2000	1000	1000	1000
35 RB-96	6.47E-04	2.33E-00	30	50	10	10	2000	1000	1000	1000
36 RB-99	7.50E-04	2.72E-00	30	50	10	10	2000	1000	1000	1000
37 SR-89	1.54E-07	5.55E-04	1	1	1	20	30	100	100	500
38 SR-90	7.78E-10	2.80E-06	1	1	1	20	30	100	100	500
39 SR-90J	7.78E-10	2.80E-06	1	1	1	20	30	100	100	500
40 SR-91	1.99E-05	7.17E-02	1	1	1	20	30	100	100	500
41 SR-92	7.11E-05	2.56E-01	1	1	1	20	30	100	100	500
42 Y-90	3.00E-06	1.08E-02	30	100	100	300	25	1000	1000	5000
43 Y-91M	2.31E-04	8.32E-01	30	100	100	300	25	1000	1000	5000
44 Y-91	1.36E-07	4.91E-04	30	100	100	300	25	1000	1000	5000
45 Y-92	5.44E-05	1.96E-01	30	100	100	300	25	1000	1000	5000
46 Y-93	1.69E-05	6.80E-02	30	100	100	300	25	1000	1000	5000
47 ZR-95	1.23E-07	4.44E-04	30	100	100	1000	330	7	7	1000
48 ZR-95J	1.23E-07	4.44E-04	30	100	100	1000	330	7	7	1000
49 ZR-97	1.13E-05	4.08E-02	30	100	100	1000	330	7	7	1000
50 ZR-97J	1.13E-05	4.08E-02	30	100	100	1000	330	7	7	1000
51 RB-95	2.29E-07	8.25E-04	100	200	200	100	10000	100	100	800

(a) For the Hanford Waste Management Environmental Impact Statement the locally measured values 170 for ^{32}P and 64 for ^{65}Zn in panfish flesh were used.

TABLE III-A-13 (Continued)

52	HO-97	1.61E-04	5.78E-11	100	200	200	100	30000	100	100	800
53	HO-99+D	2.86E-06	1.03E-12	10	100	100	100	10	10	10	1000
54	HO-99J	2.86E-06	1.03E-12	10	100	100	100	10	10	10	1000
55	IC-99A	3.22E-05	1.16E-11	10	100	100	1000	15	5	5	40
56	IC-99	1.04E-13	3.73E-10	10	100	100	1000	15	5	5	40
57	IC-101	8.25E-04	2.97E+10	10	100	100	1000	15	5	5	40
58	HO-105+L	2.02E-07	7.29E-14	3	100	100	1000	10	300	300	2000
59	HO-105+L	4.33E-05	1.56E-11	3	100	100	1000	10	300	300	2000
60	HO-106+D	2.19E-08	7.87E-15	3	100	100	1000	10	300	300	2000
61	HO-105	5.36E-06	1.93E-12	10	100	100	100	10	300	300	200
62	HO-109+L	1.43E-05	5.15E-12	10	100	100	100	10	300	300	200
63	HO-110M+D	3.17E-08	1.14E-14	1000	5000	5000	1000	2	770	770	200
64	HO-111	1.07E-06	3.85E-13	1000	5000	5000	1000	2	770	770	200
65	HO-125	8.53E-07	3.07E-13	3	3	3	10	3000	1000	1000	100
66	JO-124	1.34E-07	4.91E-14	1000	1000	1000	10000	1	10	10	1500
67	JO-125	8.14E-09	2.93E-15	1000	1000	1000	10000	1	10	10	1500
68	JO-127	2.07E-06	7.46E-13	1000	1000	1000	10000	1	10	10	1500
69	LE-125M	1.58E-07	4.98E-14	10	10	100	1000	400	75	75	100
70	LE-127M	7.36E-08	2.65E-14	10	10	100	1000	400	75	75	100
71	LE-127	2.05E-05	7.37E-12	10	10	100	1000	400	75	75	100
72	LE-129M+D	2.36E-07	8.49E-14	10	10	100	1000	400	75	75	100
73	LE-129	1.68E-04	6.03E-11	10	10	100	1000	400	75	75	100
74	LE-131M	6.42E-06	2.31E-12	10	10	100	1000	400	75	75	100
75	LE-131	4.61E-04	1.66E+10	10	10	100	1000	400	75	75	100
76	LE-132	2.47E-06	8.89E-13	10	10	100	1000	400	75	75	100
77	LE-132D	2.47E-06	8.89E-13	10	10	100	1000	400	75	75	100
78	LE-133M+D	2.31E-04	8.32E-11	10	10	100	1000	400	75	75	100
79	LE-134	2.75E-04	9.89E-11	10	10	100	1000	400	75	75	100
80	LE-129	1.29E-15	4.65E-12	20	100	100	10000	15	5	5	40
81	LE-130	1.55E-05	5.59E-12	20	100	100	10000	15	5	5	40
82	LE-131	9.97E-07	3.59E-13	20	100	100	10000	15	5	5	40
83	LE-132	8.36E-05	3.01E-11	20	100	100	10000	15	5	5	40
84	LE-133	9.17E-06	3.33E-12	20	100	100	10000	15	5	5	40
85	LE-134	2.22E-04	8.03E-11	20	100	100	10000	15	5	5	40
86	LE-135	2.86E-05	1.03E-11	20	100	100	10000	15	5	5	40
87	LE-131M	6.81E-07	2.45E-13	1	1	1	1	1	1	1	1
88	LE-133M	3.56E-06	1.28E-12	1	1	1	1	1	1	1	1
89	LE-133	1.52E-06	5.48E-13	1	1	1	1	1	1	1	1
90	LE-135M	7.42E-04	2.67E+10	1	1	1	1	1	1	1	1
91	LE-135	2.09E-05	7.54E-12	1	1	1	1	1	1	1	1
92	LE-137	2.97E-03	1.07E+11	1	1	1	1	1	1	1	1
93	LE-138	6.81E-04	2.45E+10	1	1	1	1	1	1	1	1
94	LS-134M	6.64E-05	2.39E-11	30	50	10	10	2000	100	100	500

TABLE III-A-13 (Continued)

95	CS-134	1.07E-08	3.36E-05	50	50	10	10	2000	100	100	500
96	CS-135	7.53E-09	2.64E-05	50	50	10	10	2000	100	100	500
97	CS-136	5.17E-07	2.22E-03	50	50	10	10	2000	100	100	500
98	CS-137	7.51E-10	2.63E-06	50	50	10	10	2000	100	100	500
99	CS-138	3.58E-04	1.29E+00	50	50	10	10	2000	100	100	500
100	CS-139	1.22E-03	4.36E+00	50	50	10	10	2000	100	100	500
101	CA-139	1.39E-04	5.02E-01	3	3	3	100	4	200	200	500
102	CA-140	6.28E-07	2.26E-03	3	3	3	100	4	200	200	500
103	CA-140B	6.28E-07	2.26E-03	3	3	3	100	4	200	200	500
104	CA-141	6.42E-04	2.31E+00	3	3	3	100	4	200	200	500
105	CA-142	1.05E-03	3.78E+00	3	3	3	100	4	200	200	500
106	CA-140	4.78E-06	1.72E-02	30	100	100	300	25	1000	1000	5000
107	CA-141	4.94E-05	1.78E-01	30	100	100	300	25	1000	1000	5000
108	CA-142	1.26E-04	4.52E-01	30	100	100	300	25	1000	1000	5000
109	CE-141	2.43E-07	8.75E-04	30	100	100	300	1	1000	1000	4000
110	CE-143	5.01E-06	2.09E-02	30	100	100	300	1	1000	1000	4000
111	CE-144+U	2.33E-06	1.02E-04	30	100	100	300	1	1000	1000	4000
112	PR-143	3.89E-07	2.12E-03	100	1000	1000	1000	25	1000	1000	5000
113	PR-144	6.09E-04	2.41E+00	100	1000	1000	1000	25	1000	1000	5000
114	PO-147	7.22E-07	2.63E-03	100	1000	1000	1000	25	1000	1000	5000
115	PO-147	6.39E-09	3.02E-05	100	1000	1000	1000	25	1000	1000	5000
116	PO-145	1.49E-06	5.35E-03	100	1000	1000	1000	25	1000	1000	5000
117	PO-149	3.64E-06	1.31E-02	100	1000	1000	1000	25	1000	1000	5000
118	PO-151	6.06E-06	2.47E-02	100	1000	1000	1000	25	1000	1000	5000
119	PO-153	4.08E-06	1.47E-02	100	1000	1000	1000	25	1000	1000	5000
120	PO-155	5.36E-07	1.93E-03	100	1000	1000	1000	25	1000	1000	5000
121	W-161	5.72E-08	2.06E-04	10	10	100	100	1200	10	10	1200
122	W-165	1.07E-07	3.65E-04	10	10	100	100	1200	10	10	1200
123	W-167	6.06E-06	2.97E-02	10	10	100	100	1200	10	10	1200
124	U-237	1.19E-06	4.28E-03	10	10	10	67	2	60	60	1
125	NP-238	3.83E-06	1.33E-02	10	10	10	6	10	400	400	300
126	NP-239	3.42E-06	1.23E-02	10	10	10	6	10	400	400	300
127	PU-238	2.56E-10	9.23E-07	3	200	200	1000	4	100	100	350
128	PU-239	9.03E-13	3.25E-09	3	200	200	1000	4	100	100	350
129	PU-240	3.33E-12	1.23E-08	3	200	200	1000	4	100	100	350
130	PU-241+U	1.66E-09	5.99E-06	3	200	200	1000	4	100	100	350
131	PU-242	5.61E-14	2.09E-10	3	200	200	1000	4	100	100	350
132	AM-241	4.81E-13	1.73E-09	25	1000	1000	5000	25	1000	1000	5000
133	AM-243+U	2.77E-12	9.96E-09	25	1000	1000	5000	25	1000	1000	5000
134	CM-242	4.92E-08	1.77E-04	25	1000	1000	5000	25	1000	1000	5000
135	CM-244	1.25E-09	4.52E-06	25	1000	1000	5000	25	1000	1000	5000
136	CF-252	6.31E-09	2.99E-05	25	1000	1000	5000	25	1000	1000	5000

TABLE III-A-13 (Continued)

	BODY	SKIN	FOET	GILLI	THYROID	BONE	SKIN	POLY	SKIN	BODY
1	0	0	0	0	0	0	0	0	0	0
2	1.4E-11	3.5E-09	1.27E-07	1.40E-08	1.27E-07	0	0	0	3.50E-09	0
3	5.5E-07	1.4E-06	0	0	0	0	0	0	0	0
4	1.1E-06	1.1E-06	7.80E-05	1.93E-03	0	6.30E-07	8.00E-09	6.80E-09	2.30E-06	1.80E-06
5	1.8E-06	2.3E-06	1.77E-05	3.26E-06	1.77E-05	1.77E-05	1.80E-08	1.60E-08	4.40E-06	4.00E-06
6	3.5E-06	4.5E-06	1.71E-06	3.73E-06	1.71E-06	1.71E-06	2.90E-08	2.50E-08	9.30E-06	7.80E-06
7	3.5E-09	8.2E-07	7.44E-06	2.15E-05	0	1.93E-04	0	0	6.30E-07	6.40E-09
8	3.3E-10	1.2E-07	0	0	0	0	0	0	1.30E-07	6.20E-10
9	1.1E-06	1.6E-06	0	0	0	0	0	0	3.20E-06	2.40E-06
10	2.7E-06	2.0E-06	3.87E-09	5.19E-05	0	5.26E-09	1.50E-08	1.30E-08	4.30E-06	3.70E-06
11	2.4E-08	2.9E-08	2.67E-09	2.69E-07	1.50E-09	0	2.60E-10	2.20E-10	6.40E-08	5.20E-08
12	7.8E-07	8.1E-07	6.68E-07	1.38E-05	0	0	6.80E-09	5.80E-09	1.30E-06	1.50E-06
13	1.9E-06	2.4E-06	2.94E-03	3.60E-06	0	0	1.30E-08	1.10E-08	4.60E-06	3.20E-06
14	3.9E-11	1.6E-09	1.48E-07	5.41E-07	0	6.78E-07	0	0	3.60E-10	6.40E-11
15	1.9E-06	1.2E-06	3.68E-06	3.31E-05	0	4.12E-06	9.40E-09	8.00E-09	2.60E-06	2.20E-06
16	1.6E-07	1.2E-07	2.92E-07	4.47E-06	0	0	1.00E-09	9.10E-10	2.70E-07	2.20E-07
17	6.2E-07	1.1E-06	1.68E-06	1.52E-05	0	0	8.20E-09	7.00E-09	2.30E-06	1.80E-06
18	2.3E-06	2.5E-06	4.70E-06	3.94E-05	0	0	2.00E-08	1.70E-08	5.40E-06	4.60E-06
19	0	0	1.20E-06	1.61E-06	0	3.92E-05	0	0	0	0
20	4.8E-07	1.1E-06	3.22E-06	1.99E-06	0	5.46E-07	4.30E-09	3.70E-07	1.90E-06	1.00E-06
21	1.7E-07	2.8E-07	3.91E-06	6.85E-06	0	0	1.70E-09	1.50E-09	5.20E-07	3.70E-07
22	4.9E-07	5.6E-07	5.88E-06	9.78E-06	0	3.46E-06	4.60E-09	4.00E-09	1.20E-06	1.10E-06
23	3.4E-07	6.8E-07	3.65E-06	2.40E-05	0	1.65E-07	3.40E-09	2.90E-09	1.20E-06	7.50E-07
24	7.1E-10	2.5E-07	1.34E-09	2.90E-09	0	1.09E-08	0	0	2.80E-07	1.60E-09
25	2.4E-06	2.9E-06	2.34E-06	2.53E-06	0	0	2.20E-08	1.90E-08	6.30E-06	5.30E-06
26	7.5E-09	2.7E-07	3.87E-03	5.61E-08	0	0	9.30E-11	6.40E-11	3.10E-07	1.70E-08
27	1.6E-06	3.2E-06	5.26E-06	4.15E-13	0	0	1.40E-08	1.20E-08	5.30E-06	3.50E-06
28	6.7E-09	9.7E-07	2.20E-09	0	0	0	0	0	1.10E-06	1.40E-08
29	0	7.0E-10	0	0	0	0	0	0	7.90E-09	3.10E-09
30	1.3E-07	3.2E-07	0	0	0	0	0	0	5.10E-07	2.80E-07
31	2.2E-09	1.6E-07	0	0	0	0	0	0	1.30E-07	4.70E-09
32	1.3E-06	2.7E-06	0	0	0	0	0	0	4.60E-06	2.70E-06
33	1.5E-06	2.5E-06	0	0	0	0	0	0	4.10E-06	3.30E-06
34	8.0E-06	6.8E-07	1.50E-05	4.27E-06	0	0	7.20E-10	6.30E-10	8.50E-07	1.70E-07
35	5.6E-07	2.7E-06	3.26E-06	0	0	0	4.00E-09	3.50E-09	3.60E-06	1.20E-06
36	2.1E-06	2.8E-06	2.86E-06	0	0	0	1.80E-08	1.50E-08	5.80E-06	4.50E-06
37	2.1E-09	4.9E-07	9.13E-06	4.98E-05	0	3.20E-04	6.50E-13	5.60E-13	5.40E-07	4.60E-09
38	2.4E-10	1.3E-07	8.95E-05	1.23E-04	0	3.36E-04	0	0	1.50E-07	5.40E-10
39	6.1E-09	8.6E-07	2.65E-10	1.65E-04	0	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-08
40	6.9E-07	1.6E-06	2.43E-07	2.87E-05	0	5.82E-06	8.30E-09	7.10E-09	2.70E-06	1.90E-06
41	1.1E-06	1.3E-06	9.35E-08	4.31E-05	0	2.16E-06	1.00E-08	9.00E-09	3.10E-06	2.60E-06
42	6.1E-09	8.6E-07	2.65E-10	1.65E-04	0	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-08
43	4.6E-07	5.6E-07	3.46E-12	2.91E-10	0	8.89E-11	4.40E-09	3.80E-09	1.20E-06	1.00E-06
44	3.1E-09	5.2E-07	3.60E-09	7.50E-05	0	1.36E-07	2.70E-11	2.40E-11	5.70E-07	6.70E-09
45	2.1E-07	1.6E-06	2.50E-11	1.49E-05	0	8.57E-10	1.90E-09	1.60E-09	2.00E-06	4.60E-07
46	5.7E-06	1.2E-06	5.53E-11	6.31E-05	0	1.98E-09	7.80E-10	5.70E-10	1.40E-06	1.90E-07

TABLE III-A-13 (Continued)

47	ZK-95	6.8E-07	8.4E-07	6.34E-09	2.93E-05	0	2.70E-08	5.80E-09	5.00E-09	1.20E-06	1.50E-06
48	ZK-95U	6.4E-07	7.5E-07	1.81E-09	2.03E-05	0	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06
49	ZK-97	6.9E-07	1.4E-06	1.59E-10	1.07E-04	0	1.69E-09	6.40E-09	5.50E-09	2.40E-06	1.50E-06
50	ZK-97U	5.6E-07	1.1E-06	4.70E-12	4.09E-08	0	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06
51	NS-95	6.4E-07	7.5E-07	1.81E-09	2.03E-05	0	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06
52	NS-97	5.6E-07	1.1E-06	4.70E-12	4.09E-08	0	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06
53	NO-99+D	2.2E-07	5.8E-07	7.92E-07	9.85E-06	0	0	2.20E-09	1.90E-09	9.10E-07	4.70E-07
54	NO-99U	1.1E-07	1.3E-07	2.01E-06	2.00E-06	0	1.77E-09	9.50E-10	8.30E-10	2.40E-07	2.10E-07
55	TC-99M	1.1E-07	1.3E-07	2.01E-06	2.00E-06	0	1.77E-09	1.10E-09	9.60E-10	2.70E-07	2.40E-07
56	TC-99	5.3E-11	2.4E-08	4.44E-06	5.38E-06	0	1.11E-07	0	0	2.60E-10	1.30E-10
57	TC-101	5.6E-07	7.6E-07	3.55E-09	6.54E-22	0	2.51E-16	3.00E-09	2.70E-09	1.20E-06	6.80E-07
58	KU-103+L	4.1E-07	4.9E-07	7.97E-08	2.09E-05	0	1.72E-07	4.20E-09	3.60E-09	1.10E-06	8.90E-07
59	KU-105+L	5.4E-07	1.0E-06	6.03E-09	9.19E-06	0	1.49E-08	5.10E-09	4.50E-09	1.80E-06	1.20E-06
60	KU-106+D	1.7E-07	1.5E-06	3.56E-07	1.81E-04	0	2.79E-06	1.80E-09	1.50E-09	1.90E-06	3.80E-07
61	KU-105	7.6E-06	1.6E-07	5.82E-06	1.36E-05	0	1.15E-07	7.70E-10	6.60E-10	3.00E-07	1.70E-07
62	KU-109+D	4.3E-09	3.0E-07	4.16E-06	2.05E-05	0	0	4.00E-11	3.50E-11	3.40E-07	9.30E-09
63	AS-110M+L	2.2E-06	2.4E-06	6.70E-08	5.82E-05	0	1.46E-07	2.10E-08	1.80E-08	5.30E-06	4.90E-06
64	KU-111	2.2E-06	3.2E-07	1.21E-06	4.34E-05	0	5.74E-08	2.10E-10	1.80E-10	3.30E-07	4.80E-08
65	SR-125	7.3E-08	9.1E-07	3.79E-07	1.06E-04	1.40E-07	8.33E-06	6.60E-10	5.70E-10	1.10E-06	1.60E-07
66	SR-124	1.6E-06	2.2E-06	1.10E-06	7.90E-05	6.74E-09	2.80E-06	1.50E-08	1.30E-08	4.50E-06	3.60E-06
67	SR-126	5.6E-07	4.5E-07	4.17E-07	1.86E-05	1.72E-09	1.57E-06	3.50E-09	3.10E-09	9.50E-07	7.80E-07
68	SR-127	6.7E-07	9.3E-07	1.18E-07	6.54E-05	4.67E-09	3.57E-07	6.00E-09	5.70E-09	1.80E-06	1.50E-06
69	TE-125M	1.7E-09	1.1E-06	3.49E-07	1.05E-05	7.94E-07	2.72E-06	4.80E-11	3.50E-11	1.50E-08	3.60E-09
70	TE-127M	1.2E-10	1.6E-09	7.62E-07	2.10E-05	1.61E-06	6.40E-06	1.30E-12	1.10E-12	1.80E-09	2.60E-10
71	TE-127	1.2E-09	1.6E-07	2.21E-06	8.13E-06	7.53E-08	1.03E-07	1.10E-11	1.00E-11	1.70E-07	2.80E-09
72	TE-129M+L	9.4E-06	5.7E-07	1.77E-06	5.79E-05	4.50E-06	1.17E-05	9.00E-10	7.70E-10	7.40E-07	2.10E-07
73	TE-129	6.7E-06	5.3E-07	7.61E-09	2.12E-08	2.40E-08	3.13E-08	8.40E-10	7.10E-10	7.00E-07	1.90E-07
74	TE-131M	1.0E-06	1.3E-06	4.71E-07	3.84E-05	6.92E-07	8.02E-07	9.90E-09	8.40E-09	2.70E-06	2.20E-06
75	TE-131	5.4E-07	1.1E-06	6.25E-09	3.58E-14	1.63E-08	1.95E-08	2.60E-09	2.20E-09	1.60E-06	7.40E-07
76	TE-132	1.8E-07	2.3E-07	1.54E-06	7.79E-05	1.82E-06	2.56E-06	2.00E-09	1.70E-09	4.80E-07	4.00E-07
77	TE-132D	2.0E-06	2.7E-06	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
78	TE-133M+L	1.8E-06	2.4E-06	2.35E-06	1.45E-09	3.52E-08	4.04E-08	1.70E-08	1.50E-08	5.90E-06	3.90E-06
79	TE-134	1.2E-07	1.9E-07	2.20E-08	4.40E-09	2.85E-08	3.25E-08	1.20E-09	1.00E-09	3.50E-07	2.50E-07
80	TE-129	1.1E-09	4.0E-09	6.01E-06	3.07E-07	6.18E-03	2.49E-06	9.60E-12	7.00E-12	6.20E-09	2.30E-09
81	TE-130	1.6E-06	2.3E-06	8.77E-07	1.89E-06	2.80E-04	7.44E-07	1.70E-08	1.40E-08	4.80E-06	3.90E-06
82	TE-131	5.1E-07	4.9E-07	3.37E-06	1.53E-06	1.86E-03	3.93E-06	3.40E-09	2.80E-09	9.30E-07	6.80E-07
83	TE-132	2.0E-06	2.7E-06	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
84	TE-133	4.4E-07	8.8E-07	7.62E-07	2.25E-06	4.82E-04	1.43E-06	4.50E-09	3.70E-09	1.50E-06	9.60E-07
85	TE-134	2.0E-06	2.9E-06	1.02E-07	2.25E-10	3.73E-05	1.07E-07	1.90E-08	1.60E-08	5.50E-06	4.20E-06

TABLE III-A-13 (Continued)

86	AL-135	1.5E-06	2.2E-06	4.50E-07	1.41E-06	1.76E-04	5.01E-07	1.40E-08	1.20E-08	4.00E-06	3.30E-06
87	AL-135M	2.6E-09	4.8E-08	0	0	0	0	0	0	5.60E-08	6.20E-09
88	AL-135M	2.7E-06	6.2E-08	0	0	0	0	0	0	1.00E-07	6.00E-08
89	AL-135	2.5E-03	6.9E-08	0	0	0	0	0	0	1.10E-07	5.70E-08
90	AL-135M	3.5E-07	5.2E-07	0	0	0	0	0	0	1.90E-06	7.60E-07
91	AL-135	2.1E-07	4.9E-07	0	0	0	0	0	0	7.90E-07	4.50E-07
92	AL-137	1.2E-07	1.8E-06	0	0	0	0	0	0	2.10E-06	2.70E-07
93	AL-135	1.2E-06	1.7E-06	0	0	0	0	0	0	3.40E-06	2.60E-06
94	CS-134M	7.3E-06	9.1E-08	2.4E-03	1.63E-08	0	2.25E-03	7.30E-10	6.20E-10	1.90E-07	1.60E-07
95	CS-134	1.3E-06	1.7E-06	1.90E-04	2.56E-06	0	5.29E-05	1.40E-08	1.20E-08	3.50E-06	2.90E-06
96	CS-135	2.8E-11	8.6E-09	5.64E-06	3.71E-08	0	1.44E-05	0	0	1.10E-08	6.60E-11
97	CS-136	1.9E-06	2.2E-06	1.61E-05	2.86E-06	0	6.24E-06	1.70E-08	1.50E-08	4.80E-06	4.10E-06
98	CS-137	4.7E-07	7.2E-07	5.60E-05	2.05E-06	0	6.37E-05	4.90E-09	4.20E-09	1.40E-06	1.00E-06
99	CS-138	1.7E-06	3.1E-06	5.49E-08	4.89E-13	0	5.66E-06	2.40E-08	2.10E-08	5.70E-06	4.00E-06
100	CS-139	6.2E-07	2.1E-06	3.34E-06	3.54E-30	0	3.18E-08	7.20E-09	6.30E-09	3.20E-06	1.70E-06
101	CS-139	3.7E-06	6.9E-07	2.86E-09	1.68E-07	0	9.85E-08	2.70E-09	2.40E-09	1.30E-06	7.70E-08
102	CS-140	2.2E-07	4.4E-07	1.33E-06	4.02E-05	0	2.02E-05	2.40E-09	2.10E-09	7.50E-07	4.90E-07
103	CS-140B	1.9E-06	2.7E-06	3.34E-10	9.32E-05	0	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
104	CS-141	5.2E-07	1.6E-06	1.73E-09	1.40E-17	0	5.18E-08	4.90E-09	4.30E-09	2.40E-06	1.10E-06
105	CS-142	1.0E-06	1.6E-06	1.37E-09	0	0	2.20E-08	9.00E-09	7.90E-09	3.00E-06	2.20E-06
106	CS-140	1.9E-06	2.7E-06	3.34E-10	9.32E-05	0	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
107	CS-141	2.3E-09	9.2E-07	2.93E-11	1.24E-05	0	3.90E-10	2.80E-10	2.50E-10	1.90E-06	5.10E-08
108	CS-142	2.0E-06	3.1E-06	1.44E-11	4.16E-07	0	1.29E-10	1.80E-08	1.50E-08	5.90E-06	4.50E-06
109	CS-141	5.9E-06	1.5E-07	6.86E-10	2.28E-05	0	8.83E-09	6.20E-10	5.50E-10	2.40E-07	1.30E-07
110	CS-143	2.6E-07	6.3E-07	1.33E-10	4.39E-05	0	1.60E-09	2.50E-09	2.20E-09	1.00E-06	5.70E-07
111	CS-144+U	4.0E-08	1.2E-06	1.98E-08	1.60E-04	0	3.27E-07	3.70E-10	3.20E-10	1.40E-06	8.60E-08
112	CS-143	7.5E-10	2.5E-07	4.39E-10	3.86E-05	0	8.96E-09	0	0	2.80E-07	1.60E-09
113	CS-144	2.6E-08	1.2E-06	1.59E-12	4.51E-18	0	3.13E-11	2.30E-10	2.00E-10	1.30E-06	5.60E-08
114	CS-147	1.3E-07	3.1E-07	4.92E-10	3.34E-05	0	5.43E-09	1.20E-09	1.00E-09	5.00E-07	2.80E-07
115	CS-147	3.3E-11	1.2E-08	1.22E-09	7.93E-06	0	2.36E-08	0	0	1.30E-08	7.50E-11
116	CS-146	5.2E-07	1.2E-06	6.11E-10	9.43E-05	0	7.29E-09	5.30E-09	4.60E-09	2.10E-06	1.10E-06
117	CS-149	6.9E-09	3.1E-07	6.64E-11	4.00E-05	0	1.50E-09	2.90E-11	2.50E-11	3.50E-07	1.50E-08
118	CS-151	2.3E-07	5.2E-07	6.06E-11	3.35E-05	0	7.23E-10	2.30E-09	2.20E-09	8.40E-07	5.00E-07
119	CS-153	3.0E-06	2.0E-07	5.98E-11	2.86E-05	0	9.86E-10	3.00E-10	2.70E-10	2.50E-07	6.50E-08
120	CS-155	9.8E-07	1.5E-06	1.69E-09	7.24E-05	0	1.36E-08	8.70E-09	7.60E-09	2.50E-06	2.10E-06
121	CS-161	2.5E-10	3.2E-10	5.49E-10	3.66E-07	0	1.01E-08	2.80E-12	2.10E-12	6.80E-10	5.30E-10
122	CS-165	1.4E-10	7.2E-08	1.48E-08	1.60E-05	0	4.26E-07	0	0	7.40E-08	3.20E-10
123	CS-167	3.8E-07	6.3E-07	3.12E-08	3.01E-05	0	1.11E-07	3.60E-09	3.10E-09	1.20E-06	8.30E-07
124	CS-237	1.2E-07	1.6E-07	1.47E-10	1.94E-05	0	5.53E-10	1.30E-09	1.00E-09	3.40E-07	2.60E-07
125	CS-233	3.5E-07	5.7E-07	2.11E-10	3.43E-05	0	4.27E-09	3.20E-09	2.80E-09	1.10E-06	7.70E-07
126	CS-239	1.1E-07	2.1E-07	6.46E-11	2.40E-05	0	1.20E-09	1.10E-09	9.50E-10	3.70E-07	2.40E-07
127	CS-238	6.8E-11	1.7E-09	4.39E-07	7.30E-05	0	1.76E-05	1.60E-11	1.30E-12	4.00E-09	1.50E-10
128	CS-239	5.6E-11	7.6E-10	4.12E-07	6.66E-05	0	1.65E-05	7.70E-12	7.90E-13	1.70E-09	1.20E-10
129	CS-240	6.5E-11	1.7E-09	4.16E-07	6.78E-05	0	1.65E-05	1.80E-11	1.30E-12	4.00E-09	1.40E-10
130	CS-241+U	2.8E-11	4.2E-11	4.21E-10	6.78E-07	0	1.44E-08	6.80E-12	4.60E-12	9.50E-11	6.10E-11
131	CS-242	5.1E-11	1.6E-09	3.92E-07	6.53E-05	0	1.57E-05	1.60E-11	1.10E-12	3.60E-09	1.10E-10
132	CS-241	1.8E-08	2.7E-08	1.46E-08	7.42E-05	0	1.83E-05	2.60E-10	1.80E-10	6.10E-08	3.90E-08
133	CS-243+U	1.4E-07	2.5E-07	1.41E-06	9.73E-05	0	1.77E-05	1.50E-09	1.30E-09	4.60E-07	3.10E-07
134	CS-242	1.6E-10	2.1E-09	8.26E-07	7.92E-05	0	1.25E-05	2.30E-11	5.50E-12	4.70E-09	3.40E-10
135	CS-244	1.2E-10	1.7E-09	1.51E-06	7.55E-05	0	2.24E-05	1.80E-11	2.90E-12	3.90E-09	2.60E-10
136	CS-252	6.6E-06	7.9E-06	1.16E-06	2.88E-04	0	4.65E-05	7.20E-08	6.60E-08	1.70E-05	1.40E-05

TABLE III-A-13 (Continued)

MASTER LIST OF THYROID DOSE FACTORS

ISOTOPE	MREM/YEAR PER PCI/CUBIC METER					
	---INHALATION---		---M I L K-----		LEAFY VEGETABLES	
	2 YEAR	ADULT	2 YEAR	ADULT	2 YEAR	ADULT
77 RE-132D	0.	0.	126.	9.11	4.04	1.17
80 I-129	5.74	34.3	3600.	3140.	1485.	5190.
81 I-130	2.88	1.57	83.	6.61	26.8	8.53
82 I-131	12.5	10.6	3620.	448.	1190.	589.
83 I-132	0.835	0.414	4.58	0.330	1.48	0.428
84 I-133	5.51	2.70	262.	18.7	84.1	24.1
85 I-134	0.424	0.209	0.911	0.0655	0.293	0.0844
86 I-135	2.00	0.985	31.2	2.28	10.0	2.94

TABLE III-A-14

NUCLIDE RELEASE WORKSHEET

1 H-3	35 RB-88	69 TE-125M	103 BA-140D
2 C-14	36 RE-89	70 TE-127M	104 BA-141
3 N-13	37 SR-89	71 TE-127	105 BA-142
4 F-18	38 SR-90	72 TE-129M+D	106 LA-140
5 NA-22	39 SR-90U	73 TE-129	107 LA-141
6 NA-24	40 SR-91	74 TE-131M	108 LA-142
7 F-32	41 SR-92	75 TE-131	109 CE-141
8 AK-39	42 Y-90	76 TE-132	110 CE-143
9 AK-41	43 Y-91M	77 TE-132D	111 CE-144+D
10 SC-46	44 Y-91	78 TE-133M+D	112 PR-143
11 CR-51	45 Y-92	79 TE-134	113 PR-144
12 ML-54	46 Y-93	80 I-129	114 ND-147
13 ML-56	47 ZK-95	81 I-130	115 PM-147
14 FL-55	48 ZK-95U	82 I-131	116 PM-148
15 FL-59	49 ZK-97	83 I-132	117 PM-149
16 CU-57	50 ZK-97U	84 I-133	118 PM-151
17 CU-58	51 NB-95	85 I-134	119 SM-153
18 CU-60	52 NB-97	86 I-135	120 EU-156
19 NI-63	53 MO-95+D	87 XL-131M	121 W-181
20 NI-65	54 MO-96U	88 YE-133M	122 W-185
21 CU-64	55 TC-99M	89 YE-133	123 W-187
22 ZN-65	56 TC-99	90 YE-135M	124 U-237
23 ZN-69M+L	57 TC-101	91 YE-135	125 NP-236
24 ZN-69	58 RU-103+L	92 YE-137	126 NP-239
25 BR-82	59 RU-105+L	93 YE-136	127 PU-236
26 BR-83+L	60 RU-106+U	94 CS-134M	128 PU-239
27 BR-84	61 PH-105	95 CS-134	129 PU-240
28 BR-85	62 PD-109+U	96 CS-135	130 PU-241+D
29 KR-83M	63 AG-110M+D	97 CS-136	131 PU-242
30 KR-85M	64 AG-111	98 CS-137	132 AM-241
31 KR-85	65 SN-125	99 CS-136	133 AM-243+D
32 KR-87	66 SB-124	100 CS-139	134 CM-242
33 KR-88	67 SB-125	101 PA-139	135 CM-244
34 RB-86	68 SB-127	102 PA-140	136 CF-252

ingesting fish, molluscs, crustacea and marine plants; drinking water; standing on contaminated shoreline; and swimming and boating in contaminated water.

Internal radiation doses along the fish, crustacea, molluscs, marine-plants and drinking-water pathways are computed for four organs of reference: total body, GI-LLI, thyroid and bone. External radiation doses along the shoreline,^(a) swimming and boating pathways are computed for two organs of reference: skin and total body. These external total-body doses are also listed under GI-LLI, thyroid and bone, and are included in the totals for these organs.

Program output at the user's conversational terminal consists of the total dose by pathway and organ, and an optional table of the percent contribution to the total dose by nuclide for each pathway-organ combination. A more detailed output is automatically sent to a high-speed printer. The printout includes the above information plus the section of the REL file containing the releases for the specified facility; tables of dose factors, bioaccumulation factors, decay constants, concentrations of radionuclides in the liquid effluent; and a copy of the parameters entered by the user at the time of the run.

ARRRG obtains its data from three sources:

- (1) The holdups, usages and mixing ratios by pathway, the reactor coolant flow, shoreline width factor, and the reconcentration factor parameters are entered by the user at the time of the run. Section III-A.7.5 discusses the choice of parameters to use for the reconcentration factor and mixing ratios. The standard input to be used for the other parameters in absence of information specific to the site is given in Table III-A-3.

(a) For the shoreline calculation (Equation 6), the operating lifetime of the facility, t_s , is taken to be 40 years.

- (2) The radionuclide release rates for all facilities are stored on a single large file called REL. Release rates for the given facility are stored once within REL at the time the information is received from the applicant; this is the only file ever modified by the user of ARRRG and CRITR. ARRRG automatically accesses that portion of REL headed by the facility name entered by the user at the time the run is made. There is no limit to the number of facilities and they may be in any order, although facility names must be unique. Each facility within REL requires:
- (a) A line containing the facility name, optionally followed comments. This line is printed as part of the heading on the first page and on the top of each result page.
 - (b) The word SALT or FRESH to indicate which set of bio-accumulation factors to use.
 - (c) The 136 liquid releases (Ci/yr) in the nuclide order given in Table III-A-13. Isotopes which are not released must be listed as zero, but ARRRG accepts the shorthand notation rZ to represent r consecutive zero releases.
 - (d) A blank line of one or more spaces.
- (3) The 136 nuclide names, decay constants, dose factors, and fresh and salt water bioaccumulation factors required by ARRRG are stored in the permanent file ARGIN.

Table III-A-15 shows teletype printout for a typical run, with user input indicated by wavy underlines. The worksheet of Table III-A-16 is helpful in preparing the input. The reactor name determines which set of releases from REL will be accessed by the program. The user must specify a population dose or an individual dose calculation. If a population dose calculation is specified, the user enters yearly usages for the entire population of interest; dose will be calculated in

TABLE III-A-15

TELETYPE PRINTOUT FOR SAMPLE ARRRG RUN

RUN ARRRG

ARRRG 12:49 01/14/74

REACTOR NAME?PIKES PEAK
DOSE TO POPULATION OR INDIVIDUAL (P OR I)?I
ENTER HOLDUP IN HOURS, USAGES, MIXING RATIOS
FISH?24 33.6 .03
CRUSTACEA?0 0 0
MOLLUSCS?0 0 0
ALGAE?0 0 0
DRINKING WATER?24 1430 .03
SHORELINE?5 106 .14
SWIMMING?5 416 .14
BOATING?5 416 .14
SHORE WIDTH FACTOR=.5
COOLANT FLOW IN CFS?790
WHICH RECONCENTRATION FORMULA?3

PIKES PEAK FLOW= 790 CONSTANT RECONCENTRATION= 1
PLANT LIFE= 30 YEARS SHORE WIDTH FACTOR= .5

	HOLDUP	USAGE	MIXING
FISH	24	33.6	.03
DRINKING	24	1430	.03
SHORELINE	5	106	.14
SWIMMING	5	416	.14
BOATING	5	416	.14

CONSTANTS OK?YES
PRINT PERCENTS AT TELETYPE?Y
ENTER TITLE FOR THIS CASE?SAMPLE ARRRG RUN

* * * ISOTOPES CONTRIBUTING AT LEAST 4% * * *

-TOTAL BODY--		---GI-LLI---		---THYROID---		----BONE----	
FISH							
CS-134	64%	H-3	5%	I-131	87%	CS-134	47%
CS-137	31%	TE-129M+	6%	I-133	12%	CS-137	49%
		TE-132	38%				
		CS-134	18%				
		CS-136	5%				
		CS-137	12%				
DRINKING WATER							
H-3	91%	H-3	88%	I-131	85%	I-131	54%
I-131	4%			I-133	11%	I-133	10%
						CS-134	16%
						CS-137	17%

----SKIN----		-TOTAL BODY--	
SHORELINE			
CS-134	29%	CS-134	29%
CS-137	64%	CS-137	64%
SWIMMING			
I-131	26%	I-131	27%
I-132	4%	I-132	5%
I-133	39%	I-133	35%
I-135	20%	I-135	23%

BOATING
SAME AS SWIMMING

* * * INDIVIDUAL DOSE IN MREM/YR * * *

	SKIN	BODY	GI-LLI	THYROID	BONE
FISH		1.64E-02	1.51E-03	7.56E-02	1.18E-02
DRINKING		8.45E-03	4.42E-03	2.20E-01	7.29E-04
SHORELINE	1.40E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03
SWIMMING	5.15E-04	3.68E-04	3.68E-04	3.68E-04	3.68E-04
BOATING	2.57E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04
TOTALS	2.18E-03	2.66E-02	7.69E-03	2.97E-01	1.43E-02

RUN ANOTHER CASE?N

NOW AT END
SRU'S:6.6
READY

TABLE III-A-16

ARRRG INPUT WORKSHEET

REACTOR NAME _____

☐ POPULATION or ☐ INDIVIDUAL dose calculation

	<u>HOLDUP</u>	<u>USAGE</u>	<u>MIXING RATIO</u>
Fish	_____ hr	_____ kg/yr	_____
Crustacea	_____ hr	_____ kg/yr	_____
Molluscs	_____ hr	_____ kg/yr	_____
Plants	_____ hr	_____ kg/yr	_____
Drinking water	_____ hr	_____ g/yr	_____
Shoreline	_____ hr	_____ hr/yr	_____
Swimming	_____ hr	_____ hr/yr	_____
Boating	_____ hr	_____ hr/yr	_____

SHORE WIDTH FACTOR _____ COOLANT FLOW _____ cfs

RECONCENTRATION MODELS

- ☐ 1 Simplified theoretical model
- VOLUME _____ ft³
- MAKEUP FLOW _____ cfs
- TURNOVER RATE _____ day⁻¹
- CYCLE TIME _____ hr
- ☐ 2 Empirical model
- RECYCLE FRACTION _____
- CYCLE TIME _____ hr
- ☐ 3 No reconcentration

TITLE FOR THIS CASE _____

REMARKS:

man-rem/year and appropriate table titles will be printed. If an individual dose calculation is specified, the user enters individual yearly usages; dose will be calculated in mrem/year and appropriate table titles will be printed. For a population dose calculation, specific site data is used for consumption of aquatic foods and hours of recreation. In the absence of such information, default data on per capita usage such as in Table III-A-3 is multiplied by the population living within a 50-mile radius of the site.

The holdup, mixing ratio and usage parameters are then entered by pathway. For unused pathways 0 0 0 is entered. Usages are in the units kg/yr for the four food pathways, liter/yr for the drinking water pathway, and hr/yr for the shoreline, swimming and boating pathways. After the user enters shoreline width, coolant flow and reconcentration data, the program summarizes the input for the user to check. If the response to "constants OK?" is N or NO, the user is permitted to re-enter all the parameters.

The program prints a table of dose by pathway and organ and prints totals by organ. At the user's option, a table of percent contribution to the total dose by nuclide is printed for each pathway-organ combination. If the user responds Y or YES to "run another case?", he may run ARRRG for the same facility with a different set of input constants.

Table III-A-17 shows the high-speed printer output resulting from this run. On the last page is a summary of all cases contained in the printout.

III-A.7.3 Program CRITR

CRITR calculates annual internal total-body doses to organisms resulting from radionuclides ingested with their food, using Equations 12 and 16. CRITR always calculates the internal dose to four primary organisms which are directly exposed to the radionuclides in the water: fish, crustacea, molluscs and algae. At the user's option, internal dose can also be calculated for up to six secondary organisms which feed upon one of the primary organisms.

TABLE III-A-17

HIGH SPEED PRINTER OUTPUT FOR SAMPLE ARRRG RUN

ARRRG ** ARRRG ** ARRRG ** ARRRG ** ARRRG

01/14/74

12:49

ARRRG ** ARRRG ** ARRRG ** ARRRG ** ARRRG

LISTING OF PIKES PEAK PORTION OF REL FILE:

PIKES PEAK

FRESH 1000 0 0 0 0 0 0 0 0 0 5.7E-4 6.1E-4 0 1.3E-3 6.6E-4 0
6.9E-3 5.6E-4 0 0 0 0 0 0 9.6E-4 3.4E-3 4.9E-5 0 0 0 0 0 6.2E-5
2.1E-2 1.1E-5 3.6E-4 1.3E-5 1.3E-5 2.4E-4 1.1E-5 1.9E-5 1.5E-4
3.4E-3 4.1E-5 4.3E-5 6E-5 6E-5 1.7E-5 1.7E-5 6.3E-5 1.8E-5 .26
.23 .21 0 0 4E-5 5.8E-6 1.3E-5 1.5E-5 1.4E-6 0 7E-7 0 0 0 1.4E-6
3.3E-5 2.9E-4 2.4E-4 2.8E-3 1.8E-3 1.2E-3 2.4E-4 1.6E-2 1.6E-2
7.8E-6 6.3E-6 0 6.2E-3 1.8 .21 1.9 2E-3 .52 0 0 0 0 0 0 1.4E-5
.037 0 9E-3 3.2E-2 1.5E-4 5.1E-6 1.5E-4 3.3E-4 3.3E-4 0 0 2E-4
3.3E-5 7.1E-7 6E-5 2.5E-5 5.1E-5 4.4E-5 0 1.8E-5 2.9E-6 6.5E-6
8.6E-6 2.5E-6 4.6E-6 2.3E-6 0 0 0 1.1E-5 2.4E-6 3.4E-4 0 0 0
1.8E-6 0 0 0 0 0 0

III-A-46

TABLE III-A-17 (Continued)

01/14/74

ISOTOPE	LAMBDA 1/HOURS	INITIAL RELEASE Ci/YR	RECUN. FACTOR	CONC. PCI/ LITER	BIOACCUMULATION FISH	CRUS- TACEA	MOL- LUSCS	L/KG ALGAE
1 H-3	0.43E-06	1.00E+03	1.00	1.42E+03	1	1	1	1
11 CR-51	1.04E-03	5.70E-04	1.00	8.07E-04	20	2000	2000	4000
12 MN-54	9.53E-05	6.10E-04	1.00	8.64E-04	400	90000	90000	10000
14 FE-55	3.04E-05	1.30E-03	1.00	1.84E-03	100	3200	3200	1000
15 FE-59	6.42E-04	6.60E-04	1.00	9.35E-04	100	3200	3200	1000
17 CO-58	4.05E-04	6.90E-03	1.00	9.77E-03	50	200	200	200
18 CO-60	1.50E-05	5.60E-04	1.00	7.93E-04	50	200	200	200
25 HR-82	1.96E-02	9.60E-04	1.00	1.36E-03	420	330	330	50
26 HR-83+0	2.89E-01	3.40E-03	1.00	4.82E-03	420	330	330	50
27 BR-84	1.31E+00	4.90E-05	1.00	6.94E-05	420	330	330	50
34 KB-86	1.55E-03	6.20E-05	1.00	8.78E-05	2000	1000	1000	1000
35 KB-88	2.33E+00	2.10E-02	1.00	2.97E-02	2000	1000	1000	1000
36 KB-89	2.70E+00	1.10E-05	1.00	1.56E-05	2000	1000	1000	1000
37 SK-89	5.55E-04	3.60E-04	1.00	5.10E-04	30	100	100	500
38 SK-90	2.60E-06	1.30E-05	1.00	1.84E-05	30	100	100	500
39 SK-90D	2.80E-06	1.30E-05	1.00	1.84E-05	30	100	100	500
40 SK-91	7.17E-02	2.40E-04	1.00	3.40E-04	30	100	100	500
41 SK-92	2.56E-01	1.10E-05	1.00	1.56E-05	30	100	100	500
42 Y-90	1.08E-02	1.90E-05	1.00	2.69E-05	25	1000	1000	5000
43 Y-91M	8.32E-01	1.50E-04	1.00	2.12E-04	25	1000	1000	5000
44 Y-91	4.91E-04	3.40E-03	1.00	4.82E-03	25	1000	1000	5000
45 Y-92	1.96E-01	4.10E-05	1.00	5.81E-05	25	1000	1000	5000
46 Y-93	6.80E-02	4.30E-05	1.00	6.09E-05	25	1000	1000	5000
47 ZR-95	4.44E-04	6.00E-05	1.00	8.50E-05	330	7	7	1000
48 ZR-95D	4.44E-04	6.00E-05	1.00	8.50E-05	330	7	7	1000
49 ZR-97	4.08E-02	1.70E-05	1.00	2.41E-05	330	7	7	1000
50 ZR-97D	4.08E-02	1.70E-05	1.00	2.41E-05	330	7	7	1000
51 NB-95	8.25E-04	6.30E-05	1.00	8.92E-05	30000	100	100	800
52 NB-97	5.78E-01	1.80E-05	1.00	2.55E-05	30000	100	100	800
53 MO-99+D	1.03E-02	2.60E-01	1.00	3.68E-01	10	10	10	1000
54 MO-99D	1.03E-02	2.30E-01	1.00	3.26E-01	10	10	10	1000
55 TC-99M	1.16E-01	2.10E-01	1.00	2.97E-01	15	5	5	40
58 KU-103+D	7.29E-04	4.00E-05	1.00	5.67E-05	10	300	300	2000
59 KU-105+D	1.56E-01	5.60E-06	1.00	8.22E-06	10	300	300	2000
60 RU-106+D	7.87E-05	1.30E-05	1.00	1.84E-05	10	300	300	2000
61 MH-105	1.93E-02	1.50E-05	1.00	2.12E-05	10	300	300	200
62 PD-109+D	5.15E-02	1.40E-06	1.00	1.98E-06	10	300	300	200
64 AG-111	3.85E-03	7.00E-07	1.00	9.92E-07	2	770	770	200
68 SH-127	7.46E-03	1.40E-06	1.00	1.98E-06	1	10	10	1500
69 TE-125M	4.98E-04	3.30E-05	1.00	4.67E-05	400	75	75	100

III-A-47

TABLE III-A-17 (Continued)

70	TE-127M	2.65E-04	2.90E-04	1.00	4.11E-04	400	75	75	100
71	TE-127	7.37E-02	2.90E-04	1.00	4.11E-04	400	75	75	100
72	TE-129M+U	8.49E-04	2.80E-03	1.00	3.97E-03	400	75	75	100
73	TE-129	6.03E-01	1.80E-03	1.00	2.55E-03	400	75	75	100
74	TE-131M	2.31E-02	1.20E-03	1.00	1.70E-03	400	75	75	100
75	TE-131	1.65E+00	2.40E-04	1.00	3.40E-04	400	75	75	100
76	TE-132	8.89E-03	1.80E-02	1.00	2.27E-02	400	75	75	100
77	TE-132U	8.89E-03	1.80E-02	1.00	2.27E-02	400	75	75	100
78	TE-133M+U	8.32E-01	1.80E-06	1.00	1.10E-05	400	75	75	100
79	TE-134	9.89E-01	8.30E-06	1.00	8.92E-06	400	75	75	100
81	I-130	5.59E-02	8.20E-03	1.00	8.78E-03	15	5	5	40
82	I-131	3.59E-03	1.80E+00	1.00	2.55E+00	15	5	5	40
83	I-132	3.01E-01	2.10E-01	1.00	2.97E-01	15	5	5	40
84	I-133	3.30E-02	1.90E+00	1.00	2.69E+00	15	5	5	40
85	I-134	8.00E-01	2.00E-03	1.00	2.83E-03	15	5	5	40
86	I-135	1.03E-01	5.20E-01	1.00	7.37E-01	15	5	5	40
94	CS-134M	2.39E-01	1.40E-05	1.00	1.93E-05	2000	100	100	500
95	CS-134	3.86E-05	3.70E-02	1.00	5.24E-02	2000	100	100	500
97	CS-136	2.27E-03	9.00E-03	1.00	1.27E-02	2000	100	100	500
98	CS-137	2.63E-06	3.20E-02	1.00	4.53E-02	2000	100	100	500
99	CS-138	1.29E+00	1.50E-04	1.00	2.12E-04	2000	100	100	500
100	CS-139	4.38E+00	5.10E-06	1.00	7.22E-06	2000	100	100	500
101	BA-139	5.02E-01	1.50E-04	1.00	2.12E-04	4	200	200	500
102	BA-140	2.25E-03	3.30E-04	1.00	4.67E-04	4	200	200	500
103	BA-140U	2.25E-03	3.30E-04	1.00	4.67E-04	4	200	200	500
106	LA-140	1.72E-02	2.00E-04	1.00	2.83E-04	25	1000	1000	5000
107	LA-141	1.78E-01	3.30E-05	1.00	4.67E-05	25	1000	1000	5000
108	LA-142	4.52E-01	7.10E-07	1.00	1.01E-06	25	1000	1000	5000
109	CE-141	4.75E-04	8.00E-05	1.00	8.50E-05	1	1000	1000	4000
110	CE-143	2.09E-02	2.50E-05	1.00	3.54E-05	1	1000	1000	4000
111	CE-144+U	1.02E-04	5.10E-05	1.00	7.22E-05	1	1000	1000	4000
112	PM-143	2.12E-03	4.40E-05	1.00	6.23E-05	25	1000	1000	5000
114	PM-147	2.60E-03	1.80E-05	1.00	2.55E-05	25	1000	1000	5000
115	PM-147	3.02E-05	2.90E-06	1.00	4.11E-06	25	1000	1000	5000
116	PM-148	5.35E-03	8.50E-06	1.00	9.21E-06	25	1000	1000	5000
117	PM-149	1.31E-02	8.80E-06	1.00	1.25E-05	25	1000	1000	5000
118	PM-151	2.47E-02	2.50E-06	1.00	3.54E-06	25	1000	1000	5000
119	SM-153	1.47E-02	4.60E-06	1.00	6.52E-06	25	1000	1000	5000
120	EU-156	1.93E-03	2.30E-06	1.00	3.28E-06	25	1000	1000	5000
124	U-237	4.28E-03	1.10E-05	1.00	1.58E-05	2	60	60	1
125	NP-238	1.35E-02	2.40E-06	1.00	3.40E-06	10	400	400	300
126	NP-239	1.23E-02	3.40E-04	1.00	4.82E-04	10	400	400	300
130	PU-241+U	5.99E-06	1.80E-06	1.00	2.55E-06	4	100	100	350

TABLE III-A-17 (Continued)

01/14/74

-----ADULT DOSE FACTORS-----									
ISOTOPE	-----INGESTION-----				-----SMOKE LINE-----		-----SWIMMING-----		
	BOOY	GI-LLI	THYROID	BONE	SKIN	BOOY	SKIN	BOOY	
1 H-3	1.27E-07	0.40E-05	1.27E-07	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	
11 C-14	2.67E-07	0.69E-07	1.59E-07	.00E+00	2.60E-10	2.20E-10	0.40E-08	5.20E-08	
12 MN-54	0.65E-07	1.30E-05	.00E+00	.00E+00	6.60E-09	5.80E-09	1.80E-06	1.50E-06	
14 C-14	1.48E-07	0.41E-07	.00E+00	0.78E-07	.00E+00	.00E+00	3.60E-10	0.40E-11	
15 Fe-59	3.60E-06	3.31E-05	.00E+00	4.12E-06	9.40E-09	8.00E-09	2.60E-06	2.20E-06	
17 Co-58	1.68E-06	1.52E-05	.00E+00	.00E+00	8.20E-09	7.00E-09	2.30E-06	1.80E-06	
18 Co-60	4.70E-06	3.94E-05	.00E+00	.00E+00	2.00E-06	1.70E-06	5.40E-06	4.60E-06	
25 Rn-82	2.34E-06	2.53E-06	.00E+00	.00E+00	2.20E-08	1.90E-08	6.30E-06	5.30E-06	
26 Rn-83+D	3.87E-06	5.01E-06	.00E+00	.00E+00	9.30E-11	6.40E-11	3.10E-07	1.70E-08	
27 Rn-84	5.26E-06	4.15E-13	.00E+00	.00E+00	1.40E-08	1.20E-08	5.30E-06	3.50E-06	
34 Rn-86	1.00E-05	4.27E-06	.00E+00	.00E+00	7.20E-10	6.30E-10	8.50E-07	1.70E-07	
35 Rn-88	3.26E-05	.00E+00	.00E+00	.00E+00	4.00E-09	3.50E-09	3.60E-06	1.20E-06	
36 Rn-89	2.86E-05	.00E+00	.00E+00	.00E+00	1.80E-08	1.50E-08	5.80E-06	4.50E-06	
37 Sr-89	9.13E-06	4.98E-05	.00E+00	3.20E-04	6.50E-13	5.60E-13	5.40E-07	4.60E-09	
38 Sr-90	0.95E-05	1.23E-04	.00E+00	3.36E-04	.00E+00	.00E+00	1.50E-07	5.40E-10	
39 Sr-90D	2.65E-10	1.05E-04	.00E+00	9.86E-09	.00E+00	.00E+00	9.60E-07	1.30E-08	
40 Sr-91	2.43E-07	2.07E-05	.00E+00	5.82E-06	8.30E-09	7.10E-09	2.90E-06	1.90E-06	
41 Sr-92	9.35E-08	4.31E-05	.00E+00	2.16E-06	1.00E-08	9.00E-09	3.10E-06	2.60E-06	
42 Y-90	2.65E-10	1.05E-04	.00E+00	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-08	
43 Y-91	3.48E-12	2.91E-10	.00E+00	8.89E-11	4.40E-09	3.80E-09	1.20E-06	1.00E-06	
44 Y-91	3.60E-09	7.50E-05	.00E+00	1.36E-07	2.70E-11	2.40E-11	5.70E-07	6.70E-09	
45 Y-92	2.50E-11	1.49E-05	.00E+00	0.57E-10	1.90E-09	1.60E-09	2.00E-06	4.50E-07	
46 Y-93	5.53E-11	0.31E-05	.00E+00	1.98E-09	7.80E-10	5.70E-10	1.40E-06	1.90E-07	
47 Zr-95	6.34E-09	2.93E-05	.00E+00	2.70E-08	5.80E-09	5.00E-09	1.80E-06	1.50E-06	
48 Zr-95D	1.41E-09	2.03E-05	.00E+00	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06	
49 Zr-97	1.59E-10	1.07E-04	.00E+00	1.69E-09	0.40E-09	5.50E-09	2.40E-06	1.50E-06	
50 Zr-97D	4.70E-12	4.09E-08	.00E+00	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06	
51 Nb-95	1.81E-09	2.03E-05	.00E+00	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06	
52 Nb-97	4.70E-12	4.09E-08	.00E+00	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06	
53 Mo-99+D	7.92E-07	9.65E-06	.00E+00	.00E+00	2.20E-09	1.90E-09	9.10E-07	4.70E-07	
54 Mo-99D	2.01E-08	2.00E-06	.00E+00	1.77E-09	9.50E-10	8.30E-10	2.40E-07	2.10E-07	
55 Tc-99M	2.01E-06	2.00E-06	.00E+00	1.77E-09	1.10E-09	9.60E-10	2.70E-07	2.40E-07	
58 Ru-103+D	7.87E-06	2.09E-05	.00E+00	1.72E-07	4.20E-09	3.60E-09	1.10E-06	8.90E-07	
59 Ru-103+D	6.03E-09	9.19E-06	.00E+00	1.49E-08	5.10E-09	4.50E-09	1.80E-06	1.20E-06	
60 Ru-106+D	3.56E-07	1.01E-04	.00E+00	2.79E-06	1.80E-09	1.50E-09	1.90E-06	3.60E-07	
61 Rh-105	5.82E-06	1.36E-05	.00E+00	1.15E-07	7.70E-10	6.60E-10	3.00E-07	1.70E-07	
62 Pd-109+D	4.16E-06	2.05E-05	.00E+00	.00E+00	4.00E-11	3.50E-11	3.40E-07	9.30E-09	
64 Ag-111	1.21E-08	4.34E-05	.00E+00	5.74E-08	2.10E-10	1.80E-10	3.80E-07	4.80E-08	
68 Sb-127	1.18E-07	0.54E-05	4.07E-09	3.57E-07	6.60E-09	5.70E-09	1.80E-06	1.50E-06	
69 Te-125M	3.49E-07	1.05E-05	7.94E-07	2.72E-06	4.20E-11	3.50E-11	1.50E-08	3.60E-09	

TABLE III-A-17 (Continued)

70 TE-127M	7.62E-07	2.10E-05	1.01E-06	6.40E-06	1.30E-12	1.10E-12	1.80E-09	2.60E-10
71 TE-127	2.21E-06	5.13E-06	7.53E-06	1.03E-07	1.10E-11	1.00E-11	1.70E-07	2.80E-09
72 TE-129M+D	1.77E-06	5.79E-05	4.50E-06	1.17E-05	9.00E-10	7.70E-10	7.40E-07	2.10E-07
73 TE-129	7.61E-09	2.12E-06	2.40E-08	3.13E-08	8.40E-10	7.10E-10	7.00E-07	1.90E-07
74 TE-131M	4.71E-07	3.64E-05	6.92E-07	6.02E-07	9.90E-09	6.40E-09	2.70E-06	2.20E-06
75 TE-131	6.25E-09	3.58E-14	1.63E-08	1.95E-08	2.60E-09	2.20E-09	1.60E-06	7.40E-07
76 TE-132	1.54E-06	7.79E-05	1.62E-06	2.56E-06	2.00E-09	1.70E-09	4.80E-07	4.00E-07
77 TE-132D	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
78 TE-133M+D	2.35E-06	1.45E-09	3.52E-08	4.04E-08	1.70E-08	1.50E-08	5.00E-06	3.90E-06
79 TE-134	2.20E-06	4.40E-09	2.85E-08	3.25E-08	1.20E-09	1.00E-09	3.50E-07	2.50E-07
81 I-130	8.77E-07	1.69E-05	2.80E-04	7.44E-07	1.70E-08	1.40E-08	4.80E-06	3.90E-06
82 I-131	3.37E-06	1.53E-06	1.86E-03	3.93E-06	3.40E-09	2.80E-09	9.30E-07	6.80E-07
83 I-132	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
84 I-133	7.62E-07	2.25E-06	4.82E-04	1.43E-06	4.50E-09	3.70E-09	1.50E-06	9.60E-07
85 I-134	1.02E-07	2.25E-10	3.73E-05	1.07E-07	1.90E-08	1.60E-08	5.50E-06	4.20E-06
86 I-135	4.50E-07	1.41E-06	1.76E-04	5.01E-07	1.40E-08	1.20E-08	4.00E-06	3.30E-06
94 CS-134M	2.43E-06	1.63E-05	.00E+00	2.25E-08	7.30E-10	6.20E-10	1.90E-07	1.60E-07
95 CS-134	1.00E-04	2.56E-06	.00E+00	5.29E-05	1.40E-08	1.20E-08	3.50E-06	2.90E-06
97 CS-136	1.81E-05	2.66E-06	.00E+00	6.24E-06	1.70E-08	1.50E-08	4.80E-06	4.10E-06
98 CS-137	5.60E-05	2.05E-06	.00E+00	6.37E-05	4.90E-09	4.20E-09	1.40E-06	1.00E-06
99 CS-138	5.49E-08	4.69E-13	.00E+00	5.66E-08	2.40E-08	2.10E-08	5.70E-06	4.00E-06
100 CS-139	1.97E-08	3.54E-30	.00E+00	3.18E-08	7.20E-09	6.30E-09	3.20E-06	1.70E-06
101 HA-139	2.88E-09	1.68E-07	.00E+00	9.85E-08	2.70E-09	2.40E-09	1.00E-06	7.70E-06
102 HA-140	1.33E-06	4.02E-05	.00E+00	2.02E-05	2.40E-09	2.10E-09	7.50E-07	4.90E-07
103 HA-140D	3.34E-10	9.32E-05	.00E+00	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
106 LA-140	3.34E-10	9.32E-05	.00E+00	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
107 LA-141	2.03E-11	1.24E-05	.00E+00	3.90E-10	2.80E-10	2.50E-10	1.00E-06	5.10E-08
108 LA-142	1.44E-11	4.10E-07	.00E+00	1.29E-10	1.80E-08	1.50E-08	5.90E-06	4.50E-06
109 CE-141	6.88E-10	2.28E-05	.00E+00	8.83E-09	6.20E-10	5.50E-10	2.40E-07	1.30E-07
110 CE-143	1.33E-10	4.39E-05	.00E+00	1.60E-09	2.50E-09	2.20E-09	1.00E-06	5.70E-07
111 CE-144+D	1.98E-06	1.69E-04	.00E+00	3.27E-07	3.70E-10	3.20E-10	1.40E-06	8.60E-08
112 PR-143	4.39E-10	3.66E-05	.00E+00	8.96E-09	.00E+00	.00E+00	2.80E-07	1.60E-09
114 NU-147	4.03E-10	3.34E-05	.00E+00	5.43E-09	1.20E-09	1.00E-09	5.00E-07	2.80E-07
115 PM-147	1.22E-09	7.93E-06	.00E+00	2.36E-08	.00E+00	.00E+00	1.30E-08	7.50E-11
116 PM-148	6.11E-10	9.43E-05	.00E+00	7.29E-09	5.30E-09	4.60E-09	2.00E-06	1.10E-06
117 PM-149	8.64E-11	4.00E-05	.00E+00	1.50E-09	2.90E-11	2.50E-11	3.50E-07	1.50E-08
118 PM-151	6.06E-11	3.35E-05	.00E+00	7.23E-10	2.30E-09	2.20E-09	8.40E-07	5.00E-07
119 SM-153	5.98E-11	2.86E-05	.00E+00	9.86E-10	3.00E-10	2.70E-10	2.50E-07	6.50E-08
120 EU-156	1.69E-09	7.24E-05	.00E+00	1.36E-08	8.70E-09	7.60E-09	2.80E-06	2.10E-06
124 U-237	1.47E-10	1.94E-05	.00E+00	5.53E-10	1.30E-09	1.00E-09	3.40E-07	2.60E-07
125 NP-238	2.11E-10	3.43E-05	.00E+00	4.27E-09	3.20E-09	2.80E-09	1.10E-06	7.70E-07
126 NP-239	6.46E-11	2.40E-05	.00E+00	1.20E-09	1.10E-09	9.50E-10	3.70E-07	2.40E-07
130 PU-241+D	4.21E-10	6.78E-07	.00E+00	1.44E-08	6.80E-12	4.60E-12	9.50E-11	6.10E-11

TABLE III-A-17 (Continued)

CASE 1:

SAMPLE AMRG RUN

01/14/74

ISOTOPES CONTRIBUTING AT LEAST 4% TO DOSE

	--T O T A L B O D Y--			--G I - L L I--			--T H Y R O I D--			--B O N E--		
FISH	CS-134	1.00E-02	64%	H-3	5.22E-05	5%	I-131	5.58E-02	87%	CS-134	5.58E-03	47%
	CS-137	5.12E-03	31%	TE-129M+	9.07E-05	6%	I-133	5.68E-03	12%	CS-137	5.62E-03	49%
				TE-132	5.75E-04	38%						
				CS-134	2.70E-04	18%						
				CS-135	6.97E-05	5%						
				CS-137	1.87E-04	12%						
TOTALS	BODY	1.54E-02		GI-LLI	1.51E-03		THYROID	7.56E-02		BONE	1.18E-02	
DRINKING WATER	H-3	7.72E-03	91%	H-3	3.89E-03	88%	I-131	1.87E-01	85%	I-131	3.94E-04	54%
	I-131	3.38E-04	4%				I-133	2.52E-02	11%	I-133	7.48E-05	10%
										CS-134	1.19E-04	16%
										CS-137	1.24E-04	17%
TOTALS	BODY	6.45E-03		GI-LLI	4.42E-03		THYROID	2.20E-01		BONE	7.29E-04	
SHORELINE	CS-134	4.07E-04	29%	CS-134	3.49E-04	29%						
	CS-137	9.04E-04	64%	CS-137	7.74E-04	64%						
TOTALS	SKIN	1.40E-03		BODY	1.20E-03							
SWIMMING	I-131	1.36E-04	26%	I-131	9.92E-05	27%						
	I-132	2.12E-05	4%	I-132	1.89E-05	5%						
	I-133	1.99E-04	39%	I-133	1.28E-04	35%						
	I-135	1.03E-04	20%	I-135	8.46E-05	23%						
TOTALS	SKIN	5.15E-04		BODY	3.68E-04							
BOATING	SAME AS SWIMMING											
TOTALS	SKIN	2.57E-04		BODY	1.84E-04							

III-A-51

TABLE III-A-17 (Continued)

CASE 1: SAMPLE AKRRG RUN

01/14/74

	HOLDUP TIME HOURS	USAGE PER YR	MIXING RATIO
FISH	24	33.6	.03
DRINKING WATER	24	1430	.03
SHORELINE	5	106	.14
SWIMMING	5	416	.14
BOATING	5	416	.14

PLANT LIFE= 30 YEARS SHORE WIDTH FACTOR= .5

RECONCENTRATION FORMULA NUMBER 3

COOLANT FLOW TO PLANT = 790 CUBIC FEET/SEC = 7.06E+11 LITERS/YEAR

III-A-52

	-----DOSE TO INDIVIDUAL, MREM/YEAR-----				
	SKIN	BODY	GI-LLI	THYROID	BONE
FISH		1.64E-02	1.51E-03	7.56E-02	1.18E-02
DRINKING WATER		8.45E-03	4.42E-03	2.20E-01	7.29E-04
SHORELINE	1.40E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03
SWIMMING	5.15E-04	3.68E-04	3.68E-04	3.68E-04	3.68E-04
BOATING	2.57E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04
TOTALS	2.18E-03	2.66E-02	7.69E-03	2.97E-01	1.43E-02

TABLE III-A-17 (Continued)

SUBJECT: N.Y. OF ...

PIRES: PEA

CASE 1: SAMPLE AHHHG RUN

AHHHG ** AHHHG ** AHHHG ** AHHHG ** AHHHG

01/14/74

12:54

AHHHG ** AHHHG ** AHHHG ** AHHHG ** AHHHG

III-A-53

MAIL TO: NM ROBINSON, 3717 BLDG, 300 AREA, RICHLAND, WASHINGTON 99352

Program output at the user's terminal consists of internal dose to all four primary organisms of the selected organ radius, internal dose to the selected secondary organisms, optional percentage contribution to internal dose by nuclide for each selected primary and secondary organism, and an optional table of release rates and concentrations of radio-nuclides in the liquid effluent by isotope. CRITR produces no high-speed printer output.

CRITR obtains its input from three sources:

- (1) The reactor coolant flow, reconcentration parameters, holdup, mixing ratio and information characterizing each organism are entered by the user at the time of the run. Section III-A.7.5 discusses the choice of parameters to use for the reconcentration factor and mixing ratios. The standard input we use for the other parameters in absence of information specific to the site is given in Table III-A-9.
- (2) The reactor release rate file REL is shared by ARRRG and CRITR. The discussion of REL in Section III-A.7.2 also applies to CRITR.
- (3) The file ARGIN is also shared by ARRRG and CRITR, and the discussion of ARGIN in Section III-A.7.2 also applies to CRITR. The file CRITEN Table III-A-18 contains a tabulation by nuclide of effective energy per disintegration for seven critter^(a) radii between 1.4 cm and 20 cm and for the total body of man.

Table III-A-19 shows teletype printout for a typical run, with user input indicated by wavy underlines. The reactor name determines which set of releases from REL will be accessed by the program. A title is entered to identify the teletype printout, but is not otherwise used by the

(a) In CRITR jargon, "critter" means "organism."

TABLE III-A-18

FILE CRITEN

1 FILE FOR CRITEN ENERGIES (MEV)	FOR VARIOUS EFFECTIVE RADII OF MUSCLE							
2 ISO	1.4 CM	2 CM	3 CM	5 CM	7 CM	10 CM	20 CM	MAN
10 H-3	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.01
20 C-14	.05	.05	.05	.05	.05	.05	.05	.05
30 N-13	.538	.557	.587	.646	.701	.777	.983	1.13
40 F-18	.285	.304	.334	.391	.444	.518	.717	.861
50 NA-22	.286	.325	.387	.507	.619	.775	1.20	1.51
60 NA-24	.712	.771	.868	1.05	1.23	1.48	2.19	2.74
70 P-32	.695	.695	.695	.695	.695	.695	.695	.695
80 AK-39	.194	.194	.194	.194	.194	.194	.194	.194
90 AK-41	.519	.541	.576	.642	.705	.793	1.04	1.22
100 SC-46	.197	.232	.290	.399	.501	.644	1.03	1.32
110 CH-51	.00222	.00276	.00363	.00529	.00685	.00901	.0149	.0191
120 MN-54	.0364	.0514	.0758	.122	.166	.227	.392	.512
130 MN-56	.875	.904	.951	1.04	1.13	1.24	1.57	1.82
140 FE-55	.00726	.00726	.00726	.00726	.00726	.00726	.00726	.00726
150 FE-59	.171	.191	.224	.286	.346	.428	.655	.824
160 CO-57	.0390	.0409	.0439	.0496	.0550	.0626	.0840	.100
170 CO-58	.0728	.0905	.119	.174	.226	.297	.492	.633
180 CO-60	.195	.237	.306	.437	.560	.732	1.21	1.56
190 NI-63	.0176	.0176	.0176	.0176	.0176	.0176	.0176	.0176
200 NI-65	.641	.651	.666	.695	.723	.762	.869	.949
210 CU-64	.133	.137	.143	.154	.165	.180	.220	.249
220 ZN-65	.0289	.0366	.0544	.0846	.113	.153	.261	.342
230 ZN-69M+D	.0400	.0477	.0603	.0842	.107	.138	.221	.282
240 ZN-69	.32	.32	.32	.32	.32	.32	.32	.32
250 BR-82	.248	.294	.368	.510	.643	.828	1.33	1.70
260 BR-83+D	.363	.363	.364	.364	.364	.365	.366	.367
270 BR-84	1.31	1.34	1.39	1.47	1.56	1.67	2.00	2.25
280 BR-85	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
290 KR-83M	.0438	.0438	.0438	.0438	.0438	.0438	.0438	.0438
300 KR-85M	.245	.248	.252	.260	.268	.279	.309	.331
310 KR-85	.224	.224	.224	.224	.224	.225	.225	.225
320 KR-87	1.21	1.24	1.27	1.34	1.41	1.50	1.77	1.97
330 KR-88	.449	.475	.517	.599	.677	.786	1.09	1.33
340 RB-86	.666	.666	.671	.676	.680	.687	.705	.719
350 RB-88	2.15	2.16	2.18	2.21	2.24	2.28	2.40	2.49
360 RB-89	.694	.733	.797	.919	1.03	1.20	1.64	1.98
370 SR-89	.564	.564	.564	.564	.564	.564	.564	.564
380 SR-90	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
390 SR-90D	.939	.939	.939	.939	.939	.939	.939	.939
400 SR-91	.702	.721	.752	.812	.867	.944	1.15	1.31
410 SR-92	.249	.272	.310	.381	.449	.543	.805	1.00
420 Y-90	.939	.939	.939	.939	.939	.939	.939	.939
430 Y-91M	.0518	.0615	.0773	.107	.135	.174	.280	.355
440 Y-91	.590	.590	.591	.591	.591	.591	.592	.592
450 Y-92	1.47	1.47	1.48	1.49	1.51	1.52	1.57	1.61
460 Y-93	1.18	1.18	1.18	1.19	1.19	1.20	1.22	1.23
470 ZR-95	.227	.254	.297	.380	.458	.565	.857	1.07
480 ZR-95D	.0767	.0906	.113	.156	.197	.253	.405	.515
490 ZR-97	.763	.778	.802	.848	.891	.951	1.11	1.23
500 ZR-97D	.500	.512	.532	.570	.606	.656	.790	.887
510 NB-95	.0767	.0906	.113	.156	.197	.253	.405	.515
520 NB-97	.500	.512	.532	.570	.606	.656	.790	.887
530 MO-99+D	.419	.423	.430	.444	.457	.475	.524	.561
540 MO-99D	.084	.084	.084	.084	.084	.084	.084	.084
550 TC-99M	.132	.134	.138	.144	.150	.158	.181	.199
560 TC-99	.084	.084	.084	.084	.084	.084	.084	.084
570 TC-101	.485	.492	.503	.524	.543	.570	.643	.697
580 RU-103+D	.116	.125	.140	.168	.194	.230	.328	.399
590 RU-105+D	.496	.508	.527	.563	.597	.644	.772	.865
600 RU-106+D	1.44	1.44	1.45	1.46	1.47	1.49	1.53	1.56
610 RM-105	.158	.159	.162	.167	.172	.179	.198	.212
620 PO-109+D	.389	.389	.389	.389	.389	.390	.390	.391
630 AG-110M+D	.188	.235	.311	.456	.593	.782	1.30	1.68
640 AG-111	.361	.362	.362	.364	.365	.367	.372	.376
650 SN-125	.906	.907	.910	.914	.919	.925	.942	.954
660 SB-124	.459	.491	.544	.644	.739	.871	1.24	1.51

TABLE III-A-18 (Continued)

670 SB-125	.105	.113	.126	.150	.173	.205	.291	.353
680 SB-127	.433	.448	.472	.518	.561	.620	.782	.899
690 TE-125M	.111	.111	.112	.112	.112	.113	.113	.114
700 TE-127M	.00197	.00197	.00197	.00198	.00199	.00200	.00203	.00205
710 TE-127	.223	.223	.223	.223	.223	.224	.224	.224
720 TE-129M+D	.599	.601	.605	.612	.619	.627	.651	.667
730 TE-129	.535	.538	.541	.548	.555	.563	.585	.601
740 TE-131M	.269	.291	.327	.396	.460	.550	.796	.978
750 TE-131	.786	.791	.800	.817	.833	.855	.916	.961
760 TE-132	.121	.125	.131	.143	.154	.169	.211	.242
770 TE-132D	.581	.624	.693	.826	.950	1.12	1.59	1.94
780 TE-133M+D	.502	.542	.605	.726	.840	.998	1.43	1.74
790 TE-134	.114	.117	.122	.130	.138	.148	.175	.194
800 I-129	.0474	.0475	.0476	.0478	.0479	.0481	.0485	.0487
810 I-130	.388	.427	.490	.611	.724	.881	1.31	1.61
820 I-131	.206	.213	.224	.245	.266	.293	.368	.422
830 I-132	.581	.624	.693	.826	.950	1.12	1.59	1.94
840 I-133	.467	.478	.497	.533	.566	.613	.738	.829
850 I-134	.779	.838	.934	1.12	1.29	1.53	2.19	2.67
860 I-135	.481	.514	.566	.667	.761	.893	1.26	1.53
870 XE-131M	.136	.136	.136	.137	.137	.137	.138	.139
880 XE-133M	.176	.177	.178	.180	.182	.184	.191	.196
890 XE-133	.137	.137	.138	.140	.141	.143	.148	.152
900 XE-135M	.118	.126	.139	.163	.186	.217	.302	.363
910 XE-135	.330	.335	.342	.355	.368	.386	.434	.469
920 XE-137	1.68	1.68	1.68	1.69	1.70	1.71	1.74	1.76
930 XE-138	.505	.527	.562	.630	.694	.784	1.04	1.23
940 CS-134M	.0483	.0496	.0517	.0558	.0597	.0652	.0805	.0922
950 CS-134	.230	.259	.306	.396	.480	.596	.913	1.14
960 CS-135	.058	.058	.058	.058	.058	.058	.058	.058
970 CS-136	.233	.273	.337	.458	.573	.732	1.17	1.49
980 CS-137	.257	.267	.284	.316	.346	.388	.500	.582
990 CS-138	1.18	1.22	1.27	1.38	1.48	1.62	2.02	2.32
1000 CS-139	1.61	1.61	1.62	1.64	1.66	1.68	1.75	1.79
1010 BA-139	.927	.927	.929	.931	.933	.936	.944	.950
1020 BA-140	.315	.320	.328	.343	.357	.376	.428	.465
1030 BA-140D	.698	.734	.793	.907	1.01	1.16	1.58	1.89
1040 BA-141	1.10	1.11	1.12	1.16	1.19	1.23	1.36	1.44
1050 BA-142	.601	.622	.650	.722	.783	.869	1.10	1.28
1060 LA-140	.698	.734	.793	.907	1.01	1.16	1.58	1.89
1070 LA-141	.966	.967	.967	.969	.970	.972	.977	.981
1080 LA-142	.937	.973	1.03	1.14	1.25	1.40	1.82	2.14
1090 CE-141	.173	.174	.175	.179	.182	.187	.199	.209
1100 CE-143	.420	.426	.435	.453	.470	.493	.555	.601
1110 CE-144+D	1.32	1.32	1.32	1.33	1.33	1.33	1.34	1.35
1120 PR-143	.314	.314	.314	.314	.314	.314	.314	.314
1130 PR-144	1.23	1.23	1.23	1.24	1.24	1.24	1.24	1.25
1140 ND-147	.257	.259	.264	.272	.280	.291	.320	.342
1150 PM-147	.0620	.0620	.0620	.0620	.0620	.0620	.0620	.0620
1160 PM-148	.727	.737	.755	.788	.819	.862	.982	1.07
1170 PM-149	.366	.367	.367	.367	.368	.368	.370	.371
1180 PM-151	.327	.332	.340	.356	.370	.390	.445	.484
1190 SM-153	.270	.271	.272	.273	.275	.277	.283	.288
1200 EU-156	.471	.490	.521	.580	.636	.714	.930	1.09
1210 W-181	.00316	.00316	.00317	.00318	.00320	.00322	.00327	.00331
1220 W-185	.144	.144	.144	.144	.144	.144	.144	.144
1230 W-187	.331	.339	.353	.379	.403	.437	.529	.595
1240 U-237	.142	.146	.151	.158	.165	.174	.200	.223
1250 NP-238	.263	.270	.282	.306	.327	.357	.440	.513
1260 NP-239	.203	.205	.208	.212	.217	.223	.240	.260
1270 PU-238	5.51	5.51	5.51	5.51	5.51	5.51	5.51	55.0
1280 PU-239	5.15	5.15	5.15	5.15	5.15	5.15	5.15	51.5
1290 PU-240	5.16	5.16	5.16	5.16	5.16	5.16	5.16	51.6
1300 PU241+D	.00535	.00535	.00535	.00535	.00535	.00535	.00535	.00636
1310 PU-242	4.90	4.90	4.90	4.90	4.90	4.90	4.90	48.9
1320 AM-241	5.51	5.51	5.51	5.52	5.52	5.52	5.52	54.8
1330 AM-243+D	5.28	5.28	5.28	5.29	5.29	5.29	5.30	52.7
1340 CM-242	6.11	6.11	6.11	6.11	6.11	6.11	6.11	61.1
1350 CM-244	5.80	5.80	5.80	5.80	5.80	5.80	5.80	58.0
1360 CF-252	12.2	12.2	12.2	12.2	12.2	12.2	12.2	165.

TABLE III-A-19

TELETYPE PRINTOUT FOR SAMPLE CRITR RUN

RUN CRITR

CRITR 13:30 01/14/74

REACTOR NAME? PIKES PEAK

TITLE? SAMPLE CRITR RUN

ENTER COOLING FLOW IN CFS? 800
WHICH RECONCENTRATION FORMULA? 3

FOR PRIMARY CRITTER * * * *

ENTER HOLDUP TIME IN HOURS & MIXING RATIO? 0 1
ENTER CRITTER RADIUS IN CM. 72

PIKES PEAK FLOW= 800 CONSTANT RECONC=1

HOLDUP= 0 MIXING RATIO= 1 RADIUS= 2

CONSTANTS OK? YES

FISH INTERNAL DOSE = 4.5 MRAD/YR

CRUSTACEA INTERNAL DOSE = 1.84 MRAD/YR

MOLLUSC INTERNAL DOSE = 1.84 MRAD/YR

ALGAE INTERNAL DOSE = 7.17 MRAD/YR

FOR SECONDARY CRITTER * * * *

NAME OF CRITTER? HERON
ENTER HOLDUP TIME IN HOURS & MIXING RATIO? 0 1
ENTER CRITTER RADIUS IN CM. 77
ENTER FOOD TYPE? FISH
ENTER FOOD INTAKE RATE IN GRAMS/DAY? 600
ENTER CRITTER MASS IN KG? 4.6

HOLDUP = 0 MIXING RATIO = 1

FOOD TYPE = FISH INTAKE RATE = 600

RADIUS= 7 MASS= 4.6 CONSTANTS OK? Y

INTERNAL DOSE FOR HERON = 25.6827 MRAD/YR

ANOTHER SECONDARY CRITTER? N

PERCENTAGES? Y

MINIMUM 275

* * * CONTRIBUTIONS TO CRITTER DOSE > 5 % * * *

ISOTOPE T	RELEASE CI/YR	RECONC. FACTOR	CUNC. PCI/L	RI/ACCUM. FACTOR	BODY BUR. PCI/KG	DOSE MRAD/YR	PERCENT
FISH							
RB-88	2.10E-02	1.00	2.9E-02	2000	5.9E+01	2.4E+00	52.7
I-133	1.90E+00	1.00	2.7E+00	15	4.0E+01	3.6E-01	7.9
CS-134	3.70E-02	1.00	5.2E-02	2000	1.0E+02	5.0E-01	11.1
CS-137	3.20E-02	1.00	4.5E-02	2000	9.0E+01	4.5E-01	9.9
CRUSTACEA							
H-3	1.00E+03	1.00	1.4E+03	1	1.3E+03	1.4E-01	7.4
RB-88	2.10E-02	1.00	2.9E-02	1000	2.9E+01	1.2E+00	64.5
I-133	1.90E+00	1.00	2.7E+00	5	1.3E+01	1.2E-01	6.5
MOLLUSC							
H-3	1.00E+03	1.00	1.4E+03	1	1.3E+03	1.4E-01	7.4
RB-88	2.10E-02	1.00	2.9E-02	1000	2.9E+01	1.2E+00	64.5
I-133	1.90E+00	1.00	2.7E+00	5	1.3E+01	1.2E-01	6.5
ALGAE							
RB-88	2.10E-02	1.00	2.9E-02	1000	2.9E+01	1.2E+00	16.5
MW-99+D	2.60E-01	1.00	3.6E-01	1000	3.6E+02	2.9E+00	40.1
MW-99D	2.30E-01	1.00	3.2E-01	1000	3.2E+02	5.1E-01	7.0
I-131	1.80E+00	1.00	2.5E+00	40	1.0E+02	4.0E-01	5.6
I-133	1.90E+00	1.00	2.7E+00	40	1.1E+02	9.5E-01	13.3
HERON							
CS-134	3.70E-02	1.00	5.2E-02	2000	1.6E+03	1.4E+01	56.4
CS-137	3.20E-02	1.00	4.5E-02	2000	1.5E+03	9.9E+00	38.6

TABLE III-A-19 (Continued)

DO YOU WANT TOTAL LIST OF RELEASES?Y

ISOTOPE	RELEASE CI/YR	CONCENTRATION PCI/LITER
H-3	1.00E+03	1.40E+03
CR-51	5.70E-04	7.97E-04
MN-54	6.10E-04	8.53E-04
FE-55	1.30E-03	1.82E-03
FE-59	6.60E-04	9.23E-04
CU-58	6.90E-03	9.65E-03
CU-60	5.60E-04	7.83E-04
RP-82	9.60E-04	1.34E-03
RR-83+D	3.40E-03	4.76E-03
RR-84	4.90E-05	6.85E-05
RR-86	6.20E-05	8.67E-05
RR-88	2.10E-02	2.94E-02
RR-89	1.10E-05	1.54E-05
SR-89	3.60E-04	5.04E-04
SR-90	1.30E-05	1.82E-05
SR-90D	1.30E-05	1.82E-05
SR-91	2.40E-04	3.36E-04
SR-92	1.10E-05	1.54E-05
Y-90	1.90E-05	2.66E-05
Y-91M	1.50E-04	2.10E-04
Y-91	3.40E-03	4.76E-03
Y-92	4.10E-05	5.73E-05
Y-93	4.30E-05	6.01E-05
ZR-95	6.00E-05	8.39E-05
ZR-95D	6.00E-05	8.39E-05
ZR-97	1.70E-05	2.38E-05
ZR-97D	1.70E-05	2.38E-05
NR-95	6.30E-05	8.61E-05
NR-97	1.80E-05	2.52E-05
MU-99+D	2.60E-01	3.64E-01
MU-99D	2.30E-01	3.20E-01
TC-99M	2.10E-01	2.94E-01
RU-103+D	4.00E-05	5.59E-05
RU-105+D	5.80E-06	8.11E-06
RU-106+D	1.30E-05	1.82E-05
RH-105	1.50E-05	2.10E-05
PD-109+D	1.40E-06	1.96E-06
AG-111	7.00E-07	9.79E-07
SR-127	1.40E-06	1.96E-06
TE-125M	3.30E-05	4.62E-05
TE-127M	2.90E-04	4.06E-04
TE-127	2.90E-04	4.06E-04
TE-129M+D	2.80E-03	3.92E-03
TE-129	1.80E-03	2.52E-03
TE-131M	1.20E-03	1.68E-03
TE-131	2.40E-04	3.36E-04
TE-132	1.60E-02	2.24E-02
TE-132D	1.60E-02	2.24E-02
TE-133M+D	7.80E-06	1.09E-05
TE-134	6.30E-06	8.61E-06
I-130	6.20E-03	8.67E-03
I-131	1.80E+00	2.52E+00
I-132	2.10E-01	2.94E-01
I-133	1.90E+00	2.66E+00
I-134	2.00E-03	2.80E-03
I-135	5.20E-01	7.27E-01
CS-134M	1.40E-05	1.96E-05
CS-134	3.70E-02	5.18E-02
CS-136	9.00E-03	1.26E-02
CS-137	3.20E-02	4.48E-02
CS-138	1.50E-04	2.10E-04
CS-139	5.10E-06	7.13E-06
BA-139	1.50E-04	2.10E-04
RA-140	3.30E-04	4.62E-04
RA-140D	3.30E-04	4.62E-04
LA-140	2.00E-04	2.80E-04
LA-141	3.30E-05	4.62E-05
LA-142	7.10E-07	9.93E-07
CE-141	6.00E-05	8.39E-05
CE-143	2.50E-05	3.50E-05
CE-144+D	5.10E-05	7.13E-05
PR-143	4.40E-05	6.15E-05
ND-147	1.80E-05	2.52E-05
PM-147	2.90E-06	4.06E-06
PM-148	6.50E-06	9.09E-06
PM-149	8.80E-06	1.23E-05
PM-151	2.50E-06	3.50E-06
SM-153	4.60E-06	6.43E-06
EU-156	2.30E-06	3.22E-06
U-237	1.10E-05	1.54E-05
NP-238	2.40E-06	3.36E-06
NP-239	3.40E-04	4.76E-04
PU-241+D	1.80E-06	2.52E-06

DON'T FORGET EXTERNAL DOSES

THANK YOU ----- CALL AGAIN

NOW AT END
SRU'S:4.6
READY

program. Holdup time in hours, mixing ratio and effective critter radius in cm is then entered for the primary critter. The program summarizes the input for the user to check, and if the response to "constant OK?" is N or NO, the user is given a chance to re-enter the parameters. CRITR then calculates and prints the internal dose to the four primary organisms of the given radius: fish, crustacea, molluscs and algae.

Any name is allowed for the secondary critter. The holdup time, mixing ratio and the radius are entered. The tabulated radius in CRITEN closest to the user-specified radius is used to scale this dose factor to the size of the organism. The food type may be specified using any of the following names:

<u>Response to "food type?"</u>	<u>Organism Used for Dose Calculation</u>
fish	fish
crustacea, shellfish, lobsters	crustacea
molluscs, oysters, clams	molluscs
algae, plants	algae

The program examines only the first two letters of "food type" so the operator need not be concerned whether his response is singular or plural, or is a variant spelling. After entering the food intake rate and mass, the user is given a chance to examine and reject the parameters. CRITR uses the adult total-body ingestion dose factors to calculate internal doses, then calculates and prints the internal dose for the secondary critter.

By answering Y or YES to "another secondary critter?" the user may repeat the secondary critter portion of the calculation, up to a maximum of six secondary critters. At user option, a table of percent contribution to each internal dose by nuclide is printed, for each nuclide contributing at least a user-specified minimum percent. The release, recirculation factor, concentration, bioaccumulation factor, body burden, dose and percent contribution is printed for each nuclide. Also at user option, a list of releases and water concentrations is printed for all nuclides.

III-A.7.4 Program GRONK

GRONK (Gas Release of NuKlides) calculates annual dose resulting from radionuclide releases in gaseous effluents, using Equations 8 and 9. Skin and total-body dose to an individual and total-body dose to the population are calculated in 16 sectors and in up to 10 annular rings out to 50 miles from the point of release. An optional calculation is the thyroid dose via the inhalation, milk and leafy vegetable pathways at a user-specified set of ranges.

Meteorology is accepted in either the Pasquill or Hanford format. The user may specify the release height of the effluents, a plume rise constant, a building-wake correction and a meteorology height correction. If the optional thyroid dose calculation is selected, the user may specify a grazing period, vegetable consumption period and the vegetable consumption rate.

A detailed output is automatically sent to a high-speed printer. This output contains:

- the population table supplied by the user
- the meteorology tables supplied by the user
- the meteorology tables after any normalization is performed by the program
- the releases, decay constants and dose factors used by the program
- the percent contribution by nuclide to dose at the point of release (termed "at the stack" in the printout)
- a table of computed $\bar{x}/Q'$
- tables of skin and total-body dose to individual and total-body dose to population
- average dose to population in annular rings
- tables of thyroid dose if that option has been selected.

At the time of the run, the user may request that any combination of these tables also be printed at his conversational terminal.

GRONK obtains its data from three sources:

- (1) The user specifies at the time of the run the items indicated in Table III-A-20. Due to the large number of possible user options GRONK does not operate in a question-and-answer mode as do ARRRG and CRITR. Instead, at the beginning of the case the user enters letters representing his chosen options. If any of the selected options require user-specified parameters, GRONK will request only those parameters required.
- (2) A single file contains all the information necessary to characterize a facility for GRONK. This file is named Gxxxx, where xxxx stands for the first four letters of the facility name, and is the only file ever modified by the user of GRONK. The information for a given reactor is stored once in Gxxxx at the time the information is received from the applicant. The program automatically accesses the Gxxxx file indicated by the reactor name entered by the user at the time the run is made. Gxxxx contains the radionuclide release rates, population distribution out to 50 miles in 16 sectors and up to 10 annular rings, meteorological data in tables of joint frequency of occurrence of wind speed, direction and stability condition, and certain miscellaneous input. The stability classifications may be those of the Pasquill or Hanford model, or both models may be entered for use in separate runs. Detailed rules for the formation of file Gxxxx are given in Table III-A-21.
- (3) The 136 nuclide names, decay constants, total-body and skin dose factors, and thyroid dose factors required by GRONK are stored in the permanent file GIN. A table of Pasquill σ_z versus range by stability condition is stored in the permanent file TONIC

TABLE III-A-20

GRONK INPUT WORKSHEET

REACTOR NAME: _____

RELEASE LIST NAME: _____ (if more than one set of release rates)

COMMENTS: _____

MODEL: ☐ PASQUILL MODEL ☐ HANFORD MODEL

RELEASE HEIGHT: ☐ SAME AS PREVIOUS CASE (=0 if case #1) ☐ GROUND RELEASE ☐ ELEVATED RELEASE height= _____

EXTERNAL RANGES: ☐ BUILT-IN RANGES ☐ NEW RANGES (miles): _____ ☐ SAME AS PREVIOUS CASE

PLUME RISE: ☐ SAME AS PREVIOUS CASE (=0 if case #1) ☐ PLUME RISE CONSTANT= _____ meter²/second

WAKE FACTOR: ☐ USE BUILDING WAKE FACTOR

WIND SPEED: ☐ USE METEOROLOGY HEIGHT CORRECTION

THYROID: ☐ ALSO CALCULATE THYROID DOSES
 GRAZING PERIOD _____ month/year
 VEGETABLE CONSUMPTION PERIOD _____ month/year
 CHILD VEGETABLE CONSUMPTION _____ kiloqram/year
 ADULT VEGETABLE CONSUMPTION _____ kiloqram/year
 NEW RANGES (miles): _____ or same as external ranges ("escape" key)

ADD TABLES: ☐ ADD SUCCESSIVE CASES (Use for all except last case in group)

PRINTING TABLES AT TELETYPE:

- ☐ 0 Print population table at teletype
- ☐ 1 Print raw meteorology tables at teletype
- ☐ 2 Print derived meteorology tables at teletype
- ☐ 3 Print releases, decay constants and dose factors at teletype
- ☐ 4 Print percent by nuclide at teletype
- ☐ 5 Print X/Q table at teletype
- ☐ 6 Print individual skin dose table at teletype
- ☐ 7 Print individual total body dose table at teletype
- ☐ 8 Print population total body dose table at teletype
- ☐ 9 Print thyroid dose tables at teletype
- ☐ x Print average population dose table at teletype

For additional cases, fill out another sheet or list differences below:

FOR OPERATOR'S USE:

Option words: #1 _____ #2 _____ #3 _____ #4 _____ #5 _____

Final options: ☐ END RUN ☐ END RUN, THEN OFF ☐ END RUN, THEN RERUN GRONK FOR A NEW REACTOR

(Table III-A-22). In the past some applicants have specified nonstandard Pasquill conditions G and G+; here the σ_z for these conditions is to be 0.6 times the σ_z for condition F.

GRONK uses linear interpolation for ranges which fall between the tabulated ranges in TONIC.

Table III-A-23 shows the teletype printout for a typical run, with user input indicated by wavy underlines. A worksheet such as that in Table III-A-20 is essential in preparing the input and should be referred to during the following discussion of input to GRONK.

TABLE III-A-21

RULES FOR FORMATION FOR FILE GXXXX

Before running GRONK for a new facility, you must create a master file containing the permanent data GRONK will need for that facility. The file shall contain the following data in order.

1. The facility name optionally followed by comments, all on a single line. This line is printed as part of the heading on the first page and on the top of each result page. The total length of this line cannot exceed 72 characters.
2. For each release list:
 - a. The word RELEASE, followed by the release list title (enclose title in quotes if more than one word). These items are optional if there is only one release list.
 - b. The 136 releases for the facility in Ci/yr in the nuclide order given in Table III-A-14. Use as many lines as you need. Nuclides which are not released must be listed as zero, but the program accepts the shorthand notation rZ to represent r consecutive zero releases. (This notation is not allowed anywhere else in the file.)
3. The word RANGES.
4. The ranges in miles for which the data in the population table are tabulated. Up to ten ranges are allowed.
5. A blank line of at least one space.

6. A line containing:
 - a. The word POPULATION.
 - b. The date of the population table. If the date is not known, use two adjacent quotation marks. If more than one word is needed to characterize the date of the population table, enclose the words in quotation marks (example: "1970 seasonal").
 - c. The name of the sector direction which begins the population table (but see step 18).
7. The population table. Enter the numbers in the same order that GRONK prints them. Use as many lines as you need. The first sector direction must be the same one you specified in step 6, and the sectors must follow in clockwise order.
8. A line containing:
 - a. The name of the model (HANFORD or PASQUILL).
 - b. The number of sectors in the meteorology tables (only allowed value is 16).
 - c. The name of the sector direction which begins the meteorology tables (but see step 18).
 - d. The wind-sensor height in meters to use in the wind-speed correction formula. Enter zero if you do not know the height; this will cause building-wake correction requests to be ignored.
 - e. The building height in meters to use in the building-wake correction formula. Enter zero if you do not know the height; this will cause wind-speed correction requests to be ignored.
9. The average speed in mph for each column in the meteorology table. A maximum of ten speed categories are allowed.
10. A blank line of at least one space.
11. The column heading (maximum five characters each) to appear in the printout for each speed column of the meteorology table.

12. For each stability condition, the following information:

- a. An abbreviation for the name of the stability condition (quote marks required if more than one word).
- b. If the meteorology table is given in percent of all occurrences across all stability conditions, enter the number 100.

If the meteorology table is given in number of observations, enter the total number of observations for all conditions combined. If the total number of observations is not known, enter the number zero. The program will automatically sum and print the total number of observations, and you should then use this number to change Gxxxx before the next run. When zero is used, the "standard form" meteorology output is suppressed.

If the meteorology data for each stability condition table sums to 100%: enter the percentage of time that the given stability condition occurs.

- c. The percentage (or number) of times the wind direction is listed as variable for each speed interval; use zeroes if not listed. Each value will be distributed equally among all directions in its speed interval.
- d. The percentage (or number) of times the wind is listed as calm; use zero if not listed. This value will be distributed equally among all directions in the lowest speed interval.
- e. The meteorology table for the given stability condition. Enter the numbers in the same order that GRONK prints them. Use as many lines as you need. The first sector direction must be the same one you specified in step 8c, and the sectors must follow in clockwise order.^(a)

13. For the Hanford model, the stability conditions must be in the order: very stable, moderately stable, neutral and unstable. For the Pasquill model, the stability conditions must be in the order: A, B, C, D, E, F, G (optional), and G+ (optional).

- (a) The directions used by GRONK are the directions of the people receiving dose (the direction towards which the wind blows). Since meteorology tables received from applicants usually use the direction from which the winds originate, the sector data must be rotated 180° for use in GRONK.

Both Hanford and Pasquill model meteorology (steps 8 to 12) may be listed for the same reactor, but the Hanford model must be first.

14. (Optional) The word NOTES, followed by as many lines of descriptive comments as you require.
15. The name of the master file containing the data will be G + the first four letters of the reactor name. Example: The Aquirre reactor data is stored on file GAGUI.
16. Naming directions: Direction names in GRONK are the 16 primary compass directions (N, NNE, NE, ENE, etc.), and the 16 directions midway between them (N-NNE, NNE-NE, NE-ENE, etc.).
17. Naming sectors: All sectors are named for the direction of the center of the sector. Examples: if the sector boundaries are NW and NNW, the sector name is NW-NNW. If the sector boundaries are NE-ENE and ENE-E, the sector name is ENE.
18. Agreement Between Population and Meteorology Sectors
 - Any desired sector may be chosen to begin the meteorology tables;(a) that same starting sector must be used for every stability condition.
 - If the population sectors are offset one-half sector from the meteorology sectors, then for population dose computations the population is adjusted by averaging adjacent sectors. The sector chosen to begin the population table must be one of the two closest to the sector which begins the meteorology tables.
 - If there is no offset between population and meteorology sectors, then the same sector must begin the population and meteorology tables.

Example: if the first meteorology sector is N (S in meteorologist's terminology), allowed first population sectors are either NNW-N, N or N-NNE.

- (a) The directions used by GRONK are the directions of the people receiving dose (the directions towards which the wind blows). Since meteorology tables received from applicants usually use the direction from which the winds originate, the sector data must be rotated 180° for use in GRONK.

TABLE III-A-22

FILE TONIC

THE FILE TONIC IS A TABLE OF SIGMA-Z VERSUS RANGE USED BY GRONK. IT IS STORED IN INTERNAL FORMAT, HENCE IT CANNOT BE LISTED DIRECTLY. THE TABLE BELOW GIVES THE CONTENTS OF TONIC.

RANGE, METERS	PASQUILL A	PASQUILL B	PASQUILL C	PASQUILL D	PASQUILL E	PASQUILL F	PASQUILL G, G+
0	15.5	10.2	7.6	4.9	3.0	1.5	.9
100	15.5	10.2	7.6	4.9	3.0	1.5	.9
120	18.0	12.0	9.0	5.5	3.0	1.7	1.0
150	23.0	15.0	11.4	6.8	4.4	2.3	1.3
200	31.0	20.0	14.5	8.7	5.7	3.0	1.8
250	43.0	25.5	18.0	10.5	7.1	3.8	2.3
300	55.0	31.0	21.0	12.1	8.3	4.7	2.8
400	90.0	43.0	28.0	15.8	11.0	6.2	3.7
500	135.0	55.0	34.0	19.0	13.0	7.7	4.6
600	200.0	70.0	40.8	22.0	15.0	9.0	5.4
700	270.0	85.0	47.0	24.7	17.0	10.2	6.1
800	380.0	100.0	52.5	27.5	19.0	11.5	6.9
900	530.0	120.0	59.0	30.0	20.4	12.7	7.6
1000	740.0	140.0	64.0	32.0	22.0	13.5	8.1
1500	1000.0	243.0	93.0	44.0	30.0	18.3	11.0
2000	1000.0	400.0	116.0	53.5	37.0	21.7	13.0
3000	1000.0	900.0	165.0	70.0	46.5	27.6	16.6
4000	1000.0	1000.0	210.0	84.0	55.0	32.0	19.2
5000	1000.0	1000.0	249.0	96.0	61.0	35.5	21.3
6000	1000.0	1000.0	300.0	105.0	67.0	38.6	23.2
7000	1000.0	1000.0	340.0	118.0	71.0	41.2	24.7
8000	1000.0	1000.0	380.0	128.0	77.0	44.0	26.4
9000	1000.0	1000.0	405.0	135.0	80.0	46.0	27.6
10000	1000.0	1000.0	440.0	145.0	84.0	48.0	28.8
15000	1000.0	1000.0	618.0	175.0	98.0	56.0	33.6
20000	1000.0	1000.0	760.0	204.0	110.0	60.8	36.5
30000	1000.0	1000.0	1000.0	248.0	125.0	70.0	42.0
40000	1000.0	1000.0	1000.0	290.0	135.0	75.0	45.0
50000	1000.0	1000.0	1000.0	320.0	145.0	80.0	48.0
60000	1000.0	1000.0	1000.0	348.0	155.0	83.0	49.8
70000	1000.0	1000.0	1000.0	380.0	160.0	87.0	52.2
80000	1000.0	1000.0	1000.0	400.0	165.0	90.0	54.0
90000	1000.0	1000.0	1000.0	420.0	175.0	92.0	55.2
100000	1000.0	1000.0	1000.0	440.0	175.0	93.0	55.8
1E36	1000.0	1000.0	1000.0	440.0	175.0	93.0	55.8

TABLE III-A-23

TELETYPE PRINTOUT FOR SAMPLE GRONK RUN

RUN GRONK

GRONK 13:11 01/14/74

REACTOR NAME? MARC FOUR

OPTION WORD? LIMW

ENTER COMMENTS FOR THIS CASE? SAMPLE GRONK RUN

RELEASE HEIGHT+UNITS=?30M

ENTER GRAZING PERIOD, VEGETABLE CONSUMPTION PERIOD (MO/YR)?10.5

ENTER 2-YEAR-OLD VEG CONSUMPTION, ADULT VEG CONSUMPTION (KG/YR)?18.72

ENTER THYROID RANGES IN MILES. END THE SET WITH A BLANK LINE

?.5 1.5
?

POPULATION TOTAL BODY DOSE= .72 MANREM/YEAR

OPTION WORD? E

NOW AT END

SRU'S:16.3

READY

The reactor name determines which reactor data file will be accessed by the program. The option word is a combination of letters which tells GRONK the features that the user desires in the calculation. The letters may be entered in any order and spaces are allowed. The user may select one option from each of the following categories:

Meteorology Model

- Option H: use Hanford Meteorology tables.
- Option H not selected: use Pasquill meteorology tables.

Release Height

- Option G: the effluents are released from ground level.
- Option L: GRONK will later ask for the release height desired by the user. Sample responses are 100F to represent 100 ft or 70M to represent 70 meters.

- Neither options G nor L selected: the release height will be the same as that used in the previous case [it will be assumed equal to zero (ground level release) if this selection is made for the first case].

External Ranges

- Option R: the user will be asked later to enter the ranges for which $\bar{X}/Q'$ and skin and total-body dose to individual will be calculated. If this option is selected, GRONK will not have the information necessary to calculate total-body dose to population.
- Option S: the ranges for skin and total body calculations will be the same as those used in the previous case (built-in ranges will be assumed if this selection is made for the first case).
- Neither options R nor S selected: the "built-in" ranges specified for the population table in paragraph 4 of Table III-A-21 will be used for skin and total body calculation. Total-body dose to population will be calculated.

Plume Rise

- Option P: the release height h in Equation 9 is replaced by $h + \frac{\text{plume rise constant (meter}^2/\text{sec)}}{\bar{u}_j}$ (Reference 15).
- Option P not selected: the plume rise constant will be the same as that used in the previous case (it will be assumed equal to zero if this selection is made for the first case).

Wake Factor

- Option W: in Equation 9, σ_z^2 is everywhere replaced by $\sigma_z^2 + (\text{building height})^2/2\pi$, but is not allowed to increase beyond the maximum value of $3\sigma_z^2$. The building height is that specified in paragraph 8e of Table III-A-21.
- Option W not selected: no building-wake correction is applied.

Wind Speed

- Option M: let h_a be the larger of the effluent release height or 10 meters. Let h_s be the wind sensor height specified in paragraph 8d of Table III-A-21. Then the average wind speeds $\bar{u}_j$ are corrected by the factor $(h_a/h_s)^{0.25}$ for Hanford neutral and unstable, and for Pasquill A, B, C and D stability conditions; and by the factor $(h_a/h_s)^{0.5}$ for Hanford moderately stable and very stable, and for Pasquill E, F, G and G+ stability conditions.
- Option M not selected: no meteorological height correction factor is applied.

Thyroid

- Option T: a thyroid dose calculation will follow the skin and total-body dose calculations. GRONK will ask the user to enter grazing period, vegetable consumption periods and desired ranges for the thyroid calculation. Special feature: if the user presses the "escape" key when asked to enter thyroid ranges, the ranges previously selected for external doses are automatically used.
- Option T not selected: no thyroid calculation is made.

Adding Tables It is sometimes desirable to sum the doses for a group of successive cases; for example, when both stack and vent releases occur. To invoke this feature, the option letter A is used for all cases except the last case in the group. GRONK will compute and print both summed and unsummed tables.

Printing Tables at Teletype The user may select as many options as desired from the list in Table III-A-20. If printing option "8" is not chosen, the integrated man-rem total-body dose to population, if calculated, will be printed at the teletype. The selected tables will be printed at the teletype in the same format as they appear on the high-speed printer output. It is possible that some of the tables may be folded unless the user's conversational terminal has a width of at least 125 columns.

More than one set of release rates may be stored on the file Gxxxx. If GRONK determines that more than one list of releases is present, it will ask the user to enter the name of the desired list. (This feature was not used in the sample run.)

When the case is completed, GRONK will again request an option word. If the user desires to run another case for the same facility, he may enter another option word as described above. To indicate that the run is completed, he enters one of the following option letters:

- E End the run
- F End the run, then end the session as if an OFF command had been issued
- N End the run, then rerun GRONK for a new facility.

Table III-A-24 shows the high-speed printer output resulting from the sample run. On the last page is a summary of all cases contained in the printout.

III-A.7.5 Mixing Ratios and Reconcentration Formula

Mixing ratios and reconcentration factors are required by both ARRRG and CRITR. This section discusses the methods of choosing the proper parameters to use as input for these sections of the programs.

The mixing ratio, M_p , accounts for the dilution of the liquid effluent between the point of discharge and the point of exposure, and is best determined from hydrological studies. If the temperature increase which would result at the point of exposure solely from mixing is known, then the mixing ratio may be estimated from

$$M_p = \frac{T_p - T_A}{T_0 - T_A}$$

TABLE III-A-24

HIGH-SPEED PRINTER OUTPUT FOR SAMPLE GRONK RUN

GRONK ** GRONK ** GRONK ** GRONK ** GRONK

01/14/74 13:12

GRONK ** GRONK ** GRONK ** GRONK ** GRONK

1980 POPULATION TABLE

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	0	0	29	21	67	575	37,850	131,050	18,000	13,200	200,792
NNE	0	3	67	218	80	831	7,950	14,450	15,650	6,850	46,099
NE	0	15	0	70	33	2,486	59,950	55,050	17,800	12,000	147,404
ENE	0	0	0	0	17	989	53,250	52,800	20,950	11,850	139,856
E	0	0	0	0	5	1,804	7,250	9,900	7,250	12,950	39,159
ESE	0	0	0	0	17	3,511	6,000	4,950	19,100	14,100	47,678
SE	0	0	0	0	12	953	4,900	15,150	6,100	6,700	33,815
SSE	0	0	0	0	10	430	4,500	12,500	33,750	23,850	75,040
S	0	0	0	0	0	82	3,250	12,450	83,850	88,350	187,982
SSW	0	0	0	0	37	314	5,650	5,900	6,450	11,400	29,751
SW	0	0	0	7	34	196	7,900	10,850	6,250	16,300	41,537
WSW	0	0	0	38	48	743	6,750	6,950	7,500	9,300	31,329
W	0	0	4	90	34	833	2,150	4,050	9,500	31,000	47,661
WNW	0	0	83	18	64	131	3,800	3,950	15,350	17,850	41,246
NW	0	2	7	0	22	162	2,150	7,750	16,250	72,900	99,243
NNW	0	19	82	18	15	131	37,650	13,250	16,750	15,350	83,265
TOTALS	0	39	272	480	495	14,171	250,950	361,000	300,500	363,950	1,291,857
CUM TOTL	0	39	311	791	1,286	15,457	266,407	627,407	927,907	1,291,857	1,291,857

III-A-72

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL A CATEGORY METEOROLOGY AS INPUT FROM FILE PERCENT OF ALL OCCURRENCES							PASQUILL A CATEGORY METEOROLOGY IN STANDARD FORM PERCENT OF ALL OCCURRENCE						
	0-3	4-7	8-12	13-16	19+	TOTALS		0-3	4-7	8-12	13-18	19+	TOTALS
N	.05	.07	.03	.00	.00	.16	N	.05	.07	.03	.00	.00	.16
NNE	.03	.05	.02	.01	.00	.11	NNE	.03	.05	.02	.01	.00	.11
NE	.08	.12	.06	.00	.00	.25	NE	.08	.12	.06	.00	.00	.25
ENE	.01	.12	.05	.00	.00	.17	ENE	.01	.12	.05	.00	.00	.17
E	.08	.15	.03	.00	.00	.27	E	.08	.15	.03	.00	.00	.27
ESE	.03	.13	.05	.00	.00	.21	ESE	.03	.13	.05	.00	.00	.21
SE	.06	.20	.03	.01	.00	.30	SE	.06	.20	.03	.01	.00	.30
SSE	.06	.09	.02	.01	.00	.18	SSE	.06	.09	.02	.01	.00	.18
S	.08	.08	.02	.00	.00	.18	S	.08	.08	.02	.00	.00	.18
SSW	.04	.03	.01	.00	.00	.09	SSW	.04	.03	.01	.00	.00	.09
SW	.03	.08	.07	.00	.00	.18	SW	.03	.08	.07	.00	.00	.18
WSW	.03	.08	.05	.00	.00	.16	WSW	.03	.08	.05	.00	.00	.16
W	.05	.14	.02	.00	.00	.21	W	.05	.14	.02	.00	.00	.21
WNW	.02	.08	.01	.00	.00	.11	WNW	.02	.08	.01	.00	.00	.11
NW	.03	.05	.02	.00	.00	.10	NW	.03	.05	.02	.00	.00	.10
NNW	.02	.12	.00	.00	.00	.14	NNW	.02	.12	.00	.00	.00	.14
VARBL	.00	.00	.00	.00	.00	.00							
CALM	.00					.00							
TOTALS	.69	1.57	.51	.03	.00	2.80	TOTALS	.69	1.57	.51	.03	.00	2.80

III-A-73

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL B CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCESPASQUILL B CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS		0-3	4-7	8-12	13-18	19+	TOTALS
N	.11	.24	.06	.00	.00	.41	N	.11	.24	.06	.00	.00	.41
NNE	.05	.09	.07	.00	.00	.22	NNE	.05	.09	.07	.00	.00	.22
NE	.13	.31	.33	.02	.00	.80	NE	.13	.31	.33	.02	.00	.80
ENE	.04	.31	.38	.03	.00	.77	ENE	.04	.31	.38	.03	.00	.77
E	.09	.28	.21	.06	.00	.63	E	.09	.28	.21	.06	.00	.63
ESE	.04	.18	.10	.00	.00	.32	ESE	.04	.18	.10	.00	.00	.32
SE	.04	.20	.23	.05	.00	.51	SE	.04	.20	.23	.05	.00	.51
SSE	.04	.13	.08	.00	.00	.25	SSE	.04	.13	.08	.00	.00	.25
S	.13	.27	.20	.02	.00	.61	S	.13	.27	.20	.02	.00	.61
SSW	.01	.09	.13	.01	.00	.24	SSW	.01	.09	.13	.01	.00	.24
SW	.05	.17	.25	.02	.00	.50	SW	.05	.17	.25	.02	.00	.50
WSW	.02	.07	.15	.03	.00	.27	WSW	.02	.07	.15	.03	.00	.27
W	.03	.24	.20	.00	.00	.47	W	.03	.24	.20	.00	.00	.47
WNW	.05	.15	.07	.01	.00	.28	WNW	.05	.15	.07	.01	.00	.28
NW	.05	.22	.02	.00	.00	.29	NW	.05	.22	.02	.00	.00	.29
NNW	.04	.09	.07	.00	.00	.20	NNW	.04	.09	.07	.00	.00	.20
VARBL	.00	.00	.00	.00	.00	.00							
CALM	.00					.00							
TOTALS	.91	3.05	2.55	.27	.00	6.77	TOTALS	.91	3.05	2.55	.27	.00	6.77

III-A-74

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL C CATEGORY METEOROLOGY AS INPUT FROM FILE PERCENT OF ALL OCCURRENCES							PASQUILL C CATEGORY METEOROLOGY IN STANDARD FORM PERCENT OF ALL OCCURRENCE						
	0-3	4-7	8-12	13-18	19+	TOTALS		0-3	4-7	8-12	13-18	19+	TOTALS
N	.06	.24	.16	.05	.00	.51	N	.06	.24	.16	.05	.00	.51
NNE	.04	.18	.30	.09	.00	.62	NNE	.04	.18	.30	.09	.00	.62
NE	.05	.32	1.00	.30	.07	1.74	NE	.05	.32	1.00	.30	.07	1.74
ENE	.04	.38	.92	.25	.06	1.66	ENE	.04	.38	.92	.25	.06	1.66
E	.10	.42	.45	.24	.02	1.23	E	.10	.42	.45	.24	.02	1.23
ESE	.03	.10	.25	.15	.02	.56	ESE	.03	.10	.25	.15	.02	.56
SE	.09	.18	.26	.14	.02	.71	SE	.09	.18	.28	.14	.02	.71
SSE	.04	.15	.15	.01	.01	.36	SSE	.04	.15	.15	.01	.01	.36
S	.12	.18	.33	.10	.01	.75	S	.12	.18	.33	.10	.01	.75
SSW	.05	.24	.21	.03	.00	.53	SSW	.05	.24	.21	.03	.00	.53
SW	.06	.36	.80	.25	.02	1.49	SW	.06	.36	.80	.25	.02	1.49
WSW	.03	.27	.54	.12	.00	.96	WSW	.03	.27	.54	.12	.00	.96
W	.08	.40	.58	.06	.00	1.11	W	.08	.40	.58	.06	.00	1.11
WNW	.03	.23	.31	.03	.00	.61	WNW	.03	.23	.31	.03	.00	.61
NW	.03	.16	.16	.01	.00	.36	NW	.03	.16	.16	.01	.00	.36
NNW	.03	.16	.10	.00	.00	.30	NNW	.03	.16	.10	.00	.00	.30
VARBL	.00	.00	.00	.00	.00	.00							
CALM	.00					.00							
TOTALS	.88	3.99	6.55	1.85	.24	13.51	TOTALS	.88	3.99	6.55	1.85	.24	13.51

III-A-75

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL D CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCESPASQUILL D CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.10	.24	.61	.22	.03	1.21
NNE	.10	.25	.85	.47	.02	1.70
NE	.15	.52	2.17	.76	.10	3.71
ENE	.07	.55	1.07	.42	.07	2.18
E	.08	.39	.47	.36	.09	1.40
ESE	.13	.28	.20	.33	.09	1.03
SE	.08	.29	.44	.54	.25	1.60
SSE	.06	.20	.33	.30	.14	1.03
S	.12	.40	.76	.43	.07	1.78
SSW	.11	.42	1.06	.37	.02	1.98
SW	.17	.82	2.08	.66	.09	3.82
WSW	.07	.42	1.28	.54	.03	2.35
W	.07	.50	.96	.12	.00	1.64
WNW	.05	.20	.28	.06	.00	.58
NW	.08	.35	.32	.08	.00	.83
NNW	.06	.16	.16	.07	.01	.46
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	1.50	5.98	13.05	5.72	1.04	27.29

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.10	.24	.61	.22	.03	1.21
NNE	.10	.25	.85	.47	.02	1.70
NE	.15	.52	2.17	.76	.10	3.71
ENE	.07	.55	1.07	.42	.07	2.18
E	.08	.39	.47	.36	.09	1.40
ESE	.13	.28	.20	.33	.09	1.03
SE	.08	.29	.44	.54	.25	1.60
SSE	.06	.20	.33	.30	.14	1.03
S	.12	.40	.76	.43	.07	1.78
SSW	.11	.42	1.06	.37	.02	1.98
SW	.17	.82	2.08	.66	.09	3.82
WSW	.07	.42	1.28	.54	.03	2.35
W	.07	.50	.96	.12	.00	1.64
WNW	.05	.20	.28	.06	.00	.58
NW	.08	.35	.32	.08	.00	.83
NNW	.06	.16	.16	.07	.01	.46
TOTALS	1.50	5.98	13.05	5.72	1.04	27.29

III-A-76

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL E CATEGORY METEOROLOGY AS INPUT FROM FILE PERCENT OF ALL OCCURRENCES							PASQUILL E CATEGORY METEOROLOGY IN STANDARD FORM PERCENT OF ALL OCCURRENCE						
	0-3	4-7	8-12	13-18	19+	TOTALS		0-3	4-7	8-12	13-18	19+	TOTALS
N	.20	.43	.55	.07	.00	1.25	N	.20	.43	.55	.07	.00	1.25
NNE	.07	.32	.75	.09	.00	1.24	NNE	.07	.32	.75	.09	.00	1.24
NE	.21	.75	1.85	.20	.00	3.00	NE	.21	.75	1.85	.20	.00	3.00
ENE	.13	.46	.54	.03	.00	1.17	ENE	.13	.46	.54	.03	.00	1.17
E	.15	.53	.24	.03	.00	.95	E	.15	.53	.24	.03	.00	.95
ESE	.16	.17	.20	.09	.01	.63	ESE	.16	.17	.20	.09	.01	.63
SE	.26	.43	.73	.32	.13	1.87	SE	.26	.43	.73	.32	.13	1.87
SSE	.21	.31	.61	.37	.06	1.56	SSE	.21	.31	.61	.37	.06	1.56
S	.15	.44	.97	.38	.06	2.00	S	.15	.44	.97	.38	.06	2.00
SSW	.12	.32	.67	.12	.01	1.24	SSW	.12	.32	.67	.12	.01	1.24
SW	.18	.73	1.21	.13	.00	2.25	SW	.18	.73	1.21	.13	.00	2.25
WSW	.05	.37	.45	.05	.00	.92	WSW	.05	.37	.45	.05	.00	.92
W	.16	.53	.40	.02	.00	1.12	W	.16	.53	.40	.02	.00	1.12
WNW	.08	.35	.23	.01	.00	.66	WNW	.08	.35	.23	.01	.00	.66
NW	.12	.40	.36	.01	.00	.89	NW	.12	.40	.36	.01	.00	.89
NNW	.15	.46	.24	.05	.00	.90	NNW	.15	.46	.24	.05	.00	.90
VARHL	.00	.00	.00	.00	.00	.00							
CALM	.00					.00							
TOTALS	2.41	7.00	10.00	1.97	.27	21.66	TOTALS	2.41	7.00	10.00	1.97	.27	21.66

III-A-77

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL F CATEGORY METEOROLOGY AS INPUT FROM FILE PERCENT OF ALL OCCURRENCES							PASQUILL F CATEGORY METEOROLOGY IN STANDARD FORM PERCENT OF ALL OCCURRENCE						
	0-3	4-7	8-12	13-18	19+	TOTALS		0-3	4-7	8-12	13-18	19+	TOTALS
N	.21	.72	1.29	.03	.00	2.26	N	.21	.72	1.29	.03	.00	2.26
NNE	.15	.66	1.50	.03	.00	2.35	NNE	.15	.66	1.50	.03	.00	2.35
NE	.21	1.08	2.80	.05	.00	4.14	NE	.21	1.08	2.80	.05	.00	4.14
ENE	.24	.87	.96	.00	.00	2.07	ENE	.24	.87	.96	.00	.00	2.07
E	.28	.74	.50	.05	.00	1.56	E	.28	.74	.50	.05	.00	1.56
ESE	.19	.44	.32	.02	.00	.98	ESE	.19	.44	.32	.02	.00	.98
SE	.16	.57	.73	.07	.00	1.52	SE	.16	.57	.73	.07	.00	1.52
SSE	.14	.55	.55	.10	.00	1.35	SSE	.14	.55	.55	.10	.00	1.35
S	.22	.69	.88	.05	.00	1.84	S	.22	.69	.88	.05	.00	1.84
SSW	.22	.54	.80	.02	.00	1.58	SSW	.22	.54	.80	.02	.00	1.58
SW	.15	.69	1.04	.03	.00	1.91	SW	.15	.69	1.04	.03	.00	1.91
WSW	.10	.45	.53	.01	.00	1.10	WSW	.10	.45	.53	.01	.00	1.10
W	.07	.37	.77	.00	.00	1.21	W	.07	.37	.77	.00	.00	1.21
WNW	.09	.43	.60	.01	.00	1.13	WNW	.09	.43	.60	.01	.00	1.13
NW	.20	.68	1.03	.01	.00	1.92	NW	.20	.68	1.03	.01	.00	1.92
NNW	.15	.43	.46	.02	.00	1.06	NNW	.15	.43	.46	.02	.00	1.06
VARBL	.00	.00	.00	.00	.00	.00							
CALM	.00					.00							
TOTALS	2.79	9.90	14.76	.52	.00	27.97	TOTALS	2.79	9.90	14.76	.52	.00	27.97

III-A-78

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRUNK RUN

01/14/74

ISOTOPE	RELEASE CI/YEAR	LAMBDA 1/SEC	EXTERNAL DOSE FACTORS MREM/HR PER PCI/CUBIC METER		THYROID DOSE FACTORS -- MREM/YEAR PER PCI/CUBIC METER					
			TOTAL BODY	SKIN	---INHALATION---		---PM I L K---		LEAFY VEGETABLES	
					2 YEAR	ADULT	2 YEAR	ADULT	2 YEAR	ADULT
29 KR-83M	11.896	1.04E-04	0	7.6E-10						
30 KR-85M	64.16	4.39E-05	1.3E-07	3.2E-07						
31 KR-85	3186.8	2.04E-09	2.2E-09	1.6E-07						
32 KR-87	34.616	1.52E-04	1.3E-06	2.7E-06						
33 KR-88	111.12	6.86E-05	1.5E-06	2.0E-06						
36 RB-89	0.546	7.50E-04	2.1E-06	2.8E-06						
82 I-131	0.170	9.97E-07	3.1E-07	4.9E-07	12.5	10.6	3620.	448.	1190.	589.
84 I-133	0.130	9.17E-06	4.4E-07	8.8E-07	5.51	2.70	262.	18.7	84.1	24.1
87 XE-131M	80.04	6.81E-07	2.8E-09	4.8E-08						
88 XE-133M	123.40	3.56E-06	2.7E-08	6.0E-08						
89 XE-133	10036	1.52E-06	2.5E-08	6.9E-08						
90 XE-135M	7.352	7.42E-04	3.5E-07	5.0E-07						
91 XE-135	186.88	2.09E-05	2.1E-07	4.9E-07						
92 XE-137	5.392	2.97E-03	1.2E-07	1.8E-06						
93 XE-138	25.544	6.81E-04	1.2E-06	1.7E-06						

PASQUILL MODEL
 30 METER RELEASE
 BUILT-IN TOTAL BODY/SKIN RANGES
 BUILDING WAKE FACTOR APPLIED. BUILDING HEIGHT= 56.3 METERS
 WIND SPEEDS CORRECTED FROM 36.576 METERS TO 30 METERS
 PERFORM THYROID CALCULATION
 GRAZING PERIOD= 10 MONTHS/YEAR
 VEGETABLE CONSUMPTION PERIOD= 5 MONTHS/YEAR
 2-YEAR-OLD VEGETABLE CONSUMPTION= 18 KILOGRAMS/YEAR
 ADULT VEGETABLE CONSUMPTION= 72 KILOGRAMS/YEAR

III-A-79

TABLE III-A-24 (Continued)

CASE 1: WARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRUNK RUN

01/14/74

CONTRIBUTION TO DOSE AT RELEASE POINT

ISOTOPE	TOTAL DOSE	SKIN DOSE	INHALATION 2 YR ADULT	---MILK--- 2 YR ADULT	VEGETABLES 2 YR ADULT
31 K-85		30 %			
32 K-87		5 %			
33 K-88	30 %	15 %			
52 I-131			69 %	60 %	93 %
54 I-133			31 %	20 %	7 %
59 Xe-133	45 %	41 %			
91 Xe-135	7 %	5 %			
93 Xe-135	5 %				

CASE 1: WARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRUNK RUN

01/14/74

TABLE OF CH1 / W

PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	9.34E-07	2.46E-07	1.15E-07	7.50E-08	5.25E-08	2.60E-08	1.03E-08	5.01E-09	3.66E-09	2.66E-09	1.48E-08
NNE	8.73E-07	2.30E-07	1.10E-07	6.99E-08	4.88E-08	2.41E-08	9.47E-09	5.24E-09	3.41E-09	2.47E-09	1.38E-08
NE	1.79E-06	4.46E-07	2.17E-07	1.35E-07	9.39E-08	4.61E-08	1.81E-08	1.01E-08	6.54E-09	4.73E-09	2.77E-08
ENE	1.05E-06	2.65E-07	1.27E-07	8.14E-08	5.66E-08	2.77E-08	1.08E-08	6.05E-09	3.94E-09	2.85E-09	1.67E-08
E	9.29E-07	2.30E-07	1.09E-07	7.05E-08	4.91E-08	2.41E-08	9.47E-09	5.22E-09	3.41E-09	2.46E-09	1.43E-08
ESE	6.13E-07	1.53E-07	7.29E-08	4.63E-08	3.23E-08	1.59E-08	6.25E-09	3.49E-09	2.27E-09	1.64E-09	9.47E-09
SE	9.40E-07	2.27E-07	1.08E-07	6.83E-08	4.76E-08	2.34E-08	9.18E-09	5.05E-09	3.28E-09	2.38E-09	1.43E-08
SSE	7.38E-07	1.80E-07	8.67E-08	5.61E-08	3.92E-08	1.94E-08	7.63E-09	4.10E-09	2.70E-09	1.96E-09	1.14E-08
S	1.06E-06	2.59E-07	1.23E-07	7.63E-08	5.46E-08	2.68E-08	1.05E-08	5.85E-09	3.80E-09	2.76E-09	1.63E-08
SSW	8.70E-07	2.19E-07	1.04E-07	6.59E-08	4.58E-08	2.24E-08	8.77E-09	4.95E-09	3.20E-09	2.31E-09	1.35E-08
SW	1.41E-06	3.20E-07	1.50E-07	9.40E-08	6.53E-08	3.17E-08	1.22E-08	7.00E-09	4.55E-09	3.27E-09	2.10E-08
WSW	7.54E-07	1.73E-07	8.11E-08	5.10E-08	3.56E-08	1.72E-08	6.84E-09	3.86E-09	2.49E-09	1.79E-09	1.13E-08
W	8.28E-07	1.96E-07	8.67E-08	5.57E-08	3.85E-08	1.87E-08	7.21E-09	4.09E-09	2.65E-09	1.92E-09	1.23E-08
WNW	5.11E-07	1.29E-07	6.14E-08	3.94E-08	2.75E-08	1.35E-08	5.32E-09	2.91E-09	1.90E-09	1.36E-09	7.93E-09
NW	7.44E-07	2.01E-07	9.72E-08	6.16E-08	4.32E-08	2.14E-08	8.49E-09	4.63E-09	3.01E-09	2.19E-09	1.19E-08
NNW	5.65E-07	1.46E-07	7.01E-08	4.45E-08	3.12E-08	1.54E-08	6.09E-09	3.29E-09	2.14E-09	1.56E-09	8.86E-09
TOTALS	1.47E-05	3.62E-06	1.72E-06	1.09E-06	7.62E-07	3.74E-07	1.46E-07	8.16E-08	5.30E-08	3.83E-08	2.26E-05
CUM TOTL	1.47E-05	1.83E-05	2.00E-05	2.11E-05	2.19E-05	2.22E-05	2.24E-05	2.25E-05	2.25E-05	2.26E-05	2.26E-05

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN

01/14/74

SKIN DOSE TO INDIVIDUAL, MREM/YEAR

PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	4.33E-01	1.11E-01	5.20E-02	3.25E-02	2.24E-02	1.07E-02	3.98E-03	2.07E-03	1.30E-03	9.21E-04	6.70E-01
NNE	4.05E-01	1.04E-01	4.90E-02	3.06E-02	2.11E-02	1.00E-02	3.73E-03	1.97E-03	1.24E-03	8.70E-04	6.27E-01
NE	8.33E-01	2.02E-01	9.46E-02	5.91E-02	4.06E-02	1.93E-02	7.17E-03	3.80E-03	2.38E-03	1.68E-03	1.26E+00
ENE	5.02E-01	1.21E-01	5.61E-02	3.54E-02	2.42E-02	1.14E-02	4.21E-03	2.24E-03	1.41E-03	9.94E-04	7.58E-01
E	4.29E-01	1.03E-01	4.79E-02	3.03E-02	2.08E-02	9.82E-03	3.62E-03	1.90E-03	1.20E-03	8.49E-04	6.49E-01
ESE	2.83E-01	6.83E-02	3.18E-02	1.98E-02	1.36E-02	6.42E-03	2.37E-03	1.26E-03	7.92E-04	5.59E-04	4.28E-01
SE	4.35E-01	1.02E-01	4.74E-02	2.96E-02	2.03E-02	9.63E-03	3.56E-03	1.87E-03	1.17E-03	8.29E-04	6.51E-01
SSE	3.41E-01	8.35E-02	3.90E-02	2.43E-02	1.57E-02	7.96E-03	2.96E-03	1.53E-03	9.63E-04	6.81E-04	5.19E-01
S	4.91E-01	1.17E-01	5.43E-02	3.39E-02	2.33E-02	1.11E-02	4.09E-03	2.17E-03	1.36E-03	9.60E-04	7.39E-01
SSW	4.06E-01	9.87E-02	4.60E-02	2.85E-02	1.96E-02	9.24E-03	3.40E-03	1.83E-03	1.14E-03	8.02E-04	6.15E-01
SW	6.55E-01	1.45E-01	6.64E-02	4.13E-02	2.81E-02	1.32E-02	4.80E-03	2.65E-03	1.65E-03	1.15E-03	9.59E-01
WSW	3.50E-01	7.84E-02	3.60E-02	2.26E-02	1.53E-02	7.18E-03	2.61E-03	1.45E-03	9.03E-04	6.32E-04	5.15E-01
W	3.84E-01	8.40E-02	3.84E-02	2.42E-02	1.65E-02	7.74E-03	2.82E-03	1.52E-03	9.54E-04	6.72E-04	5.60E-01
WNW	2.37E-01	5.81E-02	2.71E-02	1.71E-02	1.18E-02	5.59E-03	2.07E-03	1.08E-03	6.78E-04	4.81E-04	3.61E-01
NW	3.44E-01	9.06E-02	4.25E-02	2.67E-02	1.84E-02	8.80E-03	3.28E-03	1.70E-03	1.07E-03	7.57E-04	5.38E-01
NNW	2.61E-01	6.55E-02	3.07E-02	1.91E-02	1.32E-02	6.27E-03	2.33E-03	1.20E-03	7.53E-04	5.34E-04	4.00E-01
TOTALS	6.79E+00	1.63E+00	7.59E-01	4.75E-01	3.26E-01	1.54E-01	5.70E-02	3.02E-02	1.90E-02	1.34E-02	1.03E+01
CUM TOTL	6.79E+00	8.42E+00	9.18E+00	9.65E+00	9.98E+00	1.01E+01	1.02E+01	1.02E+01	1.02E+01	1.03E+01	1.03E+01

III-A-81

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN

01/14/74

TOTAL BODY DOSE TO INDIVIDUAL, MREM/YEAR

PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	1.40E-01	3.47E-02	1.60E-02	9.83E-03	6.68E-03	3.06E-03	1.06E-03	5.19E-04	3.13E-04	2.14E-04	2.12E-01
NNE	1.31E-01	3.29E-02	1.52E-02	9.35E-03	6.35E-03	2.92E-03	1.02E-03	5.05E-04	3.03E-04	2.06E-04	2.00E-01
NE	2.69E-01	6.42E-02	2.95E-02	1.81E-02	1.23E-02	5.65E-03	1.96E-03	9.83E-04	5.89E-04	4.01E-04	4.03E-01
ENE	1.62E-01	3.80E-02	1.73E-02	1.08E-02	7.25E-03	3.29E-03	1.13E-03	5.66E-04	3.40E-04	2.32E-04	2.41E-01
E	1.38E-01	3.23E-02	1.47E-02	9.12E-03	6.14E-03	2.78E-03	9.49E-04	4.68E-04	2.83E-04	1.94E-04	2.05E-01
ESE	9.09E-02	2.13E-02	9.70E-03	5.93E-03	3.99E-03	1.80E-03	6.16E-04	3.08E-04	1.85E-04	1.27E-04	1.35E-01
SE	1.40E-01	3.21E-02	1.46E-02	8.96E-03	6.06E-03	2.76E-03	9.51E-04	4.70E-04	2.82E-04	1.93E-04	2.06E-01
SSE	1.10E-01	2.62E-02	1.20E-02	7.34E-03	4.98E-03	2.28E-03	7.88E-04	3.85E-04	2.31E-04	1.58E-04	1.64E-01
S	1.58E-01	3.68E-02	1.68E-02	1.03E-02	6.96E-03	3.17E-03	1.10E-03	5.45E-04	3.27E-04	2.24E-04	2.35E-01
SSW	1.31E-01	3.10E-02	1.42E-02	8.65E-03	5.83E-03	2.65E-03	9.07E-04	4.59E-04	2.75E-04	1.87E-04	1.95E-01
SW	2.12E-01	4.58E-02	2.06E-02	1.26E-02	8.47E-03	3.83E-03	1.30E-03	6.77E-04	4.03E-04	2.72E-04	3.06E-01
WSW	1.13E-01	2.48E-02	1.12E-02	6.90E-03	4.62E-03	2.09E-03	7.09E-04	3.71E-04	2.21E-04	1.49E-04	1.64E-01
W	1.24E-01	2.65E-02	1.19E-02	7.39E-03	4.96E-03	2.24E-03	7.62E-04	3.87E-04	2.31E-04	1.58E-04	1.78E-01
WNW	7.63E-02	1.83E-02	8.39E-03	5.21E-03	3.53E-03	1.61E-03	5.56E-04	2.71E-04	1.63E-04	1.12E-04	1.14E-01
NW	1.11E-01	2.85E-02	1.32E-02	8.08E-03	5.49E-03	2.52E-03	8.75E-04	4.26E-04	2.56E-04	1.75E-04	1.70E-01
NNW	8.39E-02	2.05E-02	9.41E-03	5.75E-03	3.90E-03	1.78E-03	6.12E-04	2.95E-04	1.77E-04	1.22E-04	1.26E-01
TOTALS	2.19E+00	5.14E-01	2.35E-01	1.44E-01	9.75E-02	4.44E-02	1.53E-02	7.64E-03	4.58E-03	3.12E-03	3.26E+00
CUM TOTL	2.19E+00	2.70E+00	2.94E+00	3.08E+00	3.18E+00	3.23E+00	3.24E+00	3.25E+00	3.25E+00	3.26E+00	3.26E+00

III-A-82

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR - 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN

01/14/74

TOTAL BODY DOSE TO POPULATION, MAN-REM/YEAR											PASQUILL MODEL
RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	.00E+00	.00E+00	4.65E-04	2.06E-04	4.47E-04	1.76E-03	4.02E-02	6.80E-02	5.63E-03	2.82E-03	1.20E-01
NNE	.00E+00	9.87E-05	1.02E-03	2.04E-03	5.08E-04	2.43E-03	8.09E-03	7.30E-03	4.74E-03	1.41E-03	2.76E-02
NE	.00E+00	9.62E-04	.00E+00	1.27E-03	4.06E-04	1.40E-02	1.18E-01	5.41E-02	1.05E-02	4.81E-03	2.04E-01
ENE	.00E+00	.00E+00	.00E+00	.00E+00	1.23E-04	3.26E-03	6.02E-02	2.99E-02	7.12E-03	2.75E-03	1.03E-01
E	.00E+00	.00E+00	.00E+00	.00E+00	3.07E-05	5.01E-03	6.88E-03	4.64E-03	2.05E-03	2.51E-03	2.11E-02
ESE	.00E+00	.00E+00	.00E+00	.00E+00	6.79E-05	6.33E-03	3.69E-03	1.52E-03	3.54E-03	1.79E-03	1.69E-02
SE	.00E+00	.00E+00	.00E+00	.00E+00	7.27E-05	2.63E-03	4.66E-03	7.12E-03	1.72E-03	1.30E-03	1.75E-02
SSE	.00E+00	.00E+00	.00E+00	.00E+00	4.98E-05	9.79E-04	3.54E-03	4.81E-03	7.81E-03	3.78E-03	2.10E-02
S	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	2.60E-04	3.56E-03	6.79E-03	2.75E-02	1.98E-02	5.78E-02
SSW	.00E+00	.00E+00	.00E+00	.00E+00	2.16E-04	8.31E-04	5.13E-03	2.71E-03	1.77E-03	2.13E-03	1.28E-02
SW	.00E+00	.00E+00	.00E+00	8.84E-05	2.88E-04	7.51E-04	1.03E-02	7.35E-03	2.52E-03	4.44E-03	2.57E-02
WSW	.00E+00	.00E+00	.00E+00	2.62E-04	2.22E-04	1.55E-03	4.79E-03	2.58E-03	1.66E-03	1.39E-03	1.24E-02
W	.00E+00	.00E+00	4.76E-05	6.65E-04	1.69E-04	1.86E-03	1.64E-03	1.57E-03	2.20E-03	4.88E-03	1.30E-02
WNW	.00E+00	.00E+00	6.96E-04	9.37E-05	2.26E-04	2.11E-04	2.11E-03	1.07E-03	2.51E-03	1.99E-03	8.91E-03
NW	.00E+00	5.70E-05	9.23E-05	.00E+00	1.21E-04	4.08E-04	1.88E-03	3.30E-03	4.16E-03	1.28E-02	2.28E-02
NNW	.00E+00	3.90E-04	7.71E-04	1.03E-04	5.85E-05	2.33E-04	2.30E-02	3.90E-03	2.97E-03	1.87E-03	3.33E-02
TOTALS	.00E+00	1.51E-03	3.09E-03	4.73E-03	3.01E-03	4.26E-02	2.97E-01	2.07E-01	8.83E-02	7.04E-02	7.18E-01
CUM TOTL	.00E+00	1.51E-03	4.60E-03	9.33E-03	1.23E-02	5.49E-02	3.52E-01	5.59E-01	6.47E-01	7.18E-01	7.18E-01

III-A-83

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN

01/14/74

CUMULATIVE RADIUS (MILES)	CUMULATIVE 1980 POPULATION	CUMULATIVE DOSE (MAN-REM/YR)	AVERAGE ANNUAL DOSE (MREM/YR)
1	0	0	
2	39	.0015	.039
3	311	.0046	.015
4	791	.0093	.012
5	1,286	.012	.0096
10	15,457	.055	.0036
20	266,407	.35	.0013
30	627,407	.56	.00089
40	927,907	.65	.0007
50	1,291,857	.72	.00056

III-A-84

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN

01/14/74

THYROID DOSE
.5 MILES

PASQUILL MODEL

	CHI/9 SEC/1000	NUCLIDE CONCENTRATION, PCI/CUBIC METER						DOSE FROM INHALATION		PATHWAY MILK		MREM/YR LEAFY VEGETABLES		
		-----								-----		-----		
		TE-1320	I-129	I-130	I-131	I-132	I-133	I-135	2 YR	ADULT	2 YR	ADULT	2 YR	ADULT
N	9.4E-07				5.1E-03		3.8E-03		8.4E-02	6.4E-02	1.6E+01	1.9E+00	2.6E+00	1.3E+00
NNE	8.7E-07				4.7E-03		3.6E-03		7.9E-02	6.0E-02	1.5E+01	1.8E+00	2.5E+00	1.2E+00
NE	1.8E-06				4.7E-03		7.4E-03		1.6E-01	1.2E-01	3.1E+01	3.7E+00	5.0E+00	2.4E+00
ENE	1.1E-06				5.8E-03		4.4E-03		4.7E-02	7.4E-02	1.9E+01	2.2E+00	3.0E+00	1.5E+00
E	9.3E-07				5.0E-03		3.8E-03		8.4E-02	6.3E-02	1.6E+01	1.9E+00	2.6E+00	1.3E+00
ESE	6.1E-07				3.3E-03		2.5E-03		5.5E-02	4.2E-02	1.1E+01	1.3E+00	1.7E+00	8.4E-01
SE	4.4E-07				5.1E-03		3.9E-03		8.5E-02	6.4E-02	1.6E+01	1.9E+00	2.6E+00	1.3E+00
SSE	7.4E-07				4.0E-03		3.0E-03		6.6E-02	5.0E-02	1.3E+01	1.5E+00	2.1E+00	1.0E+00
S	1.1E-06				5.7E-03		4.4E-03		4.5E-02	7.2E-02	1.8E+01	2.2E+00	3.0E+00	1.4E+00
SSW	8.8E-07				4.7E-03		3.6E-03		7.9E-02	6.0E-02	1.5E+01	1.8E+00	2.5E+00	1.2E+00
SW	1.4E-06				7.0E-03		5.8E-03		1.3E-01	9.6E-02	2.4E+01	2.9E+00	4.0E+00	1.9E+00
WSW	7.5E-07				4.1E-03		3.1E-03		6.8E-02	5.1E-02	1.3E+01	1.6E+00	2.1E+00	1.0E+00
W	8.3E-07				4.5E-03		3.4E-03		7.4E-02	5.6E-02	1.4E+01	1.7E+00	2.3E+00	1.1E+00
WNW	5.1E-07				2.8E-03		2.1E-03		4.6E-02	3.5E-02	8.8E+00	1.1E+00	1.4E+00	7.0E-01
NW	7.4E-07				4.0E-03		3.1E-03		6.7E-02	5.1E-02	1.3E+01	1.5E+00	2.1E+00	1.0E+00
NNW	5.1E-07				3.0E-03		2.3E-03		5.1E-02	3.9E-02	4.7E+00	1.2E+00	1.6E+00	7.7E-01

III-A-85

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN

01/14/74

THYROID DOSE
1.5 MILES

PASQUILL MODEL

	CHI/W SEC/M**3	NUCLIDE CONCENTRATION, PCI/CUBIC METER						DOSE FROM INHALATION		PATHWAY MILK		MEM/YR LEAFY VEGETABLES	
		-----						-----		-----		-----	
		TE-1320	I-129	I-130	I-131	I-132	I-133	I-135	2 YR	ADULT	2 YR	ADULT	2 YR
N	2.5E-07				1.3E-03		1.0E-03	2.2E-02	1.7E-02	4.2E+00	5.1E-01	6.9E-01	3.3E-01
NNE	2.3E-07				1.2E-03		9.4E-04	2.1E-02	1.6E-02	3.9E+00	4.8E-01	6.5E-01	3.1E-01
NE	4.5E-07				2.4E-03		1.8E-03	4.0E-02	3.0E-02	7.6E+00	9.3E-01	1.3E+00	6.1E-01
ENE	2.7E-07				1.4E-03		1.1E-03	2.4E-02	1.8E-02	4.6E+00	5.5E-01	7.5E-01	3.6E-01
E	2.3E-07				1.2E-03		9.3E-04	2.1E-02	1.6E-02	3.9E+00	4.8E-01	6.5E-01	3.1E-01
ESE	1.5E-07				8.2E-04		6.2E-04	1.4E-02	1.0E-02	2.6E+00	3.2E-01	4.3E-01	2.1E-01
SE	2.3E-07				1.2E-03		9.2E-04	2.0E-02	1.5E-02	3.9E+00	4.7E-01	6.4E-01	3.1E-01
SSE	1.9E-07				1.0E-03		7.5E-04	1.7E-02	1.3E-02	3.2E+00	3.8E-01	5.2E-01	2.5E-01
S	2.6E-07				1.4E-03		1.1E-03	2.3E-02	1.8E-02	4.4E+00	5.4E-01	7.3E-01	3.5E-01
SSW	2.2E-07				1.2E-03		8.9E-04	2.0E-02	1.5E-02	3.8E+00	4.5E-01	6.2E-01	3.0E-01
SW	3.2E-07				1.7E-03		1.3E-03	2.9E-02	2.2E-02	5.5E+00	6.6E-01	9.0E-01	4.4E-01
WSW	1.7E-07				9.3E-04		7.1E-04	1.6E-02	1.2E-02	3.0E+00	3.6E-01	4.9E-01	2.4E-01
W	1.9E-07				1.0E-03		7.6E-04	1.7E-02	1.3E-02	3.2E+00	3.9E-01	5.2E-01	2.5E-01
WNW	1.3E-07				6.9E-04		5.2E-04	1.2E-02	8.8E-03	2.2E+00	2.7E-01	3.6E-01	1.8E-01
NW	2.0E-07				1.1E-03		8.2E-04	1.8E-02	1.4E-02	3.4E+00	4.2E-01	5.7E-01	2.7E-01
NNW	1.5E-07				7.9E-04		5.9E-04	1.3E-02	9.9E-03	2.5E+00	3.0E-01	4.1E-01	2.0E-01

III-A-86

TABLE III-A-24 (Continued)

S U M M A R Y O F R U N P E R C E N T F O U R 2 U N I T S

CASE 1: S A M P L E G R O N K R U N
P A S Q U I L L M O D E L 30 M E T E R R E L E A S E W A K E F A C T O R W I N D S P E E D T H Y

G R O N K ** G R O N K ** G R O N K ** G R O N K ** G R O N K

01/14/74

13:12

G R O N K ** G R O N K ** G R O N K ** G R O N K ** G R O N K

III-A-87

MAIL TO: NM ROBINSON, BATTELLE-NORTHWEST, 3717 BLDG, 300 AREA, RICHLAND, WASHINGTON 99352

where T_A = ambient temperature of the receiving sink,
 T_p = temperature which would exist at the point of exposure
for pathway p if no evaporation or radiation effects
were present
 T_0 = temperature of the effluent at the outlet.

The value for T_p can be estimated from a plot of isotherms due to mixing only in the receiving waters.

The reconcentration factor, N_i , accounts for the extent to which effluent is recycled through the reactors. ARRRG and CRITR allow the user a choice of the following reconcentration models:

- (1) If the cooling water is drawn from a cooling pond, small lake or reservoir which is connected to a larger body of water or is fed by a stream, then:

$$N_i = \left[1 - \frac{(F - L) e^{-\lambda_i t_c}}{F + V \lambda_T} \right]^{-1} \quad (17)$$

- (2) If the cooling water intake is downriver from the outfall or on a lake or ocean site and arranged such that recirculation occurs, then

$$N_i = \frac{1 - \left[g e^{-\lambda_i t_c} \right]^{n+1}}{1 - g e^{-\lambda_i t_c}} \quad (18)$$

- (3) If there is no reconcentration, for example, if the cooling water is drawn from a river in which the outfall is below the intake, then

$$N_i = 1.0 \quad (19)$$

where g = recycle fraction (the mixing ratio at the point of intake)
(unitless)
 F = coolant flow (ft³/sec)
 L = makeup flow (water drawn into the intake to replace losses)
(ft³/sec)
 V = pond volume (ft³)
 λ_T = pond turnover rate (sec⁻¹)
 t_c = cycle time (hr)
 λ_i = decay constant (hr⁻¹)
 n = number of cycles during facility lifetime = $\frac{\text{plant life (hr)}}{t_c}$

The above three models were chosen for the programs because they apply to the most common reconcentration situations. Unusual cases could require that special reconcentration formulas be added to the program.

Equation 18 is the closed form of the series

$$N_i = 1 + G_i + G_i^2 + G_i^3 + \dots + G_i^n \quad (19a)$$

where $G_i = g \exp(-\lambda_i t_c)$ for nuclide i .

Formula 1, the most complex of the reconcentration models, is used for sites on a cooling pond, lake or reservoir where the water is exchanged by stream flow or connection with a larger body of water such as the ocean. It can also be used for a system of cooling canals where a fresh dilution stream (makeup) is injected into the inlet pipe along with the recycled water from the cooling pond. From elementary considerations of mass balance, assuming steady state conditions and instantaneous mixing in the cooling pond, Formula 1 is of the form of Formula 2 with $n \rightarrow \infty$ and with the recycle fraction a function of hydrological parameters and the radionuclide decay constant (Figure III-A-1),

$$N_i = \left[1 - \frac{(F - L) e^{-\lambda_i t_c}}{(F - L) + V(\lambda_T + \frac{L}{V})} \right]^{-1} \quad (17)$$

FIGURE III-A-1 RECONCENTRATION IN REACTOR EFFLUENT DUE TO RECYCLING THROUGH A COOLING POND

The volume, V , for Formula 1 may be taken to be a series of canals, a pond, small bay, small lake, etc. However, the model loses credibility if V is very large since instantaneous mixing in V was assumed; therefore, Formula 2 should be used for large V .

During an ARRRG or CRITR run, the program will ask "which reconcentration formula?" The user should then enter one of the numbers 1, 2 or 3. The programs will next ask for only those parameters which are needed for the selected reconcentration formula.

III-A.7.6 Treatment Of Parent-Daughter Nuclide Pairs

Parent-daughter nuclide pairs require special consideration, since decay of parent into daughter represents an additional source of the daughter nuclide in the environment and in the body. Effects of parent decay subsequent to intake into the body are already accounted for in the calculation of decay energy and internal dose factors by ICRP methods.

Accumulation of a daughter nuclide in primary aquatic organisms may be controlled by the bioaccumulation factor of either the parent or daughter, or both. To ensure that calculated doses are always conservative, a pseudo-nuclide is devised which has the half-life and bioaccumulation factors of the parent, but the decay energy and dose factors of the daughter. Pseudo-nuclides are placed in the nuclide master list with a name formed by appending the letter D to the parent name. The release rate assigned to the pseudo-nuclide is the release of the parent multiplied by the fraction of the parent decay which passes through the daughter nuclide.

The doses calculated from the combination of the pseudo-nuclide plus daughter nuclide will always be at least as large as the true dose from the daughter. Furthermore, accumulation of the daughter on sediments is conservatively calculated, since the longer half-life of the parent is used for the pseudo-nuclide.

A simplification of the above method is possible when the daughter has a radiological half-life which is short compared to that of its parent and compared to the elapsed time between release of the nuclide and exposure. Since the environmental behavior of the daughter will always follow that of the parent, the decay energy of the daughter is included with that of the parent for the calculation of external dose factors. The symbol "+D" is appended to the parent name to indicate that the external dose factors are modified. Thus, whenever a parent nuclide release is specified, the result of the dose calculations will be as though an additional equilibrium amount of the daughter nuclide is specified. The daughter nuclide itself will appear separately in the master list if it can be released independently of the parent.

III-A PART 1 REFERENCES

1. Atomic Energy Commission, "Proposed Rule Making for Amendment to 10 CFR Part 50, Environmental Effects of Transportation of Fuel and Waste from Nuclear Power Reactors," Federal Register, vol. 38, no. 23, p. 3334, 1973.
2. J. K. Soldat, Modeling of Environmental Pathways and Radiation Doses from Nuclear Facilities, USAEC Report BNWL-SA-3939, Pacific Northwest Laboratory, Richland, WA. 1971.
3. J. F. Fletcher, W. L. Dotson (compilers), HERMES - A Digital Computer Code for Estimating Regional Radiological Effects From The Nuclear Power Industry, USAEC Report HEDL-TME-71-168, Hanford Engineering Development Laboratory, Richland, WA, 1971.
4. International Commission on Radiological Protection, Report of ICRP Committee II on Permissible Dose for Internal Radiation, ICRP Publication 2, Pergamon Press, New York, 1959.
5. M. M. Miller and D. A. Nash, Regional and Other Related Aspects of Shellfish Consumption - Some Preliminary Findings from the 1969 Consumer Panel Survey, U.S. Dept. of Commerce, National Marine Fisheries Service, Circular 361, June 1971.
6. J. K. Soldat, "A Statistical Study of the Habits of Fishermen Utilizing the Columbia River Below Hanford," Chapter 35 in (W. C. Reinig, Ed.), Environmental Surveillance in the Vicinity of Nuclear Facilities, Charles C. Thomas Publishers, Springfield, IL, 1970.
7. J. F. Honstead, Recreational Use of the Columbia River-Evaluation of Environmental Exposure, USAEC Report BNWL-CC-2299, Pacific Northwest Laboratory, Richland, WA, 1969.
8. J. K. Soldat, "Conversion of Survey Meter Readings to Concentration ($\mu\text{Ci}/\text{m}^2$)," Item 04.3.4 in Emergency Radiological Plans and Procedures, K. R. Heid (Ed.), USAEC Report HW-70935, Hanford Laboratories, Richland, WA, 1962.
9. C. M. Lederer, J. M. Hollander and I. Pearlman, Table of Isotopes, 6th Ed., John Wiley and Sons, Inc., New York, 1967.
10. S. E. Thompson, C. A. Burton, D. J. Quinn and Y. C. Ng, Concentration Factors of Chemical Elements in Edible Aquatic Organisms, USAEC Report UCRL-50564 Rev. 1, University of California, Lawrence Livermore Laboratory, October 1972.

III-A PART 1 REFERENCES (Continued)

11. A. M. Freke, "A Model for the Approximate Calculation of Safe Rates of Discharge of Radioactive Wastes into Marine Environments," Health Physics, vol. 13, p. 743, 1965.
12. J. L. Nelson, "Distribution of Sediments and Associated Radionuclides in the Columbia River below Hanford," (D. W. Pearce and J. K. Green, Eds.), Hanford Radiological Sciences Research and Development Annual Report for 1964, USAEC Report BNWL-36, Pacific Northwest Laboratories, Richland, WA, 1965.
13. G. L. Toombs, P. B. Culter (compilers), Comprehensive Final Report for the Lower Columbia River Environmental Survey in Oregon June 5, 1961 - July 31, 1967, Oregon State Board of Health, Div. of Sanitation and Engineering, Portland, OR, 1968.
14. Handbook of Radiological Protection, Part I: Data, prepared by a Panel of the Radioactivity Advisory Committee, (H. J. Dunster, Chairman), Dept. of Employment, Dept. of Health and Social Security, Ministry of Health and Social Services, Northern Ireland, number SBN 11 360079 8, Her Majesty's Stationery Office, London, England, 1971.
15. D. H. Slade (Ed.), Meteorology and Atomic Energy - 1968, USAEC Div. of Tech. Infor. Extension, TID-24190, Oak Ridge, TN, 1968.
16. P. M. Bryant, "Data for Assessments Concerning Controlled and Accidental Releases of ^{131}I and ^{137}Cs to Atmosphere," Health Physics, vol. 17, pp. 51-57, 1969.
17. International Commission on Radiological Protection, Report of Committee IV on Evaluation of Radiation Doses to Body Tissues from Internal Contamination due to Occupational Exposure, ICRP Publication 10, Pergamon Press, New York, pp. 65-66, 1968.
18. P. S. Rohwer and S. V. Kaye, Age Dependent Models for Estimating Internal Dose in Feasibility Evaluations of Plowshare Events, USAEC Report ORNL-TM-2229, Oak Ridge National Laboratory, Oak Ridge, TN, 1968.
19. H. N. Wellman, J. G. Kereiakes and B. M. Branson, "Total- and Partial-Body Counting of Children for Radiopharmaceutical Dosimetry Data," pp. 133-156 in (R. J. Cloutier, C. L. Edwards, W. S. Snyder Eds.), Medical Radionuclides: Radiation Dose and Effects, Proceedings of a Symposium held at Oak Ridge, TN. December 8-11, 1969, (Symposium Series 20), USAEC Div. of Techn. Inform., Oak Ridge, TN, June 1970.

III-A PART 1 REFERENCES (Continued)

20. K. E. Cowser et al., Dose Estimation Studies Related to Proposed Construction of an Atlantic-Pacific Interoceanic Canal with Nuclear Explosives: Phase I, USAEC Report ORNL-4101, Oak Ridge National Laboratory, Oak Ridge, TN.

APPENDIX III-A PART 2

Program FOOD

III-A Part 2 Program FOOD

III-A.1 Introduction

Program FOOD is designed to calculate radiation doses to man from ingestion of foods, such as produce, milk, eggs and meat produced on farms irrigated with water containing radionuclides. Concentrations of the radionuclides in the water and ingestion dose factors (mrem/yr per pCi/yr intake) are obtained by FOOD directly from the program ARRRG previously discussed in Appendix III-A, Part 1 and in Reference 1.

FOOD is based upon the use of sprinkler irrigation since this method of application should result in higher radionuclide concentrations in plants (and animals consuming them) than surface irrigation because of foliar deposition. Surface irrigation can be simulated if necessary by setting the factor for foliar retention to zero by editing the program. In addition, the program output lists the fractions of the individual radionuclide concentrations in the plants which result from foliar deposition and from soil uptake.

The program accounts for the consumption by the animals of both contaminated feed and drinking water. Since the program output lists the radionuclide concentrations in the final product, the internal radiation dose to beef, cattle, swine and chickens could be estimated in a manner analogous to calculation of internal dose to man. The assumption would have to be made that the concentration of the radionuclides in the meat represented the average equilibrium concentration in the whole animal.

III-A.2 Irrigated Vegetation

The concentration of radioactive material in vegetation results from deposition onto the plant foliage and from uptake from the soil of prior depositions on the ground. The model used for estimating the transfer of radionuclides from irrigation water to plants through both leaves and soil to food products was derived¹ for a study of the potential doses to people from a nuclear power complex in the year 2000.

The equation for the model is presented below in slightly modified form. The first term in brackets relates to the concentration derived from direct foliar deposition during the growing season; the second term, to uptake from soil, and reflects the deposition throughout the total life of the nuclear facility. Thus for a uniform release rate

$$C_{iv} = d_i \left[\frac{r T_v (1 - e^{-\lambda_{Ei} t_e})}{Y_v \lambda_{Ei}} + \frac{B_{iv} (1 - e^{-\lambda_i t_b})}{P \lambda_i} \right] e^{-\lambda_i t_h} \quad (1)$$

where

- C_{iv} • concentration of radionuclide i in edible portion of plant v (pCi/kg)
- d_i • deposition rate [pCi/(m²·hr)]
- r • fraction of deposition retained on plant (unitless), taken to be 0.25 for sprinkler irrigation
- T_v • factor for the translocation of externally deposited radionuclide to edible parts of plants (unitless). Assumed to be independent of radionuclide and taken to be 1 for leafy vegetables and fresh forage, and 0.1 for all other produce, including grain.
- λ_{Ei} • effective removal constant of radionuclide i from plant (hr⁻¹) $\lambda_{Ei} = \lambda_i + \lambda_w$, where λ_w = weathering removal constant = 0.693/14 (day⁻¹)
- t_e • time of above ground exposure of crop to contamination during growing season (hr)
- Y_v • plant yield [kg(wet weight)/m²]
- B_{iv} • concentration factor for plant uptake of nuclide i to edible part of plant from soil [pCi/kg(wet weight) per pCi/kg (dry soil)]
- t_b • time for buildup of radionuclide in soil (hr), taken to be 30 years for typical power reactor

- P • soil "surface density" [kg(dry soil)/m²]. Assuming a uniform mixing of all radionuclides in a plowlayer of 15 cm (6 in.) depth, P has a value of approximately 224 kg/m².
- t_h • holdup time (hr⁻¹). The time between the time from harvest to consumption of the food.

The deposition rate d_i from irrigation water is defined by the relation

$$d_i = C_{iw} I \text{ (water deposition)} \quad (2)$$

where

- C_{iw} • concentration of radionuclide i in water used for irrigation (pCi/ℓ)
- I • irrigation rate [ℓ/(m²·hr)]. Amount of water sprinkled on unit area of field in 1 hour.

The dose rate in mrem/yr to a particular organ r would then be given by Equation 3 for n radionuclides i via a particular vegetable pathway v:

$$R_{vr} = \sum_{i=1}^n C_{iv} U_v D_{ivr} \quad (3)$$

where

- R_{vr} • the dose rate to organ r from all nuclides via pathway v (ingestion of a particular irrigated food)
- C_{iv} • the concentration of nuclide i in the media of pathway v
- U_v • usage: the intake rate of food v
- D_{ivr} • a dose factor: a number specific to a given nuclide i, pathway v, and organ r which can be used to calculate radiation dose from the intake rate of that radionuclide. In this instance pathway v is ingestion and the dose factor has units of mrem/yr per pCi/yr ingested. (These factors are listed under the ARRRG program description in Appendix III-A, Part 1.)

III-A.3 Animal Products

The radionuclide concentration in an animal product such as meat, milk or eggs is dependent on the amount of contaminated feed or forage eaten by the animal and its uptake of contaminated water. The following equation describes this model for the concentration in animal products.²

$$C_{ia} = S_{ia} \left[C_{iF} Q_F + C_{iaw} Q_{aw} \right] \quad (4)$$

where

- C_{ia} • concentration in animal produce (pCi/l) or (pCi/kg)
- S_{ia} • transfer coefficient of radionuclide i from daily intake of animal to edible portion of animal product [pCi/l (milk) per pCi/day] or [pCi/kg (animal product) per pCi/day]
- C_{iF} • concentration of nuclide i in feed or forage (pCi/kg) calculated from Equation 1 above
- Q_F • consumption rate of contaminated feed or forage by animal (kg/day)
- C_{iaw} • concentration of nuclide i in water consumed by animals (pCi/l). Assumed usually to be equal to C_{iw}
- Q_{aw} • consumption rate of contaminated water by animal (l/day)

The second set of terms in the brackets in Equation 4 can be omitted if the animal does not drink contaminated water. Average consumption rates assumed for this study are listed in Table III-A-25.

The dose from the consumption of animal products is given by Equation 3 with C_{ia} substituted for C_{iv} .

For a cow grazing on fresh forage, t_e in Equation 1 is set equal to 720 hours (30 days), the typical time for a cow to return to a particular portion of the grazing site.

TABLE III-A-25
ANIMAL CONSUMPTION RATES^(a)

	QF Feed or Forage (kg/day)	QAW Water (l/day)
Milk cow	55 (pasture grass)	60
Beef cattle	68 (stored feed grain)	50
Pig	4.2 (stored feed grain)	10
Chicken	0.12 (grain)	0.3

(a) From Reference 2 Page 108, Table III-10.

Values for the various plant concentration factors and animal product transfer coefficients for the elements considered are given in Table III-A-26. For the plant concentration factors Reference 2 was consulted and modified at times. Transfer coefficients were also taken from the literature where available for beef,² pork,² poultry,² eggs,^{2,3} and milk.⁴ The milk transfer coefficients of Reference 4 were reduced by a factor of one-half to account for average transfer of radionuclides from grass to milk via a cow, rather than maximum.

For the Hanford Waste Management Operations Environmental Impact Statement the contribution to the radiation doses to the Maximum Individual were estimated using the parameters listed in Table III-A-27. Essentially no wheat or pasture land is irrigated with Columbia River water downstream of the Hanford project. On infrequent occasions hay harvested from irrigated land is fed to milk cows and traces of ⁶⁵Zn will appear for short periods of times in farm milk.

The dose to the total population in the vicinity of Hanford from irrigated foods was estimated as explained in the main text. It was assumed that a total of less than 2000 persons could be fed with the

TABLE III-A-26

PLANT CONCENTRATION FACTORS AND ANIMAL
PRODUCT TRANSFER COEFFICIENTS^(a)

Element	B _{iv}	S _{ia}				
	Plant Soil (Dimensionless)	Egg/Feed (day/egg)	Milk/Feed (day/l)	Beef/Feed (day/kg)	Pork/Feed (day/kg)	Poultry/Feed (day/kg)
H	0.2	1	0.01	1	1	1
C	5.5	1	0.0075	1.0	1	1
Na	0.05	0.01	0.025	0.05	0.1	0.01
P	1.1	0.1	0.012	0.033	0.54	0.19
Sc	0.0011	*	2.5 x 10 ⁻⁶	*	*	*
Cr	0.00025	*	0.0011	*	*	*
Mn	0.029	0.005	0.00012	0.005	0.01	0.001
Fe	0.0004	0.005	0.0006	0.001	0.005	0.001
Co	0.0094	0.005	0.0005	0.001	0.005	0.001
Ni	0.019	0.005	0.0034	0.001	0.005	0.001
Cu	0.13	0.010	0.007	0.002	0.005	0.002
Zn	0.4	0.0002	0.02	0.002	0.005	0.002
Sr	0.2	0.007	0.001	0.002	0.008	0.0009
Y	0.0025	1 x 10 ⁻⁵	1 x 10 ⁻⁵	0.006	0.01	0.004
Zr	0.00017	6 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.0005	0.001	0.0001
Nb	0.0094	2 x 10 ⁻⁵	0.0012	0.0005	0.001	0.0001
Mo	0.13	0.0070	0.0038	0.01	0.02	0.002
Tc	0.25	*	0.012	*	*	*
Ru	0.01	7 x 10 ⁻⁵	5 x 10 ⁻⁷	0.001	0.005	0.0003
Rh	0.13	7 x 10 ⁻⁵	0.005	0.001	0.005	0.0003
Sn	0.0025	1 x 10 ⁻⁵	0.0025	0.0025	0.005	0.002
Sb	0.011	*	0.00075	*	*	*
Te	1.3	0.007	0.0005	0.005	0.01	0.01
I	0.02	0.03	0.01	0.02	0.09	0.004
Cs	0.003	0.02	0.007	0.03	0.04	0.4
Ba	0.005	0.006	0.0003	0.0005	0.002	0.0005
La	0.0025	4 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.01	0.004
Ce	0.0005	5 x 10 ⁻⁵	1 x 10 ⁻⁵	0.001	0.005	0.0006
Pr	0.0025	4 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.01	0.004
Nd	0.0024	4 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.01	0.004
Pm	0.0025	4 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.01	0.004
Sm	0.0025	4 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.01	0.004
Eu	0.0025	4 x 10 ⁻⁵	5.5 x 10 ⁻⁶	0.005	0.01	0.004
U	0.0025	5 x 10 ⁻⁵	0.0005	0.005	0.0001	0.004
Np	0.0025	5 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.0001	0.004
Pu	0.00025	5 x 10 ⁻⁵	7.5 x 10 ⁻⁷	0.005	0.0001	0.004
Am	0.00025	5 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.0001	0.004
Cm	0.0025	5 x 10 ⁻⁵	2.5 x 10 ⁻⁶	0.005	0.0001	0.004

*Value unknown or very small; assumed to be zero for calculations.

(a) For use in Equations 1 and 4.

TABLE III-A-27

FOOD INPUT WORKSHEET

REACTOR NAME HEIS - 100-N + 100-F + 300 A

DATE May 1974

TITLE Dose to Maximum Individual

FOOD TYPES	HOLDUP (day)	CONSUMPTION (kg/yr or /yr)	IRRIGATION RATE (l/m ² /mo)	YIELD (kg/m ²)	GROWING PERIOD (day)
1. Leafy Vegetables	1	30 ^(b)	150	1.5	90
2. O.A.G. ^(a) Vegetables	1	30 ^(b)	160	0.7	60
3. Potatoes	10	110	180	4.0	90
4. Other Root Vegetables	1	72	150	5.0	90
5. Berries	1	30	150	2.7	60
6. Melons	1	40	150	0.8	90
7. Orchard Fruit	10	265	150	1.7	90
8. Wheat	10	80	0	0.72	90
9. Other Grain	1	8 ^(b)	150	1.4	90
10. Eggs	1	30	150	(0.84) ^(c)	90
11. Milk	1	274 ^(b)	0	(1.3)	30 ^(d)
12. Beef	15	40	140	(0.84)	90
13. Pork	15	40	140	(0.84)	90
14. Poultry	1	18	140	(0.84)	90

RIVER FLOW IN CFS 160,000

MIXING RATIO 1

RECONCENTRATION MODELS

- ☐ 1 Simplified theoretical model
 VOLUME _____ ft³
 MAKEUP FLOW _____ cfs

TURNOVER RATE _____ day⁻¹
 CYCLE TIME _____ hr

- ☐ 2 Empirical model
 RECYCLE FRACTION _____

CYCLE TIME _____ hr

- ☒ 3 No reconcentration

NOTES:

(a) Other Above Ground

(b) During irrigation season only.

(c) () indicates yield of animal feed.

(d) Length of time before cow returns to same piece of pasture.

river-irrigated foods produced at the Ringold and Riverview areas. Since the average adult diet is generally about one-half of the Maximum Individual's diet, the man-rem dose to the population would be approximately numerically equal to the total-body dose (in mrem) to the maximum individual, that is

$$2000(\text{people}) \times 0.5(\text{diet}) \times 10^{-3} \left(\frac{\text{rem}}{\text{mrem}} \right) = 1.0$$

III-A PART 2 REFERENCES

1. J. K. Soldat, et al., Models and Computer Codes for Evaluating Environmental Radiation Doses, USAEC Report BNWL-1754, Battelle, Pacific Northwest Laboratory, Richland, WA, February 1974.
2. J. F. Fletcher and W. L. Dotson (compilers), HERMES - A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry, USAEC Report HEDL-TME-71-168, Hanford Engineering Development Laboratory, Richland, WA, 1971.
3. F. R. Mraz, et al., "Fission Product Metabolism in Hens and Transference to Eggs," Health Physics, vol. 10, pp. 777-782, 1964.
4. Y. C. Ng, et al., Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices - IV, Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere, USAEC Report, UCRL-50163, Pt.IV. Lawrence Radiation Lab., Univ. of California, Livermore, CA, 1968.

APPENDIX III-B

DESCRIPTION OF MATHEMATICAL MODELS USED IN DOSE CALCULATIONS

III-B DESCRIPTION OF MATHEMATICAL MODELS USED IN DOSE CALCULATIONS

This appendix describes mathematical models used to calculate external and internal doses from the accidental release of radionuclides from nuclear facilities.

III-B.1 Atmospheric Dispersion Models

The atmospheric dispersion of radionuclides can be described mathematically by a bivariate normal distribution model which has been in use at Hanford for many years. The standard deviations of the cloud concentration in the crosswind lateral and vertical directions can be estimated from any of the several methods in common use; i.e., Sutton's parameters, Hanford equations, or Pasquill's curves. Using this model, the air concentration at ground level is given by:

$$X = \frac{Q'}{\pi \sigma_y \sigma_z \bar{u}_h} \exp \left(-y^2/2 \sigma_y^2 - h^2/2 \sigma_z^2 \right) \quad (1)$$

where:

- X • ground level air concentration at the coordinates x and y , Ci/m^3
- x • downwind distance measured from point of release, meters
- y • crosswind distance measured horizontally from centerline of cloud, meters
- Q' • apparent rate of release at receptor, $\text{Ci/sec}^{(a)}$
- σ_y • crosswind lateral standard deviation of cloud concentration, m
- σ_z • crosswind vertical standard deviation of cloud concentration, m
- $\bar{u}_h$ • average wind speed at the height of release in direction of travel, m/sec
- h • height of release, m

(a) apparent rate of release at receptor is the rate of release at the source corrected for radioactive decay during time of transport to receptor

III-B.1.1 Accidental Release

The time-integrated air concentration is convenient to use when calculating doses resulting from accidental releases of short duration. Also, use of the cloud centerline air concentration results in a maximum estimate of this quantity thereby maximizing the resultant dose. The centerline time-integrated air concentration is given by:

$$E_o = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}_h} \exp (-h^2/2\sigma_z^2) \quad (2)$$

where:

- E_o • time-integrated air concentration at ground level beneath the centerline of the cloud, Ci·sec/m³
- Q • total release from source, curies.

The crosswind standard deviations, σ_y and σ_z , for stable atmospheric conditions are calculated by the Hanford model^{1,2} as follows:

$$\sigma_y^2 = A [T - \alpha(1 - e^{-T/\alpha})] \quad (3a)$$

$$\sigma_z^2 = a(1 - e^{-k^2 T^2}) + bT \quad (3b)$$

where: T • transport time from point of release to point of interest, sec

and: $A = c + d(\sigma_\theta \bar{u})$

$$\alpha = \frac{A}{2(\sigma_\theta \bar{u})^2}$$

and a, b, c, d, k and $(\sigma_\theta \bar{u})$ are parameters describing the atmospheric condition. Table III-B-1 summarizes parameter values used in this study.

TABLE III-B-1

VALUES OF METEOROLOGICAL PARAMETERS
FOR THE HANFORD MODEL

<u>Parameter</u>	<u>Moderately Stable Conditions</u>	<u>Very Stable Conditions</u>
a	97	34
b	0.33	0.025
c	13	13
d	230	230
k	2.5×10^{-4}	8.8×10^{-4}

MINIMUM VALUES OF $(\sigma_{\theta} \bar{u})$

<u>Assumed Duration of Release, min</u>	<u>$(\sigma_{\theta} \bar{u})$</u>
10	0.024
60	0.040
120	0.080
240	0.10
480	0.18

Crosswind standard deviations calculated for unstable and neutral conditions with Sutton's parameters are:

$$\sigma_y^2 = 0.5C_y^2 \times (2 - n) \quad (4a)$$

$$\sigma_z^2 = 0.5C_z^2 \times (2 - n) \quad (4b)$$

where:

- n • atmospheric stability index
- C_y • virtual diffusion parameter in the horizontal crosswind direction
- C_z • virtual diffusion parameter in the vertical crosswind direction.

Representative values of the parameters n, C_y and C_z are tabulated in Table III-B-2.

Numerical values of σ_y and σ_z in use at Hanford representative of Pasquill's curves are listed in Tables III-B-3 and III-B-4.

III-B.1.2 Chronic Release

Normal operations involving chronic low level release rates usually requires determination of average air concentrations within geometric sectors surrounding the facility. These average concentrations are determined by:

$$\bar{x}_{\text{sect}} = \frac{0.01 Q' f_d}{w} \left(\frac{2}{\pi} \right)^{1/2} \sum_i \sum_j \frac{f_{ij} \exp \left[-h^2 / 2 (\sigma_z^2)_{ij} \right]}{(\sigma_z)_{ij} (\bar{u}_h)_i} \quad (5)$$

TABLE III-B-2

NUMERICAL VALUES OF ATMOSPHERIC DISPERSION PARAMETERS
FOR NEUTRAL AND UNSTABLE ATMOSPHERES

<u>Parameter</u>	<u>Release Level</u>	<u>Wind Speed</u>	<u>Unstable</u>	<u>Neutral</u>
C_y	Ground	1 m/s	0.35	0.21
		5 m/s	0.30	0.15
		10 m/s	0.28	0.14
	Elevated	1 m/s	0.30	0.15
		5 m/s	0.26	0.12
		10 m/s	0.24	0.11
C_z	Ground	1 m/s	0.35	0.17
		5 m/s	0.30	0.14
		10 m/s	0.28	0.13
	Elevated	1 m/s	0.30	0.15
		5 m/s	0.26	0.12
		10 m/s	0.24	0.11
n			0.20	0.25

TABLE III-B-3

VALUES OF σ_y FOR PASQUILL STABILITY CATEGORIES

DISTANCE METERS	σ_y for Pasquill Type					
	A	B	C	D	E	F
100	21	16	12	8.0	6.0	3.9
150	34	24	18	12	9.0	6.0
250	54	40	28	20	14	9.8
350	75	55	40	26	20	14
500	100	76	55	37	28	18
700	140	110	76	51	37	26
1,000	200	150	110	72	52	36
1,500	290	220	160	100	75	52
2,500	450	340	240	160	120	81
3,500	610	460	330	220	160	110
5,000	830	630	450	310	220	150
7,000	1,100	840	610	420	300	210
10,000	1,600	1,200	850	570	410	280
15,000	2,200	1,700	1,200	810	570	400
25,000	3,400	2,600	1,800	1,200	880	610
35,000	4,500	3,500	2,500	1,700	1,200	820
50,000	6,200	4,700	3,400	2,300	1,600	1,100
70,000	8,200	6,400	4,700	3,000	2,100	1,500
100,000	11,000	8,500	6,300	4,100	2,800	2,000

TABLE III-B-4

VALUES OF σ_z FOR PASQUILL STABILITY CATEGORIES

DISTANCE METERS	σ_z for Pasquill Type					
	A	B	C	D	E	F
100	15	10	7.8	4.7	3.0	1.4
150	22	15	11	6.8	4.3	2.2
250	43	26	18	10	7.1	4.0
350	70	37	24	14	9.4	5.3
500	140	57	34	19	13	7.6
700	270	86	46	25	17	10
1,000	670	140	64	33	22	14
1,500	2,000	240	90	43	29	18
2,500	2,000	580	140	62	41	25
3,500	2,000	1,200	190	76	50	30
5,000	2,000	2,000	260	95	61	35
7,000	2,000	2,000	340	120	72	41
10,000	2,000	2,000	440	140	84	47
15,000	2,000	2,000	600	170	99	55
25,000	2,000	2,000	880	220	120	64
35,000	2,000	2,000	1,100	260	130	72
50,000	2,000	2,000	1,400	320	140	79
70,000	2,000	2,000	1,800	370	160	86
100,000	2,000	2,000	2,000	450	170	94

where terms not previously defined are:

- $\bar{X}_{\text{sect}}$ • sector average air concentration at ground, Ci/m³
- w • sector width ($=2\pi x/n$), meters
- n • number of equal sized sectors in 360 degrees
- f_{ij} • joint frequency of occurrence release in sector
for wind speed interval i and stability class j.

III-B.2 Total Body Tissue Dose from Gamma Radiation

The basic equation for the external total body tissue dose rate from a gamma emitting radionuclide present in the incremental volume of a cloud is:³

$$d_Y = K_k \frac{\chi B(\mu_k r) \exp(-\mu_k r)}{4\pi r^2} dx dy dz \quad (6)$$

where:

- d_Y • incremental dose rate to tissue, (rad/sec)/(MeV/dis),
from gamma radiation emitted from an incremental
cloud volume, dx, dy, dz at a distance r meters from
the point of interest
- χ • concentration in incremental cloud volume, Ci/m³
- $B(\mu_k r)$ • dose buildup factor for air
- μ_k • total linear attenuation coefficient in air, m⁻¹,
for photons with gamma energy in energy group k
- K_k • dose conversion factor, (rad·m²)/(Ci·sec) per MeV/
disintegration.

$$K_k = \frac{3.70 \times 10^{10} \frac{\text{dis}}{\text{Ci} \cdot \text{sec}} \cdot 1.60 \times 10^{-6} \frac{\text{erg}}{\text{MeV}} \cdot 10^{-4} \frac{\text{m}^2}{\text{cm}^2} \left(\frac{\mu_\alpha}{\rho} \right)_k}{100 \frac{\text{ergs}}{\text{g} \cdot \text{rad}}}$$

$$= 0.0592 \left(\frac{\mu_\alpha}{\rho} \right)_k$$

where:

$\left(\frac{\mu_a}{\rho}\right)_k$ • mass absorption coefficient, cm^2/g in tissue for average gamma energy of energy group k.

A quadratic expression is used to calculate the dose buildup factor.

$$B(\mu_k r) = 1 + A_k \mu_k r = \alpha_k (\mu_k r)^2 \quad (7)$$

where:

A_k and α_k are constants empirically determined to fit buildup factor data of Berger.⁴

Since dose rate is a function of γ -ray energy, the gamma spectrum has been divided into energy groups. The incremental dose is calculated separately as a function of photon energy and integrated over the cloud volume to obtain dose rate factors for each energy group. The dose rate factors are coupled with radionuclide release rate data, duration of release, and site climatology data to give dose.

The beta dose calculation is considerably simpler than the gamma dose calculation. Because of the short range of beta particles in air, the radionuclide cloud may be assumed to be semi-infinite in dimension. With this assumption, the tissue beta dose is:¹

$$D_d^\beta = 0.23 \bar{E}_\beta Q(E/Q) (D_d/D_0) \quad (8)$$

where:

- D_d^β • beta dose at depth d in tissue, rads
- $\bar{E}_\beta$ • average beta energy, MeV/dis
- Q • quantity of radionuclide released, Ci
- E • time-integrated air concentration, $\text{Ci} \cdot \text{sec}/\text{m}^3$
- D_d/D_0 • depth dose correction factor.

The depth dose correction factors for several tissue depths have been calculated⁵ and their energy dependence is illustrated in Figure III-B-1.

FIGURE III-B-1 RATIO OF DEPTH DOSE TO SURFACE DOSE AS A FUNCTION BETA ENERGY SPECTRA (for infinite plane source of infinite thickness and for allowed spectra)

III-B.3 Inhalation Dose Models

Two lung models have been recommended by the International Commission on Radiological Protection (ICRP). The initial lung model, recommended in ICRP Publication 2 and hereinafter referred to as the ILM, treats the inhaled material as either soluble or insoluble. When the inhaled material is soluble, the uptake by other organs is assumed to be essentially instantaneous. The more sophisticated lung model, recently recommended by ICRP Publication 19 and hereinafter referred to as the TGLM, treats the inhaled material in a more complex way. The derived equations for estimating the dose to organs other than the lung are considerably more complex than those for the ILM. A computer program has been developed for calculating the dose to lung and other organs using the TGLM.⁶

III-B.3.1 ILM

The dose to an organ of interest via inhalation using the ILM, from a radionuclide accidentally released to the atmosphere, is given by:

$$D = f_a k P_s \left\{ \left[1 - \exp(-\lambda_e t) \right] \right\}, \text{ rem}$$

$$P_s = b Q' \tau (E/Q) = b Q (E/Q), \mu\text{Ci}$$

$$D = b (f_a k) Q (E/Q) \left\{ \left[1 - \exp(-\lambda_e t) \right] \right\}, \text{ rem} \quad (9)$$

where:

- D • dose to organ of interest delivered over time t, rem
- f_a • fractional uptake, via inhalation by organ of interest
- k • dose conversion factor for organ of interest, rem per μCi in organ
- P_s • quantity inhaled, μCi
- λ_e • effective elimination rate constant, d^{-1}
- t • time following initial intake, d
- b • ventilation rate for standard man, cm^3/sec

- $b = 350 \text{ cm}^3/\text{sec}$ (8 hour working rates)
- $b = 230 \text{ cm}^3/\text{sec}$ (24 hour daily rate)
- Q' • atmospheric release rate, Ci/sec
- τ • duration of release (exposure), sec
- Q • quantity released, Ci
- E/Q • time integrated air concentration normalized to quantity released, Ci-sec/ m^3 per Ci.

The dose from inhalation during chronic atmospheric releases is given by:

$$D = f_a k \frac{P}{\lambda_e} \left\{ \lambda_e t - [1 - \exp(-\lambda_e t)] \right\} \quad (10)$$

where previously undefined terms are:

P • daily intake, $\mu\text{Ci}/\text{day}$

$P = 86400 b \bar{\chi}_{\text{sect.}}$

When the chronic intake is interrupted at time, t_1 say, then the dose is determined by:

$$D = f_a k \frac{P}{\lambda_e} \left(\lambda_e t - \left\{ \exp \left[-\lambda_e (t - t_1) \right] \right\} [1 - \exp (-\lambda_e t_1)] \right) \quad (10a)$$

III-B.3.2 TGLM

The mathematical model for calculating the dose to an organ of interest via inhalation using the TGLM is considerably more complex than that utilized by the ILM. In the TGLM, the respiratory tract is divided into three regions, the nasopharyngeal (NP), the tracheobronchial (TB), and the pulmonary (P). The schematic representation of the respiratory tract used in the development of the mathematical model for the deposition and clearance of inhaled radionuclides is shown in Figure III-B-2. Deposition is assumed to vary with the aerodynamic properties of the aerosol distribution and is described by the three parameters D_3 , D_4 , and D_5 . These

FIGURE III-B-2 SCHEMATIC DIAGRAM OF ICRP TASK GROUP LUNG MODEL

parameters represent the fraction of the inhaled material initially deposited in the NP, TB and P regions, respectively. Each of the three regions of deposition are further subdivided into two or more subcompartments, each representing the fraction of material initially in a compartment that is subject to a certain clearance process. This fraction is represented by f_k , where k indicates the clearance pathway. The quantity of material in the TB region, for example, cleared by process (c) is then represented by the product $f_c D_4 Q_I$. Values of the (f_k) and the clearance half times T_k for each clearance process for the three solubility classes of aerosols used in the computer code are shown in Table III-B-5.⁶ Values of the deposition fractions D_3 , D_4 , and D_5 as function of activity median aerodynamic diameter in the form of a graph have been published.⁷

The respiratory tract model was incorporated into the simple metabolic model.⁸ Transport of the radionuclides from the respiratory tract, lymph, and G.I. tract to organs and tissues where significant accumulations of the inhaled activity occur, is assumed to take place via the blood. The report of the Task Group⁷ describes this translocation of the activity from the respiratory tract and lymph to the blood in some detail. Of the material clearing from the respiratory tract through the G.I. tract, a constant fraction is assumed to be taken up by the blood. Uptake by the nth organ or tissue is assumed to be a constant fraction of the amount entering the blood stream at any time. Once in the nth organ, the activity is assumed to clear the organ and the body at a constant rate.

The dose commitment for both individual and population inhalation exposure was based on an inhalation time equivalent to either the duration of the release, the accidental releases or one year for a chronic release. In this study, two dose commitment values are usually calculated - one corresponding to the dose delivered in the first year following exposure and the other corresponding to the dose delivered over a 50-year interval following exposure.

TABLE III-B-5

VALUES OF THE CLEARANCE PARAMETERS
FOR THE TASK GROUP LUNG MODEL

COMPARTMENT	k ^(a)	SOLUBILITY CLASS					
		D		W		Y	
		T _k ^(b)	f _k ^(c)	T _k	f _k	T _k	f _k
NP	a	0.01	0.5	0.01	0.1	0.01	0.01
	b	0.01	0.5	0.40	0.9	0.4	0.99
TB	c	0.01	0.95	0.01	0.5	0.01	0.01
	d	0.2	0.05	0.2	0.5	0.2	0.99
P	e	0.5	0.8	50	0.15	500	0.05
	f	n.a.	n.a.	1	0.4	1	0.4
	g	n.a.	n.a.	50	0.4	500	0.4
	h	0.5	0.2	50	0.05	500	0.15
L	i	0.5	1	50	1	1000	0.9

(a) Metabolic pathways from lung.

(b) Removal half time in days from compartment via pathway k.

(c) Fraction removed from compartment via pathway k.

Notation for the equations found in this section is as follows:

$D_{1n}(T_1)$ is the dose equivalent in rem received by the nth organ or tissue by time T_1 during continuous inhalation of a radioactive aerosol.

$D_{2n}(T_2)$ is the dose equivalent in rem received by the nth organ or tissue by time T_2 following the termination of continuous inhalation of a radioactive aerosol.

$Q_{1n}(T_1)$ is the quantity of radioactive material in μCi present in the nth organ or tissue as a function of time during continuous inhalation of a radioactive aerosol.

$Q_{2n}(T_2)$ is the quantity of radioactive material in μCi present in the nth organ or tissue following the termination of continuous inhalation of a radioactive aerosol.

E_n is the effective absorbed energy per disintegration in $\frac{\text{MeV} \cdot \text{rem}}{\text{dis} \cdot \text{rad}}$ for the nth organ or tissue.

M_n is the mass in grams of the nth organ or tissue over which the dose is to be averaged.

λ_k^b is the biological removal rate constant for the kth subcompartment of the respiratory tract in seconds.

λ is the radiological decay constant of the nuclide of interest in seconds.

λ_k is the total removal rate constant for the kth subcompartment of the respiratory tract in seconds and equals $\lambda_k^b + \lambda$.

λ_n^b is the biological removal rate constant for the nth organ or tissue in seconds.

- λ_n is the total effective removal rate constant for the nth organ or tissue in seconds and equals $\lambda_n^b + \lambda$.
- f_2^i is the fraction of material in the blood that reaches the organ or tissue of interest.
- f_1 is the fraction of material in the G.I. tract that reaches the blood.
- P_0 is the rate at which the radioactive aerosol is inhaled in $\mu\text{Ci/sec}$.
- f_k is the fraction of the material in a deposition region, NP, etc., that clears by the kth pathway.
- D_3 is the fraction of the material inhaled deposited in the NP region.
- D_4 is the fraction of the material inhaled deposited in the TB region.
- D_5 is the fraction of the material inhaled deposited in the P region.
- T_1 is the total uptake time in seconds.
- T_2 is the time following termination of uptake, usually 1 or 50 years.

Developing the equations to describe the lung clearance model was divided into two parts. The first part is concerned with describing the quantity present and the dose to the respiratory tract subcompartments and other organs during the inhalation of radionuclides. The second part, requiring a different set of equations, describes the burdens in and the dose to the organs or tissues for a contiguous period of time following the termination of uptake.

During uptake, the equations for computing the quantity of radionuclide in the eight subcompartments of the respiratory tract have the form

$$Q_{1Pe}(t) = f_e D_5 P_o \frac{(1-e^{-\lambda_e t})}{\lambda_e} \quad (11)$$

The equations for the removable quantity in the lymph are complicated by the fact that both equal and unequal rates for transfer paths into and out of the lymph are involved. This is due to the dependence of transfer rate upon the solubility class of the radionuclide. Thus, two equations are needed to compute the quantity in the lymph.

For the case $\lambda_h \neq \lambda_i$, i.e., class y solubility in the current version of the model:

$$Q_{LMi}(t) = \frac{\lambda_h^b f_i f_h P_o D_5}{\lambda_h} \left[\frac{(1-e^{-\lambda_i t})}{\lambda_i} - \frac{(e^{-\lambda_i t} - e^{-\lambda_h t})}{\lambda_h - \lambda_i} \right] \quad (12)$$

and for the case $\lambda_h = \lambda_i$, i.e., class D and W in the current version of the model:

$$Q_{LMi}(t) = \frac{\lambda_h^b f_i f_h P_o D_5}{\lambda_h} \left[\frac{(1-e^{-\lambda_i t})}{\lambda_i} - t e^{-\lambda_i t} \right] \quad (13)$$

With the preceding equations, the equations describing the quantity of radionuclide in an organ as a function of time during uptake can be derived by:

$$Q_{1n}(t) = f_2' P_o \sum_{j=a}^g C_j \left[\frac{(1-e^{-\lambda_n t})}{\lambda_n} - \frac{(e^{-\lambda_n t} - e^{-\lambda_j t})}{(\lambda_j - \lambda_n)} \right] + L \quad (14)$$

where:

L = the contribution to the organ burden from material passing through the lymph,

and:

$$C_a = \lambda_a^b f_a D_3 / \lambda_a$$

$$C_b = \lambda_b^b f_b D_3 f_1 / \lambda_b$$

$$C_c = \lambda_c^{b_{fc}} D_4 / \lambda_c$$

$$C_d = \lambda_d^{b_{fd}} D_4 f_1 / \lambda_d$$

$$C_e = \lambda_e^{b_{fe}} D_5 / \lambda_e$$

$$C_f = \lambda_f^{b_{ff}} D_5 f_1 / \lambda_f$$

$$C_g = \lambda_g^{b_{fg}} D_5 f_1 / \lambda_g$$

The lymph pathway contributions to the organ burden for the two situations are calculated as follows:

for $\lambda_h \neq \lambda_i$:

$$L = f_2' C_h \left\{ \frac{1}{\lambda_i} \left[\frac{(1-e^{-\lambda_n t})}{\lambda_n} - \frac{(e^{-\lambda_n t} - e^{-\lambda_i t})}{(\lambda_i - \lambda_n)} \right] - \frac{1}{(\lambda_i - \lambda_n)} \left[\frac{(e^{-\lambda_n t} - e^{-\lambda_i t})}{(\lambda_i - \lambda_n)} \right] - \frac{(e^{-\lambda_n t} - e^{-\lambda_h t})}{(\lambda_h - \lambda_n)} \right\} \quad (15)$$

$$\text{where: } C_h = \frac{\lambda_i \lambda_h f_i f_h D_5}{\lambda_h}$$

for $\lambda_h = \lambda_i$:

$$L = f_2' C_h \left\{ \frac{1}{\lambda_i} \left[\frac{(1-e^{-\lambda_n t})}{\lambda_i} \right] - \frac{(e^{-\lambda_n t} - e^{-\lambda_i t})}{(\lambda_i - \lambda_n)} - \frac{(e^{-\lambda_n t} - e^{-\lambda_i t}) (\lambda_i - \lambda_n) (t+1)}{(\lambda_i - \lambda_n)^2} \right\} \quad (16)$$

The calculation of the dose equivalents received by the tissues at risk are based on the following:

$$D_{1n}(t) = \frac{5.92 \times 10^{-4} E_n}{M_n} \int_0^t Q_{1n}(\tau) d\tau \quad (17)$$

where

$$5.92 \times 10^{-4} = 3.7 \times 10^4 \left(\frac{\text{dis/sec}}{\mu\text{Ci}} \right) 1.6 \times 10^{-6} \left(\frac{\text{ergs}}{\text{MeV}} \right) 10^{-2} \left(\frac{\text{rads}}{\text{erg/g}} \right).$$

The dose computations for the pulmonary lung and the nth organ or tissue at the end of inhalation uptake for a time T_1 are made using the following equations:

for the pulmonary lung:

$$D_{lp}(T_1) = \frac{5.92 \times 10^{-4} E_p P_{oD5}}{M_p} \sum_{j=e}^h \frac{f_j}{\lambda_j} \left(T_1 - \frac{1 - e^{-\lambda_j T_1}}{\lambda_j} \right) \quad (18)$$

where M_p is the mass of the lung in grams

for the nth organ or tissue when $\lambda_h \neq \lambda_i$:

$$D_{ln} = 5.92 \times 10^{-4} \frac{E_n P_{oD5} f'_2}{M_n} \left\{ \sum_{j=a}^g C_j \left[T_1 - A_n - \left(\frac{A_n - A_j}{\lambda_j - \lambda_n} \right) \right] \right. \\ \left. + \frac{C_h}{\lambda_i} \left[\frac{T_1 - A_n}{\lambda_n} - \frac{A_n - A_i}{(\lambda_i - \lambda_n)} \right] - \frac{C_h}{(\lambda_h - \lambda_i)} \left[\frac{A_n - A_i}{(\lambda_i - \lambda_n)} \right. \right. \\ \left. \left. - \frac{A_n - A_h}{\lambda_h - \lambda_n} \right] \right\} \quad (19)$$

where:

$$A_n = \frac{1 - \exp(-\lambda_n T_1)}{\lambda_n}$$

$$A_j = \frac{1 - \exp(-\lambda_j T_1)}{\lambda_j}$$

$$A_i = \frac{1 - \exp(-\lambda_i T_1)}{\lambda_i}$$

$$A_h = \frac{1 - \exp(-\lambda_h T_1)}{\lambda_h}$$

for the nth organ or tissue when $\lambda_h = \lambda_i$:

$$\begin{aligned} D_n(T_1) = & 5.92 \times 10^{-4} \frac{E_n P_o f'_2}{M_n} \left(\sum_{j=a}^g C_j \left(\frac{T_1 - A_n}{\lambda_n} - \frac{A_n - A_j}{\lambda_j - \lambda_n} \right) \right. \\ & + \frac{C_n}{\lambda_i} \left(\frac{T_1 - A_n}{\lambda_n} - \frac{A_n - A_i}{\lambda_i - \lambda_n} \right) - \frac{C_h}{(\lambda_i - \lambda_n)^2} \left\{ A_i - A_n \right. \\ & \left. \left. + \frac{(\lambda_i - \lambda_n)}{\lambda_i^2} \left[1 - (\lambda_i T_1 + 1) e^{-\lambda_i T_1} \right] \right\} \right) \end{aligned} \quad (20)$$

where C_j and C_h are as previously defined.

Now for the time following termination of uptake, the equations used to calculate the respiratory tract burden and the other organ or tissue burdens become:

$$Q_{2j}(T_2) = Q_{1j}(T_1) e^{-\lambda_j T_2} \quad (21)$$

where: $Q_{2j}(T_2)$ is the respiratory tract subcompartment burden at a time T_2 following the termination of inhalation uptake.

$Q_{1j}(T_1)$ is the respiratory tract subcompartment burden at the end of inhalation uptake for a time T_1 .

For the burden in the n th organ when $\lambda_h \neq \lambda_i$

$$\begin{aligned}
 Q_{2n}(T_2) = & Q_{1n}(T_1)e^{-\lambda_n T_2} + f_2' \lambda_i^b Q_{1LMi}(T_1) \frac{(e^{-\lambda_i T_2} - e^{-\lambda_n T_2})}{(\lambda_n - \lambda_i)} \\
 & + f_2' \left\{ \sum_{j=a}^g \frac{C_j'}{(\lambda_j - \lambda_n)} (e^{-\lambda_n T_2} - e^{-\lambda_j T_2}) \right. \\
 & \left. + C_h' \left[\frac{(e^{-\lambda_n T_2} - e^{-\lambda_i T_2})}{(\lambda_i - \lambda_n)} - \frac{(e^{-\lambda_n T_2} - e^{-\lambda_h T_2})}{(\lambda_h - \lambda_n)} \right] \right\} \quad (22)
 \end{aligned}$$

where:

$$C_a' = \lambda_a^b Q_{1a}(T_1)$$

$$C_b' = \lambda_b^b Q_{1b}(T_1) f_1$$

$$C_c' = \lambda_c^b Q_{1c}(T_1)$$

$$C_d' = \lambda_d^b Q_{1d}(T_1) f_1$$

$$C_e' = \lambda_e^b Q_{1e}(T_1)$$

$$C_f' = \lambda_f^b Q_{1f}(T_1) f_1$$

$$C_g' = \lambda_g^b Q_{1g}(T_1) f_1$$

$$C_h' = \lambda_i^b Q_{1h}(T_1) / (\lambda_h - \lambda_i)$$

For the burden in the nth organ when $\lambda_n = \lambda_i$:

$$\begin{aligned}
 Q_{2n}(T_2) &= Q_{1n}(T_1)e^{-\lambda_n T_2} = f_2' \lambda_i^b Q_{1LMi}(T_1) \frac{(e^{-\lambda_i T_2} - e^{-\lambda_n T_2})}{(\lambda_n - \lambda_i)} \\
 &+ f_2' \left(\sum_{j=a}^g \frac{c_j'}{(\lambda_j - \lambda_n)} (e^{-\lambda_n T_2} - e^{-\lambda_j T_2}) \right. \\
 &\left. + \frac{c_h'}{(\lambda_i - \lambda_n)} \left\{ e^{-\lambda_n T_2} - e^{-\lambda_i T_2} \left[(\lambda_i - \lambda_n) T_2 - 1 \right] \right\} \right) \quad (23)
 \end{aligned}$$

The effective total dose to the pulmonary lung due to inhalation uptake for a time T_1 followed by a period of no additional uptake for a time T_2 is computed using the following equation.

$$D_{1p}(T_2) = 5.92 \times 10^{-4} E_p P_o \left[\sum_{j=e}^h \frac{f_j D_5}{\lambda_j^2} (1 - e^{-\lambda_j T_1}) (1 - e^{-\lambda_j T_2}) \right] + D_{1p}(T_1) \quad (24)$$

where: $D_{1p}(T_1)$ is the effective dose to the pulmonary lung during the uptake period.

Total effective dose to the nth organ as a result of inhalation uptake for a time T_1 followed by a period of no additional uptake for a time T_2 is computed using the equation that follows:

$$\begin{aligned}
 D_{2n}(T_2) &= 5.92 \times 10^{-4} \frac{E_n}{M_n} \left(Q_{1n}(T_1) B_n + f_2' \left\{ \sum_{j=a}^h \frac{\lambda_j^b c_j'}{(\lambda_j - \lambda_n)} (B_n - B_j) \right. \right. \\
 &+ \frac{\lambda_i^b Q_{1LMi}(T_1)}{\lambda_n} \left[T_2 - B_n + D_{1n}(T_1) \right] \\
 &\left. \left. + c_h' \left(\frac{B_n - B_i}{\lambda_i - \lambda_n} - z \right) \right\} \right) \quad (25)
 \end{aligned}$$

where:

$$Z = \frac{B_n - B_h}{\lambda_h - \lambda_i} \quad \text{when } \lambda_i \neq \lambda_h$$

or:

$$Z = \frac{B_i}{\lambda_i} (\lambda_i T + 1) \quad \text{when } \lambda_i = \lambda_h$$

and:

$$B_n = \frac{1 - e^{-\lambda_n T_2}}{\lambda_n}$$

$$B_h = \frac{1 - e^{-\lambda_h T_2}}{\lambda_h}$$

$$B_i = \frac{1 - e^{-\lambda_i T_2}}{\lambda_i}$$

$$B_j = \frac{1 - e^{-\lambda_j T_2}}{\lambda_j}$$

In addition, the equation for Q_{1n} is dependent on whether $\lambda_i = \lambda_h$ or not, so the choice of equations for the burden and dose computation must be consistent throughout.

III-B.4 Population Doses

The population dose from accidental releases is calculated for selected organs of reference from both external radiation and internal deposition resulting from inhalation. This calculation presumes the 1973 population distribution described in Appendix II.3-A.

Population dose for an accidental release is calculated by combining the dose to an individual for each sector as a function of distance, using the joint frequency distribution of wind speed and direction versus atmospheric stability as a probability function. In other words, it is assumed that the joint frequency distribution describes the probability that an individual at a particular distance from the point of release

in a specified sector will be exposed to the plume. The population dose then can be described by:

$$D_p^n = \sum_{r,k} f(i,j,k) D_{(i,j,r)}^n \rho(r,k) \text{ man-rem} \quad (26)$$

where:

- D_p^n • population dose with organ n as the organ of reference, man-rem
- $f(i,j,k)$ • joint frequency distribution describing fraction of time that wind blows within wind speed interval i, during atmospheric stability class, j in an angular sector, k
- $D_{(i,j,r)}^n$ • dose to an individual at a downwind distance, r with organ n as the organ of reference, rem
- $\rho(r,k)$ • population density at radial distance, r in sector, k.

The 1973 population distribution centered on the 200 Area facilities was used to calculate population doses. The joint frequency distribution used was for the Hanford Meteorological Station as described in Section II. The dose was calculated to an individual at the midpoint of each annular sector for each of several organs of reference. The population dose for the population out to 50 miles from either area was then calculated using Equation 26 with appropriate values of r and k for annular sectors.

III-B REFERENCES

1. D. H. Slade, Ed, Meteorology and Atomic Energy, U.S. Atomic Energy Commission Division of Technical Information, TID-24190, 1968..
2. J. J. Fuquay, C. L. Simpson and W. T. Hinds, Estimates of Ground Level Air Exposures Resulting from Protracted Emissions from 70-Meter Stacks at Hanford, HW-80204, 1964.
3. D. L. Streng, M. M. Hendrickson and E. C. Watson, RACER - A Computer Program for Calculating Potential External Dose from Airborne Fission Products Following Postulated Reactor Accidents, BNWL-B-69, Battelle, Pacific Northwest Laboratories, Richland, WA, June 1971.
4. M. J. Berger, Engineering Compendium on Radiation Shielding, Vol. I p. 218, Springer-Verlag, New York, Inc., 1968.
5. G. J. Hine and G. L. Brownell, Radiation Dosimetry, Academic Press, Inc., New York, NY, 1956.
6. Task Group of Committee 2, ICRP, The Metabolism of Compounds of Plutonium and Other Actinides, ICRP Publication 19, Pergamon Press, Oxford, 1972.
7. Task Group of Committee 2, ICRP, Task Group on Lung Dynamics for Committee II of the ICRP, Health Physics, Vol. 12, p. 173, 1966.
8. Paul G. Voilleque, AERIN, A Code for the Acute Aerosol Inhalation Exposure Calculations, Health Physics, Vol. 19, p. 427, 1970.

APPENDIX III-C

ACCIDENT ESTIMATION TECHNIQUES

III-C ACCIDENT ESTIMATION TECHNIQUES

Evaluating the consequences of accidents requires an integration of many scientific disciplines. Once an accident is postulated, the amount and form of material which might be released must be characterized and the resulting environmental consequences quantified.

Since accidents are unique occurrences, estimating fractions of the material released to the environment is always an exercise in judgment. At Hanford, many experimental studies on release fractions for a variety of materials, under a variety of environmental conditions have been performed.¹⁻⁹ These studies of the behavior or characteristics of various materials containing radionuclides under various conditions (heating, aging, etc.) were appropriately modified for use in the analyses to reflect differences in conditions and source materials. Where possible, release values bracketing the postulated accident conditions were considered and technical judgment applied to obtain a "reasonable but larger than anticipated" inventory release value. When no data existed, an estimate was made using engineering principles and the known characteristics of the physical form of the material.

III-C.1 Calculation of Doses from Atmospheric Releases

The environmental consequences of the accidental release of radionuclides to the atmosphere which might result from each postulated accident were evaluated for exposure of people to the airborne plume. Atmospheric dispersion of the released radionuclides is described in this analysis by a bivariate normal distribution model. To calculate the resulting doses to individuals, a moderately stable atmosphere was assumed to exist throughout the course of the accidental release. A windspeed of ten meters per second (22 mph) was assumed for those accidents which postulate a release based on resuspension of ground deposited contaminants; otherwise, a one meter per second windspeed was used. Population

dose calculations were based on sector average atmospheric dispersion formulae using joint frequency distributions of wind velocity and atmospheric stability characteristic of Hanford areas.

Dose calculations were made for both external exposure from submersion in the passing cloud and internal exposure from inhalation. The resulting external exposure was calculated at a depth of five centimeters, corresponding to total-body dose. Doses resulting from possible inhalation were calculated for several organs of reference including total-body, lungs, bone, and thyroid. The material inhaled was considered insoluble when calculating lung dose, and soluble when calculating dose to other organs of reference. The more recent lung model of the International Commission on Radiation Protection Task Group (TGLM) was used to calculate doses to individuals from inhalation.

Resulting population doses were estimated by calculating the dose to an individual at the sector center of several annular rings centered on either the 200 or 300 Areas. Every individual in the population within each annular sector was assumed to receive the same dose as the individual located at the sector center. The product of dose, annular sector population, and percentage of time the wind blew toward each sector was then compiled to give population dose in man-rems. (The models used in this study are discussed in Appendix III-B.)

III-C.2 Liquid Release Calculation

The movement of liquid released to the ground as a result of postulated accidents is important in the evaluation of environmental consequences. The movement of solutions of radioactive liquid waste through porous media systems under a variety of conditions was estimated using the PERCOL model.¹⁰ This model determines concentration changes on the basis of chemical thermodynamic equilibria between the porous media and solution systems. In soils from the Hanford Reservation studied in experimental columns, the effects of ion exchange, sorption, dissolution

and precipitation are dominant over the effects of diffusion and dispersion. Therefore, diffusion and dispersion are neglected in this model, but are included in the more refined multidimensional transport model.

Assumptions used in PERCOL are:

- Dispersion, diffusion and evaporation are neglected.
- Seepage velocity is slow enough for sorption and chemical equilibrium to be attained.
- Cation exchange capacity is constant for each porous medium type.
- Binary equations approximate the complex cation exchange in porous media.
- Equilibrium states are path independent.
- Anion exchange is negligible.
- Limestone and gypsum are considered to be the only slightly soluble salts present and their solubility is assumed to be that of the crystalline form.
- Undissociated calcium sulfate is the only complex ion formed.
- Activity coefficients follow the extended Debye-Huckel theory.
- Uniform moisture content is present.
- Reactions of microions are determined by the macroions present as described by factorial design regression coefficients.

The formulation and parameters used to calculate radiation doses to residents of the Hanford vicinity from postulated accidental releases of radioactive material to surface and groundwater are incorporated in a multicomponent computer model. The pertinent codes in this model are ARRRG, and FOOD. Although originally designed for annual doses from chronic releases, modification of the input parameters such as exposure hours, dilution in receiving waters, etc., allows calculation of internal and external doses from acute exposure to radionuclides in the environment.

Excerpts from a complete description¹¹ of the model and computation codes is given in Appendix III-A. These codes represent a simplified version in an interactive computer language of the complex codes developed for the AEC's Year-2000 studies.^{12,13}

Equations and parameters required for calculation of internal radiation doses from ingested radionuclides were given by the ICRP.¹⁴ The equations used to calculate doses from external exposure to water and ground deposits may be found in Reference 15.

III-C REFERENCES

1. J. Mishima, A Review of Research on Plutonium Releases During Overheating and Fires, HW-83668, General Electric-HAPO, Richland, WA, August 1964.
2. J. Mishima, L. C. Schwendiman and C. A. Radasch, Plutonium Release Studies, III. Release from Plutonium Bearing Powders, BNWL-786, Battelle, Pacific Northwest Laboratories, Richland, WA, July 1968.
3. J. Mishima and L. C. Schwendiman, The Amount and Characteristics of Plutonium Made Airborne Under Thermal Stress, BNWL-SA-3379, Battelle, Pacific Northwest Laboratories, Richland, WA, October 1970.
4. J. Mishima, L. C. Schwendiman and C. A. Radasch, Plutonium Release Studies, IV. Fractional Release from Heating Plutonium Nitrate Solutions in a Flowing Air Stream, BNWL-931, Battelle, Pacific Northwest Laboratories, Richland, WA, November 1968.
5. J. Mishima and L. C. Schwendiman, Fractional Airborne Release of Uranium (Representing Plutonium) During the Burning of Contaminated Waste, BNWL-1730, Battelle, Pacific Northwest Laboratories, Richland, WA, April 1973.
6. J. Mishima and L. C. Schwendiman, Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents, BNWL-1732, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1973.
7. G. A. Sehmel, Particle Resuspension from Asphalt Roads Caused by Car and Truck Traffic, BNWL-SA-4175, Battelle, Pacific Northwest Laboratories, Richland, WA, January 1972.
8. I. S. Jones and S. F. Pond, "Some Experiments to Determine the Resuspension Factor of Plutonium from Various Surfaces" in Surface Contamination (B. R. Fish, Ed.), Pergamon Press, NY, 1967.
9. H. Glauberman, W. R. Boatmann and A. J. Breslin, "Studies of the Significance of Surface Contamination," in Surface Contamination (B. R. Fish, Ed.), Pergamon Press, NY, 1967.
10. R. C. Routson and R. J. Serne, One Dimensional Model of Movement of Trace Radioactive Solute Through Soil Columns: The PERCOL Model, BNWL-1718, Battelle, Pacific Northwest Laboratories, Richland, WA, 1972.

III-C REFERENCES (Continued)

11. J. K. Soldat, N. M. Robinson and D. A. Baker, Models and Computer Codes for Evaluating Environmental Radiation Doses, BNWL-1754, Battelle, Pacific Northwest Laboratories, Richland, WA, 1974.
12. J. K. Soldat, "Radiation Dose Model," pp. 81-161, (J. F. Fletcher and W. L. Dotsen, Compilers), HERMES--A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry, USAEC Report HEDL-TME-71-168, Hanford Engineering Development Laboratory, Richland, WA, 1971.
13. J. K. Soldat, D. A. Baker and J. P. Corley, "Applications of a General Computational Model for Composite Environmental Radiation Doses," pp. 483-489, Environmental Behavior of Radionuclides Released in the Nuclear Industry, proceedings of a symposium held in Aix-en-Provence, France, May 14-18, 1973, International Atomic Energy Agency, Vienna, Austria, 1973.
14. International Commission on Radiological Protection, Permissible Dose for Internal Radiation, Report of Committee II, ICRP Publ. 2, Pergamon Press, NY, 1959.
15. G. J. Hine and G. L. Brownell, Radiation Dosimetry, Academic Press, Inc., NY, 1965, 2nd printing 1958.

APPENDIX III-D

RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK

APPENDIX III-D

RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK

		<u>Page</u>
Table	III-D-1	Weight Inventory by Nuclide, Grams
	III-D-2	Radioactivity by Nuclide, Curies
	III-D-3	Thermal Power by Nuclide, Watts
		III-D-5
		III-D-17
		III-D-25

III-D RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK

Attached are Tables showing the radionuclide inventories for a waste storage tank that were used in the Accident Analysis Section of this Impact Statement. The inventories are developed for a million-gallon waste tank.

The tank is assumed to be filled over a 15-month period with waste from 2200 US tons of 0.94% of ^{235}U N Reactor fuel irradiated to 1380 MWd/T. The waste enters the tank after 200 days of cooling and contains no xenon or krypton, 0.1% of the uranium and plutonium, 10% of the neptunium, and 20% of the iodine in the fuel. In this inventory, all the cesium and strontium are assumed to remain in the waste with no B Plant processing. In this respect, the waste is atypical because B Plant processing usually removes 95% of the cesium and strontium.

Inventories are presented for the fission products and actinides from the time of filling of the tank to 100,000,000-yr cooling in the following order:

Table III-D-1 Weight Inventory by Nuclide, grams

Table III-D-2 Radioactivity by Nuclide, Curies

Table III-D-3 Thermal Power by Nuclide, Watts

In reading the tables, the following interpretations are required:

CHARGE: value per ton of waste entering the tank

SEPARATION: total value at time tank is completely filled

TABLE III-D-1
WEIGHT INVENTORY BY NUCLIDE, GRAMS

TABLE III-D-1

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1340.440. FLUX= 2.17E+13N/C*2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
H 3	2.71E-03	5.75E+00	5.44E+00	5.14E+00	4.84E+00	4.34E+00	3.28E+00	2.47E+00	1.86E+00	1.06E+00	3.44E-01	2.06E-02
GF 72	1.25E-04	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01
GF 73	5.18E-04	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00
GF 74	1.74E-03	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00
AS 75	3.47E-03	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00
GF 76	1.13E-02	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01
SE 76	4.84E-06	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
SE 77	3.87E-02	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01
SE 78	9.65E-02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02
SE 79	2.55E-01	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02
RR 79	2.31E-05	5.45E-02	6.05E-02	6.65E-02	7.24E-02	8.44E-02	1.14E-01	1.44E-01	1.74E-01	2.34E-01	3.54E-01	6.53E-01
SF 80	4.26E-01	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02
BP 81	6.96E-01	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03
SE 82	1.51E+00	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03
PR 85	4.50E+00	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03
SP 86	7.25E-04	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00
RR 87	1.18E+01	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04
SP 87	3.42E-08	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05	7.55E-05
SP 88	1.71E+01	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04
SP 89	7.14E-01	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02	2.63E+02
Y 89	2.26E+01	5.09E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04
SP 90	2.75E+01	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04	5.96E+04
Y 90	7.15E-03	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01	1.56E+01
ZR 90	5.07E-01	2.83E+03	3.43E+03	4.90E+03	6.28E+03	8.94E+03	1.51E+04	2.05E+04	2.52E+04	3.32E+04	4.43E+04	5.66E+04
Y 91	1.35E+00	5.58E+02	7.54E+00	1.02E-01	1.37E-03	2.51E-07	1.13E-16	5.06E-26	2.28E-35	4.59E-54	0.	0.
ZP 91	2.84E+01	6.49E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04
ZP 92	3.12E+01	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04
ZP 93	3.42E+01	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04
ZP 93	3.42E+01	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04
NR 93	1.15E-05	4.54E-02	7.70E-02	1.07E-01	1.36E-01	1.89E-01	2.99E-01	3.85E-01	4.52E-01	5.46E-01	1.15E+00	2.84E+00
NR 93	2.23E-07	1.70E-03	4.82E-03	9.52E-03	1.57E-02	3.23E-02	9.50E-02	1.83E-01	2.90E-01	5.46E-01	1.15E+00	2.84E+00
ZQ 94	3.50E+01	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04
ZP 95	2.15E+00	9.83E+02	2.00E+01	4.08E-01	8.30E-03	3.44E-06	1.20E-14	4.22E-23	1.48E-31	1.81E-48	0.	0.
NR 95	2.64E-03	1.25E+00	2.45E-02	4.99E-04	1.00E-05	4.21E-09	1.48E-17	5.16E-26	1.81E-34	2.22E-51	0.	0.
NB 95	2.25E+00	1.04E+03	2.39E+01	4.88E-01	9.94E-03	4.02E-06	1.41E-14	4.93E-23	1.72E-31	1.72E-31	1.72E-31	1.72E-31
MO 95	3.11E+01	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04
ZP 96	3.63E+01	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04
MO 96	3.31E-02	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01
MO 97	3.54E+01	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04
MO 98	3.52E+01	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04
TC 99	3.73E+01	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04
RJ 99	8.94E-05	3.62E-01	6.30E-01	8.99E-01	1.17E+00	1.70E+00	3.05E+00	4.39E+00	5.73E+00	8.42E+00	1.38E+01	2.72E+01
MO100	3.95E+01	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04
RJ100	1.65E-01	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02
RJ101	3.27E+01	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04
RJ102	2.89E+01	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04
RJ103	2.89E+01	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04
RJ104	1.77E+01	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04
PD104	4.24E-01	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02
PD105	4.50E+00	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04
RJ106	4.68E+00	6.95E+03	3.49E+03	1.75E+03	8.31E-04	2.09E-04	6.65E-06	2.11E-07	6.72E-09	6.80E-12	6.95E-18	7.34E-33
PD106	4.43E-06	6.58E-03	3.30E-03	1.66E-03	8.31E-04	2.09E-04	6.65E-06	2.11E-07	6.72E-09	6.80E-12	6.95E-18	7.34E-33
PD106	4.65E+00	1.36E+04	1.70E+04	1.88E+04	2.03E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1340.MWD. FLUX= 2.1E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

CHARGE	SEPARATION	1.7E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
PD107	4.80E+00	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04
AG107	3.36E-07	1.38E-03	2.43E-03	3.47E-03	4.52E-03	6.61E-03	1.18E-02	1.71E-02	2.23E-02	3.28E-02	5.37E-02
PD108	2.90E+00	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03
CD108	1.92E-10	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07
AG109	1.51E+00	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03
CD109	8.01E-14	1.27E-10	7.29E-11	4.17E-11	2.38E-11	7.80E-12	4.77E-13	2.92E-14	1.79E-15	6.69E-18	9.38E-23
PD110	6.37E-01	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03
AG110	9.35E-04	1.18E+00	4.35E-01	1.60E-01	5.44E-02	7.96E-03	5.35E-05	3.60E-07	2.42E-09	1.04E-13	2.23E-22
AG110	1.36E-10	1.72E-07	6.32E-09	2.32E-03	8.54E-09	1.16E-09	7.77E-12	5.22E-14	3.51E-16	1.59E-20	3.24E-29
CD110	4.67E-02	1.04E+02	1.04E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02
CD111	3.61E-01	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02
CD112	2.11E-01	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02
CD113	4.65E-05	9.93E-02	4.45E-02	8.99E-02	8.99E-02	7.75E-02	6.05E-02	4.73E-02	3.69E-02	2.25E-02	4.36E-03
CD113	5.44E-02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02
IN113	1.56E-06	6.47E-03	1.13E-02	1.58E-02	2.02E-02	2.82E-02	4.52E-02	5.85E-02	8.86E-02	6.32E-02	9.73E-02
CD114	3.51E-01	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02
SN114	2.70E-04	6.10E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06
IN115	1.13E-01	2.44E+02	2.44E+02	2.44E+02	2.44E+02	2.44E+02	2.44E+02	2.44E+02	2.44E+02	2.44E+02	2.44E+02
SN115	6.01E-03	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01
CD116	1.19E-01	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02
SN116	9.55E-03	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01
SN117	1.23E-01	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02
SN118	1.24E-01	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02
SN119	1.59E-04	1.99E-01	7.24E-02	2.63E-02	9.55E-03	7.98E-06	5.05E-08	3.20E-10	1.28E-14	2.06E-23	0.
SN119	1.31E-01	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02
SN120	1.38E-01	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02
SN121	2.13E-04	6.45E-05	6.78E-05	6.72E-05	6.40E-05	6.54E-05	6.25E-05	5.97E-05	5.71E-05	5.21E-05	4.34E-05
SH121	1.55E-01	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02
SN122	1.65E-01	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02
TF122	5.42E-04	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00
SN123	3.49E-02	3.00E+01	3.45E+00	5.22E-01	6.44E-02	1.20E-03	4.81E-06	1.93E-12	7.73E-17	1.24E-25	3.21E-43
SR123	1.48E-01	3.77E+02	4.03E+02	4.06E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
TE123	1.08E-08	8.32E-06	9.56E-07	1.10E-06	1.10E-06	1.67E-10	3.35E-15	6.72E-20	1.35E-24	5.42E-34	8.78E-53
TE123	1.16E-07	2.71E-04	2.74E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04
SN124	2.31E-01	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02
SR124	1.23E-05	5.19E-03	7.64E-04	1.12E-03	1.06E-08	3.59E-12	2.44E-21	1.71E-30	1.18E-39	5.66E-58	0.
TE124	1.79E-04	4.15E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01
SR125	2.46E-01	4.70E+02	3.53E+02	2.81E+02	2.17E+02	1.30E+02	3.61E+01	9.99E+00	2.77E+00	2.13E-01	1.25E-03
TF125	5.67E-03	1.13E+01	6.85E+00	6.85E+00	5.30E+00	3.17E+00	8.79E-01	2.44E-01	6.75E-02	5.18E-03	3.06E-05
TF125	4.29E-02	1.73E+02	2.49E+02	3.66E+02	4.31E+02	5.21E+02	6.17E+02	6.44E+02	6.51E+02	6.54E+02	6.54E+02
SN126	5.07E-01	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03
SR126	1.83E-10	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.02E-07
SR126	1.74E-07	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.77E-04	3.77E-04
TF126	8.46E-04	1.92E+00	1.92E+00	1.93E+00	1.94E+00	1.96E+00	1.99E+00	2.03E+00	2.07E+00	2.15E+00	2.30E+00
TF127	5.59E-02	4.67E+01	3.49E+00	3.91E-01	3.04E-02	3.69E-04	3.35E-09	3.03E-14	2.75E-19	2.26E-29	1.53E-49
TF127	1.95E-04	1.45E-01	1.42E-02	1.39E-03	1.38E-04	1.31E-06	1.13E-11	1.08E-16	9.77E-22	8.04E-32	5.44E-52
IN127	2.49E-01	6.32E+02	6.59E+02	6.72E+02	6.72E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02
TF128	4.00E+00	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03
XF128	4.20E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00
IN129	1.71E+00	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03
XF129	3.05E-03	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.71E+00	6.72E+00
TF130	1.65E+01	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.1E+13N/CM**2-SEC

NUCLID CONCENTRATIONS, GRAMS
HAZIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHANGE	SEPARATION	1.0E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
XE130	3.92E-02	8.42E+01	8.42E+01	8.42E+01	8.42E+01	8.62E+01	9.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01
XE131	2.42E+01	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04
XE132	3.77E+01	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04
CS133	5.30E+01	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
XE134	6.49E+01	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05
CS134	5.19E-01	9.34E+02	6.56E+02	4.75E+02	3.34E+02	1.72E+02	3.18E+01	5.86E+00	1.08E+00	3.68E-02	4.26E-05	1.95E-12
BA134	1.37E-01	5.01E+02	7.64E+02	9.60E+01	1.10E+03	1.26E+03	1.40E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03
CS135	1.13E+01	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04
BA135	3.46E-06	1.16E-02	1.73E-02	2.30E-01	2.07E-02	4.02E-02	6.88E-02	9.75E-02	1.26E-01	1.83E-01	2.98E-01	5.84E-01
XE136	9.55E+01	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05
BA136	2.20E-01	4.85E+02	4.45E+02	4.85E+01	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02
CS137	5.17E+01	1.12E+05	1.10E+05	1.07E+05	1.05E+05	1.00E+05	8.91E+04	7.94E+04	7.07E+04	5.61E+04	3.54E+04	1.11E+04
BA137	7.82E-06	1.70E-02	1.56E-02	1.62E-02	1.58E-02	1.51E-02	1.35E-02	1.20E-02	1.07E-02	6.48E-03	5.34E-03	1.05E+05
BA137	8.89E-01	2.55E+03	5.12E+03	8.62E+03	1.11E+04	1.58E+04	2.67E+04	3.64E+04	4.51E+04	5.97E+04	8.04E+04	1.05E+05
BA138	4.97E+01	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05
LA139	5.49E+01	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05
CE140	5.61E+01	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05
PR141	5.30E+01	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05
CF142	5.09E+01	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05
NO142	5.23E-02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02
NO143	4.64E+01	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05
CF144	2.43E+01	3.25E+04	1.33E+04	5.46E+03	2.24E+03	3.77E+02	4.37E+00	5.08E-02	5.89E-04	7.94E-08	1.44E-15	6.39E-35
PR144	1.03E-03	1.37E-01	5.63E-01	2.31E-01	1.39E-02	1.85E-04	2.15E-06	2.49E-08	3.36E-12	6.09E-20	2.70E-39	
NO144	2.42E+01	7.41E+04	9.33E+04	1.01E+05	1.04E+05	1.06E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05
NO145	3.39E+01	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04
PM147	2.75E+01	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04
SM147	1.44E+01	3.14E+04	2.42E+04	1.85E+04	1.42E+04	8.39E+03	2.23E+03	5.95E+02	1.59E+02	1.13E+01	5.68E-02	1.02E-07
SM147	3.37E+00	1.24E+04	2.01E+04	2.57E+04	3.00E+04	3.59E+04	4.20E+04	4.37E+04	4.41E+04	4.43E+04	4.43E+04	4.43E+04
NO148	1.58E+01	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04
SM148	1.00E+00	2.21E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03
SM149	1.48E+00	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03
NO150	6.78E+00	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04
SM150	1.08E+01	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04
SM151	4.11E+00	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03	8.99E+03
EU151	2.14E-02	9.12E+01	1.63E+02	2.33E+02	3.04E+02	4.42E+02	7.80E+02	1.10E+03	1.42E+03	2.00E+03	3.05E+03	5.03E+03
SM152	4.15E+00	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03
EU152	1.35E-03	2.86E+00	2.79E+00	2.55E+00	2.40E+00	2.14E+00	1.61E+00	1.20E+00	9.01E-01	5.06E-01	1.59E-01	8.88E-03
GO152	8.15E-04	1.82E+00	1.87E+00	1.91E+00	1.95E+00	2.02E+00	2.17E+00	2.29E+00	2.37E+00	2.48E+00	2.58E+00	2.62E+00
EU153	2.33E+00	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03
GO153	5.24E-06	6.49E-03	2.24E-03	8.01E-04	2.81E-04	3.47E-05	1.84E-07	9.96E-10	5.34E-12	1.53E-16	1.26E-25	0.
SM154	1.15E+00	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03
EU154	1.22E-01	2.61E+02	2.50E+02	2.39E+02	1.44E+02	2.10E+02	1.69E+02	1.36E+02	1.10E+02	7.11E+01	2.99E+01	3.43E+00
GO154	3.41E-03	1.49E+01	2.60E+01	3.66E+01	4.67E+01	6.57E+01	1.07E+02	1.40E+02	1.66E+02	2.05E+02	2.46E+02	2.72E+02
EU155	1.75E-01	3.07E+02	2.09E+02	1.43E+02	7.73E+01	4.52E+01	6.67E+00	9.83E-01	1.45E-01	3.15E-03	1.49E-06	7.23E-15
GO155	4.32E-02	1.73E+02	2.70E+02	3.37E+02	3.82E+02	4.34E+02	4.73E+02	4.78E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02
GO156	7.90E-01	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03
GO157	6.06E-03	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01
GO158	2.80E-01	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02
TR159	4.35E-02	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01
GO160	1.81E-02	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01
TR160	6.75E-05	3.40E-02	1.02E-03	3.04E-05	6.01E-07	8.10E-10	1.93E-17	4.59E-25	1.07E-32	6.21E-48	0.	0.
OY160	5.97E-04	1.43E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1349.4WD, FLUX= $2.17 \times 10^{13} \text{ CM}^{-2} \text{ SEC}^{-1}$

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
DY161	7.06E-03	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01
DY162	3.21E-03	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00
DY163	1.44E-03	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00
DY164	3.93E-04	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01
MO165	2.68E-04	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01
MO166	6.73E-08	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04
ER166	9.69E-05	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01
ER167	1.13E-06	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03
SURTOT	1.42E+03	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06
TOTAL	1.42E+03	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1360,MWD; FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
H 3	2.71E-03	5.83E+00	2.66E-07	1.98E-24	0.	0.	0.	0.	0.	0.	0.	0.
GE 72	1.29E-04	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01
GE 73	5.18E-04	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00
GE 74	1.74E-03	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00
AS 75	3.47E-03	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00
GF 76	1.13E-02	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01
SE 76	4.84E-06	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
SE 77	3.82E-02	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01
SE 78	9.65E-02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02
SE 79	2.55E-01	5.61E+02	5.59E+02	5.55E+02	5.44E+02	5.04E+02	4.08E+02	1.93E+02	2.29E+01	1.31E+02	0.	0.
BR 79	2.31E-05	5.30E-02	1.95E+00	6.00E+00	1.77E+01	5.68E+01	1.54E+02	3.68E+02	5.38E+02	5.61E+02	5.61E+02	5.61E+02
SE 80	4.26E-01	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02
BR 81	6.96E-01	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03
SE 82	1.51E+00	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03
RB 85	4.50E+00	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03
SR 86	7.25E-04	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00
RB 87	1.18E+01	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04
SR 87	3.47E-08	7.55E-05	1.84E-04	4.37E-04	1.16E-03	3.69E-03	1.09E-02	3.62E-02	1.08E-01	3.61E-01	3.61E+00	3.61E+01
SR 88	1.71E+01	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04
Y 89	2.26E+01	5.08E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04
SR 90	2.75E+01	5.99E+04	3.67E+01	1.17E-06	4.43E-28	0.	0.	0.	0.	0.	0.	0.
Y 90	7.15E-03	1.56E+01	9.54E-03	3.03E-10	1.15E-31	0.	0.	0.	0.	0.	0.	0.
ZR 90	5.07E-01	1.67E+03	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04
ZR 91	2.94E-01	6.45E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04
ZR 92	3.12E+01	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04
ZR 93	3.42E+01	7.52E+04	7.52E+04	7.52E+04	7.51E+04	7.49E+04	7.42E+04	7.18E+04	6.55E+04	4.74E+04	7.41E+02	6.49E-16
NR 93M	1.15E-05	3.75E-02	6.82E-01	6.82E-01	6.81E-01	6.79E-01	6.72E-01	6.51E-01	5.94E-01	4.30E-01	6.72E-03	5.88E-21
NR 93	2.23E-07	1.12E-03	9.78E+00	3.41E+01	1.04E+02	3.40E+02	1.03E+03	3.39E+03	9.73E+03	2.78E+04	7.45E+04	7.52E+04
ZR 94	3.50E+01	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04
MO 95	3.11E+01	7.49E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04
ZR 96	3.63E+01	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04
MO 96	3.31E-02	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01
MO 97	3.54E+01	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04
MO 98	3.52E+01	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04
TC 99	3.73E+01	8.22E+04	8.21E+04	8.19E+04	8.14E+04	7.95E+04	7.45E+04	5.93E+04	3.08E+04	3.13E+03	5.23E-10	0.
RU 99	8.94E-05	2.96E-01	8.08E+01	2.68E+02	8.02E+02	2.64E+03	7.67E+03	2.29E+04	5.13E+04	7.90E+04	8.22E+04	8.22E+04
MO100	3.95E+01	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04
RU100	1.69E-01	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02
RU101	3.27E+01	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04
RU102	2.89E+01	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04
RM103	2.24E+01	4.98E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04
RU104	1.77E+01	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04
PD104	4.24E-01	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02
PD105	9.50E+00	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04
PD106	4.66E+00	1.25E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04
PD107	4.80E+00	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.03E+04	9.57E+03	3.93E+03	5.30E-01
AG107	3.36E-07	1.13E-03	3.15E-01	1.05E+00	3.11E+00	1.05E+01	3.13E+01	1.04E+02	3.09E+02	9.96E+02	6.64E+03	1.06E+04
PD108	2.90E+00	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03
CD108	1.92E-10	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07
AG109	1.51E+00	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03
PD110	6.37E-01	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03
CD110	4.67E-02	1.03E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1340.4WD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRA4S
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
CD111	3.61E-01	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02
CD112	2.11E-01	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02
CD113M	4.65E-05	1.01E-01	3.57E-08	3.20E-23	0.	0.	0.	0.	0.	0.	0.	0.
CD113	5.64E-02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02
IN113	1.56E-06	5.27E-03	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01
CD114	3.51E-01	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02
SN114	2.70E-04	6.08E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06
IN115	1.13E-01	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02
SN115	6.01E-03	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01
CD116	1.19E-01	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02
SN116	9.55E-03	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01
SN117	1.23E-01	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02
SN118	1.24E-01	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02
SN119	1.31E-01	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02
SN120	1.34E-01	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02
SN121M	3.13E-04	6.86E-05	4.45E-06	7.52E-09	9.04E-17	0.	0.	0.	0.	0.	0.	0.
SB121	1.55E-01	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02
SN122	1.65E-01	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02
TE122	5.42E-04	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00
SB123	1.48E-01	3.65E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
TE123	1.16E-07	2.67E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04
SN124	2.31E-01	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02
TE124	1.79E-04	4.12E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01
TE125	4.29E-02	1.44E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02
SN126	5.07E-01	1.11E+03	1.11E+03	1.11E+03	1.04E+03	9.05E+02	5.57E+02	1.39E+02	1.09E+00	0.	0.	0.
SB126M	1.83E-10	4.03E-07	4.02E-07	4.00E-07	3.94E-07	3.76E-07	3.27E-07	2.01E-07	5.04E-08	3.94E-10	0.	0.
SB126	1.74E-07	3.78E-04	3.77E-04	3.75E-04	3.70E-04	3.52E-04	3.07E-04	1.89E-04	4.72E-05	3.69E-07	0.	0.
TE126	8.64E-04	1.92E+00	4.23E+00	9.61E+00	2.48E+01	7.65E+01	2.11E+02	5.59E+02	9.77E+02	1.12E+03	1.12E+03	1.12E+03
I127	2.49E-01	6.14E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02
TE128	4.00E+00	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03
I129	1.71E+00	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.76E+03	3.73E+03	3.62E+03	2.51E+03	6.40E+01
XE129	1.90E-10	5.72E-05	4.62E-07	1.54E-01	4.61E-01	1.54E+00	4.61E+00	1.53E+01	4.58E+01	1.51E+02	1.26E+03	3.71E+03
TE130	1.65E+01	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04
XE131	1.20E-09	3.11E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05
CS133	5.30E+01	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
BA134	1.33E-01	4.25E+02	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03
CS135	1.13E+01	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04
BA135	3.66E-06	1.02E-02	1.73E+00	5.74E+00	1.72E+01	5.72E+01	1.71E+02	5.66E+02	1.66E+03	5.11E+03	2.23E+04	2.48E+04
BA136	2.20E-01	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02
CS137	5.17E+01	1.13E+05	1.10E+02	1.05E+05	9.04E+26	0.	0.	0.	0.	0.	0.	0.
BA137M	7.82E+06	1.71E-02	1.67E-05	1.58E-12	1.37E-32	0.	0.	0.	0.	0.	0.	0.
BA137	8.89E-01	2.92E+03	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
BA138	4.97E+01	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05
LA139	5.49E+01	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05
CE140	5.61E+01	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05
PR141	5.30E+01	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05
CE142	5.09E+01	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05
NO142	5.23E-02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02
NO143	4.64E+01	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05
NO144	2.42E+01	6.75E+04	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05
NO145	3.39E+01	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04
NO146	2.79E+01	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
SM147	3.37E+00	1.08E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04
ND148	1.58E+01	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04
SM148	1.00E+00	2.21E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03
SM149	1.48E+00	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03
ND150	6.78E+00	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04
SM150	1.08E+01	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04
SM151	4.11E+00	9.01E+03	8.26E+02	3.13E+00	3.77E-07	0.	0.	0.	0.	0.	0.	0.
EU151	2.14E+02	7.37E+01	8.26E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03
SM152	4.15E+00	9.13E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03
EU152	1.35E+03	2.90E+00	8.67E-08	2.41E-25	0.	0.	0.	0.	0.	0.	0.	0.
GD152	8.15E+04	1.81E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00
EU153	2.33E+00	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03
SM154	1.15E+00	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03
EU154	1.22E+01	2.64E+02	6.00E-04	4.08E-17	0.	0.	0.	0.	0.	0.	0.	0.
GD154	3.61E+03	1.22E+01	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02
GD155	4.32E+02	1.45E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02
GD156	7.90E+01	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03
GD157	6.06E+03	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01
GD158	2.80E+01	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02
TD159	4.35E+02	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01
GD160	1.81E+02	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01
DY160	5.97E+04	1.41E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00
DY161	7.04E+03	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01
DY162	3.21E+03	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00
DY163	1.44E+03	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00
DY164	3.93E+04	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01
MO165	2.68E+04	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01
MO166M	6.73E+08	1.48E+04	1.24E-04	8.30E-05	2.62E-05	4.59E-07	4.43E-12	1.23E-29	0.	0.	0.	0.
ER166	9.69E+05	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01
ER167	1.13E+06	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03
SUBTOT	1.15E+03	2.56E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06
TOTAL	1.20E+03	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, HIGHNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
HF	4	5.43E-04	1.33E+00	1.38E+00	1.41E+00	1.44E+00	1.51E+00	1.66E+00	1.81E+00	1.97E+00	2.27E+00	2.86E+00
TL20R		1.20E-14	2.13E-11	1.46E-11	1.02E-11	7.10E-12	3.55E-12	7.28E-13	2.67E-13	1.87E-13	1.58E-13	1.31E-13
PA206		1.67E-14	5.53E-12	3.40E-11	1.33E-10	3.24E-10	1.17E-09	7.92E-09	2.42E-08	5.34E-08	1.62E-07	6.37E-07
PA207		5.73E-13	6.66E-09	2.35E-09	5.08E-08	8.03E-08	1.92E-07	6.08E-07	1.22E-06	2.00E-06	3.98E-06	9.13E-06
PA208		1.45E-09	7.75E-06	1.35E-05	1.75E-05	2.03E-05	2.37E-05	2.65E-05	2.72E-05	2.76E-05	2.81E-05	2.91E-05
PA210		8.21E-14	8.57E-10	2.82E-09	5.98E-09	1.03E-08	2.01E-08	7.01E-08	1.40E-07	2.30E-07	4.56E-07	1.04E-06
PA211		2.03E-15	1.11E-12	2.30E-12	3.34E-12	4.34E-12	6.25E-12	1.05E-11	1.42E-11	1.74E-11	2.24E-11	2.89E-11
PA212		6.83E-12	1.24E-08	8.48E-09	5.93E-09	4.10E-09	2.66E-09	4.23E-09	1.55E-09	1.09E-09	9.20E-10	7.58E-10
RI209		5.19E-14	2.99E-10	5.72E-10	8.45E-10	1.12E-09	1.68E-09	3.10E-09	4.61E-09	6.24E-09	9.97E-09	2.02E-08
RI210		5.32E-17	5.45E-13	1.84E-12	3.91E-12	6.73E-12	1.46E-11	4.58E-11	9.18E-11	1.50E-10	2.98E-10	6.78E-10
RI212		6.65E-13	1.18E-09	8.08E-10	5.65E-10	3.40E-10	1.96E-10	4.03E-11	1.48E-11	1.04E-11	8.77E-12	7.23E-12
RO210		4.51E-14	7.44E-12	3.14E-11	7.62E-11	1.42E-10	3.35E-10	1.26E-09	2.53E-09	4.14E-09	8.20E-09	1.87E-08
RN220		1.04E-14	1.88E-11	1.29E-11	9.03E-12	6.32E-12	3.14E-12	6.44E-13	2.37E-13	1.68E-13	1.40E-13	1.15E-13
RN222		4.32E-15	2.23E-11	4.26E-11	6.21E-11	8.30E-11	1.25E-10	2.28E-10	3.31E-10	4.34E-10	6.43E-10	1.06E-09
RA223		9.78E-14	5.33E-10	1.11E-09	1.60E-09	2.02E-09	3.00E-09	5.06E-09	6.83E-09	8.35E-09	1.08E-08	1.39E-08
RA224		5.95E-11	1.07E-07	7.34E-08	5.16E-08	3.67E-08	1.79E-08	3.68E-09	1.35E-09	9.47E-10	8.01E-10	6.60E-10
RA225		7.21E-15	1.71E-11	1.72E-11	1.73E-11	1.74E-11	1.75E-11	1.84E-11	1.97E-11	2.14E-11	2.59E-11	3.97E-11
RA226		6.77E-10	3.45E-06	6.64E-06	9.63E-06	1.30E-05	1.94E-05	3.54E-05	5.15E-05	6.77E-05	1.00E-04	1.65E-04
RA228		1.00E-16	5.56E-13	1.06E-12	1.52E-12	1.94E-12	2.65E-12	3.92E-12	4.69E-12	5.16E-12	5.65E-12	6.01E-12
AC225		4.60E-15	1.15E-11	1.14E-11	1.17E-11	1.17E-11	1.19E-11	1.25E-11	1.33E-11	1.44E-11	1.75E-11	2.68E-11
AC227		8.71E-11	4.18E-07	7.78E-07	1.13E-06	1.47E-06	2.11E-06	3.54E-06	4.81E-06	5.87E-06	7.57E-06	9.78E-06
TH227		1.72E-13	8.90E-10	1.77E-09	2.57E-09	3.34E-09	4.81E-09	8.12E-09	1.09E-08	1.34E-08	1.73E-08	2.23E-08
TH228		1.14E-09	2.05E-05	1.43E-05	1.00E-05	7.02E-06	3.48E-06	7.15E-07	2.63E-07	1.85E-07	1.56E-07	1.29E-07
TH229		1.43E-09	3.14E-06	3.15E-06	3.17E-06	3.17E-06	3.22E-06	3.38E-06	3.61E-06	3.92E-06	4.74E-06	7.28E-06
TH230		1.70E-04	3.75E-01	3.75E-01	3.76E-01	3.76E-01	3.77E-01	3.79E-01	3.81E-01	3.83E-01	3.87E-01	3.95E-01
TH231		1.51E-08	1.78E-07	6.36E-08	6.36E-08	6.36E-08	6.36E-08	6.37E-08	6.37E-08	6.37E-08	6.37E-08	6.37E-08
TH232		5.57E-06	1.23E-02	1.23E-02	1.23E-02	1.23E-02	1.23E-02	1.24E-02	1.25E-02	1.26E-02	1.28E-02	1.31E-02
TH234		1.25E-05	2.17E-03	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05
PA231		8.21E-04	1.81E-02	1.81E-02	1.81E-02	1.82E-02	1.82E-02	1.83E-02	1.83E-02	1.84E-02	1.86E-02	1.88E-02
PA233		3.29E-07	1.32E-04	7.44E-05	7.44E-05	7.45E-05	7.45E-05	7.45E-05	7.52E-05	7.54E-05	7.60E-05	7.71E-05
PA234M		4.23E-10	7.30E-08	9.59E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10
PA234		1.48E-10	2.56E-08	3.32E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10
U232		2.03E-09	4.86E-05	5.42E-06	5.84E-06	6.10E-06	6.55E-06	6.81E-06	6.65E-06	6.39E-06	5.82E-06	4.81E-06
U233		4.53E-07	2.01E-03	2.83E-03	3.59E-03	4.35E-03	5.80E-03	9.25E-03	1.27E-02	1.62E-02	2.32E-02	3.73E-02
U234		6.67E-02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.48E+02	1.49E+02
U235		7.14E+00	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04
U236		2.62E-01	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.78E+02	5.78E+02	5.79E+02
U237		4.90E-10	1.05E-06	9.98E-07	9.52E-07	9.04E-07	8.28E-07	6.55E-07	5.18E-07	4.10E-07	2.57E-07	1.01E-07
U238		8.97E+02	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06
NP237		9.79E-01	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.17E+03	2.18E+03	2.19E+03	2.21E+03	2.24E+03
NP239		2.81E-09	1.88E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.86E-05
PU236		1.50E-09	2.84E-06	2.23E-06	1.75E-06	1.37E-06	8.43E-07	2.50E-07	7.41E-08	2.20E-08	1.93E-09	1.49E-11
PU238		4.21E-04	2.59E+00	3.64E+00	3.84E+00	3.80E+00	3.82E+00	3.70E+00	3.58E+00	3.47E+00	3.25E+00	2.86E+00
PU239		1.06E+00	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03
PU240		1.04E-01	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.28E+02
PU241		1.59E-02	3.40E+01	3.25E+01	3.10E+01	2.94E+01	2.69E+01	2.13E+01	1.69E+01	1.33E+01	8.35E+00	3.27E+00
PU242		8.53E-04	1.88E+00	1.88E+00	1.88E+00	1.88E+00	1.88E+00	1.89E+00	1.89E+00	1.90E+00	1.91E+00	1.93E+00
AM241		4.44E-01	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.08E+03	1.05E+03	1.02E+03
AM242M		6.11E-04	1.34E+00	1.33E+00	1.33E+00	1.33E+00	1.31E+00	1.28E+00	1.25E+00	1.22E+00	1.17E+00	1.07E+00
AM242		7.34E-09	1.61E-05	1.60E-05	1.60E-05	1.59E-05	1.57E-05	1.54E-05	1.50E-05	1.47E-05	1.40E-05	1.28E-05
AM243		1.03E-02	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.25E+01	2.24E+01
CM242		1.40E-03	1.38E+00	2.94E-01	6.48E-02	1.62E-02	3.74E-03	3.09E-03	3.02E-03	2.95E-03	2.82E-03	2.57E-03

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1390.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
CM243	4.12E-06	4.95E-03	8.76E-03	8.57E-03	8.34E-03	8.03E-03	7.21E-03	6.47E-03	5.81E-03	4.67E-03	3.03E-03	1.03E-03
CM244	1.53E-04	3.29E-01	3.17E-01	3.05E-01	2.93E-01	2.72E-01	2.24E-01	1.85E-01	1.53E-01	1.04E-01	4.85E-02	7.15E-03
CM245	6.24E-07	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.37E-03
CM246	7.64E-04	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.67E-05	1.67E-05	1.66E-05
CM247	4.57E-12	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08
CM248	1.69E-14	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.71E-11	3.71E-11	3.71E-11
SURTOT	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
TOTAL	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
HE 4	5.83E-04	1.31E+00	8.92E+00	1.77E+01	2.41E+01	3.25E+01	4.76E+01	6.73E+01	9.36E+01	1.95E+02	8.65E+02	4.71E+03
TL207	2.64E-17	1.10E-13	5.64E-12	8.19E-12	1.53E-11	3.84E-11	9.04E-11	1.75E-10	2.03E-10	2.03E-10	2.01E-10	1.84E-10
PB206	1.67E-16	2.13E-12	5.46E-05	7.35E-04	8.41E-03	1.23E-01	1.27E+00	1.21E+01	6.70E+01	2.70E+02	2.63E+03	2.61E+04
PB207	5.73E-13	3.86E-09	1.05E-04	4.71E-04	2.00E-03	1.67E-02	1.17E-01	8.76E-01	3.88E+00	1.47E+01	1.54E+02	1.48E+03
PB208	1.45E-09	6.12E-06	3.32E-05	3.36E-05	3.36E-05	3.36E-05	3.40E-05	3.84E-05	7.82E-05	5.31E-04	4.59E-02	2.34E+00
PB209	5.59E-17	1.46E-13	6.74E-12	7.87E-11	7.46E-10	7.25E-09	4.06E-08	1.57E-07	3.47E-07	3.87E-07	1.98E-08	4.72E-21
PB210	8.21E-14	5.14E-10	1.29E-05	5.01E-05	1.45E-04	8.26E-04	2.70E-03	6.48E-03	9.36E-03	8.42E-03	8.10E-03	7.98E-03
PB211	2.03E-16	8.45E-13	4.35E-11	6.31E-11	1.14E-10	2.96E-10	6.98E-10	1.35E-09	1.56E-09	1.57E-09	1.55E-09	1.42E-09
PB212	6.83E-12	1.32E-08	6.85E-12	1.04E-14	5.00E-15	1.57E-14	5.01E-14	1.75E-13	5.32E-13	1.76E-12	1.56E-11	5.82E-11
PB214	2.03E-17	7.91E-14	3.16E-11	1.24E-10	4.80E-10	2.04E-09	6.68E-09	1.60E-08	2.31E-08	2.08E-08	2.00E-08	1.97E-08
BI209	5.18E-14	2.13E-10	1.29E-04	4.74E-05	1.30E-03	4.71E-02	8.95E-01	1.40E+01	1.14E+02	6.27E+02	2.75E+03	2.87E+03
BI210	5.32E-17	3.23E-13	4.36E-04	3.27E-08	1.27E-07	5.40E-07	1.76E-06	4.23E-06	6.11E-06	5.50E-06	5.29E-06	5.22E-06
BI211	1.21E-17	5.03E-14	2.59E-12	3.76E-12	7.04E-12	1.70E-11	4.14E-11	8.03E-11	9.31E-11	9.32E-11	9.24E-11	8.47E-11
BI213	1.42E-17	3.53E-14	1.63E-12	1.90E-11	1.80E-10	1.75E-09	8.82E-09	3.80E-08	8.34E-08	9.37E-08	4.78E-09	1.14E-21
BI214	1.49E-17	5.41E-14	2.33E-11	9.11E-11	3.54E-10	1.50E-09	4.91E-09	1.18E-08	1.70E-08	1.53E-08	1.47E-08	1.45E-08
PO210	4.51E-16	3.82E-12	2.30E-07	9.02E-07	3.51E-06	1.44E-05	4.86E-05	1.17E-04	1.68E-04	1.51E-04	1.46E-04	1.44E-04
PO218	2.34E-18	9.17E-15	3.57E-12	1.44E-11	5.55E-11	2.37E-10	7.74E-10	1.84E-09	2.68E-09	2.41E-09	2.32E-09	2.29E-09
RN222	4.39E-15	1.68E-11	6.74E-09	2.64E-08	1.03E-07	4.35E-07	1.47E-06	3.41E-06	4.93E-06	4.43E-06	4.26E-06	4.20E-06
RA223	9.78E-14	4.06E-10	2.09E-08	3.03E-08	5.67E-08	1.42E-07	3.35E-07	6.48E-07	7.51E-07	7.52E-07	7.46E-07	6.83E-07
RA224	5.95E-11	1.15E-07	5.94E-11	9.05E-14	4.34E-14	1.37E-13	4.36E-13	1.53E-12	4.63E-12	1.54E-11	1.36E-10	5.07E-10
RA225	7.21E-15	1.70E-11	7.81E-10	9.12E-09	8.64E-08	8.40E-07	4.70E-06	1.82E-05	4.02E-05	4.49E-05	2.29E-06	5.47E-19
RA226	6.77E-10	2.67E-06	1.05E-03	4.11E-03	1.60E-02	6.78E-02	2.21E-01	5.31E-01	7.68E-01	6.90E-01	6.64E-01	6.55E-01
RA228	1.00E-16	4.26E-13	8.04E-12	1.36E-11	3.00E-11	4.38E-11	2.98E-10	1.04E-09	3.17E-09	1.05E-08	9.27E-08	3.47E-07
AC225	4.60E-15	1.14E-11	5.28E-10	6.16E-09	5.84E-08	5.68E-07	3.18E-06	1.23E-05	2.71E-05	3.03E-05	1.55E-06	3.70E-19
AC227	8.71E-11	3.28E-07	1.47E-05	2.14E-05	3.44E-05	1.00E-04	2.36E-04	4.57E-04	5.24E-04	5.30E-04	5.25E-04	4.81E-04
TM227	1.72E-13	6.87E-10	3.34E-04	4.86E-04	9.04E-08	2.28E-07	5.37E-07	1.04E-06	1.20E-06	1.21E-06	1.20E-06	1.09E-06
TM228	1.16E-08	2.23E-05	1.16E-04	1.77E-11	8.56E-12	2.67E-11	8.50E-11	2.98E-10	9.04E-10	3.00E-09	2.64E-08	9.89E-08
TM229	1.43E-09	3.14E-06	1.43E-04	1.67E-03	1.58E-02	1.54E-01	8.62E-01	3.34E+00	7.37E+00	8.23E+00	4.20E+01	1.00E-13
TM230	1.70E-04	3.75E-01	4.47E-01	7.45E-01	1.60E+00	4.33E+00	1.12E+01	2.69E+01	3.90E+01	3.51E+01	3.38E+01	3.33E+01
TM231	1.51E-08	2.53E-07	4.37E-04	6.39E-04	6.44E-08	6.59E-08	6.90E-08	7.24E-08	7.30E-08	7.29E-08	7.23E-08	6.62E-08
TM232	5.57E-06	1.23E-02	1.72E-02	2.90E-02	6.43E-02	2.01E-01	6.39E-01	2.24E+00	6.79E+00	2.25E+01	1.99E+02	7.43E+02
TM234	1.25E-05	3.58E-03	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.83E-05	2.80E-05
PA231	8.21E-04	1.81E-02	2.25E-02	3.27E-02	6.11E-02	1.53E-01	3.62E-01	6.99E-01	8.10E-01	8.12E-01	8.04E-01	7.37E-01
PA233	3.29E-07	1.64E-04	8.46E-05	1.04E-04	1.11E-04	1.12E-04	1.11E-04	1.08E-04	1.02E-04	8.09E-05	4.39E-06	9.66E-19
PA234M	4.23E-10	1.21E-07	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.56E-10	9.43E-10
PA234	1.44E-10	4.22E-08	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.26E-10
U232	2.02E-09	4.71E-06	4.34E-07	5.15E-10	2.25E-18	0.	0.	0.	0.	0.	0.	0.
U233	4.53E-07	1.81E-03	2.29E-01	8.80E-01	2.87E+00	9.40E+00	2.88E+01	8.25E+01	1.65E+02	1.85E+02	9.48E+00	2.26E-12
U234	6.67E-02	1.47E+02	1.51E+02	1.51E+02	1.51E+02	1.50E+02	1.48E+02	1.41E+02	1.26E+02	1.09E+02	1.06E+02	1.05E+02
U235	7.16E+00	1.57E+04	1.58E+04	1.58E+04	1.57E+04	1.63E+04	1.71E+04	1.79E+04	1.80E+04	1.80E+04	1.79E+04	1.64E+04
U236	2.62E-01	5.77E+02	5.84E+02	5.99E+02	6.37E+02	7.22E+02	7.92E+02	8.01E+02	7.96E+02	7.80E+02	6.01E+02	4.42E+01
U238	8.97E-02	1.97E+06	1.47E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.94E+06
NP237	9.79E-01	2.16E+03	2.57E+03	3.03E+03	3.43E+03	3.24E+03	3.21E+03	3.14E+03	2.95E+03	2.35E+03	1.27E+02	2.80E-11
NP239	2.81E-04	1.88E-05	1.42E-05	1.71E-05	1.43E-05	1.75E-06	1.24E-06	2.18E-09	3.33E-17	3.66E-18	2.50E-18	5.58E-20
PU238	4.21E-04	2.15E+00	6.24E-01	1.70E-02	1.76E-06	2.43E-20	0.	0.	0.	0.	0.	0.
PU239	1.06E+00	2.33E+03	2.31E+03	2.27E+03	2.14E+03	1.76E+03	1.01E+03	1.38E+02	4.71E-01	1.11E-09	9.48E-12	2.12E-13
PU240	1.04E-01	2.29E+02	2.23E+02	2.07E+02	1.64E+02	8.23E+01	1.06E+01	8.10E-03	1.01E-11	2.30E-15	2.49E-15	1.17E-15
PU241	1.59E-02	3.44E-01	2.97E-05	2.24E-06	1.40E-06	1.05E-06	1.97E-07	5.57E-10	2.90E-17	0.	0.	0.
PU242	8.53E-04	1.88E+00	2.06E+00	2.11E+00	2.11E+00	2.08E+00	2.01E+00	1.76E+00	1.22E+00	3.40E-01	2.43E-08	0.
AM241	4.88E-01	1.07E+03	4.86E+02	2.24E+02	9.12E+00	1.55E-04	5.77E-06	1.63E-08	8.96E-16	0.	0.	0.
AM242M	6.11E-04	1.34E+00	3.42E-01	1.41E-02	1.54E-06	2.13E-20	0.	0.	0.	0.	0.	0.
AM242	7.34E-09	1.62E-05	4.10E-06	1.69E-07	1.85E-11	2.55E-25	0.	0.	0.	0.	0.	0.

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1330.0WD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
AM243	1.03E-02	2.26E+01	2.20E+01	2.07E+01	1.77E+01	9.15E+00	1.49E+00	2.63E-03	4.02E-11	4.42E-12	3.02E-12	6.74E-14
CM242	1.40E-03	1.83E+00	8.27E-04	3.38E-05	3.72E-09	5.13E-23	0.	0.	0.	0.	0.	0.
CM243	4.12E-06	9.00E-03	1.36E-05	3.54E-12	5.46E-31	0.	0.	0.	0.	0.	0.	0.
CM244	1.53E-04	3.32E-01	3.41E-06	7.93E-14	5.01E-23	1.86E-22	5.46E-22	1.70E-21	4.24E-21	8.15E-21	8.80E-21	4.14E-21
CM245	6.29E-07	1.38E-03	1.35E-03	1.27E-03	1.07E-03	5.97E-04	1.12E-04	3.16E-07	1.64E-14	0.	0.	0.
CM246	7.64E-09	1.68E-05	1.61E-05	1.45E-05	1.08E-05	3.86E-06	2.04E-07	6.87E-12	1.15E-24	0.	0.	0.
CM247	4.57E-12	1.01E-04	1.01E-04	1.01E-04	1.01E-04	1.00E-04	1.00E-04	1.00E-04	9.93E-09	9.64E-09	6.59E-09	1.47E-10
CM248	1.69E-14	3.72E-11	3.71E-11	3.71E-11	3.64E-11	3.64E-11	3.50E-11	3.06E-11	2.06E-11	5.19E-12	1.05E-19	0.
SUBTOT	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
TOTAL	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06

TABLE III-D-2
RADIOACTIVITY BY NUCLIDE, CURIES

TABLE III-D-2

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1350.000, FLUX= 2.17E+13/CM**2-SEC

MULTIPLE RADIOACTIVITY, CURIES

BASIS = 200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
H 3	2.42E+01	5.58E+04	4.27E+04	4.38E+04	4.71E+04	4.21E+04	3.18E+04	2.40E+04	1.81E+04	1.03E+04	3.33E+03	1.99E+02
SF 74	1.78E+02	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.90E+01
SR 87	9.74E+07	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03
SP 89	2.02E+04	7.43E+06	5.71E+04	4.39E+02	3.38E+00	2.00E+04	5.39E+15	1.45E+25	3.91E+36	2.83E+57	0.	0.
SP 90	3.66E+03	8.43E+06	4.22E+06	8.02E+06	7.05E+06	7.45E+06	6.59E+06	5.82E+06	5.15E+06	4.02E+06	2.46E+06	7.16E+05
Y 90	3.66E+03	8.50E+06	4.22E+06	8.02E+06	7.05E+06	7.45E+06	6.59E+06	5.82E+06	5.15E+06	4.02E+06	2.46E+06	7.16E+05
Y 91	3.26E+04	1.36E+07	1.44E+05	2.49E+03	3.33E+01	6.12E+03	2.75E+12	1.24E+21	5.50E+31	1.12E+49	0.	0.
ZR 03	8.74E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02
NR 93K	3.24E+02	1.28E+01	1.28E+01	3.03E+01	3.73E+01	5.34E+01	8.47E+01	1.09E+02	1.28E+02	1.54E+02	1.79E+02	1.92E+02
ZR 95	4.55E+04	2.95E+07	6.24E+05	8.42E+03	1.76E+02	7.28E+02	2.55E+10	8.92E+19	3.12E+27	3.33E+44	0.	0.
NR 95M	9.47E+02	4.58E+05	6.94E+03	1.63E+02	3.73E+00	1.54E+03	5.41E+12	1.89E+20	6.63E+29	8.13E+46	0.	0.
NR 95	8.45E+04	4.25E+07	5.34E+05	1.92E+04	3.40E+02	1.58E+01	5.53E+10	1.94E+18	6.76E+27	8.30E+44	0.	0.
TC 99	6.36E+01	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03
RH103	2.54E+03	2.39E+06	4.01E+03	6.72E+00	1.13E+02	3.16E+08	4.17E+22	5.50E+36	7.26E+50	0.	0.	0.
RH103M	2.55E+03	2.40E+06	4.02E+03	6.73E+00	1.13E+02	3.16E+08	4.17E+22	5.51E+36	7.27E+50	0.	0.	0.
RH104	1.57E+04	2.33E+07	1.17E+07	5.98E+06	2.47E+06	7.42E+05	2.36E+04	7.51E+02	2.37E+01	2.41E+02	2.47E+08	2.60E+23
RH105	1.57E+04	2.33E+07	1.17E+07	5.98E+06	2.47E+06	7.42E+05	2.36E+04	7.51E+02	2.37E+01	2.41E+02	2.47E+08	2.60E+23
PD107	2.29E+04	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00
AG109M	2.12E+10	3.37E+07	1.43E+07	1.10E+07	6.31E+08	2.68E+08	1.24E+09	7.73E+11	4.73E+12	1.77E+14	2.48E+19	1.83E+31
CD109	2.12E+10	3.37E+07	1.43E+07	1.10E+07	6.31E+08	2.68E+08	1.24E+09	7.73E+11	4.73E+12	1.77E+14	2.48E+19	1.83E+31
AG110M	4.35E+09	5.55E+02	2.04E+03	7.62E+02	2.76E+02	3.74E+01	2.51E+01	1.69E+03	1.14E+05	5.13E+10	1.05E+18	0.
AG110	5.70E+01	7.23E+02	2.65E+02	9.77E+01	3.73E+01	4.85E+00	3.27E+02	2.20E+04	1.48E+06	6.67E+11	1.36E+19	0.
CD113M	1.05E+02	2.25E+01	2.14E+01	2.03E+01	1.74E+01	1.73E+01	1.37E+01	1.07E+01	8.34E+00	5.09E+00	1.89E+00	1.59E+01
CD115M	3.65E+01	1.11E+03	2.14E+01	8.57E+03	2.37E+05	1.84E+10	3.03E+23	5.01E+36	8.26E+49	0.	0.	0.
SN119M	6.94E+01	8.75E+02	2.14E+02	1.15E+02	4.13E+01	5.54E+00	3.51E+02	2.22E+04	1.41E+06	5.63E+11	9.05E+20	0.
SN121M	1.22E+02	2.66E+03	2.66E+03	2.61E+03	2.70E+03	2.54E+03	2.43E+03	2.32E+03	2.22E+03	2.03E+03	1.69E+03	1.07E+03
SN123	3.14E+04	2.54E+05	2.36E+04	4.43E+03	5.84E+02	1.02E+01	4.04E+04	1.64E+08	6.57E+13	1.06E+21	2.73E+39	0.
TF123M	4.80E+05	7.55E+02	8.04E+03	9.98E+04	1.1E+04	1.51E+06	3.04E+11	6.10E+16	1.22E+20	4.92E+30	7.97E+49	0.
SR124	2.14E+01	9.12E+01	1.34E+00	1.94E+02	2.41E+04	6.30E+08	4.35E+17	3.01E+26	2.08E+35	9.43E+54	0.	0.
SR125	2.54E+02	4.98E+05	3.05E+05	2.58E+05	2.30E+05	1.38E+05	3.82E+04	1.06E+04	2.93E+03	2.25E+02	1.33E+00	3.55E+06
TF125M	1.32E+02	2.63E+05	1.54E+05	1.23E+05	9.55E+04	5.72E+04	1.58E+04	4.39E+03	1.22E+03	4.34E+01	5.51E+01	1.47E+06
SN126	1.44E+02	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01
SR126M	1.44E+02	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01
SR126	1.44E+02	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01
TF127M	5.24E+02	3.84E+05	3.75E+04	3.65E+03	3.67E+02	3.48E+00	3.16E+05	2.86E+10	2.60E+15	2.14E+25	1.44E+45	0.
TF127	5.22E+02	3.81E+05	3.72E+04	3.65E+03	3.50E+02	3.44E+00	3.12E+05	2.83E+10	2.57E+15	2.11E+25	1.43E+45	0.
I129	2.74E+04	6.15E+01	6.15E+01	6.15E+01	6.15E+01	5.15E+01	6.15E+01	6.15E+01	6.15E+01	6.15E+01	6.15E+01	6.15E+01
CS134	5.74E+02	1.22E+06	6.67E+05	6.18E+05	4.41E+05	2.24E+05	4.14E+04	7.63E+03	1.41E+03	4.79E+01	5.55E+02	2.53E+09
CS135	9.95E+03	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01
CS137	4.50E+03	9.76E+06	9.54E+04	9.32E+06	2.11E+06	4.70E+06	7.75E+06	6.91E+06	6.15E+06	4.88E+06	3.08E+06	9.69E+05
BA137M	4.21E+03	9.13E+06	8.92E+04	8.72E+06	8.50E+06	8.13E+06	7.25E+06	6.46E+06	5.75E+06	4.57E+06	2.88E+06	9.06E+05
CE141	6.63E+03	1.52E+06	4.16E+02	2.49E+01	1.01E+04	1.65E+11	1.80E+28	1.95E+45	2.12E+62	0.	0.	0.
CE144	7.75E+04	1.04E+08	4.25E+07	1.74E+07	7.16E+06	1.20E+06	1.40E+04	1.62E+02	1.88E+00	2.54E+04	4.60E+12	2.04E+31
PR144	7.75E+04	1.04E+08	4.25E+07	1.75E+07	7.16E+06	1.20E+06	1.40E+04	1.62E+02	1.88E+00	2.54E+04	4.60E+12	2.04E+31
PM147	1.54E+04	2.92E+07	2.24E+07	1.72E+07	1.32E+07	7.79E+06	2.07E+06	5.53E+05	1.47E+05	1.05E+04	5.27E+01	9.52E+05
PM148M	9.43E+01	2.40E+04	6.77E+01	1.43E+01	3.74E+04	2.30E+09	1.84E+22	1.54E+35	1.27E+48	0.	0.	0.
PM148	7.58E+04	2.25E+03	5.44E+00	1.31E+02	3.17E+05	1.85E+10	1.51E+23	1.24E+36	1.02E+49	0.	0.	0.
SM151	1.12E+02	2.45E+05	2.43E+05	2.41E+05	2.37E+05	2.35E+05	2.26E+05	2.17E+05	2.09E+05	1.93E+05	1.64E+05	1.10E+05
EUI152	2.44E+01	5.61E+02	5.29E+02	5.00E+02	4.71E+02	4.20E+02	3.15E+02	2.36E+02	1.77E+02	9.92E+01	3.12E+01	1.74E+00
GD153	1.84E+02	2.29E+01	8.04E+00	8.93E+00	9.43E+01	1.23E+01	5.56E+04	3.52E+06	1.88E+08	5.40E+13	4.44E+22	0.
EUI154	1.77E+01	3.79E+04	3.63E+04	3.63E+04	3.63E+04	3.05E+04	2.46E+04	1.98E+04	1.59E+04	1.03E+04	4.34E+03	4.98E+02
EUI155	2.23E+02	3.91E+05	2.67E+05	1.62E+05	1.62E+05	5.77E+04	8.50E+03	1.25E+03	1.85E+02	4.02E+00	1.90E+03	9.21E+12

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1346.440, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, Curies
PLSIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
TR140	7.44E-01	3.85E-02	1.15E-01	3.44E-01	1.03E-02	4.17E-06	2.18E-13	5.20E-21	1.24E-28	7.03E-44	0.	0.
MO166M	1.21E-07	2.64E-04	2.65E-04	2.55E-04	2.45E-04	2.65E-04	2.64E-04	2.63E-04	2.63E-04	2.61E-04	2.58E-04	2.51E-04
SURTOT	4.32E+03	4.14E+09	1.70E+08	9.24E+07	6.75E+07	4.42E+07	3.07E+07	2.58E+07	2.26E+07	1.77E+07	1.10E+07	3.42E+06
TOTAL	4.32E+03	4.14E+09	1.70E+08	9.24E+07	6.75E+07	4.42E+07	3.07E+07	2.58E+07	2.26E+07	1.77E+07	1.10E+07	3.42E+06

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, Curies
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
H 3	2.62E+01	5.65E+04	2.54E+03	1.92E+20	0.	0.	0.	0.	0.	0.	0.	0.
SE 79	1.78E+02	3.91E+01	3.90E+01	3.87E+01	3.74E+01	3.51E+01	2.84E+01	1.35E+01	1.60E+00	9.16E-04	0.	0.
RB 87	9.74E+07	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03	2.14E+03
SR 90	3.89E+03	8.48E+06	5.14E+04	1.65E+04	6.26E+26	0.	0.	0.	0.	0.	0.	0.
Y 90	3.89E+03	8.48E+06	5.14E+04	1.65E+04	6.26E+26	0.	0.	0.	0.	0.	0.	0.
ZR 93	8.74E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.92E+02	1.90E+02	1.84E+02	1.58E+02	1.21E+02	1.90E+00	1.66E-18
NB 93M	3.24E+03	1.06E+01	1.93E+02	1.93E+02	1.93E+02	1.92E+02	1.90E+02	1.84E+02	1.68E+02	1.21E+02	1.90E+00	1.66E-18
TC 99	6.34E+01	1.40E+03	1.40E+03	1.40E+03	1.34E+03	1.36E+03	1.27E+03	1.01E+03	5.25E+02	5.33E+01	8.91E-12	0.
PD107	2.29E+03	5.05E+00	5.05E+00	5.05E+00	4.09E+00	5.04E+00	5.03E+00	5.00E+00	4.90E+00	4.57E+00	1.88E+00	2.53E-04
CD113M	1.05E+02	2.27E+01	8.08E+06	7.23E+21	0.	0.	0.	0.	0.	0.	0.	0.
SN121M	1.22E+06	2.67E+03	1.73E+04	2.93E+07	3.52E+15	0.	0.	0.	0.	0.	0.	0.
SN126	1.44E+02	3.16E+01	3.14E+01	3.14E+01	3.10E+01	2.95E+01	2.57E+01	1.58E+01	3.96E+00	3.09E+02	0.	0.
SB126M	1.44E+02	3.16E+01	3.14E+01	3.14E+01	3.10E+01	2.95E+01	2.57E+01	1.58E+01	3.96E+00	3.09E+02	0.	0.
SB126	1.44E+02	3.14E+01	3.13E+01	3.11E+01	3.07E+01	2.92E+01	2.54E+01	1.57E+01	3.92E+00	3.06E+02	0.	0.
I129	2.78E+04	6.15E+01	6.15E+01	6.15E+01	6.15E+01	6.15E+01	6.14E+01	6.13E+01	6.08E+01	5.91E+01	4.09E+01	1.04E-02
CS135	9.95E+03	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.18E+01	2.17E+01	2.14E+01	2.04E+01	1.74E+01	2.17E+00	2.03E-09
CS137	4.50E+03	9.82E+06	9.60E+03	9.12E+04	7.80E+24	0.	0.	0.	0.	0.	0.	0.
RA137M	4.21E+03	9.18E+06	9.98E+03	8.53E+04	7.35E+24	0.	0.	0.	0.	0.	0.	0.
SM151	1.12E+02	2.45E+05	2.25E+04	8.52E+01	1.43E+05	0.	0.	0.	0.	0.	0.	0.
EU152	2.44E+01	5.69E+02	1.70E+05	4.73E+23	0.	0.	0.	0.	0.	0.	0.	0.
EU154	1.77E+01	3.83E+04	8.70E+02	5.92E+15	0.	0.	0.	0.	0.	0.	0.	0.
MO166M	1.21E+07	2.66E+04	2.23E+04	1.49E+04	4.70E+05	8.25E+07	7.95E+12	2.21E+29	0.	0.	0.	0.
SUBTOT	1.66E+04	3.63E+07	5.34E+04	2.03E+03	1.43E+03	1.89E+03	1.78E+03	1.47E+03	9.00E+02	3.19E+02	8.26E+00	1.28E-02
TOTAL	4.34E+05	5.21E+08	5.34E+04	2.03E+03	1.43E+03	1.89E+03	1.78E+03	1.47E+03	9.00E+02	3.19E+02	8.26E+00	1.28E-02

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10,000MW, BURNUP= 1340,440, FLUX= 2.1/E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
TL207	5.01E-09	2.73E-05	5.67E-05	8.21E-05	1.07E-04	1.54E-04	2.59E-04	3.50E-04	4.28E-04	5.52E-04	7.12E-04	8.76E-04
TL208	3.51E-06	6.21E-03	4.26E-03	2.98E-03	2.04E-03	1.03E-03	2.12E-04	7.80E-05	5.46E-05	4.62E-05	3.81E-05	2.35E-05
TL209	5.89E-12	1.47E-08	1.44E-08	1.49E-08	1.50E-08	1.52E-08	1.59E-08	1.70E-08	1.84E-08	2.23E-08	3.42E-08	8.88E-08
PR209	2.54E-10	5.69E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
PR210	6.64E-12	6.95E-08	2.29E-07	4.65E-07	8.36E-07	1.81E-06	5.69E-06	1.14E-05	1.87E-05	3.70E-05	8.42E-05	2.32E-04
PR211	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
PR212	9.53E-06	1.72E-02	1.18E-02	8.27E-03	5.79E-03	2.67E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
PR214	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.45E-05	1.92E-05	3.51E-05	5.10E-05	6.64E-05	9.90E-05	1.64E-04	3.29E-04
RT210	6.61E-12	6.76E-08	2.24E-07	4.65E-07	8.36E-07	1.81E-06	5.69E-06	1.14E-05	1.87E-05	3.70E-05	8.42E-05	2.32E-04
RT211	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
RT212	9.74E-06	1.72E-02	1.14E-02	8.27E-03	5.79E-03	2.67E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
RT213	2.67E-10	6.49E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
RT214	6.64E-12	6.43E-06	6.57E-06	9.72E-06	1.45E-05	1.92E-05	3.51E-05	5.10E-05	6.64E-05	9.90E-05	1.64E-04	3.29E-04
PO210	2.03E-12	3.35E-08	1.42E-07	3.43E-07	6.39E-07	1.51E-06	5.69E-06	1.14E-05	1.87E-05	3.70E-05	8.42E-05	2.32E-04
PO211	1.51E-11	8.21E-08	1.76E-07	2.47E-07	3.71E-07	4.63E-07	7.81E-07	1.05E-06	1.29E-06	1.66E-06	2.14E-06	2.64E-06
PO212	6.24E-06	1.10E-02	7.57E-03	5.24E-03	3.71E-03	1.84E-03	3.78E-04	1.39E-04	9.71E-05	8.21E-05	6.77E-05	4.18E-05
PO213	2.61E-10	4.54E-07	6.49E-07	6.42E-07	6.26E-07	6.75E-07	7.08E-07	7.56E-07	8.19E-07	9.42E-07	1.52E-06	3.95E-06
PO214	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.45E-05	1.92E-05	3.51E-05	5.10E-05	6.64E-05	9.90E-05	1.64E-04	3.29E-04
PO215	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
PO216	9.54E-06	1.72E-02	1.14E-02	8.27E-03	5.79E-03	2.67E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
PO218	6.64E-10	3.43E-06	6.57E-06	9.72E-06	1.45E-05	1.92E-05	3.51E-05	5.10E-05	6.64E-05	9.90E-05	1.64E-04	3.29E-04
AT217	2.67E-10	6.49E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
RN219	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
RN220	9.54E-06	1.72E-02	1.14E-02	8.27E-03	5.79E-03	2.67E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
RN222	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.45E-05	1.92E-05	3.51E-05	5.10E-05	6.64E-05	9.90E-05	1.64E-04	3.29E-04
FR221	2.67E-10	6.49E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
FR223	8.69E-11	4.27E-07	7.95E-07	1.15E-06	1.50E-06	2.16E-06	3.64E-06	4.91E-06	6.00E-06	7.73E-06	9.98E-06	1.23E-05
RA223	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
RA224	9.54E-06	1.72E-02	1.14E-02	8.27E-03	5.79E-03	2.67E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
RA225	2.83E-10	6.70E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
RA226	6.70E-10	3.41E-06	6.57E-06	9.72E-06	1.45E-05	1.92E-05	3.51E-05	5.10E-05	6.64E-05	9.90E-05	1.64E-04	3.29E-04
RA228	2.35E-14	1.30E-10	2.49E-10	3.57E-10	4.74E-10	6.21E-10	9.17E-10	1.10E-09	1.21E-09	1.32E-09	1.41E-09	1.50E-09
AC225	2.67E-10	6.69E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
AC227	6.34E-09	3.05E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
AC228	2.34E-14	1.30E-10	2.49E-10	3.57E-10	4.74E-10	6.21E-10	9.17E-10	1.10E-09	1.21E-09	1.32E-09	1.41E-09	1.50E-09
TH227	5.44E-04	2.81E-05	5.00E-05	8.12E-05	1.00E-04	1.52E-04	2.57E-04	3.46E-04	4.23E-04	5.45E-04	7.04E-04	8.66E-04
TH228	9.49E-06	1.64E-02	1.18E-02	8.23E-03	5.79E-03	2.67E-03	5.90E-04	2.16E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
TH229	3.05E-10	6.72E-07	6.74E-07	6.77E-07	6.61E-07	6.90E-07	7.24E-07	7.73E-07	8.34E-07	1.01E-06	1.56E-06	4.04E-06
TH230	3.31E-06	7.29E-03	7.30E-03	7.30E-03	7.31E-03	7.33E-03	7.37E-03	7.41E-03	7.44E-03	7.52E-03	7.68E-03	8.07E-03
TH231	8.02E-03	9.43E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.38E-02	3.38E-02
TH232	6.09E-13	1.34E-09	1.34E-09	1.34E-09	1.35E-09	1.35E-09	1.36E-09	1.37E-09	1.38E-09	1.39E-09	1.43E-09	1.52E-09
TH234	2.94E-01	5.02E+01	4.59E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
PA231	3.91E-07	8.63E-04	8.64E-04	8.64E-04	8.64E-04	8.64E-04	8.70E-04	8.73E-04	8.77E-04	8.84E-04	8.98E-04	9.33E-04
PA233	6.73E-03	2.69E+00	1.52E+00	1.52E+00	1.52E+00	1.53E+00	1.53E+00	1.54E+00	1.54E+00	1.56E+00	1.58E+00	1.63E+00
PA234	2.94E-01	5.02E+01	4.59E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
PA234	2.94E-01	5.02E+01	4.59E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
U232	4.34E-08	1.04E-04	1.16E-04	1.25E-04	1.32E-04	1.40E-04	1.46E-04	1.42E-04	1.37E-04	1.25E-04	1.03E-04	6.36E-05
U233	4.25E-04	1.90E-05	2.68E-05	3.40E-05	4.12E-05	5.50E-05	8.77E-05	1.21E-04	1.53E-04	2.20E-04	3.54E-04	6.97E-04
U234	4.12E-04	9.08E-01	9.08E-01	9.08E-01	9.08E-01	9.08E-01	9.08E-01	9.10E-01	9.11E-01	9.13E-01	9.16E-01	9.21E-01
U235	1.53E-05	3.37E-02	1.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.38E-02	3.38E-02
U236	1.66E-05	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.67E-02	3.67E-02
U237	4.06E-05	8.54E-02	8.15E-02	7.78E-02	7.44E-02	6.76E-02	5.35E-02	4.23E-02	3.35E-02	2.10E-02	8.22E-03	7.91E-04

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER = 10.00MW, BURNUP = 1380.0AD, FLUX = $2.17 \times 10^{13} \text{N/CM}^2\text{-SEC}$ NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
U238	2.99E-04	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
NP237	6.91E-04	1.52E+00	1.52E+00	1.52E+00	1.52E+00	1.53E+00	1.53E+00	1.54E+00	1.54E+00	1.56E+00	1.58E+00	1.63E+00
NP239	6.93E-04	4.37E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.34E+00	4.33E+00	4.32E+00
PU236	7.95E-07	1.51E-03	1.19E-03	9.30E-04	7.69E-04	4.48E-04	1.33E-04	3.94E-05	1.17E-05	1.03E-06	7.94E-09	4.16E-14
PU238	7.11E-03	4.38E+01	4.14E+01	6.48E+01	6.59E+01	6.46E+01	6.25E+01	6.05E+01	5.86E+01	5.49E+01	4.83E+01	3.51E+01
PU239	6.49E-02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.42E+02
PU240	2.30E-02	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.04E+01	5.03E+01	5.01E+01
PU241	1.60E+00	3.41E+03	3.26E+03	3.11E+03	2.98E+03	2.70E+03	2.14E+03	1.69E+03	1.34E+03	8.37E+02	3.28E+02	3.16E+01
PU242	3.33E-06	7.32E-03	7.32E-03	7.33E-03	7.33E-03	7.34E-03	7.36E-03	7.38E-03	7.40E-03	7.44E-03	7.51E-03	7.66E-03
AM241	1.47E+00	3.68E+03	3.68E+03	3.68E+03	3.68E+03	3.67E+03	3.66E+03	3.65E+03	3.63E+03	3.59E+03	3.50E+03	3.24E+03
AM242M	5.94E-03	1.30E+01	1.30E+01	1.29E+01	1.29E+01	1.27E+01	1.25E+01	1.22E+01	1.19E+01	1.14E+01	1.04E+01	8.26E+00
AM242	5.94E-03	1.31E+01	1.30E+01	1.29E+01	1.29E+01	1.27E+01	1.25E+01	1.22E+01	1.19E+01	1.14E+01	1.04E+01	8.26E+00
CM243	1.98E-03	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.34E+00	4.33E+00	4.32E+00
CM242	4.64E+00	4.56E+03	4.74E+02	2.15E+02	5.37E+01	1.24E+01	1.02E+01	9.99E+00	9.76E+00	9.32E+00	8.51E+00	6.78E+00
CM243	1.90E-04	4.12E-01	4.03E-01	3.94E-01	3.85E-01	3.69E-01	3.32E-01	2.98E-01	2.67E-01	2.15E-01	1.39E-01	4.72E-02
CM244	1.24E-02	2.67E+01	2.57E+01	2.47E+01	2.38E+01	2.20E+01	1.82E+01	1.50E+01	1.24E+01	8.45E+00	3.93E+00	5.79E-01
CM245	1.11E-07	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.43E-04	2.43E-04	2.42E-04
CM246	2.36E-09	5.19E-06	5.19E-06	5.19E-06	5.19E-06	5.18E-06	5.18E-06	5.18E-06	5.17E-06	5.16E-06	5.15E-06	5.11E-06
SUBTOT	8.63E+00	1.21E+04	2.23E+03	7.32E+03	7.92E+03	6.71E+03	6.13E+03	5.66E+03	5.28E+03	4.73E+03	4.11E+03	3.54E+03
TOTAL	8.63E+00	1.21E+04	2.23E+03	7.32E+03	7.92E+03	6.71E+03	6.13E+03	5.66E+03	5.28E+03	4.73E+03	4.11E+03	3.54E+03

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1390.4WD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
TL207	5.01E-09	2.08E-05	1.07E-03	1.55E-03	2.91E-03	7.28E-03	1.72E-02	3.32E-02	3.85E-02	3.85E-02	3.82E-02	3.50E-02
TL208	3.51E-06	6.65E-03	3.44E-04	5.22E-09	2.93E-09	7.90E-09	2.51E-08	8.81E-08	2.67E-07	8.86E-07	7.82E-06	2.93E-05
TL209	5.88E-12	1.46E-08	6.74E-07	7.87E-06	7.46E-05	7.25E-04	4.06E-03	1.57E-02	3.47E-02	3.87E-02	1.98E-03	4.72E-16
PB209	2.54E-10	6.64E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
PB210	6.66E-12	4.17E-08	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PB211	5.02E-09	2.04E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
PB212	9.53E-06	1.85E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
PB214	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
BI210	6.61E-12	4.01E-08	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
BI211	5.02E-09	2.04E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
BI212	9.74E-06	1.85E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
BI213	2.67E-10	6.64E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
BI214	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PO210	2.03E-12	1.72E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PO211	1.51E-11	6.26E-08	3.22E-06	4.68E-06	8.74E-06	2.19E-05	5.17E-05	9.99E-05	1.16E-04	1.16E-04	1.15E-04	1.05E-04
PO212	6.24E-06	1.18E-02	4.11E-06	9.29E-09	4.50E-09	1.41E-08	4.47E-08	1.57E-07	4.75E-07	1.58E-06	1.39E-05	5.20E-05
PO213	2.61E-10	6.49E-07	3.00E-05	3.50E-04	3.31E-03	3.22E-02	1.80E-01	6.98E-01	1.54E+00	1.72E+00	8.78E-02	2.10E-14
PO214	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PO215	5.02E-09	2.04E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
PO216	9.54E-06	1.84E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
PO218	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
AT217	2.67E-10	6.63E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
RN219	5.02E-09	2.04E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
RN220	9.54E-06	1.84E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
RN222	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
FR221	2.67E-10	6.63E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
FR223	8.89E-11	3.35E-07	1.50E-05	2.18E-05	4.08E-05	1.02E-04	2.41E-04	4.66E-04	5.40E-04	5.41E-04	5.37E-04	4.91E-04
RA223	5.02E-09	2.04E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
RA224	9.53E-06	1.84E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
RA225	2.83E-10	6.68E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
RA226	6.70E-10	7.64E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
RA228	2.38E-14	9.97E-11	1.88E-09	3.17E-09	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
AC225	2.67E-10	6.63E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
AC227	6.35E-09	2.40E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
AC228	2.34E-14	9.98E-11	1.88E-09	3.17E-09	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
TM227	5.44E-09	2.17E-05	1.08E-03	1.54E-03	2.87E-03	7.20E-03	1.70E-02	3.28E-02	3.81E-02	3.81E-02	3.78E-02	3.46E-02
TM228	9.49E-06	1.83E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
TM229	3.05E-10	6.72E-07	3.07E-05	3.58E-04	3.34E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
TM230	3.31E-06	7.29E-03	9.67E-03	1.53E-02	3.11E-02	8.42E-02	2.18E-01	5.23E-01	7.57E-01	6.82E-01	6.57E-01	6.48E-01
TM231	8.02E-03	1.34E-01	3.38E-02	3.39E-02	3.41E-02	3.50E-02	3.66E-02	3.84E-02	3.87E-02	3.87E-02	3.83E-02	3.51E-02
TM232	6.09E-13	1.34E-09	1.88E-09	3.17E-09	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
TM234	2.90E-01	8.28E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.57E-01	6.48E-01
PA231	3.91E-07	8.63E-04	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
PA233	6.73E-03	3.47E+00	1.81E+00	2.13E+00	2.24E+00	2.28E+00	2.27E+00	2.22E+00	2.08E+00	1.66E+00	8.98E-02	1.98E-14
PA234M	2.90E-01	8.28E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.57E-01	6.48E-01
PA234	2.93E-04	8.38E-02	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.57E-04	6.48E-04
U232	4.34E-08	1.01E-04	9.30E-06	1.10E-08	4.81E-17	0.	0.	0.	0.	0.	0.	0.
U233	4.29E-09	1.71E-05	2.17E-03	8.15E-03	2.72E-02	9.38E-02	2.73E-01	7.82E-01	1.56E+00	1.76E+00	8.98E-02	2.14E-14
U234	4.12E-04	9.08E-01	9.33E-01	9.37E-01	9.36E-01	9.31E-01	9.16E-01	8.70E-01	7.79E-01	6.75E-01	6.57E-01	6.48E-01
U235	1.53E-05	3.37E-02	3.38E-02	3.39E-02	3.41E-02	3.50E-02	3.66E-02	3.84E-02	3.87E-02	3.87E-02	3.83E-02	3.51E-02
U236	1.66E-05	3.66E-02	3.70E-02	3.80E-02	4.04E-02	4.58E-02	5.02E-02	5.08E-02	5.05E-02	4.95E-02	3.81E-02	2.80E-03
U237	4.00E-05	8.64E-02	7.45E-08	5.62E-09	4.75E-09	2.64E-09	4.94E-10	1.40E-12	7.28E-20	0.	0.	0.

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1390.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
U238	2.99E-04	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.57E-01	6.48E-01
NP237	6.91E-04	1.52E+00	1.81E+00	2.13E+00	2.44E+00	2.28E+00	2.27E+00	2.22E+00	2.08E+00	1.66E+00	8.98E-02	1.98E-14
NP239	6.53E-04	4.38E+00	4.24E+00	3.98E+00	3.92E+00	1.70E+00	2.88E-01	5.07E-04	7.74E-12	8.51E-13	5.82E-13	1.30E-14
PU238	7.11E-03	3.63E+01	1.05E+01	2.87E-01	2.97E-05	4.10E-11	0.	0.	0.	0.	0.	0.
PU239	6.49E-02	1.43E+02	1.42E+02	1.39E+02	1.34E+02	1.08E+02	6.17E+01	8.46E+00	2.89E-02	6.79E-11	5.82E-13	1.30E-14
PU240	2.30E-02	5.05E+01	4.91E+01	4.57E+01	3.74E+01	1.82E+01	2.34E+00	1.79E-03	2.23E-12	5.08E-16	5.48E-16	2.58E-16
PU241	1.60E+00	3.45E+03	2.98E+03	2.25E+04	1.90E+04	1.06E+04	1.98E-05	5.58E-08	2.91E-15	0.	0.	0.
PU242	3.33E-06	7.32E-03	8.02E-03	8.24E-03	8.24E-03	8.11E-03	7.82E-03	6.88E-03	4.77E-03	1.33E-03	9.46E-11	0.
AM241	1.67E+00	3.68E+03	2.35E+03	7.67E+02	3.14E+01	5.32E-04	1.98E-05	5.58E-08	3.07E-15	0.	0.	0.
AM242M	5.94E-03	1.30E+01	3.32E+00	1.37E-01	1.90E-05	2.07E-19	0.	0.	0.	0.	0.	0.
AM242	5.94E-03	1.31E+01	3.32E+00	1.37E-01	1.90E-05	2.07E-19	0.	0.	0.	0.	0.	0.
AM243	1.98E-03	4.35E+00	4.24E+00	3.98E+00	3.92E+00	1.76E+00	2.88E-01	5.07E-04	7.74E-12	8.51E-13	5.82E-13	1.30E-14
CM242	4.64E+00	6.07E+03	2.73E+00	1.12E-01	1.43E-05	1.70E-19	0.	0.	0.	0.	0.	0.
CM243	1.90E-04	4.14E-01	6.24E-04	1.63E-10	2.72E-29	0.	0.	0.	0.	0.	0.	0.
CM244	1.24E-02	2.69E+01	2.76E-04	6.34E-16	4.94E-21	1.50E-20	4.42E-20	1.38E-19	3.43E-19	6.60E-19	7.12E-19	3.35E-19
CM245	1.11E-07	2.44E-04	2.38E-04	2.24E-04	1.90E-04	1.06E-04	1.97E-05	5.57E-08	2.91E-15	0.	0.	0.
CM246	2.36E-09	5.19E-06	4.96E-06	4.48E-06	3.34E-06	1.19E-06	6.29E-08	2.12E-12	3.54E-25	0.	0.	0.
SUBTOT	8.63E+00	1.37E+04	2.58E+03	9.68E+02	2.14E+02	1.39E+02	7.62E+01	2.79E+01	2.92E+01	2.91E+01	1.06E+01	9.46E+00
TOTAL	8.63E+00	1.37E+04	2.58E+03	9.68E+02	2.14E+02	1.39E+02	7.62E+01	2.79E+01	2.92E+01	2.91E+01	1.06E+01	9.46E+00

TABLE III-D-3

THERMAL POWER BY NUCLIDE, WATTS

TABLE III-D-3

N REACTOR 1947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER = 10.10MW, RUPNLP = 1380.0WD, FLUX = 2.1E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS 1947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
H 3	9.37E-04	1.99E-00	1.88E-00	1.77E-00	1.66E-00	1.50E-00	1.13E-00	8.52E-01	6.43E-01	3.66E-01	1.19E-01	7.09E-03
SE 79	6.74E-04	1.48E-02	1.44E-02	1.48E-02	1.44E-02	1.46E-02	1.44E-02	1.43E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02
RA 97	4.34E-04	1.43E-04	1.43E-04	1.40E-05	1.40E-05	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06
SR 99	7.27E-01	2.67E-04	2.66E-02	1.58E-00	1.44E-02	7.20E-07	1.94E-17	5.22E-28	1.41E-38	1.02E-59	0.	0.
SR 90	5.04E-00	1.10E-04	1.66E-04	1.05E-04	1.03E-04	9.76E-03	8.63E-03	7.63E-03	6.74E-03	5.27E-03	3.22E-03	9.37E-02
Y 90	2.24E-01	5.00E-04	4.24E-04	4.72E-04	4.01E-04	4.39E-04	3.88E-04	3.43E-04	3.03E-04	2.37E-04	1.45E-04	4.21E+03
Y 91	1.25E-02	5.19E-04	7.60E-02	9.46E-00	1.44E-01	2.33E-05	1.05E-14	4.70E-24	2.11E-33	4.27E-52	0.	0.
ZR 93	1.04E-05	2.29E-02	2.24E-02	2.24E-02	2.24E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02
NR 93M	5.77E-07	2.24E-03	3.37E-03	5.34E-03	3.62E-03	4.46E-03	1.51E-02	1.94E-02	2.27E-02	2.73E-02	3.18E-02	3.41E-02
ZR 95	2.34E-02	1.09E-05	2.22E-04	4.51E-01	1.12E-01	3.81E-04	1.33E-12	4.67E-21	1.63E-29	2.00E-46	0.	0.
NR 95M	1.35E-00	4.30E-02	1.25E-01	2.55E-01	4.14E-03	2.15E-06	7.53E-15	2.64E-23	9.23E-32	1.13E-48	0.	0.
NR 95	4.24E-02	2.05E-05	4.52E-03	9.23E-01	1.44E-00	7.60E-04	2.66E-12	9.32E-21	3.26E-29	4.00E-46	0.	0.
TC 99	4.34E-04	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01
RU103	2.41E-01	7.49E-03	1.32E-01	2.21E-02	3.71E-05	1.04E-10	1.37E-24	1.81E-38	2.39E-52	0.	0.	0.
RM103M	4.06E-00	1.14E-03	1.50E-05	3.19E-03	3.34E-06	1.50E-11	1.94E-25	2.61E-39	3.45E-53	0.	0.	0.
RU106	9.37E-01	1.39E-02	6.44E-02	3.48E-02	1.73E-02	4.40E-01	1.40E-00	4.45E-02	1.41E-03	1.43E-06	1.46E-12	1.54E-27
RM106	1.45E-02	2.45E-05	1.23E-05	6.19E-04	3.10E-04	7.80E-03	2.44E-02	7.89E-00	2.51E-01	2.54E-04	2.54E-10	2.74E-25
PD107	1.20E-17	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04	4.15E-04
AG109M	2.91E-13	3.52E-10	2.61E-10	1.15E-10	6.25E-11	2.15E-11	1.32E-12	8.06E-14	4.93E-15	1.65E-17	2.59E-22	1.91E-34
CD109	2.11E-13	3.36E-10	1.84E-10	1.10E-10	6.45E-11	2.05E-11	1.26E-12	7.69E-14	4.71E-15	1.76E-17	2.47E-22	1.82E-34
AG110M	7.41E-02	9.34E-01	3.45E-01	1.27E-01	4.67E-00	6.31E-01	4.24E-03	2.85E-05	1.92E-07	6.67E-12	1.77E-20	0.
AG110	4.14E-02	5.24E-00	1.43E-00	7.09E-01	2.61E-01	3.52E-02	2.37E-04	1.59E-06	1.07E-08	4.84E-13	9.89E-22	0.
CD113M	1.35E-00	2.97E-02	2.42E-02	2.69E-02	2.56E-02	2.32E-02	1.81E-02	1.41E-02	1.10E-02	6.72E-03	2.50E-03	2.10E-04
SN119M	7.33E-04	9.23E-01	3.35E-01	1.22E-01	4.43E-02	5.84E-03	3.70E-05	2.34E-07	1.48E-09	5.94E-14	9.55E-23	0.
SN121M	1.54E-00	3.38E-06	3.35E-06	3.32E-06	3.29E-06	3.23E-06	3.08E-06	2.95E-06	2.81E-06	2.57E-06	2.14E-06	1.36E-06
SN123	1.11E+00	9.01E-02	1.14E-02	1.57E-01	2.61E-02	3.61E-02	1.45E-06	5.80E-11	2.32E-15	3.74E-24	9.64E-42	0.
TF123M	2.84E-07	2.22E-04	2.55E-04	2.93E-06	3.31E-07	4.45E-04	8.96E-14	1.79E-18	3.60E-23	1.45E-32	2.34E-51	0.
SR124	2.94E-03	1.25E+00	1.84E-02	2.71E-04	3.44E-06	8.66E-10	5.96E-19	4.13E-28	2.66E-37	1.36E-55	0.	0.
SR125	1.67E+00	2.72E-03	1.56E-03	1.21E-03	4.34E-02	3.59E-02	1.55E-02	4.29E-01	1.19E-01	9.14E-01	5.39E-03	1.44E-08
TF125M	1.74E-01	3.49E-02	2.74E-02	2.12E-02	1.64E-02	4.82E-01	2.72E-01	7.54E-00	2.00E+00	1.61E-01	4.46E-04	2.53E-09
SN126	1.55E-04	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02
SR126M	9.72E-05	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01
SR126	1.87E-04	4.08E-01	4.04E-01	4.06E-01	4.08E-01	4.08E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01
TF127M	2.91E-01	2.16E-02	2.14E-01	2.04E-00	2.00E-01	1.92E-03	1.74E-08	1.58E-13	1.42E-18	1.18E-28	7.96E-49	0.
TF127	8.41E-01	4.14E-02	6.90E-01	5.88E-00	5.77E-01	5.55E-03	5.03E-08	4.56E-13	4.14E-18	3.40E-28	2.30E-48	0.
I129	1.83E-07	4.04E-04	4.04E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04
CS134	7.15E-03	1.29E-04	9.19E-03	6.55E-03	4.67E-03	2.38E-03	4.38E-02	8.09E-01	1.49E-01	5.08E-01	5.88E-04	2.68E-11
CS135	4.84E-06	1.04E-02	1.04E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
CS137	7.34E-00	1.60E-04	1.56E-04	1.53E-04	1.44E-04	1.42E-04	1.27E-04	1.13E-04	1.01E-04	7.99E-03	5.03E-03	1.59E-03
RA137M	1.65E+01	3.54E-04	4.51E-04	3.43E-04	3.35E-04	3.20E-04	2.85E-04	2.44E-04	2.26E-04	1.79E-04	1.13E-04	3.56E-03
CE144	6.24E-01	8.49E-04	3.48E-04	1.43E-04	5.85E-03	4.85E-02	1.14E-01	1.33E-01	1.54E-03	2.07E-07	3.76E-15	1.67E-34
PR144	6.01E-02	8.04E-05	3.30E-05	1.35E-05	5.94E-04	4.33E-03	1.08E-02	1.26E-00	1.46E-02	1.96E-06	3.56E-14	1.56E-33
PM147	8.02E-00	1.51E-04	1.16E-04	8.88E-03	6.69E-03	4.02E-03	1.07E-03	2.85E-02	7.60E-01	5.39E+00	2.72E-02	4.91E-08
PM148M	1.17E+00	3.48E-02	3.39E-01	2.03E-03	4.94E-06	2.85E-11	2.33E-24	1.91E-37	1.57E-50	0.	0.	0.
PM148	6.14E-02	1.83E-01	4.41E-02	1.06E-04	2.71E-07	1.50E-12	1.23E-25	1.01E-38	8.24E-52	0.	0.	0.
SM151	1.95E-01	4.27E-02	4.23E-02	4.20E-02	4.17E-02	4.10E-02	3.94E-02	3.79E-02	3.64E-02	3.36E-02	2.87E-02	1.92E-02
EU152	4.73E-03	1.00E-01	9.48E-00	8.95E-00	8.45E-00	7.53E-00	5.64E-00	4.23E-00	3.17E-00	1.78E+00	5.60E-01	3.12E-02
GD153	2.64E-05	3.30E-02	1.14E-02	4.07E-03	1.43E-03	1.77E-04	9.46E-07	5.06E-09	2.71E-11	7.78E-16	6.40E-25	0.
EU154	1.45E-01	7.11E-02	2.96E-02	2.95E-02	2.93E-02	2.50E-02	2.02E-02	1.62E-02	1.31E-02	8.48E-01	3.56E-01	4.09E+00
EU155	1.89E-01	3.29E-02	2.24E-02	1.53E-02	1.04E-02	4.85E-01	7.16E-00	1.06E-00	1.56E-01	3.38E-03	1.60E-06	7.76E-15
TR160	6.49E-03	3.27E-00	9.77E-05	2.92E-03	2.79E-05	7.79E-08	1.86E-15	4.42E-23	1.05E-30	5.97E-46	0.	0.
MD166M	1.30E-09	2.84E-06	2.85E-06	2.85E-06	2.85E-06	2.85E-06	2.84E-06	2.83E-06	2.82E-06	2.81E-06	2.77E-06	2.70E-06
SUBTOT	1.80E+03	1.68E-06	6.30E-05	3.37E+05	2.11E+05	1.26E+05	9.12E+04	7.95E+04	7.03E+04	5.53E+04	3.43E+04	1.05E+04

TABLE III-D-3 (Continued)

TOTAL 1.81E+03 1.49E+04 5.30E+05 3.37E+05 2.11E+05 1.26E+05 9.12E+04 7.95E+04 7.03E+04 5.53E+04 3.43E+04 1.05E+04

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.1E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS ~~307~~ ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.1E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
M 3	9.33E-04	2.01E+00	9.14E-04	6.84E-25	0.	0.	0.	0.	0.	0.	0.	0.
SE 79	6.74E-06	1.48E-02	1.48E-02	1.47E-02	1.44E-02	1.33E-02	1.09E-02	5.11E-03	6.05E-04	3.47E-07	0.	0.
RB 87	4.35E-10	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.39E-06
SR 90	5.09E+00	1.11E+04	4.80E+00	2.16E-07	4.41E-24	0.	0.	0.	0.	0.	0.	0.
Y 90	2.29E+01	4.99E+04	3.06E+01	9.72E-07	3.04E-28	0.	0.	0.	0.	0.	0.	0.
ZR 93	1.04E-05	2.29E-02	2.29E-02	2.28E-02	2.28E-02	2.24E-02	2.25E-02	2.14E-02	1.99E-02	1.44E-02	2.25E-04	1.97E-22
NB 93M	5.77E-07	1.88E-03	3.43E-02	3.43E-02	3.44E-02	3.41E-02	3.38E-02	3.27E-02	2.98E-02	2.16E-02	3.38E-04	2.96E-22
TC 99	4.30E-04	9.46E-01	9.45E-01	9.43E-01	9.47E-01	9.16E-01	8.58E-01	6.82E-01	3.55E-01	3.60E-02	6.02E-15	0.
PD107	1.90E-07	4.19E-04	4.19E-04	4.19E-04	4.14E-04	4.18E-04	4.18E-04	4.15E-04	4.07E-04	3.74E-04	1.56E-04	2.10E-08
CD113M	1.34E-05	3.00E-02	1.07E-04	9.55E-24	0.	0.	0.	0.	0.	0.	0.	0.
SN121M	1.54E-09	3.39E-06	2.20E-07	3.71E-10	4.40E-18	0.	0.	0.	0.	0.	0.	0.
SN126	1.55E-05	3.41E-02	3.41E-02	3.39E-02	3.34E-02	3.18E-02	2.77E-02	1.71E-02	4.27E-03	3.34E-05	0.	0.
SBI26M	9.72E-05	2.14E-01	2.13E-01	2.12E-01	2.04E-01	1.99E-01	1.74E-01	1.07E-01	2.67E-02	2.09E-04	0.	0.
SBI26	1.87E-04	4.04E-01	4.07E-01	4.05E-01	3.94E-01	3.80E-01	3.31E-01	2.04E-01	5.10E-02	3.94E-04	0.	0.
Y129	1.83E-07	4.04E-04	4.04E-04	4.05E-04	4.05E-04	4.05E-04	4.04E-04	4.03E-04	4.00E-04	3.89E-04	2.69E-04	6.87E-06
CS135	4.84E-04	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.04E-02	9.93E-03	8.45E-03	1.06E-03	9.88E-13
CS137	7.36E+00	1.61E+04	1.57E+01	1.49E-06	1.44E-26	0.	0.	0.	0.	0.	0.	0.
BA137M	1.65E+01	3.61E+04	3.53E+01	3.35E-06	2.44E-26	0.	0.	0.	0.	0.	0.	0.
SM151	1.95E-01	4.28E+02	3.92E+01	1.48E-01	1.74E-04	0.	0.	0.	0.	0.	0.	0.
EU152	4.73E-03	1.02E+01	3.05E-07	8.47E-25	0.	0.	0.	0.	0.	0.	0.	0.
EU154	1.45E-01	3.14E+02	7.15E-04	4.86E-17	0.	0.	0.	0.	0.	0.	0.	0.
HO166M	1.30E-09	2.86E-06	2.40E-04	1.40E-06	5.00E-07	8.87E-09	8.54E-14	2.37E-31	0.	0.	0.	0.
SUBTOT	5.22E+01	1.14E+05	1.29E+02	1.43E+00	1.66E+00	1.61E+00	1.47E+00	1.04E+00	4.98E-01	8.19E-02	2.05E-03	8.28E-06
TOTAL	1.81E+03	2.15E+06	1.24E+02	1.43E+00	1.66E+00	1.61E+00	1.47E+00	1.08E+00	4.98E-01	8.19E-02	2.05E-03	8.28E-06

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER = 10.00MW, BURNUP = 1350.0WD, FLUX = 2.1E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
TL207	1.51E-11	8.25E-04	1.71E-07	2.48E-07	3.73E-07	4.65E-07	7.84E-07	1.06E-06	1.29E-06	1.67E-06	2.15E-06	2.65E-06
TL208	8.17E-04	1.45E-04	9.32E-05	6.93E-05	4.85E-05	2.41E-05	4.95E-06	1.42E-06	1.27E-06	1.04E-06	8.87E-07	5.48E-07
TL209	9.61E-14	2.41E-10	2.43E-10	2.44E-10	2.45E-10	2.46E-10	2.47E-10	2.48E-10	3.01E-10	3.65E-10	5.60E-10	1.45E-09
PR209	2.92E-13	7.70E-10	7.76E-10	7.74E-10	7.75E-10	7.93E-10	8.32E-10	9.49E-10	9.63E-10	1.17E-09	1.79E-09	4.64E-09
PR210	2.74E-14	2.88E-12	4.49E-12	2.71E-11	3.47E-11	7.50E-11	2.36E-10	4.73E-10	7.74E-10	1.53E-09	3.49E-09	9.64E-09
PR211	1.62E-11	9.15E-04	1.70E-07	2.74E-07	3.59E-07	5.16E-07	8.70E-07	1.17E-06	1.43E-06	1.84E-06	2.34E-06	2.94E-06
PR212	1.37E-04	2.47E-05	1.70E-05	1.14E-05	8.31E-06	4.12E-06	8.44E-07	3.11E-07	2.18E-07	1.84E-07	1.52E-07	9.37E-08
PR214	1.62E-12	8.35E-04	1.60E-04	2.37E-04	3.14E-04	4.58E-06	8.54E-08	1.24E-07	1.63E-07	2.41E-07	3.99E-07	8.01E-07
RT210	1.74E-14	1.78E-10	4.02E-10	1.24E-09	2.40E-09	4.70E-09	1.50E-08	3.00E-08	4.91E-08	4.73E-08	2.22E-07	6.12E-07
RT211	1.94E-10	1.07E-06	2.21E-06	3.21E-06	4.17E-06	6.01E-06	1.01E-05	1.37E-05	1.67E-05	2.15E-05	2.78E-05	3.42E-05
RT212	1.69E-07	2.99E-04	2.05E-04	1.44E-04	1.01E-04	4.99E-05	1.02E-05	3.76E-06	2.63E-06	2.23E-06	1.84E-06	1.13E-06
RT213	1.64E-12	4.11E-03	4.15E-09	4.16E-09	4.17E-09	4.24E-09	4.44E-09	4.74E-09	5.15E-09	6.23E-09	9.57E-09	2.48E-08
RT214	9.28E-12	4.77E-08	4.14E-08	1.35E-07	1.74E-07	2.67E-07	4.68E-07	7.10E-07	9.32E-07	1.36E-06	2.28E-06	4.58E-06
PO210	6.40E-14	1.86E-03	4.44E-03	1.74E-04	2.01E-04	4.75E-08	1.79E-07	3.59E-07	5.87E-07	1.16E-06	2.65E-06	7.31E-06
PO211	6.66E-13	1.63E-03	7.33E-09	1.07E-09	1.46E-09	2.04E-08	3.46E-08	4.64E-08	5.66E-08	7.33E-08	9.46E-08	1.16E-07
PO212	3.30E-07	5.85E-04	4.01E-04	2.89E-04	1.96E-04	4.75E-05	2.00E-05	7.35E-06	5.15E-06	4.35E-06	3.59E-06	2.22E-06
PO213	1.37E-11	3.25E-08	3.24E-08	3.23E-08	3.31E-08	3.35E-08	3.51E-08	3.75E-08	4.07E-08	4.93E-08	7.56E-08	1.96E-07
PO214	3.04E-11	1.50E-07	2.44E-07	4.43E-07	5.77E-07	8.75E-07	1.60E-06	2.32E-06	3.05E-06	4.51E-06	7.46E-06	1.50E-05
PO215	2.20E-10	1.20E-06	2.44E-06	3.61E-06	4.83E-06	6.76E-06	1.14E-05	1.54E-05	1.80E-05	2.42E-05	3.13E-05	3.85E-05
PO216	3.90E-07	7.04E-04	4.44E-04	3.34E-04	2.31E-04	1.14E-04	2.41E-05	8.97E-05	6.21E-05	5.25E-05	4.33E-05	2.67E-05
PO217	2.41E-11	1.24E-07	2.34E-07	3.52E-07	4.67E-07	6.96E-07	1.27E-06	1.85E-06	2.42E-06	3.59E-06	5.93E-06	1.19E-05
AT217	1.12E-11	2.34E-09	2.34E-09	2.34E-09	2.35E-09	2.89E-08	3.03E-08	3.51E-08	4.25E-08	4.25E-08	6.52E-08	1.69E-07
AN219	2.03E-10	1.11E-06	2.30E-06	3.33E-06	4.34E-06	6.25E-06	1.05E-05	1.42E-05	1.74E-05	2.24E-05	2.89E-05	3.56E-05
AN220	3.42E-07	6.42E-04	4.44E-04	3.14E-04	2.00E-04	1.09E-04	2.24E-05	8.22E-06	5.73E-06	4.67E-06	4.01E-06	2.48E-06
HN222	2.17E-11	1.12E-07	2.14E-07	3.17E-07	4.20E-07	6.26E-07	1.14E-06	1.66E-06	2.14E-06	3.22E-06	5.33E-06	1.07E-05
FO221	9.94E-12	2.49E-08	2.51E-08	2.52E-08	2.53E-08	2.57E-08	2.69E-08	2.87E-08	3.12E-08	3.77E-08	5.79E-08	1.50E-07
FO223	2.09E-13	9.99E-10	1.85E-09	2.70E-09	3.51E-09	5.05E-09	8.52E-09	1.15E-08	1.40E-08	1.81E-08	2.34E-08	2.68E-08
RA223	1.75E-10	9.51E-07	1.47E-06	2.44E-06	3.74E-06	5.35E-06	9.04E-06	1.22E-05	1.49E-05	1.92E-05	2.48E-05	3.05E-05
RA224	3.26E-07	5.89E-04	4.05E-04	2.83E-04	1.95E-04	9.83E-05	2.02E-05	7.41E-06	5.19E-06	4.39E-06	3.62E-06	2.23E-06
RA225	1.84E-13	4.41E-10	4.44E-10	4.46E-10	4.48E-10	4.54E-10	4.76E-10	5.09E-10	5.51E-10	6.67E-10	1.02E-09	2.66E-09
RA226	1.90E-11	9.45E-08	1.46E-07	2.75E-07	3.75E-07	5.44E-07	9.92E-07	1.44E-06	1.94E-06	2.80E-06	4.63E-06	9.31E-06
AC225	9.17E-12	2.36E-04	2.32E-04	2.33E-04	2.34E-04	2.37E-04	2.48E-04	2.65E-04	2.86E-04	3.48E-04	5.34E-04	1.39E-03
AC227	3.20E-12	1.53E-04	2.44E-04	4.14E-04	5.34E-04	7.76E-04	1.31E-03	1.77E-03	2.16E-03	2.78E-03	3.59E-03	4.43E-03
AC228	1.24E-16	4.91E-13	1.32E-12	1.89E-12	2.61E-12	3.24E-12	4.87E-12	5.82E-12	6.41E-12	7.02E-12	7.46E-12	7.98E-12
TH227	1.87E-10	9.69E-07	1.43E-06	2.74E-06	3.95E-06	5.24E-06	8.63E-06	1.19E-05	1.46E-05	1.86E-05	2.42E-05	2.98E-05
TH228	3.11E-07	5.53E-04	3.46E-04	2.65E-04	1.83E-04	9.37E-05	1.92E-05	7.04E-06	4.90E-06	4.20E-06	3.46E-06	2.14E-06
TH229	9.22E-12	2.03E-02	2.04E-04	2.05E-04	2.06E-04	2.09E-04	2.19E-04	2.34E-04	2.53E-04	3.07E-04	4.71E-04	1.22E-03
TH230	9.35E-04	2.06E-04	2.06E-04	2.06E-04	2.07E-04	2.07E-04	2.09E-04	2.09E-04	2.10E-04	2.13E-04	2.17E-04	2.28E-04
TH231	6.32E-04	7.43E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05
TH232	1.47E-14	3.24E-11	3.25E-11	3.25E-11	3.26E-11	3.29E-11	3.29E-11	3.33E-11	3.37E-11	3.46E-11	3.68E-11	3.68E-11
TH234	1.03E-04	1.78E-12	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04
PA231	1.19E-04	2.63E-05	2.64E-05	2.64E-05	2.64E-05	2.64E-05	2.65E-05	2.67E-05	2.68E-05	2.70E-05	2.74E-05	2.85E-05
PA233	9.10E-06	3.64E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.07E-03	2.08E-03	2.09E-03	2.10E-03	2.13E-03	2.21E-03
PA234M	1.49E-03	2.58E-01	3.33E-03	3.34E-03	3.34E-03	3.38E-03	3.38E-03	3.39E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03
PA234	2.67E-04	4.61E-04	5.47E-06	5.48E-06	5.48E-06	5.48E-06	5.48E-06	5.48E-06	5.48E-06	5.48E-06	5.48E-06	5.48E-06
U232	1.79E-09	3.34E-06	3.72E-06	4.01E-06	4.23E-06	4.50E-06	4.68E-06	4.57E-06	4.39E-06	4.00E-06	3.30E-06	2.04E-06
U233	1.25E-10	5.54E-07	7.80E-07	9.90E-07	1.20E-06	1.60E-06	2.55E-06	3.51E-06	4.47E-06	6.40E-06	1.03E-05	2.03E-05
U234	1.19E-05	2.51E-02	2.51E-02	2.51E-02	2.51E-02	2.52E-02	2.52E-02	2.52E-02	2.52E-02	2.52E-02	2.52E-02	2.52E-02
U235	4.26E-07	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04
U236	4.51E-07	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04
U237	2.66E-08	5.67E-05	5.41E-05	5.16E-05	4.43E-05	4.49E-05	3.55E-05	2.81E-05	2.22E-05	1.39E-05	5.46E-06	5.25E-07
U238	7.56E-06	1.46E-02	1.64E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02

TABLE III-D-3 (Continued)

N REACTOR, 347 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.000W. RUCHE= 1340.4W/g FLUX= 2.1E+13N/cm**2-SEC

NUCLIDE THERMAL POWER, WATTS

BASIS # 2200 TONS 347 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
NP237	2.03E-05	4.47E-02	1.47E-02	4.47E-02	4.47E-02	4.47E-02	4.50E-02	4.52E-02	4.54E-02	4.57E-02	4.64E-02	4.80E-02
NP239	8.83E-07	5.90E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.88E-03	5.88E-03	5.88E-03	5.87E-03	5.86E-03	5.83E-03
PU236	2.77E-04	5.26E-05	4.13E-05	3.24E-05	2.54E-05	1.55E-05	4.63E-06	1.37E-06	4.07E-07	3.57E-08	2.76E-10	1.45E-15
PU238	2.35E-04	1.45E+00	2.03E+00	2.15E+00	2.15E+00	2.14E+00	2.07E+00	2.00E+00	1.94E+00	1.82E+00	1.60E+00	1.16E+00
PU239	2.02E-03	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.43E+00	4.43E+00
PU240	7.15E-04	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.56E+00
PU241	6.62E-05	1.42E-01	1.35E-01	1.25E-01	1.15E-01	1.12E-01	8.05E-02	7.01E-02	5.55E-02	3.47E-02	1.36E-02	1.31E-03
PU242	9.82E-04	2.16E-04	2.14E-04	2.15E-04	2.15E-04	2.17E-04	2.17E-04	2.18E-04	2.18E-04	2.20E-04	2.22E-04	2.26E-04
AM241	5.58E-02	1.23E+02	1.23E+02	1.23E+02	1.23E+02	1.23E+02	1.22E+02	1.22E+02	1.21E+02	1.20E+02	1.17E+02	1.08E+02
AM242M	1.49E-04	3.71E-03	3.44E-03	3.44E-03	3.44E-03	3.63E-03	3.54E-03	3.46E-03	3.39E-03	3.23E-03	2.95E-03	2.35E-03
AM247	7.92E-06	1.74E-02	1.73E-02	1.72E-02	1.71E-02	1.70E-02	1.66E-02	1.62E-02	1.59E-02	1.52E-02	1.38E-02	1.10E-02
AM243	7.23E-05	1.59E-01	1.54E-01	1.54E-01	1.54E-01	1.54E-01	1.54E-01	1.54E-01	1.54E-01	1.54E-01	1.58E-01	1.58E-01
CM242	1.71E-01	1.68E+02	3.34E+01	7.31E+00	1.48E+00	4.57E-01	3.77E-01	3.68E-01	3.60E-01	3.44E-01	3.14E-01	2.50E-01
CM243	6.97E-06	1.51E-02	1.44E-02	1.45E-02	1.42E-02	1.36E-02	1.22E-02	1.09E-02	9.81E-03	7.90E-03	5.13E-03	1.74E-03
CM244	4.34E-04	9.33E-01	2.94E-01	8.64E-01	8.31E-01	7.70E-01	6.34E-01	5.25E-01	4.34E-01	2.90E-01	1.37E-01	2.03E-02
CM245	3.48E-04	7.66E-06	7.45E-06	7.66E-06	7.66E-06	7.66E-06	7.65E-06	7.65E-06	7.65E-06	7.64E-06	7.63E-06	7.60E-06
CM246	7.74E-11	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.69E-07	1.69E-07	1.68E-07
SURTOT	2.32E-01	3.00E+02	1.45E+02	1.40E+02	1.34E+02	1.32E+02	1.32E+02	1.31E+02	1.30E+02	1.29E+02	1.25E+02	1.16E+02
TOTAL	2.32E-01	3.00E+02	1.45E+02	1.40E+02	1.34E+02	1.32E+02	1.32E+02	1.31E+02	1.30E+02	1.29E+02	1.25E+02	1.16E+02

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURRUP= 1380.MWD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
FASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
TL207	1.51E-11	6.29E-08	3.23E-06	4.70E-06	8.70E-06	2.20E-05	5.19E-05	1.00E-04	1.16E-04	1.17E-04	1.16E-04	1.06E-04
TL208	8.17E-08	1.55E-04	8.01E-08	1.22E-10	5.84E-11	1.84E-10	5.85E-10	2.05E-09	6.22E-09	2.06E-08	1.82E-07	6.81E-07
TL209	9.61E-14	2.39E-10	1.10E-04	1.29E-07	1.22E-06	1.19E-05	6.64E-05	2.57E-04	5.67E-04	6.33E-04	3.23E-05	7.72E-18
PB209	2.92E-13	7.43E-10	3.53E-04	4.11E-07	3.49E-06	3.79E-05	2.12E-04	8.21E-04	1.81E-03	2.02E-03	1.03E-04	2.47E-17
PB210	2.74E-16	1.73E-12	4.31E-04	1.65E-07	4.56E-07	2.78E-06	9.09E-06	2.18E-05	3.15E-05	2.83E-05	2.72E-05	2.69E-05
PB211	1.64E-11	6.97E-08	3.59E-06	5.21E-06	9.74E-06	2.44E-05	5.76E-05	1.11E-04	1.29E-04	1.29E-04	1.28E-04	1.17E-04
PB212	1.37E-04	2.65E-05	1.37E-04	2.04E-11	1.01E-11	3.15E-11	1.00E-10	3.51E-10	1.06E-09	3.53E-09	3.11E-08	1.17E-07
PR214	1.62E-12	6.32E-09	2.53E-06	9.90E-06	3.84E-05	1.63E-04	5.34E-04	1.28E-03	1.85E-03	1.66E-03	1.60E-03	1.58E-03
BI210	1.74E-14	1.06E-10	2.73E-04	1.07E-05	4.14E-05	1.76E-04	5.77E-04	1.38E-03	2.00E-03	1.80E-03	1.73E-03	1.70E-03
BI211	1.94E-10	8.12E-07	4.18E-05	6.07E-05	1.13E-04	2.84E-04	6.71E-04	1.30E-03	1.50E-03	1.51E-03	1.49E-03	1.37E-03
BI212	1.69E-07	3.21E-04	1.66E-07	2.52E-10	1.22E-10	3.81E-10	1.21E-09	4.25E-09	1.29E-08	4.27E-08	3.77E-07	1.41E-06
BI213	1.64E-12	4.08E-09	1.44E-07	2.20E-06	2.03E-05	2.03E-04	1.13E-03	4.39E-03	9.69E-03	1.08E-02	5.52E-04	1.32E-16
BI214	9.28E-12	3.61E-08	1.44E-05	5.66E-05	2.20E-04	9.33E-04	3.05E-03	7.32E-03	1.06E-02	9.50E-03	9.14E-03	9.02E-03
PO210	6.40E-14	5.42E-10	3.27E-05	1.28E-04	4.47E-04	2.11E-03	6.89E-03	1.65E-02	2.39E-02	2.15E-02	2.07E-02	2.04E-02
PO211	6.66E-13	2.76E-09	1.42E-07	2.05E-07	3.50E-07	9.68E-07	2.24E-06	4.41E-06	5.11E-06	5.12E-06	5.08E-06	4.65E-06
PO212	3.30E-07	6.27E-04	3.24E-07	4.92E-10	2.34E-10	7.45E-10	2.37E-09	8.30E-09	2.52E-08	8.35E-08	7.36E-07	2.76E-06
PO213	1.34E-11	3.22E-08	1.49E-05	1.74E-05	1.65E-05	1.60E-03	8.46E-03	3.47E-02	7.65E-02	8.55E-02	4.36E-03	1.04E-15
PO214	3.84E-11	1.18E-07	4.73E-05	1.85E-04	7.28E-04	3.65E-03	9.94E-03	2.39E-02	3.46E-02	3.11E-02	2.99E-02	2.95E-02
PO215	2.20E-10	9.13E-07	4.73E-05	6.43E-05	1.22E-04	3.20E-04	7.55E-04	1.44E-03	1.69E-03	1.64E-03	1.68E-03	1.54E-03
PO216	3.90E-07	7.54E-04	3.91E-07	5.93E-10	2.84E-10	8.94E-10	2.86E-09	1.00E-08	3.04E-08	1.01E-07	8.88E-07	3.32E-06
PO218	2.41E-11	9.39E-08	3.76E-05	1.47E-04	5.73E-04	2.43E-03	7.93E-03	1.90E-02	2.75E-02	2.47E-02	2.38E-02	2.35E-02
AT217	1.12E-11	2.78E-08	1.28E-06	1.50E-05	1.42E-04	1.38E-03	7.73E-03	2.94E-02	6.61E-02	7.38E-02	3.76E-03	8.99E-16
RN219	2.02E-10	8.44E-07	4.34E-05	6.31E-05	1.10E-04	2.90E-04	6.98E-04	1.35E-03	1.56E-03	1.56E-03	1.55E-03	1.42E-03
RN220	3.62E-07	6.99E-04	3.62E-07	5.50E-10	2.67E-10	8.32E-10	2.65E-09	9.28E-09	2.81E-08	9.33E-08	8.23E-07	3.08E-06
RN222	2.17E-11	8.45E-08	3.34E-06	1.32E-04	5.17E-04	2.18E-03	7.14E-03	1.71E-02	2.47E-02	2.22E-02	2.14E-02	2.11E-02
FR221	9.44E-12	2.47E-08	1.14E-04	1.33E-05	1.22E-04	1.23E-03	6.86E-03	2.65E-02	5.86E-02	6.55E-02	3.34E-03	7.98E-16
FR223	2.64E-13	7.85E-10	3.52E-08	5.11E-08	9.58E-08	2.39E-07	5.65E-07	1.09E-06	1.27E-06	1.27E-06	1.26E-06	1.15E-06
RA223	1.75E-10	7.24E-07	3.73E-05	5.41E-05	1.01E-04	2.54E-04	5.99E-04	1.16E-03	1.34E-03	1.34E-03	1.33E-03	1.22E-03
RA224	3.24E-07	6.30E-04	3.27E-07	4.96E-10	2.40E-10	7.51E-10	2.39E-09	8.37E-09	2.54E-08	8.42E-08	7.43E-07	2.78E-06
RA225	1.44E-13	4.34E-10	2.02E-04	2.35E-07	2.23E-06	2.17E-05	1.21E-04	4.70E-04	1.04E-03	1.16E-03	5.91E-05	1.41E-17
RA226	1.44E-11	7.47E-08	2.44E-05	1.15E-04	4.44E-04	1.90E-03	6.20E-03	1.44E-02	2.15E-02	1.93E-02	1.86E-02	1.83E-02
AC225	9.17E-12	2.28E-08	1.05E-06	1.23E-05	1.16E-04	1.13E-03	6.33E-03	2.45E-02	5.41E-02	6.04E-02	3.08E-03	7.37E-16
AC227	3.20E-12	1.21E-08	5.41E-07	7.85E-07	1.47E-06	3.68E-06	8.66E-06	1.68E-05	1.95E-05	1.95E-05	1.93E-05	1.77E-05
AC228	1.24E-16	5.30E-13	9.94E-12	1.68E-11	3.73E-11	1.16E-10	3.70E-10	1.30E-09	3.94E-09	1.31E-08	1.15E-07	4.31E-07
TM227	1.87E-10	7.47E-07	3.66E-05	5.29E-05	9.85E-05	2.48E-04	5.85E-04	1.13E-03	1.31E-03	1.31E-03	1.30E-03	1.19E-03
TM228	3.11E-07	6.00E-04	3.13E-07	4.75E-10	2.30E-10	7.19E-10	2.29E-09	8.01E-09	2.43E-08	8.06E-08	7.11E-07	2.66E-06
TM229	9.22E-12	2.63E-08	4.27E-07	1.08E-05	1.02E-04	4.97E-04	5.58E-03	2.16E-02	4.77E-02	5.32E-02	2.72E-03	6.49E-16
TM230	9.35E-08	2.06E-04	2.73E-04	4.31E-04	8.79E-04	2.38E-03	6.15E-03	1.48E-02	2.14E-02	1.93E-02	1.86E-02	1.83E-02
TM231	6.32E-06	1.06E-04	2.64E-05	2.67E-05	2.67E-05	2.76E-05	2.88E-05	3.03E-05	3.05E-05	3.05E-05	3.02E-05	2.77E-05
TM232	1.47E-14	3.24E-11	4.55E-11	7.68E-11	1.70E-10	5.31E-10	1.69E-09	5.92E-09	1.79E-08	5.95E-08	5.25E-07	1.97E-06
TM234	1.83E-04	2.95E-02	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04
PA231	1.15E-06	2.63E-05	3.27E-05	4.75E-05	8.85E-05	2.23E-04	5.26E-04	1.02E-03	1.18E-03	1.18E-03	1.17E-03	1.07E-03
PA233	9.10E-06	4.68E-03	2.45E-03	2.88E-03	3.00E-03	3.08E-03	3.06E-03	3.00E-03	2.81E-03	2.24E-03	1.21E-04	2.67E-17
PA234M	1.49E-03	4.26E-01	3.34E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.33E-03
PA234	2.67E-06	7.62E-04	5.94E-06	5.94E-06	5.94E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.97E-06	5.97E-06	5.88E-06
U232	1.34E-09	3.24E-06	2.98E-07	3.54E-10	1.54E-18	0.	0.	0.	0.	0.	0.	0.
U233	1.25E-10	4.98E-07	6.32E-05	2.37E-04	7.94E-04	2.73E-03	7.93E-03	2.28E-02	4.54E-02	5.11E-02	2.61E-03	6.22E-16
U234	1.15E-05	2.61E-02	2.64E-02	2.70E-02	2.64E-02	2.68E-02	2.64E-02	2.50E-02	2.24E-02	1.94E-02	1.89E-02	1.86E-02
U235	4.26E-07	9.36E-04	9.37E-04	9.40E-04	9.47E-04	9.70E-04	1.01E-03	1.07E-03	1.07E-03	1.07E-03	1.06E-03	9.74E-04
U236	4.51E-07	9.92E-04	1.00E-03	1.03E-03	1.04E-03	1.24E-03	1.36E-03	1.38E-03	1.37E-03	1.34E-03	1.03E-03	7.60E-05
U237	2.64E-08	5.74E-05	4.44E-11	3.73E-12	3.10E-12	1.75E-12	3.24E-13	9.27E-16	4.83E-23	0.	0.	0.
U238	7.56E-05	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.64E-02

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1940.MWD. FLUX= 2.1/E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
NP237	2.03E-05	4.46E-02	5.23E-02	6.27E-02	6.70E-02	6.70E-02	6.66E-02	6.51E-02	6.10E-02	4.86E-02	2.64E-03	5.81E-16
NP239	8.83E-07	5.91E-03	5.73E-03	5.38E-03	4.45E-03	2.38E-03	3.39E-04	6.85E-07	1.05E-14	1.15E-15	7.86E-16	1.75E-17
PU238	2.35E-04	1.20E+00	3.49E-01	9.52E-03	6.95E-07	1.36E-20	0.	0.	0.	0.	0.	0.
PU239	2.02E-03	4.44E+00	4.40E+00	4.32E+00	4.04E+00	3.36E+00	1.72E+00	2.63E-01	8.98E-04	2.11E-12	1.81E-14	4.03E-16
PU240	7.15E-04	1.57E+00	1.53E+00	1.42E+00	1.15E+00	5.65E-01	7.28E-02	5.57E-05	6.94E-14	1.58E-17	1.71E-17	8.04E-18
PU241	6.62E-05	1.43E-01	1.23E-07	9.33E-09	7.44E-09	4.39E-09	8.20E-10	2.32E-12	1.21E-19	0.	0.	0.
PU242	9.82E-08	2.16E-04	2.37E-04	2.43E-04	2.43E-04	2.39E-04	2.31E-04	2.03E-04	1.41E-04	3.92E-05	2.79E-12	0.
AM241	5.58E-02	1.23E+02	7.85E+01	2.56E+01	1.94E+00	1.77E-05	6.60E-07	1.86E-09	1.03E-16	0.	0.	0.
AM242M	1.69E-06	3.71E-03	9.45E-04	3.89E-05	4.22E-09	5.88E-23	0.	0.	0.	0.	0.	0.
AM242	7.92E-06	1.75E-02	4.43E-03	1.82E-04	2.00E-08	2.76E-22	0.	0.	0.	0.	0.	0.
AM243	7.23E-05	1.59E-01	1.55E-01	1.45E-01	1.21E-01	6.42E-02	1.05E-02	1.85E-05	2.82E-13	3.11E-14	2.12E-14	4.74E-16
CM242	1.71E-01	2.24E+02	1.00E-01	4.13E-03	4.54E-07	6.26E-21	0.	0.	0.	0.	0.	0.
CM243	6.97E-06	1.52E-02	2.29E-05	5.99E-12	9.22E-31	0.	0.	0.	0.	0.	0.	0.
CM244	4.34E-04	9.41E-01	9.57E-06	2.22E-17	1.55E-22	5.26E-22	1.55E-21	4.82E-21	1.20E-20	2.31E-20	2.49E-20	1.17E-20
CM245	3.48E-09	7.66E-06	7.47E-06	7.04E-06	5.40E-06	3.31E-06	6.19E-07	1.75E-09	9.12E-17	0.	0.	0.
CM246	7.74E-11	1.70E-07	1.63E-07	1.47E-07	1.10E-07	3.91E-08	2.06E-09	6.96E-14	1.16E-26	0.	0.	0.
SUBTOT	2.32E-01	3.56E+02	8.52E+01	3.16E+01	4.54E+00	4.14E+00	2.22E+00	6.69E-01	6.48E-01	6.57E-01	2.19E-01	1.91E-01
TOTAL	2.32E-01	3.56E+02	8.52E+01	3.16E+01	4.54E+00	4.14E+00	2.22E+00	6.69E-01	6.48E-01	6.57E-01	2.19E-01	1.91E-01

APPENDIX III-E

AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND

III-E. AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND

The fraction of a slurry (a solid mixed in a liquid) spilled onto the ground that can be made airborne by the action of air passing over the surface depends upon many parameters. The influence of many of the parameters is variable and unquantified. Arriving at a precise fractional release value for a complex variable situation as an outdoor spill of a waste slurry on the surface is not feasible using the data currently available.

A limited amount of data is available on the fractional release of freshly dispersed powder (uranium dioxide with an Activity Median Aerodynamic Diameter of approximately $1\ \mu\text{m}$) and liquid (0.51 g uranium nitrate hexahydrate per cubic centimeter in dilute nitric acid).¹ The fractional airborne releases in a 24-hour period at various wind speeds is:

	<u>2.5 mph</u>	<u>20 mph</u>
uranium dioxide	0.43 to 0.04	23 to 24.4
uranium nitrate	0.012	0.039
dried uranium nitrate ^(a)	0.007	1.1

The only comparable value is for the fractional release of uranium nitrate since it represents a wetted surface.

When a slurry is dispersed upon a porous surface, the liquid tends to penetrate into the surface and to separate from the solids. If the solids and surface are wetted by the liquid, solids dispersed upon the surface tend to behave as the soil surface. Since the value presented is for the liquid dispersed on soil, any entrainment of the soil coated with uranium nitrate would be measured. Entrainment of a wetted soil particle would tend to be less than dry particles of loose material in as much as the force required to overcome the surface

(a) From solid residue after exposure of greater than 24 hours at stated air velocity.

tension is added to the force required to lift the dry particle. Other mechanisms such as being trapped in the interstice of larger soil particles or the tendency of flocculent particles to adhere to surface further reduce the aerodynamic entrainment of particles.

The evaporation of the liquid is the volatilization of the most volatile components of the liquid. Thus evaporation is akin to fractional distillation. In the case of spilled waste, the most volatile component is water and the rate of heat input under these conditions would produce little force to inject solid particles into the airstream. The liquid has a high salt content and tends to form a continuous layer of solid which reduces further evaporation. The fractional release from air-dried, solid residues can be highly dependent upon the surface formed and forces applied to break up the surface.

Part of the forces applied are the turbulent eddies of air near the surface. Although the mean air velocity at the surface may be zero, fluctuations exist depending upon the air velocities and surface roughness. The air velocities in the wind tunnel experiments was measured one foot above a smooth surface of sandy soil. The stated windspeeds correspond to much higher windspeeds measured at higher levels.

Thus a fractional release of 10^{-3} fraction during a 24-hour period appears to be a reasonable, though conservative, value to use for calculations.

III-E REFERENCES

1. J. Mishima and L. C. Schwendiman, Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents, BNWL-1732, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1973.

APPENDIX III-F

TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE

III-F TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE

A ten year summary (1964-1973) of fires (excluding building fires) is summarized graphically in a joint frequency distribution, Table III-F-1, with size of fire (acres) and date of fire (months) as the joint descriptors. The marginal totals are displayed as frequency distributions in Figure III-F-1.

The average fire covered 310 acres and occurred at the end of June, but the few very large fires distort this average so greatly that other statistics are more appropriate. The mode is the most abundant observation in a sequence, and the median is that observation lying at the middle of the distribution - 50% above and below. The modal and median fires coincide, involving about 6 acres and occurring near the end of June. There are very many small fires, and very few large fires, occurring in time as a symmetric distribution around June. June is the most likely month for fire to occur because it contains the secondary maximum of precipitation (see Section II), much in the form of thunderstorms. Usually, by June, cheatgrass and bunchgrasses have matured and dried to combustible conditions. However, this is not to imply that most fires are started by lightning; no data concerning the probable source for any of the fires exists except for the few very large fires, which were indeed from cloud-to-ground lightning strikes.

The impact of fires on the ecosystem was briefly discussed in Section II on characterization of the existing environment, because fires are a natural part of an arid landscape. Since most fires were kept small, their effect on the biota was very minimal. One growing season ordinarily sees much of the fire effect erased, both in plants and animals. This may not be true for the very large fires, because the sources for restocking are then well removed from the central area of the burn.

Fires are probably more common now than in earlier times because cheatgrass is now a "naturalized" member of many communities, and cheatgrass

TABLE III-F-1

SIZE AND DATE OF FIRES ON THE
HANFORD RESERVATION
1964 THROUGH 1973

Size (Acres) Average Range		Month												Σ
		J	F	M	A	M	J	J	A	S	O	N	D	
1/2	0-1				3	3	9	3	6	2		1		27
1 1/2	1-2				2	1	1							4
3	2-4					3	1	2						6
6	4-8		2	2	3	10	13	7	5	5	4			51
12	8-16					2	3	3	1					9
24	16-32					1	2	4	1	1				9
48	32-64							1	1	1	1			4
100	64-128						1		2		1			4
200	128-256													0
400	256-512					1	3							4
800	512-1024									1				1
1500	1000-2000													0
3000	2k-4k							1						1
6000	4k-8k													0
12000	8k-16k								1					1
24000	16k-32k							1						1
Σ		0	2	2	8	21	33	22	17	10	6	1	0	122

FIGURE III-F-1 RANGE FIRES ON HANFORD SITE

burns more readily than native grasses. The repercussions from this change in floristics may foretell the demise of sagebrush, for sagebrush is killed by fire and must restock the area by reseeding from outside. Since cheatgrass is most common in the sandy soils with unstable surfaces and little water, sagebrush has an uphill battle to restore its pre-burn density in the low elevation communities. Higher elevation communities, with bluebunch wheatgrass instead of cheatgrass, presents less of a problem for restocking by sagebrush, but still, restoration of a landscape probably would not occur in normal human lifetimes. The presence or absence of industrial activities probably will make little difference in this progression, except insofar as the spread of cheatgrass is encouraged by soil disturbance or seeding.

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.4WD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
TL207	1.51E-11	6.29E-08	3.23E-06	4.70E-06	8.74E-06	2.20E-05	5.19E-05	1.00E-04	1.16E-04	1.17E-04	1.16E-04	1.06E-04
TL208	8.17E-08	1.55E-04	8.01E-08	1.22E-10	5.44E-11	1.84E-10	5.85E-10	2.05E-09	6.22E-09	2.06E-08	1.82E-07	6.81E-07
TL209	9.61E-14	2.39E-10	1.10E-09	1.29E-07	1.22E-06	1.19E-05	6.64E-05	2.57E-04	5.67E-04	6.33E-04	3.23E-05	7.72E-18
PB209	2.92E-13	7.43E-10	3.53E-04	4.11E-07	3.40E-06	3.79E-05	2.12E-04	8.21E-04	1.81E-03	2.02E-03	1.03E-04	2.47E-17
PB210	2.74E-16	1.73E-12	4.31E-08	1.65E-07	4.56E-07	2.78E-06	9.09E-06	2.18E-05	3.15E-05	2.83E-05	2.72E-05	2.69E-05
PB211	1.68E-11	6.97E-08	3.59E-04	5.21E-06	9.74E-06	2.44E-05	5.76E-05	1.11E-04	1.29E-04	1.29E-04	1.28E-04	1.17E-04
PB212	1.37E-04	2.65E-05	1.37E-04	2.08E-11	1.01E-11	3.35E-11	1.00E-10	3.51E-10	1.06E-09	3.53E-09	3.11E-08	1.17E-07
PR214	1.62E-12	6.32E-09	2.53E-06	9.90E-06	3.85E-05	1.63E-04	5.34E-04	1.28E-03	1.85E-03	1.66E-03	1.60E-03	1.58E-03
RI210	1.74E-14	1.06E-10	2.73E-06	1.07E-05	4.14E-05	1.76E-04	5.77E-04	1.38E-03	2.00E-03	1.80E-03	1.73E-03	1.70E-03
RI211	1.94E-10	8.12E-07	4.18E-05	6.07E-05	1.14E-04	2.84E-04	6.71E-04	1.30E-03	1.50E-03	1.51E-03	1.49E-03	1.37E-03
RI212	1.49E-07	3.21E-04	1.46E-07	2.52E-10	1.22E-10	3.81E-10	1.21E-09	4.25E-09	1.29E-08	4.27E-08	3.77E-07	1.41E-06
RI213	1.64E-12	4.08E-09	1.98E-07	2.20E-06	2.08E-05	2.03E-04	1.13E-03	4.39E-03	9.69E-03	1.08E-02	5.52E-04	1.32E-16
RI214	9.28E-12	3.61E-08	1.44E-05	5.66E-05	2.20E-04	9.33E-04	3.05E-03	7.32E-03	1.06E-02	9.50E-03	9.14E-03	9.02E-03
PO210	6.40E-14	5.42E-10	3.27E-05	1.28E-04	4.42E-04	2.11E-03	6.89E-03	1.65E-02	2.39E-02	2.15E-02	2.07E-02	2.04E-02
PO211	6.64E-13	2.76E-09	1.42E-07	2.06E-07	3.86E-07	9.68E-07	2.24E-06	4.41E-06	5.11E-06	5.12E-06	5.08E-06	4.65E-06
PO212	3.30E-07	6.27E-04	3.24E-07	4.92E-10	2.36E-10	7.45E-10	6.30E-09	2.37E-08	2.52E-08	8.35E-08	7.36E-07	2.76E-06
PO213	1.30E-11	3.22E-08	1.49E-05	1.74E-05	1.65E-04	1.60E-03	8.46E-03	3.47E-02	7.65E-02	8.55E-02	4.36E-03	1.04E-15
PO214	3.04E-11	1.18E-07	4.73E-05	1.85E-04	7.00E-04	3.05E-03	9.94E-03	2.39E-02	3.46E-02	3.11E-02	2.99E-02	2.95E-02
PO215	2.20E-10	9.13E-07	4.70E-05	6.43E-05	1.22E-04	3.20E-04	7.55E-04	1.44E-03	1.69E-03	1.69E-03	1.68E-03	1.54E-03
PO216	3.90E-07	7.54E-04	3.91E-07	5.93E-10	2.58E-10	8.98E-10	2.86E-09	1.00E-08	3.04E-08	1.01E-07	8.88E-07	3.32E-06
PO218	2.41E-11	9.39E-08	3.76E-05	1.47E-04	5.73E-04	2.43E-03	7.93E-03	1.90E-02	2.75E-02	2.47E-02	2.38E-02	2.35E-02
AT217	1.12E-11	2.78E-08	1.28E-06	1.50E-05	1.42E-04	1.38E-03	7.73E-03	2.94E-02	6.61E-02	7.38E-02	3.76E-03	8.99E-16
RM219	2.03E-10	8.44E-07	4.34E-05	6.31E-05	1.12E-04	2.96E-04	6.98E-04	1.35E-03	1.56E-03	1.56E-03	1.55E-03	1.42E-03
RM220	3.62E-07	6.99E-04	3.62E-07	5.50E-10	2.67E-10	8.32E-10	2.65E-09	9.28E-09	2.81E-08	9.33E-08	8.23E-07	3.08E-06
RM222	2.17E-11	8.45E-08	3.34E-05	1.32E-04	5.12E-04	2.18E-03	7.14E-03	1.71E-02	2.47E-02	2.22E-02	2.14E-02	2.11E-02
FR221	9.44E-12	2.47E-08	1.14E-04	1.33E-04	1.22E-04	1.23E-03	6.86E-03	2.65E-02	5.86E-02	6.55E-02	3.34E-03	7.98E-16
FR223	2.68E-13	7.85E-10	3.52E-08	5.11E-08	9.55E-08	2.39E-07	5.65E-07	1.04E-06	1.27E-06	1.27E-06	1.26E-06	1.15E-06
RA223	1.75E-10	7.24E-07	3.73E-05	5.41E-05	1.01E-04	2.54E-04	5.99E-04	1.16E-03	1.34E-03	1.34E-03	1.33E-03	1.22E-03
RA224	3.26E-07	6.30E-04	3.27E-07	4.96E-10	2.40E-10	7.51E-10	2.39E-09	8.37E-09	2.54E-08	8.42E-08	7.43E-07	2.78E-06
RA225	1.46E-13	4.39E-10	2.02E-08	2.35E-07	2.43E-06	2.17E-05	1.21E-04	4.70E-04	1.04E-03	1.16E-03	5.91E-05	1.41E-17
RA226	1.90E-11	7.47E-08	2.94E-05	1.15E-04	4.42E-04	1.90E-03	6.20E-03	1.49E-02	2.15E-02	1.93E-02	1.86E-02	1.83E-02
AC225	9.17E-12	2.28E-08	1.05E-06	1.23E-05	1.16E-04	1.13E-03	6.33E-03	2.45E-02	5.41E-02	6.04E-02	3.08E-03	7.37E-16
AC227	3.20E-12	1.21E-08	5.41E-07	7.85E-07	1.47E-06	3.68E-06	8.68E-06	1.68E-05	1.95E-05	1.95E-05	1.93E-05	1.77E-05
AC228	1.24E-16	5.30E-13	9.99E-12	1.68E-11	7.73E-11	1.16E-10	3.70E-10	1.30E-09	3.94E-09	1.31E-08	1.15E-07	4.31E-07
TM227	1.87E-10	7.47E-07	3.64E-05	5.29E-05	9.84E-05	2.48E-04	5.85E-04	1.13E-03	1.31E-03	1.31E-03	1.30E-03	1.19E-03
TM228	3.11E-07	6.00E-04	3.13E-07	4.75E-10	2.30E-10	7.19E-10	2.29E-09	8.01E-09	2.43E-08	8.06E-08	7.11E-07	2.66E-06
TM229	9.22E-12	2.03E-08	4.27E-07	1.08E-05	1.02E-04	9.97E-04	5.58E-03	2.16E-02	4.77E-02	5.32E-02	2.72E-03	6.49E-16
TM230	9.35E-08	2.06E-04	2.73E-04	4.31E-04	8.74E-04	2.38E-03	6.15E-03	1.48E-02	2.14E-02	1.93E-02	1.86E-02	1.83E-02
TM231	6.32E-06	1.06E-04	2.64E-05	2.67E-05	2.57E-05	2.76E-05	2.88E-05	3.03E-05	3.05E-05	3.05E-05	3.02E-05	2.77E-05
TM232	1.47E-14	3.24E-11	4.55E-11	7.68E-11	1.76E-10	5.31E-10	1.69E-09	5.92E-09	1.79E-08	5.95E-08	5.25E-07	1.97E-06
TM234	1.03E-04	2.95E-02	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.30E-04
PA231	1.19E-08	2.63E-05	3.27E-05	4.75E-05	8.84E-05	2.23E-04	5.26E-04	1.02E-03	1.18E-03	1.18E-03	1.17E-03	1.07E-03
PA233	9.10E-06	4.68E-03	2.45E-03	2.88E-03	3.08E-03	3.08E-03	3.06E-03	3.00E-03	2.81E-03	2.24E-03	1.21E-04	2.67E-17
PA234M	1.49E-03	4.26E-01	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.33E-03
PA234	2.67E-06	7.62E-04	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.97E-06	5.88E-06
U232	1.39E-09	3.24E-06	2.98E-07	3.54E-10	1.54E-18	0.	0.	0.	0.	0.	0.	0.
U233	1.25E-10	4.98E-07	5.32E-05	2.37E-04	7.91E-04	2.73E-03	7.93E-03	2.28E-02	4.54E-02	5.11E-02	2.61E-03	6.22E-16
U234	1.19E-05	2.61E-02	2.68E-02	2.70E-02	2.69E-02	2.68E-02	2.64E-02	2.50E-02	2.24E-02	1.94E-02	1.89E-02	1.86E-02
U235	4.26E-07	9.36E-04	9.37E-04	9.40E-04	9.40E-04	9.40E-04	1.01E-03	1.07E-03	1.07E-03	1.07E-03	1.06E-03	9.74E-04
U236	4.51E-07	9.92E-04	1.00E-03	1.03E-03	1.04E-03	1.24E-03	1.36E-03	1.38E-03	1.37E-03	1.34E-03	1.03E-03	7.60E-05
U237	2.64E-09	5.74E-05	4.94E-11	3.73E-12	3.16E-12	1.75E-12	3.28E-13	9.27E-16	4.83E-23	0.	0.	0.
U238	7.56E-05	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.64E-02

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. RUNTIME= 1740.0WVD. FLUX= 2.1E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR 14 REACTOR WASTE

CHARGE	SEPARATION	3.0E+02YR	3.0E+03YR	3.0E+04YR	3.0E+05YR	3.0E+06YR	1.0E+07YR	1.0E+08YR
NP237	8.93E-07	6.27E-02	6.47E-02	6.70E-02	6.95E-02	7.26E-02	7.60E-02	8.01E-02
NP239	5.93E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03
NP238	1.20E-00	9.52E-03	9.45E-07	1.36E-20	0.	0.	0.	0.
NP236	2.95E-04	3.40E-00	4.32E-00	4.07E-00	3.36E-00	2.63E-01	1.81E-14	4.03E-16
NP239	2.62E-03	4.45E-00	1.42E-00	1.13E-00	7.28E-02	5.57E-05	1.71E-17	8.04E-18
NP240	7.15E-04	1.53E-00	1.42E-00	1.36E-00	1.28E-00	1.21E-00	1.09E-07	0.
NP241	6.62E-05	1.43E-01	1.23E-01	1.04E-01	8.20E-01	2.38E-12	1.71E-17	0.
NP242	9.82E-03	2.16E-04	2.43E-04	2.39E-04	2.31E-04	2.03E-04	3.92E-05	0.
NP241	5.58E-02	1.23E+02	7.95E+01	1.06E+00	6.60E-07	1.86E-09	1.03E-16	0.
NP242	2.42E-01	3.71E+03	2.56E+05	4.56E+09	5.84E-23	0.	0.	0.
NP240	1.65E-06	3.17E-03	9.45E-04	4.56E-09	5.84E-23	0.	0.	0.
NP242	7.92E-05	1.59E-01	1.45E-01	1.21E-01	6.76E-02	0.	0.	0.
NP241	1.71E-01	2.24E+02	1.00E+01	4.13E-03	4.13E-03	3.11E-14	2.12E-14	4.70E-16
NP242	6.97E-06	1.52E-02	2.26E-06	5.99E-12	0.	0.	0.	0.
NP244	4.34E-04	9.41E-01	7.47E-04	2.22E-17	1.55E-21	4.42E-21	1.20E-20	2.49E-20
NP245	3.44E-09	7.45E-06	5.74E-06	3.31E-06	6.19E-09	1.75E-09	1.20E-17	0.
NP246	7.74E-11	1.70E-09	1.63E-07	1.10E-07	3.91E-08	2.06E-09	1.16E-26	0.
NP247	2.32E-01	3.56E+02	4.55E+01	6.54E+00	4.14E+00	6.69E-01	6.48E-01	6.57E-01
SUBTOT	2.32E-01	3.56E+02	4.55E+01	6.54E+00	4.14E+00	6.69E-01	6.48E-01	6.57E-01
TOTAL	2.32E-01	3.56E+02	4.55E+01	6.54E+00	4.14E+00	6.69E-01	6.48E-01	6.57E-01

APPENDIX III-E

AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND

100-1-100

III-E AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND

The fraction of a slurry (a solid mixed in a liquid) spilled onto the ground that can be made airborne by the action of air passing over the surface depends upon many parameters. The influence of many of the parameters is variable and unquantified. Arriving at a precise fractional release value for a complex variable situation as an outdoor spill of a waste slurry on the surface is not feasible using the data currently available.

A limited amount of data is available on the fractional release of freshly dispersed powder (uranium dioxide with an Activity Median Aerodynamic Diameter of approximately $1\text{ }\mu\text{m}$) and liquid (0.51 g uranium nitrate hexahydrate per cubic centimeter in dilute nitric acid).¹ The fractional airborne releases in a 24-hour period at various wind speeds is:

	<u>2.5 mph</u>	<u>20 mph</u>
uranium dioxide	0.43 to 0.04	23 to 24.4
uranium nitrate	0.012	0.039
dried uranium nitrate ^(a)	0.007	1.1

The only comparable value is for the fractional release of uranium nitrate since it represents a wetted surface.

When a slurry is dispersed upon a porous surface, the liquid tends to penetrate into the surface and to separate from the solids.

If the solids and surface are wetted by the liquid, solids dispersed upon the surface tend to behave as the soil surface. Since the value presented is for the liquid dispersed on soil, any entrainment of the soil coated with uranium nitrate would be measured. Entrainment of a wetted soil particle would tend to be less than dry particles of loose material in as much as the force required to overcome the surface

(a) From solid residue after exposure of greater than 24 hours at stated air velocity.

tension is added to the force required to lift the dry particle. Other mechanisms such as being trapped in the interstice of larger soil particles or the tendency of flocculent particles to adhere to surface further reduce the aerodynamic entrainment of particles.

The evaporation of the liquid is the volatilization of the most volatile components of the liquid. Thus evaporation is akin to fractional distillation. In the case of spilled waste, the most volatile component is water and the rate of heat input under these conditions would produce little force to inject solid particles into the airstream. The liquid has a high salt content and tends to form a continuous layer of solid which reduces further evaporation. The fractional release from air-dried, solid residues can be highly dependent upon the surface formed and forces applied to break up the surface.

Part of the forces applied are the turbulent eddies of air near the surface. Although the mean air velocity at the surface may be zero, fluctuations exist depending upon the air velocities and surface roughness. The air velocities in the wind tunnel experiments was measured one foot above a smooth surface of sandy soil. The stated windspeeds correspond to much higher windspeeds measured at higher levels.

Thus a fractional release of 10^{-3} fraction during a 24-hour period appears to be a reasonable, though conservative, value to use for calculations.

III-E REFERENCES

1. J. Mishima and L. C. Schwendiman, Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents, BNWL-1732, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1973.

APPENDIX III-F

TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE

III-F TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE

A ten year summary (1964-1973) of fires (excluding building fires) is summarized graphically in a joint frequency distribution, Table III-F-1, with size of fire (acres) and date of fire (months) as the joint descriptors. The marginal totals are displayed as frequency distributions in Figure III-F-1.

The average fire covered 310 acres and occurred at the end of June, but the few very large fires distort this average so greatly that other statistics are more appropriate. The mode is the most abundant observation in a sequence, and the median is that observation lying at the middle of the distribution - 50% above and below. The modal and median fires coincide, involving about 6 acres and occurring near the end of June. There are very many small fires, and very few large fires, occurring in time as a symmetric distribution around June. June is the most likely month for fire to occur because it contains the secondary maximum of precipitation (see Section II), much in the form of thunderstorms. Usually, by June, cheatgrass and bunchgrasses have matured and dried to combustible conditions. However, this is not to imply that most fires are started by lightning; no data concerning the probable source for any of the fires exists except for the few very large fires, which were indeed from cloud-to-ground lightning strikes.

The impact of fires on the ecosystem was briefly discussed in Section II on characterization of the existing environment, because fires are a natural part of an arid landscape. Since most fires were kept small, their effect on the biota was very minimal. One growing season ordinarily sees much of the fire effect erased, both in plants and animals. This may not be true for the very large fires, because the sources for restocking are then well removed from the central area of the burn.

Fires are probably more common now than in earlier times because cheatgrass is now a "naturalized" member of many communities, and cheatgrass

TABLE III-F-1

SIZE AND DATE OF FIRES ON THE
HANFORD RESERVATION
1964 THROUGH 1973

Month		J	F	M	A	M	J	J	A	S	O	N	D	Σ
Size (Acres)	Average Range													
1/2	0-1				3	3	9	3	6	2		1		27
1 1/2	1-2				2	1	1							4
3	2-4					3	1	2						6
6	4-8		2	2	3	10	13	7	5	5	4			51
12	8-16					2	3	3	1					9
24	16-32					1	2	4	1	1				9
48	32-64							1	1	1	1			4
100	64-128						1		2		1			4
200	128-256													0
400	256-512					1	3							4
800	512-1024									1				1
1500	1000-2000													0
3000	2k-4k							1						1
6000	4k-8k													0
12000	8k-16k								1					1
24000	16k-32k							1						1
Σ		0	2	2	8	21	33	22	17	10	6	1	0	122

FIGURE III-F-1 RANGE FIRES ON HANFORD SITE

burns more readily than native grasses. The repercussions from this change in floristics may foretell the demise of sagebrush, for sagebrush is killed by fire and must restock the area by reseeding from outside. Since cheatgrass is most common in the sandy soils with unstable surfaces and little water, sagebrush has an uphill battle to restore its pre-burn density in the low elevation communities. Higher elevation communities, with bluebunch wheatgrass instead of cheatgrass, presents less of a problem for restocking by sagebrush, but still, restoration of a landscape probably would not occur in normal human lifetimes. The presence or absence of industrial activities probably will make little difference in this progression, except insofar as the spread of cheatgrass is encouraged by soil disturbance or seeding.