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CONTAMINANT PATHWAY ANALYSIS
AND HEALTH RISK ASSESSMENT
OF THE METALLURGICAL LABORATORY BASIN

Randal B. Klein
Gary B. Merrell
Kirk K. Nielson
Vern C. Rogers

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JoAnn Wingard (SRs)

Authorizing Official

Date 11/21/03

by Donald Williamson 11/24/03

Rogers and Associates Engineering Corporation
P.O. Box 330
Salt Lake City, Utah 84110

Received
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EXECUTIVE SUMMARY

The Savannah River Plant (SRP), located in Southwestern South Carolina, is a major installation of the U.S. Department of Energy (DOE) for production of defense-related nuclear materials. SRP has generated various radioactive and hazardous wastes as byproducts of operations, and these have been retained on site since disposal, some for more than 30 years. Some 86 SRP waste disposal sites have been selected for assessment of doses and risks from these wastes, as may occur via any of several environmental pathways for human exposure. The assessments are part of DOE's NEPA documentation effort for the SRP.

This report addresses one of the SRP waste sites, the Metallurgical Laboratory Basin. It is located about 1830 meters from the plant boundary, between the Savannah River Laboratory and the A-Area coal pile runoff containment basin (33.340143°N, 81.733327°W). The basin received waste water effluent from the Equipment Engineering Department Metallurgical Laboratory since 1956, and is to be closed in December 1985. About 3.8 m³/day of nitric acid and water entered the basin, with trace quantities of hazardous chemicals in the 1956 to 1982 period. The basin overflows to a Carolina Bay during peak precipitation events. The basin is 33 m long, 16 m wide, and 1.5 m deep. It presently contains 1.2 m of water and contaminants. The basin is situated 38.5 m above the groundwater table, and about 13,000 m from the Savannah River.

Based on analyses of groundwater gradients, flowrates, and access to major pathways such as the Savannah River, detailed pathway dose and risk analyses were performed for the main chemical constituents using the PATHRAE computer code. The pathways analyzed included groundwater to the

river, groundwater to a well, cover erosion, food grown on site, and natural biointrusion. The basin was represented as a 372 m² facility with a thickness of 1.0 meters. Of numerous trace-level hazardous contaminants, several were selected for analysis with the bulk chemicals. The ten chemicals used in the pathway analyses were aluminum, chromium, cyanide, iron, lead, nitrate, phosphate, tetrachloromethane, 1,1,1-trichloroethane, and zinc.

The PATHRAE analyses directly addressed two scenarios: the present, no action condition, and a scenario for waste removal and site closure. With removal and closure, the wastes (340 m³) would be excavated and removed and a cover of 2-meters thickness (960 m³ clean soil) would be placed over the original basin floor. The excavated waste would be removed to the SRP hazardous waste repository. A third scenario, placement of a 1.5 m cover without removing the wastes, was also considered. The PATHRAE analyses indicated that no doses or risks occur for either of the closure scenarios via the erosion or biointrusion pathways, due to the presence of the cover soil. For the groundwater pathways, identical maximum doses were computed for all scenarios, dominated by tetrachloromethane and, to a smaller extent, 1,1,1-trichloroethane. Basin closure did not reduce risks because these solvents had already moved to the groundwater before the remedial actions. Similarly for the food pathway, the intruder penetrated the waste regardless of cover, and mobile chemicals such as the solvents, nitrates, etc. had already moved from the waste excavation zone into the underlying soils. Closure of the basin with a soil cover, with or without waste removal, was sufficient to eliminate doses and risks from the erosion and biointrusion pathways.

The risks for all pathways and all scenarios were dominated by tetrachloromethane and to a secondary extent, by 1,1,1-trichloroethane. Risks were insignificant for the river, erosion, and on-site food pathways. Similar peak risks were computed for the well water and biointrusion pathways (0.053 and 0.048 health effects per year, respectively). The well water pathway has about a 30 year peak, that occurs within the 100 years of institutional control. Health effects from the well water pathway are marginally significant, considering the conservatism in the modeling and calculation effort. However, these are not removed under any of the scenarios, and so they do not affect the remedial action decision. Based on these analyses, closure of the basin with an earthen cover would avoid the potential health effects from biointrusion. Waste excavation and removal is not justified by any significant additional benefits over the simple closure option, so the option of closure without waste removal is the indicated choice.

1. INTRODUCTION

The U.S. Department of Energy is preparing NEPA documentation for the Savannah River Plant (SRP) waste disposal activities for groundwater protection. The waste disposal activities include hazardous waste (HW), low-level radioactive waste (LLW), and mixed radioactive and hazardous waste (MW). This report has been prepared as part of the documentation for that effort. It is one of a series of site-specific reports on the various SRP waste disposal sites to analyze contaminant migration along the major exposure pathways and to assess potential human health risks. The reports characterize each site by its pertinent waste source and transport parameters, and define the representation of the site sufficient for the use of the PATHRAE computer code⁽¹⁾ to estimate contaminant transport, exposure assessment, and health risk assessment. The results of the risk assessments for each pathway are presented as analyzed for the present site conditions and also as analyzed for projected conditions following possible remedial action alternatives.

The PATHRAE computer code was chosen for the contaminant transport, exposure assessment, and human health risk analyses to provide an accepted, broadly-applicable method for use on all of the waste sites, for all pathways, using a documented and cost-efficient methodology. PATHRAE was developed for the U.S. Environmental Protection Agency for performance assessment of low-level radioactive waste disposal technologies. It was designed to analyze, as a function of time, the exposure doses and resulting health effects to critical population groups and to the offsite population. Recent extensions of the PATHRAE code have permitted the analysis of chemically toxic contaminants, as well as radiological contaminants, in the various environmental pathways.

1.1 BACKGROUND

The Savannah River Plant is located on a 121,400 ha (300,000 acre) site on the southwestern edge of the Aiken Plateau in South Carolina, adjacent to the Savannah River, as illustrated in Figure 1-1. The plant is a major installation of the U.S. Department of Energy for production of defense-related nuclear materials. As byproducts of plant operations, SRP has generated hazardous, solid and radioactive wastes, that have been retained onsite since disposal. There are 153 individual waste basins, pits or piles at SRP, some of which are more than 30 years old. The fates and impacts of the hazardous and solid wastes were evaluated and reported in 1983.(2) The control of radioactive wastes at SRP was summarized in an environmental impact statement.(3) A more recent summary of the radioactive waste disposal was given in a second volume of the 1983 study.(4) Thirty-five of the sites contain as least some radioactive materials, and twenty of these have been used exclusively for radioactive wastes. Fifteen sites contain both chemically hazardous substances and radioactive materials, which are collectively referred to as mixed wastes. Some 86 waste sites have been selected for environmental study on the basis of potential hazardous or radioactive contents.

Waste disposal practices have changed at SRP, as they have throughout the United States, during the past thirty years. It should be noted that the wastes generated at SRP have been discarded in accordance with accepted regulations or practices at the time of their disposal.(2) As hazardous or toxic classifications were developed or changed during this period, the use of many chemicals in plant operations was discontinued or reduced in response to appropriate regulations. In addition, many of the disposal

0 30 60 kilometers

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FIGURE 1-1. PHYSIOGRAPHY OF THE SOUTH CAROLINA LOCATION OF THE SAVANNAH RIVER PLANT (Reference 2).

facilities were closed in response to revisions in disposal criteria. Groundwater monitoring was also initiated at some sites to assess impacts on groundwater quality and to respond to new regulations by the South Carolina Department of Health and Environmental Control.

The Metallurgical Laboratory basin addressed in this report is one of the eighty-six hazardous chemical, radioactive, or mixed waste sites identified for NEPA consideration at SRP. This report is one of the series of reports on each of fifty-one geographical groupings of the eighty-six waste disposal sites. For defining and modeling the characteristics of the Metallurgical Laboratory basin, general geohydrology data were derived from the SRP groundwater study,⁽²⁾ and also from a more recent report⁽⁵⁾ specifically summarizing the Metallurgical Laboratory basin parameters.

1.2 GENERAL GEOLOGY AND HYDROLOGY OF THE SRP

The Savannah River Plant is located in the Upper Atlantic Coastal Plain, about 20 miles southeast of the fall line separating the Piedmont and Coastal Plain provinces. The Aiken Plateau hosting the SRP is relatively flat, sloping gradually to the southeast. Several tributaries to the Savannah River cross the plant from the northeast (Figure 1-2). The SRP is underlain by about 300 meters of unconsolidated sands, clayey sands, and sandy clays. Beneath these are dense crystalline metamorphic rock and consolidated red mudstone.

Six formations are described as underlying the SRP⁽²⁾ in the 1983 groundwater study. These formations are described as in Figure 1-3 in connection with their respective aquifers in ascending order:

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FIGURE 1-2. SURFACE HYDROLOGIC FEATURES IN THE VICINITY OF THE SAVANNAH RIVER PLANT (Reference 2).

TOPOGRAPHY	AQUIFER PROPERTIES	HYDROLOGY	FORMATION
ABSENT FROM MUCH OF NW SRP		LITTLE WATER EXCEPT THAT PERCHED ABOVE CLAY LENSES	HAWTHORN
INCISED BY CREEKS			
	$p = 0.20$ $v = 1.3 \text{ m/yr}$	DISCHARGE TO SURFACE CREEKS	BARNWELL
INCISED BY CREEKS			
TAN CLAY (DISCONTINUOUS)			
	$p = 0.20$ $v = 3.8 \text{ m/yr}$ (CENTER SRP)	DISCHARGE TO SURFACE CREEKS	
INCISED BY CREEKS	$v = 6 \text{ m/yr}$ (NW SRP)	WATER TABLE USUALLY IN THIS FORMATION	McBEAN
GREEN CLAY (DISCONTINUOUS IN NW SRP)			
	$p = 0.20$ $v = 13 \text{ m/yr}$ (CENTER SRP)	DISCHARGE TO SAVANNAH RIVER AND UPPER THREE RUNS	
INCISED BY CREEKS	$v = 6 \text{ m/yr}$ (NW SRP)	HYDRAULICALLY CONNECTED TO McBEAN IN NW	CONGAREE
HYDRAULICALLY CONNECTED TO "TUSCALOOSA"			
	$p = 0.2$ $v = 52 \text{ m/yr}$ (CENTER SRP)	RECHARGED IN NW (M-AREA) AND NEAR PAR POND	
		UPWARD FLOW TO CONGAREE NEAR H-AREA	TUSCALOOSA
CRYSTALLINE METAMORPHIC ROCK		DUNBARTON TRIASSIC BASIN	
		RAE-101211	

FIGURE 1-3. GENERAL HYDROSTRATIGRAPHIC DESCRIPTION OF THE SAVANNAH RIVER PLANT SITE (SRP).

- o "Tuscaloosa" Formation--comprised of a basal confining bed (12 m thick), a basal aquifer (91 m), a middle confining bed (12 m), an upper aquifer (46 m), and an upper confining bed (18 m). The sediments mapped as Tuscaloosa at SRP are geologically younger than the Tuscaloosa-type section in Alabama; hence the term is placed in quotation marks here to denote its use as a hydrostratigraphic term, and not as a formal stratigraphic term.
- o Ellenton Formation--partly containing an aquifer and partly a regional confining bed (18 m).
- o Congaree Formation--partly containing an aquifer (37 m).
- o McBean Formation--comprised of a lower unit of calcareous sand and an upper unit of clayey sand (24 m), separated from the Congaree by a green clay confining bed.
- o Barnwell Formation--composed of a coarse clayey sand and compact sandy clay (30 m), and generally separated from the McBean by a tan clay semi-confining bed.
- o Hawthorn Formation and surficial formations--usually unsaturated sediments that are not regionally important as aquifers.

The two aquifers in the "Tuscaloosa" Formation are used separately and in combination to yield more than 1000 gallons per minute to efficient primary wells. The sands of the Congaree formation also yield several hundred gallons per minute in several locations. The remaining sediments of the Coastal Plain transmit water on a regional scale, but yield insufficient water to wells to be classified as primary aquifers. A few dug wells and low-yield drilled wells utilize the Barnwell and McBean Formations, and thus these can be considered as minor aquifers. Confining beds retard, but do not totally prevent, interchange of water between formations.

The directions of local groundwater movement are largely controlled by the depths of incision of the various creeks in the Aiken Plateau. The direction of groundwater flow in shallow sediments is dominated by small

creeks. The directions in intermediate sediments are dominated by the major tributaries of the Savannah River (Figure 1-1), and the direction of flow in deep sediments is controlled by the Savannah River. Water in the Congaree flows toward either Upper Three Runs Creek or the Savannah River, depending on the location. There are several locations on the SRP in which creek valley penetration is sufficient to break the continuity of the Barnwell, McBean and Congaree Formations, creating groundwater "islands" and preventing lateral flow to adjacent areas within the same formation (Figure 1-4).

The groundwater head in the northwestern part of SRP decreases with depth, potentially allowing surface recharge to reach the deeper formations. In the valleys of the Upper Three Runs Creek and the Savannah River, however, water levels in the Congaree Formation are drawn down by natural discharge more than those in the "Tuscaloosa" Formation. The head reversal in the Congaree Formation therefore causes upward water gradients in the underlying formations. Although water levels in the "Tuscaloosa" Formation fluctuate with rainfall, the average levels have reportedly fallen in recent years,⁽²⁾ decreasing but not eliminating the head reversal in the Congaree Formation. Increased pumping for irrigation and for use at the SRP has affected the declines.

1.3 OBJECTIVES

The specific objectives of this report are to present a technically detailed site description for the Metallurgical Laboratory basin, to document the manner in which it was modeled by the PATHRAE computer code, and to present the results of the pathway analyses, in terms of both

FIGURE 1-4. GENERALIZED NW TO SE GEOLOGIC PROFILE ACROSS THE SAVANNAH RIVER PLANT (Reference 2.)

contaminant transport and health risks. This will provide part of a detailed assessment of environmental risks and impacts from the Metallurgical Laboratory both in its present condition and after possible remedial actions to aid in selection of the appropriate remedial action options. In a broader sense, these objectives support the general SRP operations policy of protecting the environment and the health and safety of the public and operating personnel.

1.4 SCOPE

This report addresses chemical contaminants at the Metallurgical Laboratory basin. The contaminants are modeled for impacts via a number of possible environmental pathways, including groundwater, surface water, erosion, onsite food production, and natural biointrusion. The transport of each contaminant via each possible pathway is considered, as it is presently modeled to occur, and as it is projected to occur under possible remedial action scenarios. The remedial action scenarios include (a) waste removal and closure, (b) no waste removal and closure, and (c) no action. The contaminant transport calculations are integrated with multiple human exposure analyses in the PATHRAE code for assessment of human health risks.

2. CHARACTERISTICS OF THE METALLURGICAL LABORATORY BASIN

The Metallurgical Laboratory Basin is located in the northwest part of the SRP, approximately 1830 meters from the plant boundary. The basin is between the Savannah River Laboratory and the A-Area coal pile runoff containment basin, and is shown in Figure 2-1. The SRP coordinates for the basin are 33.340143°N, 81.733327°W, or N104,114 feet, E51,556 feet as defined in Reference 5.

The Metallurgical Laboratory Basin was used for disposal of waste water effluent from the Equipment Engineering Department Metallurgical Laboratory. Since 1956, approximately 3.8 m³/day of nitric acid and water have been released to the basin. From 1956 through 1982, there were also trace amounts of hazardous chemicals used for metallographic sample preparation and corrosion testing. The basin has overflowed to Carolina Bay during peak precipitation events. In December 1985 the basin will be removed from service, as a waste water treatment facility becomes operational.

2.1 PHYSICAL CHARACTERISTICS

The dimensions of the basin are 33 meters long, 16 meters wide, and 1.5 meters deep (see Figure 2-2). At present, the basin contains approximately 1.2 meters of water and contaminants. The banks of the basin are covered with small bushes, weeds, and grass.

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FIGURE 2-1. LOCATION OF THE METALLURGICAL LABORATORY BASIN AT THE SRP.

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FIGURE 2-2. METALLURGICAL BASIN AND PERIMETER SAMPLE LOCATIONS.

2.2 CONTAMINANT INVENTORIES

During its 30 year lifetime of receiving hazardous waste, the Metallurgical Laboratory Basin received approximately 37,500 m³ of water with associated contaminants. Specifically identified as contaminant substances of interest are iron, aluminum, lead, zinc, chromium, and cyanide.⁽⁵⁾ An estimated inventory of wastes released to the basin is given in Table 2-1. Also selected for analysis are nitrate, phosphate, carbon tetrachloride, and 1,1,1-trichloroethane.

2.3 GEOHYDROLOGY

The metallurgical laboratory basin is located on the Aiken Plateau at a surface elevation of approximately 113 meters MSL. Surface drainage follows a path to the east and Tim's Branch at a distance of approximately 1370 meters.

The basin is constructed within the geologic materials of the Barnwell Formation. The upper tertiary materials (Hawthorn, Barnwell, and McBean Formations) underlying the basin are very similar, and are generally grouped as one unit. This unit consists of interbedded and intercalated sands, silts, clays, and gravels, reaching a total thickness of 53 meters. The water table is found 40 meters below the surface. According to a geologic cross section of the A/M area (Figure 2-3), this depth relates to the center of the McBean Formation.

In the A/M area, the green clay separating the Congaree Formation from the overlying McBean is less continuous than in the central SRP. Also, the horizontal movement in the Congaree is slower in the A/M area. It is found to be approximately 20 meters thick.

TABLE 2-1

ESTIMATED INVENTORY OF WASTES RELEASED TO BUILDING 723-A
METALLURGICAL LABORATORY BASIN

Chemical	Past Total Release Over 30 Years	Present Release
Acetone	20 liters	Not released after 3/83
1,1,1-trichloroethane	150 liters = 225 kg (past 3-5 yr)	Not released after 3/83
Trichloroethylene	6 liters (over 6 mo/yr)	Not released after 1978
Carbon tetrachloride	500 liters = 800 kg	Released before 1978
Hydrofluoric acid*	2 liters	Not released after 3/83
Nitraad* (as purchased is composed of HF, acetic acid, and fluoride salts)	140 liters	Not released after 3/83
Potassium cyanide or Sodium cyanide	1 liter	Not released after 1976
Cyanide (plating solution)**	4 liters	Not released after 1976
Hydrochloric acid	190 liters	45 liters/year
Nitric acid (65 percent)	39,800 liters = 25,663 kg NO ₃	1300 liters/year
Molybdic acid	10 grams	1 gram (rarely used)
Oxalic acid	23 liters	10 liters/year
Phosphoric acid	53 liters = 1.7 kg PO ₄	1.6 liters/year
Picric acid	100 grams	0.4 liters/year
Sulfuric acid	15 liters	4 liters/year
Sodium hydroxide	3 liters	2 liters/year
Potassium hydroxide	30 liters	8 liters/year
Trisodium phosphate	60 liters = 5.7 kg PO ₄	8 liters/year
Sodium sulfite	270,000 grams	11,000 grams/year
Sodium carbonate/bicarbonate	45 liters	8 liters/year
Ammonium persulfate	1 liter	0.5 liter/year
Ethyl alcohol	1,300 liters	420 liters/year
Kerosene	114 liters	Not released after 2/85
Methyl methacrylate (coldweld resin)	150 liters	6 liters/year
Water: cooling water from corrosion test, rinse water from photo process, lab rinse water	3,800 liters/day	3,800 liters/day

* Currently bottled and stored.

** Solution is reused until all metal is depleted.

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FIGURE 2-3. GEOLOGY AND HYDROLOGY NEAR THE CENTER OF A/M AREA. (GEOLOGY AND HEADS ABOVE ELEVATION OF -280 feet ARE FROM MSB-34TA; -280 TO -355 FROM 905-20A; BELOW -355 FEET EXTRAPOLATED FROM WELL P8R LOCATED AT MSB-17).

The Ellenton Formation is found below the Congaree. It consists of 15 meters of sandy lignitic micaceous clay interbedded with sand layers.

The water table aquifer (McBean Formation) is found 40 meters below the surface, and slopes at a gradient of 0.005 to the west (Figure 2-4). Water levels within the Congaree Formation also slope to the west, but at a slightly lesser gradient (Figure 2-5). Gradients within the Ellenton are gentler still, and slope more toward the south (Figure 2-5).

Data published in Reference 5 can be used to calculate horizontal groundwater velocity in the McBean Formation.

$$\text{Velocity} = \frac{(0.002 \text{ gradient})(1.58 \text{ m/day})}{0.2 \text{ porosity}} = 1.58 \times 10^{-2} \text{ m/day} = 5.8 \text{ m/year}$$

Similarly, by combining published data for the Ellenton Formation⁽⁵⁾ with vertical water gradients extracted from figures in Reference 5, it is calculated that downward water velocity through the Ellenton is only 4.5 percent of horizontal velocity in the McBean Formation.

The information given in Figures 2-4 and 1-4 suggests that the water flowing in the McBean Formation will intersect the "Tuscaloosa" Formation since the Congaree and Ellenton Formations are truncated to the west of the Metallurgical Laboratory Basin. The distance travelled through the McBean Formation is approximately 2540 meters. At that point, near the SRP boundary, groundwater flow containing contaminants is transferred to the "Tuscaloosa" Formation (Figure 2-7).

Values for effective porosity and velocity of flow in the "Tuscaloosa" Formation are estimated to be 0.2 and 52 meters/year, respectively. The flow path length in the "Tuscaloosa" Formation is approximately 10140 m from the SRP boundary to Holley Creek. Figure 2-7 shows this path plotted relative to piezometric contours in the "Tuscaloosa" Formation.

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FIGURE 2-4. WATER TABLE ELEVATIONS NEAR THE METALLURGICAL LABORATORY BASIN.

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FIGURE 2-5. WATER SURFACES IN THE CONGAREE FORMATION.

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FIGURE 2-6. WATER SURFACES IN THE ELLENTON FORMATION
(SEE P. 18 OF REF. 6).

FIGURE 2-7. WATER LEVELS AND FLOW THROUGH THE "TUSCALOOSA" FORMATION (Reference 6).

For the sake of simplicity in modeling, travel through the two aquifers will be combined for a total estimated distance of 12,700 meters. Total travel time is 437 years (McBean) plus 195 years ("Tuscaloosa"), or 632 years. This gives an average velocity of 20 meters/year. The distance is then rounded off to 13,000 meters to reflect two significant figures of accuracy.

2.4 GENERAL SITE PARAMETERS

A number of parameters are defined for the PATHRAE analyses that are considered to be global for the entire SRP facility, and will be used without change in all analyses of individual waste sites. Most of these are relatively invariant, so that a single value is sufficient to represent each waste site. In a few cases, however, a parameter is defined as global for lack of any better site-specific basis on which to define the parameter. A list of the global parameters is presented in Table 2-2, along with their respective values and units.

Several values in Table 2-2 were chosen to reflect conservatism in the modeling process. For example, transverse dispersion in the groundwater is being ignored. Waste containers are considered absent by setting their lifetime equal to zero. The areal density of plants is also based on a nominal reported value for biomass production.(7)

2.5 CONFIGURATIONS UNDER CLOSURE OPTIONS

The three options for closing the Metallurgical Laboratory basin under state and federal regulations range from no action to waste removal. Under

TABLE 2-2
GLOBAL PARAMETERS USED FOR PATHRAE ANALYSES

Parameter	Value
River flow rate	$9.1 \times 10^9 \text{ m}^3/\text{yr}$
Aquifer density	$1,600 \text{ kg/m}^3$
Transverse dispersion coefficient (Y)	$0 \text{ m}^2/\text{yr}$
Soil residual saturation	0.1 (dimensionless)
Vertical permeability of unsaturated zone	2.2 m/yr
Soil index	0.25 (dimensionless)
Fraction of diet comprised of contaminated food	0.5 (dimensionless)
Plant root depth	1.0 m
Areal density of plants	1.0 kg/m^2
Breathing rate	$8000 \text{ m}^3/\text{yr}$
Waste container lifetime	0 yr
Water infiltration rate	0.38 m/yr
Aquifer velocity	12 m/yr (McBean)
Aquifer porosity	0.3 (dimensionless)
Distance to well (parallel to aquifer)	50 m

the no-action option the site would remain in its present condition and present level of maintenance. Groundwater monitoring would continue for 30 years from existing wells. Fences and signs would be maintained around the basins, and weeds would be cut periodically.

The waste removal and closure option for this basin begins with neutralization of the pH of the basin water with 10-20 meq/l of hydrated lime or limestone. The basin water would be sent to outfall A-11. Then, 340 m³ of sediment would be excavated and sent to the SRP hazardous waste repository. The basin will then be backfilled with 960 m³ of clean soil. Groundwater monitoring would take place quarterly for the first year and annually for 30 years.

The option for no waste removal and closure includes all aspects of the waste removal option except for waste excavation, and a lesser volume of backfill is required.

3. MODELING OF THE METALLURGICAL LABORATORY BASIN

In order to analyze the contaminant pathways, human exposures, and possible health risks, the specific Metallurgical Laboratory Basin site must be represented by the modeling options available in the PATHRAE computer code. Because of the flexibility of the code, standard options are used to represent both the present basin and also its potential configurations after each of the two potential remedial action activities. The remedial actions include (a) removal of the waste and site closure without a cap and (b) no waste removal and closure without a cap. The pathways to be modeled include surface water, well water, erosion, onsite food production, and natural biointrusion.

3.1 REPRESENTATION OF SITE CHARACTERISTICS

Two main modeling applications of the PATHRAE code are used. These are the basin option and the excavation sequence of options. The seepage basin option is directly applicable to the present Metallurgical Laboratory Basin for the no action case, and is triggered in the PATHRAE code by setting TIMOP, the operating lifetime of a LLW waste facility, equal to zero. Since the seepage basin was active for a period of about 30 years, the leach fraction is defined as $1/30$ or 0.033 so that the total contents of the basin can potentially be leached into underlying soils by the end of the basin lifetime.

For the first remedial action option, waste removal and closure, the excavation sequence of options is utilized. In this case, two PATHRAE calculations are performed. In the first, the seepage basin calculation is

performed for the 30-year active life of the ponds, the chemical distributions in the groundwater, and other pathways are defined. Assuming excavation after this period, no further incoming source is considered, but the chemical inventories computed to reside in the groundwater at the time of closure and not sorbed onto surfaces of excavated soil are used as the source term for a second PATHRAE calculation.

For the second remedial action option, the same seepage basin calculation is performed as in the no-action case, except that backfill would be added. The backfill serves to alter parameters defining the surface erosion, accessibility of biointrusion (roots), and uptake into food grown on the site.

3.2 SOURCE TERM DEFINITIONS

Source terms are defined in terms of the total inventories of each of the hazardous contaminants contained in the basin.

For six of the contaminants, cyanide, lead, zinc, chromium, iron, and aluminum, soil cores were available for three locations under the basin and four additional locations outside but near to the basin (see Figure 3-1). Cyanide is extremely soluble, and therefore is expected to have leached away from the basin. Total cyanide released to the basin was 5 liters,⁽⁵⁾ and an assumed concentration of 1 molar was used. The basin is 5 feet deep and the basin samples were taken to a depth of 20 feet below the basin. Adjacent samples were taken from the ground surface to a depth of 25 feet. Therefore,

$$0' - 20' \text{ (basin depth)} = 5' - 25' \text{ (adjacent depth)}$$

RAE-101177

LEGEND

- ⊕ GROUNDWATER MONITOR WELL
- SOIL CORE
- ⊕ K-STEEL TEST BORING

DU PONT SAVANNAH RIVER PLANT
 METALLURGICAL LABORATORY BASIN
 SOIL BORING & MONITOR WELL
 LOCATION MAP
 ADAPTED FROM DUPONT DRAWING
 SSK 4-7-257

FIGURE 3-1. LOCATION OF METALLURGICAL LABORATORY BASIN BOREHOLES (Reference 5).

The three basin cores were averaged for each depth increment and then a depth-weighted average was performed since all depth increments were not equal. The four adjacent cores were treated similarly, but the 0'-5' and 5'-20' regions were calculated separately.

Finally, the three basin cores and four adjacent cores were combined, remembering that

$$0' - 20' \text{ (basin depth)} = 5' - 25' \text{ (adjacent depth)}$$

and using a three sample to four sample weighted average for the 5'-25' (adjacent datum) depth. The 5' deep pond area contains zero soil, and was treated as such when calculating the 0'-5' (adjacent datum) depth inventory. Water in the basin will have been treated and released prior to closure. Table 3-1 contains a summary of inventory calculations. The spatial limits of contamination were not determined by borehole sampling for lead, zinc, chromium, iron, or aluminum. Therefore, the actual inventories for these elements exceed those shown in Table 3-2 by an unknown amount. The calculations for Table 3-2 assume that contamination is distributed throughout 4136 m³ of soil, which has a bulk density of 1600 kg/m³.

The inventory for 1,1,1,-trichloroethane is calculated using a specific gravity of 1.5 kg/liter. Similarly, a specific gravity of 1.6 kg/liter is used for carbon tetrachloride. The mass of nitrate contained in the nitric acid is calculated assuming 65 percent of a 16N solution (diluted in water). Total phosphate is combined from the phosphoric acid and trisodium phosphate. A 1N solution of phosphoric acid is assumed and a 1M solution of trisodium phosphate is utilized in mass calculations.

TABLE 3-1

SUMMARY OF INVENTORY CALCULATIONS FOR FIVE CONTAMINANTS
RELEASED TO THE METALLURGICAL LABORATORY BASIN

<u>Contaminant</u>	<u>Depth (m)</u>	<u>Depth Weighted Concentration</u>		<u>Area and Depth Weighted</u>	<u>Area (m²)</u>
		<u>Basin (mg/liter)</u>	<u>Adjacent (mg/liter)</u>	<u>Avg. Conc. (mg/liter)</u>	
Pb	0 - 1.52	--	24.6	14.1	245
Zn	0 - 1.52	--	10.3	5.9	245
Cr	0 - 1.52	--	24.5	14.0	245
Fe	0 - 1.52	--	18463	10550	245
Al	0 - 1.52	--	22438	12822	245
Pb	1.52 - 7.62	8.4	24.9	17.8	617
Zn	1.52 - 7.62	11.3	6.6	8.6	617
Cr	1.52 - 7.62	21.5	31.9	27.4	617
Fe	1.52 - 7.62	19450	24971	22605	617
Al	1.52 - 7.62	5950	11727	9251	617

TABLE 3-2

MASS CALCULATIONS FOR CONTAMINANTS
AT METALLURGICAL LABORATORY BASIN

Contaminant	Concentration (ppm)	Volume of Soil (m ³)	Mass of Soil (kg)	Contaminant Mass* (kg)
CN	--	--	--	0.13
Pb	17.8	3764	6.022E+6	115.6
	14.1	372	5.952E+5	
Zn	8.6	3764	6.022E+6	55.3
	5.9	372	5.952E+5	
Cr	27.4	3764	6.022E+6	175.3
	14.0	372	5.952E+5	
Fe	22605	3764	6.022E+6	142407
	10550	372	5.952E+5	
Al	9251	3764	6.022E+6	63341
	12822	372	5.952E+5	

* Partial contaminant mass for Pb, Zn, Cr, Fe, Al. The spatial limits of contamination have not been found.

3.3 FACILITY PARAMETERS

The average facility parameters are defined in Table 3-3. Note that the site dimensions are taken to be those of the basin itself, and not the distances to which contamination is known to have spread, even though contaminant inventory calculations included quantities found in these exterior areas.

3.4 PATHWAY CHARACTERISTICS

The parameters defining the contaminant pathways through groundwater and other environmental paths were defined from the geohydrological data presented in Sections 1 and 2, and are presented in Table 3-4 as they were used in the PATHRAE analyses.

3.5 CHEMICAL-SPECIFIC PARAMETERS

Many of the parameters used in the PATHRAE code are specific to given elements. These are summarized in this section for documentation of the input used in the PATHRAE analyses. They include dose conversion factors and risk factors, biological uptake factors, leach rates, sorption coefficients, soil-to-plant transfer factors, and solubilities. Table 3-5 presents parameters for the chemical species. The method used for calculating health risks for the non-radioactive contaminants, as well as the data used for these calculations is contained in Reference 8.

TABLE 3-3

METALLURGICAL LABORATORY BASIN PARAMETERS
USED IN PATHRAE CALCULATIONS

<u>Parameter</u>	<u>Value</u>
Facility length (parallel to aquifer)	12 m
Facility width	31 m
Facility volume	372 m ³

TABLE 3-4

PATHWAY PARAMETERS USED IN PATHRAE CALCULATIONS

<u>Parameter</u>	<u>Value</u>
Distance to river	13,000 m
Distance from bottom of waste to water table	37.5 m
Distance to well	50 m
Length of perforated well casing	10 m

TABLE 3-5
PARAMETERS FOR CHEMICAL CONTAMINANTS USED IN PATHRAE ANALYSES

Species	Risk Parameters			K_d	Soil-Plant Transfer Factor	Solubility
	H	S	K			
CN	1.01E-01	0.5	2.	.01	1.0	--*
Pb	1.25E+09	0.1	4.	100.	0.004	--*
Zn	1.00E-04	0.5	2.	15.	0.11	6.5E-11
Cr	2.00E-02	0.5	2.	40.	0.013	0.52
Fe	--	--	--	5.	4.2E-04	--*
Al	--	--	--	5.	1.8E-04	--*
1,1,1-Triclethane	1.6E-03	1.	1.	.011	22.	1.4
Tetrachloromethane	1.3E-01	1.	1.	.022	12.	0.48
NO ₃	--	--	--	.001	1.	--*
PO ₄	--	--	--	.001	0.057	--*

* Assume transport is not limited by solubility.

3.6 DESCRIPTION OF PATHRAE ANALYSES

A total of six PATHRAE analyses were performed for analyzing the environmental transport, exposures and human health risks from the SRL Metallurgical Laboratory. Three of these were done for the no-action case. One was aimed at identifying the times (years since 1956) in which peak doses occurred for human exposures, and only addressed the groundwater pathways. The others were aimed at analyzing the exposures and risks from all pathways during the critical years and the total releases to the Savannah River over a 1000 year period. A similar set of analyses was performed for the removal and closure option, with an altered source inventory. The chemical inventory for this case was defined mainly from the soil cores around the basin, reflecting contaminants that left the waste basin and entered adjacent soils, and thus would not be excavated in the waste removal. Again, one PATHRAE analysis in this scenario was aimed at defining the years of peak concentrations, and the other two were aimed at complete dose and risk analyses and at estimating the total releases to the Savannah River over a 1000 year period. For the intermediate scenario, leaving waste in place but backfilling with 1.5 m of soil, the no-action analyses represent the groundwater and on-site farming pathways because infiltration rates are identical, and the farming would still penetrate the entire waste zone. The erosion and biointrusion pathways become zero for this scenario, since 1.5 m of cover exceeds the 1000 year erosion layer (at 1 mm per year) and the root penetration depth.

The doses and health risks associated with the Metallurgical Laboratory Basin are presented in Chapter 4. Included is a discussion of the health risks arising from the no-action scenario as well as the two remedial action scenarios.

4. DOSE AND RISK ASSESSMENT

The estimates of chemical exposure doses and health risks in this chapter are aimed at assessing the relative importance of the proposed remedial action options compared to the no action option. The dose and health risk data should be used with caution, since they are not presented for the purpose of calculating projected cancer deaths or for other health-effect assessments, but solely to give a basis to evaluate and compare remedial action alternatives. Although the PATHRAE code represents state-of-the-art technology in risk estimation, it necessarily involves numerous assumptions and generalizations that may be highly uncertain under some conditions. Hence, its application is more reliable for comparing relative risks from exposures via similar environmental pathways than for estimating absolute risks of human health effects.

Additional uncertainties in the dose and risk analyses come from the paucity of data characterizing the detailed source terms and site-specific environmental pathway transport parameters. These data inadequacies are understandable considering the costs and complexities of obtaining a significantly better data base, but they introduce large uncertainties in the dose and risk results, particularly for absolute applications. The chemical inventories and environmental parameters used in the present analyses constitute the best available parameters, and serve as an adequate basis for evaluating the proposed remedial action alternatives. The following sections describe the results of the PATHRAE calculations, and discuss the associated environmental transport, exposure doses, and health risks.

4.1 PATHRAE RESULTS

The following sections present the results of the PATHRAE dose and risk calculations for the no action and each of the remedial action cases. The chemical doses for all calculations are presented for a 70 kg person in units of milligrams of chemical intake per kilogram of body weight per day. All risks are expressed in units of health effects (HE) per year.

4.1.1 Doses and Risks with No Action

The PATHRAE analyses on the groundwater pathways to identify the peak doses for human exposures for the no action case are summarized in Table 4-1. They show that all ten chemicals cause doses in both pathways, although risks are extremely small. The years (since 1956) in which the exposures are at a maximum were computed to be grouped around 45, 669, 720, 779, and 837, and these years were accordingly selected as five of the ten years for analysis in the complete pathway analyses.

The results of the complete pathway analyses are summarized in Table 4-2 for the groundwater to river pathway, in Table 4-3 for the groundwater to well pathway, Table 4-4 for the erosion pathway, Table 4-5 for the food grown on site pathway, and Table 4-6 for the natural biointrusion pathway. Results calculated for the erosion pathway during the first 750 years were all zero, being controlled by the 1 mm/year erosion rate of the 0.75 m thick cover. Doses and risks calculated for the on-site food pathway were reduced by 372/4492, since the 372 m² site area is too small to supply the specified 0.5 of an individual's diet (4492 m² is the minimum area to support one person⁽⁹⁾). Overall doses were dominated by nitrate throughout the 1000 year period, primarily via the natural biointrusion pathway. Overall risks were dominated by tetrachloromethane throughout the 1000 year period, via the natural biointrusion and well water pathways.

TABLE 4-1

ANALYSES OF PEAK CHEMICAL EXPOSURES AND DOSES
FOR THE NO ACTION SCENARIO

<u>Path</u>	<u>Chemical</u>	<u>Years Since 1956</u>	<u>Peak Concentration (kg/m³)</u>	<u>Average Dose at Peak Time (mg/kg/day)</u>	<u>Average Risk at Peak Time (HE/yr)</u>
Groundwater to River	Aluminum	26,900	8.5E-10	1.9E-8	0
	Chromium	210,000	3.0E-13	2.3E-11	5.3E-24
	Cyanide	717	6.6E-14	7.5E-11	2.8E-22
	Iron	26,900	1.9E-9	1.0E-7	0
	Lead	525,000	8.0E-14	3.6E-12	0
	Nitrate	669	1.4E-8	1.6E-5	0
	Phosphate	669	4.0E-12	1.1E-7	0
	Tetachloromethane	779	3.7E-10	7.0E-9	9.1E-10
	111-Trichlethane	722	1.1E-10	2.1E-9	3.4E-12
	Zinc	142,000	1.0E-18	6.3E-16	2.0E-35
Groundwater to Well	Aluminum	837	7.2E-1	1.4E+1	0
	Chromium	6,430	3.3E-4	7.8E-3	6.0E-7
	Cyanide	45	3.4E-6	4.0E-3	8.1E-7
	Iron	837	1.6	4.3E+1	0
	Lead	16,000	9.0E-5	1.7E-3	9.5E-4
	Nitrate	43	6.9E-1	8.0E+2	0
	Phosphate	43	1.9E-4	1.1E-2	0
	Tetachloromethane	47	2.1E-2	4.1E-1	5.3E-2
	111-Trichlethane	45	5.9E-3	1.2E-1	1.9E-4
	Zinc	24,200	7.4E-12	5.9E-10	1.7E-23

TABLE 4-2

CONCENTRATION AND RISK SUMMARY FOR GROUNDWATER TO RIVER PATHWAY
FOR THE NO-ACTION SCENARIO^a

	Years Since 1956									
	<u>1</u>	<u>45</u>	<u>100</u>	<u>300</u>	<u>500</u>	<u>669</u>	<u>720</u>	<u>779</u>	<u>837</u>	<u>1000</u>
<u>Concentrations^b</u>										
Cyanide	0	0	0	1.8E-26	6.4E-16	5.6E-14	6.6E-14	5.2E-14	2.8E-14	1.3E-15
Nitrate	0	0	0	4.3E-19	6.8E-10	1.4E-8	1.2E-8	6.3E-9	2.5E-9	4.9E-11
Phosphate	0	0	0	1.2E-22	1.9E-13	4.0E-12	3.3E-12	1.8E-12	7.0E-13	1.4E-14
Tetrachloromethane	0	0	0	1.5E-25	3.0E-13	1.6E-10	3.0E-10	3.7E-10	3.1E-10	4.3E-11
111-Trichlethane	0	0	0	1.8E-23	9.0E-13	9.3E-11	1.1E-10	9.3E-11	5.3E-11	2.7E-12
<u>Risks</u>										
Cyanide	0	0	0	0	2.6E-26	2.0E-22	2.8E-22	1.7E-22	5.2E-23	1.2E-25
Nitrate	0	0	0	0	0	0	0	0	0	0
Phosphate	0	0	0	0	0	0	0	0	0	0
Tetrochloromethane	0	0	0	3.6E-25	7.3E-13	4.0E-10	7.3E-10	9.1E-10	7.6E-10	1.0E-10
111-Trichlethane	0	0	0	5.5E-25	2.7E-14	2.8E-12	3.4E-12	2.8E-12	1.6E-12	8.3E-14
Total Risks	0	0	0	9.1E-25	7.6E-13	4.0E-10	7.3E-10	9.1E-10	7.6E-10	1.0E-10

^a Concentrations are in kg/m³, and risks are in health effects per year.

^b All concentrations for aluminum, chromium, iron, lead, and zinc were zero.

TABLE 4-3

CONCENTRATION AND RISK SUMMARY FOR GROUNDWATER TO WELL PATHWAY
FOR THE NO-ACTION SCENARIO^a

	Years Since 1956									
	<u>1</u>	<u>45</u>	<u>100</u>	<u>300</u>	<u>500</u>	<u>669</u>	<u>720</u>	<u>779</u>	<u>837</u>	<u>1000</u>
<u>Concentrations^b</u>										
Aluminum	0	0	0	0	0	0	0	0	7.1E-1	4.6E-2
Cyanide	0	3.4E-6	4.1E-9	4.8E-14	2.0E-18	4.9E-22	4.1E-23	2.4E-24	1.4E-25	5.8E-29
Iron	0	0	0	0	0	0	0	0	1.6	1.0E-1
Nitrate	0	3.3E-1	5.8E-4	3.5E-9	7.5E-14	1.1E-17	7.7E-19	3.6E-20	1.8E-21	4.3E-25
Phosphate	0	9.4E-5	1.6E-7	1.0E-12	2.1E-17	3.1E-21	2.2E-22	1.0E-23	5.2E-25	1.2E-28
Tetrachloromethane	0	2.1E-2	3.8E-5	9.2E-10	8.0E-14	3.8E-17	3.9E-18	2.8E-19	2.1E-20	1.6E-23
111-Triclethane	0	5.9E-3	7.4E-6	9.2E-11	4.0E-15	1.1E-18	9.2E-20	5.4E-21	3.3E-22	1.4E-25
<u>Risks</u>										
Aluminum	0	0	0	0	0	0	0	0	0	0
Cyanide	0	8.1E-7	1.2E-12	1.6E-22	2.6E-31	1.7E-38	0	0	0	0
Iron	0	0	0	0	0	0	0	0	0	0
Nitrate	0	0	0	0	0	0	0	0	0	0
Phosphate	0	0	0	0	0	0	0	0	0	0
Tetrachloromethane	0	5.3E-2	9.6E-5	2.3E-9	2.0E-13	9.5E-17	9.7E-18	7.0E-19	5.3E-20	3.9E-23
111-Triclethane	0	1.9E-4	2.4E-7	2.9E-12	1.3E-16	3.4E-20	2.9E-21	1.7E-22	1.1E-23	4.5E-27
Total Risks	0	5.3E-2	9.6E-5	2.3E-9	2.0E-13	9.5E-17	9.7E-18	7.0E-19	5.3E-20	3.9E-23

^a Concentrations are in kg/m³, and risks are in health effects per year.

^b All concentrations for chromium, lead, and zinc were zero.

TABLE 4-4

DOSE AND RISK SUMMARY FOR THE EROSION PATHWAY
FOR THE NO-ACTION SCENARIO

<u>Chemical</u>	<u>Years 779 to 1000^a</u>	
	<u>Doses (mg/kg/day)</u>	<u>Risks (HE/yr)</u>
Aluminum	1.5E-7	0
Chromium	1.5E-9	2.2E-20
Cyanide	1.7E-11	1.4E-23
Iron	8.4E-7	0
Lead	5.8E-10	1.4E-29
Nitrate	3.4E-6	0
Phosphate	2.2E-8	0
Tetrachloromethane	1.7E-9	2.2E-10
111-Triclethane	5.0E-10	8.0E-13
Zinc	3.8E-9	7.3E-22
TOTAL		2.2E-10

^a All doses and risks were zero during the 1-720 year period.

TABLE 4-5

DOSE AND RISK SUMMARY FOR THE ON-SITE FOOD PATHWAY
FOR THE NO-ACTION SCENARIO^a

<u>Chemical</u>	<u>Doses (mg/kg/day)</u>	<u>Risks (HE/yr)</u>
Aluminum	1.1E-5	0
Chromium	5.5E-6	3.6E-12
Cyanide	4.9E-5	1.4E-9
Iron	2.2E-4	0
Lead	3.5E-7	3.2E-15
Nitrate	9.7	0
Phosphate	1.0E-5	0
Tetrachloromethane	6.1E-3	7.9E-4
111-Triclethane	3.1E-3	5.0E-6
Zinc	1.3E-4	1.1E-11
TOTAL		8.0E-4

^a Doses and risks were constant throughout the 100-1000 year period; institutional control is assumed during the first hundred years.

TABLE 4-6

DOSE AND RISK SUMMARY FOR THE NATURAL BIOINTRUSION PATHWAY
FOR THE NO-ACTION SCENARIO^a

<u>Chemical</u>	<u>Doses (mg/kg/day)</u>	<u>Risks (HE/yr)</u>
Aluminum	5.5E-5	0
Chromium	2.7E-5	1.1E-9
Cyanide	2.4E-4	4.3E-7
Iron	1.1E-3	0
Lead	1.7E-6	2.4E-11
Nitrate	4.9E+1	0
Phosphate	5.0E-5	0
Tetrachloromethane	3.1E-2	4.8E-2
111-Triclethane	1.5E-2	3.0E-4
Zinc	6.7E-4	3.2E-9
TOTAL		4.8E-2

a. Doses and risks were constant throughout the 100-1000 year period; institutional control is assumed during the first 100 years.

4.1.2 Doses and Risks with Waste Removal and Site Closure

The PATHRAE analyses on the two groundwater pathways to find peak exposure doses for the removal and closure scenario are summarized in Table 4-7. These again showed that all ten chemicals cause doses in both pathways. The years (since 1956) in which their exposures were maximum were again grouped around 45, 669, 720, 779, and 837, and the same ten years were selected for the pathway analysis as for the no-action scenario.

The results of the complete pathway analyses for the removal and closure scenario are summarized in Table 4-8 for the groundwater to river pathway, in Table 4-9 for the groundwater to well pathway, and in Table 4-10 for the on-site food pathway. Data for the food pathway were again reduced by 372/4492 to account for the small site area. The results were all zero for the erosion and natural biointrusion pathways due to the definitions of the cover thickness and erosion rate, and of the plant root depth. Overall doses for the removal and closure scenario were dominated by nitrate in the on-site food pathway, and overall risks were dominated by tetrachloromethane throughout the 1000 year period, via the on-site food and well water pathways.

4.1.3 Doses and Risks with Site Closure Only

The chemical doses and risks for the scenario in which the wastes are left in place, but a 1.5 m cover is installed are represented by the same data as for the no-action case for the river and well water pathways (Tables 4-2 and 4-3, respectively). This is because the additional 0.75 m cover for this scenario is not a compacted clay cap, but simply additional soil with the same permeability as the present material.

TABLE 4-7

ANALYSES OF PEAK CHEMICAL EXPOSURES AND DOSES
FOR THE REMOVAL AND CLOSURE SCENARIO

Path	Chemical	Years Since 1956	Peak Concentration (kg/m ³)	Average Dose at Peak Time (mg/kg/day)	Average Risk at Peak Time (HE/yr)
Groundwater to River	Aluminum	26,900	7.4E-10	1.6E-8	0
	Chromium	210,000	2.6E-13	2.0E-11	4.2E-24
	Cyanide	717	6.6E-14	7.5E-11	2.8E-22
	Iron	26,900	1.7E-9	9.0E-8	0
	Lead	525,000	7.5E-14	3.4E-12	0
	Nitrate	669	1.4E-8	1.6E-5	0
	Phosphate	669	4.0E-12	1.1E-7	0
	Tetrachloromethane	779	3.7E-10	7.0E-9	9.1E-10
	1,1,1-Trichloroethane	722	1.1E-10	2.1E-9	3.4E-12
	Zinc	142,000	1.0E-18	6.3E-16	2.0E-35
Groundwater to Well	Aluminum	837	6.2E-1	1.2E+1	0
	Chromium	6,430	2.9E-4	6.9E-3	4.7E-7
	Cyanide	45	3.4E-6	4.0E-3	8.1E-7
	Iron	837	1.4	3.8E+1	0
	Lead	16,000	8.4E-5	1.6E-3	7.4E-4
	Nitrate	43	6.9E-1	8.0E+2	0
	Phosphate	43	1.9E-4	1.1E-2	0
	Tetrachloromethane	47	2.1E-2	4.1E-1	5.3E-2
	1,1,1-Trichloroethane	45	5.9E-3	1.2E-1	1.9E-4
	Zinc	24,200	7.4E-12	5.9E-10	1.7E-23

TABLE 4-8

CONCENTRATION AND RISK SUMMARY FOR GROUNDWATER TO RIVER PATHWAY
FOR THE REMOVAL AND CLOSURE SCENARIO^a

		Years Since 1956									
		<u>1</u>	<u>45</u>	<u>100</u>	<u>300</u>	<u>500</u>	<u>669</u>	<u>720</u>	<u>779</u>	<u>837</u>	<u>1000</u>
<u>Concentrations^b</u>											
Cyanide	0	0	0	1.8E-26	6.4E-16	5.6E-14	6.6E-14	5.2E-14	2.8E-14	1.3E-15	
Nitrate	0	0	0	4.3E-19	6.8E-10	1.4E-8	1.2E-8	6.3E-9	2.5E-9	4.9E-11	
Phosphate	0	0	0	1.2E-22	1.9E-13	4.0E-12	3.3E-12	1.8E-12	7.0E-13	1.4E-14	
Tetrachloromethane	0	0	0	1.5E-25	3.0E-13	1.6E-10	3.0E-10	3.7E-10	3.1E-10	4.3E-11	
111-Trichlethane	0	0	0	1.8E-23	9.0E-13	9.3E-11	1.1E-10	9.3E-11	5.3E-11	2.7E-12	
<u>Risks</u>											
Cyanide	0	0	0	0	2.6E-26	2.0E-22	2.8E-22	1.7E-22	5.2E-23	1.2E-25	
Nitrate	0	0	0	0	0	0	0	0	0	0	
Phosphate	0	0	0	0	0	0	0	0	0	0	
Tetrachloromethane	0	0	0	3.6E-25	7.3E-13	4.0E-10	7.3E-10	9.1E-10	7.6E-10	1.0E-10	
111-Trichlethane	0	0	0	5.5E-25	2.7E-14	2.8E-12	3.4E-12	2.8E-12	1.6E-12	8.3E-14	
Total Risks	0	0	0	9.1E-25	7.6E-13	4.0E-10	7.3E-10	9.1E-10	7.6E-10	1.0E-10	

^a Concentrations are in kg/m³, and risks are in health effects per year.

^b All concentrations for aluminum, chromium, iron, lead, and zinc were zero.

TABLE 4-9

CONCENTRATION AND RISK SUMMARY FOR GROUNDWATER TO WELL PATHWAY
FOR THE REMOVAL AND CLOSURE SCENARIO^a

		Years Since 1956									
		<u>1</u>	<u>45</u>	<u>100</u>	<u>300</u>	<u>500</u>	<u>669</u>	<u>720</u>	<u>779</u>	<u>837</u>	<u>1000</u>
<u>Concentrations^b</u>											
Aluminum	0	0	0	0	0	0	0	0	0	6.2E-1	4.0E-2
Cyanide	0	3.4E-6	4.1E-9	4.8E-14	2.0E-18	4.9E-22	4.1E-23	2.4E-24	1.4E-25	5.8E-29	
Iron	0	0	0	0	0	0	0	0	1.4	9.0E-2	
Nitrate	0	3.3E-1	5.8E-4	3.5E-9	7.5E-14	1.1E-17	7.7E-19	3.6E-20	1.8E-21	4.3E-25	
Phosphate	0	9.4E-5	1.6E-7	1.0E-12	2.1E-17	3.1E-21	2.2E-22	1.0E-23	5.2E-25	1.2E-28	
Tetrachloromethane	0	2.1E-2	3.8E-5	9.2E-10	8.0E-14	3.8E-17	3.9E-18	2.8E-19	2.1E-20	1.6E-23	
111-Triclethane	0	5.9E-3	7.4E-6	9.1E-11	4.0E-15	1.1E-18	9.2E-20	5.4E-21	3.3E-22	1.4E-25	
<u>Risks</u>											
Aluminum	0	0	0	0	0	0	0	0	0	0	0
Cyanide	0	8.1E-7	1.2E-12	1.6E-22	2.6E-31	1.7E-38	0	0	0	0	0
Iron	0	0	0	0	0	0	0	0	0	0	0
Nitrate	0	0	0	0	0	0	0	0	0	0	0
Phosphate	0	0	0	0	0	0	0	0	0	0	0
Tetrachloromethane	0	5.3E-2	9.6E-5	2.3E-9	2.0E-13	9.5E-17	9.7E-18	7.0E-19	5.3E-20	3.9E-23	
111-Triclethane	0	1.9E-4	2.4E-7	2.9E-12	1.3E-16	3.4E-20	2.9E-21	1.7E-22	1.1E-23	4.5E-27	
Total Risks	0	5.3E-2	9.6E-5	2.3E-9	2.0E-13	9.5E-17	9.7E-18	7.0E-19	5.3E-20	3.9E-23	

^a Concentrations are in kg/m³, and risks are in health effects per year.

^b All concentrations for chromium, lead, and zinc were zero.

TABLE 4-10

DOSE AND RISK SUMMARY FOR THE ON-SITE FOOD PATHWAY
FOR THE REMOVAL AND CLOSURE SCENARIO^a

<u>Chemical</u>	<u>Doses (mg/kg/day)</u>	<u>Risks (HE/yr)</u>
Aluminum	9.5E-6	0
Chromium	4.8E-6	2.8E-12
Cyanide	4.9E-5	1.4E-9
Iron	1.9E-4	0
Lead	3.3E-7	2.5E-15
Nitrate	9.7	0
Phosphate	1.0E-5	0
Tetrachloromethane	6.1E-3	7.9E-4
111-Triclethane	3.1E-3	5.0E-6
Zinc	1.1E-4	7.2E-12
TOTAL		8.0E-4

^a Doses and risks were constant throughout the 100-1000 year period; institutional control is assumed during the first 100 years.

Therefore, infiltration is not altered, and the effects on the groundwater are identical to the no-action case. For the on-site food pathway, doses and risks are also identical to those in the no-action scenario (Table 4-5), since the intruder penetrates the entire waste thickness in both cases. The doses and risks are all zero for the erosion and biointrusion pathways, since the additional cover is sufficient to prevent doses via these pathways.

4.2 ENVIRONMENTAL TRANSPORT

The overall transport of radionuclides from the Metallurgical Laboratory Basin to the outside environment was assessed by two separate PATHRAE analyses of total releases to the Savannah River over a 1000-year period. The analyses were for the no-action scenario and for the removal and closure scenario. The analyses indicated that five of the ten chemicals in the basin inventory reached the Savannah River in both scenarios. These were cyanide, nitrate, phosphate, tetrachloromethane, and 1,1,1-trichloroethane and the total inventories released in the first 1000 year period are presented in Table 4-11. As shown, the inventories were identical with or without remedial action, and were dominated by nitrate ($2.6\text{E}+4$ kg), and organic solvents ($1.0\text{E}+3$ kg total).

4.3 DOSES AND RISKS

The maximum chemical doses and risks resulting from the Metallurgical Laboratory Basin are summarized in Table 4-12, and indicate that the waste removal and basin closure resulted in no reduction in doses and risks from

TABLE 4-11

TOTAL INVENTORIES OF CHEMICALS REACHING THE SAVANNAH RIVER
OVER A 1000-YEAR PERIOD^a

	<u>No-Action</u>	<u>Waste Removal and Closure</u>
Cyanide	1.3E-1	1.3E-1
Nitrate	2.6E+4	2.6E+4
Phosphate	7.4	7.4
Tetrachloromethane	7.8E+2	7.8E+2
111-Triclethane	2.2E+2	2.2E+2

a Inventories are in kg.

TABLE 4-12

COMPARISON OF MAXIMUM RISKS AND DOMINANT CHEMICALS

Pathway	No-Action				Closure Only or Waste Removal and Closure			
	Year Since 1956	Dominant Chemical	Dose (mg/kg/day)	Maximum Total Risk (HE/yr)	Year Since 1956	Dominant Chemical	Dose (mg/kg/day)	Maximum Total Risk (HE/yr)
Groundwater to River	779	Tetrachloro- methane	7.0E-9	9.1E-10	779	Tetrachloro- methane	7.0E-9	9.1E-10
Groundwater to Well	45	Tetrachloro- methane	4.1E-1	5.3E-2	45	Tetrachloro- methane	4.1E-1	5.3E-2
Erosion	779-1000	Tetrachloro- methane	1.7E-9	2.2E-10	--	--	0	0
Food Grown On-site	100-1000	Tetrachloro- methane	6.1E-3	8.0E-4	100-1000	Tetrachloro- methane	6.1E-3	8.0E-4
Natural Biointrusion	100-1000	Tetrachloro- methane	3.1E-2	4.8E-2	--	--	0	0

the groundwater to river pathway, from the groundwater to well pathway, or from the on-site food pathway, but it completely eliminated the doses and risks from the erosion and biointrusion pathways. The dominant chemical in all pathways for both scenarios was tetrachloromethane. The chemical with next greatest risk was 1,1,1-trichloroethane, which gave 160 times lower total risk as summed over all pathways. As shown in Table 4-12, greatest risks came from the groundwater to well and natural biointrusion pathways, with respective total risks of 0.053 and 0.048 health effects per year. These peak risks are comparable; however, the biointrusion risks do not occur simultaneously due to the 100 year institutional control. By year 100, risks from the well water pathway are down to 9.6×10^{-5} HE/yr, a relatively insignificant level. Therefore the major risk is from the biointrusion pathway, and this is avoidable under either of the closure scenarios. Although the risks from the well water pathway could be potentially significant if extended over a long period of time, they are only marginally significant (i.e., approximately $30 \text{ y} \times 5.3 \times 10^{-2} \text{ HE/y} = 1.6 \text{ HE}$) in causing 1-2 health effects during the nominal 30-year period in which the solvent pulse passes the well. These health effects are basically irreversible, as shown in Table 4-12 because the solvents are mostly already dispersed into the groundwater system, and would not be significantly recovered by excavation in the removal and closure scenario.

5. SUMMARY AND CONCLUSIONS

Releases of radiological contaminants to the environment were characterized for the Metallurgical Laboratory Basin by using pathway analysis. The basin is located in the northwest part of the SRP, about 1830 meters from the plant boundary, between the Savannah River Laboratory and the A-Area coal pile runoff contaminant basin. The basin received wastes since 1956, consisting mostly of nitric acid ($3.8 \text{ m}^3/\text{day}$), water, and smaller quantities of organic solvents and trace chemicals.

Analyses of radionuclide transport and human exposures via five environmental pathways were performed for two scenarios: the no action scenario and the waste removal and closure scenario. Assessment of a third scenario, closure without waste removal, was completed using the pathway calculations from the no-action scenario. For removal and closure, all chemicals presently in the basin were considered removed, and transport calculations considered only the contaminants that had already left the pits via groundwater pathways, as defined by soil core sample data. Pathways analyzed for human exposure included groundwater to a river, groundwater to a well, cover erosion, food grown on site, and natural biointrusion.

The PATHRAE analyses indicated that no doses or risks occur for either of the closure scenarios via the erosion or biointrusion pathways, due to the cover soil. For the groundwater pathways, identical maximum doses were computed for all scenarios, dominated by tetrachloromethene and, to a much smaller extent, 111-trichloroethane. Basin closure did not reduce risks because these solvents had already moved to the groundwater before the remedial actions. Similarly for the food pathway, the intruder penetrated the waste regardless of cover, and mobile chemicals such as the solvents,

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nitrates, etc. had already moved from the waste excavation zone into the underlying soils. Closure of the basin with a soil cover, with or without waste removal, was sufficient to eliminate doses and risks from the erosion and biointrusion pathways.

The risks for all pathways and all scenarios were dominated by tetrachloromethane and to a secondary extent, by 111-trichloroethane. Risks were insignificant for the river, erosion, and on-site food pathways. Similar peak risks were computed for the well water and biointrusion pathways (0.053 and 0.048 HE/yr respectively). The well water pathway has about a 30 year peak, that occurs within the 100 years of institutional control. The health effects from the well water pathway are marginally significant, considering the conservatism in the modeling and calculation effort. However, these are not removed under any of the scenarios, and so they do not affect the remedial action decision. Based on these analyses, closure of the basin with an earthen cover would avoid the potential health effects from biointrusion. Waste excavation and removal is not justified by any significant additional benefits over the simple closure option, so the option of closure without waste removal is the indicated choice.

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