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ENVIRONMENTAL INFORMATION DOCUMENT

RADIOACTIVE WASTE BURIAL GROUNDS

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

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PREFACE

This document provides environmental information on postulated closure options for the Radioactive Waste Burial Grounds at the Savannah River Plant and was developed as background technical documentation for the Department of Energy's proposed Environmental Impact Statement (EIS) on waste management activities for groundwater protection at the plant. The results of groundwater and atmospheric pathway analyses, accident analysis, and other environmental assessments discussed in this document are based upon a conservative analysis of all foreseeable scenarios as defined by the National Environmental Policy Act (CFR, 1986). The scenarios do not necessarily represent actual environmental conditions. This document is not meant to be used as a closure plan or other regulatory document to comply with required federal or state environmental regulations.

Technical assistance in the environmental analyses of waste-site closures was provided by Clemson University; GeoTrans, Inc.; JBF Associates, Inc.; S. S. Papadopulos & Associates, Inc.; Radiological Assessments Corporation; Rogers and Associates Engineering Corporation; Science Applications International Corporation; C. B. Shedrow Environmental Consultants, Inc.; Exploration Software; and Verbatim Typing and Editing.

SUMMARY

The Radioactive Waste Burial Grounds are central waste storage sites used for disposal of radioactive solid waste at the Savannah River Plant (SRP). There are three facilities: (1) Building No. 643-G, a 3.1E+05 m^2 area used from 1952 through 1972; (2) Building No. 643-7G, a 4.8E+05 m^2 site, contiguous to the original area, which received waste generated beginning in 1969; and (3) a closure area (Building No. 643-28G) within 643-7G, defined in 1986 to be closed as a mixed waste management facility. This closure area (643-28G) has received materials defined as hazardous by the Resource Conservation and Recovery Act (RCRA). A variety of waste disposal methods have been employed throughout the period of operation.

Groundwater beneath the site has been monitored to aid in evaluating environmental impacts and in selecting proper closure strategies. The major waste component in the groundwater is tritium; however, 34 radionuclides and 10 nonradioactive constituents were assessed for potential environmental impacts. A statistical analysis of available monitoring data was not conducted for these waste sites because the groundwater monitoring wells at the Radioactive Waste Burial Grounds were installed and sampled using a variety of protocols.

The closure options considered for the Radioactive Waste Burial Grounds are waste removal and closure, no waste removal and closure, and no action. The predominant pathways for human exposure to chemical and/or radioactive constituents are through surface, subsurface, and atmospheric transport. Modeling calculations were made to determine the risks to human population via these general pathways for the three postulated closure options. An ecological assessment was conducted to predict the environmental impacts on aquatic and terrestrial biota. The relative costs for each of the closure options were estimated.

The environmental impact evaluation indicates that the human health risks for all closure options are relatively low. Calculated risks are dominated by radionuclides (primarily tritium) during the assumed period of institutional control--no exposure is anticipated through the subject pathways during this period. Following the period of institutional control, the maximum calculated risks are from radionuclides (primarily tritium, ^{90}Sr, and ^{237}Np) in the groundwater to well at 1 m pathway, radionuclides (primarily ^{90}Sr and ^{137}Cs) in the reclaimed-farmland pathway, and noncarcinogens (primarily mercury) in the reclaimed-farmland pathway. The no action option has significantly higher risks than the other closure options for several constituents and several pathways. For example, calculated radioactive risks from the

reclaimed-farmland pathway are greater than 1.0E-06 HE/yr for the no action option and are well below 1.0E-06 HE/yr for the waste removal and no waste removal closure options. Calculated occupational doses are high for the waste removal and closure option (approximately 1,890 person-rem), while occupational exposures are insignificant for the other closure options. Conservative analysis indicates a potential for limited aquatic and terrestrial ecological impacts due primarily to lead for all closure options.

The relative costs for the options are $10,125 million for waste removal and closure, $125 million for no waste removal and closure, and $38 million for no action.

NATURE OF DISPOSAL

GEOGRAPHICAL LOCATION

The Radioactive Waste Burial Grounds (Figure 1) are solid radioactive waste storage sites centrally located at the Savannah River Plant used to store all radioactive solid waste produced at the plant, as well as periodic shipments from other U.S. Department of Energy (DOE) facilities. The Burial Grounds occupy 7.9E+05 m^2 between the F and H separations areas, approximately 10 km from the nearest plant boundary. The original area, designated Building No. 643-G, is a quadrilateral shape with corners at the following coordinates:

SRP Coordinates (ft)*		Latitude and Longitude	
N 75277	E 54411	33.281042°N	81.669748°W
N 76150	E 55081	33.284066°N	81.669680°W
N 73900	E 58080	33.283983°N	81.657413°W
N 73346	E 57586	33.281951°N	81.657637°W

Site 643-G began receiving waste in 1952 and was filled in 1972. Operations then shifted to a contiguous site, the 643-7G Burial Ground. Site 643-7G is a polygonal shape with corners at the following coordinates:

SRP Coordinates (ft)*		Latitude and Longitude	
N 76000	E 55876	33.285031°N	81.667296°W
N 76800	E 55876	33.286801°N	81.668850°W
N 76800	E 57600	33.289614°N	81.664310°W
N 76475	E 57548	33.288810°N	81.663816°W
N 76475	E 58800	33.290853°N	81.660519°W
N 73780	E 58800	33.284892°N	81.655284°W
N 75100	E 57000	33.284875°N	81.662588°W
N 75600	E 57000	33.285981°N	81.663559°W
N 75600	E 56400	33.285002°N	81.665139°W

Site 643-28G, a closure area within 643-7G, was defined in 1986.

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* Coordinates relative to the SRP grid, a local Department of Energy plane system whose "grid north" is approximately 36.4° west of true north at SRP.

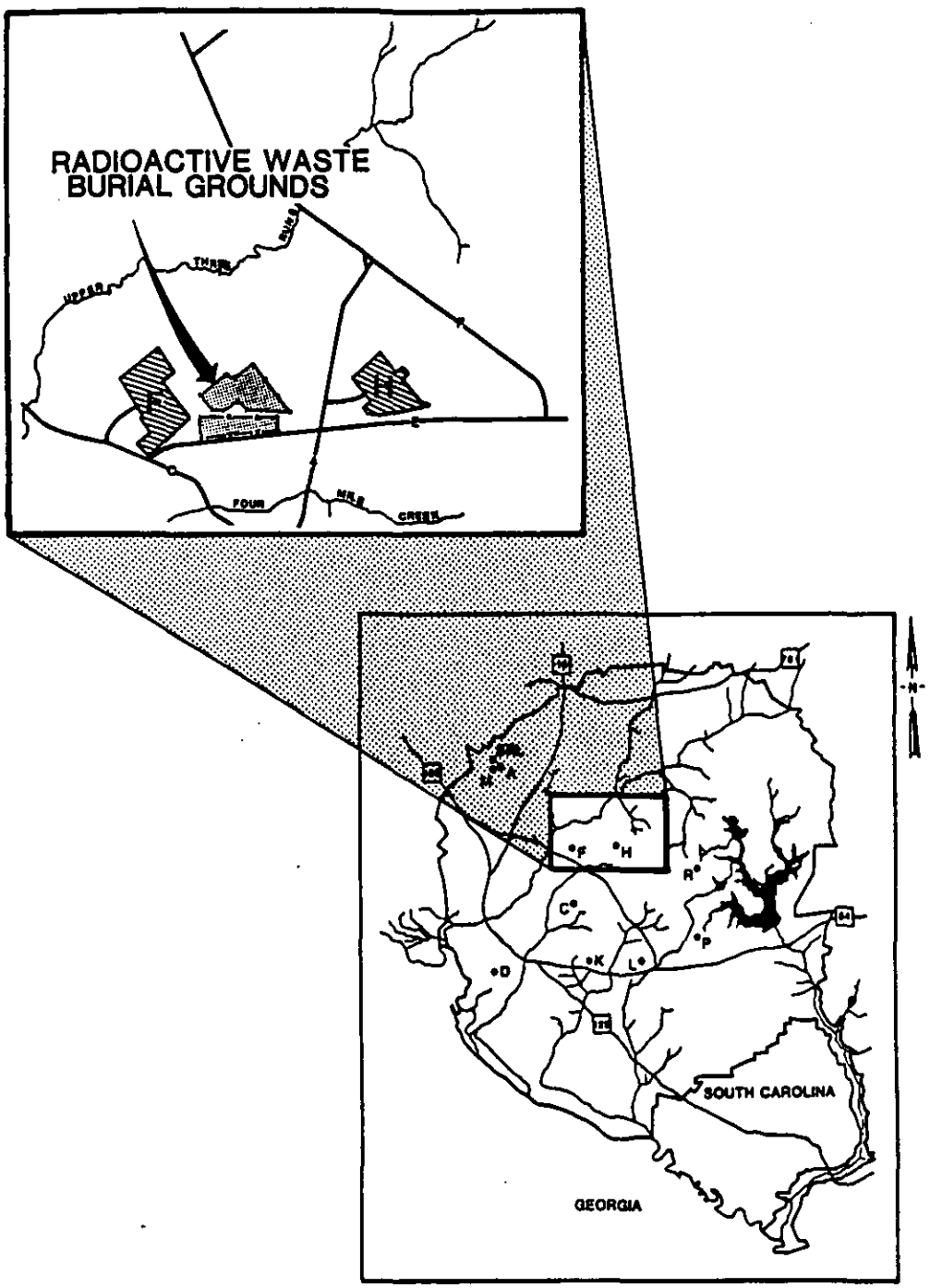


FIGURE 1. Location of the Radioactive Waste Burial Grounds

SITE DIMENSIONS

Site 643-G occupies approximately 3.1E+05 m^2, and sites 643-7G and 643-28G occupy approximately 4.8E+05 m^2. Copies of engineering drawings of these facilities are presented in Appendix A.

HISTORY OF DISPOSAL

The Burial Grounds are divided into sections for accommodating disposal of various levels and types of radioactivity in waste materials: transuranic (TRU) alpha waste, low-level waste (alpha and beta-gamma), intermediate-level beta-gamma waste (intermediate-level beta-gamma and low-level beta-gamma solid radioactive wastes are segregated according to radiation measurement), and waste generated offsite. The Burial Grounds are operated in compliance with DOE Orders regarding radioactive waste disposal. Examples of the materials in storage include:

- Contaminated equipment--obsolete or failed tanks, pipes, jumpers, and other process equipment from the radiochemical separations areas.
- Reactor hardware and resins--fuel components and housings not containing irradiated fuel and spent deionizer resins.
- Spent lithium-aluminum targets--the waste target alloy after tritium has been extracted.
- Oil from pumps in the tritium facilities and reactor areas--before bulk storage was started, the oil was placed in drums containing an absorbent material and buried.
- Mercury from gas pumps in tritium facilities--before 1968, radioactively contaminated mercury was buried in 1-L polyethylene bottles contained within a 0.02 m^3 steel can. Approximately 9,000 kg of mercury are buried in the 643-G Burial Ground.
- Incidental waste from laboratory and production operations--small equipment, spent air filters, clothes, analytical waste, decontamination residues, plastic sheeting, and gloves.
- Shipments from offsite--for example, tritiated waste from Mound Laboratory, ^{238}Pu process waste from Los Alamos Scientific Laboratory and Mound Laboratory, debris from two U.S. military airplane accidents in foreign countries, and U.S. Navy submarine components.

Until 1965, transuranic waste was buried in plastic bags and cardboard boxes in earthen trenches designated specifically for this waste. Between 1965 and 1974, TRU waste was segregated according to TRU content into two categories. Waste containing less than 0.1 Ci per package was buried unencapsulated in alpha trenches. Waste containing greater than 0.1 Ci per package was buried in retrievable concrete containers 1.8 m in diameter and 2.0 m high. Waste that did not fit into the prefabricated concrete containers was encapsulated in concrete. Inorganic constituents such as lead (used to shield a variety of waste forms or discarded due to high contamination levels) and cadmium (from control rods, safety rods, and shielding) have been placed in the Burial Grounds. Current practices, which are described in the following section, were initiated in 1974 and updated in 1984 and 1986.

The estimated volume and curie content of solid radioactive waste buried nonretrievably from 1952 through May 1985 are shown in Table 1. The majority of this waste is contained in plastic bags and cardboard boxes and is thus subject to leaching if contacted by water-saturated soil. Radionuclides in the category "Other Alpha Emitters" are ^{242}Pu, ^{241}Am, ^{243}Am, ^{233}U, enriched U, depleted U, natural U, ^{252}Cf, ^{237}Np, and ^{232}Th.

CURRENT STATUS

A paved road to the entrance and many unpaved roads inside the fenced burial ground areas provide access for trucks, the usual transportation mode for solid waste. A railroad spur permits shipments of large pieces of equipment from operating areas and offsite.

Records are kept of the contents, radiation level, and approximate storage location of each shipment of waste. All shipments are described by the generator. This information is recorded, and permanent computerized records are maintained on duplicate magnetic tapes. The location of the burial/storage area for each shipment of waste is defined by an approximately 30-m grid system laid out in 1962. These grids are further divided into 6-m squares.

Trenches, for storing intermediate level SRP bulky non-containerized low-level (alpha and beta-gamma) and containerized offsite wastes, are excavated 6 m wide, 6 m deep, and up to 300 m long called Shallow Land Burial (SLB) trenches. Since mid-1984, newly generated low-level waste has been containerized in metal boxes or metal drums and is currently stored in an Engineered Low Level Trench (ELLT). This trench is much wider, approximately 40 m, than SLB trenches and allows more efficient use of space by allowing equipment to drive into the excavation and stack and organize the waste packages. Waste forms emplaced in the SLB trenches are covered with soil shortly after emplacement to

TABLE 1

Radionuclide Inventory for Waste Buried in Trenches at SRP Burial Grounds from 1952 Through 1985

Radionuclide	Volume (m^3)	Amount Buried (Ci)	
		Original	Decayed (1986)
^{3}H	24,000	4,090,000	1,830,000
Fission Products	266,000	711,000	18,729
Induced Activity	30,800	3,410,000	348,000
^{60}Co	4,920	1,110,000	413,000
^{137}Cs	-	-	~10,000
^{90}Sr	-	-	~10,000
Other Alpha Emitters	54,200	93.3	87.3
Other Alpha Emitters (composition percentage by activity)			
^{233}U	0.788		
Depleted U	62.74		
Enriched U	0.32		
Natural U	3.30		
^{242}Pu	0.002		
^{241}Am	6.69		
^{252}Cf	25.93		
^{237}Np	0.17		
^{232}Th	0.06		

Note: Data are based upon corrected and updated information from the Computerized Burial Ground Records (COBRA) as of 2/5/86.

maintain radiation control and reduce potential for contamination spread. Ultimately, all trenches filled with waste are backfilled with a minimum of 1.2 m of soil to reduce surface radiation rates to less than 5 mrem/hr, to reduce the potential for contaminant spread, and to minimize plant and animal intrusion into the waste.

In 1974, procedures were modified to reflect new criteria governing retrievable storage of solid transuranic waste. Transuranic wastes contaminated with greater than 10 nCi TRU/g are now protected from contact with water-saturated soil and stored in containers that can be retrieved intact and free of external contamination for at least 20 years from the time of storage. Combustible and noncombustible wastes are stored in separate containers. Polyethylene-lined galvanized drums are used as the primary container; waste packages containing more than 0.5 Ci are additionally protected by enclosure in large concrete cylinders that can hold up to 14 drums. Containers, including concrete cylinders, are stored on a concrete pad with a monitoring sump and covered with 1.2 m of earth. In 1985, the soil cover was discontinued to facilitate recovery of TRU wastes. Canyon equipment and other bulky wastes that may be contaminated with transuranic radionuclides to greater than 10 nCi/g and also intensely contaminated with gamma emitters are stored directly in SLB trenches. Transuranic waste contaminated with less than 10 nCi TRU/g is designated low-level alpha waste and is buried in the same trenches with other low-level wastes.

Waste contaminated with beta-gamma emitters is separated into two categories for burial: low-level beta-gamma and intermediate-level beta-gamma. Low-level beta-gamma waste is defined as waste radiating less than 300 mrem/hr at 7.6 cm from an unshielded container. Intermediate-level beta-gamma waste is defined as waste radiating greater than 300 mrem/hr at 7.6 cm from an unshielded package. Containerized low-level beta-gamma waste is buried in an ELLT with low-level alpha waste, and the noncontainerized fraction (soil and bulky items that do not fit in standard containers) is emplaced in a SLB trench. The intermediate-level waste is buried in segregated SLB trenches.

A method for improving the disposal method for intermediate-level waste is being developed using demonstration projects. The demonstrations, entitled Greater Confinement Disposal (GCD), provide a method for encapsulating the waste in concrete/grout and monitoring the solidified waste forms for water leaching of any radionuclides. The demonstrations provide cylindrical holes (20 have been constructed) that are 2.1 m in diameter and 9.2 m deep and a trench (currently under construction) with cells that are 15.3 m wide, 7.6 m long, and approximately 9.2 m deep. Waste packages are emplaced in the demonstrations, and concrete/grout is poured around the containers for stabilization.

Most waste forms generated offsite are buried in SLB trenches that are segregated from SRP waste. U.S. Navy submarine components are emplaced in specially designed disposal units.

Degraded solvent from the Separations Area and tritiated pump oil from reactor and tritium facilities are stored in 10 bitumastic-coated mild steel tanks, 95 m^3 capacity each, installed in 1975. Each tank is monitored weekly for leaks by measuring the tank liquid level. The yearly generation rate of solvent and oil is approximately 11.4 m^3 and 22.7 m^3, respectively. A program is currently under way to incinerate the degraded solvent; approximately 655 m^3 have been burned (through 1/87) and 100 m^3 remain in inventory. Tritiated oil incineration began in 1987; approximately 5 m^3 have been burned (through 1/87) and 67 m^3 remain in storage.

Mixed waste, non-byproduct radioactive wastes, and hazardous substance contaminated wastes have been stored within the Radioactive Waste Burial Grounds. Radioactively contaminated tritiated pump oil, retired or failed equipment containing mercury, and PCB-contaminated material characterize the mixed waste currently in storage. The waste is contained in welded stainless-steel containers or metal drums and stored within large, concrete cylinders to minimize the potential for radionuclide release. Newly generated mixed waste is stored in a building (643-29G) permitted by the South Carolina Department of Health and Environmental Control (DHEC).

Figure 2 shows zones within the Burial Grounds containing transuranic alpha waste, low-level waste, intermediate-level waste, offsite waste, solvent/oil storage, and mixed-waste storage.

Some of the wastes sent to the Burial Grounds contain materials that may be classified hazardous under the Resource Conservation and Recovery Act (RCRA). In acknowledgment of the disposal of this material, a closure plan was filed on November 23, 1985, with the South Carolina Department of Health and Environmental Control for the affected area. A closure area, the 643-28G Mixed Waste Management Facility (MWMF), was designated within the existing 643-7G Burial Ground (Figure 2). The 643-28G MWMF is an area where candidate mixed wastes were placed prior to March 1986. This area has individual trenches that have been grouped together and there are plans for its closure under a revised closure plan. Candidate mixed wastes placed in the MWMF trenches consist of scintillation fluids, waste lubricating oil held on absorbent material and sealed in 208.5-L drums, lead, cadmium, and silver. It is important to note that in the context of the closure plan, mixed wastes are defined as wastes that are hazardous (as defined by RCRA) and radioactive. These wastes are not byproduct materials as defined by the DOE proposal published in the November 1, 1985, Federal Register (Volume 50, No. 212).

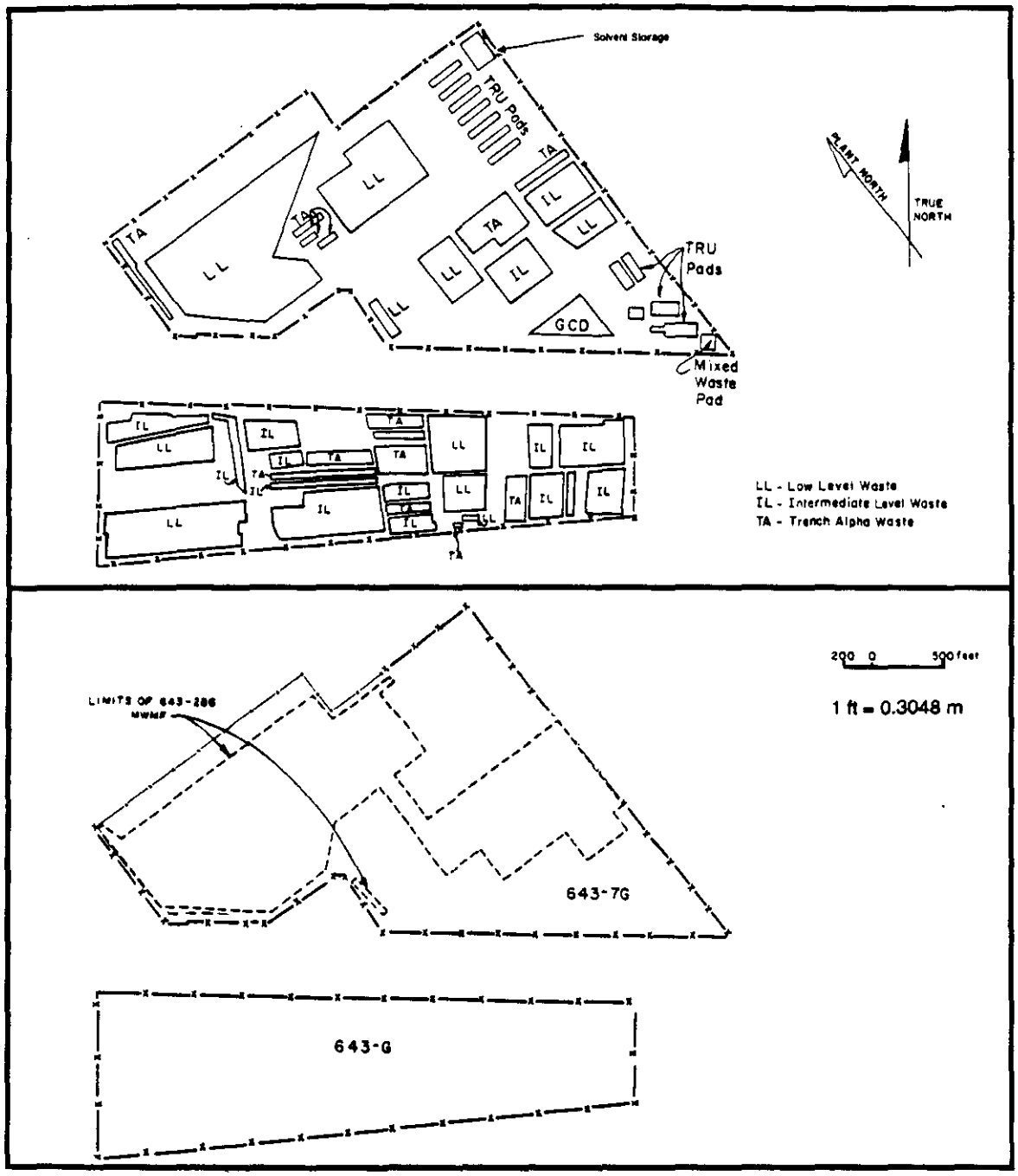


FIGURE 2. Burial Grounds Showing Zones of Filled Trench Alpha, Intermediate- and Low-Level Beta-Gamma Waste, and Solvent Storage and the Boundary of 643-28G MWMF

Routine Burial Ground operations were interrupted on March 10, 1986, when results from an independent testing laboratory showed that metallic lead was a RCRA hazardous material. Disposal operations for all radioactive waste containing lead or any other listed hazardous substance were discontinued, and a plan was implemented to ensure that all other wastes are certified free of hazardous materials. All areas of the 643-7G Burial Ground that may have received lead or any other hazardous material (643-28G MWMF, Figure 2) will be included in a revised closure plan for submittal to DHEC. Routine disposal of certified waste will continue in the nonaffected portions of the Burial Grounds.

GEOHYDROLOGIC SETTING

PHYSIOGRAPHY

The Savannah River Plant lies mostly on the Aiken Plateau as defined by Cooke (1936). The Aiken Plateau is bounded by the Savannah and Congaree rivers (Figure 3) and slopes from an elevation of 198 m at the Fall Line to an elevation of approximately 76 m (all elevations based on mean sea level). The surface of the Aiken Plateau is highly dissected and is characterized by broad, interfluvial areas with narrow, steep-sided valleys. Relief is locally as much as 91 m (Siple, 1967). The plateau is generally well drained although small, poorly drained depressions occur. The area is underlain by a wedge of seaward-dipping unconsolidated and semi-consolidated sediments.

The Burial Grounds are located in an interstream area between two tributaries of the Savannah River, Upper Three Runs Creek to the north and Four Mile Creek to the south (Figure 4). The ground surface at the Burial Grounds is relatively flat with elevations across the site ranging approximately from 85 m to 98 m. A topographic map of the Burial Grounds is shown in Figure 5. Precipitation that falls on the Burial Grounds is carried from the site in engineered drainages shown as arrows in Figure 5. These drainages vary in depth and slope.

The average slope of the ground surface from the Burial Grounds to Four Mile Creek is approximately 0.07 m/m.

HYDROSTRATIGRAPHY

A descriptive and graphic log of the subsurface geology near the central part of the SRP site, where much of the geohydrologic data have been collected in the past, along with a tentative correlation of stratigraphic terminology, is presented in Figure 6 (Christensen & Gordon, 1983). It should be noted that recent studies have found that the sediments mapped as Tuscaloosa at SRP are geologically younger than the Tuscaloosa-type section in Alabama. Therefore, from a purely stratigraphic point of view, it is improper to continue to use the term Tuscaloosa for these sediments. However, in this report the term Tuscaloosa Formation will be retained, but "Tuscaloosa" will be placed within quotation marks to indicate that it is used as a hydrostratigraphic term and not as a formal stratigraphic term. Table 2 describes the lithologic and water-bearing characteristics of the different stratigraphic units.

Of particular geohydrologic significance are three major confining beds shown in Figure 6: (from the top down) the Tan Clay, Green Clay, and Ellenton Formation. These confining beds retard the vertical movement of groundwater.

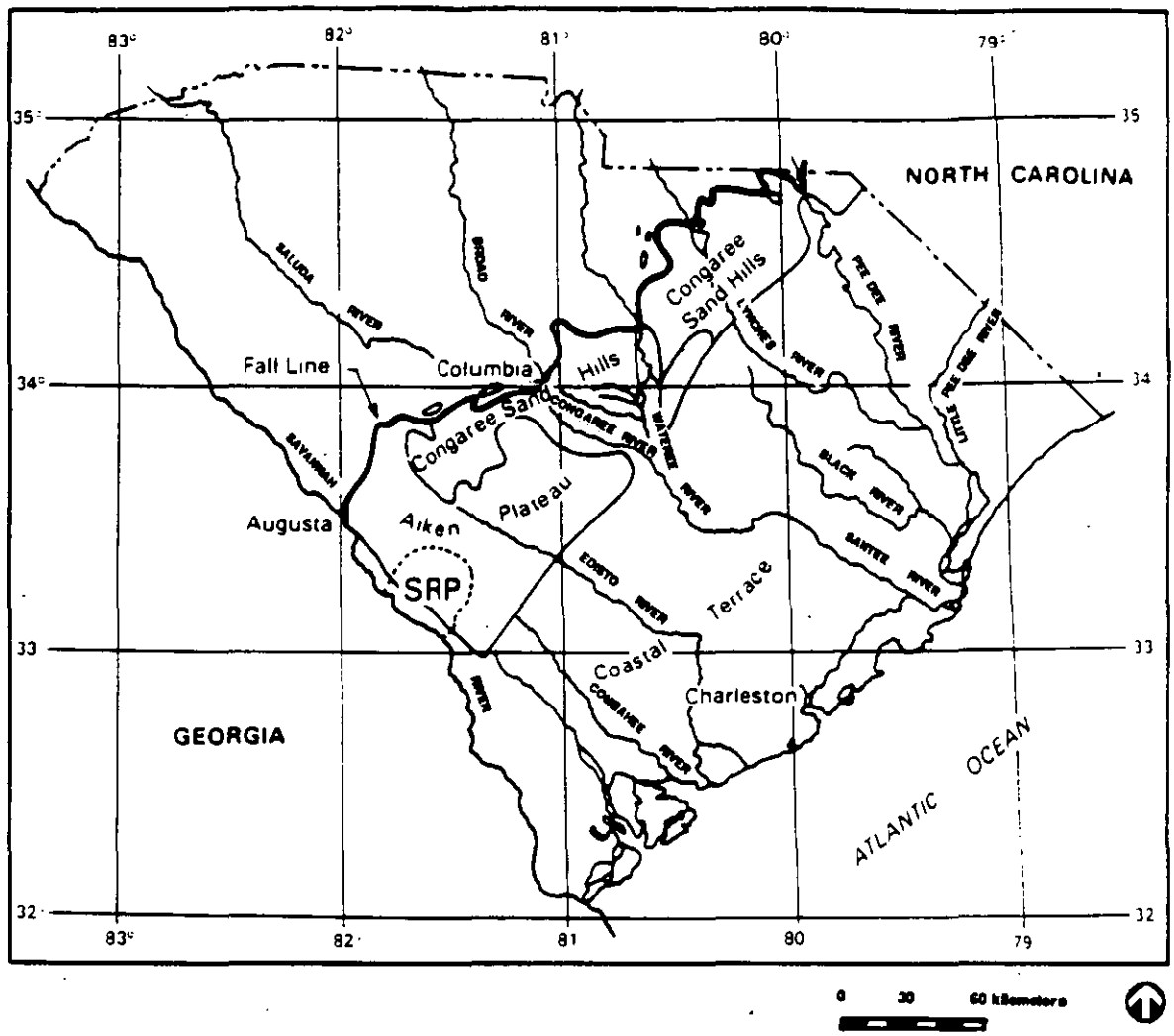


FIGURE 3. Physiography of the Savannah River Region

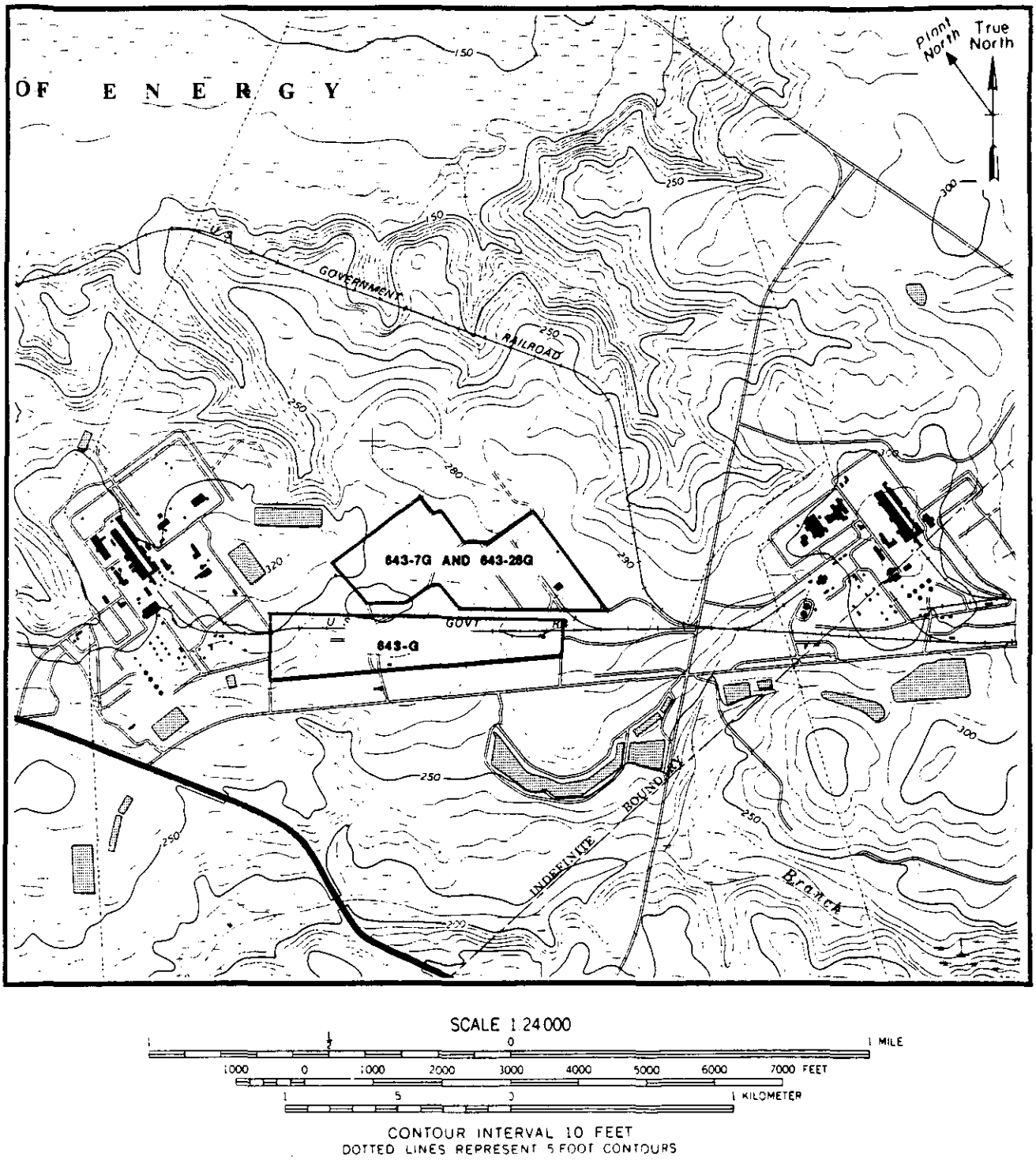


FIGURE 4. Location of the Radioactive Waste Burial Grounds on New Ellenton SW Quadrangle 7.5 Minute Series Topographic Map

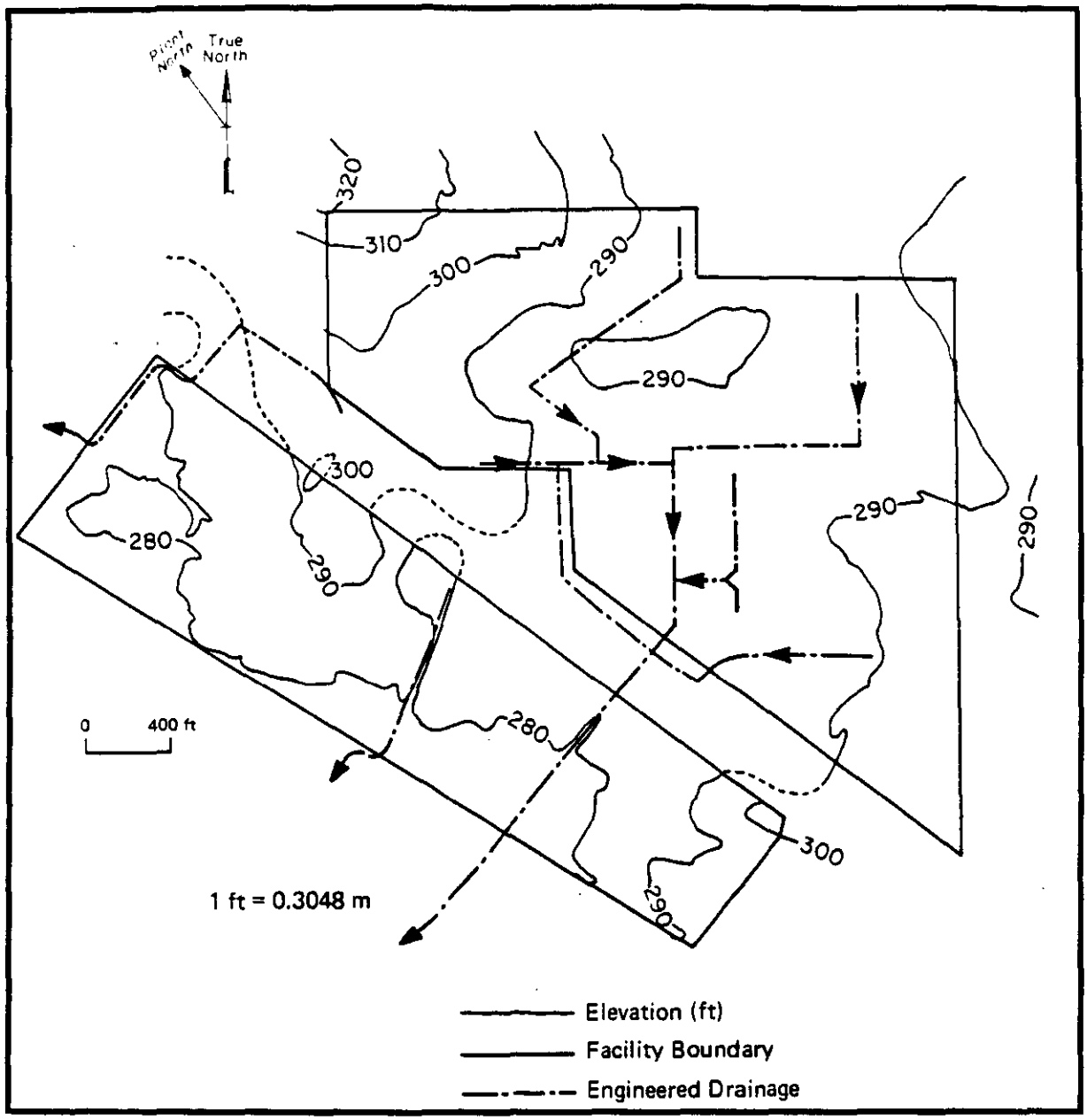


FIGURE 5. Topography and Drainage in the Radioactive Waste Burial Grounds

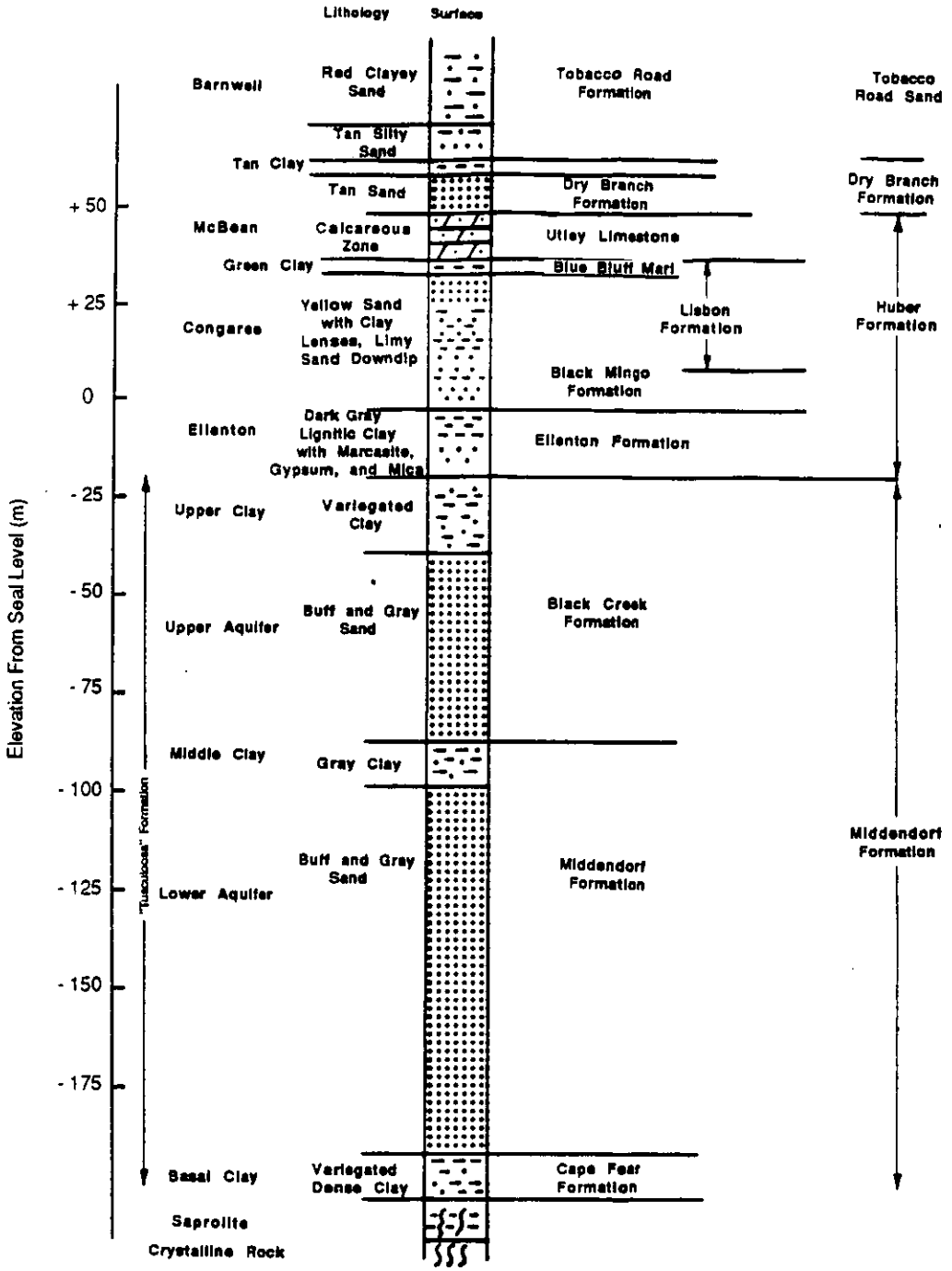


FIGURE 6. Tentative Correlation of Stratigraphic Terminology of the Southwestern South Carolina Coastal Plain

TABLE 2

Hydrostratigraphic Units Underlying the Savannah River Plant

Formation	Geologic Age	Outcrop	Description	Water Yield	Thickness (m)
Alluvium	Recent	River and creek bottoms	Fine to coarse sand, silt, and clay	Very little	0 to 9.1
Terrace Deposits	Pleistocene	In flood plains and terraces of stream valleys	Tan to gray sand, clay, silt, and gravel on higher terraces	Moderate to none	0 to 9.1
Hawthorn	Miocene	Interfluvial areas	Tan, red, and purple sandy clay with numerous clastic dikes	Little or none	0 to 24.4
Barnwell	Eocene	Large part of ground surface near streams	Red, brown, yellow, and buff, fine to coarse sand and sandy clay	Limited but sufficient for domestic use	0 to 27.4
McBean Congaree	Eocene	In banks of larger streams	Yellow-brown to green, fine to coarse, glauconite quartz sand, intercalated with green, red, yellow, and tan clay, sandy marl, and lenses of siliceous limestone	Moderate to large	30.5 to 76.2
Ellenton	Paleocene	None on plant	Dark gray to black sandy lignitic micaceous clay containing disseminate crystalline gypsum and coarse quartz sand	Moderate to large from discontinuous sand layers; higher sulfate and iron than water from other formations.	1.5 to 30.5
"Tuscaloosa"	Upper Cretaceous	None on plant	Tan, buff, red, and white; crossbedded, micaceous quartzitic and arkosic sand and gravel imbedded with red, brown, and purple clay and white kaolin	Large, up to 7.6 m^3/min soft, low in total solids	~182.9
Newark Series "Red Beds"	Triassic Period	None on plant	Dark-brown and brick-red sandstone, siltstone, and clay-stone containing gray calcareous patches; fanglomerates near border	Very little	>914.4
Basement rocks of the Slate Belt and Charlotte Group	Precambrian and Paleozoic Eras	None on plant	Hornblende gneiss, chlorite-hornblende schist, lesser amounts of quartzite; covered by saprolite layer derived from basement rock	Very little	Many thousands

Note: Modified from Siple (1967).

In the Burial Grounds the sediments are saturated with groundwater beginning at a depth of approximately 12 m. Part of this water flows to Four Mile Creek and part to Upper Three Runs Creek as shown by a water-table map of the area (Figure 7). Measurements in cluster wells show that the pressure in sediments in the Congaree Formation is lower than pressures both above and below. Thus, water flows to the Congaree Formation from both above and below, limiting the depth of circulation of water from the Burial Grounds.

A cross section extending from Four Mile Creek across the interstream area to Upper Three Runs Creek through the Burial Grounds is shown in Figure 8. The difference in elevation between the two stream beds is apparent. The bed of Upper Three Runs Creek has eroded approximately 16.8 m deeper than that of Four Mile Creek at the Burial Grounds area. This difference in bed elevation has displaced the water-table divide about 300 m toward the Four Mile Creek side. Flow paths toward Four Mile Creek are thus more shallow and shorter than flow paths toward Upper Three Runs Creek.

The gradient from the southern edge of the 643-G Burial Ground to Four Mile Creek is 0.01 m/m and that from the northern boundary of the 643-7G Burial Ground to Upper Three Runs is 0.02 m/m (Figure 8). Figure 9 shows a detailed water-table map of the Burial Grounds.

Figure 10 shows a piezometric map of the McBean Formation, and Figure 11 shows a piezometric map of the Congaree Formation. The gradient in the McBean Formation from the southern edge of the 643-G Burial Ground to Four Mile Creek is 0.009 m/m in a southwesterly direction and that from the 643-7G Burial Ground to Upper Three Runs Creek is 0.017 m/m. In the valley adjacent to Upper Three Runs Creek, the water table is in the McBean Formation. The gradient in the Congaree Formation from either burial ground to Upper Three Runs Creek is approximately 0.003 m/m.

Figure 12 presents a regional piezometric map of the "Tuscaloosa" Formation. Horizontal gradients in this formation are toward the Savannah River. The vertical head relationship near the 643-G Burial Ground is presented in Figure 13.

HYDROLOGIC CHARACTERISTICS

The hydraulic properties of the geologic framework determine the ease and the rate at which the groundwater moves through the various formations. The properties of most importance are transmissivity/permeability, porosity, storativity, and leakance. Effective porosity and permeability (hydraulic conductivity) are

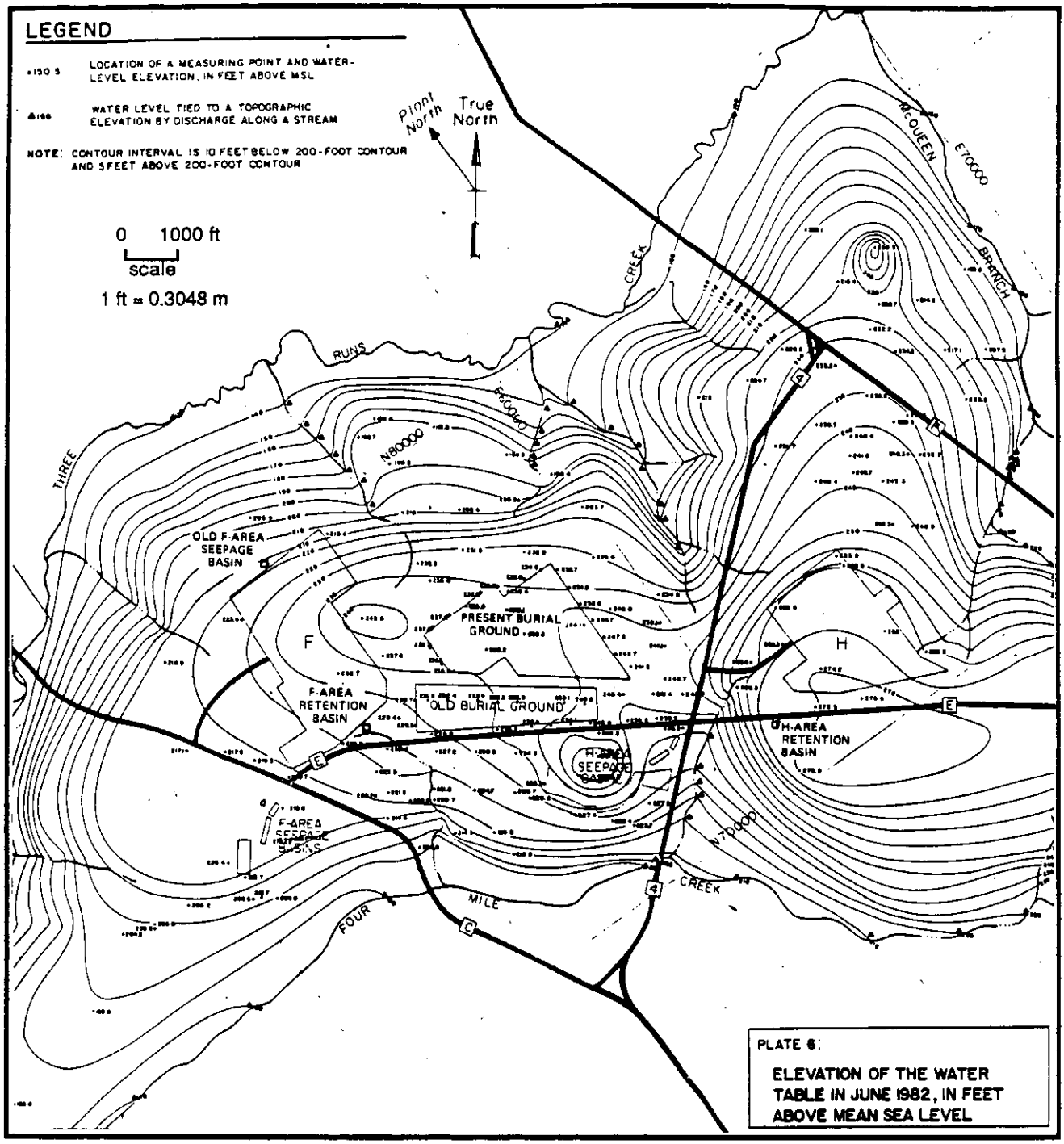


FIGURE 7. Water-Table Map in the Vicinity of the Burial Grounds

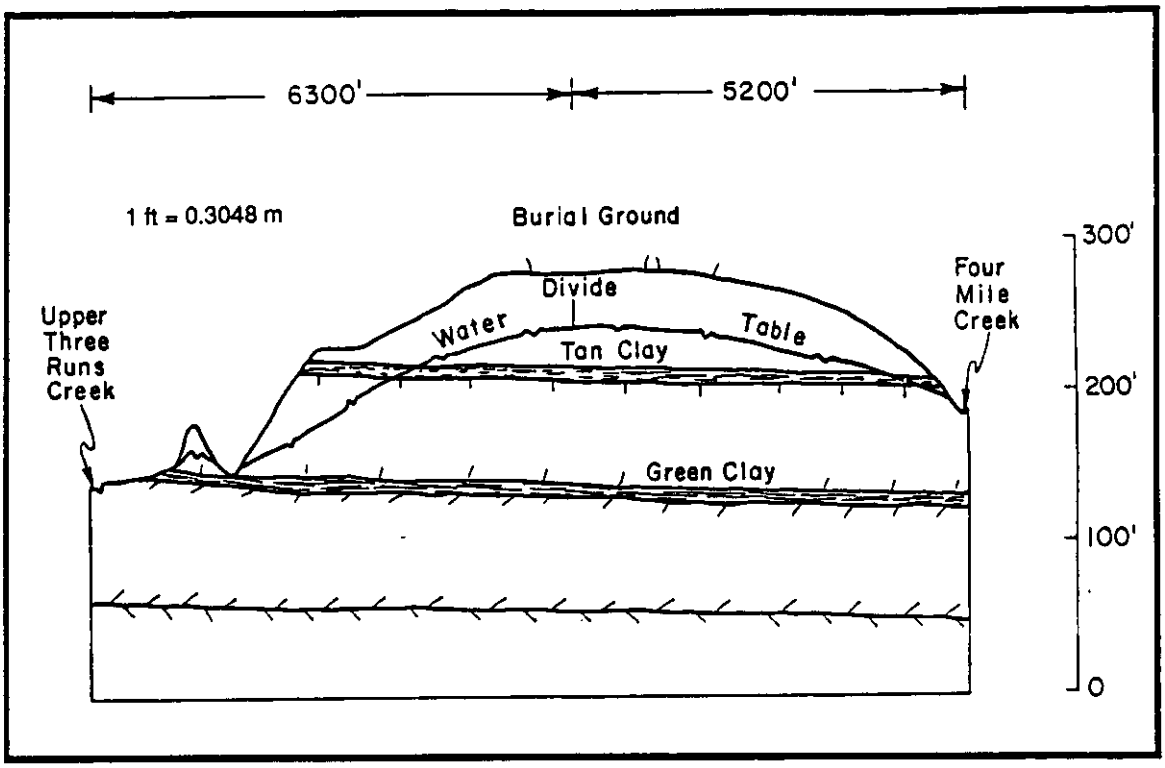


FIGURE 8. Cross Section Through the Burial Grounds Showing Displacement of Water-Table Divide Toward Four Mile Creek

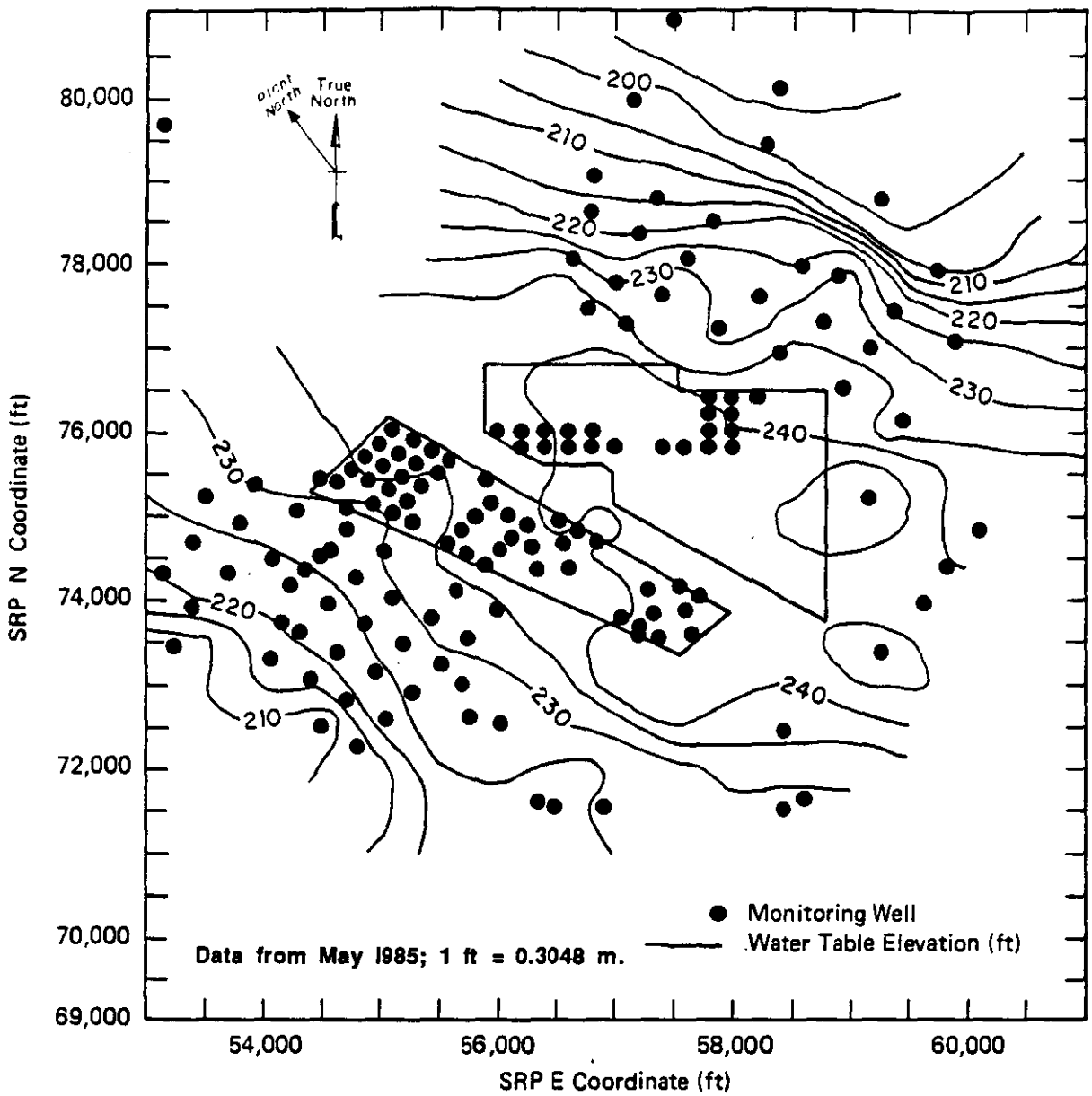


FIGURE 9. Water-Table Map in the Immediate Vicinity of the Burial Grounds

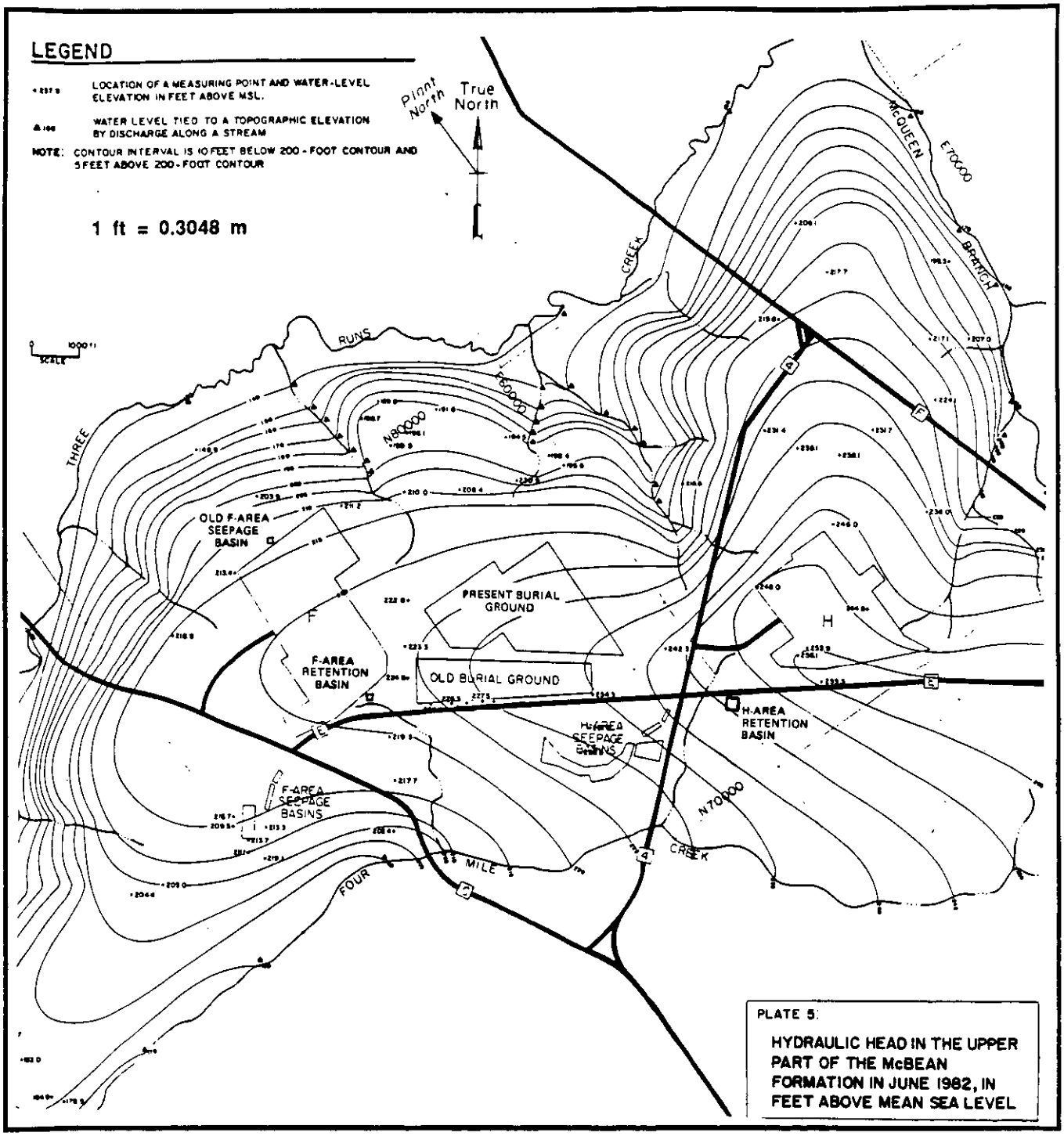


FIGURE 10. Piezometric Map of the McBean Formation

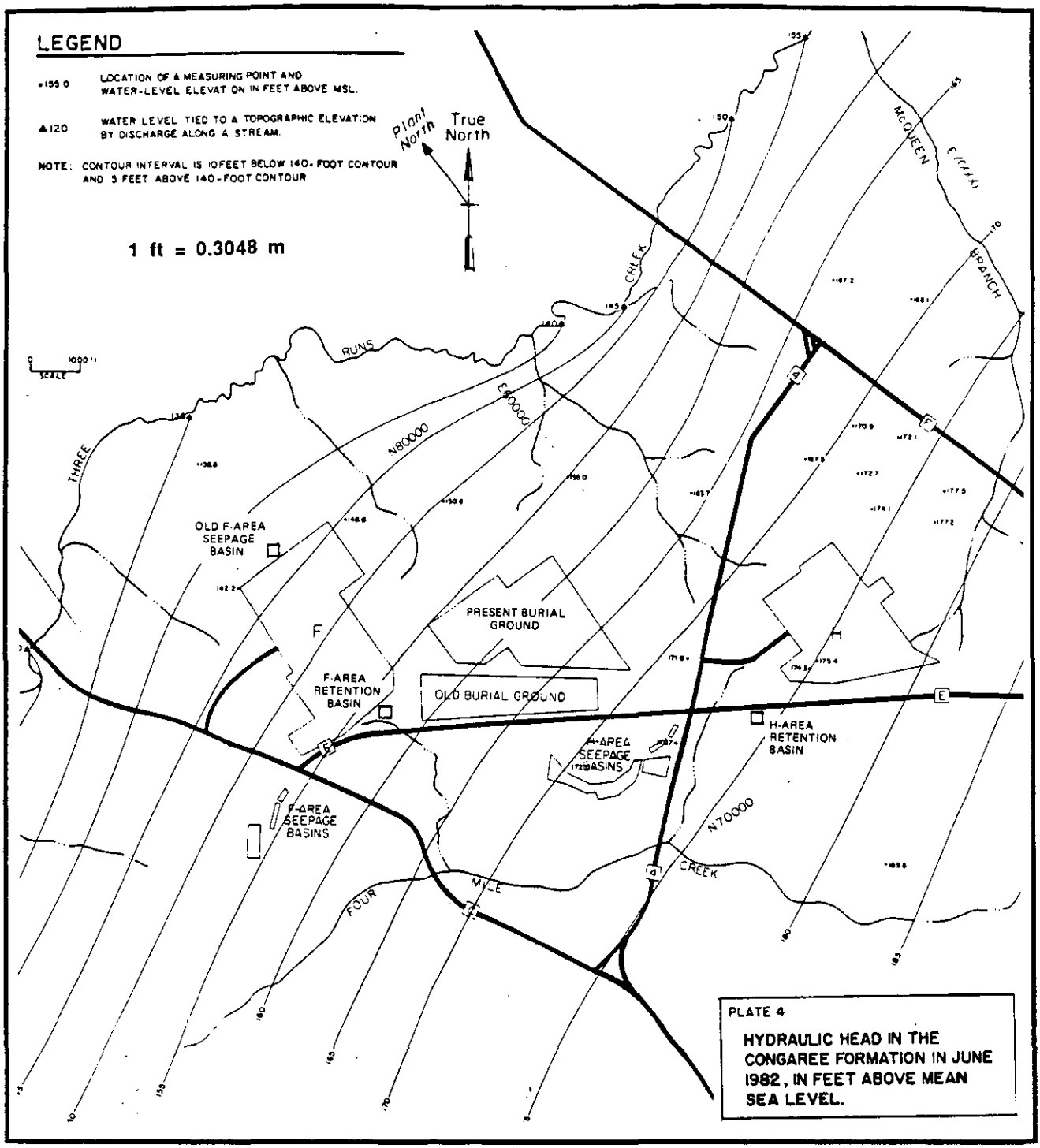


FIGURE 11. Piezometric Map of the Congaree Formation

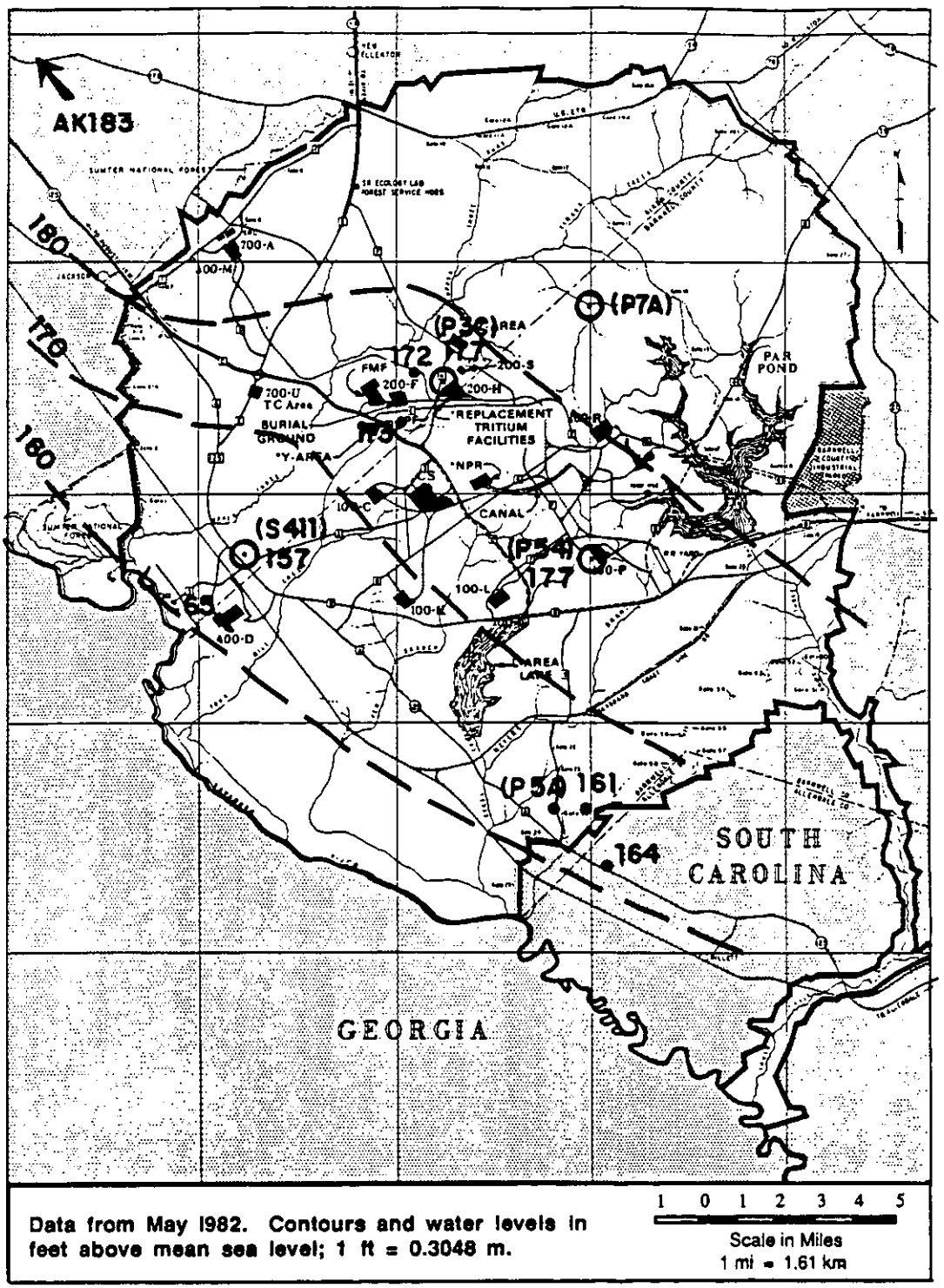
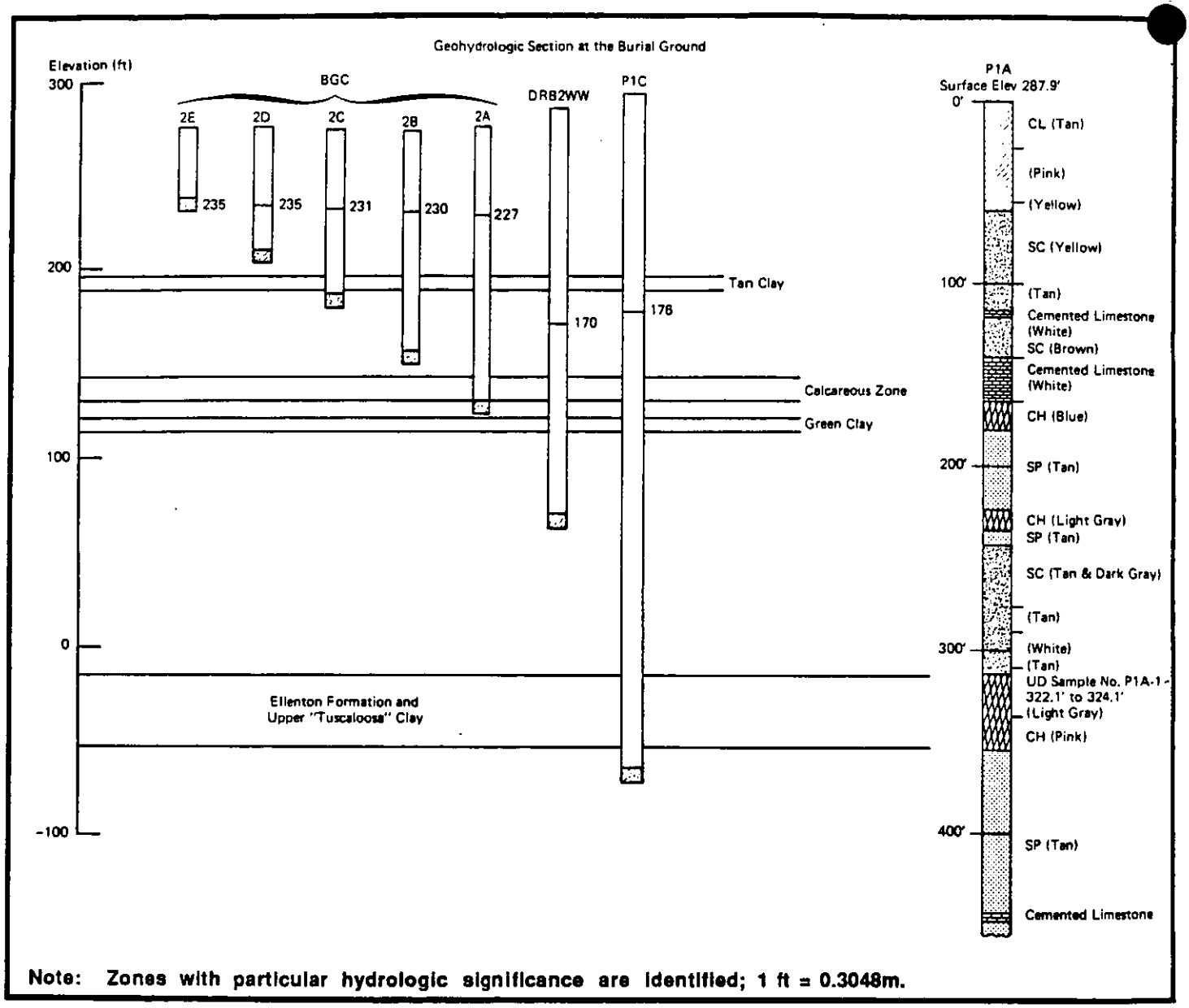


FIGURE 12. Piezometric Map of the "Tuscaloosa" Formation



Note: Zones with particular hydrologic significance are identified; 1 ft = 0.3048m.

FIGURE 13. Vertical Head Relationships in Well Log from Burial Ground Wells

the most important properties affecting the ability of geologic materials to transmit water. Effective porosity is a measure of the amount of interconnected pore space available for fluid transmission, while hydraulic conductivity is a measure of the ease with which water can be transmitted through a porous material. These hydrologic characteristics are discussed in the paragraphs below for the Burial Grounds.

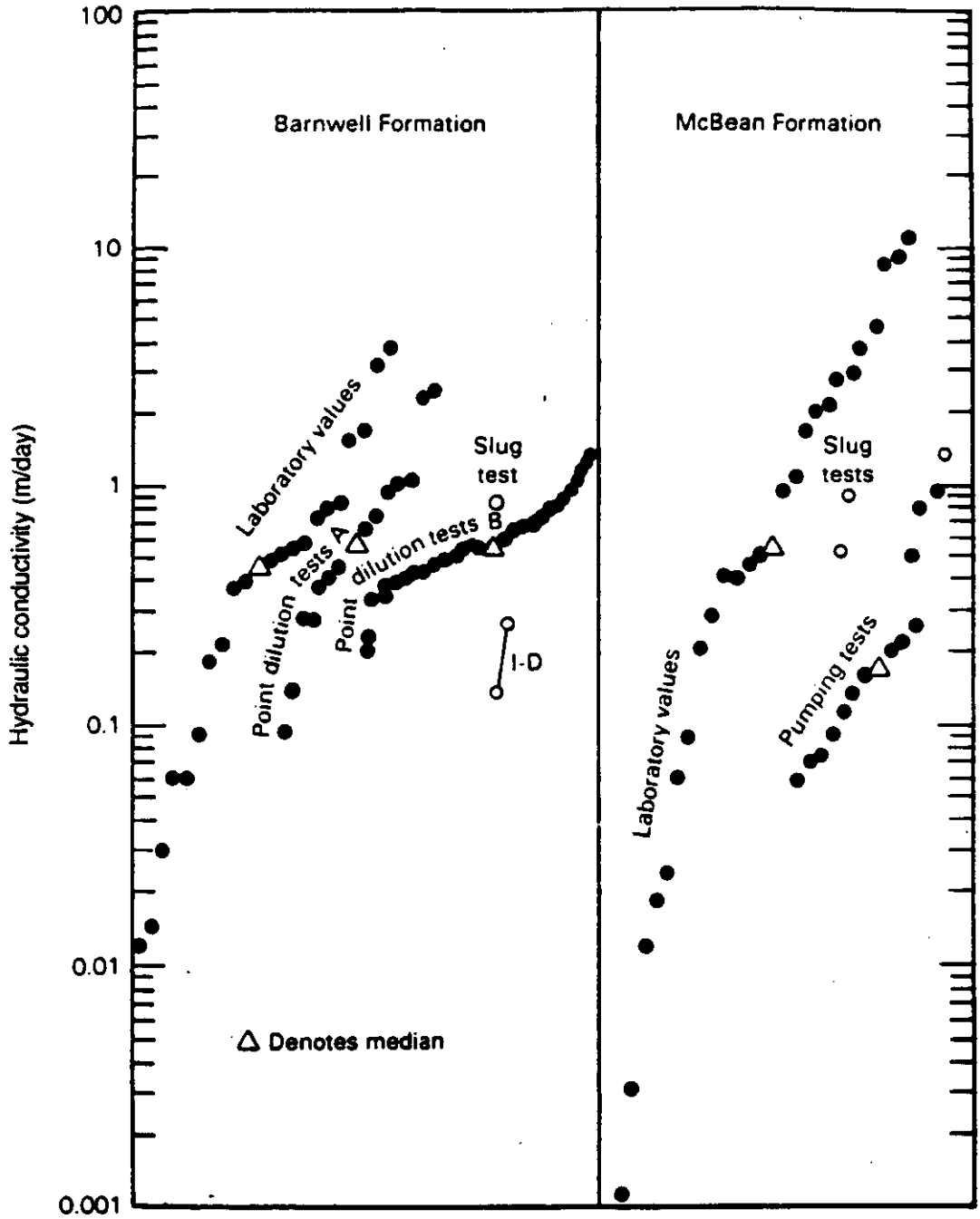
Total porosity of the clayey sands that make up the Barnwell, McBean, and Congaree formations ranges approximately from 35% to 60% (Root, 1980). Effective porosity is lower, and values of 20% have been assumed.

Field and Laboratory Measurements

Hydraulic conductivity values in the Burial Grounds area have been determined by laboratory tests, slug tests, tracer tests, small-scale single well pumping and recovery tests, large-scale pumping tests with observation wells, and numerical simulation. Figure 14 shows the results of laboratory tests, slug tests, point dilution tracer tests, and pumping tests in the Barnwell and McBean formations (Marine & Root, 1976). Figure 15 gives the results of slug tests, drawdown tests, and recovery tests in the same region, including some values for the Congaree Formation. Table 3 gives hydraulic conductivities for the three Tertiary formations as determined by small-scale pumping tests (Parizek & Root, 1986). Tables 4, 5, and 6 give hydraulic conductivities for the Barnwell, McBean, and Congaree formations, respectively, as determined by slug tests (Parizek & Root, 1986). Table 7 gives the results of small-scale pumping tests for the three Tertiary formations in the immediate vicinity of the F-Area Seepage Basins. Table 8 gives results of large-scale pumping tests on the McBean and Congaree formations at SRP, but not in the area of the Burial Grounds.

Using only pumping test values, it appears that the hydraulic conductivity of the Barnwell Formation ranges from 0.07 m/day by a small-scale recovery test to 4.0 m/day as determined by a large-scale pumping test (D'Appolonia, 1981). The hydraulic conductivity of the McBean Formation ranges from 0.014 m/day to 5.8 m/day and that of the Congaree from 0.36 m/day to 40 m/day. If slug tests are used, the range is even greater. A hydraulic conductivity range of at least 2 orders of magnitude has been observed for all three of these formations.

Rain falling on the Burial Grounds seeps down through an unsaturated zone to enter the saturated zone at the water table and then moves horizontally and vertically to outcrop in surface streams. Tracer tests have shown that the flow rate in the unsaturated zone immediately beneath the Burial Grounds is approximately 2 m/yr.



Note: Ordered in ascending value for each set of field or laboratory tests (Marine & Root, 1976).

FIGURE 14. Horizontal Conductivities of the Barnwell and McBean Formations in the Separations Area at SRP

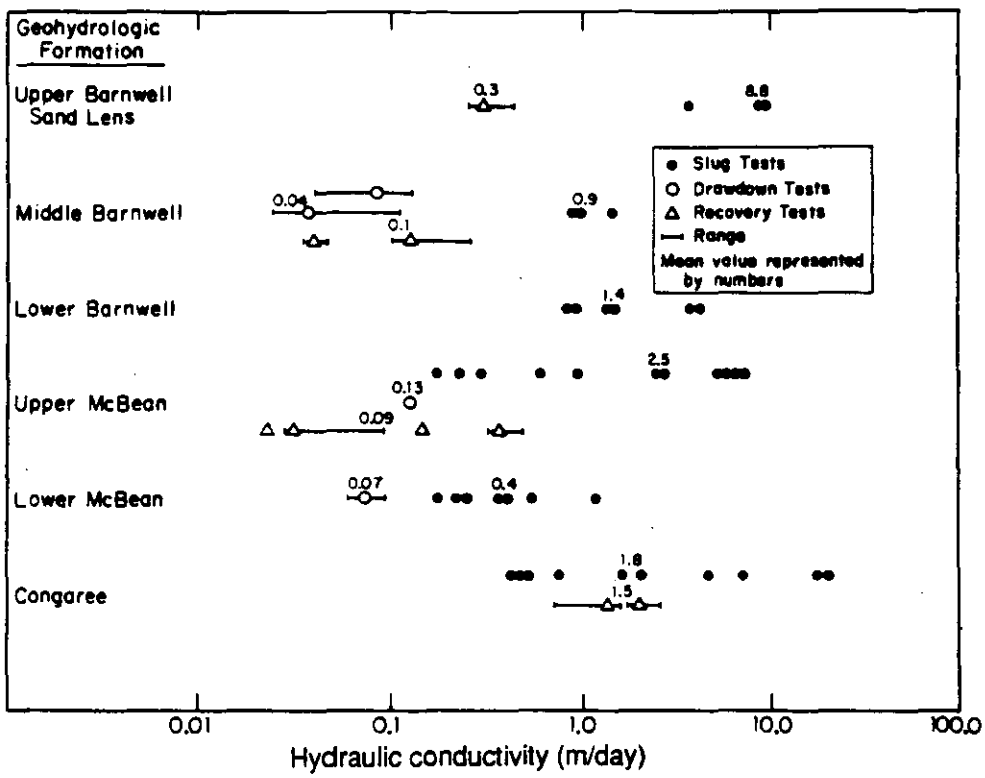


FIGURE 15. Hydraulic Conductivity Values From Selected Hydrostratigraphic Units Near the Center of SRP

TABLE 3

Small-Scale Pumping Test Results

Well	Transmissivity (m^2/day)	Thickness (m)	Hydraulic Conductivity (m/day)	Screened Zone	Location
HC 2F			0.55	UB	H Area
H 54	2.3	13	0.18	LB	H Area and Road E
ZW 4	3.6	4.9	0.73	LB	North of Burial Ground
HC 2E			0.19	LB	H Area
HC 6B			0.13	LB	H Area
HC 4B			0.070	LB	H Area
BGC 1D			0.11	LB	Burial Ground
G 28			0.16	LB	Burial Ground
F 73	6.7	14	0.49	UM	Road F at Road 4
H 64	9.3	12	0.76	UM	H Area along Road E
F 55	4.9	14	0.37	UM	North of Burial Ground
HC 1C			0.29	UM	H Area
HC 3D			1.7	UM	H Area
HC 9B			0.46	UM	Northeast of H Area
HC 13B			0.027	UM	H Area
HC 8C			0.15	UM	North of Burial Ground
HC 7B			0.040	UM	East of Road F
HC 4A			0.11	UM	H Area
BGC 1C			0.030	UM	Burial Ground
F 66	0.89	7.0	0.13	LM	Road F at Road 4
H 53	6.5	13	0.49	LM	H-Area Seepage Basin
F 60	2.6	12	0.21	LM	F-Area Seepage Basin
F 65	6.1	10	0.61	LM	West of F Area
HC 6A			0.073	LM	H Area
FC 1B			0.014	LM	F Area
HC 3A			0.79	C	H Area
FC 2A			0.37	C	F Area
HC 8B			0.37	C	North of Burial Ground

Note: Stratigraphic units are designated as UB = Upper Barnwell Formation; LB = Lower Barnwell Formation; UM = Upper McBean Formation; LM = Lower McBean Formation; and C = Congaree Formation.

TABLE 4

Slug Test Conductivities, Barnwell Formation

Well	Conductivity (m/day)
M 37B	0.0276
M 37C	0.1144
HC 4B	0.3044
HC 11C	0.3078
HC 1D	0.3573
FC 2F	0.5779
BGC 2D	0.6075
HC 2E	0.6574
HC 6B	0.6627
BGC 3D	0.6845
HC 3E	0.7471
BGC 1D	0.7476
SDS 3A	0.8368
HC 5B	1.442
HC 1E	3.735
HC 2F	3.735
HC 3F	4.441

Median = 0.66 m/day

TABLE 5

Slug Test Conductivities, McBean Formation

Well	Conductivity (m/day)	Well	Conductivity (m/day)
FC 1C	0.0013	BGC 3F	0.2879
BGC 3H	0.0040	BGC 1C	0.3037
BGC 2A	0.0046	HC 1B	0.3913
BGC 3C	0.0080	BGC 2C	0.3983
SDS 7C	0.0085	BGC 3L	0.4016
BGC 3B	0.0108	FC 3E	0.4246
FC 1B	0.0219	HC 4A	0.4696
SDS 12B	0.0251	BGC 3K	0.4383
FC 3D	0.0468	HC 6A	0.4723
BGC 3I	0.0607	BGC 3G	0.8167
M 37A	0.0730	FC 2D	0.8322
BGG 3J	0.0935	SDS 7B	0.9699
BGC 1B	0.0962	SDS 17	1.010
HC 2C	0.1027	HC 2D	1.096
HC 16B	0.1047	SDS 4	1.181
HC 14B	0.1162	HC 15B	1.245
HC 5A	0.1294	HC 1C	1.304
HC 13B	0.1358	HC 8C	1.442
BGC 1A	0.1388	FC 4E	1.460
HC 7B	0.1618	HC 12B	1.551
BGC 2B	0.1800	HC 9B	1.748
HC 2H	0.2595	FC 5D	3.963
HC 10B	0.2786	BGC 3D	4.846

Median = 0.29 m/day

TABLE 6

Slug Test Conductivities, Congaree Formation

Well	Conductivity (m/day)
FC 5C	0.0003
FC 5B	0.0106
SDS 7A	0.0114
H 35D	0.0567
HC 1A	0.1694
FC 2B	0.1793
HC 2B	0.3573
SDS 12A	0.3682
FC 1A	0.4474
FC 3C	0.5074
HC 2A	0.8620
HC 8B	1.826
FC 4B	2.448
FC 2A	2.558
FC 3B	3.618
HC 3B	3.652
HC 3A	3.822

Median = 0.448 m/day

TABLE 7

Summary of Pumping Test Results Near the Burial Grounds

Well	Aquifer	Pump Rate (L/min)	Hydraulic Conductivity (m/day)
FSB 87D	Water table	9.5	0.13
FSB 76C	McBean	23.9	5.24
FSB 78C	McBean	16.7	0.17
FSB 87C	McBean	9.5	0.29
			Avg = 1.9
FSB 76A	Congaree	13.3	0.93
FSB 78A	Congaree	16.7	0.25
FSB 78B	Congaree	22.0	1.48
FSB 79A	Congaree	28.9	43.6
FSB 87A	Congaree	21.3	15.6
FSB 87B	Congaree	20.1	0.12
			Avg = 10.3

TABLE 8

Pumping Test Results from the McBean and Congaree Formations

SRP Area Location	Aquifer Thickness (m)	Transmissivity (m^2/day)	Hydraulic Conductivity (m/day)
C	18	730	40
CS	15	89	5.8
P	32	1,200	39
M	18	14	0.73

Note: Data are from Christensen and Gordon (1983). Area designations are C = C Area (McBean), CS = Central Shops (McBean), P = P Area (Congaree), and M = M Area (McBean and Congaree) with formations given here in parentheses.

Though sediments in the Burial Grounds area and vicinity are highly heterogeneous, flow over a distance apparently tends to reduce the effects of this variability. Sixteen groundwater velocity tritium tracer tests were made throughout the area over the years. Simultaneously, water-table gradients were observed. A least square linear regression analysis of the data shows a strong correlation between water-table gradient and groundwater velocity. The average velocity varies at the rate of 14.5 m/yr/1% gradient, with a correlation coefficient of 0.988.

Water flowing through porous media such as the Burial Grounds sediments exhibits a distribution of velocities in the small flow channels due to heterogeneity of the media and to a friction gradient extending from the channel walls out to the center where friction is least. As a result, a tracer released into the system will assume a normal distribution in the longitudinal direction as flow proceeds. The leading edge of the distribution will precede the centroid by some multiple of the centroid depending on pore and grain characteristics.

Results of a flow experiment in the southwest corner of the Burial Grounds are shown in Figure 16. Three tritium sources (residues of irradiated lithium-aluminum after the thermal extraction of the tritium) were buried in 1957 and observed at intervals until 1970. The figure shows tritium location in groundwater at the time of the test in October 1970. The centroid was 76 m downgradient, but the leading edge had not arrived at detection wells 80 m beyond the centroid. The leading edge was moving no more than twice the average rate. The conservative estimate to apply to the leading edge is, therefore, twice the average rate.

Applying these rates to observed water-table gradients on flow paths originating in the east, middle, and southwest parts of the 643-G Burial Ground produces results shown in Figure 17. The figure shows the estimated time required for tritium released at the head of the flow path to move to the outcrop. The average velocities for these three flow paths are 12 m/yr, 18 m/yr, and 24 m/yr. These velocities are consistent with the detailed horizontal (and vertical) velocities that resulted from calibrated groundwater models. The modeling data are summarized in the next section; the calibrated model coefficients and data represent the best current understanding of the hydrology of the central area of SRP.

Groundwater Modeling

Groundwater flow at the central part of SRP (F and H areas and the Radioactive Waste Burial Grounds) has been simulated by several modelers. Siple (1967) was the first to summarize the regional

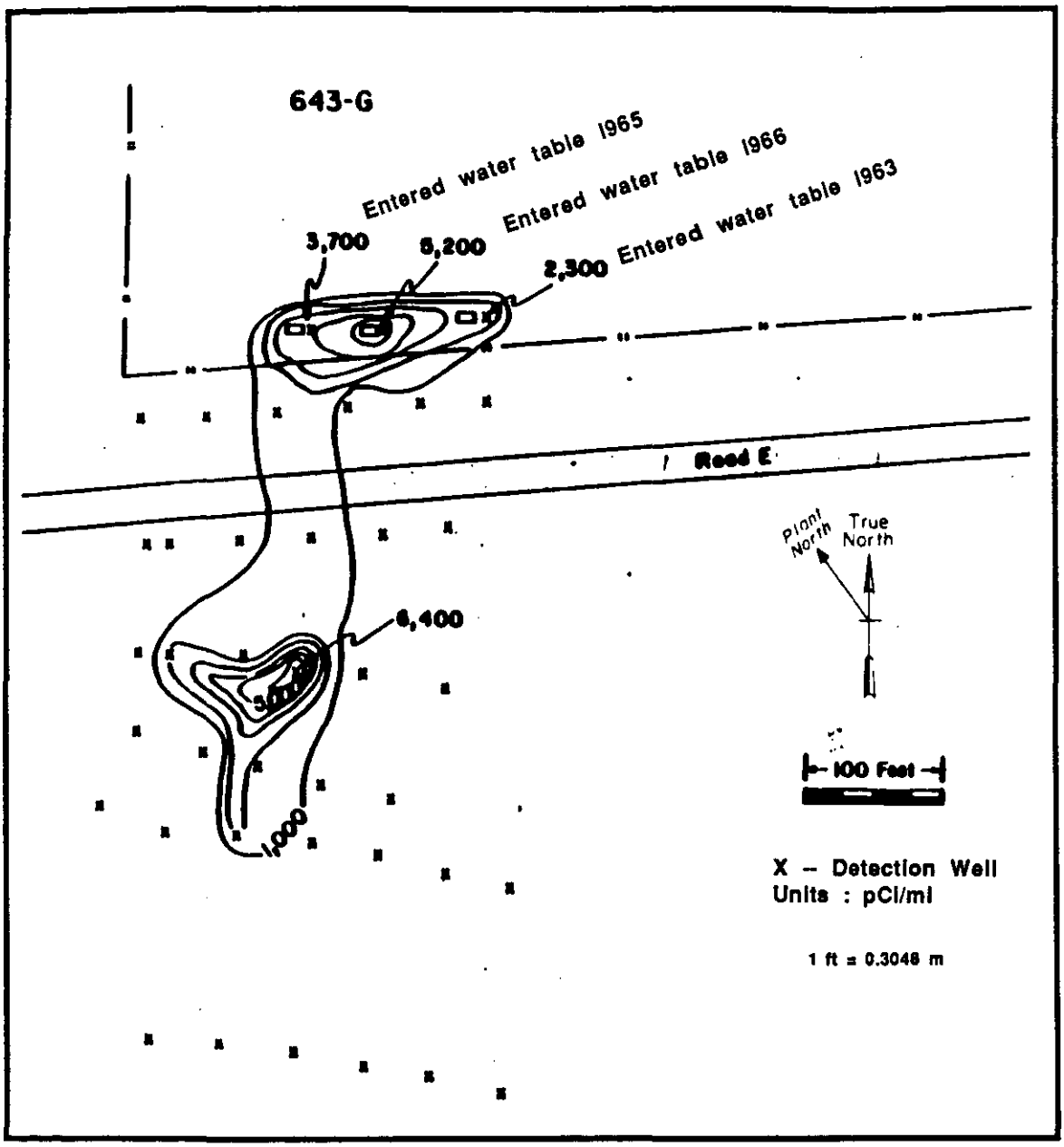


FIGURE 16. Tritium from Spent Melt Test in Groundwater in October 1970

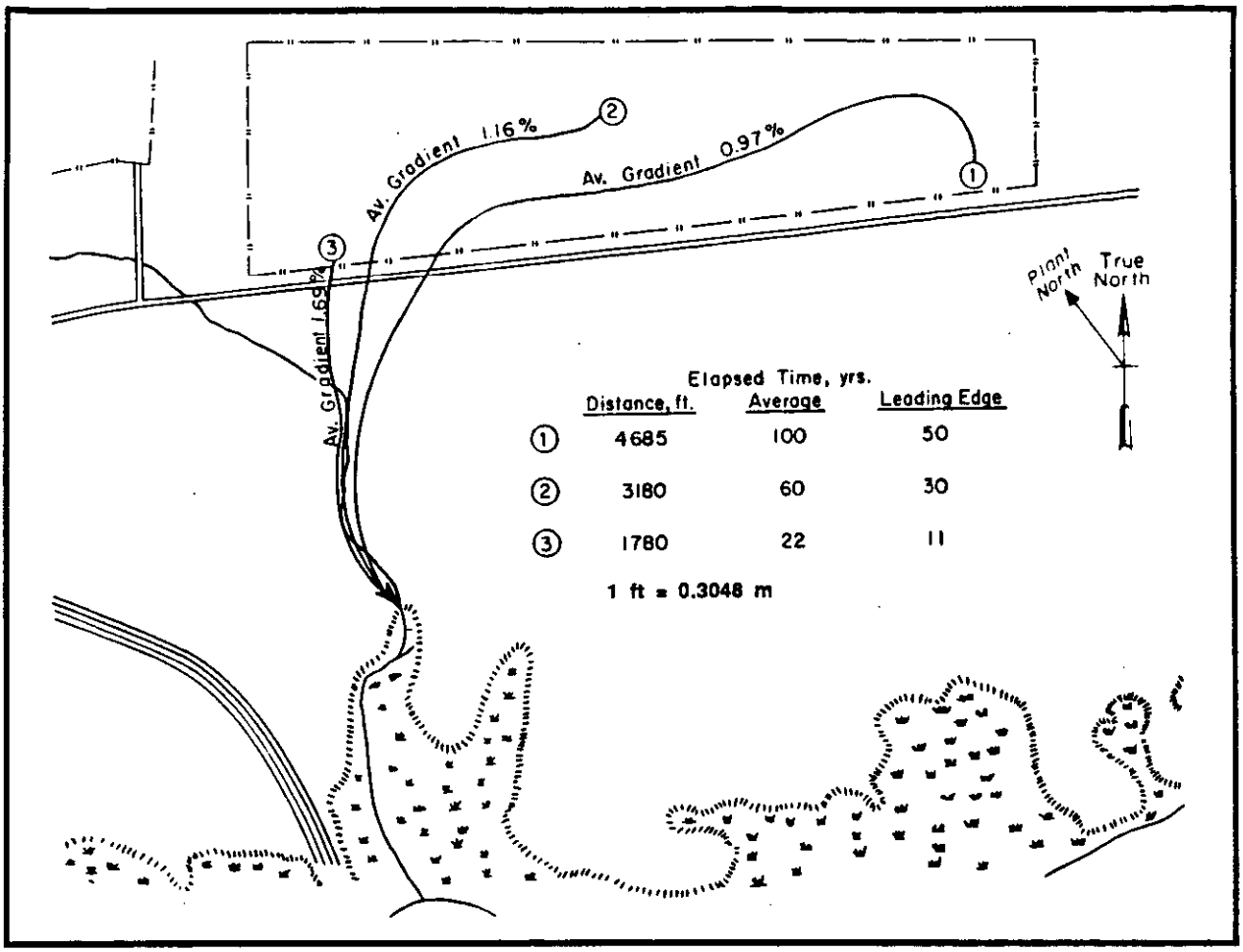


FIGURE 17. Time for Water and Tritium to Travel 643-G Burial Ground Flow Paths

groundwater hydrology. Marine and Root (1976) developed a conceptual model of the groundwater flow system for the area. Root (1983) developed a three-dimensional, six-layer finite difference flow model of a 6 km^2 area near the Radioactive Waste Burial Grounds. Root (1983) considered the Barnwell and McBean formations near the Burial Grounds. Parizek and Root (1986) expanded this model to consider a 27.7 km^2 area bounded by Upper Three Runs Creek, Four Mile Creek, and McQueen Branch. They considered a three-formation system: Barnwell, McBean, and Congaree.

None of the previous modeling efforts comprehensively addressed contaminant transport and risk. A three-dimensional flow and transport model was developed by GeoTrans (Duffield et al., 1986a, 1986b) for the F and H areas and the Radioactive Waste Burial Grounds to aid in assessment of these sites (Figure 18). This model is more comprehensive than the previous models in that contaminant transport calculations are coupled with water level/flow calculations and the "Tuscaloosa" Formation is considered.

Groundwater at this site was modeled with the United States Geological Survey (USGS) three-dimensional code (McDonald & Harbaugh, 1984). The three-dimensional capabilities of this code are appropriate for the proper treatment of the vertically variable hydrostratigraphy and boundary conditions at the central part of SRP. Transport calculations were made using the Sandia Waste Isolation Flow and Transport (SWIFT) code. These codes are well documented and publically available.

Prior to the simulation of groundwater flow at the site with the McDonald and Harbaugh code, the estimation of hydraulic parameters in the model, such as horizontal and vertical conductivities, was performed with an automatic parameter estimation code developed by GeoTrans. The automatic hydraulic parameter estimation algorithm incorporated in the Trescott (1975) USGS three-dimensional flow code systematically selects a set of hydraulic parameter values that provides a least-squares match between observed and calculated water levels. The process of automatically determining the values of hydraulic parameters generates quantitative estimates of the sensitivity of hydraulic heads to hydraulic parameter changes. The hydraulic parameter values estimated by this code were used in the final simulations performed with the McDonald and Harbaugh code.

The modeled domain, covering an area of 6,645 m by 6,675 m, is discretized into a finite difference grid consisting of 39 rows and 39 columns (Figure 19). The grid spacing along the columns and rows varies between 122 m and 457 m. Grid spacing was varied over the area to provide the greatest detail in the vicinity of the F- and H-Area seepage basins and the Radioactive Waste Burial Grounds.

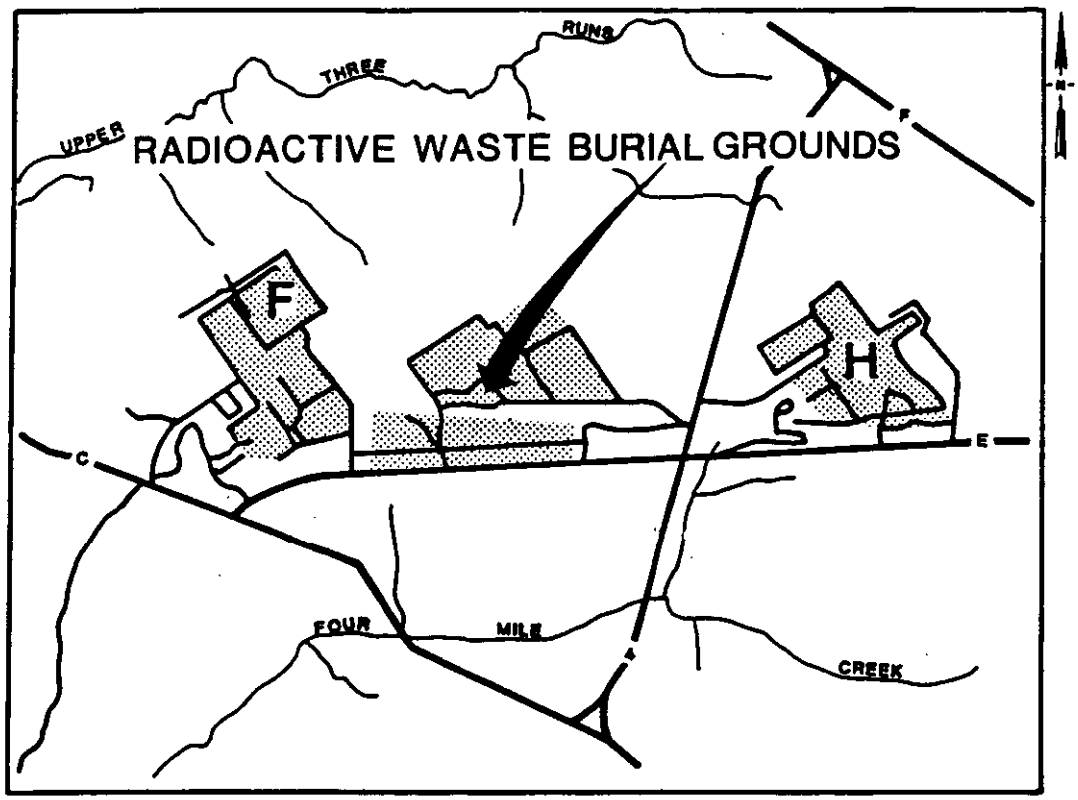


FIGURE 18. Groundwater Flow Model Study Area

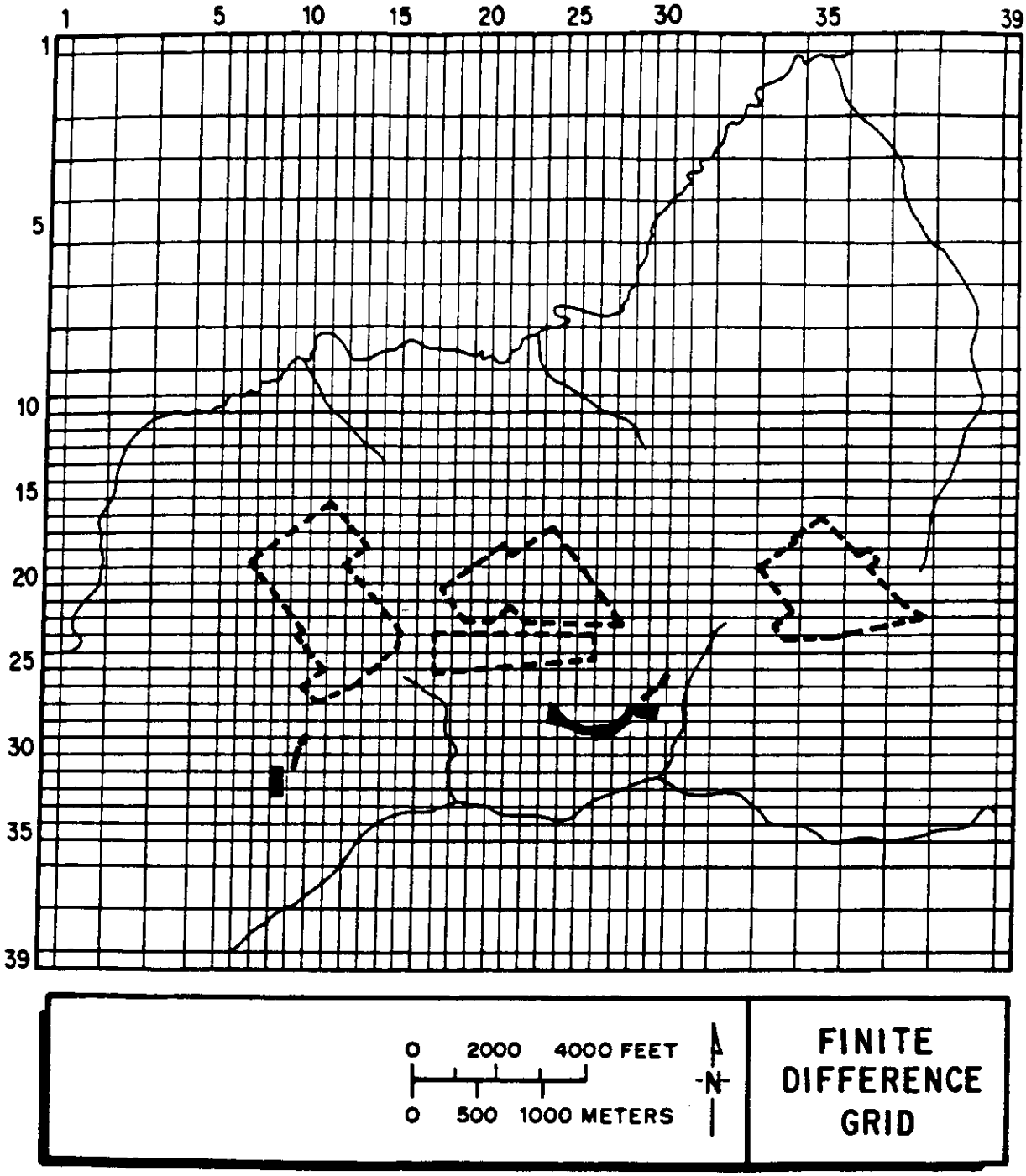


FIGURE 19. Finite Difference Grid Used For Groundwater Flow and Transport Model

Vertical discretization is used to represent the interstratified aquifers and the aquitards in the modeled area. Each aquifer unit is represented as a single layer. The aquitards are not discretized, but instead are represented by leakance coefficients. The leakance coefficient is used to calculate the flux of water passing vertically through the aquitard. A schematic of the vertical discretization is given in Figure 20. The automatic parameter estimation procedure was also used to estimate transmissive properties and leakance coefficients of the aquifers and aquitards.

Historical water level data from 1977 to 1979 were used for parameter estimation and model calibration. The parameters (Table 9) were calculated for different horizontal zones in order to represent the variable nature of the Tan and Green Clay aquitards (Figure 21). The Barnwell aquifer was broken into zones similarly to represent varying transmissive properties (Figure 22).

The calculated hydraulic conductivity range of 0.2 to 1.1 m/day for the Barnwell aquifer encompasses the average values for the small-scale pumping tests (0.27 m/day) and slug tests (0.66 m/day). The calculated hydraulic conductivity for the McBean Formation (1.2 m/day) is within the range of the small-scale pumping tests (0.027 to 1.7 m/day), the slug tests (0.0013 to 4.8 m/day), and the FSB well series pump tests (0.17 to 5.24 m/day).

Computer-generated water-table contours (combined Barnwell and McBean formations) and piezometric surfaces (Congaree and "Tuscaloosa" formations) are shown in Figures 23, 24, and 25. The residual head differences between the calculated heads and the measured heads are presented on the maps. The residuals range from less than 0.4 m to about 1.5 m.

The calculated water-table contours (Figure 23) are similar in shape to the measured contours for the water table (Figure 8). The calculated contours in the Congaree Formation (Figure 25) are also similar to the measured contours (Figure 11) in shape.

The direction and velocity of groundwater flow computed by the model for the Barnwell, McBean, Congaree, and "Tuscaloosa" formations are presented in Figures 26 through 33. For each formation, the first figure indicates the direction of flow at each node, and the second figure indicates the approximate horizontal and vertical velocity in several zones within the modeling area.

The flow directions and velocities are consistent with hydrologic controls (outcrop streams and elevations) described earlier. In general, flow in the water table (Barnwell/McBean) is toward Upper Three Runs Creek and tributaries in the northern part of the model area and toward Four Mile Creek in the southern part of the model area. Flow in the Congaree Formation is toward Upper

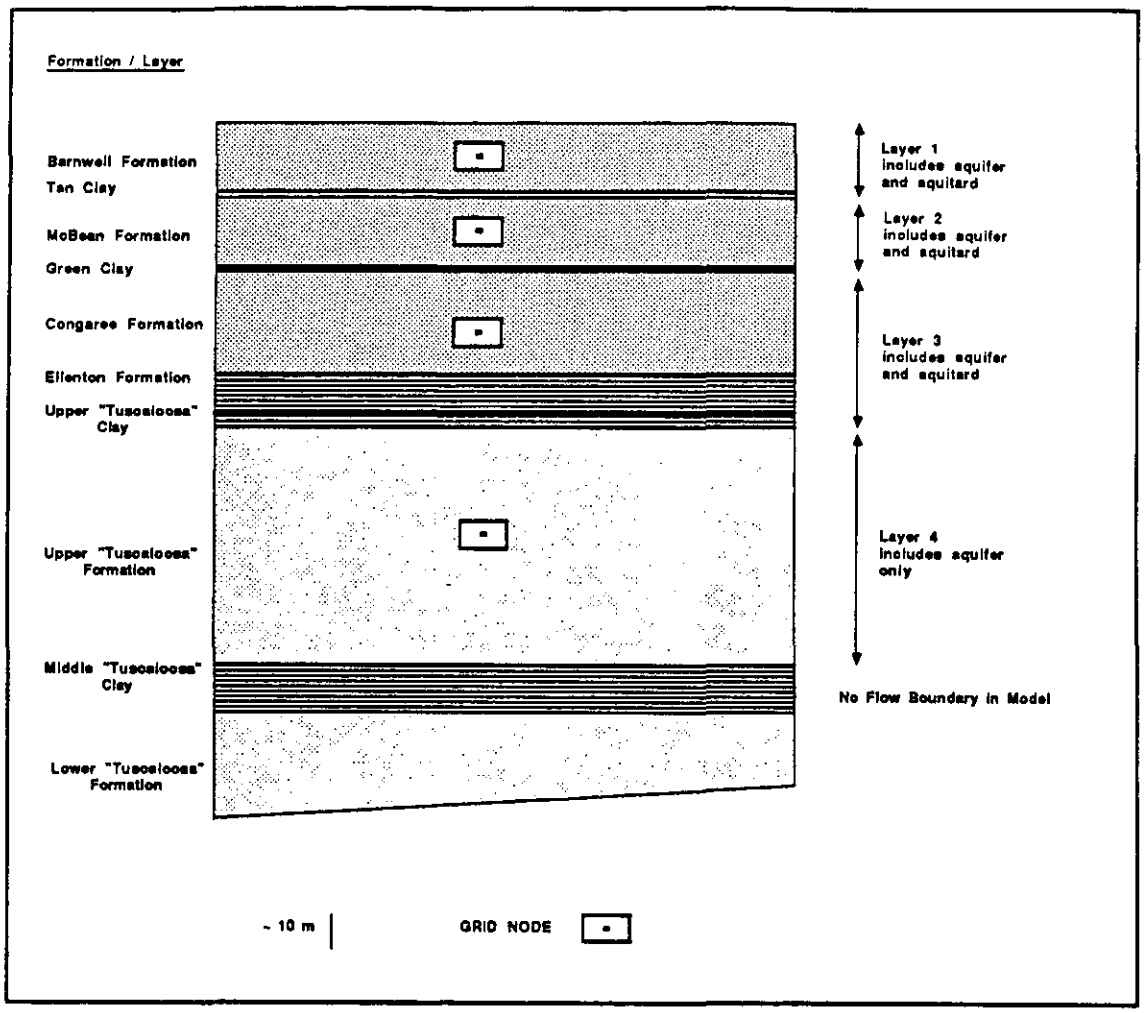


FIGURE 20. Vertical Discretization of Formations in the Study Area for the Groundwater Flow Model

TABLE 9

Hydraulic Characteristics of the Separations Area Obtained from a Steady-State Model Calibration

Hydrostratigraphic Unit	Hydraulic Parameter	Model Estimate
Upper "Tuscaloosa" Formation	Transmissivity	910 m^2/day
Congaree Formation	Transmissivity	350 m^2/day
McBean Formation	Hydraulic conductivity	1.2 m/day
Barnwell Formation	Hydraulic conductivity	0.2-1.1 m/day
Ellenton Formation confining bed*	Leakance coefficient	4.7E-11 day^{-1}
	Vertical hydraulic conductivity	2.9E-10 m/day
Green Clay confining bed**	Leakance coefficient	(1.7-4.4)E-05 day^{-1}
	Vertical hydraulic conductivity	(2.6-6.7)E-05 m/day
Tan Clay confining bed†	Leakance coefficient	(2.4-5.5)E-04 day^{-1}
	Vertical hydraulic conductivity	(2.2-5.2)E-04 m/day

Note: Data are from Duffield et al. (1986).

* Saturated thickness = 6.1 m.
** Saturated thickness = 1.5 m.
† Saturated thickness = 0.9 m.

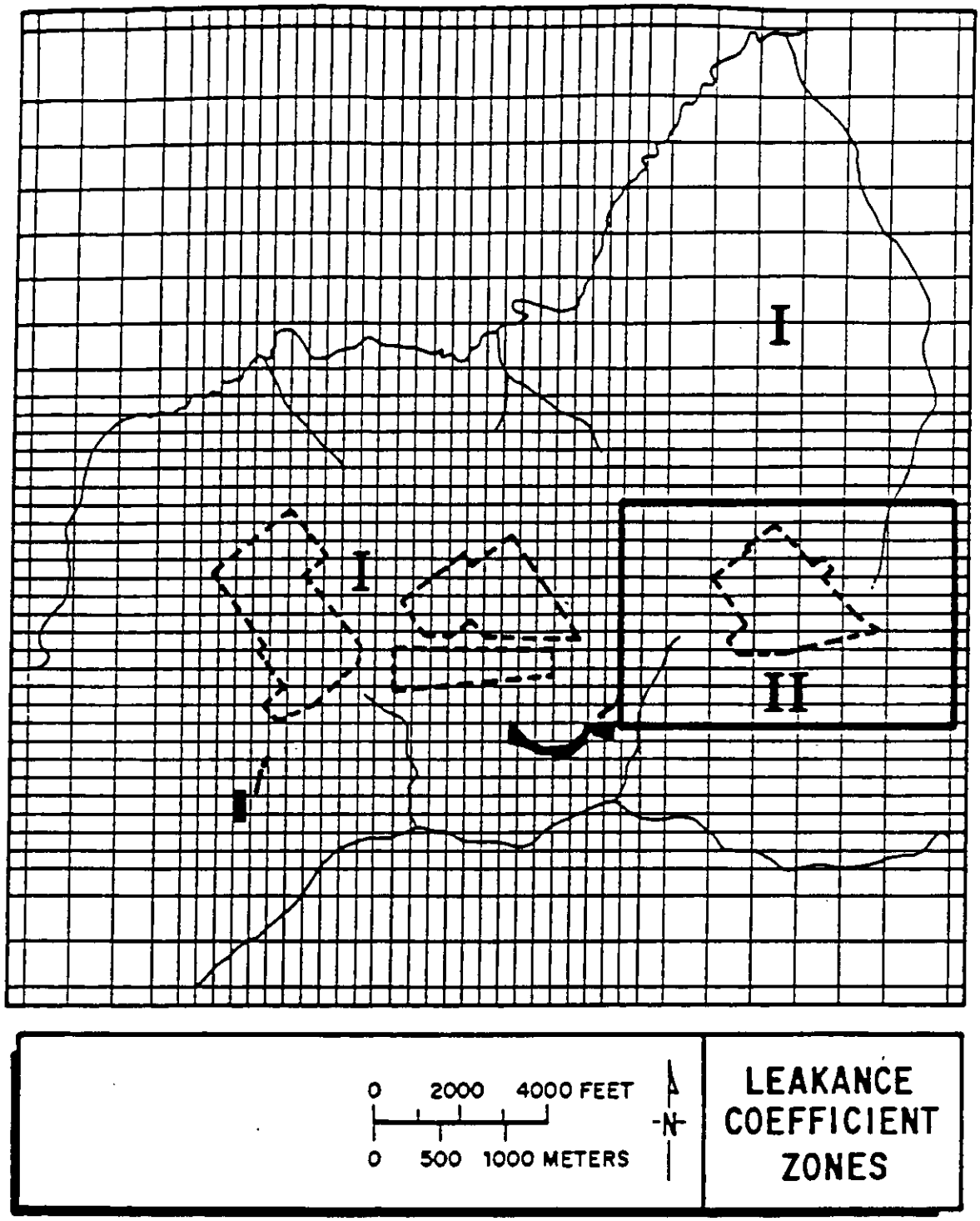


FIGURE 21. Leakance Coefficient Zones for the Green Clay and Tan Clay Confining Beds

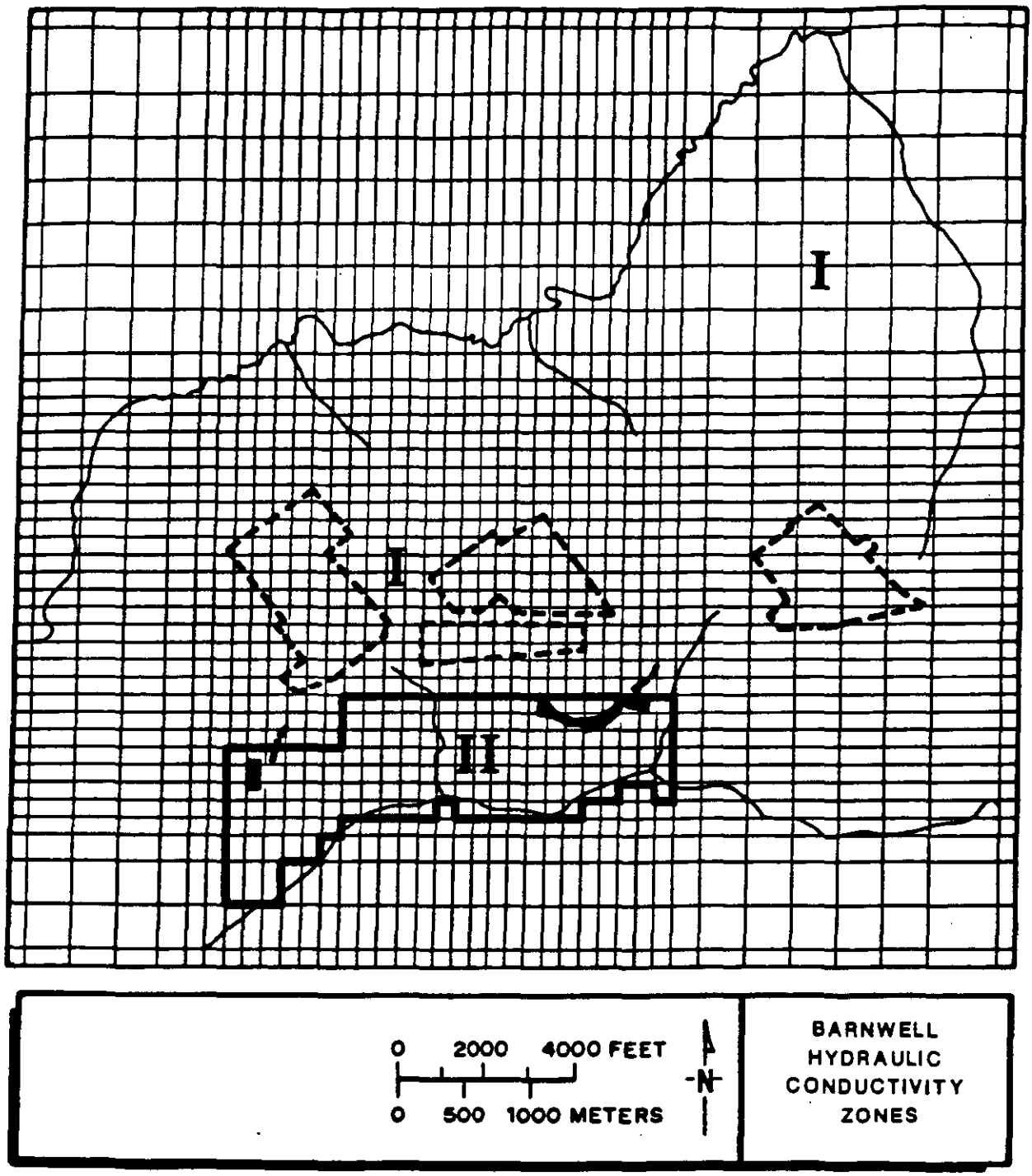


FIGURE 22. Hydraulic Conductivity Zones for the Barnwell Formation

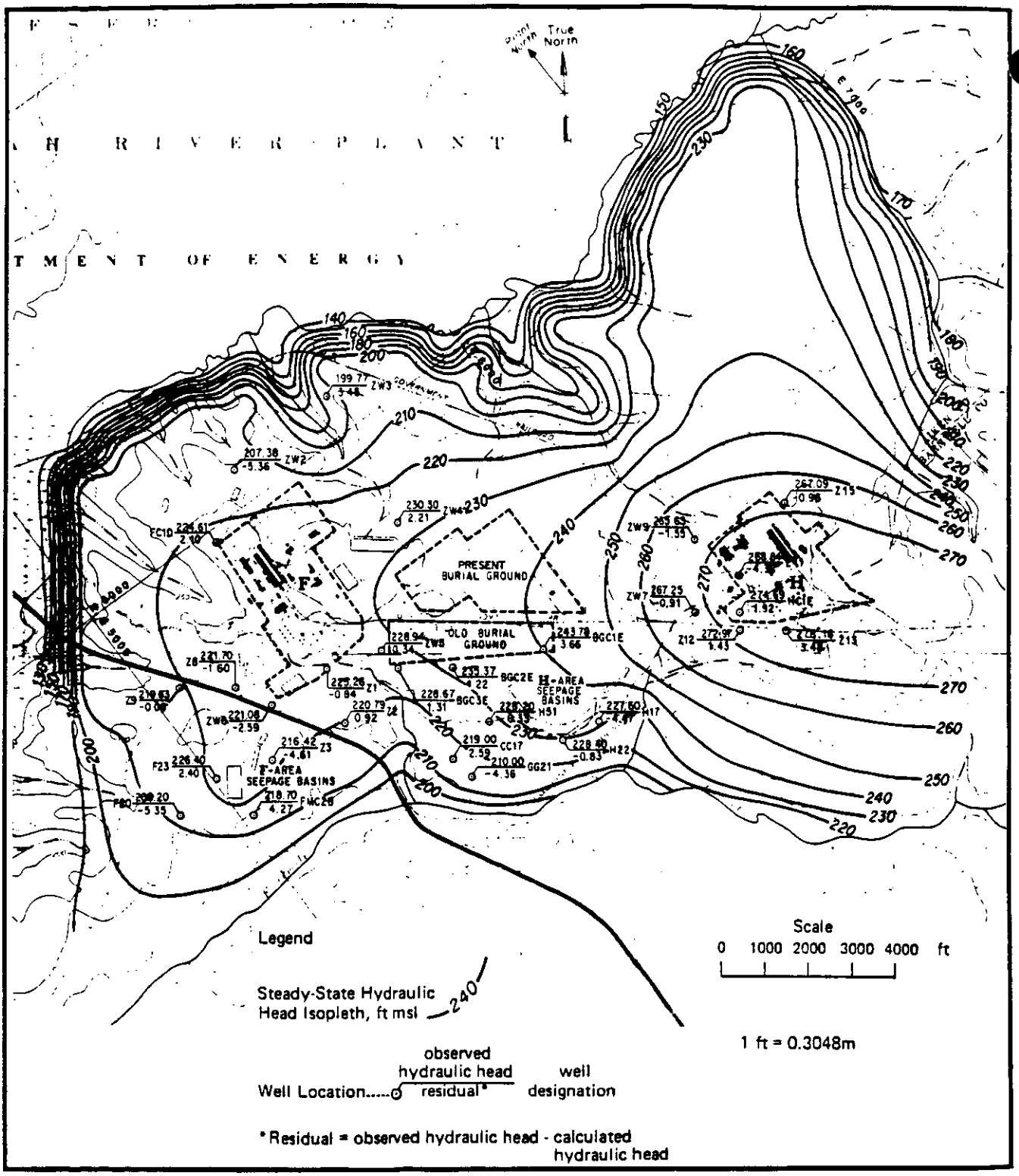


FIGURE 23. Calculated Steady-State Hydraulic Heads for the Water Table

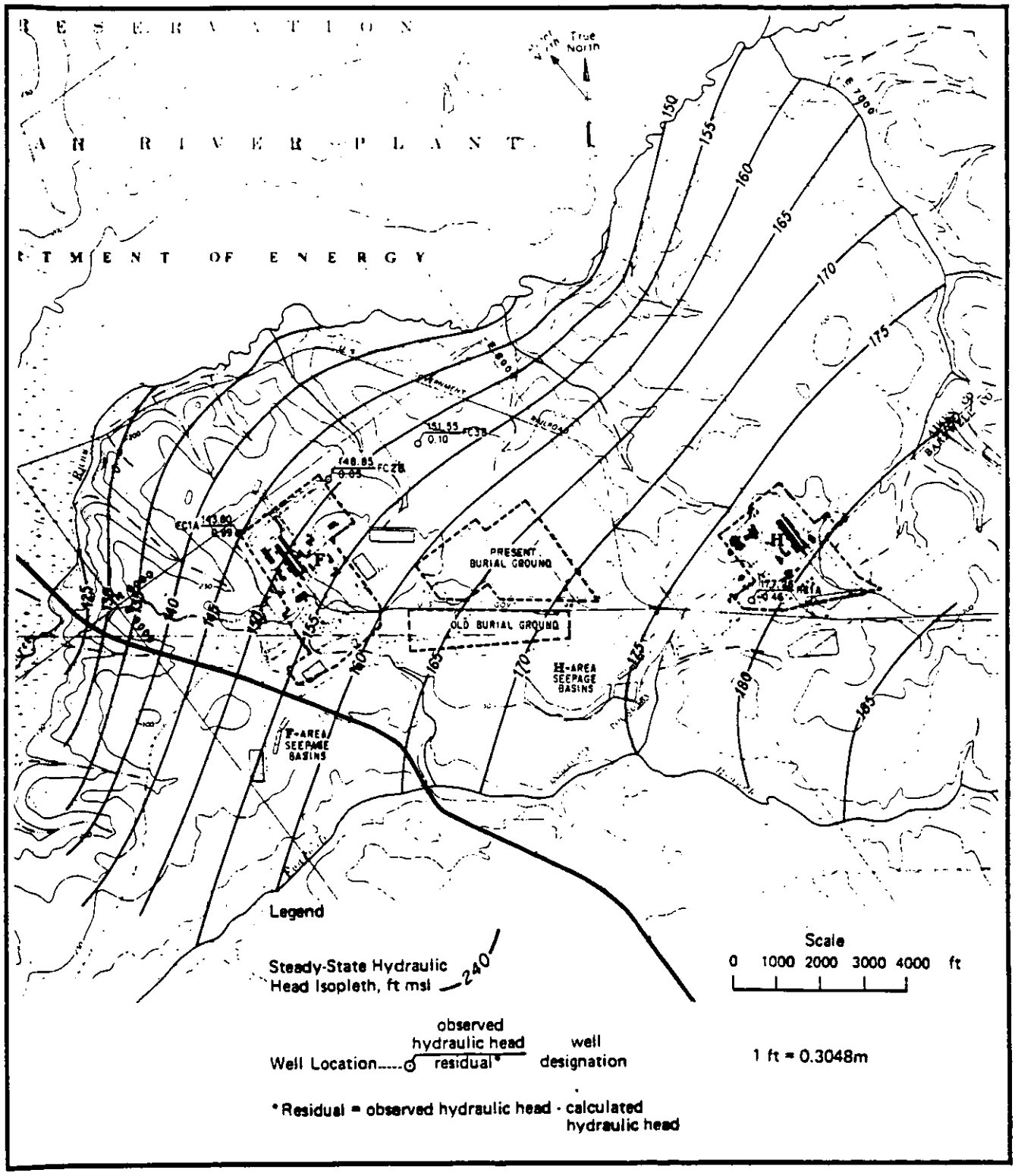


FIGURE 24. Computer-Generated Piezometric Surface of the Congaree Formation

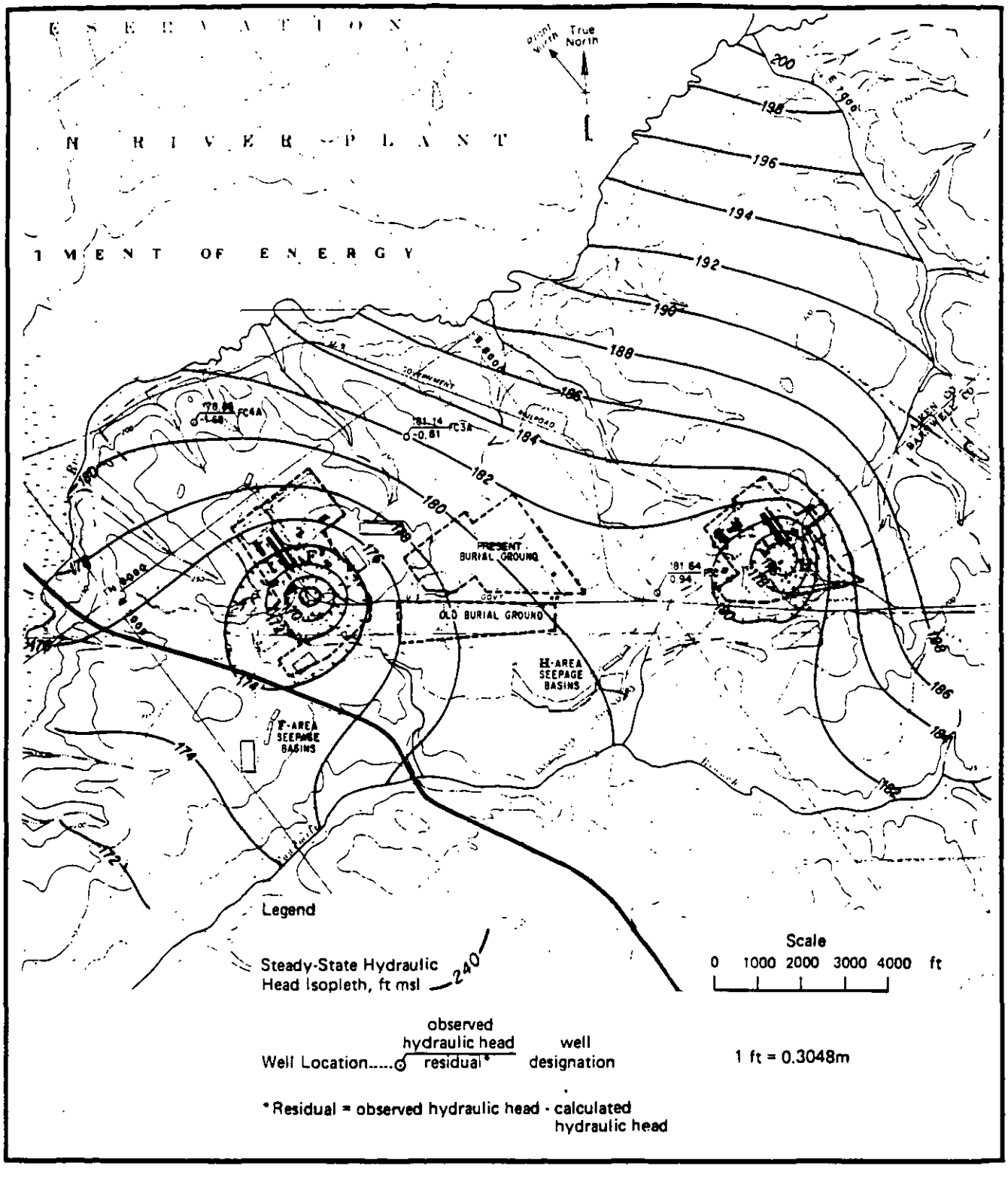


FIGURE 25. Computer-Generated Piezometric Surface of the "Tuscaloosa" Formation

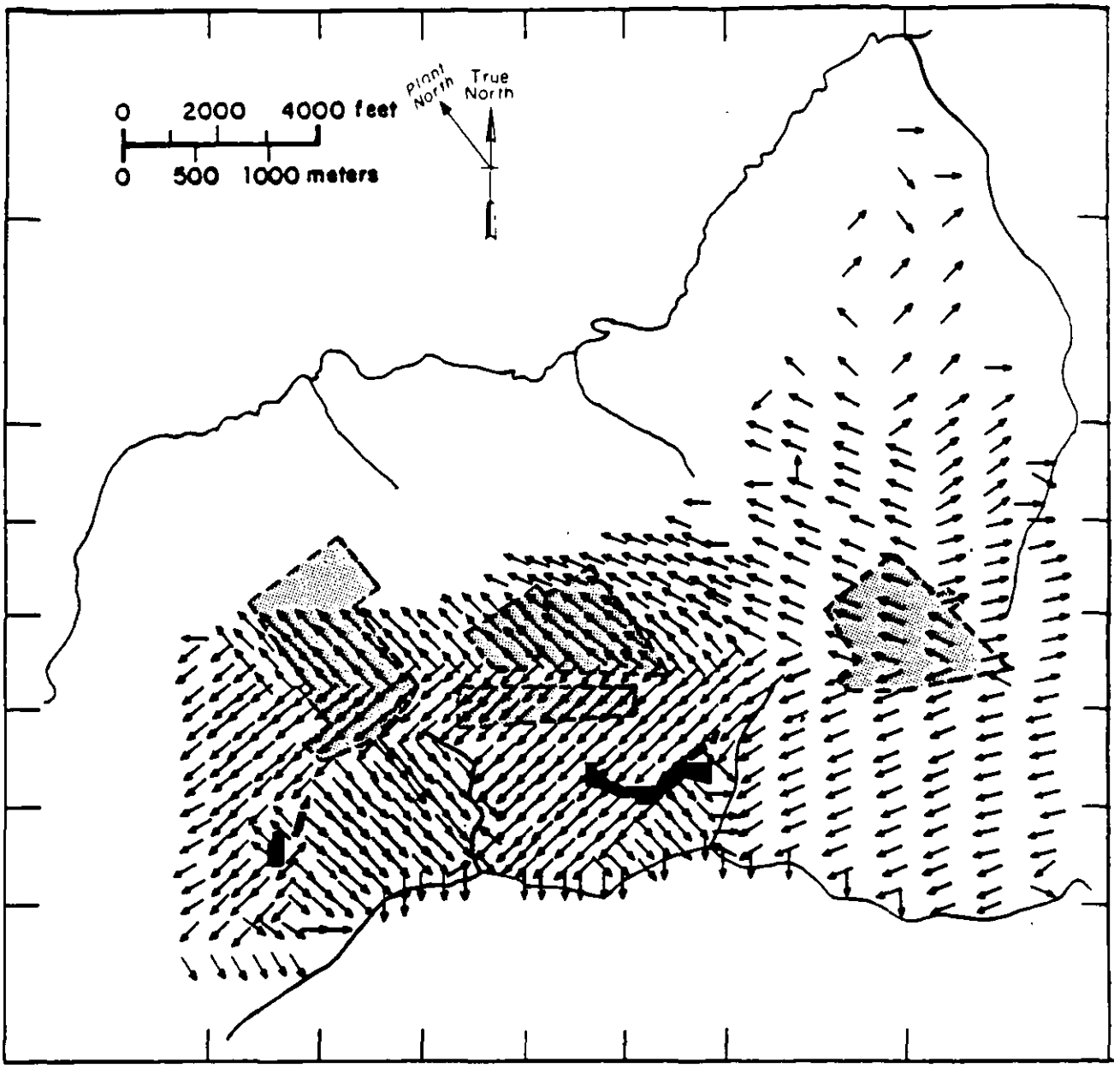


FIGURE 26. Horizontal Water Flow Direction in Barnwell Formation

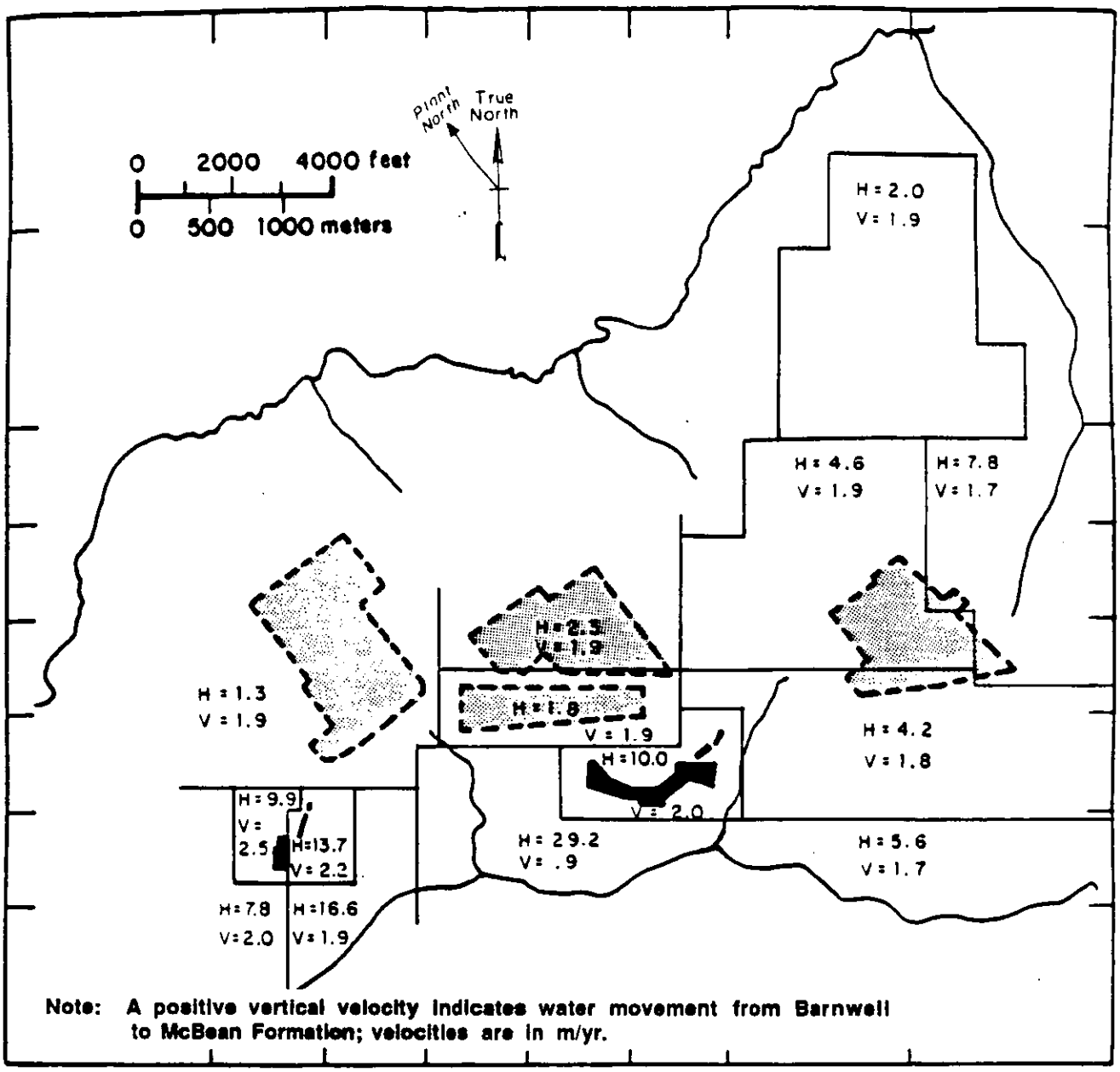


FIGURE 27. Horizontal (H) and Vertical (V) Groundwater Velocities in the Barnwell Formation

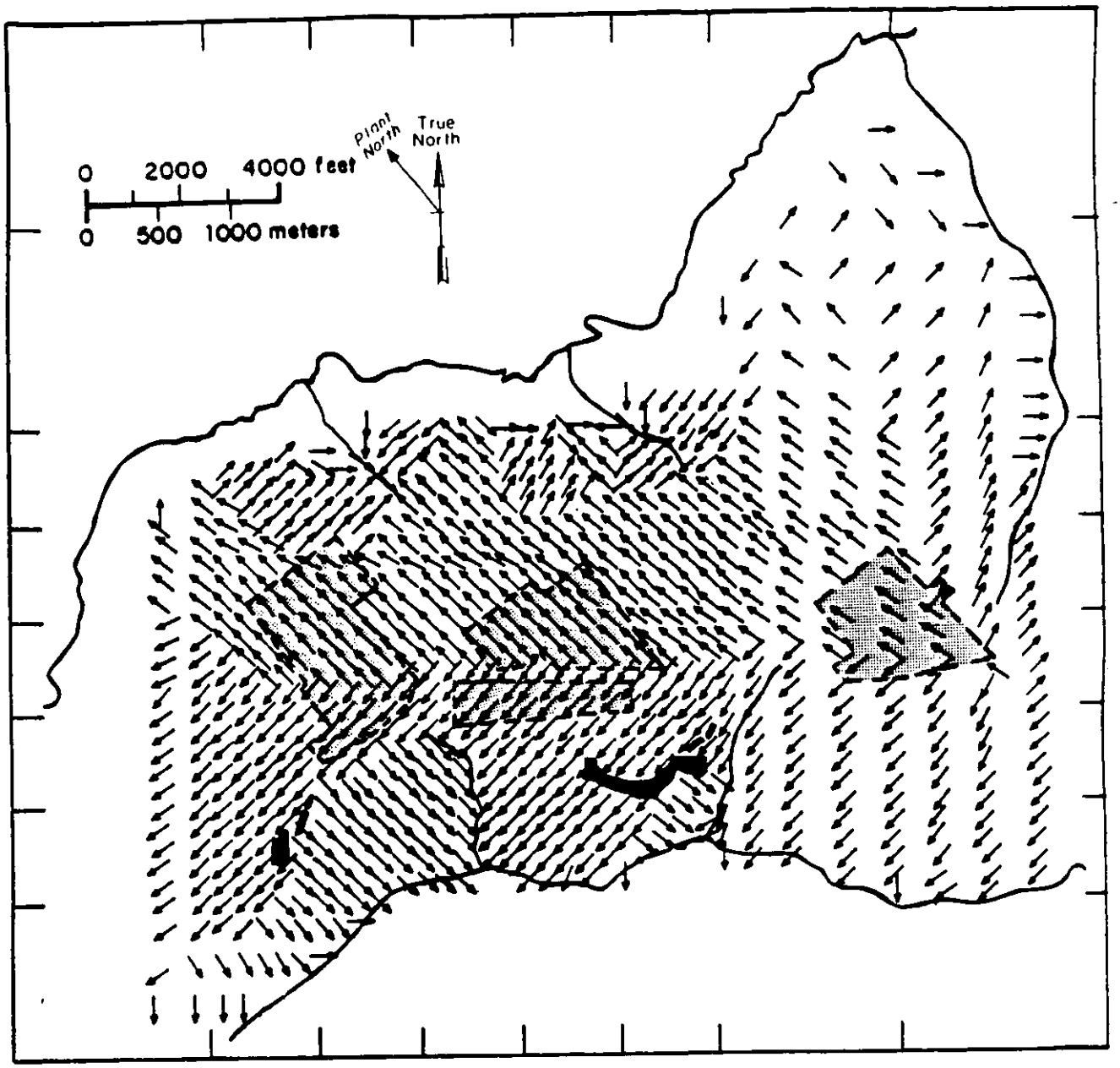


FIGURE 28. Horizontal Water Flow Direction in McBean Formation

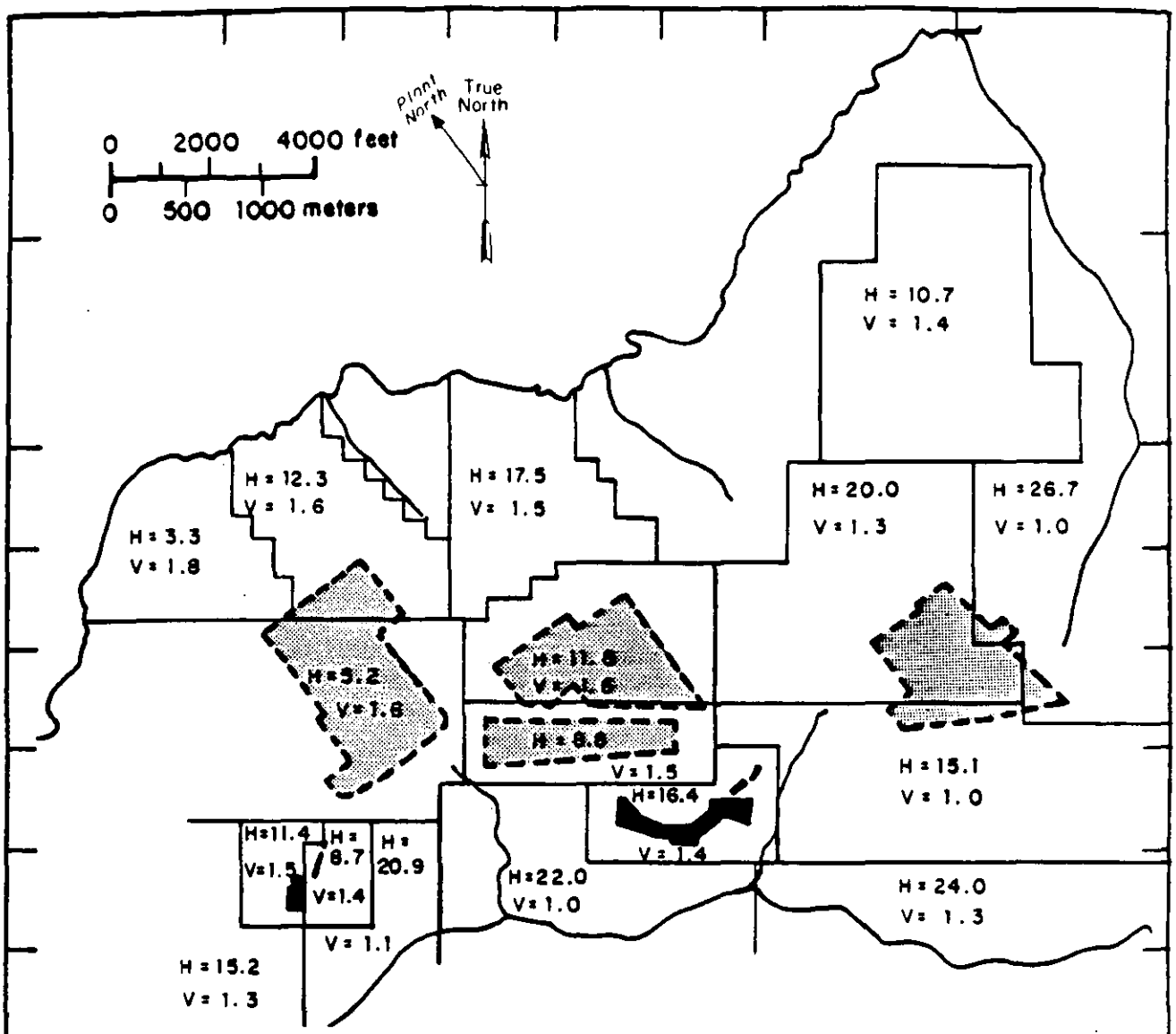


FIGURE 29. Horizontal (H) and Vertical (V) Groundwater Velocities in the McBean Formation

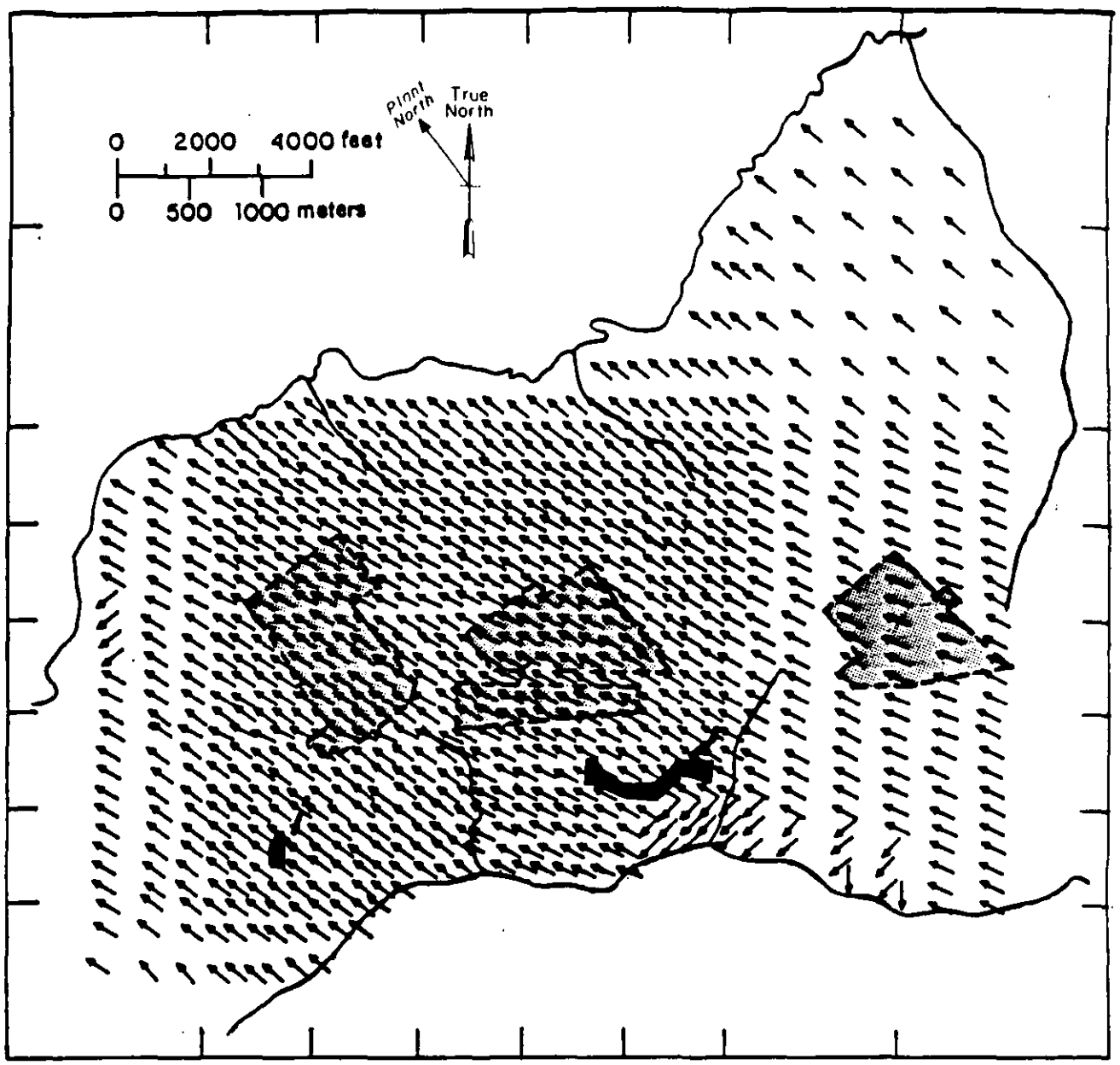


FIGURE 30. Horizontal Water Flow Direction in Congaree Formation

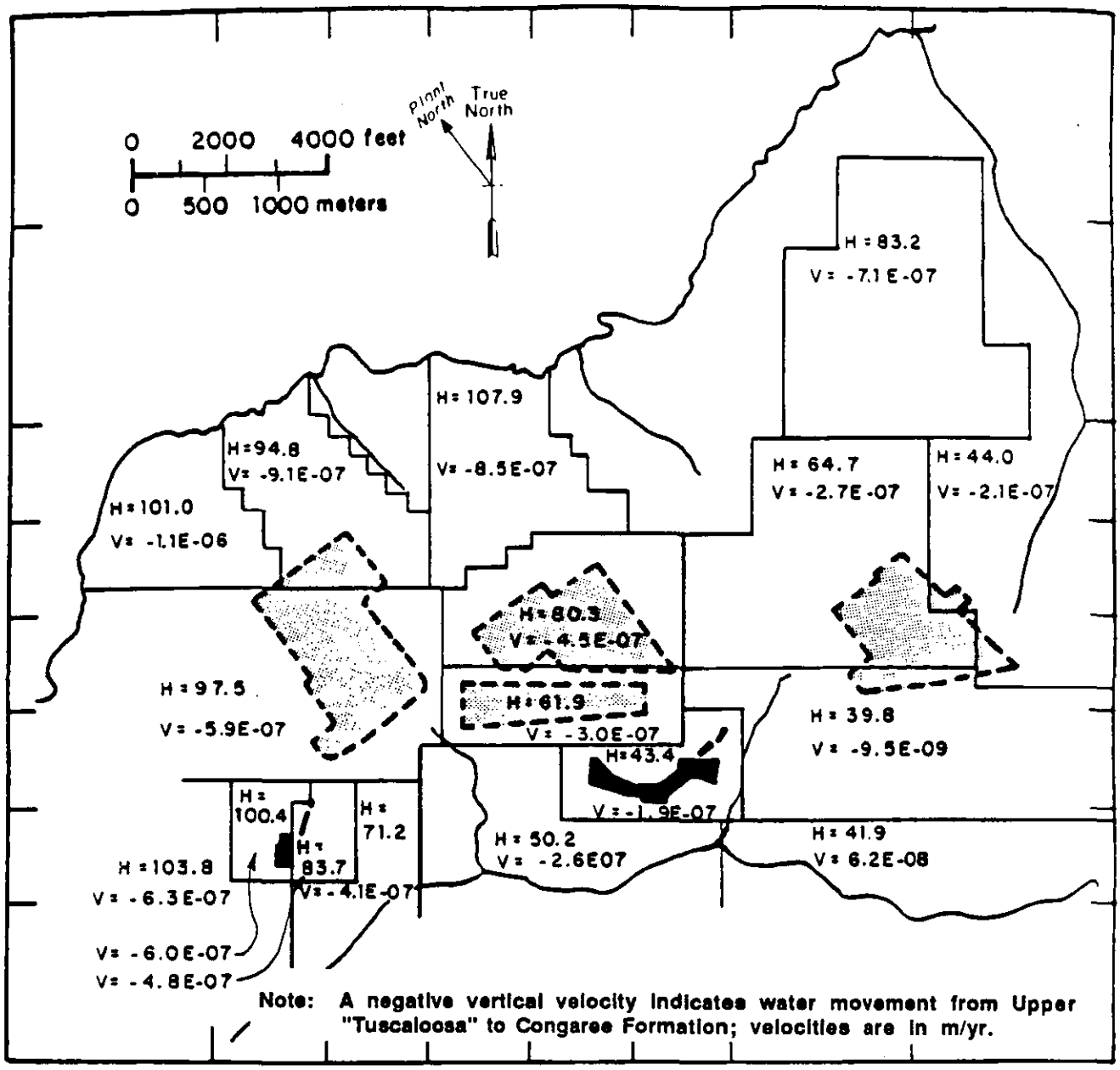


FIGURE 31. Horizontal (H) and Vertical (V) Groundwater Velocities in the Congaree Formation

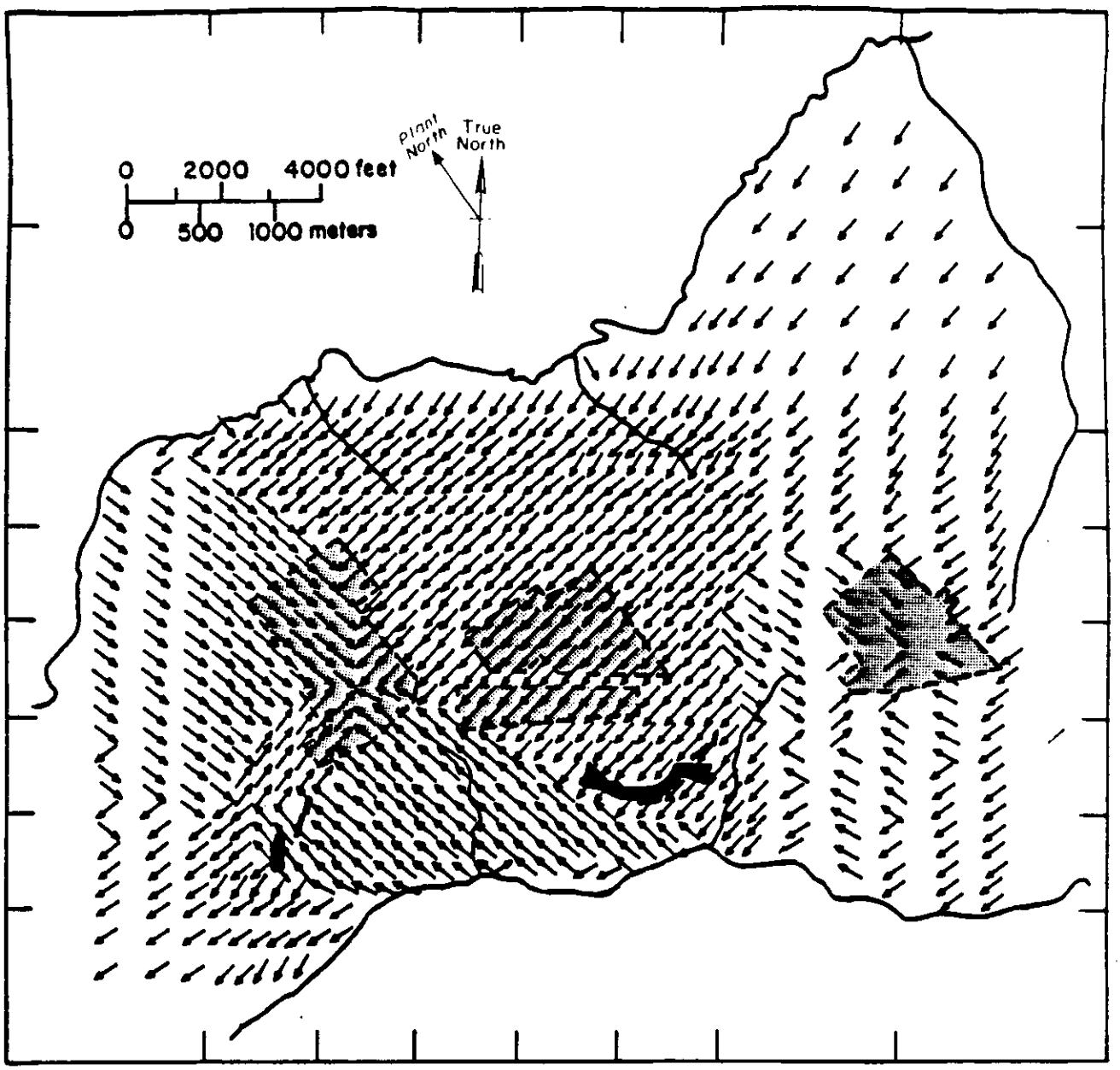


FIGURE 32. Horizontal Water Flow Direction in Upper "Tuscaloosa" Formation

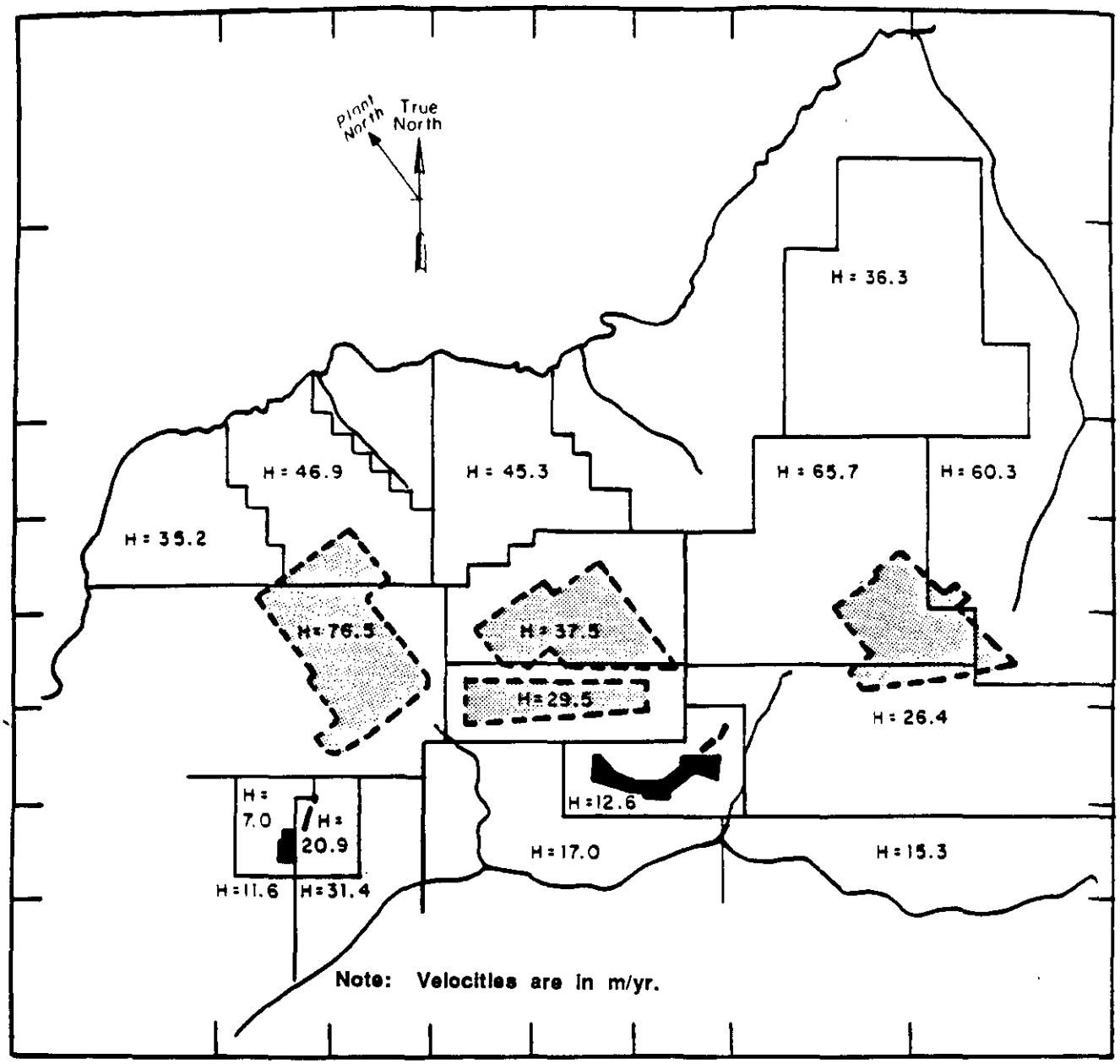
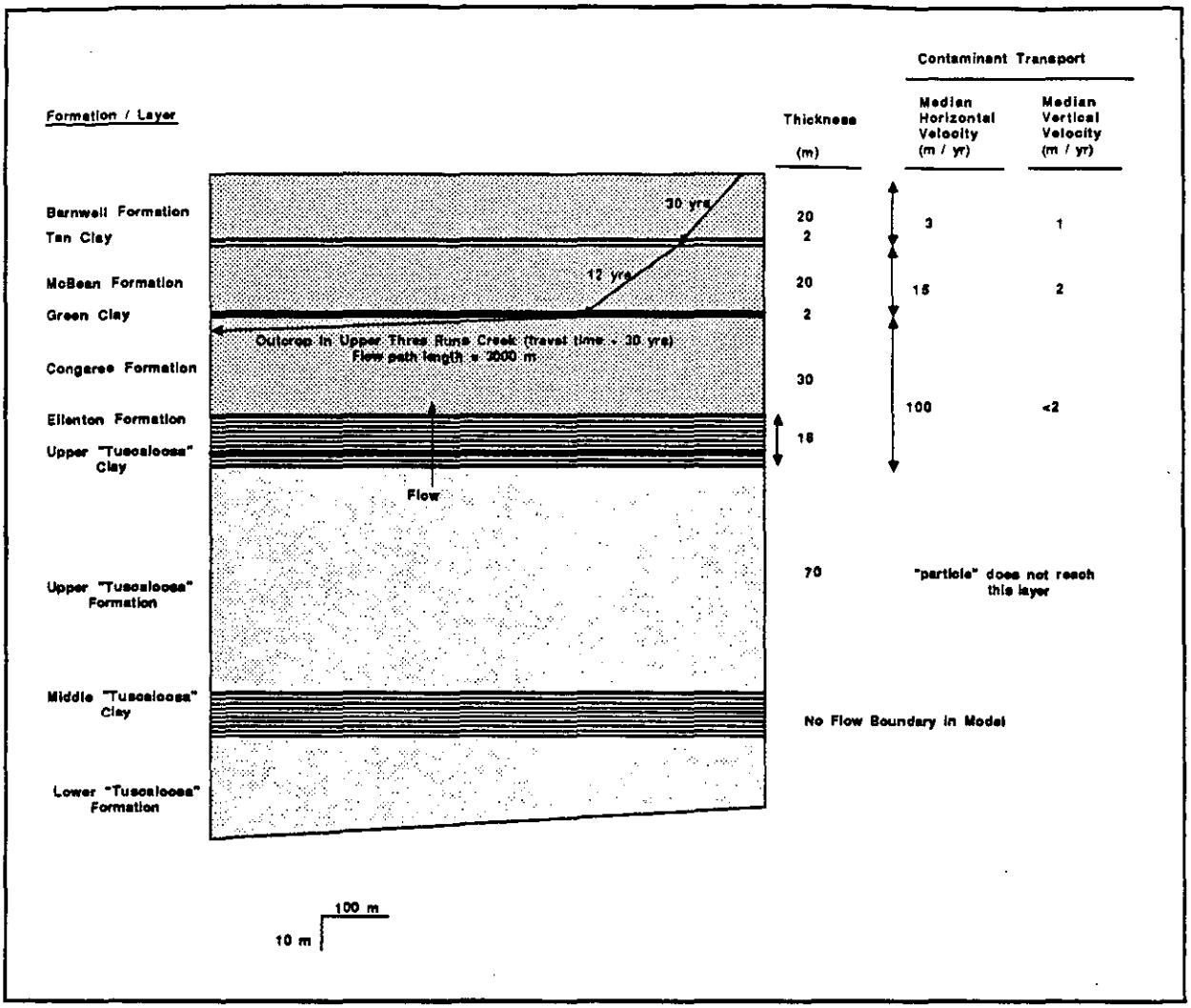


FIGURE 33. Horizontal (H) Groundwater Velocities in the Upper "Tuscaloosa" Formation

Three Runs Creek, and flow in the "Tuscaloosa" is toward the Savannah River. Horizontal velocities near the Burial Grounds are about 2 m/yr (Barnwell), 10 m/yr (McBean), 70 m/yr (Congaree), and 35 m/yr ("Tuscaloosa").

The flow path of a conservative constituent can be calculated by a particle-tracking method that follows the flow path of a particle (e.g., a waste component) originating at a particular point on the finite difference grid. The particle-tracking path of a point chosen near F-Area Seepage Basin 3 is shown in Figure 34. From this position, the particle travels both horizontally and vertically in the Barnwell Formation toward Four Mile Creek for approximately 30 years. At this time the particle enters the McBean Formation and continues to travel horizontally and vertically until it enters the Congaree Formation after approximately 12 more years. The particle then flows in the Congaree, cropping out in Upper Three Runs Creek after approximately 30 more years (total travel time of 72 years).

A downward flow of groundwater from the Barnwell to the McBean Formation occurs at an average velocity of 2 m/yr and from the McBean to the Congaree Formation at an average of 1.5 m/yr. Groundwater flow across the Ellenton confining bed is upward from the "Tuscaloosa" Formation to the Congaree Formation in almost every node in the modeled area and averages 1.0E-07 m/yr near the Burial Grounds. These modeling results, which represent the centroid of any contaminant plume, indicate that the potential for large quantities of constituents to enter the "Tuscaloosa" Formation as a result of flow/transport is minimal.



Note: Arrows indicate path of plume centroid.

FIGURE 34. Summary of Typical Particle Tracking of Mobile Contaminants from the Burial Grounds

WASTE SITE CHARACTERIZATION

Past burial practices at the Savannah River Plant resulted in waste directly contacting soil in a near-surface backfilled trench. Monitoring of waste constituents has been carried out by measuring water beneath and downgradient of the site.

GROUNDWATER MONITORING DATA

Well Locations

In the early 1970s a grid of water-table wells was installed on 61-m centers in 643-G (the original Burial Ground). In 1974-75, a grid of wells on 122-m centers was installed in the downgradient area south of the 643-G Burial Ground. The grid of wells in the 643-7G Burial Ground was started in the late 1970s as burial space was filled.

All 125 grid wells in the system are shown in Figure 35, including wells in the downgradient area south of the Burial Grounds. Figures 36 and 37 identify the grid wells for the 643-G and 643-7G Burial Grounds, respectively.

Deeper flow paths resulting from curvilinear water movement are monitored by clusters of wells screened at successively deeper levels. Figure 38 shows screen placements in relation to important hydrostratigraphic units in well clusters located at intervals along the south fence of the 643-G Burial Ground. Wells are identified at each cluster by letters beginning with the deepest well.

In addition to groundwater wells, the 643-G Burial Ground also contains 22 trench wells and 11 dry boreholes. The trench wells monitor for perched water in contact with waste, a condition that occasionally has been found. The dry boreholes are used to make in-situ gamma radiation measurements.

Radionuclide Analysis in the 643-G Burial Ground

During 1984, there were 733 analyses for tritium, gross alpha, and gross nonvolatile beta radioactivity performed on groundwater samples from the 64 operational grid wells in the 643-G Burial Ground. Nominal sampling frequency was quarterly. Annual average radionuclide concentrations for each well for 1984 are given in Table 10, which also contains 1983 results for comparison.

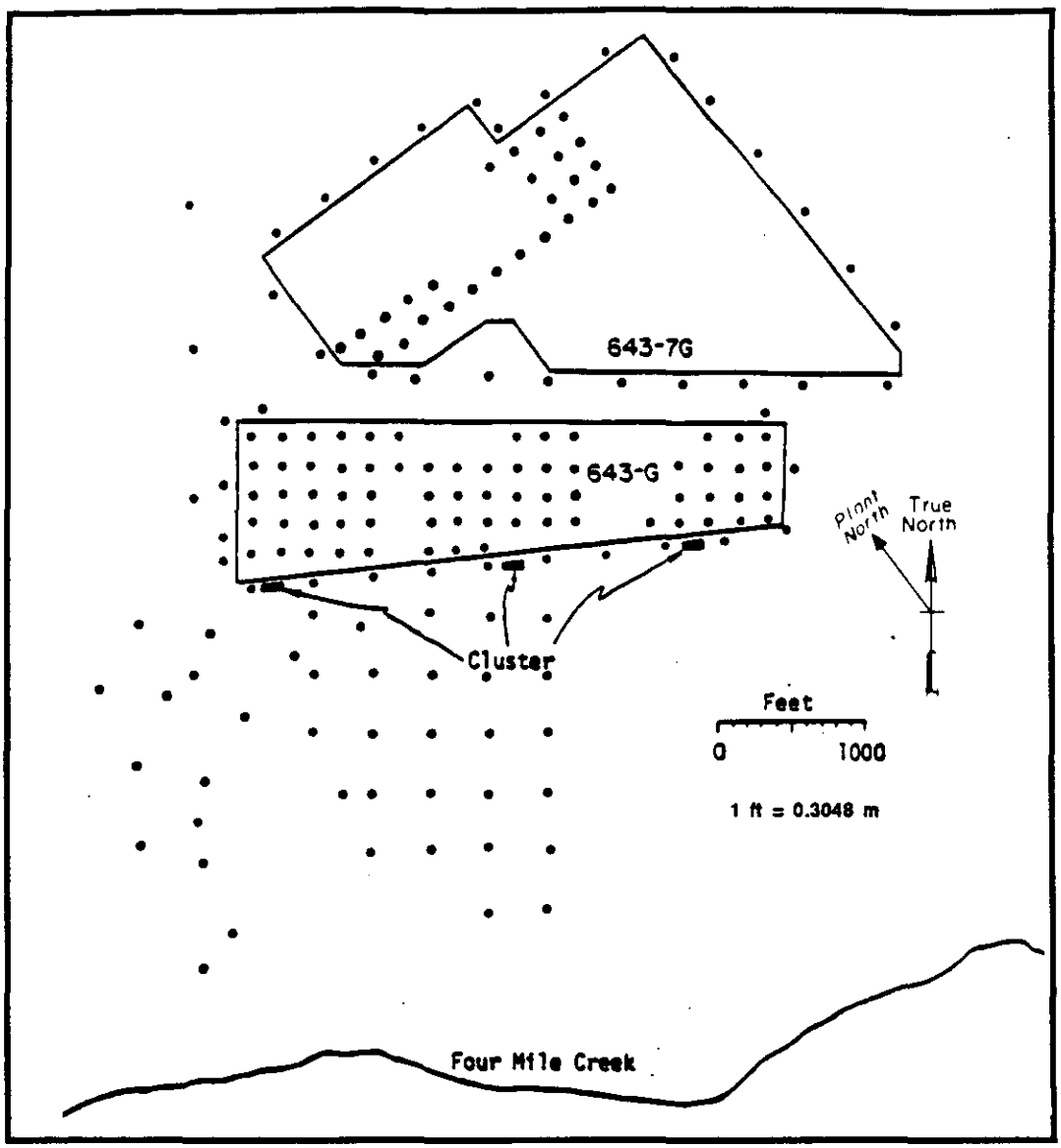


FIGURE 35. Burial Grounds Monitoring Wells

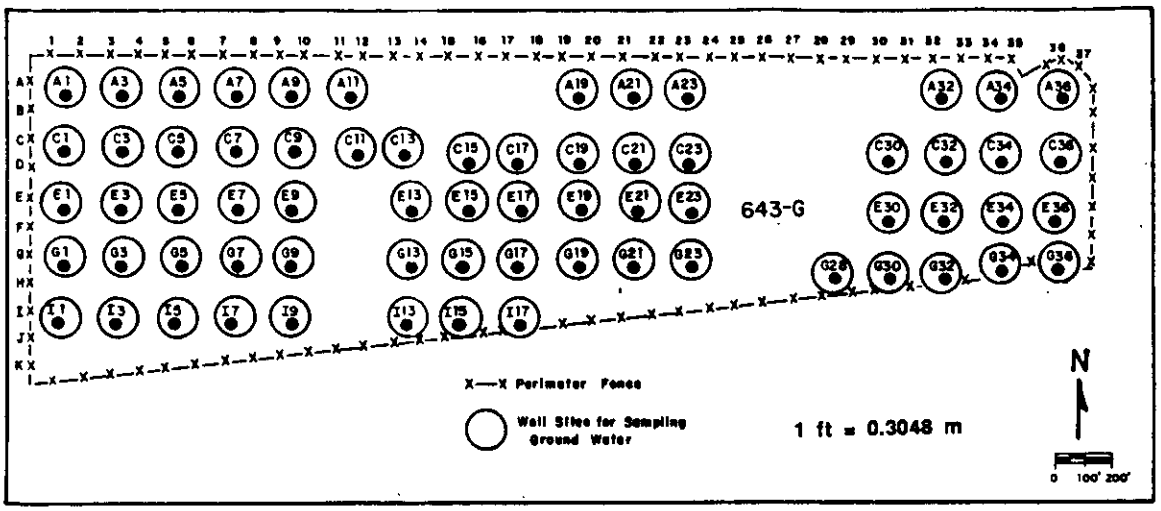


FIGURE 36. Grid Wells in the 643-G Burial Ground

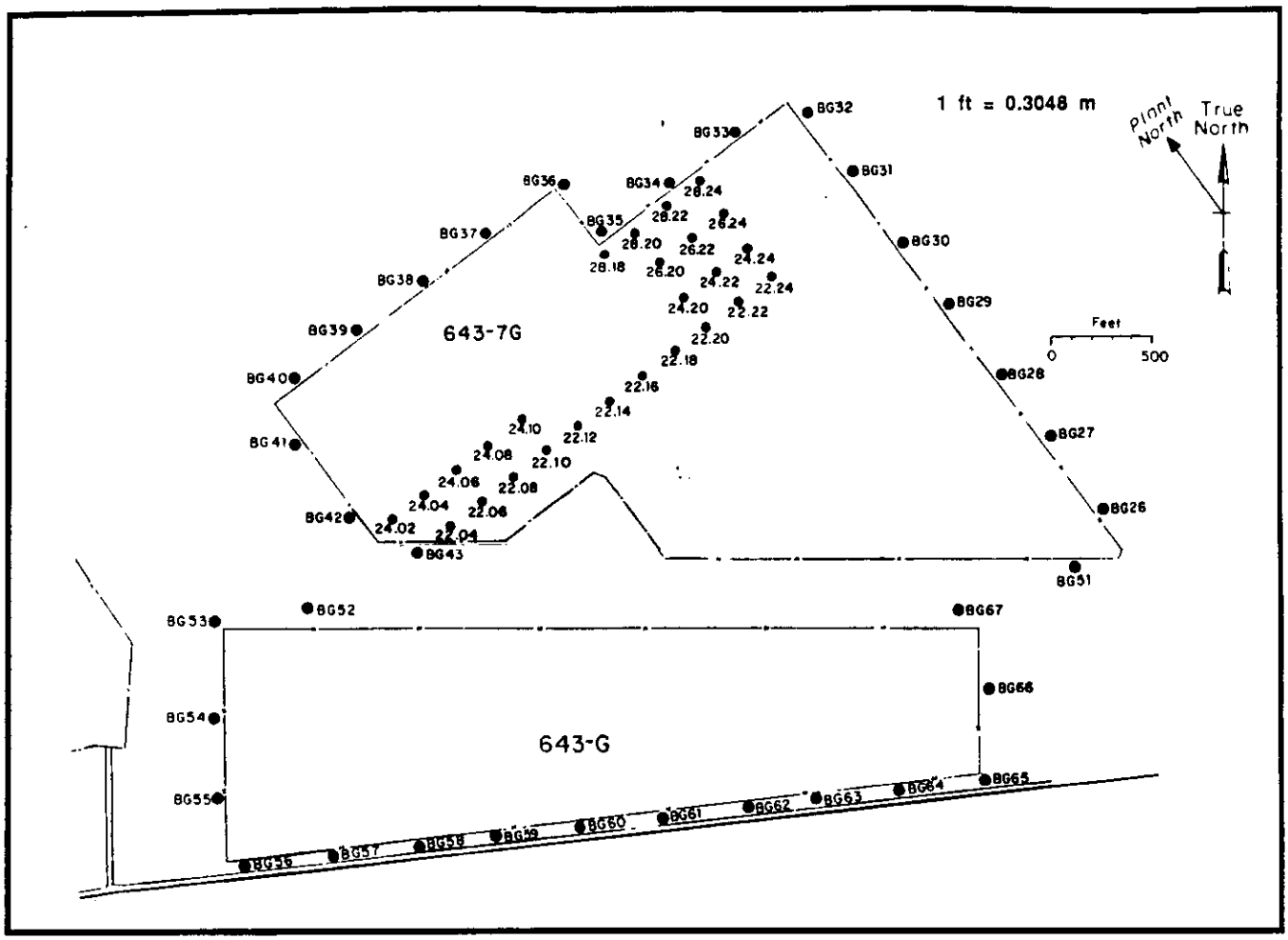
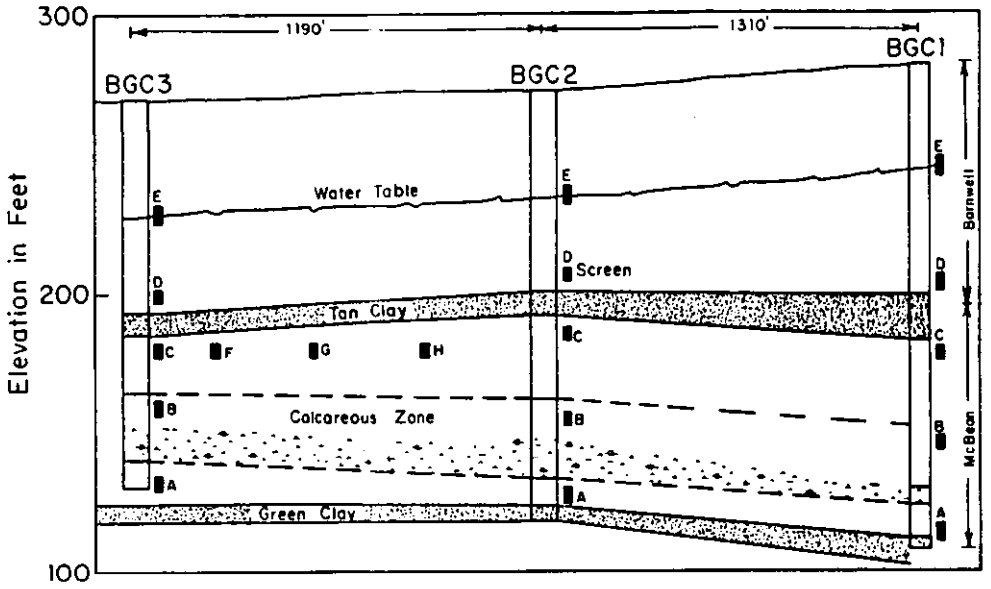


FIGURE 37. Grid Wells in the 643-7G and 643-28G Burial Grounds



1 ft = 0.3048 m

FIGURE 38. Cross Section Along South 643-G Fence Showing Hydrostratigraphic Units, Water Table, and Screen Placement in Cluster Wells

TABLE 10

Radionuclide Concentrations in 643-G Grid Wells

Well	Alpha (pCi/L) 1983	Alpha (pCi/L) 1984	Nonvolatile Beta (pCi/L) 1983	Nonvolatile Beta (pCi/L) 1984	Tritium (μCi/L) 1983	Tritium (μCi/L) 1984
MGA 1	1	1	4	5	47	217
MGA 3	1	<1	176	210	31	79
MGA 5	1	1	5	5	222	1,022
MGA 7	1	2	9	6	10	12
MGA 9	-	-	-	-	-	-
MGA 11	-	3	-	<1	-	1
MGA 19	<1	1	<1	1	0.07	0.07
MGA 21	1	1	3	<1	0.08	0.01
MGA 23	<1	<1	<1	<1	0.04	0.01
MGA 32	2	1	4	6	0.40	0.5
MGA 34	1	<1	4	21	0.07	0.09
MGA 36*	1	1	2	2	0.90	7
MGC 1	<1	<1	40	20	1	6
MGC 3	1	<1	1	11	269	165
MGC 5	<1	1	8	12	11	138
MGC 7	<1	1	1	2	60	642
MGC 9*	<1	<1	4	4	9	24
MGC 11*	1	<1	2	1	0.02	0.03
MGC 13	1	1	3	12	0.10	0.4
MGC 15	1	6	7	2	0.03	0.07
MGC 17	2	4	1	1	0.03	0.09
MGC 19*	1	<1	4	2	0.03	0.03
MGC 21	1	2	2	4	2	6
MGC 23*	1	1	4	2	22	15
MGC 30	2	2	2	2	0.08	0.1
MGC 32*	1	1	5	6	27	7
MGC 34	1	<1	48	3,602	0.2	0.6
MGC 36*	1	1	3	2	1	3
MGE 1	1	1	3	7	6	25
MGE 3	1	2	2	4	138	639
MGE 5	2	1	2	2	35	19
MGE 7	<1	1	<1	1	1	10
MGE 9*	<1	<1	-	2	0.03	0.04
MGE 13	1	1	<1	2	0.1	0.08

* Wells monitored by the Health Protection Department; all others monitored by the Savannah River Laboratory.

TABLE 10, Contd

Radionuclide Concentrations in 643-G Grid Wells

Well	Alpha (pCi/L) 1983	Alpha (pCi/L) 1984	Nonvolatile Beta (pCi/L) 1983	Nonvolatile Beta (pCi/L) 1984	Tritium (μCi/L) 1983	Tritium (μCi/L) 1984
MGE 15	-	-	-	-	-	-
MGE 17	2	1	8	8	0.1	0.1
MGE 19	<1	<1	8	6	0.6	0.6
MGE 21*	1	2	2	3	1	2
MGE 23	3	3	6	73	0.3	0.4
MGE 30*	1	1	6	4	0.1	0.2
MGE 32	4	1	2	34	17	73
MGE 34*	1	1	12	8	32	51
MGE 36	<1	1	1	4	57	725
MGG 1	1	<1	3	3	9	54
MGG 3	2	2	3	1	2	4
MGG 5	<1	1	3	<1	0.6	0.3
MGG 7	<1	<1	42	192	11	32
MGG 9	2	1	29	28	17	18
MGG 13	2	1	2	<1	43	130
MGG 15*	1	1	4	2	9	20
MGG 17	1	<1	3	2	3	4
MGG 19*	1	1	10	11	0.06	0.1
MGG 21	116	231	8,774	15,453	46	26
MGG 23*	<1	<1	1	2	1	0.6
MGG 28*	<1	<1	2	2	0.07	0.1
MGG 30	<1	1	6	1	3	6
MGG 32	1	<1	<1	100	209	445
MGG 34*	1	1	1	6	659	353
MGG 36*	<1	1	3	2	9	23
MGI 1	5	2	54	179	33	42
MGI 3	-	-	-	-	-	-
MGI 5	<1	3	10	9	21	149
MGI 7	1	1	836	14	93	398
MGI 9	1	1	1	2	5	0.9
MGI 13	6	6	78	68	0.6	2
MGI 15	17	9	25	27	0.08	0.2
MGI 17	4	3	21	4	0.3	0.06

* Wells monitored by the Health Protection Department; all others monitored by the Savannah River Laboratory.

Gross alpha and gross nonvolatile beta concentrations averaged over all grid wells in the 643-G Burial Ground for each year since 1974 are given in Table 11. These annual averages exclude well MGG 21, which contains considerably more gross alpha and gross nonvolatile beta activity than the other wells. The annual average gross alpha concentration for the remaining wells has been approximately constant and relatively low for the last several years. Average gross nonvolatile beta concentration increased in 1984 after having been relatively low and constant for the previous 5 years.

Data from well MGG 21 are excluded to avoid distortion of the averages. The anomalous behavior of well MGG 21 is known to be localized to a small area because surrounding wells are unaffected. A study is in progress to determine the reason for anomalous migration of radioactivity at well MGG 21. Estimates of the amounts of radionuclides localized in groundwater around well MGG 21 are 2 mCi of alpha and 110 mCi of nonvolatile beta, based on the 1984 concentrations.

In 1984, five wells in the 643-G Burial Ground had gross alpha concentrations >3 pCi/L; two of these (MGG 21 and MGI 15) contained >6 pCi/L of gross alpha. Eight wells had gross nonvolatile beta concentrations >50 pCi/L; five of these (including MGG 21) contained >100 pCi/L of gross nonvolatile beta. All remaining wells in the 643-G Burial Ground contained <3 pCi/L gross alpha and <50 pCi/L gross nonvolatile beta.

During the time that the tributylphosphate-kerosene extraction solvents were stored in underground tanks, approximately 1.6 m^3 of solvent were released to the groundwater due to tank leaks and process upsets. Some of the fission and activation products measured in grid wells are attributed directly (or by enhanced mobility) to this source: MGC 15, MGC 17, MGE 13, MGE 17, MGE 19, MGG 13, MGG 15, MGG 17, MGG 19, MGI 7, MGI 9, MGI 13, MGI 15, and MGI 17. Additionally, decontamination of equipment using complexing agents may be responsible for migration of radionuclides to wells MGA 31, MGC 1, and MGC 3.

Tritium concentrations averaged over all grid wells in the 643-G Burial Ground for each year since 1974 are given in Table 12. Tritium, in contrast to the alpha and nonvolatile beta emitters, is readily leached from waste and is present as a plume in the groundwater beneath the Burial Grounds. In 1984, 49 wells in the 643-G Burial Ground had tritium concentrations >0.1 Ci/L.

Estimates of the total amount of tritium in the groundwater beneath the 643-G Burial Ground are given in Table 12. For 1984, the estimate is 36,800 Ci. Some of the assumptions in these estimates are now in doubt, particularly the assumption that the

TABLE 11

Annual Average Concentrations of Radioactivity in 643-G Grid Wells

Year	Wells Sampled	Alpha (pCi/L)	Nonvolatile Beta (pCi/L)
1974	42	2	27
1975	42	3	16
1976	65	9	40
1977	66	3	41
1978	66	5	73
1979	66	2	18
1980	65	2	13
1981	65	3	18
1982	64	2	18
1983	63	2	25
1984	63	1	76

Note: Data do not include values from well MGG 21 due to anomalous behavior.

TABLE 12

Estimates of Tritium in Groundwater Beneath 643-G

Year	Average Concentration (μCi/L)	Tritium in 643-G Plume (Ci)
1974	31.6	13,300
1975	59.8	25,200
1976	58.0	24,400
1977	59.0	24,800
1978	90.4	38,100
1979	65.8	27,700
1980	91.6	38,600
1981	88.8	37,400
1982	57.7	24,300
1983	34.7	14,600
1984	87.5	36,800

tritium concentration found in a water-table well is representative of tritium throughout the saturated thickness. Soil corings in the 643-G Burial Ground are planned to search for plume dips and to develop a better basis for calculation of the groundwater tritium inventory.

Assays for individual radionuclides in 643-G groundwater also have been performed by methods capable of detecting ultra-low levels. Such assays were performed on samples from selected wells with a history of gross alpha and/or gross nonvolatile beta radioactivity. Table 13 summarizes the results of these measurements. Twenty wells were analyzed for gamma emitters; as shown in Table 13, ^{60}Co and ^{137}Cs were the only gamma emitters observed, other than natural radioactivity, at levels >8 pCi/L. Seventeen wells showed no gamma emitters, two wells contained only ^{137}Cs, and one well contained both ^{60}Co and ^{137}Cs.

Table 13 shows results for 12 wells assayed for ^{90}Sr at levels >6 pCi/L. Seven of the wells showed no ^{90}Sr, four wells contained small detectable levels, and one well was significantly higher in ^{90}Sr than the others. The high well (MGG 21) is also high in alpha emitters and is chemically anomalous.

Table 13 also shows results for 12 wells assayed by low-level alpha pulse height analysis. ^{238}Pu and ^{239}Pu were the only plutonium alpha emitters observed at levels >1 pCi/L. Four of the wells showed no plutonium alpha emitters, five wells contained only ^{238}Pu, and three wells contained both ^{238}Pu and ^{239}Pu.

Radionuclide Analysis in the 643-7G and 643-28G Burial Grounds

During 1984, there were 267 analyses for tritium, gross alpha, and gross nonvolatile beta radioactivity performed on groundwater samples from the 23 grid wells in the 643-7G and 643-28G Burial Grounds. Nominal sampling frequency was quarterly. Annual average radionuclide concentrations for each well for 1984 are given in Table 14, which also contains 1983 results for comparison. Concentrations averaged over all grid wells in the 643-7G and 643-28G Burial Grounds for each year since 1981 are given in Table 15.

The annual average gross alpha concentration for the 643-7G and 643-28G grid wells has been approximately constant and relatively low since the wells were installed in 1980. In 1984, two wells had gross alpha concentrations >3 pCi/L, one of which (well 22.18) contained >6 pCi/L of gross alpha. Based on the 1984 concentrations, groundwater beneath the portion of the 643-7G and 643-28G Burial Grounds monitored by grid wells is estimated to contain 0.5 mCi of alpha emitters.

TABLE 13

Radionuclide Content of Groundwater Wells at the Burial Grounds

Radionuclide	Concentration (pCi/L) Average	Range	Number of Wells	Detection Limit (pCi/L)
^{60}Co	13	-	1 of 20	8
^{90}Sr*	19	7-30	4 of 11	6
^{137}Cs	12	10-16	3 of 20	8
^{238}Pu	5	2-17	8 of 12	1
^{239}Pu	3	2-4	3 of 12	1
Gamma**	-	-	0 of 20	8

* In addition, one well contained 1,600 pCi/L of ^{90}Sr.
** No gamma emitters other than ^{60}Co and ^{137}Cs were observed.

TABLE 14

Radionuclide Concentrations in 643-7G and 643-28G Grid Wells

Well	Alpha (pCi/L)		Nonvolatile Beta (pCi/L)		Tritium (µCi/L)	
	1983	1984	1983	1984	1983	1984
22.04	1	1	3	7	0.09	0.3
22.06	3	2	3	5	13	20
22.08	1	1	1	2	21	79
22.10	2	2	6	1	0.5	1
22.12	<1	1	3	2	0.07	0.2
22.14	-	1	-	1	-	0.04
22.16	3	2	3	5	0.03	0.05
22.18	7	7	5	8	0.03	0.03
22.20	1	2	3	1	0.02	0.04
22.22	<1	1	3	1	0.02	0.03
24.02	1	1	3	1	0.07	0.2
24.04	1	<1	7	2	0.2	0.7
24.06	<1	<1	4	1	0.7	2
24.08	2	2	8	2	0.2	10
24.10	1	1	1	2	0.02	5
24.20	<1	1	1	2	0.3	5
24.22	1	1	4	3	0.04	0.4
26.20	1	1	8	3	1	1
26.22	1	2	4	15	0.07	0.3
28.18	2	3	11	9	0.2	0.2
28.20	<1	<1	14	15	1	2
28.22	4	4	8	10	155	292
28.24	2	2	1	1	1	0.02

TABLE 15

Annual Average Concentrations of Radioactivity in 643-7G and 643-28G Grid Wells

	Average Annual Concentration			Tritium in 643-7G and 643-28G Plume*
	Alpha (pCi/L)	Nonvolatile Beta (pCi/L)	Tritium (μCi/L)	(Ci)
1981	3	19	0.6	200
1982	3	20	2.8	900
1983	2	5	8.8	2,800
1984	2	4	18.0	5,600

* Estimated tritium in groundwater beneath the portion of the 643-7G and 643-28G Burial Grounds monitored by grid wells.

Average gross nonvolatile beta concentration in 1984 also was relatively low and about the same as in 1983. In 1984, none of the grid wells in the 643-7G and 643-28G Burial Grounds had gross nonvolatile beta concentrations >50 pCi/L. Based on the 1984 concentrations, the groundwater beneath the portion of the 643-7G and 643-28G Burial Grounds monitored by grid wells is estimated to contain 1 mCi of nonvolatile beta emitters.

Tritium concentrations averaged over all grid wells in the 643-7G and 643-28G Burial Grounds have increased steadily since 1981. Estimates of the total amount of tritium in the groundwater beneath the portion of the 643-7G and 643-28G Burial Grounds monitored by grid wells are given in Table 15. For 1984, the estimate is 5,600 Ci of tritium. In addition, substantial amounts of tritium are expected in groundwater beneath portions of the 643-7G and 643-28G Burial Grounds not monitored by grid wells, particularly the eastern corner. Most of these areas are not yet amenable to well installation because of active burial operations. As an indication of the amounts of tritium in the eastern sides of the 643-7G and 643-28G Burial Grounds, a special study in 1983 of a 2,028 m^2 site there showed approximately 2,000 Ci of tritium in the groundwater at that area. Numerous known burials of tritium waste in the eastern portion of the area suggest that a tritium plume will develop there also.

Summary of Radionuclide Analyses

Contour maps of 1984 radioactivity concentrations in groundwater beneath the Burial Grounds are shown in Figures 39 through 41. The overall pattern of radioactivity in the 643-G grid wells has changed little since 1979.

As shown in Figure 39, only well MGG 21 has any significant concentration of gross alpha radioactivity. Well MGG 21 has had anomalously high amounts of alpha throughout its history. The alpha emitters present have been identified as primarily ^{238}Pu and ^{239}Pu. Other isolated areas of the Burial Grounds intermittently show concentrations of gross alpha >3 pCi/L. In 1984, seven such areas were found.

Areas containing significant amounts of gross nonvolatile beta radioactivity are shown in Figure 40. As in previous years, well MGG 21 has anomalously high amounts of beta activity, identified as mostly ^{90}Sr. Well MGG 34 had relatively high nonvolatile beta concentrations for the first time in 1984. Other wells with significant concentrations are MGA 3, MGG 7, MGG 32, and MGI 1. Seven zones, primarily in the 643-G Burial Ground, had nonvolatile beta concentrations >10 pCi/L. Oblath (1986) has reported recent analyses of ^{99}Tc and ^{129}I with maximum values of 4.4 pCi/L and 13 pCi/L, respectively.

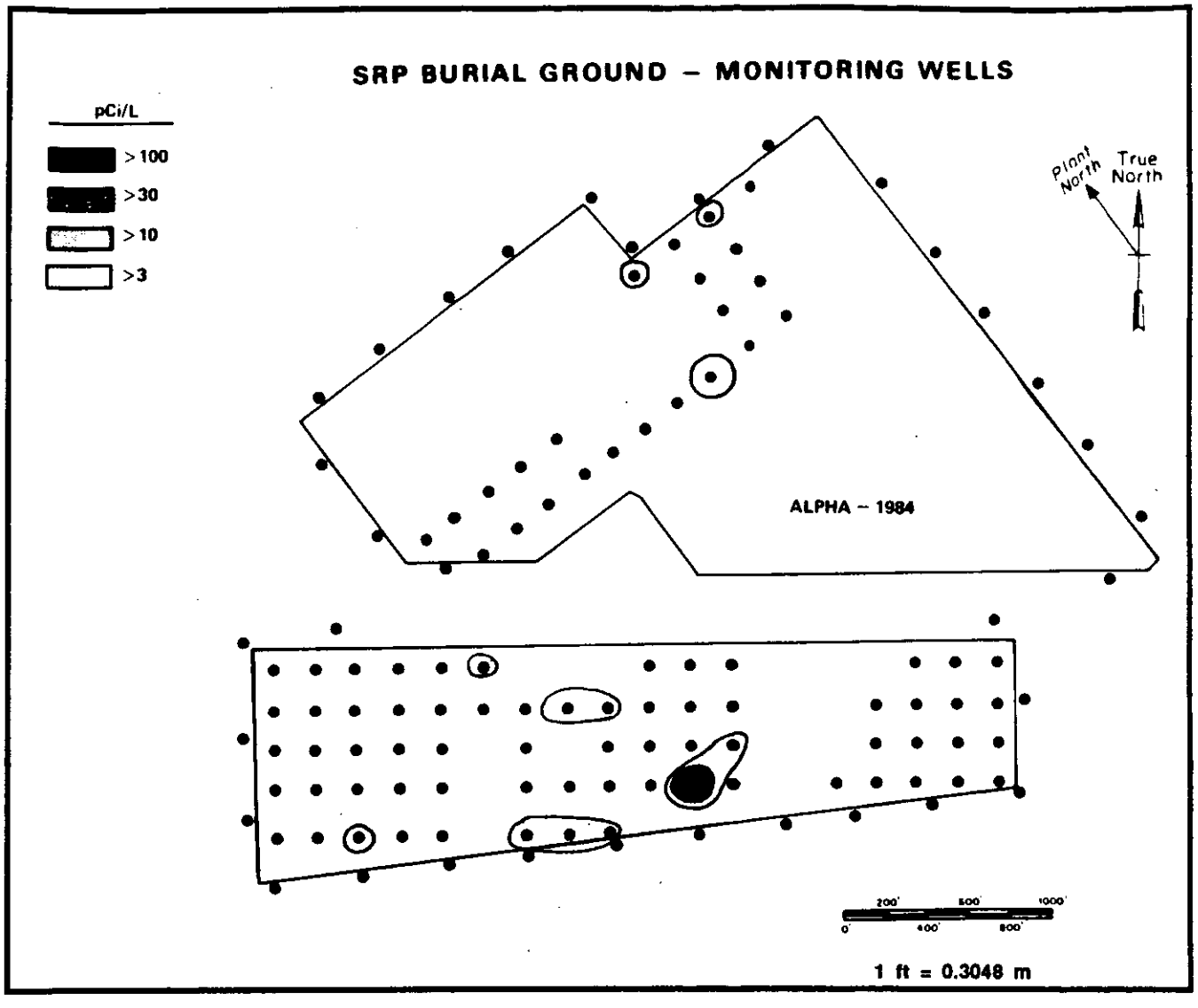


FIGURE 39. Gross Alpha Zones in Groundwater at the Burial Grounds

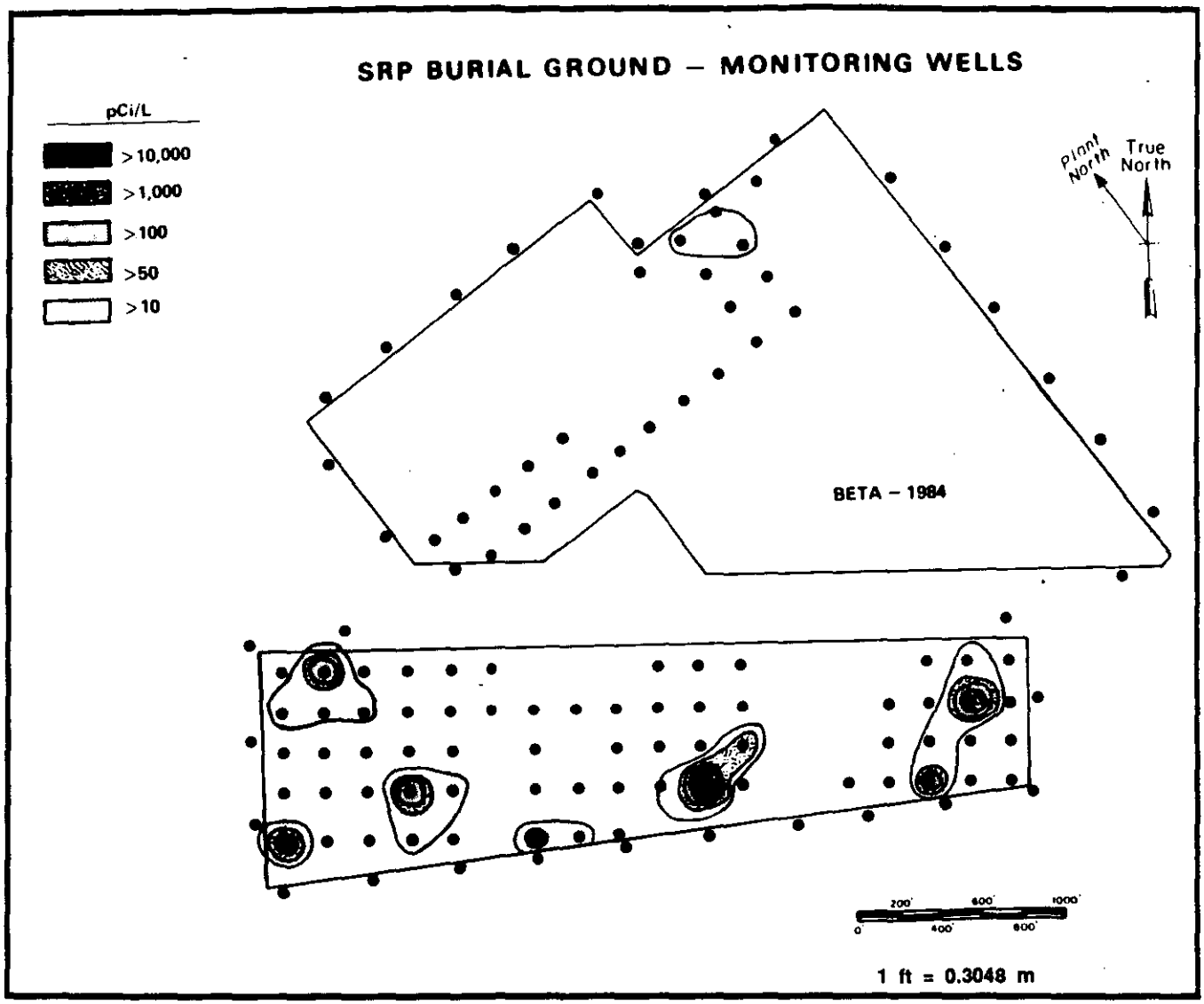


FIGURE 40. Gross Nonvolatile Beta Zones in Groundwater at the Burial Grounds

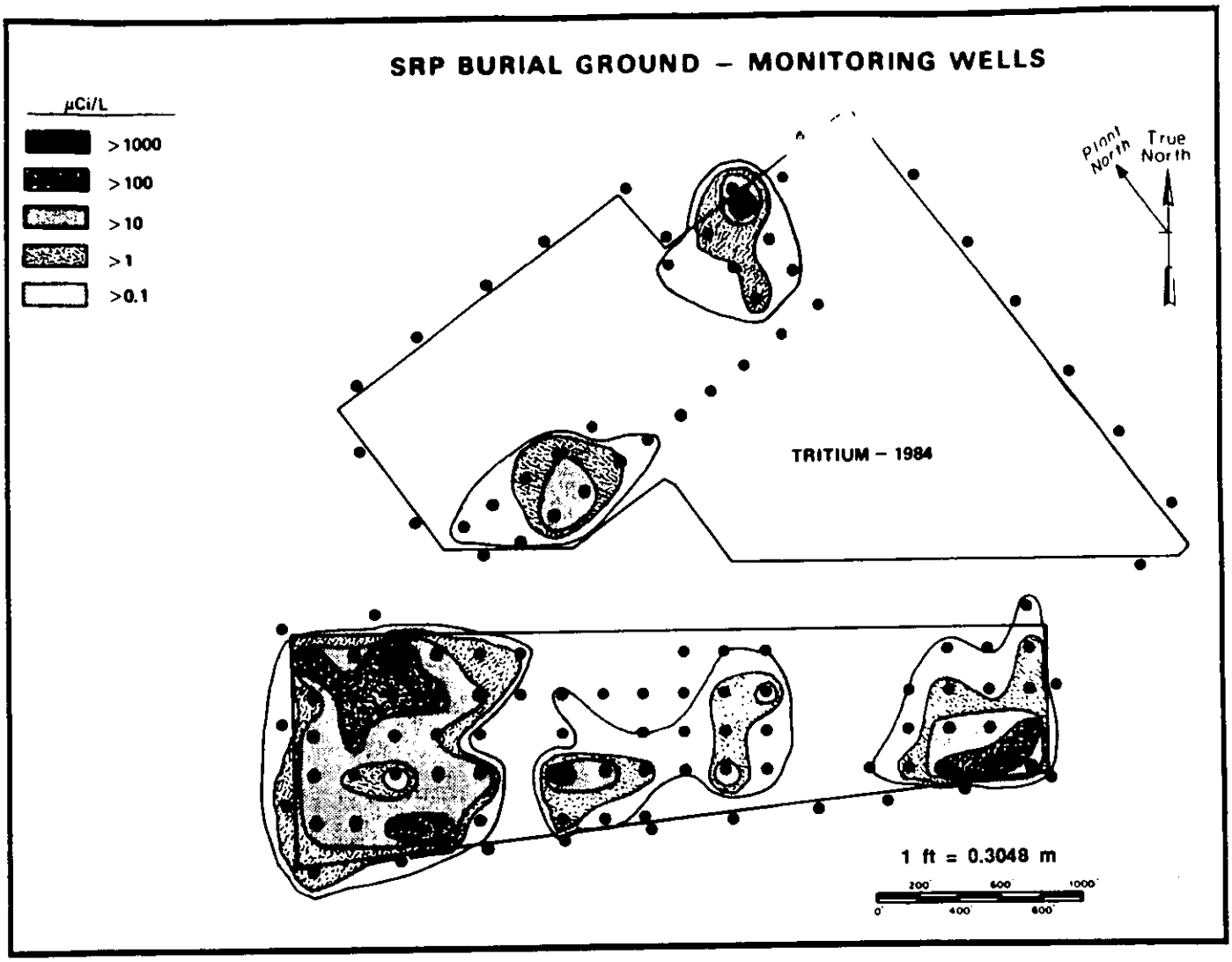


FIGURE 41. Tritium Zones in Groundwater at the Burial Grounds

Unlike most other radionuclides, tritium is readily leached and moves freely with flowing groundwater. Tritium is found in five large zones of the Burial Grounds (Figure 41). In 1984, the zone in the western portion of the 643-G Burial Ground had the highest tritium concentrations. The zone in the eastern portion of the 643-G Burial Ground continues to show large amounts of tritium, although the high concentrations observed in well MGG 34 in previous years have diminished considerably. Numerous burials of tritium waste in the western and eastern zones of the 643-G Burial Ground are known to have occurred prior to 1972. The zone in the central portion of the 643-G Burial Ground contains well MGG 21, which had the highest concentration of tritium in the Burial Grounds (1973-1977), but which has declined steadily since then. Two zones of tritium are found in the 643-7G Burial Ground, with the northern zone around well 28.22.

Nonradioactive Monitoring Data

In addition to the surveillance program for radioactive constituents in the groundwater, nonradioactive chemical species have been measured in the Burial Grounds. The construction of the wells, sampling methods, and analysis techniques used to collect these data were not consistent with current protocol; therefore, the data should be viewed as preliminary. The data are useful, however, in identifying possible constituents of concern to aid in planning of site closure and the ultimate design of a protocol monitoring well network. Proposed protocol wells for these facilities are shown in Figure 42. Installation of these wells is under way and completion is expected in 1987.

Existing Burial Ground monitoring wells have been sampled for mercury each year since 1981. The results of these studies are presented in Table 16 (Oblath, 1985a). A maximum concentration of 2.9 ppb was observed in 1984. All other wells had concentrations <0.9 ppb. Forty-three wells contained mercury at a concentration greater than 0.1 ppb (the concentration measured in the control wells).

Table 17 presents an analysis of lead and cadmium in Burial Ground monitoring wells that were measured in 1984 (Oblath, 1985b). The maximum value for lead is 398 µg/L and for cadmium is 365 µg/L. The median (background) lead and cadmium concentrations in SRP groundwater are approximately 15 µg/L and 2 µg/L, respectively (Looney et al., 1986). Approximately 77% of the measurements for lead in grid wells exceed the background concentration, and 97% of the grid wells exceed the background concentration for cadmium.

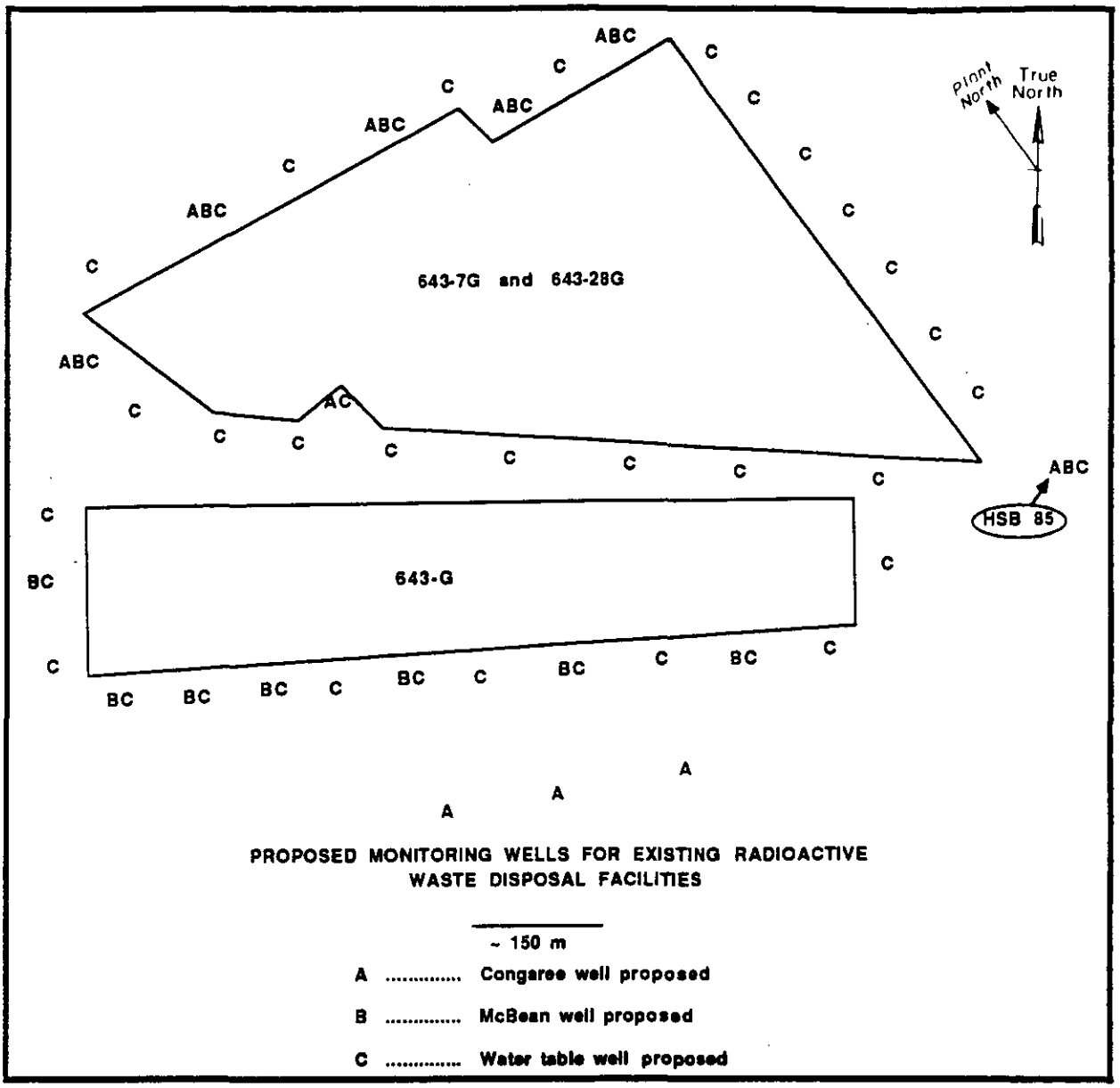


FIGURE 42. Initial Proposal for Protocol Monitoring Wells for the Existing and Previous Radioactive Waste Disposal Facilities

TABLE 16

Mercury Concentrations in Monitoring Wells at the Radioactive Waste Burial Grounds

Well No.	Mercury Concentrations (µg/L) November 1981	March 1982	November 1982	November 1983	November 1984
MGA 1	<0.1	<0.05	<0.05	0.26	0.06
3	<0.1	0.05	0.05	0.23	<0.02
5	<0.1	0.32	0.35	0.58	2.86
7	<0.1	<0.05	<0.05	0.12	<0.02
9	<0.1	0.06	0.08	0.11	0.05
11	<0.1	0.15	<0.05	0.20	<0.02
19	<0.1	0.26	<0.05	0.06	0.12
21	<0.1	<0.05	0.07	0.13	0.06
23	<0.1	0.13	<0.05	<0.05	0.16
32	0.7	0.42	0.32	0.13	0.20
34	<0.1	<0.05	0.05	0.10	<0.02
36	<0.1	0.07	<0.05	<0.05	<0.02
MGC 1	<0.1	0.05	<0.05	0.09	<0.02
3	<0.1	0.10	<0.05	<0.05	0.08
5	-	<0.05	<0.05	<0.05	<0.02
7	0.3	0.43	0.29	<0.05	0.03
9	<0.1	<0.05	<0.05	<0.05	<0.02
11	-	-	<0.05	<0.05	<0.02
13	<0.1	0.05	<0.05	<0.05	0.09
15	<0.1	<0.05	0.08	0.06	0.06
17	<0.1	0.06	0.22	0.50	0.52
19	<0.1	<0.05	<0.05	0.13	<0.02
21	1.3	1.56	0.69	0.44	0.38
23	0.4	0.76	0.79	0.07	0.07
30	<0.1	0.22	0.11	0.14	0.15
32	<0.1	<0.05	0.13	0.25	0.42
34	-	0.43	<0.05	0.21	0.11
36	<0.1	<0.05	0.15	<0.05	0.05
MGE 1	<0.1	<0.05	<0.05	0.09	0.02
3	<0.1	0.05	0.19	<0.05	0.06
5	<0.1	0.06	0.05	<0.05	0.12
7	<0.1	0.05	<0.05	0.11	0.02
9	<0.1	0.05	<0.05	<0.05	0.03
13	<0.1	<0.05	<0.05	<0.05	0.16
15	-	-	-	-	0.10
17	-	<0.05	<0.05	0.06	0.09
19	0.2	0.06	<0.05	0.10	0.21
21	<0.1	0.15	<0.05	<0.05	0.17
23	0.2	<0.05	<0.05	<0.05	0.11
30	<0.1	<0.05	<0.05	<0.05	0.47
32	<0.1	<0.05	0.09	0.20	0.86
34	<0.1	<0.05	<0.05	0.07	0.14
36	<0.1	<0.05	<0.05	<0.05	0.14

Note: Number following < sign indicates the detection limit for the measurement. - Indicates well was not analyzed.

TABLE 16, Contd

Well No.	Mercury Concentrations (µg/L) November 1981	March 1982	November 1982	November 1983	November 1984
MGG 1	<0.1	<0.05	<0.05	0.06	0.14
3	<0.1	<0.05	<0.05	<0.05	0.19
5	<0.1	0.07	0.09	0.11	0.16
7	<0.1	<0.05	0.06	<0.05	0.11
9	<0.1	<0.05	0.08	<0.05	0.08
13	<0.1	<0.05	<0.05	0.12	0.08
15	<0.1	<0.05	<0.05	<0.05	0.10
17	<0.1	0.78	0.20	0.13	0.18
19	<0.1	<0.05	<0.05	<0.05	0.09
21	<0.1	<0.05	0.05	<0.05	<0.02
23	0.1	0.33	<0.05	<0.05	0.11
28	<0.1	0.07	0.49	0.27	0.47
30	<0.1	<0.05	<0.05	0.08	0.07
32	<0.1	<0.05	0.09	<0.05	0.09
34	<0.1	0.05	0.06	0.08	0.27
36	<0.1	<0.05	<0.05	<0.05	0.15
MGI 1	1.4	0.20	0.08	<0.05	0.04
3	-	-	-	0.09	0.11
5	<0.1	0.05	0.06	<0.05	<0.02
7	<0.1	<0.05	0.05	<0.05	<0.02
9	<0.1	0.06	0.06	0.12	0.13
13	0.4	0.51	0.26	0.26	0.33
15	<0.1	<0.05	<0.05	<0.05	0.14
17	80.1	<0.05	<0.05	<0.05	0.17
22.04	0.3	0.06	0.12	<0.05	0.23
06	0.2	<0.05	<0.05	-	-
08	0.3	<0.05	0.07	<0.05	0.12
10	0.3	<0.05	<0.05	-	-
12	0.1	<0.05	0.08	<0.05	0.12
16	0.2	<0.05	<0.05	0.07	0.04
18	0.5	<0.05	<0.05	-	-
20	<0.1	<0.05	<0.05	<0.05	0.11
22	0.5	<0.05	<0.05	-	-

Note: Number following < sign indicates the detection limit for the measurement. - Indicates well was not analyzed.

TABLE 16, Contd

Well No.	Mercury Concentrations (ug/L) November 1981	March 1982	November 1982	November 1983	November 1984
24.02	<0.1	<0.05	<0.05	0.18	0.08
04	0.2	0.10	0.13	-	-
06	<0.1	<0.05	<0.05	0.11	0.12
08	<0.1	<0.05	<0.05	-	-
10	<0.1	<0.05	0.08	0.08	0.08
20	0.2	0.05	0.11	-	-
22	<0.1	<0.05	<0.05	0.09	0.17
26.20	0.2	80.05	0.06	<0.05	0.26
22	-	0.07	<0.05	-	-
28.18	<0.1	0.05	<0.05	0.08	0.25
20	0.2	<0.05	<0.05	-	-
22	<0.1	<0.05	0.06	0.13	0.19
PDQ 5	<0.2	-	<0.1	<0.2	<0.2
PDQ 5	-	-	-	<0.2	-
BG 109	<0.1	<0.05	<0.05	0.07	0.14
BG 110	-	-	-	0.10	<0.2
1.0 ppb standard	1.2	1.02	1.09	0.92	0.74
0.1 ppb standard	0.4	0.12	0.17	0.07	0.21
2.0 ppb standard	2.3	2.28	2.06	1.87	1.40
Distilled water	0.2	<0.05	<0.05	<0.05	0.02

Note: Number following < sign indicates the detection limit for the measurement. - Indicates well was not analyzed.

TABLE 17

Lead and Cadmium Concentrations in Monitoring Wells at the Radioactive Waste Burial Grounds

Well ID	Concentrations (µg/L) Lead	Cadmium	Well ID	Concentrations (µg/L) Lead	Cadmium
MGA 1	129	75	MGG 1	34	18
3	57	47	3	45	23
5	84	74	5	64	57
7	49	9	7	15	58
9	28	6	9	21	101
11	26	71	13	30	64
19	35	65	15	12	20
21	45	57	17	21	33
23	14	35	19	26	28
32	33	60	21	27	9
34	127	100	23	74	10
36	10	20	28	10	14
			30	96	20
MGC 1	124	68	32	51	48
3	398	131	34	27	28
5	78	121	36	42	32
7	81	37			
9	43	26	MGI 1	38	10
11	16	4	3	107	56
13	18	9	5	80	74
15	42	32	7	23	365
17	82	62	9	77	71
19	39	3	13	30	26
21	12	50	15	14	30
23	5	2	17	9	3
30	23	17			
32	8	3	22.04	35	3
34	49	14	08	11	5
36	11	22	12	16	9
			16	4	14
MGE 1	58	111	20	17	16
3	34	31			
5	68	13	24.02	24	4
7	58	49	06	46	6
9	42	4	10	147	7
13	16	3	22	16	9
15	9	87			
17	42	56	26.20	20	8
19	31	39			
21	13	7	28.18	6	1
23	19	4	22	10	1
30	6	65			
32	12	57	BG 109	1	8
34	13	26			
36	25	25	Avg =	42.7	38.9
			Min =	4	1
			Max =	398	365
			Std dev =	51.3	48.2

Note: Data obtained in 1984.

Preliminary studies indicate that several organic substances may be present in grid well water (Hoeffner et al., 1985). Some substances were related to waste oil, spent solvents, or liquid scintillation wastes. Reanalysis of these wells using standard EPA protocol is recommended to aid in determining the nature and extent of organic contamination (if any) in the Burial Grounds.

STATISTICAL ANALYSIS OF GROUNDWATER DATA

Protocol monitoring wells are not available for these facilities; therefore, statistical analysis is not possible at this time. A general discussion of upgradient versus downgradient concentrations in nearby groundwater is presented in the previous section.

IDENTIFICATION OF CONTAMINANT SUBSTANCES AND ESTIMATED INVENTORIES

Chemical constituents that have been disposed of at existing waste sites at SRP have been identified and their inventories estimated. This information is used to assess the environmental impacts and health risks associated with the various site closure options being considered. All available records have been reviewed to determine which substances were released to the waste sites during their operational histories. Where available, these records include groundwater monitoring data, waste-site characterization studies, influent waste stream measurements, and process chemical records. These inventories provide the source term information required to calculate the transport and potential risk for each material.

The concentrations of chemical constituents released to each waste site were compared to special selection criteria (Looney et al., 1986a). If the groundwater or soil concentration of a given constituent exceeded its selection criterion, the material was designated for inclusion in the transport modeling and risk assessment studies. Additionally, if large amounts of specific chemicals with a health or environmental risk were believed to have been released to a site (based upon inventory or process use), these constituents were also designated for assessment, even if the soil or groundwater characterization data did not indicate their presence.

Table 18 lists the contaminants selected for environmental assessment of the Radioactive Waste Burial Grounds. These constituents were chosen based upon records that document their placement in the Burial Grounds or their detection in area groundwater samples (Looney et al., 1986a). These disposal quantities reflect the assumption that retrievably stored TRU wastes are removed in all options.

TABLE 18

Materials Selected for Environmental Assessment

Selected Constituents	Estimated Disposal Mass or Activity (Undecayed Total)
^{241}Am	4.0E+01 Ci
^{243}Am	2.3E-02 Ci
^{137}Ba	1.7E+04 Ci
^{14}C	6.6E-03 Ci
^{252}Cf	2.4E+01 Ci
^{244}Cm	3.9E+04 Ci
^{60}Co	3.3E+06 Ci
^{134}Cs	1.4E+04 Ci
^{137}Cs	1.7E+04 Ci
^{154}Eu	2.4E+03 Ci
^{155}Eu	2.0E+03 Ci
^{3}H	4.1E+06 Ci
^{129}I	1.4E+01 Ci
^{59}Ni	6.6E+00 Ci
^{63}Ni	3.5E+05 Ci
^{237}Np	1.3E-01 Ci
^{147}Pm	9.6E+04 Ci
^{238}Pu	5.3E+03 Ci
^{239}Pu	6.4E+02 Ci
^{241}Pu	3.3E+02 Ci
^{242}Pu	2.6E-02 Ci
^{87}Rb	3.3E-05 Ci
^{106}Rh	1.2E+04 Ci
^{106}Ru	1.2E+04 Ci
^{125}Sb	3.3E+03 Ci
^{79}Se	6.6E-01 Ci
^{151}Sm	9.2E+02 Ci
^{90}Sr	1.7E+04 Ci
^{99}Tc	2.0E+01 Ci
^{228}Th	1.3E-02 Ci
^{232}Th	1.0E-01 Ci
^{233}U	1.3E+00 Ci
^{234}U	8.0E+00 Ci
^{235}U	9.7E-01 Ci
^{236}U	1.8E-01 Ci
^{238}U	6.4E+01 Ci
^{90}Y	1.7E+04 Ci
Cadmium	2.0E+03 kg
Lead	1.0E+05 kg
Mercury	1.0E+04 kg
Naphthalene	4.0E+03 kg
Toluene	1.3E+04 kg
Trimethylbenzene	1.3E+04 kg
Xylene	2.1E+04 kg

CLOSURE OPTIONS

The Radioactive Waste Burial Grounds will be closed at some future date in accordance with all applicable state and federal regulations. Many closure options for these sites could be developed and evaluated for environmental soundness and cost effectiveness. To establish a range for potential environmental consequences and funding requirements for closure of these sites, three basic options have been examined:

- Waste removal and closure
- No waste removal and closure
- No action

These options were not developed specifically for regulatory compliance, but to bound the potential impact of possible future closure actions. The specific details of the commitments to maintenance, monitoring, and cap design in this section were selected primarily for the purpose of deriving reasonable and consistent relative cost estimates.

The primary objective of remedial action during closure would be to reduce the transport of radionuclides contained in the buried waste to areas outside the waste disposal area. This can be accomplished in general by such means as reducing the vertical and/or horizontal water input to the waste and reducing the probability of plant, animal, or human intrusion into the waste.

Closure is assumed to take place after the waste disposal facility has been filled and at some time during the period of institutional control. The methods generally employed to reduce water infiltration and intrusion probability are:

- Capping the facility with soil, clay, compacted clay, man-made materials such as cement or plastics or combinations of these materials.

- Installing barrier walls around the facility with materials such as cement or a bentonite-clay mixture of different thickness. Barrier walls can be partial, enclosing one or two sides of the facility, or they can be encompassing.

- Combining capping and barrier walls.

Site caps and barrier walls reduce the amount of vertical and/or horizontal water infiltration. The thickness and hardness of the cap can be varied depending on the concern for human intrusion. The final soil cover on the cap can be made to support a variety of plant life. Deep-rooted vegetation can be prevented for long periods of time by providing a long-lasting altered climax vegetation of dense plant life such as bamboo or honeysuckle.

Studies have been made, as described, for example, in Cook (1986), on the effectiveness and costs of providing caps and barrier walls on and around the older section of the disposal area (643-G). This 3.1E+05 m^2 area was filled by 1972. In this study it was assumed that the cap extended past the sides of the 3.1E+05 m^2 area, covering a total area that is 25% larger. The major results of the modeling study are presented in the paragraphs below.

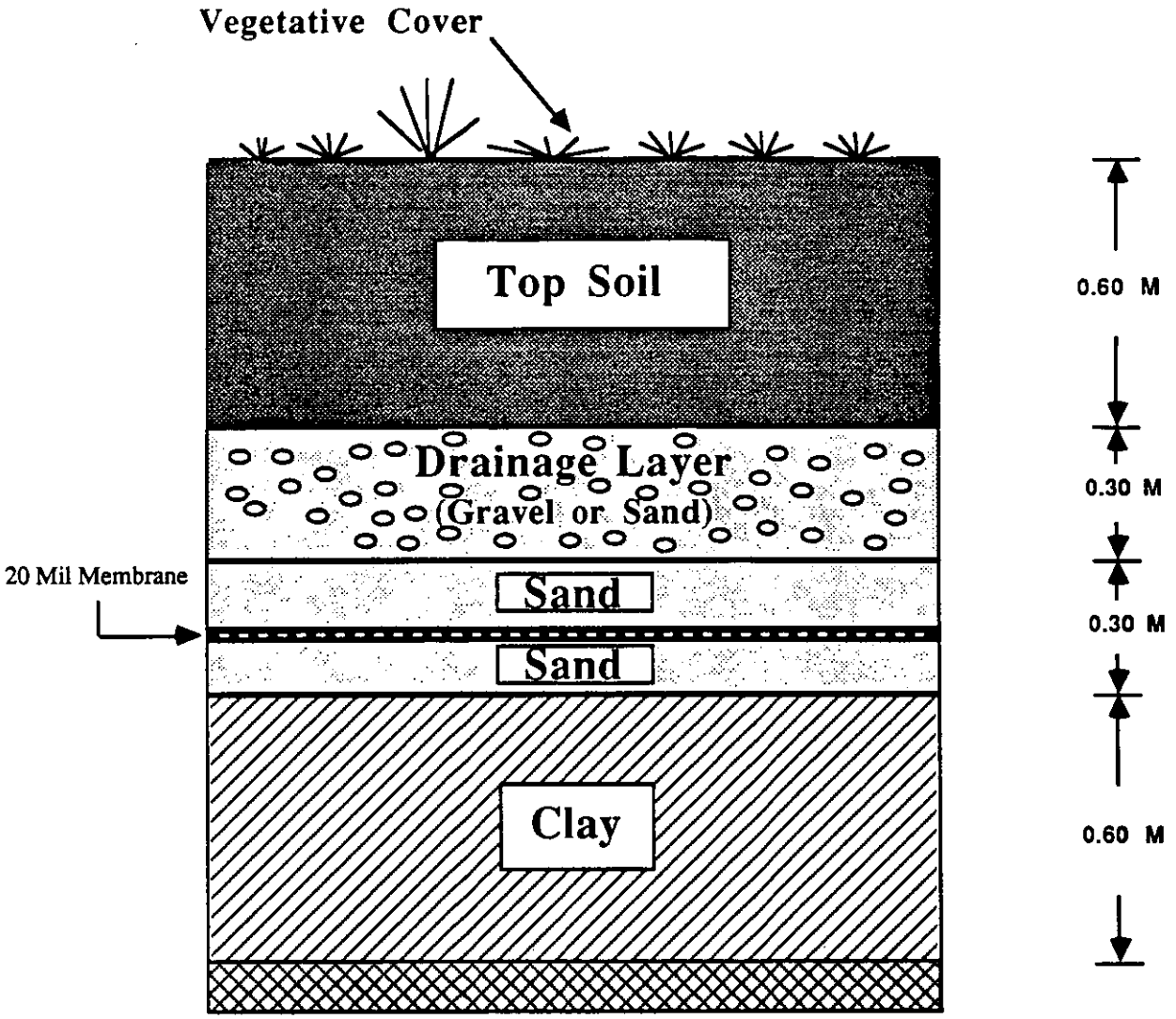
The modeling studies documented in Cook (1986), show that capping alone can reduce water infiltration to and through the waste by 63 to 66%. The caps studied ranged from sandy topsoil, with a permeability of 7.0E-04 cm/s, to clayey soil with a permeability of 6.0E-05, to soils containing a 0.6-m thick layer of compacted bentonite clay with an assumed permeability of 1.0E-08 cm/s. The cap thickness was varied from 1.2 to 4.3 m.

Flow reductions due to barrier or cutoff walls were also described in Cook (1986). The cutoff walls are assumed to be 30.5 m deep and 0.9 m thick, made from a slurry. Permeability of the cutoff walls is assumed to be 1.0E-06 to 1.0E-07 cm/s. Two types of slurries were studied: a soil-bentonite clay slurry and a cement-bentonite slurry. Additional remedial actions such as groundwater withdrawal and treatment are also to be evaluated for this site.

As described above, a variety of remedial action options are under consideration for closure of the 643-G and 643-7G Burial Grounds. Additional data are required prior to determining the actual remedial action to be carried out; however, the site cap option was selected to allow determination of costs, risks, and benefits. The location of a groundwater divide across the area minimizes the utility of a barrier wall; thus, it was not considered for this analysis. For this assessment, a cap would be placed on the 643-G and 643-7G Burial Grounds. This cap (Figure 43) would cover approximately 8.0E+05 m^2. The cap (or equivalent) would be covered with shallow-rooted vegetation. The volumes of material required are 4.8E+05 m^3 of topsoil, 2.4E+05 m^3 of drainage sand, 2.4E+05 m^3 of buffer sand, 8.0E+05 m^2 of 20-mil plastic liner, and 4.8E+05 m^3 of compacted clay.

WASTE REMOVAL AND CLOSURE

For the waste removal and closure option, excavation of the waste disposal area would entail removal of the waste and soil from the waste trenches and disposal of it in a waste storage/disposal facility or the removal of the waste from the waste trenches, processing it by sorting, size reduction, and stabilization and redisposing of the treated waste at a waste storage/disposal facility.



Note: Permeability of drainage layer is >1.03E-03 cm/s. Permeability of clay is <1.0E-07 cm/s. Infiltration reduction is 99%.

FIGURE 43. Schematic Diagram of a Low-Permeability Cap

Without prejudging excavation, but based on experience at other sites (for example, excavation work at the TRU waste storage area at Idaho Falls), excavation is a difficult, manpower-intensive, worker exposure-intensive process. At SRP, where the solid waste was buried with no intention of retrieval, the following special problems would have to be addressed and solved before excavation could proceed:

- Removal of contaminated solvent tanks
- High radiation intensities of 300 R/hour or more of many of the metal waste forms containing induced or surface contamination activity--spent melt crucibles, irradiated reactor fuel and target housings and hardware, fuel reprocessing vessels, etc.
- Contaminated mercury, disposed of in plastic bottles during the period from startup to about 1968
- Classified waste forms, disposed of beneath very high radiation intensity waste. Excavation of this waste may not be consistent with national security policy.
- Heavy, shielded, Navy reactor core vessels and other Navy components
- Contaminated heavy equipment that has ended its useful life at the waste disposal area, such as large cranes, trucks, and earth-moving equipment
- Concrete monoliths, unreinforced, containing alpha waste
- Greater Confinement Disposal (GCD) boreholes--cylindrical concrete monoliths (2.1 m in diameter, 6.1 m long, buried 4.9 m below the ground surface after closure) and GCD trenches.

Excavation would require excavating machines, either remotely operated or operated by personnel in shielded cabs, to excavate waste along known trench lines. The excavation would be larger and deeper than the original trench to assure that adjacent soil, possibly contaminated, would also be excavated. The excavation process would take place in a covered area to prevent rain water from contacting the excavated waste.

The estimated length of trench to be excavated is about 64,000 linear m, based on 50% use of the Burial Ground area. About 3.0E+06 m^3 of waste and contaminated soil would have to be excavated. A partial excavation option, which focused waste removal on areas of high activity or high subsidence potential based on survey data, is also possible. A partial excavation option would result in lower waste removal estimates than above; however, current data

and technologies are inadequate for determining the magnitude of the reduction (if any). Additionally, reasonable partial excavation options would leave residual radionuclide concentrations in excess of DOE guidelines for unrestricted sites.

After excavation, the waste-soil mixture would be sent to a process area where the mixture would be sorted, assayed, size-reduced, stabilized, and packaged for transport and disposal. The sorting process would take place on a number of conveyor belts and would be accomplished by remote sorting with manipulators. Small pieces and soil could be removed by a sorter such as a bouncing ball screen arrangement that is part of the conveyor system. Waste treatment would include such processes as incineration, shredding, compaction, stabilization with grout, etc. Waste and soil with very low levels of radioactivity could be returned to the original waste disposal area. The trigger value for the activity/concentrations would have to be determined--a present de minimus value for low-level waste does not exist.

Residual waste following treatment and sorting would be placed in metal boxes and transported to an appropriate waste storage/disposal facility. The disposal volume to be evaluated should be 3.0E+06 m^3; uncertainties regarding treatment and handling preclude estimation of any volume reduction.

Excavation and waste processing have been studied previously for unconsolidated TRU waste disposed of at SRP (DOE, 1979). This study shows that excavation costs would be about $25,000 per linear meter of trench (1979 dollars), and that waste treatment costs would be about $44,200 per linear meter of trench excavated (1979 dollars). These costs do not account for the special problems outlined earlier.

After excavation, the original waste disposal area would be closed using the low-permeability cap described above. The site would remain fenced and current engineered drainage continued. Reseeding and mowing would be carried out as needed. Grade would be re-established and the cap repaired following any subsidence events. Perimeter wells and well clusters would be used for monitoring groundwater (sampled quarterly for 1 year, then annually for a minimum of 99 years). Institutional control would continue for 100 years following closure. Site maintenance and groundwater monitoring as needed would continue for the entire period of institutional control.

NO WASTE REMOVAL AND CLOSURE

The no waste removal and closure option would consist of leaving the waste in place and closing the site using the low-permeability cap described above. The site would remain fenced and current engineered drainage continued. Reseeding and mowing would be carried out as needed. Grade would be re-established and the cap repaired following any subsidence events. Perimeter wells and well clusters would be used for monitoring groundwater as described above. Site maintenance and groundwater monitoring as needed would continue for the entire period of institutional control.

NO ACTION

The no action option would continue present operation until SRP operation ceases, followed by a period of institutional control generally considered to last for 100 years. Present operations of the filled portions of the Burial Grounds consist of

- Maintaining present fencing and surface drainage patterns
- Correcting trench subsidence as it occurs by backfilling with clean soil
- Reseeding as required with a shallow-rooted grass cover
- Frequent mowing to prevent onset of deep-rooted vegetation
- Monitoring for chemical and radioactive contamination in the existing perimeter wells and well clusters
- Maintaining control of access to the facility (security).

The operations described above would be applied to the entire 7.9E+05 m^2 of the facility; however, subsidence occurrences in the first-used section of the waste disposal facility, 643-G, are expected to be infrequent because waste disposal has not taken place in that area since 1972. Site maintenance and groundwater monitoring as needed would continue for the entire period of institutional control.

ESTIMATES OF ENVIRONMENTAL IMPACTS

The environmental consequences due to closure actions at waste disposal facilities can be grouped into two categories. The first is the relative risk to human health resulting from potential exposure to waste materials transported through groundwater or atmospheric pathways. The second is the potential impact on the aquatic and terrestrial ecosystems due to transport of waste materials into these environments.

Estimates of the environmental impacts in terms of potential human health risk and ecological upsets due to the postulated closure options for the Radioactive Waste Burial Grounds have been completed. The results of these evaluations are given in the following sections along with the details of analysis.

Three premises are assumed in the analysis of potential environmental consequences. First, it is assumed that the Department of Energy (DOE) will maintain institutional control over the SRP site for 100 years beyond 1985. This assumption is reasonable in light of current production planning and projected scheduling for site decommissioning. Second, the basic time period for the long-term analyses has been set at 1,000 years beyond 1985 because Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC) guidelines specify 1,000 years as a reasonable time for projected calculations. Third, it is assumed that nearly all (99%) of the current waste source is removed in the waste removal and closure option.

HUMAN HEALTH RISKS

Pathway Analysis

In a general sense, exposure of waste materials in a disposal facility to a human population can occur only as a result of transport via surface, subsurface, or atmospheric pathways. At SRP the surface and subsurface pathways of most importance are groundwater movement to water wells, groundwater movement to surface streams, erosion of waste materials and movement to a surface stream, consumption of food produced from farmland reclaimed over a waste site, consumption of crops grown from natural biointrusion of land over a waste site, and direct exposure to gamma radiation. The relevant atmospheric pathways for human exposure are inhalation of waste particulates or gases in air, ingestion of foodstuffs containing waste materials resulting from deposition of air particulates on the ground surface, and external radiation from air particulates deposited on the ground. Computer codes for simulating transport of waste constituents through surface, subsurface, and atmospheric pathways are described briefly below and in more detail in Stephenson et al. (1987).

Surface and Subsurface Pathways

To calculate the human health risks associated with surface and subsurface transport of radioactive and nonradioactive waste materials, the PATHRAE computer code was chosen. Developed for the EPA for performance assessment calculations of low-level radioactive waste sites, the code has been modified to perform transport and risk calculations for nonradioactive waste materials as well.

The PATHRAE methodology was used to calculate the surface and subsurface pathway scenarios of interest at the Radioactive Waste Burial Grounds. These pathways are groundwater movement to nearby hypothetical water wells, groundwater movement to surface streams and ultimately to the Savannah River, waste erosion and movement to a surface stream and ultimately to the Savannah River, consumption of food grown on reclaimed farmland over the waste site, consumption of crops grown from natural biointrusion into the waste site, and direct gamma exposure.

For groundwater movement to nearby water wells, the pathway consists of downward migration of the modeled waste components through advection and diffusion or as a result of dissolution in percolating precipitation. The PATHRAE calculations assume that a small fraction of the cationic contaminants will be in a more highly transportable form (K_d = 0.001 mL/g) to account for chemical speciation and factors that result in high mobility of cations (low pH, organic and/or inorganic complexation). This fraction is termed the facilitated transport fraction. This assumption results in a conservative calculation of the transport of cations through the hydrologic system in the time period of interest and is in agreement with groundwater monitoring results. These waste components move downward through the unsaturated zone to the aquifer below the disposal site. They mix with water in the saturated zone of the aquifer and move to nearby wells located downgradient (in the sense of aquifer flow). Two hypothetical well scenarios are analyzed: one immediately adjacent to the waste disposal facility (at 1 m) and one downstream from the edge of the facility (at 100 m). The models for both vertical and horizontal movement of waste materials account for chemical retardation by the soils. Once withdrawn from the well, the water is assumed to be consumed directly by individuals or used to irrigate crops that are then consumed by these same individuals.

For groundwater movement to surface streams, the pathway is similar to the one described above, but the modeled waste components are assumed to continue to move through the aquifer until released to surface waters. For the purpose of analyzing the potential impacts of releases through this pathway, the release is assumed to be into nearby surface streams and ultimately into the

Savannah River, with its downstream consumer populations. For modeling purposes, the waste components are assumed to be transported instantaneously to the Savannah River without further dilution and to be completely mixed with water in the Savannah River.

The scenario for erosion and movement to a surface stream involves the gradual removal of the cover over the disposed waste by erosion and eventually the slow removal of the waste itself. The time required for erosion of the total cover depth is calculated. Then erosion operates on the waste materials by removing a given amount (specific depth) from the top of the waste each year. A conservative assumption is made that the modeled eroded waste components flow over the ground surface and into the surface stream in the same year they are removed from the disposed waste volume. Once the waste components reach the surface stream, they are assumed to be transported instantaneously to the Savannah River without further dilution and to be completely mixed with water in the Savannah River.

The pathway for consumption of food grown on reclaimed farmland accounts for potential exposure of individuals to waste materials through the human food chain. This pathway assumes that reclamation activities are required to cause exposure to waste materials. The means for disturbing the waste materials are modeled as drilling wells through the waste and excavating basements for homes. A volume of waste excavated by these activities is assumed to be completely mixed with a volume of soil down to 1 m. The soil mixture then is assumed to be used to grow a representative set of edible crops and forage for milk- and meat-producing animals. Individuals are assumed to get some fraction of their food needs from contaminated crops, meat, and milk.

A slightly different pathway involves consumption of crops whose roots have grown through subsurface sediments by natural biointrusion. Vegetation roots are presumed to take up waste constituents, and these crops, contaminated by root uptake, are directly consumed by humans. The distinction here is that no reclamation activities are imposed, only crops are consumed, and then only directly.

The direct gamma exposure pathway calculates the external radiation dose to an individual standing directly over a waste site. The cover material over the waste is allowed to erode at a specified rate, so the degree of shielding provided by the cover may decrease in time. For this pathway the conservative assumption is made that no loss of contaminants occurs by leaching to the groundwater pathways. The time dependence of the source term is described solely by radioactive decay.

Atmospheric Pathway

Modeling calculations to determine potential risk to human populations due to atmospheric transport of waste materials have been made using a variety of computer codes. The pathway scenarios considered for the Radioactive Waste Burial Grounds are inhalation of polluted air, ingestion of contaminated foodstuffs, and exposure to direct gamma radiation.

Atmospheric source terms for the site must first be estimated from soil inventories. Atmospheric source terms account for volatilization of select contaminants (i.e., organics), dust generated by suspension of contaminated soil due to wind erosion (saltation), and dust generated as a consequence of excavation of contaminated soil from the site. The time-dependent nature of atmospheric source terms must also be estimated to account for the time period of interest in this analysis (1,000 years). SESOIL, an EPA soil layer model, is used to estimate the soil contaminant concentration profiles as a function of time. The model accounts for potential upward transport (volatilization) and downward movement (infiltration) of each contaminant for each closure option. Airborne contaminant loadings are estimated using SESOIL and MARIAH (a newly developed computer code that employs a National Oceanographic and Atmospheric Administration box model and EPA source term equations). SESOIL estimates the amount of contamination entering the atmosphere over time from the site via volatilization. MARIAH estimates suspended dust loading to the atmosphere and excavation-generated dust loading due to digging, vehicular movement, and dumping. The source term for potential atmospheric transport away from the site--the contaminant loading due to dust--is the product of the dust loading and the contaminant concentration in the top soil layer.

The transport of contaminants from a waste disposal facility to potential receptor sites through atmospheric dispersion is modeled using the XOQDOQ computer code (Sagendorf et al., 1982), an NRC model that is used for routine atmospheric dispersion calculations at SRP. The calculated dispersion has been verified by environmental measurements of tritium (Marter, 1984). The XOQDOQ transport code uses a modified Gaussian plume model to estimate contaminant concentration as a function of distance and direction from a waste site. Time-dependent contaminant source strength and meteorological conditions are also input parameters.

Calculation of the transport of materials from SRP by the atmosphere is based on meteorological conditions that are measured continuously at seven on-plant meteorological towers and at a 366-m television transmitting tower 30 km northwest of the geometric center of SRP. For this analysis, meteorological dispersion and

deposition were calculated with meteorological measurements over a 5-year period (1975 through 1979) collected at a meteorological tower located near the center of the SRP site (H Area).

After waste contaminant concentrations at potential receptor locations are determined, the results are translated into individual and population exposures. The maximum exposed individual at the site boundary and general population exposures to airborne contaminants via inhalation, ingestion, and direct gamma radiation pathways are estimated for nonradioactive and radioactive constituents.

Nonradioactive Constituents

The CONEX computer code uses XOQDOQ transport results and local population demographics to estimate time-dependent population exposures to nonradioactive constituents. The TERREX computer code also uses XOQDOQ transport results along with local crop production data and local population demographics to estimate population exposures to contaminated foodstuffs. The population demographics used in the CONEX and TERREX codes are estimated using a population growth model. Using census data from 1980 as the initial basis, the population growth model estimates the surrounding population from 1980 to 2050. After 2050, the population is assumed to be constant. After the end of the assumed period of institutional control (2085), it is assumed that the SRP reservation is inhabited by the public. Hence, the air receptor is closer to the waste site at the end of the period of institutional control.

Risk posed to the public population from nonradioactive constituents is calculated using a newly developed computer code called MILENIUM. For each potentially airborne contaminant, the MILENIUM code translates time-dependent exposure results into a population dose and into a maximum exposed individual dose. Calculated doses are then converted to risk estimates in the MILENIUM code.

Radioactive Constituents

To calculate the human health risks associated with atmospheric transport of radioactive waste materials, transport and dosimetry models developed by the NRC and others for assessing the effects of operations of licensed commercial nuclear facilities were chosen (NRC, 1977a, 1977b; ICRP, 1978). The radioactive transport and dose models have been implemented in the computer codes MAXIGASP and POPGASP as well as XOQDOQ. MAXIGASP is a computer program to calculate maximum and average doses to offsite individuals from atmospheric releases. POPGASP is a computer program to calculate population doses from atmospheric releases. Both of these codes are SRL-modified versions of the NRC program

GASPAR (Eckerman et al., 1980). The modifications are those needed to meet the requirements for input of specific SRP physical and biological data. The basic calculational methods used in the GASPAR program were not modified.

Radioactive materials released to the environment generally become involved in a complex series of physical, chemical, and biological processes. Some of these processes involve dilution while others involve physical or biological reconcentration, followed by transfer through various pathways to man.

Annual average concentration and deposition factors calculated with the XOQDOQ program are used in the MAXIGASP and POPGASP programs along with data on population distribution, vegetable crop production, milk production, and meat production to calculate offsite radiation exposure. The major exposure pathways considered in the calculation of atmospheric doses are briefly described as follows:

Pathway	Description
Plume	External dose from radioactive materials transported by the atmosphere
Ground	External dose from radioactive material deposited on the ground
Inhalation	Internal dose from inhalation of radioactive materials transported by the atmosphere
Vegetation	Internal dose from consumption of vegetable food crops that contain radioactive material deposited from the atmosphere
Milk	Internal dose from consumption of milk that contains radioactive material deposited from the atmosphere into the human food chain through livestock
Meat	Internal dose from consumption of meat products that contain radioactive material deposited from the atmosphere into the human food chain through livestock

Occupational Exposure

Risk posed to the worker involved in waste excavation activities of nonradioactive constituents is estimated using the MARIAH and MILENIUM computer codes. The MARIAH code estimates the amount

of dust generated during the excavation of a waste site and the time required to complete the activity. The MILENIUM code uses these results and appropriate conversion factors to estimate excess worker risk. A conservative assumption built into these models is that the occupational work force would not use any special protective clothing during waste excavation operations. In actuality, operating policy and federal standards require all workers to use protective clothing if exposure potential is present. Risk for workers would be reduced by a factor of 50 if they use standard respiratory equipment.

Radiation exposure pathways are evaluated to calculate risks attributable to closure activities. Exposure from the following pathways are considered: internal dose (from inhalation) to personnel directly involved in cleanup activities; external dose to personnel directly involved in cleanup activities; and external dose to personnel involved in transportation of contaminated waste.

For the inhalation pathway, parameters such as the size of the work force, volume of waste to be excavated, and the number of work days required to excavate the waste are estimated. Concentrations of waste constituents in the air to which workers are exposed at the waste site were calculated with dust generation and resuspension models described previously and combined with work-force parameters to estimate worker inhalation exposure, dose commitment, and risk.

Exposures due to external irradiation of site workers are estimated using the DECOM computer code (Till & Moore, 1986), a pathway analysis methodology that calculates the quantity of contaminated soil that must be removed in order to keep exposures from all potential pathways below a value selected by the user. External dose rate is calculated using the dose factors of Kocher and Sjoreen (1985). The model employed in DECOM accounts for radionuclide contaminations in 15-cm increments of depth and estimated exposure from the top 15 cm as well as the contribution from contaminated soil beneath the exposed layer. Worker exposure is estimated for the work crew (excluding truck drivers) by assuming workers are exposed to the external radiation field at each area for the period of cleanup required for the area. Exposure of drivers to external radiation is assumed to occur during transport of excavated waste from the site to a waste storage/disposal facility. The total time of exposure for each driver is assumed to be 4 hr/day for the period of cleanup required for the area. The exposure rate is conservatively assumed to be equal to the external exposure rate at 1 m above the ground calculated by DECOM. No credit for shielding provided by the metal boxes is taken into account.

It is assumed there will be no release of radioactive materials from the metal boxes during routine transport. Further, because the material is being transported within the boundary of the Savannah River Plant, it is assumed there will be no exposure to the public and no significant exposure to employees on site involved in activities not related to the cleanup of this area.

Risk Assessment Procedure

Risk assessment may be divided into three major components: (1) hazard assessment, consisting of hazard identification and dose-response assessment; (2) exposure assessment; and (3) risk characterization. These fundamental steps are common to all assessments of the risk of exposure to pollutants, regardless of the substances under investigation; the species, populations, or environmental systems at risk; the medium (or media) in which exposure occurs; the route of exposure; or the adverse effects under consideration.

Hazard assessment involves the identification of waste contaminants of concern (i.e., as subject of the risk assessment) and an initial determination of the intrinsic toxicity of these contaminants under consideration (dose-response assessment). Exposure assessment is the process of measuring or estimating the intensity, duration, and frequency of exposure to these contaminants. Other elements critical to the exposure assessment are the identification of routes of exposure and the determination of human and/or nonhuman receptors at risk. The final component of the risk assessment process, risk characterization, can be defined as the process of estimating the incidence of an adverse effect under the various conditions of exposure described in the exposure assessment. Risk characterization is conducted by combining the results of the exposure and hazard (dose-response) assessments.

Risk assessment procedures for nonradioactive and radioactive constituents are briefly described below and are treated in more detail in King et al. (1987).

Nonradioactive Constituents

It is common practice to consider risk characterization for carcinogens and noncarcinogens separately because of a fundamental difference in the way organisms typically respond to these classes of compounds. For noncarcinogens, toxicologists recognize the existence of a threshold of exposure below which there is only a very small likelihood of adverse health effects in an exposed population. Exposure to carcinogenic compounds, however, is not characterized by the existence of a threshold. Rather, all levels of exposure are considered to carry a risk of adverse effects.

The procedure for calculating risk of exposure to carcinogenic compounds is well documented (EPA, 1985a: National Research Council, 1983; Rodricks, 1984). A nonthreshold dose-response model is used to calculate a unit risk value (risk per unit dose) for each chemical. The risk per unit dose (unit carcinogenic risk) is then multiplied by the estimated average daily lifetime dose experienced by the exposed individual or population to derive an estimate of risk (R) as follows:

$$R = D \times UCR$$

where D = average daily lifetime dose (mg/kg body weight/day). A 50-year exposure lifetime and 70-kg body weight are assumed.

UCR = unit carcinogenic risk estimate $[(mg/kg\ body\ weight/day)^{-1}]$

The risk value is an explicit estimate of risk and will have a value between 0 and 1. In this environmental analysis, this risk is called chemical carcinogenic risk and for an exposed individual has units of health effects (HE) per lifetime; for an exposed population the units are simply health effects. In evaluating risk of exposure to more than one carcinogen, the risk values for each compound may be summed to give an overall estimate of total carcinogenic risk (EPA, 1985a; Rodricks, 1984). This summing is done for each source of environmental release, for each associated exposure pathway, and for each receptor group at risk of exposure.

The traditionally accepted practice of evaluating exposure to noncarcinogenic compounds has been to determine a no-observable-effect-level (NOEL) experimentally and to divide this level by a safety factor in order to establish an acceptable human dose. This acceptable human dose has been labeled as an acceptable daily intake (ADI) by the National Research Council (1983). The ADI then is then compared to the average daily dose experienced by an exposed individual, to obtain a measure of risk (R) as follows:

$$R = D/ADI$$

where D = average daily dose (mg/kg body weight/day). A one-year exposure period and 70-kg body weight are assumed.

ADI = acceptable daily intake for chronic exposure (mg/kg body weight/day)

The method of developing acceptable limits of exposure implies that the application of safety factors of various magnitudes to an experimentally derived NOEL will ensure minimal risk. The acceptable exposure levels (e.g., ADIs) are typically derived by making assumptions about the nature of dose-response relationships at low doses and by drawing inferences based upon the available data (National Research Council, 1983).

The risk values derived for noncarcinogens will vary from <1 to >1. This risk is called noncarcinogenic risk, and for an exposed individual has units of ADI fraction. Unlike the estimates of R derived for carcinogens, however, R values for noncarcinogens cannot be meaningfully summed to obtain an overall estimate of noncarcinogenic risk from a given waste site for a given exposure pathway and receptor group. However, as a method of estimating the relative hazard of a mixture of noncarcinogenic chemicals, the noncarcinogenic risk values for an exposed individual will be summed and called the EPA Hazard Index (a unitless parameter). The basis for such treatment of risk results is the EPA Guidelines (EPA, 1985b) for health risk assessment of chemical mixtures, in which EPA defines a hazard index of the mixture based on the assumption of additivity. Because a threshold dose-response model is used in calculating noncarcinogenic risk, it is not meaningful to extrapolate noncarcinogenic population risks. The ADI fraction and the EPA Hazard Index are not mathematical predictions of incidence of effects or severity, but are only numerical indicators of the transition between acceptable and possibly unacceptable exposure levels.

It is important to emphasize that the proposed methods for evaluating carcinogenic and noncarcinogenic hazards have been used only in evaluating the relative risk of adverse effects from postulated closure options at a given waste site or from one site to the next at the Savannah River Plant. The methods as proposed by EPA and National Research Council are not to be assumed to be a quantitative evaluation and prediction of the incidence of adverse effects in exposed populations. The proposed methods are a tool for relative assessment of risk (i.e., comparison across sites or across closure options).

The data base (King et al., 1987) for UCRs and ADIs for inhalation and ingestion pathways was derived from the EPA Superfund Public Health Evaluation Manual (EPA, 1985a), which was designed to conform to EPA's proposed risk assessment guidelines (EPA, 1985b; Federal Register, 1984) and to serve as a framework for analyzing public health risks and for developing design goals for closure options.

Radioactive Constituents

The risk associated with exposure to radioactive materials is typically characterized by a linear no-threshold model for establishing the likelihood of adverse health effects. Most scientists generally acknowledge the lack of a threshold of exposure; that is, all levels of exposure are considered to carry a finite risk of adverse effects.

Estimates of health risks associated with calculated exposures to radioactivity were made using the guidelines of the International Commission on Radiological Protection (ICRP, 1975, 1977). The detrimental health effects against which radiation protection is required are known as somatic and hereditary. Radiation effects are called somatic if they become manifest in the exposed individual and hereditary if they affect the individual's descendants. Carcinogenesis is considered to be the chief somatic risk of irradiation at low doses and, therefore, the main problem in radiation protection.

The units of radiation dose to an individual are usually expressed in millirem (mrem). To put this in perspective, an individual receives an average annual radiation dose of 93 mrem from natural sources of radiation in the vicinity of the SRP. Population dose commitment is the sum of individual dose commitments in a population group and is expressed in units of person-rem.

Radiological doses are calculated with dose factor (King et al., 1987) based on methodology developed by the ICRP as reported in its Publication 30 (ICRP, 1978) and recently implemented by DOE. These dose factors relate intake of radioactive materials through ingestion and inhalation to the dose commitment received for 50 years following intake.

The procedure for determining the risk of exposure to a radionuclide requires two basic calculations. First, the radionuclide intake in a given year is multiplied by a dose conversion factor for the specific radionuclide of interest to establish a dose equivalent value. Mathematically this is represented as follows:

$$CEDE = C \times DCF$$

where CEDE = committed effective dose equivalent for a given environmental pathway (mrem/yr)

C = calculated annual intake of radioactivity for a given environmental pathway (pCi)

DCF = dose conversion factor for a given radionuclide based on ICRP guidelines (mrem/pCi)

Second, the risk of radiation exposure is found by multiplying the committed effective dose equivalent by the risk conversion factor. This equation is as follows:

$$R = CEDE \times RCF$$

where R = radioactive risk (health effects/yr of intake)

RCF = risk conversion factor (health effects/mrem)

For this environmental analysis, radioactive risk to an individual is the incremental probability of a health effect (somatic and genetic) over the 50-year lifetime of an adult male resulting from chronic intake in the first year. The units for individual risk are health effects (HE) per year of intake. Radioactive risk to the exposed population is an estimate of the projected number of incremental health effects (somatic and genetic) for the exposed population. The units for radioactive risk to a population are health effects for the receptor group during the time period of interest.

Although the frequency of effects resulting from radiation exposure is dependent on age, sex, type of radiation, and other factors, a review of reports by the Committee on the Biological Effects of Ionizing Radiation (NAS, 1980), the ICRP (ICRP, 1977), and the Office of Radiation Programs of the Environmental Protection Agency (EPA, 1985c) indicates that, for average populations, a reasonable range for the risk conversion factor is 1.65E-04 to 2.80E-04 adverse effects per rem of dose. For this assessment, a conservative value reflecting the upper limit of the above range has been chosen to convert dose to health effects for water, terrrestrial, atmospheric, and occupational pathways.

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 other health-effect assessments, but are presented solely to give a basis to evaluate and compare waste-site closure action alternatives. Although the codes used in the risk assessment process represent state-of-the-art technology in risk estimation, they necessarily involve numerous assumptions and generalizations that may be highly uncertain under some conditions. Hence, their application is more reliable for comparing relative risks from exposures via similar environmental pathways than for estimating absolute risks of human health effects.

Results

Surface and Subsurface Pathways

The surface and subsurface pathways for transport of waste materials, the resulting potential exposures to the human population, and the excess risk posed to human health for the postulated closure options for the Radioactive Waste Burial Grounds have been calculated using the PATHRAE code. Standard options are used to represent both the current waste-site conditions and its potential configurations covered in the closure options. The pathways modeled are groundwater movement to hypothetical water wells nearby, groundwater movement to surface steams, water erosion and movement to a surface stream, consumption of food grown on

reclaimed farmland, consumption of crops grown through natural biointrusion, and direct gamma exposure. All scenarios with the exception of groundwater movement and waste erosion to surface streams are assumed to occur immediately after the 100 years of institutional control. The groundwater movement and waste erosion pathways to surface streams may occur before the end of the assumed 100-year period of institutional control. It should be noted that the events may not occur for many hundreds of years, if at all, even without institutional control.

The modeling of the Radioactive Waste Burial Grounds is based on several assumptions concerning the waste inventory and the operating history of the facility. Facility 643-G was operated from 1952 until 1972. In 1972, site 643-7G began accepting wastes. The total waste inventory at each site is assumed to have been placed in the facility in a uniform fashion from 1952 to the present. During operation of the Burial Grounds, a water seepage rate of 0.38 m/yr is assumed. This rate leads to a vertical water velocity of approximately 2.8 m/yr.

For the closure options in which a low-permeability cap is applied, several parameters would change. The water seepage rate would be reduced by 90% and this, in turn, would reduce the assumed vertical water velocity in the unsaturated zone. The cap would also alter parameters defining the surface erosion, biointrusion, and food production pathways.

For the waste excavation option, the contaminant source term is appropriately reduced. The vertical water velocity and the contaminant retardation factors are used to determine the extent of waste migration. This information is used to calculate the amount of each contaminant removed by excavation. For contaminants with low mobility, which remain almost entirely within the top few centimeters of soil, it is assumed that 99% of the contaminant is removed by excavation (i.e., 1% is assumed to remain, even if removal is calculated to be 100%).

Source terms are defined in terms of the total amount of each contaminant disposed of in the Burial Grounds. The estimated inventories of contaminants are based on disposal records and analyses of groundwater samples from the monitoring wells. The criteria for selection of contaminants for analysis and the estimated waste inventory are given in Looney et al. (1987a). Table 19 shows the contaminant inventory used for PATHRAE calculations.

The average facility parameters are defined in Table 20. The sites are represented as a single rectangle with a surface area equivalent to the sum of the areas of the three burial ground sites.

TABLE 19

Inventory for Radioactive Waste Burial Grounds

Radionuclide	Undecayed Disposal Amount (Ci)	Radionuclide	Undecayed Disposal Amount (Ci)
^{3}H	4.1E+06	^{155}Eu	2.0E+03
^{14}C	6.6E-03	^{228}Th	1.3E-02
^{60}Co	3.3E+06	^{232}Th	1.0E-01
^{59}Ni	6.6E+00	^{233}U	1.3E+00
^{63}Ni	3.5E+05	^{234}U	8.0E+00
^{79}Se	6.6E-01	^{235}U	9.7E-01
^{87}Rb	3.3E-05	^{236}U	1.8E-01
^{90}Sr	1.7E+04	^{238}U	6.4E+01
^{90}Y	1.7E+04	^{237}Np	1.3E-01
^{99}Tc	2.0E+01	^{238}Pu	5.3E+03
^{106}Ru	1.2E+04	^{239}Pu	6.4E+02
^{125}Sb	3.3E+03	^{241}Pu	3.3E+02
^{129}I	1.4E+01	^{242}Pu	2.6E-02
^{134}Cs	1.4E+04	^{241}Am	4.0E+01
^{137}Cs	1.7E+04	^{243}Am	2.3E-02
^{147}Pm	9.7E+04	^{244}Cm	3.9E+04
^{151}Sm	9.2E+02	^{248}Cm*	1.4E-04
^{154}Eu	2.4E+03		

Chemicals and Metals	Disposal Mass (kg)
Cadmium	2.0E+03
Lead	1.0E+05
Mercury	1.0E+04
Napthalene	4.0E+03
Toluene	1.3E+04
Trimethylbenzene	1.3E+04
Xylene	2.1E+04

* Decay product of ^{252}Cf.

TABLE 20

Radioactive Waste Burial Grounds Facility Parameters for PATHRAE Calculations

Parameter	Site 643-G	Sites 643-7G & 643-28G
Facility length	280 m	440 m
Facility width	1,100 m	1,100 m
Waste thickness	5 m	5 m
Cover thickness	1.2 m	1.2 m

The parameters defining the contaminant pathways through groundwater and other environmental paths were defined from the geohydrological data presented earlier and are presented in Tables 21 and 22 as they were used in the PATHRAE analyses.

The geohydrologic information presented previously indicates that the water flow pattern in the vicinity of the Radioactive Waste Burial Grounds is very complex; a groundwater divide occurs in this area, and water flows north to Upper Three Runs Creek, south to Four Mile Creek, and vertically into the Congaree Formation. The PATHRAE model assumes a single flow path and calculates the groundwater and outcrop concentration along the path. The flow path assumed for this site is based on southerly flow in the water-table aquifer toward Four Mile Creek. The water is assumed to crop out at this point and then flow to the Savannah River. A complete flow path is shown schematically in Figure 44. Note that the particle tracking analysis described earlier indicates that much of the water from the Burial Grounds enters the Congaree Formation and crops out in Upper Three Runs Creek. A flow path to Four Mile Creek was chosen for conservatism.

The selected flow path results in maximum wetlands, stream, and downstream impacts (especially for radionuclides). The path through the Congaree Formation to Upper Three Runs Creek would approximately double the flow time, and groundwater concentrations would be below those reported for the Four Mile Creek outcrop.

Many of the parameters used in the PATHRAE code are specific to given chemicals or radionuclides. They include dose conversion factors (DCF), unit carcinogenic risk (UCR) factors, acceptable daily intakes (ADI), sorption coefficients (K_d), soil-plant transfer factors, solubilities, and facilitated transport fractions. Table 23 presents these parameters for radionuclides, and Table 24 presents corresponding parameters for chemical species.

One set of PATHRAE analyses was performed for each closure option for analyzing the environmental transport, exposures, and human health risks from the Burial Grounds. Each set consisted of four computer runs. The first run identified the times (years) at which peak doses occurred for human exposures and only addressed the groundwater pathways. The second analyzed the exposures and risks from all pathways at specified future times. The third calculated total releases to the Savannah River, and the fourth analysis calculated the contaminant concentrations in groundwater fluxes at the outcrop location.

The PATHRAE concentration, dose, and risk calculations for each of the closure options are presented in the following sections. In reporting concentrations (and corresponding doses and risks) the cutoff value has been set arbitrarily at 1.0E-20.

TABLE 21

General Pathway Parameters for PATHRAE Calculations

Parameter	Value
River flow rate	9.1E+09 m^3/yr
Aquifer density	1,600 kg/m^3
Aquifer porosity	0.2 (dimensionless)
Soil residual saturation	0.1 (dimensionless)
Vertical permeability of unsaturated zone	2.2 m/yr
Soil index	0.25 (dimensionless)
Plant root depth	1.0 m
Areal density of plants	1.0 kg/m^2

TABLE 22

Hydrological Pathway Parameters for PATHRAE Calculations

Parameter	Value
Distance of groundwater flow to creek	1,000 m
Distance from bottom of waste to water table	6 m
Distance to wells	1 m, 100 m
Water seepage rate	
No action	0.38 m/yr
With cap	0.038 m/yr
Vertical water velocity	
No action	2.8 m/yr
With cap	0.45 m/yr
Horizontal groundwater velocity	10 m/yr

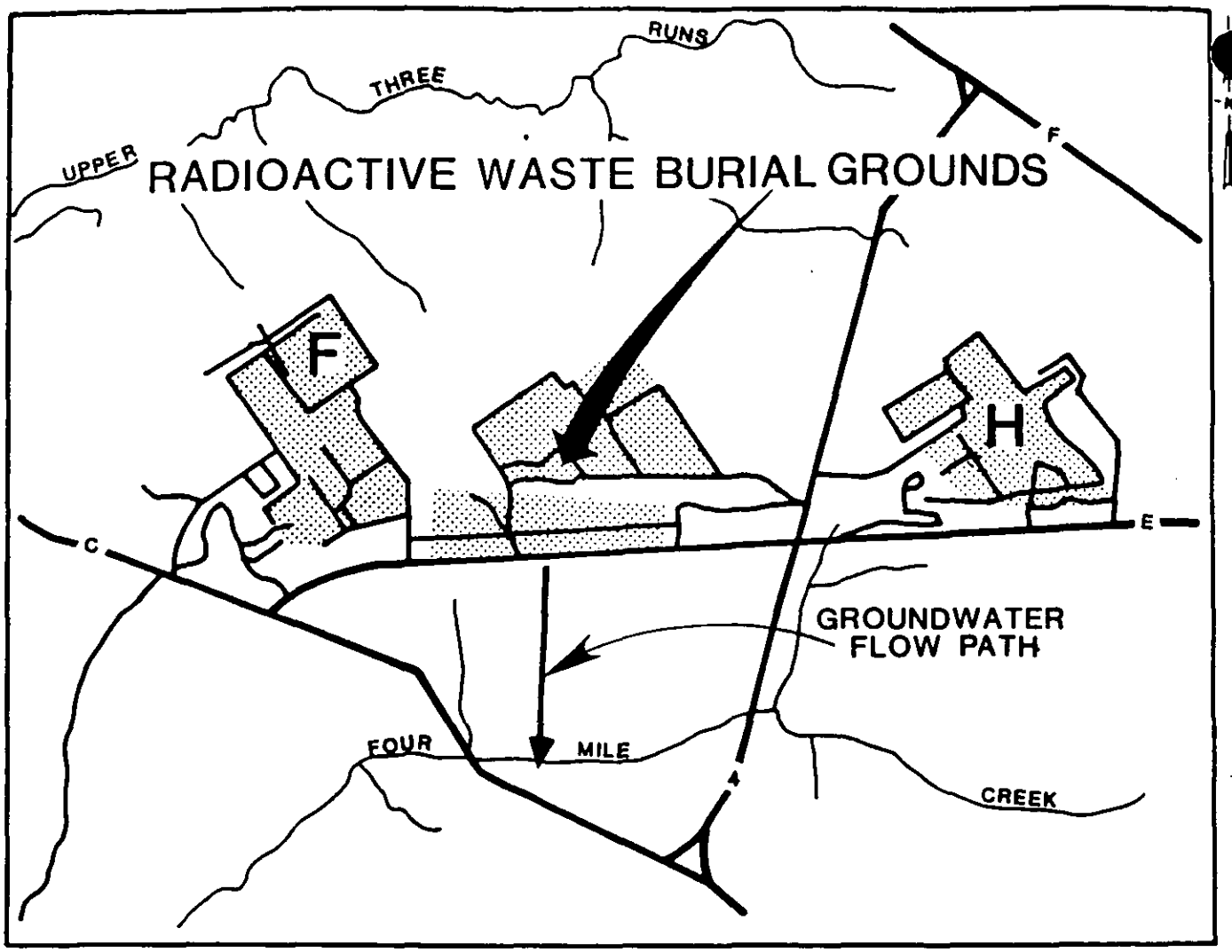


FIGURE 44. Groundwater Flow Path from the Radioactive Waste Burial Grounds

TABLE 23

Radionuclide-Specific Data for PATHRAE Analyses

Radionuclide	DCF for Ingestion* (mrem/pCi)	K_d** (mL/g)	Soil-Plant Transfer Factor*	Solubility** (moles/L)	Facilitated Transport Fraction**
^{3}H	6.3E-08	1.0E-03	4.8E+00	†	-
^{14}C	2.1E-06	1.0E-02	5.5E+00	†	-
^{60}Co	2.6E-05	1.0E+01	9.4E-03	1.0E-02	2.0E-06
^{59}Ni	2.0E-07	1.0E+02	1.9E-02	1.0E-02	2.0E-03
^{63}Ni	5.4E-07	1.0E+02	1.9E-02	1.0E-02	2.0E-03
^{79}Se	8.3E-06	2.5E+00	1.3E+00	†	-
^{87}Rb	4.8E-06	5.0E+00	1.3E-01	†	-
^{90}Sr	1.3E-04	8.0E+00	1.7E-02	†	1.0E-04
^{90}Y	1.0E-05	8.0E-00	1.7E-02	†	1.0E-04
^{99}Tc	1.3E-06	1.0E-03	2.5E-01	†	-
^{106}Ru	2.1E-05	1.6E+02	5.0E-02	1.0E-10	-
^{125}Sb	2.6E-06	4.0E+03	1.1E-02	1.0E-04	-
^{129}I	2.8E-04	2.0E-01	2.0E-02	1.0E-02	-
^{134}Cs	7.4E-05	5.0E+02	1.0E-02	†	1.0E-04
^{137}Cs	5.0E-05	5.0E+02	1.0E-02	†	1.0E-04
^{147}Pm	9.5E-07	1.0E+03	2.5E-03	†	-
^{151}Sm	3.4E-07	1.0E+03	2.5E-03	†	-
^{154}Eu	9.1E-06	1.0E+03	2.5E-03	†	-
^{155}Eu	1.3E-06	1.0E+03	2.5E-03	†	-
^{228}Th	3.8E-04	1.0E+02	4.2E-03	1.0E-04	-
^{232}Th	2.8E-03	1.0E+02	4.2E-03	1.0E-04	-
^{233}U	2.7E-04	4.0E+01	2.5E-03	†	1.0E-03
^{234}U	2.6E-04	4.0E+01	2.5E-03	†	1.0E-03
^{235}U	2.5E-04	4.0E+01	2.5E-03	†	1.0E-03
^{238}U	2.3E-04	4.0E+01	2.5E-03	†	1.0E-03
^{237}Np	3.9E-02	1.0E+01	2.5E-03	1.0E+01	-
^{238}Pu	3.8E-04	1.0E+02	2.5E-04	1.0E-13	2.0E-04
^{239}Pu	4.3E-04	1.0E+02	2.5E-04	1.0E-13	2.0E-04
^{241}Pu	8.6E-06	1.0E+02	2.5E-04	1.0E-13	2.0E-04
^{242}Pu	4.1E-04	1.0E+02	2.5E-04	1.0E-13	2.0E-04
^{241}Am	2.2E-03	1.0E+02	2.5E-04	1.0E-01	-
^{243}Am	2.2E-03	1.0E+02	2.5E-04	1.0E-01	-
^{244}Cm	1.1E-03	3.0E+03	2.5E-03	1.0E-14	-
^{248}Cm	8.1E-03	3.0E+03	2.5E-03	1.0E-14	-

* Data from King et al. (1987).
** Data from Looney et al. (1987b).
† Transport not limited by solubility.

TABLE 24

Chemical-Specific Data for PATHRAE Analyses

Chemical	ADI* (mg/kg/day)	K_d** (mL/g)	Soil-Plant Transfer Factor*	Solubility** (mg/L)	Facilitated Transport Fraction **
Cadmium	2.9E-04	6.0E+00	3.0E-01	†	2.0E-03
Lead	1.4E-03	1.0E+02	6.8E-02	†	3.0E-02
Mercury	2.8E-04	1.0E+04	3.8E-01	†	1.0E-03
Naphthalene	2.6E-01	8.0E-03	8.6E-01	†	-
Toluene	2.9E-02	2.7E-02	1.6E+00	5.35E+02	-
Trimethylbenzene	6.4E-01	5.0E-01	5.4E-01	†	-
Xylene	1.0E-02	5.0E-02	1.0E+00	†	-

* Data from King et al. (1987).
** Data from Looney et al. (1987b).
† Transport not limited by solubility.

Values smaller than this are reported as zero (0.0) in the tables. Time is measured in years since (or before) 1985 in all tables. Because of the assumed period of institutional control, analysis of the pathways for groundwater to wells, reclaimed farmland, and direct gamma exposure is not applicable prior to 100 years.

Waste Removal and Closure

During the operational life of the facilities, constituents leached downward with infiltrating water, the amount depending on the retention of each individual constituent by the soil medium. For the waste removal and closure option, 99% of the constituents that would not have leached out of the 1-m waste layer are assumed to be removed by the excavation process. For several of the most mobile contaminants, none of the inventory remains to receive benefit from excavation.

The PATHRAE analyses of the groundwater pathways to identify peak doses for human exposure for the waste removal and closure option are summarized in Table 25 for radionuclides and Table 26 for chemical constituents. Significant calculated doses, greater than 25 mrem/yr, occur during the period of institutional control in the well pathways; note that no exposure through these pathways is anticipated (the maximum calculated dose during this period would be about 1.1E+05 mrem/yr in the well at 1 m pathway). The maximum calculated radioactive dose following the period of institutional control is low, occurring in Year 100 in the well at 1 m pathway (approximately 10 mrem/yr, dominated by tritium). Noncarcinogenic risks for chemical constituents are low (no ADI fractions exceed 1, except lead which has a calculated ADI fractions in the well at 1 m pathway during the period of institutional control of 26). The time dependence of the well at 1 m pathway analyses for the radionuclide and chemical constituents is summarized in Tables 27 and 28, respectively. Similar results for the well at 100 m pathway are presented in Tables 29 and 30. The time dependence of the groundwater-to-river pathway analyses is summarized in Tables 31 and 32. Constituent fluxes at the assumed groundwater outcrop and concentrations in the groundwater for use in wetlands assessment are given in Tables 33 and 34. Tables 35 and 36 contain the results for the reclaimed-farmland pathway, and Table 37 contains the results for the direct gamma exposure pathway.

No Waste Removal and Closure

Under this option, the infiltration during facility operation was assumed to have passed through the waste prior to the subject closure action. More than half the inventories of contaminants

TABLE 25

Peak Radionuclide Calculations for the Waste Removal and Closure Option

Pathway	Radionuclide	Peak Concentration (Ci/m^3)	Peak Year Since 1985	Dose (mrem/yr)	Radioactive Risk (HE/yr)
Groundwater to well at 1 m	^{14}C	3.1E-11	18	3.7E-05	1.0E-11
	^{60}Co	2.4E-21	227	3.9E-14	1.1E-20
	^{60}Co*	2.5E-06	-28	4.1E+01	1.1E-05
	^{134}Cs*	2.3E-07	-28	1.2E+01	3.4E-06
	^{137}Cs*	9.4E-07	-28	3.3E+01	9.4E-06
	^{3}H	2.1E+00	-28	1.1E+05	2.9E-02
	^{129}I	8.4E-15	306	1.4E-06	3.9E-13
	^{59}Ni*	8.4E-09	-28	1.1E-03	3.0E-10
	^{63}Ni*	4.4E-04	-28	1.5E+02	4.3E-05
	^{238}Pu*	6.7E-07	-28	1.2E+02	3.3E-05
	^{239}Pu*	8.3E-08	-28	1.6E+01	4.6E-06
	^{241}Pu*	3.5E-08	-28	1.4E-01	3.8E-08
	^{242}Pu*	3.6E-12	-28	6.9E-04	1.9E-10
	^{79}Se	6.0E-10	734	6.9E-03	1.9E-09
	^{90}Sr	3.2E-10	195	2.0E-02	5.6E-09
	^{90}Sr*	1.0E-06	-28	6.3E+01	1.8E-05
	^{99}Tc	1.3E-05	-28	9.5E+01	2.7E-05
	^{233}U*	8.6E-10	-28	1.1E-01	3.1E-08
	^{234}U*	5.2E-09	-28	6.4E-01	1.8E-07
	^{235}U*	6.3E-10	-28	7.5E-02	2.1E-08
	^{236}U*	1.2E-10	-28	1.4E-02	4.0E-09
	^{238}U*	4.1E-08	-28	4.5E+00	1.3E-06
	^{90}Y	3.2E-10	195	1.5E-03	4.3E-10
	^{90}Y*	1.0E-06	-28	4.8E+00	1.4E-06
Groundwater to well at 100 m	^{14}C	3.0E-11	46	3.7E-05	1.0E-11
	^{60}Co*	4.7E-07	-24	7.7E+00	2.1E-06
	^{134}Cs*	2.1E-08	-25	1.1E+00	3.1E-07
	^{137}Cs*	2.9E-07	-23	1.0E+01	2.9E-06
	^{3}H	5.6E-01	-23	2.8E+04	7.8E-03
	^{129}I	8.4E-15	400	1.4E-06	3.9E-13
	^{59}Ni*	3.0E-09	-22	3.8E-04	1.1E-10
	^{63}Ni*	1.5E-04	-22	5.2E+01	1.4E-05
	^{238}Pu*	2.2E-07	-22	4.0E+01	1.1E-05
	^{239}Pu*	2.9E-08	-22	5.8E+00	1.6E-06
	^{241}Pu*	9.2E-09	-23	3.7E-02	1.0E-08
	^{242}Pu*	1.3E-12	-22	2.4E-04	6.8E-11
	^{79}Se	5.8E-10	759	6.7E-03	1.9E-09
	^{90}Sr	9.7E-13	335	6.1E-05	1.7E-11
	^{90}Sr*	3.1E-07	-23	1.9E+01	5.4E-06
	^{99}Tc	4.6E-06	-22	3.3E+01	9.3E-06
	^{233}U*	3.0E-10	-22	3.9E-02	1.1E-08
	^{234}U*	1.8E-09	-22	2.3E-01	6.3E-08
	^{235}U*	2.2E-10	-22	2.6E-02	7.4E-09
	^{236}U*	4.2E-11	-22	5.0E-03	1.4E-09
	^{238}U*	1.5E-08	-22	1.6E+00	4.5E-07
	^{90}Y	9.7E-13	335	4.7E-06	1.3E-12
	^{90}Y*	3.1E-07	-23	1.5E+00	4.2E-07
Groundwater to river	^{14}C	9.8E-16	252	6.7E-08	1.9E-14
	^{60}Co*	2.7E-16	24	6.8E-09	1.9E-15
	^{134}Cs*	9.4E-21	4	1.0E-11	2.8E-18
	^{137}Cs*	1.3E-13	72	9.1E-05	2.6E-11
	^{3}H	1.9E-08	48	9.8E-04	2.8E-10
	^{129}I	2.8E-19	967	5.4E-11	1.5E-17
	^{59}Ni*	1.3E-14	109	3.3E-09	9.3E-16
	^{63}Ni*	3.2E-10	96	2.3E-04	6.3E-11
	^{238}Pu*	4.0E-13	92	7.4E-05	2.1E-11
	^{239}Pu*	1.2E-13	109	2.6E-05	7.2E-12
	^{241}Pu*	4.2E-16	48	1.7E-09	4.9E-16
	^{242}Pu*	5.0E-18	109	1.0E-09	2.8E-16
	^{90}Sr*	1.2E-13	71	1.1E-05	3.0E-12
	^{99}Tc	1.9E-11	109	1.4E-04	4.0E-11
	^{233}U*	1.3E-15	109	1.7E-07	4.7E-14
	^{234}U*	7.7E-15	109	9.8E-07	2.8E-13
	^{235}U*	9.3E-16	109	1.1E-07	3.2E-14
	^{236}U*	1.8E-16	109	2.2E-08	6.1E-15
	^{238}U*	6.2E-14	109	6.9E-06	1.9E-12
	^{90}Y*	1.2E-13	71	8.3E-07	2.3E-13

* Facilitated transport fraction.

TABLE 26

Peak Chemical Calculations for the Waste Removal and Closure Option

Pathway	Chemical	Peak Concentration (mg/L)	Peak Year Since 1985	Noncarcinogenic Risk (ADI fraction)
Groundwater to well at 1 m	Cadmium*	2.6E-03	-28	1.6E-01
	Lead*	1.9E+00	-28	2.6E+01
	Mercury*	6.5E-03	-28	3.8E+00
	Naphthalene	2.1E-03	250	1.5E-04
	Toluene	6.9E-03	170	4.3E-04
	Trimethylbenzene	6.2E-03	410	1.8E-04
	Xylene	1.1E-02	230	2.0E-02
Groundwater to well at 100 m	Cadmium*	9.1E-04	-22	5.8E-02
	Lead*	6.8E-01	-22	9.1E+00
	Mercury*	2.3E-03	-22	1.3E+00
	Naphthalene	2.1E-03	310	1.5E-04
	Toluene	6.9E-03	240	4.3E-04
	Trimethylbenzene	6.2E-03	570	1.8E-04
	Xylene	1.1E-02	290	2.0E-02
Groundwater to river	Cadmium*	3.9E-09	110	9.6E-07
	Lead*	2.9E-06	110	9.4E-05
	Mercury*	9.6E-09	110	1.5E-05
	Naphthalene	7.1E-08	740	5.1E-09
	Toluene	2.3E-07	520	1.5E-08
	Xylene	3.7E-07	660	6.8E-07

* Facilitated transport fraction.

TABLE 27

Radionuclide Results for Groundwater to Well at 1 m Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (Ci/m^3)							
^{3}H	1.2E-04	1.4E-09	7.1E-15	3.1E-20	0.0	0.0	0.0
^{14}C	3.0E-11	3.0E-11	3.0E-11	6.2E-12	3.6E-14	1.5E-19	0.0
^{60}Co	7.1E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.3E-10	4.3E-13	5.8E-16	7.0E-19	0.0	0.0	0.0
^{63}Ni	3.7E-06	6.4E-09	4.6E-12	3.0E-15	1.9E-18	0.0	0.0
^{79}Se	4.6E-10	5.5E-10	5.8E-10	5.9E-10	5.9E-10	6.0E-10	2.7E-10
^{87}Rb	5.8E-16	3.4E-15	4.1E-15	4.3E-15	4.5E-15	4.6E-15	4.7E-15
^{90}Sr	1.4E-09	3.2E-10	6.2E-11	6.7E-12	6.4E-13	5.4E-15	4.0E-18
^{90}Y	1.4E-09	3.2E-10	6.2E-11	6.7E-12	6.4E-13	5.4E-15	4.0E-18
^{99}Tc	2.1E-07	6.6E-10	8.9E-13	1.1E-15	1.3E-18	0.0	0.0
^{129}I	8.4E-15	8.4E-15	8.4E-15	8.4E-15	8.4E-15	8.4E-15	8.4E-15
^{137}Cs	1.5E-09	4.9E-13	6.7E-17	0.0	0.0	0.0	0.0
^{233}U	1.4E-11	4.4E-14	5.9E-17	7.2E-20	0.0	0.0	4.9E-13
^{234}U	8.3E-11	2.6E-13	3.6E-16	4.3E-19	0.0	0.0	2.9E-12
^{235}U	1.0E-11	3.2E-14	4.3E-17	5.3E-20	0.0	0.0	3.6E-13
^{236}U	1.9E-12	6.1E-15	8.2E-18	0.0	0.0	0.0	6.8E-14
^{238}U	6.6E-10	2.1E-12	2.8E-15	3.5E-18	0.0	0.0	2.3E-11
^{237}Np	0.0	0.0	9.0E-13	1.3E-12	1.5E-12	1.7E-12	1.8E-12
^{238}Pu	4.8E-09	7.0E-12	4.3E-15	2.4E-18	0.0	0.0	0.0
^{239}Pu	1.3E-09	4.2E-12	5.7E-15	6.9E-18	0.0	0.0	0.0
^{241}Pu	2.8E-12	5.1E-17	0.0	0.0	0.0	0.0	0.0
^{242}Pu	5.4E-14	1.7E-16	2.3E-19	0.0	0.0	0.0	0.0
Dose (mrem/yr)							
^{3}H	5.8E+00	7.3E-05	3.6E-10	1.6E-15	0.0	0.0	0.0
^{14}C	3.6E-05	3.7E-05	3.6E-05	7.6E-06	4.4E-08	1.8E-13	0.0
^{60}Co	1.2E-06	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.7E-05	5.5E-08	7.4E-11	9.0E-14	0.0	0.0	0.0
^{63}Ni	1.3E+00	2.2E-03	1.6E-06	1.0E-09	6.6E-13	0.0	0.0
^{79}Se	5.3E-03	6.4E-03	6.7E-03	6.8E-03	6.9E-03	6.9E-03	3.2E-03
^{87}Rb	3.7E-09	2.2E-08	2.6E-08	2.8E-08	2.9E-08	3.0E-08	3.0E-08
^{90}Sr	8.7E-02	2.0E-02	3.9E-03	4.2E-04	4.0E-05	3.4E-07	2.5E-10
^{90}Y	6.7E-03	1.5E-03	3.0E-04	3.2E-05	3.1E-06	2.6E-08	1.9E-11
^{99}Tc	1.5E+00	4.9E-03	6.6E-06	8.0E-09	9.7E-12	0.0	0.0
^{129}I	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06
^{137}Cs	5.2E-02	1.7E-05	2.4E-09	0.0	0.0	0.0	0.0
^{233}U	1.8E-03	5.6E-06	7.6E-09	9.3E-12	0.0	0.0	6.2E-05
^{234}U	1.0E-02	3.3E-05	4.4E-08	5.4E-11	0.0	0.0	3.6E-04
^{235}U	1.2E-03	3.8E-06	5.1E-09	6.2E-12	0.0	0.0	4.2E-05
^{236}U	2.3E-04	7.2E-07	9.8E-10	0.0	0.0	0.0	8.0E-06
^{238}U	7.2E-02	2.3E-04	3.1E-07	3.8E-10	0.0	0.0	2.6E-03
^{237}Np	0.0	0.0	1.6E-02	2.4E-02	2.7E-02	3.0E-02	3.3E-02
^{238}Pu	8.4E-01	1.2E-03	7.6E-07	4.2E-10	0.0	0.0	0.0
^{239}Pu	2.6E-01	8.4E-04	1.1E-06	1.4E-09	0.0	0.0	0.0
^{241}Pu	1.1E-05	2.0E-10	0.0	0.0	0.0	0.0	0.0
^{242}Pu	1.0E-05	3.3E-08	4.4E-11	0.0	0.0	0.0	0.0
Total Dose	9.9E+00	3.9E-02	2.8E-02	3.2E-02	3.5E-02	3.9E-02	4.0E-02
Radioactive Risk (HE/yr)							
	2.8E-06	1.1E-08	7.9E-09	8.9E-09	9.8E-09	1.1E-08	1.1E-08

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 28

Chemical Results for Groundwater to Well at 1 m Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (mg/L)							
Cadmium	4.1E-05	7.7E-05	1.0E-04	1.1E-04	1.2E-04	1.2E-04	1.3E-04
Lead	3.1E-02	9.9E-05	1.3E-07	1.6E-10	2.0E-13	3.0E-19	0.0
Mercury	1.0E-04	3.3E-07	4.5E-10	5.4E-13	6.6E-16	0.0	0.0
Naphthalene	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	1.8E-03
Toluene	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03	5.6E-03
Trimethylbenzene	6.2E-03	6.2E-03	6.2E-03	6.2E-03	6.2E-03	6.2E-03	6.2E-03
Xylene	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.0E-02
Noncarcinogenic Risk (ADI fraction)							
Cadmium	2.6E-03	4.9E-03	6.5E-03	7.1E-03	7.5E-03	7.8E-03	8.0E-03
Lead	4.1E-01	1.3E-03	1.8E-06	2.2E-09	2.6E-12	4.0E-18	0.0
Mercury	6.1E-02	1.9E-04	2.6E-07	3.2E-10	3.9E-13	0.0	0.0
Naphthalene	1.5E-04	1.5E-04	1.5E-04	1.5E-04	1.5E-04	1.5E-04	1.3E-04
Toluene	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	3.5E-04
Trimethylbenzene	1.8E-04	1.8E-04	1.8E-04	1.8E-04	1.8E-04	1.8E-04	1.8E-04
Xylene	2.0E-02	2.0E-02	2.0E-02	2.0E-02	2.0E-02	2.0E-02	1.9E-02
EPA Hazard Index	4.9E-01	2.7E-02	2.7E-02	2.8E-02	2.8E-02	2.8E-02	2.7E-02

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 29

Radionuclide Results for Groundwater to Well at 100 m Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (Ci/m^3)							
^{3}H	1.6E-04	3.6E-09	2.1E-14	1.0E-19	0.0	0.0	0.0
^{14}C	3.0E-11	3.0E-11	3.0E-11	8.8E-12	8.7E-14	4.8E-19	0.0
^{60}Co	9.4E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.0E-10	1.1E-12	1.8E-15	2.3E-18	0.0	0.0	0.0
^{63}Ni	5.4E-06	1.6E-08	1.4E-11	9.9E-15	6.7E-18	0.0	0.0
^{79}Se	3.3E-11	2.3E-10	3.8E-10	4.7E-10	5.2E-10	5.7E-10	2.7E-10
^{87}Rb	0.0	1.2E-16	8.3E-16	1.7E-15	2.4E-15	3.4E-15	4.1E-15
^{90}Sr	2.0E-09	1.0E-12	8.3E-13	6.1E-13	1.3E-13	2.4E-15	2.6E-18
^{90}Y	2.0E-09	1.0E-12	8.3E-13	6.1E-13	1.3E-13	2.4E-15	2.6E-18
^{99}Tc	3.0E-07	1.7E-09	2.7E-12	3.6E-15	4.6E-18	0.0	0.0
^{129}I	8.3E-15	8.4E-15	8.4E-15	8.4E-15	8.4E-15	8.4E-15	8.4E-15
^{137}Cs	2.1E-09	1.2E-12	2.0E-16	2.7E-20	0.0	0.0	0.0
^{233}U	2.0E-11	1.1E-13	1.8E-16	2.4E-19	0.0	0.0	0.0
^{234}U	1.2E-10	6.7E-13	1.1E-15	1.4E-18	0.0	0.0	0.0
^{235}U	1.5E-11	8.1E-14	1.3E-16	1.7E-19	0.0	0.0	0.0
^{236}U	2.8E-12	1.5E-14	2.5E-17	3.3E-20	0.0	0.0	0.0
^{238}U	9.6E-10	5.3E-12	8.6E-15	1.1E-17	1.5E-20	0.0	0.0
^{237}Np	0.0	0.0	2.0E-16	2.7E-14	1.3E-13	4.6E-13	9.4E-13
^{238}Pu	6.9E-09	1.8E-11	1.3E-14	7.9E-18	0.0	0.0	0.0
^{239}Pu	1.9E-09	1.1E-11	1.7E-14	2.3E-17	2.9E-20	0.0	0.0
^{241}Pu	3.8E-12	1.3E-16	0.0	0.0	0.0	0.0	0.0
^{242}Pu	7.8E-14	4.3E-16	7.0E-19	0.0	0.0	0.0	0.0
Dose (mrem/yr)							
^{3}H	8.0E+00	1.8E-04	1.1E-09	5.1E-15	0.0	0.0	0.0
^{14}C	3.7E-05	3.7E-05	3.6E-05	1.1E-05	1.1E-07	5.9E-13	0.0
^{60}Co	1.5E-06	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.5E-05	1.4E-07	2.2E-10	3.0E-13	0.0	0.0	0.0
^{63}Ni	1.9E+00	5.5E-03	4.8E-06	3.4E-09	2.3E-12	0.0	0.0
^{79}Se	3.8E-04	2.7E-03	4.5E-03	5.5E-03	6.1E-03	6.6E-03	3.1E-03
^{87}Rb	0.0	7.5E-10	5.3E-09	1.1E-08	1.5E-08	2.2E-08	2.6E-08
^{90}Sr	1.2E-01	6.4E-05	5.2E-05	3.9E-05	8.5E-06	1.5E-07	1.7E-10
^{90}Y	9.5E-03	5.0E-06	4.0E-06	3.0E-06	6.5E-07	1.1E-08	1.3E-11
^{99}Tc	2.2E+00	1.2E-02	2.0E-05	2.7E-08	3.4E-11	0.0	0.0
^{129}I	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06
^{137}Cs	7.4E-02	4.4E-05	7.1E-09	9.5E-13	0.0	0.0	0.0
^{233}U	2.6E-03	1.4E-05	2.3E-08	3.1E-11	0.0	0.0	0.0
^{234}U	1.5E-02	8.2E-05	1.3E-07	1.8E-10	0.0	0.0	0.0
^{235}U	1.7E-03	9.6E-06	1.6E-08	2.1E-11	0.0	0.0	0.0
^{236}U	3.3E-04	1.8E-06	3.0E-09	3.9E-12	0.0	0.0	0.0
^{238}U	1.1E-01	5.8E-04	9.4E-07	1.3E-09	1.6E-12	0.0	0.0
^{237}Np	0.0	0.0	3.6E-06	4.9E-04	2.4E-03	8.4E-03	1.7E-02
^{238}Pu	1.2E+00	3.1E-03	2.3E-06	1.4E-09	0.0	0.0	0.0
^{239}Pu	3.8E-01	2.1E-03	3.4E-06	4.5E-09	5.7E-12	0.0	0.0
^{241}Pu	1.5E-05	5.0E-10	0.0	0.0	0.0	0.0	0.0
^{242}Pu	1.5E-05	8.2E-08	1.3E-10	0.0	0.0	0.0	0.0
Total Dose	1.4E+01	2.7E-02	5.3E-03	6.9E-03	9.5E-03	1.6E-02	2.1E-02
Radioactive Risk (HE/yr)							
	3.9E-06	7.5E-09	1.5E-09	1.9E-09	2.7E-09	4.5E-09	5.8E-09

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 30

Chemical Results for Groundwater to Well at 100 m Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (mg/L)							
Cadmium	6.0E-05	4.0E-07	1.0E-05	2.9E-05	4.8E-05	7.7E-05	1.0E-04
Lead	4.5E-02	2.5E-04	4.1E-07	5.4E-10	6.9E-13	1.1E-18	0.0
Mercury	1.5E-04	8.3E-07	1.4E-09	1.8E-12	2.3E-15	0.0	0.0
Naphthalene	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.0E-03
Toluene	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.2E-03
Trimethylbenzene	6.1E-03	6.2E-03	6.2E-03	6.2E-03	6.2E-03	6.2E-03	6.2E-03
Xylene	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Noncarcinogenic Risk (ADI fraction)							
Cadmium	3.8E-03	2.6E-05	6.6E-04	1.9E-03	3.1E-03	4.9E-03	6.5E-03
Lead	6.0E-01	3.3E-03	5.4E-06	7.2E-09	9.1E-12	1.5E-17	0.0
Mercury	8.8E-02	4.9E-04	7.9E-07	1.1E-09	1.3E-12	0.0	0.0
Naphthalene	1.5E-04	1.5E-04	1.5E-04	1.5E-04	1.5E-04	1.5E-04	1.4E-04
Toluene	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	3.9E-04
Trimethylbenzene	1.8E-04	1.8E-04	1.8E-04	1.8E-04	1.8E-04	1.8E-04	1.8E-04
Xylene	2.0E-02	2.0E-02	2.0E-02	2.0E-02	2.0E-02	2.0E-02	2.0E-02
EPA Hazard Index	7.1E-01	2.5E-02	2.1E-02	2.3E-02	2.4E-02	2.5E-02	2.7E-02

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 31

Radionuclide Results for Groundwater-to-River Pathway for the Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration (Ci/m^3)								
^{14}C	3.3E-20	4.8E-16	9.7E-16	9.8E-16	8.4E-16	1.3E-16	1.1E-20	0.0
^{60}Co	2.4E-17	1.5E-18	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.9E-16	1.0E-13	2.4E-15	2.3E-18	0.0	0.0	0.0	0.0
^{3}H	1.7E-10	5.2E-09	6.5E-12	2.3E-16	0.0	0.0	0.0	0.0
^{129}I	0.0	0.0	6.3E-20	1.7E-19	2.4E-19	2.7E-19	2.8E-19	2.8E-19
^{59}Ni	3.2E-18	1.2E-14	2.2E-15	2.0E-17	6.3E-20	0.0	0.0	0.0
^{63}Ni	1.4E-13	3.1E-10	3.3E-11	1.6E-13	2.7E-16	3.0E-19	0.0	0.0
^{238}Pu	2.1E-15	3.9E-13	3.6E-14	1.5E-16	2.1E-19	0.0	0.0	0.0
^{239}Pu	3.2E-16	1.2E-13	2.2E-14	2.0E-16	6.2E-19	0.0	0.0	0.0
^{241}Pu	3.0E-18	1.3E-16	2.3E-19	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	4.9E-18	8.9E-19	0.0	0.0	0.0	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	3.0E-20	4.9E-18	1.7E-16
^{90}Sr	1.9E-16	9.2E-14	2.0E-15	1.7E-18	0.0	0.0	0.0	0.0
^{99}Tc	4.9E-15	1.9E-11	3.4E-12	3.1E-14	9.8E-17	2.1E-19	0.0	0.0
^{233}U	3.3E-18	1.3E-15	2.3E-16	2.1E-18	0.0	0.0	0.0	0.0
^{234}U	2.0E-17	7.6E-15	1.4E-15	1.2E-17	3.9E-20	0.0	0.0	0.0
^{235}U	2.4E-18	9.2E-16	1.7E-16	1.5E-18	0.0	0.0	0.0	0.0
^{236}U	4.6E-19	1.7E-16	3.2E-17	2.9E-19	0.0	0.0	0.0	0.0
^{238}U	1.6E-16	6.1E-14	1.1E-14	9.9E-17	3.1E-19	0.0	0.0	0.0
^{90}Y	1.9E-16	9.2E-14	2.0E-15	1.7E-18	0.0	0.0	0.0	0.0
Dose (mrem/yr)								
^{14}C	2.3E-12	3.3E-08	6.6E-08	6.7E-08	5.7E-08	9.1E-09	9.4E-13	0.0
^{60}Co	6.1E-10	3.9E-11	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.4E-07	7.2E-05	1.7E-06	1.6E-09	0.0	0.0	0.0	0.0
^{3}H	8.5E-06	2.7E-04	3.3E-07	1.2E-11	0.0	0.0	0.0	0.0
^{129}I	0.0	0.0	1.2E-11	3.3E-11	4.8E-11	5.3E-11	5.4E-11	5.4E-11
^{59}Ni	8.5E-13	3.3E-09	5.9E-10	5.4E-12	1.7E-14	0.0	0.0	0.0
^{63}Ni	1.0E-07	2.3E-04	2.3E-05	1.1E-07	1.9E-10	2.2E-13	0.0	0.0
^{238}Pu	3.8E-07	7.3E-05	6.6E-06	2.8E-08	4.0E-11	0.0	0.0	0.0
^{239}Pu	6.7E-08	2.5E-05	4.6E-06	4.1E-08	1.3E-10	0.0	0.0	0.0
^{241}Pu	1.3E-11	5.5E-10	9.7E-13	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	9.9E-10	1.8E-10	0.0	0.0	0.0	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	6.4E-13	1.0E-10	3.7E-09
^{90}Sr	1.7E-08	8.3E-06	1.8E-07	1.5E-10	0.0	0.0	0.0	0.0
^{99}Tc	3.7E-08	1.4E-04	2.5E-05	2.3E-07	7.3E-10	1.5E-12	0.0	0.0
^{233}U	4.4E-10	1.7E-07	3.0E-08	2.7E-10	0.0	0.0	0.0	0.0
^{234}U	2.5E-09	9.7E-07	1.8E-07	1.6E-09	5.0E-12	0.0	0.0	0.0
^{235}U	2.9E-10	1.1E-07	2.0E-08	1.8E-10	0.0	0.0	0.0	0.0
^{236}U	5.6E-11	2.1E-08	3.9E-09	3.5E-11	0.0	0.0	0.0	0.0
^{238}U	1.8E-08	6.8E-06	1.2E-06	1.1E-08	3.5E-11	0.0	0.0	0.0
^{90}Y	1.3E-09	6.3E-07	1.4E-08	1.1E-11	0.0	0.0	0.0	0.0
Total Dose	8.9E-05	8.2E-04	6.4E-05	5.0E-07	5.9E-08	9.2E-09	1.8E-10	4.4E-09
Radioactive Risk (HE/yr)								
	2.5E-11	2.3E-10	1.8E-11	1.4E-13	1.7E-14	2.6E-15	5.0E-17	1.2E-15

TABLE 32

Chemical Results for Groundwater-to-River Pathway for the Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration (mg/L)								
Cadmium	9.9E-13	3.8E-09	6.9E-10	6.2E-12	2.0E-14	4.2E-17	0.0	1.1E-16
Dibutylphosphate	1.8E-14	7.5E-10	3.8E-10	1.3E-11	1.5E-13	1.0E-15	2.7E-20	0.0
Lead	7.4E-10	2.8E-06	5.2E-07	4.7E-09	1.5E-11	3.1E-14	8.9E-20	0.0
Mercury	2.5E-12	9.5E-09	1.7E-09	1.6E-11	4.9E-14	1.0E-16	0.0	0.0
Naphthalene	1.8E-16	8.2E-09	4.6E-08	6.7E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08
Toluene	1.1E-12	8.3E-08	2.1E-07	2.3E-07	2.3E-07	2.3E-07	2.3E-07	2.3E-07
Tributylphosphate	0.0	8.0E-15	7.5E-09	6.7E-07	4.8E-06	1.3E-05	2.7E-05	2.6E-05
Trimethylbenzene	0.0	1.3E-09	3.7E-08	1.1E-07	1.7E-07	2.0E-07	2.0E-07	2.0E-07
Xylene	1.9E-14	6.7E-08	2.8E-07	3.6E-07	3.7E-07	3.7E-07	3.7E-07	3.7E-07
Noncarcinogenic Risk (ADI fraction)								
Cadmium	2.5E-10	9.5E-07	1.7E-07	1.6E-09	4.9E-12	1.0E-14	0.0	2.7E-14
Lead	2.4E-08	9.3E-05	1.7E-05	1.5E-07	4.8E-10	1.0E-12	2.9E-18	0.0
Mercury	3.8E-09	1.5E-05	2.7E-06	2.4E-08	7.6E-11	1.6E-13	0.0	0.0
Naphthalene	1.3E-17	5.9E-10	3.3E-09	4.8E-09	5.0E-09	5.1E-09	5.1E-09	5.1E-09
Toluene	7.3E-14	5.3E-09	1.4E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08
Trimethylbenzene	0.0	3.9E-11	1.1E-09	3.3E-09	5.0E-09	5.7E-09	6.0E-09	6.0E-09
Xylene	3.5E-14	1.3E-07	5.2E-07	6.7E-07	6.8E-07	6.8E-07	6.8E-07	6.8E-07
EPA Hazard Index	2.8E-08	1.1E-04	2.0E-05	9.1E-07	7.0E-07	7.0E-07	7.0E-07	7.0E-07

TABLE 33

Radionuclide Activity Outcrop Data for the Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration in Groundwater at Outcrop (Ci/m^3)								
^{3}H	6.3E-05	1.6E-04	2.0E-07	7.0E-12	0.0	0.0	0.0	0.0
^{14}C	1.3E-14	2.9E-11	3.0E-11	3.0E-11	2.5E-11	4.0E-12	3.3E-16	0.0
^{60}Co	8.9E-12	4.7E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.2E-12	3.7E-10	6.7E-11	6.1E-13	1.9E-15	0.0	0.0	0.0
^{63}Ni	5.4E-08	9.5E-06	9.9E-07	4.8E-09	8.1E-12	9.2E-15	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	1.1E-14	1.4E-12	3.6E-11
^{90}Sr	7.3E-11	2.8E-09	6.0E-11	5.0E-14	0.0	0.0	0.0	0.0
^{90}Y	7.3E-11	2.8E-09	6.0E-11	5.0E-14	0.0	0.0	0.0	0.0
^{99}Tc	1.9E-09	5.7E-07	1.0E-07	9.4E-10	3.0E-12	6.3E-15	0.0	0.0
^{129}I	0.0	0.0	5.8E-15	8.0E-15	8.3E-15	8.4E-15	8.4E-15	8.4E-15
^{137}Cs	7.2E-11	3.0E-09	7.2E-11	6.8E-14	0.0	0.0	0.0	0.0
^{233}U	1.2E-12	3.8E-11	6.9E-12	6.3E-14	0.0	0.0	0.0	0.0
^{234}U	7.5E-12	2.3E-10	4.2E-11	3.8E-13	1.2E-15	0.0	0.0	0.0
^{235}U	9.0E-13	2.8E-11	5.0E-12	4.6E-14	0.0	0.0	0.0	0.0
^{236}U	1.7E-13	5.3E-12	9.6E-13	8.7E-15	0.0	0.0	0.0	0.0
^{238}U	6.0E-11	1.8E-09	3.3E-10	3.0E-12	9.5E-15	0.0	0.0	0.0
^{238}Pu	7.7E-10	1.2E-08	1.1E-09	4.5E-12	6.5E-15	0.0	0.0	0.0
^{239}Pu	1.2E-10	3.7E-09	6.6E-10	6.0E-12	1.9E-14	0.0	0.0	0.0
^{241}Pu	1.1E-12	4.0E-12	7.0E-15	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	1.5E-13	2.7E-14	0.0	0.0	0.0	0.0	0.0
Contaminant Flux at Outcrop (Ci/yr)								
^{3}H	1.5E+00	4.8E+01	5.9E-02	2.1E-06	0.0	0.0	0.0	0.0
^{14}C	3.0E-10	4.4E-06	8.8E-06	8.9E-06	7.7E-06	1.2E-06	9.9E-11	0.0
^{60}Co	2.2E-07	1.4E-08	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.9E-08	1.1E-04	2.0E-05	1.8E-07	5.8E-10	0.0	0.0	0.0
^{63}Ni	1.3E-03	2.9E+00	3.0E-01	1.5E-03	2.5E-06	2.8E-09	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	2.7E-10	4.5E-08	1.6E-06
^{90}Sr	1.8E-06	8.4E-04	1.8E-05	1.5E-08	0.0	0.0	0.0	0.0
^{90}Y	1.8E-06	8.4E-04	1.8E-05	1.5E-08	0.0	0.0	0.0	0.0
^{99}Tc	4.5E-05	1.7E-01	3.1E-02	2.8E-04	8.9E-07	1.9E-09	0.0	0.0
^{129}I	0.0	0.0	5.7E-10	1.5E-09	2.2E-09	2.5E-09	2.5E-09	2.5E-09
^{137}Cs	1.7E-06	9.1E-04	2.2E-05	2.1E-08	0.0	0.0	0.0	0.0
^{233}U	3.0E-08	1.1E-05	2.1E-06	1.9E-08	0.0	0.0	0.0	0.0
^{234}U	1.8E-07	6.9E-05	1.3E-05	1.1E-07	3.6E-10	0.0	0.0	0.0
^{235}U	2.2E-08	8.4E-06	1.5E-06	1.4E-08	0.0	0.0	0.0	0.0
^{236}U	4.2E-09	1.6E-06	2.9E-07	2.6E-09	0.0	0.0	0.0	0.0
^{238}U	1.4E-06	5.5E-04	1.0E-04	9.0E-07	2.8E-09	0.0	0.0	0.0
^{238}Pu	1.9E-05	3.6E-03	3.2E-04	1.4E-06	1.9E-09	0.0	0.0	0.0
^{239}Pu	2.9E-06	1.1E-03	2.0E-04	1.8E-06	5.6E-09	0.0	0.0	0.0
^{241}Pu	2.8E-08	1.2E-06	2.1E-09	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	4.5E-08	8.1E-09	0.0	0.0	0.0	0.0	0.0

TABLE 34

Chemical Concentration Outcrop Data for the Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration in Groundwater at Outcrop (mg/L)								
Cadmium	3.8E-07	1.1E-04	2.1E-05	1.9E-07	5.9E-10	1.3E-12	0.0	4.1E-11
Lead	2.8E-04	8.6E-02	1.6E-02	1.4E-04	4.4E-07	9.4E-10	2.7E-15	0.0
Mercury	9.4E-07	2.9E-04	5.2E-05	4.7E-07	1.5E-09	3.1E-12	0.0	0.0
Naphthalene	7.8E-11	1.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03
Toluene	4.6E-07	6.1E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03	6.9E-03
Trimethylbenzene	0.0	3.2E-04	3.8E-03	5.8E-03	6.1E-03	6.2E-03	6.2E-03	6.2E-03
Xylene	7.9E-09	7.2E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Contaminant Flux at Outcrop (kg/yr)								
Cadmium	9.0E-06	3.5E-02	6.3E-03	5.7E-05	1.8E-07	3.8E-10	0.0	9.8E-10
Lead	6.8E-03	2.6E+01	4.7E+00	4.2E-02	1.3E-04	2.8E-07	8.1E-13	0.0
Mercury	2.3E-05	8.6E-02	1.6E-02	1.4E-04	4.5E-07	9.4E-10	0.0	0.0
Naphthalene	1.7E-09	7.5E-02	4.2E-01	6.1E-01	6.4E-01	6.4E-01	6.4E-01	6.4E-01
Toluene	1.0E-05	7.6E-01	1.9E+00	2.1E+00	2.1E+00	2.1E+00	2.1E+00	2.1E+00
Trimethylbenzene	0.0	1.2E-02	3.4E-01	1.0E+00	1.6E+00	1.8E+00	1.9E+00	1.9E+00
Xylene	1.7E-07	6.1E-01	2.6E+00	3.3E+00	3.3E+00	3.3E+00	3.3E+00	3.3E+00

TABLE 35

Radionuclide Results for Reclaimed-Farmland Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Dose (mrem/yr)							
^{241}Am	1.3E-08	1.1E-08	9.4E-09	8.0E-09	6.9E-09	5.0E-09	3.2E-09
^{243}Am	7.8E-12	7.7E-12	7.6E-12	7.4E-12	7.3E-12	7.1E-12	6.8E-12
^{244}Cm	3.5E-08	6.7E-10	1.3E-11	2.6E-13	5.0E-15	1.9E-18	0.0
^{248}Cm	8.1E-14	8.1E-14	8.1E-14	8.1E-14	8.1E-14	8.0E-14	8.0E-14
^{60}Co	2.6E-10	4.7E-16	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.4E-06	1.4E-07	1.4E-08	1.4E-09	1.4E-10	1.4E-12	1.4E-15
^{154}Eu	9.9E-13	2.8E-16	8.2E-20	0.0	0.0	0.0	0.0
^{129}I	1.2E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
^{59}Ni	9.6E-12	9.5E-12	9.5E-12	9.4E-12	9.4E-12	9.3E-12	9.1E-12
^{63}Ni	6.6E-07	3.5E-07	1.9E-07	9.8E-08	5.2E-08	1.5E-08	2.2E-09
^{237}Np	1.1E-09	1.0E-09	1.0E-09	9.7E-10	9.4E-10	8.7E-10	7.7E-10
^{147}Pm	2.4E-20	0.0	0.0	0.0	0.0	0.0	0.0
^{238}Pu	2.6E-08	1.2E-08	5.3E-09	2.4E-09	1.1E-09	2.2E-10	2.0E-11
^{239}Pu	8.8E-09	8.8E-09	8.7E-09	8.6E-09	8.6E-09	8.4E-09	8.3E-09
^{241}Pu	2.3E-13	1.2E-15	6.2E-18	3.2E-20	0.0	0.0	0.0
^{242}Pu	3.4E-13	3.4E-13	3.4E-13	3.4E-13	3.4E-13	3.3E-13	3.3E-13
^{87}Rb	1.7E-13	1.5E-13	1.4E-13	1.3E-13	1.2E-13	1.0E-13	8.0E-14
^{125}Sb	2.7E-19	0.0	0.0	0.0	0.0	0.0	0.0
^{79}Se	2.0E-07	1.8E-07	1.5E-07	1.3E-07	1.2E-07	8.7E-08	5.7E-08
^{151}Sm	6.2E-11	2.9E-11	1.4E-11	6.6E-12	3.1E-12	7.1E-13	7.5E-14
^{90}Sr	1.9E-05	1.6E-06	1.4E-07	1.1E-08	9.6E-10	6.8E-12	4.0E-15
^{99}Tc	1.0E-06	7.7E-08	5.7E-09	4.2E-10	3.2E-11	1.7E-13	7.1E-17
^{125}Te	4.1E-17	0.0	0.0	0.0	0.0	0.0	0.0
^{232}Th	4.5E-11	4.4E-11	4.4E-11	4.4E-11	4.4E-11	4.3E-11	4.3E-11
^{233}U	8.9E-10	8.8E-10	8.7E-10	8.6E-10	8.5E-10	8.3E-10	8.0E-10
^{234}U	5.6E-09	5.7E-09	5.8E-09	5.7E-09	5.7E-09	5.6E-09	5.4E-09
^{235}U	6.0E-10	5.9E-10	5.9E-10	5.8E-10	5.7E-10	5.6E-10	5.4E-10
^{236}U	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10
^{238}U	3.6E-08	3.6E-08	3.6E-08	3.5E-08	3.5E-08	3.4E-08	3.3E-08
^{90}Y	1.5E-06	1.2E-07	1.0E-08	8.8E-10	7.4E-11	5.2E-13	3.1E-16
Total Dose	2.4E-05	2.7E-06	7.4E-07	4.7E-07	3.9E-07	3.2E-07	2.6E-07
Radioactive Risk (HE/yr)							
	6.9E-12	7.7E-13	2.1E-13	1.3E-13	1.1E-13	8.9E-14	7.4E-14

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 36

Chemical Results for Reclaimed-Farmland Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Noncarcinogenic Risk (ADI fraction)							
Cadmium	2.1E-08	1.9E-08	1.8E-08	1.7E-08	1.6E-08	1.4E-08	1.1E-08
Lead	2.0E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08	1.9E-08	1.9E-08
Mercury	3.6E-06	3.6E-06	3.6E-06	3.6E-06	3.6E-06	3.6E-06	3.6E-06
Naphthalene	6.8E-10	6.2E-10	5.6E-10	5.1E-10	4.6E-10	3.8E-10	2.8E-10
Toluene	3.5E-09	3.2E-09	2.9E-09	2.6E-09	2.4E-09	1.9E-09	1.4E-09
Trimethylbenzene	5.8E-10	5.3E-10	4.8E-10	4.4E-10	4.0E-10	3.3E-10	2.5E-10
Xylene	1.1E-07	9.6E-08	8.7E-08	7.9E-08	7.2E-08	5.9E-08	4.4E-08
EPA Hazard Index	3.9E-06	3.7E-06	3.7E-06	3.7E-06	3.7E-06	3.7E-06	3.6E-06

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 37

Radionuclide Results for Direct Gamma Exposure Pathway for the Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Dose (mrem/yr)							
^{60}Co	1.8E-27	4.0E-33	8.8E-39	0.0	0.0	0.0	0.0
^{137}Cs	7.5E-33	7.5E-34	7.5E-35	7.5E-36	7.5E-37	9.7E-39	0.0
^{154}Eu	7.5E-31	2.6E-34	9.2E-38	0.0	0.0	0.0	0.0
Total Dose	1.8E-27	5.0E-33	7.5E-35	7.5E-36	7.5E-37	9.7E-39	0.0
Radioactive Risk (HE/yr)							
	5.0E-34	1.4E-39	2.1E-41	2.1E-42	2.1E-43	2.7E-45	0.0

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

with low retardation coefficients will have been transported downward to the water table by this time. A reduction in radionuclide transport does occur after emplacement of the cap because infiltration rates and leach rates are reduced. Therefore, the dose from the groundwater pathways are reduced and peak doses and risks occur at later times compared to the no action option.

The results for the no waste removal and closure option are presented in Tables 38 through 50. Similar to the waste removal and closure option, significant levels of radionuclides (primarily tritium) are calculated in the wells during the assumed period of institutional control. Quantitative predictions for all constituents are similar to the waste removal and closure option. A few constituents that are partially excavated in the waste removal and closure option are higher in the no waste removal and closure option (e.g., ^{90}Sr is approximately 100 times higher).

No Action

The results of the PATHRAE analyses for the no action option are presented in Tables 51 through 63. Similar to the other options, significant levels of radionuclides (primarily tritium) are calculated in the wells during the period of institutional control. Quantitative predictions for many constituents are higher than other options (primarily materials that are in the unsaturated zone at the time of closure). For example, ^{90}Sr is approximately 10 times higher for the modeling of the no action option than the no waste removal and closure option.

Summary

The total calculated releases of constituents to the Savannah River are presented in Tables 64 through 66. Assuming a population of 100,000, the total radioactive risks over 1,000 years to the downstream population are 5.8E-03 HE for the no action option and 5.6E-03 HE for the waste removal and no waste removal and closure options. The maximum radiological and chemical doses are summarized in Table 67.

The PATHRAE analyses indicate that no doses or risks occur for the erosion or natural biointrusion pathways for any of the closure options for either chemical or radioactive constituents. For the groundwater to well pathways similar maximum doses were computed for all scenarios. Calculated risks are dominated by tritium, ^{237}Np, ^{90}Sr, and lead. The calculated risk for the reclaimed-farmland pathway is highest for the no action option (radioactive risk of about 1.6E-06 HE/yr in Year 100, primarily ^{90}Sr, ^{90}Y, and ^{137}Cs, and noncarcinogenic risk of 1.4 ADI fraction, primarily

TABLE 38

Peak Radionuclide Calculations for the No Waste Removal and Closure Option

Pathway	Radionuclide	Peak Concentration (Ci/m^3)	Peak Year Since 1985	Dose (mrem/yr)	Radioactive Risk (HE/yr)
Groundwater to well at 1 m	^{14}C	6.3E-11	180	7.7E-05	2.2E-11
	^{60}Co	2.4E-19	230	3.9E-12	1.1E-18
	^{60}Co*	2.5E-06	-28	4.1E+01	1.1E-05
	^{134}Cs*	2.3E-07	-28	1.2E+01	3.4E-06
	^{137}Cs*	9.4E-07	-28	3.3E+01	9.4E-06
	^{3}H	2.1E+00	-28	1.1E+05	2.9E-02
	^{129}I	8.4E-13	300	1.4E-04	3.9E-11
	^{59}Ni*	8.4E-09	-28	1.1E-03	3.0E-10
	^{63}Ni*	4.4E-04	-28	1.5E+02	4.3E-05
	^{238}Pu*	6.7E-07	-28	1.2E+02	3.3E-05
	^{239}Pu*	8.3E-08	-28	1.6E+01	4.6E-06
	^{241}Pu*	3.5E-08	-28	1.4E-01	3.8E-08
	^{242}Pu*	3.6E-12	-28	6.9E-04	1.9E-10
	^{79}Se	3.0E-09	730	3.5E-02	9.9E-09
	^{90}Sr	3.2E-08	200	2.0E+00	5.6E-07
	^{90}Sr*	1.0E-06	-28	6.3E+01	1.8E-05
	^{99}Tc	1.3E-05	-28	9.5E+01	2.7E-05
	^{233}U*	8.6E-10	-28	1.1E-01	3.1E-08
	^{234}U*	5.2E-09	-28	6.4E-01	1.8E-07
	^{235}U*	6.3E-10	-28	7.5E-02	2.1E-08
	^{236}U*	1.2E-10	-28	1.4E-02	4.0E-09
	^{238}U*	4.1E-08	-28	4.5E+00	1.3E-06
	^{90}Y	3.2E-08	200	1.5E-01	4.3E-08
	^{90}Y*	1.0E-06	-28	4.8E+00	1.4E-06
Groundwater to well at 100 m	^{14}C	6.3E-11	46	7.7E-05	2.2E-11
	^{60}Co*	4.7E-07	-24	7.7E+00	2.1E-06
	^{134}Cs*	2.1E-08	-25	1.1E+00	3.1E-07
	^{137}Cs*	2.9E-07	-23	1.0E+01	2.9E-06
	^{3}H	5.6E-01	-23	2.8E+04	7.8E-03
	^{60}Co*	4.7E-07	-24	7.7E+00	2.1E-06
	^{134}Cs*	2.1E-08	-25	1.1E+00	3.1E-07
	^{137}Cs*	2.9E-07	-23	1.0E+01	2.9E-06
	^{3}H	5.6E-01	-23	2.8E+04	7.8E-03
	^{129}I	8.4E-13	400	1.4E-04	3.9E-11
	^{59}Ni*	3.0E-09	-22	3.8E-04	1.1E-10
	^{63}Ni*	1.5E-04	-22	5.2E+01	1.4E-05
	^{238}Pu*	2.2E-07	-22	4.0E+01	1.1E-05
	^{239}Pu*	2.9E-08	-22	5.8E+00	1.6E-06
	^{241}Pu*	9.2E-09	-23	3.7E-02	1.0E-08
	^{242}Pu*	1.3E-12	-22	2.4E-04	6.8E-11
	^{79}Se	2.9E-09	760	3.4E-02	9.5E-09
	^{90}Sr*	3.1E-07	-23	1.9E+01	5.4E-06
	^{90}Sr	9.7E-11	330	6.1E-03	1.7E-09
	^{99}Tc	4.6E-06	-22	3.3E+01	9.3E-06
	^{233}U*	3.0E-10	-22	3.9E-02	1.1E-08
	^{234}U*	1.8E-09	-22	2.3E-01	6.3E-08
	^{235}U*	2.2E-10	-22	2.6E-02	7.4E-09
	^{236}U*	4.2E-11	-22	5.0E-03	1.4E-09
	^{238}U*	1.5E-08	-22	1.6E+00	4.5E-07
	^{90}Y	9.7E-11	330	4.7E-04	1.3E-10
	^{90}Y*	3.1E-07	-23	1.5E+00	4.2E-07
Groundwater to river	^{14}C	2.0E-14	252	1.4E-07	3.9E-14
	^{60}Co*	2.7E-16	24	6.8E-09	1.9E-15
	^{134}Cs*	9.4E-21	4	1.0E-11	2.8E-18
	^{137}Cs*	1.3E-13	72	9.1E-05	2.6E-11
	^{3}H	1.9E-08	48	9.8E-04	2.8E-10
	^{129}I	2.8E-17	967	5.4E-09	1.5E-15
	^{59}Ni*	1.3E-14	109	3.3E-09	9.3E-16
	^{63}Ni*	3.2E-10	96	2.3E-04	6.3E-11
	^{238}Pu*	4.0E-13	92	7.4E-05	2.1E-11
	^{239}Pu*	1.2E-13	109	2.6E-05	7.2E-12
	^{241}Pu*	4.2E-16	48	1.7E-09	4.9E-16
	^{242}Pu*	5.4E-18	109	1.1E-09	3.0E-16
	^{90}Sr*	1.2E-13	71	1.1E-05	3.0E-12
	^{99}Tc	1.9E-11	109	1.4E-04	4.0E-11
	^{233}U*	1.3E-15	109	1.7E-07	4.7E-14
	^{234}U*	7.7E-15	109	9.8E-07	2.8E-13
	^{235}U*	9.3E-16	109	1.1E-07	3.2E-14
	^{236}U*	1.8E-16	109	2.2E-08	6.1E-15
	^{238}U*	6.2E-14	109	6.9E-06	1.9E-12
	^{90}Y*	1.2E-13	71	8.3E-07	2.3E-13

* Facilitated transport fraction.

TABLE 39

Peak Chemical Calculations for the No Waste Removal and Closure Option

Pathway	Chemical	Peak Concentration (mg/L)	Peak Year Since 1985	Noncarcinogenic Risk (ADI fraction)
Groundwater to well at 1 m	Cadmium*	2.6E-03	-28	1.6E-01
	Lead*	1.9E+00	-28	2.6E+01
	Mercury*	6.5E-03	-28	3.8E+00
	Naphthalene	1.3E-02	250	9.3E-04
	Toluene	4.3E-02	160	2.7E-03
	Trimethylbenzene	4.0E-02	410	1.2E-03
	Xylene	6.8E-02	220	1.3E-01
Groundwater to well at 100 m	Cadmium*	9.1E-04	-22	5.8E-02
	Lead*	6.8E-01	-22	9.1E+00
	Mercury*	2.3E-03	-22	1.3E+00
	Naphthalene	1.3E-02	360	9.3E-04
	Toluene	4.3E-02	230	2.7E-03
	Trimethylbenzene	4.0E-02	570	1.2E-03
	Xylene	6.8E-02	330	1.3E-01
Groundwater to river	Cadmium*	3.9E-09	110	9.6E-07
	Lead*	2.9E-06	110	9.4E-05
	Mercury*	9.6E-09	110	1.5E-05
	Naphthalene	4.4E-07	810	3.1E-08
	Toluene	1.4E-06	570	9.0E-08
	Xylene	2.3E-06	660	4.2E-06

* Facilitated transport fraction.

TABLE 40

Radionuclide Results for Groundwater to Well at 1 m Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (Ci/m^3)							
^{3}H	1.2E-04	1.4E-09	7.1E-15	3.1E-20	0.0	0.0	0.0
^{14}C	6.3E-11	6.2E-11	6.1E-11	1.3E-11	7.4E-14	3.0E-19	0.0
^{60}Co	7.1E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.3E-10	4.3E-13	5.8E-16	7.0E-19	0.0	0.0	0.0
^{63}Ni	3.7E-06	6.4E-09	4.6E-12	3.0E-15	1.9E-18	0.0	0.0
^{79}Se	2.3E-09	2.8E-09	2.9E-09	3.0E-09	3.0E-09	3.0E-09	1.4E-09
^{87}Rb	1.1E-14	6.2E-14	7.4E-14	8.0E-14	8.2E-14	8.5E-14	8.7E-14
^{90}Sr	1.4E-09	3.2E-08	6.2E-09	6.7E-10	6.4E-11	5.4E-13	4.0E-16
^{90}Y	1.4E-09	3.2E-08	6.2E-09	6.7E-10	6.4E-11	5.4E-13	4.0E-16
^{99}Tc	2.1E-07	6.6E-10	8.9E-13	1.1E-15	1.3E-18	0.0	0.0
^{129}I	8.4E-13	8.4E-13	8.4E-13	8.4E-13	8.4E-13	8.4E-13	8.4E-13
^{137}Cs	1.5E-09	4.9E-13	6.7E-17	0.0	0.0	0.0	0.0
^{233}U	1.4E-11	4.4E-14	5.9E-17	7.2E-20	0.0	0.0	4.9E-11
^{234}U	8.3E-11	2.6E-13	3.6E-16	4.3E-19	0.0	0.0	2.9E-10
^{235}U	1.0E-11	3.2E-14	4.3E-17	5.3E-20	0.0	0.0	3.6E-11
^{236}U	1.9E-12	6.1E-15	8.2E-18	0.0	0.0	0.0	6.8E-12
^{238}U	6.6E-10	2.1E-12	2.8E-15	3.5E-18	0.0	0.0	2.3E-09
^{237}Np	0.0	0.0	9.0E-11	1.3E-10	1.5E-10	1.7E-10	1.8E-10
^{238}Pu	4.8E-09	7.0E-12	4.3E-15	2.4E-18	0.0	0.0	0.0
^{239}Pu	1.3E-09	4.2E-12	5.7E-15	6.9E-18	0.0	0.0	0.0
^{241}Pu	2.8E-12	5.1E-17	0.0	0.0	0.0	0.0	0.0
^{242}Pu	5.8E-14	1.8E-16	2.5E-19	0.0	0.0	0.0	0.0
Dose (mrem/yr)							
^{3}H	5.8E+00	7.3E-05	3.6E-10	1.6E-15	0.0	0.0	0.0
^{14}C	7.7E-05	7.6E-05	7.5E-05	1.6E-05	9.1E-08	3.7E-13	0.0
^{60}Co	1.2E-06	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.7E-05	5.5E-08	7.4E-11	9.0E-14	0.0	0.0	0.0
^{63}Ni	1.3E+00	2.2E-03	1.6E-06	1.0E-09	6.6E-13	0.0	0.0
^{79}Se	2.7E-02	3.3E-02	3.4E-02	3.5E-02	3.5E-02	3.5E-02	1.6E-02
^{87}Rb	6.7E-08	4.0E-07	4.7E-07	5.1E-07	5.2E-07	5.4E-07	5.5E-07
^{90}Sr	8.7E-02	2.0E+00	3.9E-01	4.2E-02	4.0E-03	3.4E-05	2.5E-08
^{90}Y	6.7E-03	1.5E-01	3.0E-02	3.2E-03	3.1E-04	2.6E-06	1.9E-09
^{99}Tc	1.5E+00	4.9E-03	6.6E-06	8.0E-09	9.7E-12	0.0	0.0
^{129}I	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04
^{137}Cs	5.2E-02	1.7E-05	2.4E-09	0.0	0.0	0.0	0.0
^{233}U	1.8E-03	5.6E-06	7.6E-09	9.3E-12	0.0	0.0	6.2E-03
^{234}U	1.0E-02	3.3E-05	4.4E-08	5.4E-11	0.0	0.0	3.6E-02
^{235}U	1.2E-03	3.8E-06	5.1E-09	6.2E-12	0.0	0.0	4.2E-03
^{236}U	2.3E-04	7.2E-07	9.8E-10	0.0	0.0	0.0	8.0E-04
^{238}U	7.2E-02	2.3E-04	3.1E-07	3.8E-10	0.0	0.0	2.6E-01
^{237}Np	0.0	0.0	1.6E+00	2.4E+00	2.7E+00	3.0E+00	3.3E+00
^{238}Pu	8.4E-01	1.2E-03	7.6E-07	4.2E-10	0.0	0.0	0.0
^{239}Pu	2.6E-01	8.4E-04	1.1E-06	1.4E-09	0.0	0.0	0.0
^{241}Pu	1.1E-05	2.0E-10	0.0	0.0	0.0	0.0	0.0
^{242}Pu	1.1E-05	3.5E-08	4.7E-11	0.0	0.0	0.0	0.0
Total Dose	1.0E+01	2.2E+00	2.1E+00	2.5E+00	2.7E+00	3.1E+00	3.6E+00
Radioactive Risk (HE/yr)							
	2.8E-06	6.1E-07	5.8E-07	6.9E-07	7.7E-07	8.6E-07	1.0E-06

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 41

Chemical Results for Groundwater to Well at 1 m Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (mg/L)							
Cadmium	4.1E-05	2.7E-03	3.6E-03	3.9E-03	4.1E-03	4.3E-03	4.4E-03
Lead	3.1E-02	9.9E-05	1.3E-07	1.6E-10	2.0E-13	3.0E-19	0.0
Mercury	1.0E-04	3.3E-07	4.5E-10	5.4E-13	6.6E-16	0.0	0.0
Naphthalene	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.1E-02
Toluene	4.3E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02	3.5E-02
Trimethylbenzene	4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02
Xylene	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.3E-02
Noncarcinogenic Risk (ADI fraction)							
Cadmium	2.6E-03	1.7E-01	2.3E-01	2.5E-01	2.6E-01	2.7E-01	2.8E-01
Lead	4.1E-01	1.3E-03	1.8E-06	2.2E-09	2.6E-12	4.0E-18	0.0
Mercury	6.1E-02	1.9E-04	2.6E-07	3.2E-10	3.9E-13	0.0	0.0
Naphthalene	9.3E-04	9.3E-04	9.3E-04	9.3E-04	9.3E-04	9.3E-04	7.9E-04
Toluene	2.7E-03	2.7E-03	2.7E-03	2.7E-03	2.7E-03	2.7E-03	2.2E-03
Trimethylbenzene	1.2E-03	1.2E-03	1.1E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03
Xylene	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.1E-01
EPA Hazard Index	6.1E-01	3.0E-01	3.6E-01	3.8E-01	3.9E-01	4.0E-01	3.9E-01

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 42

Radionuclide Results for Groundwater to Well at 100 m Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (Ci/m^3)							
^{3}H	1.6E-04	3.6E-09	2.1E-14	1.0E-19	0.0	0.0	0.0
^{14}C	6.3E-11	6.2E-11	6.1E-11	1.8E-11	1.8E-13	9.9E-19	0.0
^{60}Co	9.4E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.0E-10	1.1E-12	1.8E-15	2.3E-18	0.0	0.0	0.0
^{63}Ni	5.4E-06	1.6E-08	1.4E-11	9.9E-15	6.7E-18	0.0	0.0
^{79}Se	1.7E-10	1.2E-09	2.0E-09	2.4E-09	2.7E-09	2.9E-09	1.4E-09
^{87}Rb	0.0	2.2E-15	1.5E-14	3.1E-14	4.4E-14	6.2E-14	7.6E-14
^{90}Sr	2.0E-09	1.0E-12	8.3E-11	6.1E-11	1.3E-11	2.4E-13	2.6E-16
^{90}Y	2.0E-09	1.0E-12	8.3E-11	6.1E-11	1.3E-11	2.4E-13	2.6E-16
^{99}Tc	3.0E-07	1.7E-09	2.7E-12	3.6E-15	4.6E-18	0.0	0.0
^{129}I	8.3E-13	8.4E-13	8.4E-13	8.4E-13	8.4E-13	8.4E-13	8.4E-13
^{137}Cs	2.1E-09	1.2E-12	2.0E-16	2.7E-20	0.0	0.0	0.0
^{233}U	2.0E-11	1.1E-13	1.8E-16	2.4E-19	0.0	0.0	0.0
^{234}U	1.2E-10	6.7E-13	1.1E-15	1.4E-18	0.0	0.0	0.0
^{235}U	1.5E-11	8.1E-14	1.3E-16	1.7E-19	0.0	0.0	0.0
^{236}U	2.8E-12	1.5E-14	2.5E-17	3.3E-20	0.0	0.0	0.0
^{238}U	9.6E-10	5.3E-12	8.6E-15	1.1E-17	1.5E-20	0.0	0.0
^{237}Np	0.0	0.0	2.0E-14	2.7E-12	1.3E-11	4.6E-11	9.4E-11
^{238}Pu	6.9E-09	1.8E-11	1.3E-14	7.9E-18	0.0	0.0	0.0
^{239}Pu	1.9E-09	1.1E-11	1.7E-14	2.3E-17	2.9E-20	0.0	0.0
^{241}Pu	3.8E-12	1.3E-16	0.0	0.0	0.0	0.0	0.0
^{242}Pu	8.4E-14	4.7E-16	7.6E-19	0.0	0.0	0.0	0.0
Dose (mrem/yr)							
^{3}H	8.0E+00	1.8E-04	1.1E-09	5.1E-15	0.0	0.0	0.0
^{14}C	7.7E-05	7.6E-05	7.5E-05	2.2E-05	2.2E-07	1.2E-12	0.0
^{60}Co	1.5E-06	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.5E-05	1.4E-07	2.2E-10	3.0E-13	0.0	0.0	0.0
^{63}Ni	1.9E+00	5.5E-03	4.8E-06	3.4E-09	2.3E-12	0.0	0.0
^{79}Se	1.9E-03	1.4E-02	2.3E-02	2.8E-02	3.1E-02	3.4E-02	1.6E-02
^{87}Rb	0.0	1.4E-08	9.6E-08	2.0E-07	2.8E-07	4.0E-07	4.8E-07
^{90}Sr	1.2E-01	6.4E-05	5.2E-03	3.9E-03	8.5E-04	1.5E-05	1.7E-08
^{90}Y	9.5E-03	5.0E-06	4.0E-04	3.0E-04	6.5E-05	1.1E-06	1.3E-09
^{99}Tc	2.2E+00	1.2E-02	2.0E-05	2.7E-08	3.4E-11	0.0	0.0
^{129}I	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04
^{137}Cs	7.4E-02	4.4E-05	7.1E-09	9.5E-13	0.0	0.0	0.0
^{233}U	2.6E-03	1.4E-05	2.3E-08	3.1E-11	0.0	0.0	0.0
^{234}U	1.5E-02	8.2E-05	1.3E-07	1.8E-10	0.0	0.0	0.0
^{235}U	1.7E-03	9.6E-06	1.6E-08	2.1E-11	0.0	0.0	0.0
^{236}U	3.3E-04	1.8E-06	3.0E-09	3.9E-12	0.0	0.0	0.0
^{238}U	1.1E-01	5.8E-04	9.4E-07	1.3E-09	1.6E-12	0.0	0.0
^{237}Np	0.0	0.0	3.6E-04	4.9E-02	2.4E-01	8.4E-01	1.7E+00
^{238}Pu	1.2E+00	3.1E-03	2.3E-06	1.4E-09	0.0	0.0	0.0
^{239}Pu	3.8E-01	2.1E-03	3.4E-06	4.5E-09	5.7E-12	0.0	0.0
^{241}Pu	1.5E-05	5.0E-10	0.0	0.0	0.0	0.0	0.0
^{242}Pu	1.6E-05	8.8E-08	1.4E-10	0.0	0.0	0.0	0.0
Total Dose	1.4E+01	3.8E-02	2.9E-02	8.1E-02	2.7E-01	8.8E-01	1.7E+00
Radioactive Risk (HE/yr)							
	3.9E-06	1.1E-08	8.2E-09	2.3E-08	7.6E-08	2.5E-07	4.8E-07

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 43

Chemical Results for Groundwater to Well at 100 m Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (mg/L)							
Cadmium	6.0E-05	1.4E-05	3.7E-04	1.0E-03	1.7E-03	2.7E-03	3.6E-03
Lead	4.5E-02	2.5E-04	4.1E-07	5.4E-10	6.9E-13	1.1E-18	0.0
Mercury	1.5E-04	8.3E-07	1.4E-09	1.8E-12	2.3E-15	0.0	0.0
Naphthalene	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.2E-02
Toluene	4.3E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02	3.9E-02
Trimethylbenzene	4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02
Xylene	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.7E-02
Noncarcinogenic Risk (ADI fraction)							
Cadmium	3.8E-03	9.0E-04	2.3E-03	6.5E-02	1.1E-01	1.7E-01	2.3E-01
Lead	6.0E-01	3.3E-03	5.4E-06	7.2E-09	9.1E-12	1.5E-17	0.0
Mercury	8.8E-02	4.9E-04	7.9E-07	1.1E-09	1.3E-12	0.0	0.0
Naphthalene	9.3E-04	9.1E-04	9.3E-04	9.3E-04	9.3E-04	9.3E-04	8.8E-04
Toluene	2.7E-03	2.7E-03	2.7E-03	2.7E-03	2.7E-03	2.7E-03	2.4E-03
Trimethylbenzene	1.1E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03
Xylene	1.2E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.2E-01
EPA Hazard Index	2.1E-01	1.4E-01	1.3E-01	2.0E-01	2.4E-01	3.0E-01	3.5E-01

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 44

Radionuclide Results for Groundwater-to-River Pathway for the No Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration (Ci/m^3)								
^{14}C	6.9E-20	9.9E-16	2.0E-15	2.0E-15	1.7E-15	2.8E-16	2.2E-20	0.0
^{60}Co	2.4E-17	1.5E-18	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.9E-16	1.0E-13	2.4E-15	2.3E-18	0.0	0.0	0.0	0.0
^{3}H	1.7E-10	5.2E-09	6.5E-12	2.3E-16	0.0	0.0	0.0	0.0
^{129}I	0.0	2.9E-19	6.3E-18	1.7E-17	2.4E-17	2.7E-17	2.8E-17	2.8E-17
^{59}Ni	3.2E-18	1.2E-14	2.2E-15	2.0E-17	6.3E-20	0.0	0.0	0.0
^{63}Ni	1.4E-13	3.1E-10	3.3E-11	1.6E-13	2.7E-16	3.0E-19	0.0	0.0
^{238}Pu	2.1E-15	3.9E-13	3.6E-14	1.5E-16	2.1E-19	0.0	0.0	0.0
^{239}Pu	3.2E-16	1.2E-13	2.2E-14	2.0E-16	6.2E-19	0.0	0.0	0.0
^{241}Pu	3.0E-18	1.3E-16	2.3E-19	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	5.3E-18	9.6E-19	0.0	0.0	0.0	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	1.5E-19	2.5E-17	8.9E-16
^{90}Sr	1.9E-16	9.2E-14	2.0E-15	1.7E-18	0.0	0.0	0.0	0.0
^{99}Tc	4.9E-15	1.9E-11	3.4E-12	3.1E-14	9.8E-17	2.1E-19	0.0	0.0
^{233}U	3.3E-18	1.3E-15	2.3E-16	2.1E-18	0.0	0.0	0.0	0.0
^{234}U	2.0E-17	2.0E-18	7.6E-15	1.4E-15	1.2E-17	3.9E-20	0.0	0.0
^{235}U	2.4E-18	9.2E-16	1.7E-16	1.5E-18	0.0	0.0	0.0	0.0
^{236}U	4.6E-19	1.7E-16	3.2E-17	2.9E-19	0.0	0.0	0.0	0.0
^{238}U	1.6E-16	6.1E-14	1.1E-14	9.9E-17	3.1E-19	0.0	0.0	0.0
^{90}Y	1.9E-16	9.2E-14	2.0E-15	1.7E-18	0.0	0.0	0.0	0.0
Dose (mrem/yr)								
^{14}C	4.7E-12	6.7E-08	1.4E-07	1.4E-07	1.2E-07	1.9E-08	1.5E-12	0.0
^{60}Co	6.1E-10	3.9E-11	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.4E-07	7.2E-05	1.7E-06	1.6E-09	0.0	0.0	0.0	0.0
^{3}H	8.5E-06	2.7E-04	3.3E-07	1.2E-11	0.0	0.0	0.0	0.0
^{129}I	0.0	5.7E-11	1.2E-09	3.3E-09	4.8E-09	5.3E-09	5.4E-09	5.4E-09
^{59}Ni	8.5E-13	3.3E-09	5.9E-10	5.4E-12	1.7E-14	0.0	0.0	0.0
^{63}Ni	1.0E-07	2.3E-04	2.3E-05	1.1E-07	1.9E-10	2.2E-13	0.0	0.0
^{238}Pu	3.8E-07	7.3E-05	6.6E-06	2.8E-08	4.0E-11	0.0	0.0	0.0
^{239}Pu	6.7E-08	2.5E-05	4.6E-06	4.1E-08	1.3E-10	0.0	0.0	0.0
^{241}Pu	1.3E-11	5.5E-10	9.7E-13	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	1.1E-09	1.9E-10	0.0	0.0	0.0	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	3.3E-12	5.3E-10	1.9E-08
^{90}Sr	1.7E-08	8.3E-06	1.8E-07	1.5E-10	0.0	0.0	0.0	0.0
^{99}Tc	3.7E-08	1.4E-04	2.5E-05	2.3E-07	7.3E-10	1.5E-12	0.0	0.0
^{233}U	4.4E-10	1.7E-07	3.0E-08	2.7E-10	0.0	0.0	0.0	0.0
^{234}U	2.5E-09	9.7E-07	1.8E-07	1.6E-09	5.0E-12	0.0	0.0	0.0
^{235}U	2.9E-10	1.1E-07	2.0E-08	1.8E-10	0.0	0.0	0.0	0.0
^{236}U	5.6E-11	2.1E-08	3.9E-09	3.5E-11	0.0	0.0	0.0	0.0
^{238}U	1.8E-08	6.8E-06	1.2E-06	1.1E-08	3.5E-11	0.0	0.0	0.0
^{90}Y	1.3E-09	6.3E-07	1.4E-08	1.1E-11	0.0	0.0	0.0	0.0
Total Dose	8.9E-05	8.2E-04	6.4E-05	5.7E-07	1.2E-07	2.4E-08	6.0E-09	2.4E-08
Radioactive Risk (HE/yr)								
	2.5E-11	2.3E-10	1.8E-11	1.6E-13	3.5E-14	6.7E-15	1.7E-15	6.8E-15

TABLE 45

Chemical Results for Groundwater-to-River Pathway for the No Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration (mg/L)								
Cadmium	9.9E-13	3.8E-09	6.9E-10	6.2E-12	2.0E-14	4.2E-17	6.1E-20	3.7E-15
Lead	7.4E-10	2.8E-06	5.2E-07	4.7E-09	1.5E-11	3.1E-14	8.9E-20	0.0
Mercury	2.5E-12	9.5E-09	1.7E-09	1.6E-11	4.9E-14	1.0E-16	0.0	0.0
Naphthalene	1.1E-15	5.1E-08	2.8E-07	4.1E-07	4.3E-07	4.4E-07	4.4E-07	4.4E-07
Toluene	7.1E-12	5.2E-07	1.3E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06
Trimethylbenzene	0.0	8.7E-09	2.4E-07	7.2E-07	1.1E-06	1.3E-06	1.3E-06	1.3E-06
Xylene	1.2E-13	4.2E-07	1.7E-06	2.2E-06	2.3E-06	2.3E-06	2.3E-06	2.3E-06
Noncarcinogenic Risk (ADI fraction)								
Cadmium	2.5E-10	9.5E-07	1.7E-07	1.6E-09	4.9E-12	1.0E-14	1.5E-17	9.4E-13
Lead	2.4E-08	9.3E-05	1.7E-05	1.5E-07	4.8E-10	1.0E-12	2.9E-18	0.0
Mercury	3.8E-09	1.5E-05	2.7E-06	2.4E-08	7.6E-11	1.6E-13	0.0	0.0
Naphthalene	8.1E-17	3.6E-09	2.0E-08	3.0E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08
Toluene	4.5E-13	3.3E-08	8.4E-08	9.0E-08	9.0E-08	9.0E-08	9.0E-08	9.0E-08
Trimethylbenzene	0.0	2.5E-10	7.1E-09	2.1E-08	3.3E-08	3.7E-08	3.9E-08	3.9E-08
Xylene	2.2E-13	7.7E-07	3.2E-06	4.1E-06	4.2E-06	4.2E-06	4.2E-06	4.2E-06
EPA Hazard Index	2.8E-08	1.1E-04	2.3E-05	4.4E-06	3.9E-06	4.2E-06	4.2E-06	4.2E-06

TABLE 46

Radionuclide Activity Outcrop Data for the No Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration in Groundwater at Outcrop (Ci/m^3)								
^{3}H	6.3E-05	1.6E-04	2.0E-07	7.0E-12	0.0	0.0	0.0	0.0
^{14}C	2.7E-14	5.9E-11	6.2E-11	6.1E-11	5.3E-11	8.3E-12	6.8E-16	0.0
^{60}Co	8.9E-12	4.7E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.2E-12	3.7E-10	6.7E-11	6.1E-13	1.9E-15	0.0	0.0	0.0
^{63}Ni	5.4E-08	9.5E-06	9.9E-07	4.8E-09	8.1E-12	9.2E-15	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	5.5E-14	7.2E-12	1.8E-10
^{90}Sr	7.3E-11	2.8E-09	6.0E-11	5.0E-14	0.0	0.0	0.0	0.0
^{90}Y	7.3E-11	2.8E-09	6.0E-11	5.0E-14	0.0	0.0	0.0	0.0
^{99}Tc	1.9E-09	5.7E-07	1.0E-07	9.4E-10	3.0E-12	6.3E-15	0.0	0.0
^{129}I	0.0	6.6E-14	5.8E-13	8.0E-13	8.3E-13	8.4E-13	8.4E-13	8.4E-13
^{137}Cs	7.2E-11	3.0E-09	7.2E-11	6.8E-14	0.0	0.0	0.0	0.0
^{233}U	1.2E-12	3.8E-11	6.9E-12	6.3E-14	0.0	0.0	0.0	0.0
^{234}U	7.5E-12	2.3E-10	4.2E-11	3.8E-13	1.2E-15	0.0	0.0	0.0
^{235}U	9.0E-13	2.8E-11	5.0E-12	4.6E-14	0.0	0.0	0.0	0.0
^{236}U	1.7E-13	5.3E-12	9.6E-13	8.7E-15	0.0	0.0	0.0	0.0
^{238}U	6.0E-11	1.8E-09	3.3E-10	3.0E-12	9.2E-15	0.0	0.0	0.0
^{238}Pu	7.7E-10	1.2E-08	1.1E-09	4.5E-12	6.5E-15	0.0	0.0	0.0
^{239}Pu	1.2E-10	3.7E-09	6.6E-10	6.0E-12	1.9E-14	0.0	0.0	0.0
^{241}Pu	1.1E-12	4.0E-12	7.0E-15	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	1.6E-13	2.9E-14	0.0	0.0	0.0	0.0	0.0
Contaminant Flux at Outcrop (Ci/yr)								
^{3}H	1.5E+00	4.8E+01	5.9E-02	2.1E-06	0.0	0.0	0.0	0.0
^{14}C	6.3E-10	9.0E-06	1.8E-05	1.8E-05	1.6E-05	2.5E-06	2.0E-10	0.0
^{60}Co	2.2E-07	1.4E-08	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.9E-08	1.1E-04	2.0E-05	1.8E-07	5.8E-10	0.0	0.0	0.0
^{63}Ni	1.3E-03	2.9E+00	3.0E-01	1.5E-03	2.5E-06	2.8E-09	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	0.0	1.4E-09	2.3E-07	8.1E-06
^{90}Sr	1.8E-06	8.4E-04	1.8E-05	1.5E-08	0.0	0.0	0.0	0.0
^{90}Y	1.8E-06	8.4E-04	1.8E-05	1.5E-08	0.0	0.0	0.0	0.0
^{99}Tc	4.5E-05	1.7E-01	3.1E-02	2.8E-04	8.9E-07	1.9E-09	0.0	0.0
^{129}I	0.0	2.6E-09	5.7E-08	1.5E-07	2.2E-07	2.5E-07	2.5E-07	2.5E-07
^{137}Cs	1.7E-06	9.1E-04	2.2E-05	2.1E-08	0.0	0.0	0.0	0.0
^{233}U	3.0E-08	1.1E-05	2.1E-06	1.9E-08	0.0	0.0	0.0	0.0
^{234}U	1.8E-07	6.9E-05	1.3E-05	1.1E-07	3.6E-10	0.0	0.0	0.0
^{235}U	2.2E-08	8.4E-06	1.5E-06	1.4E-08	0.0	0.0	0.0	0.0
^{236}U	4.2E-09	1.6E-06	2.9E-07	2.6E-09	0.0	0.0	0.0	0.0
^{238}U	1.4E-06	5.5E-04	1.0E-04	9.0E-07	2.8E-09	0.0	0.0	0.0
^{238}Pu	1.9E-05	3.6E-03	3.2E-04	1.4E-06	1.9E-09	0.0	0.0	0.0
^{239}Pu	2.9E-06	1.1E-03	2.0E-04	1.8E-06	5.6E-09	0.0	0.0	0.0
^{241}Pu	2.8E-08	1.2E-06	2.1E-09	0.0	0.0	0.0	0.0	0.0
^{242}Pu	0.0	4.8E-08	8.8E-09	0.0	0.0	0.0	0.0	0.0

TABLE 47

Chemical Concentration Outcrop Data for the No Waste Removal and Closure Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration in Groundwater at Outcrop (mg/L)								
Cadmium	3.8E-07	1.1E-04	2.1E-05	1.9E-07	5.9E-10	1.3E-12	2.6E-14	1.4E-09
Lead	2.8E-04	8.6E-02	1.6E-02	1.4E-04	4.4E-07	9.4E-10	2.7E-15	0.0
Mercury	9.4E-07	2.9E-04	5.2E-05	4.7E-07	1.5E-09	3.1E-12	0.0	0.0
Naphthalene	4.8E-10	6.6E-03	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02
Toluene	2.8E-06	3.8E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02	4.3E-02
Trimethylbenzene	0.0	2.1E-03	2.5E-02	3.7E-02	4.0E-02	4.0E-02	4.0E-02	4.0E-02
Xylene	4.9E-08	4.5E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02	6.8E-02
Contaminant Flux at Outcrop (kg/yr)								
Cadmium	9.0E-06	3.5E-02	6.3E-03	5.7E-05	1.8E-07	3.8E-10	5.6E-13	3.4E-08
Lead	6.8E-03	2.6E+01	4.7E+00	4.2E-02	1.3E-04	2.8E-07	8.1E-13	0.0
Mercury	2.3E-05	8.6E-02	1.6E-02	1.4E-04	4.5E-07	9.4E-10	0.0	0.0
Naphthalene	1.0E-08	4.6E-01	2.6E+00	3.8E+00	3.9E+00	4.0E+00	4.0E+00	4.0E+00
Toluene	6.5E-05	4.7E+00	1.2E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01
Trimethylbenzene	0.0	7.9E-02	2.2E+00	6.6E+00	1.0E+01	1.2E+01	1.2E+01	1.2E+01
Xylene	1.1E-06	3.8E+00	1.6E+01	2.0E+01	2.1E+01	2.1E+01	2.1E+01	2.1E+01

TABLE 48

Radionuclide Results for Reclaimed-Farmland Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Dose (mrem/yr)							
^{241}Am	1.3E-06	1.1E-06	9.4E-07	8.0E-07	6.9E-07	5.0E-07	3.2E-07
^{243}Am	7.8E-10	7.7E-10	7.6E-10	7.4E-10	7.3E-10	7.1E-10	6.8E-10
^{244}Cm	3.5E-06	6.7E-08	1.3E-09	2.6E-11	5.0E-13	1.9E-16	0.0
^{248}Cm	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.3E-12	8.3E-12
^{60}Co	2.6E-08	4.7E-14	8.5E-20	0.0	0.0	0.0	0.0
^{134}Cs	5.2E-19	1.3E-33	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.4E-04	1.4E-05	1.4E-06	1.4E-07	1.4E-08	1.4E-10	1.4E-13
^{154}Eu	9.9E-11	2.8E-14	8.2E-18	0.0	0.0	0.0	0.0
^{129}I	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05
^{59}Ni	9.6E-10	9.5E-10	9.5E-10	9.4E-10	9.4E-10	9.3E-10	9.1E-10
^{63}Ni	6.6E-05	3.5E-05	1.9E-05	9.8E-06	5.2E-06	1.5E-06	2.2E-07
^{237}Np	1.1E-07	1.0E-07	1.0E-07	9.7E-08	9.4E-08	8.7E-08	7.7E-08
^{147}Pm	2.4E-18	0.0	0.0	0.0	0.0	0.0	0.0
^{238}Pu	2.6E-06	1.2E-06	5.3E-07	2.4E-07	1.1E-07	2.2E-08	2.1E-09
^{239}Pu	8.9E-07	8.8E-07	8.8E-07	8.8E-07	8.8E-07	8.7E-07	8.6E-07
^{241}Pu	2.3E-11	1.2E-13	6.2E-16	3.2E-18	1.7E-20	0.0	0.0
^{242}Pu	3.4E-11	3.4E-11	3.4E-11	3.4E-11	3.4E-11	3.3E-11	3.3E-11
^{87}Rb	3.0E-12	2.8E-12	2.6E-12	2.4E-12	2.2E-12	1.9E-12	1.5E-12
^{125}Sb	2.7E-17	0.0	0.0	0.0	0.0	0.0	0.0
^{79}Se	1.0E-06	9.0E-07	7.8E-07	6.8E-07	5.9E-07	4.4E-07	2.9E-07
^{151}Sm	6.2E-09	2.9E-09	1.4E-09	6.6E-10	3.1E-10	7.1E-11	7.5E-12
^{90}Sr	1.9E-03	1.6E-04	1.4E-05	1.1E-06	9.6E-08	6.8E-10	4.0E-13
^{99}Tc	1.0E-06	7.7E-08	5.7E-09	4.2E-10	3.2E-11	1.7E-13	7.1E-17
^{125}Te	4.1E-15	0.0	0.0	0.0	0.0	0.0	0.0
^{232}Th	4.5E-09	4.4E-09	4.4E-09	4.4E-09	4.4E-09	4.3E-09	4.3E-09
^{233}U	8.9E-08	8.8E-08	8.7E-08	8.6E-08	8.5E-08	8.3E-08	8.0E-08
^{234}U	5.6E-07	5.7E-07	5.8E-07	5.7E-07	5.7E-07	5.6E-07	5.4E-07
^{235}U	6.0E-08	5.9E-08	5.9E-08	5.8E-08	5.7E-08	5.6E-08	5.4E-08
^{236}U	1.1E-08	1.1E-08	1.1E-08	1.1E-08	1.1E-08	1.1E-08	1.1E-08
^{238}U	3.6E-06	3.6E-06	3.6E-06	3.5E-06	3.5E-06	3.4E-06	3.3E-06
^{90}Y	1.5E-04	1.2E-05	1.0E-06	8.8E-08	7.4E-09	5.2E-11	3.1E-14
Total Dose	2.3E-03	2.5E-04	5.7E-05	3.3E-05	2.6E-05	2.2E-05	2.0E-05
Radioactive Risk (HE/yr)							
	6.5E-10	6.9E-11	1.6E-11	9.1E-12	7.4E-12	6.1E-12	5.6E-12

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 49

Chemical Results for Reclaimed-Farmland Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Noncarcinogenic Risk (ADI fraction)							
Cadmium	7.3E-07	6.8E-07	6.3E-07	5.9E-07	5.5E-07	4.8E-07	3.9E-07
Lead	2.0E-06	2.0E-06	2.0E-06	2.0E-06	2.0E-06	1.9E-06	1.9E-06
Mercury	3.6E-04	3.6E-04	3.6E-04	3.6E-04	3.6E-04	3.6E-04	3.6E-04
Naphthalene	4.2E-09	3.8E-09	3.4E-09	3.1E-09	2.8E-09	2.3E-09	1.7E-09
Toluene	2.2E-08	2.0E-08	1.8E-08	1.6E-08	1.5E-08	1.2E-08	8.9E-09
Trimethylbenzene	3.8E-09	3.4E-09	3.1E-09	2.8E-09	2.6E-09	2.1E-09	1.6E-09
Xylene	6.6E-07	6.0E-07	5.4E-07	4.9E-07	4.4E-07	3.6E-07	2.7E-07
EPA Hazard Index	3.6E-04	3.6E-04	3.6E-04	3.6E-04	3.6E-04	3.6E-04	3.6E-04

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 50

Radionuclide Results for Direct Gamma Exposure Pathway for the No Waste Removal and Closure Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Dose (mrem/yr)							
^{241}Am	5.8E-16	6.5E-16	7.3E-16	8.3E-16	9.3E-16	1.2E-15	1.7E-15
^{60}Co	5.9E-10	1.3E-15	0.0	0.0	0.0	0.0	0.0
^{137}Cs	9.8E-11	1.2E-11	1.6E-12	2.0E-13	2.5E-14	3.9E-16	7.7E-19
^{154}Eu	7.0E-12	2.4E-15	8.5E-19	0.0	0.0	0.0	0.0
^{238}Pu	1.1E-15	6.6E-16	3.9E-16	2.3E-16	1.4E-16	4.9E-17	1.0E-17
^{234}U	2.6E-19	3.7E-19	5.0E-19	6.7E-19	9.0E-19	1.6E-18	3.8E-18
Total Dose	7.0E-10	1.2E-11	1.6E-12	2.0E-13	2.6E-14	1.6E-15	1.7E-15
Radioactive Risk (HE/yr)							
	1.9E-16	3.5E-18	4.4E-19	5.5E-20	7.2E-21	4.5E-22	4.8E-22

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 51

Peak Radionuclide Calculations for the No Action Option

Pathway	Radionuclide	Peak Concentration (Ci/m^3)	Peak Year Since 1985	Dose (mrem/yr)	Radioactive Risk (HE/yr)
Groundwater to well at 1 m	^{14}C	6.5E-10	3	8.0E-04	2.2E-10
	^{60}Co	2.4E-18	230	4.0E-11	1.1E-17
	^{60}Co*	2.5E-06	-28	4.1E+01	1.1E-05
	^{134}Cs*	2.3E-07	-28	1.2E+01	3.4E-06
	^{137}Cs*	9.4E-07	-28	3.3E+01	9.4E-06
	^{3}H	2.1E+00	-28	1.1E+05	2.9E-02
	^{129}I	8.4E-12	300	1.4E-03	3.9E-10
	^{59}Ni*	8.4E-09	-28	1.1E-03	3.0E-10
	^{63}Ni*	4.4E-04	-28	1.5E+02	4.3E-05
	^{237}Np	1.5E-09	435	2.7E+01	7.6E-06
	^{238}Pu*	6.7E-07	-28	1.2E+02	3.3E-05
	^{239}Pu*	8.3E-08	-28	1.6E+01	4.6E-06
	^{241}Pu*	3.5E-08	-28	1.4E-01	3.8E-08
	^{242}Pu*	3.6E-12	-28	6.9E-04	1.9E-10
	^{87}Rb	7.3E-13	200	4.6E-06	1.3E-12
	^{79}Se	2.8E-08	87	3.3E-01	9.2E-08
	^{90}Sr	3.5E-07	200	2.2E+01	6.2E-06
	^{90}Sr*	1.0E-06	-28	6.3E+01	1.8E-05
	^{99}Tc	1.3E-05	-28	9.5E+01	2.7E-05
	^{233}U*	8.6E-10	-28	1.1E-01	3.1E-08
	^{234}U*	5.2E-09	-28	6.4E-01	1.8E-07
	^{235}U*	6.3E-10	-28	7.5E-02	2.1E-08
	^{236}U*	1.2E-10	-28	1.4E-02	4.0E-09
	^{238}U*	4.1E-08	-28	4.5E+00	1.3E-06
	^{90}Y	3.5E-07	200	1.7E+00	4.7E-07
	^{90}Y*	1.0E-06	-28	4.8E+00	1.4E-06
Groundwater to well at 100 m	^{14}C	6.2E-10	5	7.6E-04	2.1E-10
	^{60}Co*	4.7E-07	-24	7.7E+00	2.1E-06
	^{134}Cs*	2.1E-08	-25	1.1E+00	3.1E-07
	^{137}Cs*	2.9E-07	-23	1.0E+01	2.9E-06
	^{3}H	5.6E-01	-23	2.8E+04	7.8E-03
	^{129}I	8.4E-12	400	1.4E-03	3.9E-10
	^{59}Ni*	3.0E-09	-22	3.8E-04	1.1E-10
	^{63}Ni*	1.5E-04	-22	5.2E+01	1.4E-05
	^{237}Np	4.0E-10	793	7.4E+00	2.1E-06
	^{238}Pu*	2.2E-07	-22	4.0E+01	1.1E-05
	^{239}Pu*	2.9E-08	-22	5.8E+00	1.6E-06
	^{241}Pu*	9.2E-09	-23	3.7E-02	1.0E-08
	^{242}Pu*	1.3E-12	-22	2.4E-04	6.8E-11
	^{87}Rb	2.0E-13	390	1.3E-06	3.5E-13
	^{79}Se	7.7E-09	180	8.9E-02	2.5E-08
	^{90}Sr	1.1E-09	330	6.7E-02	1.9E-08
	^{90}Sr*	3.1E-07	-23	1.9E+01	5.4E-06
	^{99}Tc	4.6E-06	-22	3.3E+01	9.3E-06
	^{233}U*	3.0E-10	-22	3.9E-02	1.1E-08
	^{234}U*	1.8E-09	-22	2.3E-01	6.3E-08
	^{235}U*	2.2E-10	-22	2.6E-02	7.4E-09
	^{236}U*	4.2E-11	-22	5.0E-03	1.4E-09
	^{238}U*	1.5E-08	-22	1.6E+00	4.5E-07
	^{90}Y	1.1E-09	330	5.2E-03	1.5E-09
	^{90}Y*	3.1E-07	-23	1.5E+00	4.2E-07
Groundwater to river	^{14}C	6.0E-15	110	4.0E-07	1.1E-13
	^{60}Co*	1.3E-15	18	3.3E-08	9.4E-15
	^{134}Cs*	8.7E-20	3	9.3E-11	2.6E-17
	^{137}Cs*	1.9E-13	53	1.4E-04	3.9E-11
	^{3}H	4.9E-08	35	2.5E-03	7.0E-10
	^{129}I	2.8E-16	970	5.4E-08	1.5E-14
	^{59}Ni*	1.3E-14	920	3.4E-09	9.5E-16
	^{63}Ni*	3.6E-10	77	2.6E-04	7.2E-11
	^{238}Pu*	4.7E-13	74	8.7E-05	2.4E-11
	^{239}Pu*	1.3E-13	92	2.6E-05	7.4E-12
	^{241}Pu*	1.0E-15	36	4.2E-09	1.2E-15
	^{242}Pu*	5.5E-18	92	1.1E-09	3.1E-16
	^{90}Sr*	1.9E-13	52	1.7E-05	4.7E-12
	^{99}Tc	2.0E-11	92	1.5E-04	4.1E-11
	^{233}U*	1.3E-15	92	1.7E-07	4.8E-14
	^{234}U*	7.9E-15	92	1.0E-06	2.8E-13
	^{235}U*	9.5E-16	92	1.2E-07	3.3E-14
	^{236}U*	1.8E-16	92	2.2E-08	6.2E-15
	^{238}U*	6.1E-14	92	7.1E-06	2.0E-12
	^{90}Y*	1.9E-13	52	1.3E-06	3.6E-13

* Facilitated transport fraction.

TABLE 52

Peak Chemical Calculations for the No Action Option

Pathway	Chemical	Peak Concentration (mg/L)	Peak Year Since 1985	Noncarcinogenic Risk (ADI fraction)
Groundwater to well at 1 m	Cadmium	3.7E-02	250	2.3E+00
	Cadmium*	2.6E-03	-28	1.6E-01
	Lead*	1.9E+00	-28	2.6E+01
	Mercury*	6.5E-03	-28	3.8E+00
	Naphthalene	1.3E-01	71	9.4E-03
	Toluene	4.3E-01	70	2.7E-02
	Trimethylbenzene	4.3E-01	74	1.2E-02
	Xylene	7.0E-01	71	1.3E+00
Groundwater to well at 100 m	Cadmium	1.0E-02	470	6.4E-01
	Cadmium*	9.1E-04	-22	5.8E-02
	Lead*	6.8E-01	-22	9.1E+00
	Mercury*	2.3E-03	-22	1.3E+00
	Naphthalene	1.3E-01	70	9.3E-03
	Toluene	4.3E-01	68	2.7E-02
	Trimethylbenzene	4.2E-01	77	1.2E-02
	Xylene	7.0E-01	72	1.3E+00
Groundwater to river	Cadmium*	3.9E-09	92	9.8E-07
	Lead*	3.0E-06	92	9.6E-05
	Mercury*	9.8E-09	92	1.5E-05
	Naphthalene	2.4E-06	210	1.7E-07
	Toluene	9.8E-06	160	6.2E-07
	Trimethylbenzene	5.3E-06	320	1.5E-07
	Xylene	1.4E-05	190	2.5E-05

* Facilitated transport fraction.

TABLE 53

Radionuclide Results for Groundwater to Well at 1 m Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (Ci/m^3)							
^{3}H	4.6E-05	3.5E-10	1.7E-15	0.0	0.0	0.0	0.0
^{14}C	7.1E-11	3.5E-13	7.4E-16	1.4E-18	0.0	0.0	0.0
^{60}Co	3.0E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	5.0E-11	1.0E-13	1.3E-16	1.6E-19	0.0	0.0	0.0
^{63}Ni	1.4E-06	1.6E-09	1.1E-12	6.9E-16	4.5E-19	0.0	0.0
^{79}Se	1.7E-08	2.3E-09	1.5E-09	1.4E-09	1.4E-09	1.4E-09	1.3E-09
^{87}Rb	1.2E-13	7.2E-13	1.6E-13	6.7E-14	3.9E-14	3.8E-14	3.7E-14
^{90}Sr	5.3E-10	3.5E-07	6.9E-08	3.2E-09	1.3E-10	3.6E-13	2.0E-16
^{90}Y	5.3E-10	3.5E-07	6.9E-08	3.2E-09	1.3E-10	3.6E-13	2.0E-16
^{99}Tc	7.8E-08	1.6E-10	2.1E-13	2.5E-16	3.0E-19	0.0	0.0
^{129}I	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12
^{137}Cs	5.6E-10	1.2E-13	1.5E-17	0.0	0.0	0.0	0.0
^{233}U	5.2E-12	1.1E-14	1.4E-17	1.7E-20	0.0	0.0	4.8E-10
^{234}U	3.1E-11	6.5E-14	8.3E-17	1.0E-19	0.0	0.0	2.9E-09
^{235}U	3.8E-12	7.8E-15	1.0E-17	1.2E-20	0.0	0.0	3.5E-10
^{236}U	7.1E-13	1.5E-15	1.9E-18	0.0	0.0	0.0	6.7E-11
^{238}U	2.5E-10	5.1E-13	6.6E-16	8.0E-19	0.0	0.0	2.3E-08
^{237}Np	0.0	0.0	9.8E-10	1.4E-09	7.4E-10	2.3E-10	8.2E-11
^{238}Pu	1.8E-09	1.7E-12	1.0E-15	5.5E-19	0.0	0.0	0.0
^{239}Pu	5.0E-10	1.0E-12	1.3E-15	1.6E-18	0.0	0.0	0.0
^{241}Pu	1.1E-12	1.2E-17	0.0	0.0	0.0	0.0	0.0
^{242}Pu	2.2E-14	4.5E-17	5.8E-20	0.0	0.0	0.0	0.0
Dose (mrem/yr)							
^{3}H	2.3E+00	1.8E-05	8.3E-11	0.0	0.0	0.0	0.0
^{14}C	8.7E-05	4.3E-07	9.0E-10	1.7E-12	0.0	0.0	0.0
^{60}Co	4.8E-07	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	6.4E-06	1.3E-08	1.7E-11	2.1E-14	0.0	0.0	0.0
^{63}Ni	4.8E-01	5.4E-04	3.7E-07	2.4E-10	1.5E-13	0.0	0.0
^{79}Se	1.9E-01	2.6E-02	1.7E-02	1.7E-02	1.7E-02	1.6E-02	1.5E-02
^{87}Rb	7.8E-07	4.6E-06	1.0E-06	4.3E-07	2.5E-07	2.4E-07	2.4E-07
^{90}Sr	3.3E-02	2.2E+01	4.3E+00	2.0E-01	8.0E-03	2.3E-05	1.3E-08
^{90}Y	2.6E-03	1.7E+00	3.3E-01	1.5E-02	6.2E-04	1.7E-06	9.9E-10
^{99}Tc	5.7E-01	1.2E-03	1.5E-06	1.8E-09	2.2E-12	0.0	0.0
^{129}I	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03
^{137}Cs	2.0E-02	4.2E-06	5.5E-10	0.0	0.0	0.0	0.0
^{233}U	6.6E-04	1.4E-06	1.8E-09	2.1E-12	0.0	0.0	6.1E-02
^{234}U	3.9E-03	8.0E-06	1.0E-08	1.2E-11	0.0	0.0	3.6E-01
^{235}U	4.5E-04	9.3E-07	1.2E-09	1.4E-12	0.0	0.0	4.2E-02
^{236}U	8.5E-05	1.8E-07	2.3E-10	0.0	0.0	0.0	7.9E-03
^{238}U	2.7E-02	5.6E-05	7.2E-08	8.8E-11	0.0	0.0	2.5E+00
^{237}Np	0.0	0.0	1.8E+01	2.6E+01	1.3E+01	4.1E+00	1.5E+00
^{238}Pu	3.2E-01	3.0E-04	1.8E-07	9.7E-11	0.0	0.0	0.0
^{239}Pu	9.9E-02	2.0E-04	2.6E-07	3.2E-10	0.0	0.0	0.0
^{241}Pu	4.3E-06	5.0E-11	0.0	0.0	0.0	0.0	0.0
^{242}Pu	4.1E-06	8.6E-09	1.1E-11	0.0	0.0	0.0	0.0
Total Dose	4.1E+00	2.4E+01	2.3E+01	2.6E+01	1.3E+01	4.1E+00	4.5E+00
Radioactive Risk (HE/yr)							
	1.1E-06	6.7E-06	6.3E-06	7.3E-06	3.8E-06	1.1E-06	1.3E-06

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 54

Chemical Results for Groundwater to Well at 1 m Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (mg/L)							
Cadmium	1.6E-05	3.1E-02	1.6E-02	6.0E-03	3.1E-03	2.0E-03	1.9E-03
Lead	1.2E-02	2.4E-05	3.1E-08	3.8E-11	4.6E-14	7.0E-20	0.0
Mercury	3.9E-05	8.0E-08	1.0E-10	1.3E-13	1.5E-16	0.0	0.0
Naphthalene	8.1E-02	2.3E-02	1.0E-03	2.4E-05	5.0E-07	1.9E-10	1.4E-15
Toluene	2.9E-01	2.2E-02	1.4E-04	6.0E-07	2.3E-09	3.3E-14	0.0
Trimethylbenzene	1.9E-01	1.4E-01	3.8E-02	5.1E-03	5.3E-04	4.5E-06	2.9E-09
Xylene	4.5E-01	8.6E-02	2.1E-03	2.9E-05	3.6E-07	5.1E-11	8.8E-17
Noncarcinogenic Risk (ADI fraction)							
Cadmium	9.9E-04	2.0E+00	1.0E+00	3.8E-01	2.0E-01	1.2E-01	1.2E-01
Lead	1.6E-01	3.2E-04	4.1E-07	5.0E-10	6.1E-13	9.3E-19	0.0
Mercury	2.3E-02	4.7E-05	6.0E-08	7.3E-11	8.8E-14	0.0	0.0
Naphthalene	5.7E-03	1.6E-03	7.1E-05	1.7E-06	3.5E-08	1.4E-11	1.0E-16
Toluene	1.8E-02	1.4E-03	9.0E-06	3.7E-08	1.4E-10	2.1E-15	0.0
Trimethylbenzene	5.4E-03	4.0E-03	1.1E-03	1.5E-04	1.5E-05	1.3E-07	8.4E-11
Xylene	8.2E-01	1.6E-01	3.8E-03	5.4E-05	6.6E-07	9.4E-11	1.6E-16
EPA Hazard Index	1.0E+00	2.2E+00	1.0E+00	3.8E-01	2.0E-01	1.2E-01	1.2E-01

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 55

Radionuclide Results for Groundwater to Well at 100 m Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (Ci/m^3)							
^{3}H	7.9E-05	9.4E-10	5.1E-15	2.4E-20	0.0	0.0	0.0
^{14}C	1.0E-10	8.6E-13	2.2E-15	4.5E-18	0.0	0.0	0.0
^{60}Co	5.0E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	9.0E-11	2.8E-13	4.2E-16	5.5E-19	0.0	0.0	0.0
^{63}Ni	2.5E-06	4.2E-09	3.3E-12	2.3E-15	1.6E-18	0.0	0.0
^{79}Se	2.2E-09	7.5E-09	4.9E-09	2.8E-09	1.6E-09	1.4E-09	1.4E-09
^{87}Rb	0.0	2.5E-14	1.6E-13	2.0E-13	1.7E-13	9.9E-14	4.3E-14
^{90}Sr	9.3E-10	2.7E-13	9.1E-10	6.8E-10	1.3E-10	1.2E-12	5.6E-16
^{90}Y	9.3E-10	2.7E-13	9.1E-10	6.8E-10	1.3E-10	1.2E-12	5.6E-16
^{99}Tc	1.4E-07	4.3E-10	6.4E-13	8.4E-16	1.1E-18	0.0	0.0
^{129}I	8.3E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12	8.4E-12
^{137}Cs	9.9E-10	3.2E-13	4.8E-17	0.0	0.0	0.0	0.0
^{233}U	9.2E-12	2.9E-14	4.3E-17	5.6E-20	0.0	0.0	0.0
^{234}U	5.6E-11	1.7E-13	2.6E-16	3.4E-19	0.0	0.0	0.0
^{235}U	6.7E-12	2.1E-14	3.1E-17	4.1E-20	0.0	0.0	0.0
^{236}U	1.3E-12	4.0E-15	5.9E-18	0.0	0.0	0.0	0.0
^{238}U	4.4E-10	1.4E-12	2.1E-15	2.7E-18	0.0	0.0	0.0
^{237}Np	0.0	0.0	2.1E-13	2.9E-11	1.4E-10	3.8E-10	3.5E-10
^{238}Pu	3.2E-09	4.6E-12	3.1E-15	1.8E-18	0.0	0.0	0.0
^{239}Pu	8.8E-10	2.8E-12	4.1E-15	5.3E-18	0.0	0.0	0.0
^{241}Pu	1.9E-12	3.3E-17	0.0	0.0	0.0	0.0	0.0
^{242}Pu	3.9E-14	1.2E-16	1.8E-19	0.0	0.0	0.0	0.0
Dose (mrem/yr)							
^{3}H	4.0E+00	4.7E-05	2.6E-10	1.2E-15	0.0	0.0	0.0
^{14}C	1.2E-04	1.0E-06	2.7E-09	5.6E-12	0.0	0.0	0.0
^{60}Co	8.1E-07	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.1E-05	3.6E-08	5.3E-11	6.9E-14	0.0	0.0	0.0
^{63}Ni	8.6E-01	1.4E-03	1.1E-06	8.0E-10	5.4E-13	0.0	0.0
^{79}Se	2.5E-02	8.7E-02	5.6E-02	3.2E-02	1.9E-02	1.6E-02	1.6E-02
^{87}Rb	0.0	1.6E-07	1.0E-06	1.2E-06	1.1E-06	6.3E-07	2.7E-07
^{90}Sr	5.9E-02	1.7E-05	5.7E-02	4.3E-02	8.3E-03	7.7E-05	3.5E-08
^{90}Y	4.5E-03	1.3E-06	4.4E-03	3.3E-03	6.4E-04	6.0E-06	2.7E-09
^{99}Tc	1.0E+00	3.2E-03	4.7E-06	6.2E-09	7.8E-12	0.0	0.0
^{129}I	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03
^{137}Cs	3.5E-02	1.1E-05	1.7E-09	0.0	0.0	0.0	0.0
^{233}U	1.2E-03	3.7E-06	5.5E-09	7.2E-12	0.0	0.0	0.0
^{234}U	6.9E-03	2.1E-05	3.2E-08	4.2E-11	0.0	0.0	0.0
^{235}U	8.0E-04	2.5E-06	3.7E-09	4.8E-12	0.0	0.0	0.0
^{236}U	1.5E-04	4.7E-07	7.1E-10	0.0	0.0	0.0	0.0
^{238}U	4.8E-02	1.5E-04	2.3E-07	2.9E-10	0.0	0.0	0.0
^{237}Np	0.0	0.0	3.9E-03	5.3E-01	2.6E+00	7.0E+00	6.4E+00
^{238}Pu	5.6E-01	8.1E-04	5.5E-07	3.3E-10	0.0	0.0	0.0
^{239}Pu	1.8E-01	5.5E-04	8.2E-07	1.1E-09	0.0	0.0	0.0
^{241}Pu	7.5E-06	1.3E-10	0.0	0.0	0.0	0.0	0.0
^{242}Pu	7.4E-06	2.3E-08	3.4E-11	0.0	0.0	0.0	0.0
Total Dose	6.7E+00	9.5E-02	1.2E-01	6.1E-01	2.6E+00	7.0E+00	6.4E+00
Radioactive Risk (HE/yr)							
	1.9E-06	2.6E-08	3.5E-08	1.7E-07	7.3E-07	2.0E-06	1.8E-06

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 56

Chemical Results for Groundwater to Well at 100 m Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Concentration (mg/L)							
Cadmium	2.8E-05	1.6E-04	4.2E-03	9.2E-03	9.9E-03	7.0E-03	3.4E-03
Lead	2.1E-02	6.5E-05	9.7E-08	1.3E-10	1.6E-13	2.6E-19	0.0
Mercury	6.9E-05	2.2E-07	3.2E-10	4.2E-13	5.3E-16	0.0	0.0
Naphthalene	8.2E-02	3.4E-02	2.2E-03	6.4E-05	1.5E-06	6.4E-10	5.1E-15
Toluene	3.1E-01	4.0E-02	3.7E-04	1.8E-06	7.4E-09	1.2E-13	0.0
Trimethylbenzene	2.4E-01	1.6E-01	6.1E-02	1.1E-02	1.3E-03	1.3E-05	9.4E-09
Xylene	4.6E-01	1.4E-01	4.8E-03	8.1E-05	1.1E-06	1.7E-10	3.2E-16
Noncarcinogenic Risk (ADI fraction)							
Cadmium	1.8E-03	1.0E-02	2.6E-01	5.9E-01	6.3E-01	4.4E-01	2.2E-01
Lead	2.8E-01	8.6E-04	1.3E-06	1.7E-09	2.1E-12	3.4E-18	0.0
Mercury	4.0E-02	1.3E-04	1.9E-07	2.5E-10	3.1E-13	0.0	0.0
Naphthalene	5.8E-03	2.4E-03	1.5E-04	4.5E-06	1.0E-07	4.5E-11	3.6E-16
Toluene	2.0E-02	2.5E-03	2.3E-05	1.1E-07	4.7E-10	7.4E-15	0.0
Trimethylbenzene	6.8E-03	4.6E-03	1.7E-03	3.0E-04	3.7E-05	3.7E-07	2.7E-10
Xylene	8.5E-01	2.5E-01	8.8E-03	1.5E-04	2.0E-06	3.2E-10	5.8E-16
EPA Hazard Index	1.2E+00	2.6E-01	2.6E-01	5.9E-01	6.3E-01	4.4E-01	2.2E-01

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 57

Radionuclide Results for Groundwater-to-River Pathway for the No Action Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration (Ci/m^3)								
^{14}C	7.1E-19	5.8E-15	1.5E-15	2.1E-17	1.1E-19	0.0	0.0	0.0
^{60}Co	2.4E-16	2.6E-18	0.0	0.0	0.0	0.0	0.0	0.0
^{134}Cs	8.0E-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.9E-15	1.1E-13	1.1E-15	7.1E-19	0.0	0.0	0.0	0.0
^{3}H	1.7E-09	6.7E-09	3.1E-12	7.3E-17	0.0	0.0	0.0	0.0
^{129}I	0.0	2.9E-18	6.3E-17	1.7E-16	2.4E-16	2.0E-15	2.0E-16	2.0E-16
^{59}Ni	3.2E-17	1.3E-14	1.0E-15	6.3E-18	1.7E-20	0.0	0.0	0.0
^{63}Ni	1.4E-12	3.3E-10	1.5E-11	5.0E-14	7.4E-17	7.0E-20	0.0	0.0
^{238}Pu	2.1E-15	4.2E-13	1.6E-14	4.7E-17	5.8E-20	0.0	0.0	0.0
^{239}Pu	3.2E-16	1.2E-13	9.9E-15	6.2E-17	1.7E-19	0.0	0.0	0.0
^{241}Pu	3.1E-17	1.7E-16	1.1E-19	0.0	0.0	0.0	0.0	0.0
^{242}Pu	1.4E-20	5.4E-18	4.4E-19	0.0	0.0	0.0	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	1.8E-20	1.0E-18	2.0E-16	4.0E-15
^{90}Sr	2.0E-15	1.0E-13	9.1E-16	5.2E-19	0.0	0.0	0.0	0.0
^{99}Tc	5.0E-14	1.9E-11	1.6E-12	9.7E-15	2.7E-17	5.0E-20	0.0	0.0
^{233}U	3.3E-18	1.3E-15	1.0E-16	6.4E-19	0.0	0.0	0.0	0.0
^{234}U	2.0E-17	7.8E-15	6.2E-16	3.9E-18	1.1E-20	0.0	0.0	0.0
^{235}U	2.4E-18	9.4E-16	7.5E-17	4.7E-19	0.0	0.0	0.0	0.0
^{236}U	4.6E-19	1.8E-16	1.4E-17	8.9E-20	0.0	0.0	0.0	0.0
^{238}U	1.6E-16	6.2E-14	5.0E-15	3.1E-17	8.5E-20	0.0	0.0	0.0
^{90}Y	2.0E-15	1.0E-13	9.1E-16	5.2E-19	0.0	0.0	0.0	0.0
Dose (mrem/yr)								
^{14}C	4.8E-11	3.9E-07	9.9E-08	1.4E-09	7.3E-12	0.0	0.0	0.0
^{60}Co	6.2E-09	6.6E-11	0.0	0.0	0.0	0.0	0.0	0.0
^{134}Cs	8.6E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.4E-06	8.1E-05	8.0E-07	5.1E-10	0.0	0.0	0.0	0.0
^{3}H	8.6E-05	3.4E-04	1.6E-07	3.7E-12	0.0	0.0	0.0	0.0
^{129}I	0.0	5.7E-10	1.2E-08	3.3E-08	4.8E-08	4.0E-08	5.0E-08	5.0E-08
^{59}Ni	8.6E-12	3.3E-09	2.7E-10	1.7E-12	4.6E-15	0.0	0.0	0.0
^{63}Ni	1.0E-06	2.4E-04	1.1E-05	3.6E-08	5.3E-11	5.0E-14	0.0	0.0
^{238}Pu	3.8E-07	7.7E-05	3.0E-06	8.6E-09	1.1E-11	0.0	0.0	0.0
^{239}Pu	6.7E-08	2.6E-05	2.1E-06	1.3E-08	3.5E-11	0.0	0.0	0.0
^{241}Pu	1.3E-10	7.0E-10	4.5E-13	0.0	0.0	0.0	0.0	0.0
^{242}Pu	2.8E-12	1.1E-09	8.7E-11	0.0	0.0	0.0	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	3.9E-13	3.0E-11	4.0E-09	9.0E-08
^{90}Sr	1.8E-07	9.3E-06	8.2E-08	4.7E-11	0.0	0.0	0.0	0.0
^{99}Tc	3.7E-07	1.4E-04	1.2E-05	7.2E-08	2.0E-10	4.0E-13	0.0	0.0
^{233}U	4.4E-10	1.7E-07	1.4E-08	8.5E-11	0.0	0.0	0.0	0.0
^{234}U	2.5E-09	9.9E-07	7.9E-08	4.9E-10	1.4E-12	0.0	0.0	0.0
^{235}U	2.9E-10	1.2E-07	9.2E-09	5.7E-11	0.0	0.0	0.0	0.0
^{236}U	5.6E-11	2.2E-08	1.7E-09	1.1E-11	0.0	0.0	0.0	0.0
^{238}U	1.8E-08	7.0E-06	5.6E-07	3.5E-09	9.6E-12	0.0	0.0	0.0
^{90}Y	1.3E-08	7.2E-07	6.3E-09	3.6E-12	0.0	0.0	0.0	0.0
Total Dose	8.9E-05	9.3E-04	2.9E-05	1.7E-07	4.8E-08	5.3E-08	5.9E-08	1.5E-07
Radioactive Risk (HE/yr)								
	2.5E-11	2.6E-10	8.2E-12	4.7E-14	1.4E-14	1.5E-14	1.6E-14	4.1E-14

TABLE 58

Chemical Results for Groundwater-to-River Pathway for the No Action Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration (mg/L)								
Cadmium	1.0E-11	3.9E-09	3.1E-10	1.9E-12	5.3E-15	1.1E-17	6.9E-19	4.2E-14
Lead	7.5E-09	2.9E-06	2.3E-07	1.5E-09	4.0E-12	8.0E-15	2.2E-20	0.0
Mercury	2.5E-11	9.7E-09	7.8E-10	4.9E-12	1.3E-14	2.7E-17	0.0	0.0
Naphthalene	1.1E-14	5.1E-07	2.3E-06	1.3E-06	2.0E-07	1.3E-08	1.7E-11	3.0E-16
Toluene	7.2E-11	5.2E-06	8.1E-06	9.3E-07	1.8E-08	1.7E-10	6.2E-15	0.0
Trimethylbenzene	0.0	9.3E-08	2.5E-06	5.2E-06	4.2E-06	1.8E-06	8.5E-08	2.1E-10
Xylene	1.2E-12	4.2E-06	1.4E-05	4.9E-06	3.9E-07	1.4E-08	5.9E-12	2.2E-17
Noncarcinogenic Risk (ADI fraction)								
Cadmium	2.5E-09	9.7E-07	7.8E-08	4.9E-10	1.3E-12	2.7E-15	1.7E-16	1.0E-11
Lead	2.4E-07	9.5E-05	7.6E-06	4.8E-08	1.3E-10	2.6E-13	7.1E-19	0.0
Mercury	3.8E-08	1.5E-05	1.2E-06	7.5E-09	2.1E-11	4.1E-14	0.0	0.0
Naphthalene	8.2E-16	3.7E-08	1.7E-07	9.6E-08	1.4E-08	9.0E-10	1.2E-12	2.1E-17
Toluene	4.6E-12	3.3E-07	5.2E-07	6.0E-08	1.2E-09	1.1E-11	4.0E-16	0.0
Trimethylbenzene	0.0	2.7E-09	7.3E-08	1.5E-07	1.2E-07	5.2E-08	2.5E-09	6.1E-12
Xylene	2.2E-12	7.9E-06	2.5E-05	9.1E-06	7.3E-07	2.5E-08	1.1E-11	4.1E-17
EPA Hazard Index	2.8E-07	1.2E-04	3.5E-05	1.1E-05	8.7E-06	2.0E-05	4.0E-05	3.9E-05

TABLE 59

Radionuclide Activity Outcrop Data for the No Action Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration in Groundwater at Outcrop (Ci/m^3)								
^{3}H	6.3E-04	2.0E-04	9.3E-08	2.2E-12	0.0	0.0	0.0	0.0
^{14}C	2.8E-13	1.8E-10	4.4E-11	6.5E-13	3.3E-15	0.0	0.0	0.0
^{60}Co	8.8E-11	7.9E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	1.2E-11	3.8E-10	3.0E-11	1.9E-13	5.2E-16	0.0	0.0	0.0
^{63}Ni	5.3E-07	1.0E-05	4.5E-07	1.5E-09	2.2E-12	2.4E-15	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	7.1E-15	6.4E-13	5.9E-11	7.9E-10
^{90}Sr	7.3E-10	3.1E-09	2.8E-11	1.6E-14	0.0	0.0	0.0	0.0
^{90}Y	7.3E-10	3.1E-09	2.8E-11	1.6E-14	0.0	0.0	0.0	0.0
^{99}Tc	1.9E-08	5.9E-07	4.7E-08	2.9E-10	8.1E-13	1.6E-15	0.0	0.0
^{129}I	0.0	6.6E-13	5.8E-12	8.0E-12	8.3E-12	8.4E-12	8.4E-12	8.4E-12
^{134}Cs	2.7E-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	7.1E-10	3.4E-09	3.3E-11	2.1E-14	0.0	0.0	0.0	0.0
^{233}U	1.2E-12	3.9E-11	3.1E-12	1.9E-14	0.0	0.0	0.0	0.0
^{234}U	7.5E-12	2.4E-10	1.9E-11	1.2E-13	3.2E-16	0.0	0.0	0.0
^{235}U	9.0E-13	2.8E-11	2.3E-12	1.4E-14	0.0	0.0	0.0	0.0
^{236}U	1.7E-13	5.4E-12	4.3E-13	2.7E-15	0.0	0.0	0.0	0.0
^{238}U	6.0E-11	1.9E-09	1.5E-10	9.4E-13	2.6E-15	0.0	0.0	0.0
^{238}Pu	7.7E-10	1.3E-08	4.9E-10	1.4E-12	1.8E-15	0.0	0.0	0.0
^{239}Pu	1.2E-10	3.7E-09	3.0E-10	1.9E-12	5.1E-15	0.0	0.0	0.0
^{241}Pu	1.1E-11	5.0E-12	3.3E-15	0.0	0.0	0.0	0.0	0.0
^{242}Pu	5.2E-15	1.6E-13	1.3E-14	0.0	0.0	0.0	0.0	0.0
Contaminant Flux at Outcrop (Ci/yr)								
^{3}H	1.5E+01	6.1E+01	2.8E-02	6.7E-07	0.0	0.0	0.0	0.0
^{14}C	6.5E-09	5.3E-05	1.3E-05	1.9E-07	9.8E-10	0.0	0.0	0.0
^{60}Co	2.2E-06	2.4E-08	0.0	0.0	0.0	0.0	0.0	0.0
^{59}Ni	2.9E-07	1.1E-04	9.2E-06	5.7E-08	1.6E-10	0.0	0.0	0.0
^{63}Ni	1.3E-02	3.0E+00	1.4E-01	4.5E-04	6.7E-07	7.1E-10	0.0	0.0
^{79}Se	0.0	0.0	0.0	0.0	1.7E-10	1.6E-08	1.9E-06	3.9E-05
^{90}Sr	1.8E-05	9.5E-04	8.3E-06	4.7E-09	0.0	0.0	0.0	0.0
^{90}Y	1.8E-05	9.5E-04	8.3E-06	4.7E-09	0.0	0.0	0.0	0.0
^{99}Tc	4.5E-04	1.8E-01	1.4E-02	8.8E-05	2.4E-07	4.9E-10	0.0	0.0
^{129}I	0.0	2.6E-08	5.7E-07	1.5E-06	2.2E-06	2.5E-06	2.5E-06	2.5E-06
^{134}Cs	7.3E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	1.7E-05	1.0E-03	1.0E-05	6.4E-09	0.0	0.0	0.0	0.0
^{233}U	3.0E-08	1.2E-05	9.4E-07	5.9E-09	0.0	0.0	0.0	0.0
^{234}U	1.8E-07	7.1E-05	5.7E-06	3.5E-08	9.7E-11	0.0	0.0	0.0
^{235}U	2.2E-08	8.6E-06	6.8E-07	4.3E-09	0.0	0.0	0.0	0.0
^{236}U	4.2E-09	1.6E-06	1.3E-07	8.1E-10	0.0	0.0	0.0	0.0
^{238}U	1.4E-06	5.7E-04	4.5E-05	2.8E-07	7.8E-10	0.0	0.0	0.0
^{238}Pu	1.9E-05	3.8E-03	1.5E-04	4.2E-07	5.3E-10	0.0	0.0	0.0
^{239}Pu	2.9E-06	1.1E-03	9.0E-05	5.6E-07	1.5E-09	0.0	0.0	0.0
^{241}Pu	2.8E-07	1.5E-06	9.8E-10	0.0	0.0	0.0	0.0	0.0
^{242}Pu	1.3E-10	5.0E-08	4.0E-09	0.0	0.0	0.0	0.0	0.0

TABLE 60

Chemical Concentration Outcrop Data for the No Action Option

	Years Since 1985							
	0	100	200	300	400	500	700	1000
Concentration in Groundwater at Outcrop (mg/L)								
Cadmium	3.7E-06	1.2E-04	9.4E-06	5.9E-08	1.6E-10	3.2E-13	2.9E-13	1.6E-08
Lead	2.8E-03	8.8E-02	7.0E-03	4.4E-05	1.2E-07	2.4E-10	6.6E-16	0.0
Mercury	9.3E-06	2.9E-04	2.3E-05	1.5E-07	4.0E-10	8.1E-13	0.0	0.0
Naphthalene	4.9E-09	6.6E-02	7.1E-02	4.1E-02	6.0E-03	3.8E-04	5.0E-07	9.0E-12
Toluene	2.9E-05	3.8E-01	2.5E-01	2.8E-02	5.6E-04	5.1E-06	1.9E-10	0.0
Trimethylbenzene	0.0	2.2E-02	2.4E-01	1.6E-01	1.3E-01	5.3E-02	2.6E-03	6.3E-06
Xylene	5.0E-07	4.6E-01	4.1E-01	1.5E-01	1.2E-02	4.1E-04	1.8E-07	6.8E-13
Contaminant Flux at Outcrop (kg/yr)								
Cadmium	9.1E-05	3.5E-02	2.8E-03	1.8E-05	4.9E-08	9.7E-11	6.4E-12	3.8E-07
Lead	6.8E-02	2.7E+01	2.1E+00	1.3E-02	3.6E-05	7.3E-08	2.0E-13	0.0
Mercury	2.3E-04	8.8E-02	7.1E-03	4.4E-05	1.2E-07	2.4E-10	0.0	0.0
Naphthalene	1.0E-07	4.6E+00	2.1E+01	1.2E+01	1.8E+00	1.1E-01	1.5E-04	2.7E-09
Toluene	6.5E-04	4.7E+01	7.4E+01	8.5E+00	1.7E-01	1.5E-03	5.7E-08	0.0
Trimethylbenzene	0.0	8.5E-01	2.3E+01	4.7E+01	3.8E+01	1.6E+01	7.7E-01	1.9E-03
Xylene	1.1E-05	3.9E+01	1.2E+02	4.5E+01	3.6E+00	1.2E-01	5.4E-05	2.0E-10

TABLE 61

Radionuclide Results for Reclaimed-Farmland Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Dose (mrem/yr)							
^{241}Am	4.8E-03	3.9E-03	3.2E-03	2.6E-03	2.2E-03	1.5E-03	8.1E-04
^{243}Am	2.9E-06	2.8E-06	2.6E-06	2.5E-06	2.3E-06	2.1E-06	1.7E-06
^{244}Cm	1.4E-02	2.6E-04	5.1E-06	1.0E-07	1.9E-09	7.4E-13	5.5E-18
^{248}Cm	3.3E-08	3.3E-08	3.3E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08
^{60}Co	8.5E-05	1.3E-10	1.9E-16	0.0	0.0	0.0	0.0
^{134}Cs	2.0E-15	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	5.6E-01	5.5E-02	5.5E-03	5.4E-04	5.4E-05	5.3E-07	5.1E-10
^{154}Eu	3.9E-07	1.1E-10	3.2E-14	9.0E-18	0.0	0.0	0.0
^{129}I	5.6E-02	5.6E-02	5.6E-02	5.6E-02	5.6E-02	5.6E-02	5.6E-02
^{59}Ni	3.6E-06	3.4E-06	3.3E-06	3.1E-06	3.0E-06	2.7E-06	2.3E-06
^{63}Ni	2.5E-01	1.3E-01	6.4E-02	3.2E-02	1.7E-02	4.3E-03	5.6E-04
^{237}Np	2.8E-04	1.7E-04	1.1E-04	6.9E-05	4.4E-05	1.7E-05	4.2E-06
^{147}Pm	9.3E-15	0.0	0.0	0.0	0.0	0.0	0.0
^{238}Pu	1.0E-02	4.6E-03	2.1E-03	9.4E-04	4.3E-04	8.7E-05	8.1E-06
^{239}Pu	3.5E-03	3.5E-03	3.5E-03	3.4E-03	3.4E-03	3.4E-03	3.4E-03
^{241}Pu	8.5E-08	4.2E-10	2.1E-12	1.1E-14	5.3E-17	1.3E-21	1.7E-28
^{242}Pu	1.3E-07	1.2E-07	1.2E-07	1.1E-07	1.1E-07	9.7E-08	8.4E-08
^{87}Rb	5.1E-09	2.0E-09	8.0E-10	3.1E-10	1.2E-10	2.0E-11	1.2E-12
^{125}Sb	1.1E-17	0.0	0.0	0.0	0.0	0.0	0.0
^{79}Se	7.6E-04	1.2E-04	2.0E-05	3.3E-06	5.5E-07	1.5E-08	6.4E-11
^{151}Sm	2.4E-05	1.1E-05	5.4E-06	2.5E-06	1.2E-06	2.7E-07	2.8E-08
^{90}Sr	4.4E+00	2.2E-01	1.1E-02	5.3E-04	2.6E-05	6.4E-08	7.7E-12
^{99}Tc	2.3E-18	0.0	0.0	0.0	0.0	0.0	0.0
^{125}Te	1.6E-11	0.0	0.0	0.0	0.0	0.0	0.0
^{232}Th	1.7E-05	1.6E-05	1.5E-05	1.4E-05	1.4E-05	1.3E-05	1.1E-05
^{233}U	3.1E-04	2.8E-04	2.5E-04	2.2E-04	1.9E-04	1.5E-04	1.1E-04
^{234}U	2.0E-03	1.8E-03	1.6E-03	1.5E-03	1.3E-03	1.0E-03	7.3E-04
^{235}U	2.1E-04	1.9E-04	1.7E-04	1.5E-04	1.3E-04	1.0E-04	7.3E-05
^{236}U	4.0E-05	3.6E-05	3.2E-05	2.8E-05	2.5E-05	2.0E-05	1.4E-05
^{238}U	1.3E-02	1.1E-02	1.0E-02	9.0E-03	8.0E-03	6.3E-03	4.4E-03
^{90}Y	3.4E-01	1.7E-02	8.3E-04	4.1E-05	2.0E-06	4.9E-09	6.0E-13
Total Dose	5.7E+00	5.0E-01	1.6E-01	1.1E-01	8.9E-02	7.3E-02	6.6E-02
Radioactive Risk (HE/yr)							
	1.6E-06	1.4E-07	4.4E-08	3.0E-08	2.5E-08	2.0E-08	1.9E-08

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 62

Chemical Results for Reclaimed-Farmland Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Noncarcinogenic Risk (ADI fraction)							
Cadmium	1.4E-03	6.4E-04	3.0E-04	1.4E-04	6.3E-05	1.3E-05	1.3E-06
Lead	7.4E-03	7.1E-03	6.8E-03	6.5E-03	6.2E-03	5.6E-03	4.9E-03
Mercury	1.4E+00	1.4E+00	1.4E+00	1.4E+00	1.4E+00	1.4E+00	1.4E+00
Naphthalene	6.7E-06	2.5E-06	9.0E-07	3.3E-07	1.2E-07	1.7E-08	8.2E-10
Toluene	3.4E-05	1.3E-05	4.7E-06	1.7E-06	6.3E-07	8.5E-08	4.2E-09
Trimethylbenzene	5.9E-06	2.2E-06	8.0E-07	3.0E-07	1.1E-07	1.5E-08	7.3E-10
Xylene	1.0E-03	3.8E-04	1.4E-04	5.2E-05	1.9E-05	2.6E-06	1.3E-07
EPA Hazard Index	1.4E+00	1.4E+00	1.4E+00	1.4E+00	1.4E+00	1.4E+00	1.4E+00

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 63

Radionuclide Results for Direct Gamma Exposure Pathway for the No Action Option

	Years Since 1985						
	100	200	300	400	500	700	1000
Dose (mrem/yr)							
^{241}Am	1.3E-05	1.4E-05	1.6E-05	1.7E-05	1.9E-05	2.4E-05	3.2E-05
^{243}Am	9.2E-13	1.4E-12	2.1E-12	3.2E-12	4.8E-12	1.1E-11	3.8E-11
^{244}Cm	3.7E-06	9.3E-08	2.3E-09	5.8E-11	1.5E-12	9.2E-16	1.4E-20
^{60}Co	2.3E-03	5.1E-09	1.1E-14	2.4E-20	5.1E-26	0.0	0.0
^{134}Cs	3.6E-16	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	5.9E-02	7.4E-03	9.1E-04	1.1E-04	1.4E-05	2.1E-07	4.0E-10
^{154}Eu	1.2E-04	4.0E-08	1.4E-11	4.7E-15	1.6E-18	0.0	0.0
^{129}I	0.0	0.0	0.0	0.0	0.0	0.0	1.7E-20
^{237}Np	2.6E-12	4.1E-12	6.3E-12	9.6E-12	1.5E-11	3.5E-11	1.2E-10
^{238}Pu	1.9E-05	1.1E-05	6.4E-06	3.8E-06	2.2E-06	7.5E-07	1.5E-07
^{239}Pu	5.6E-13	9.5E-13	1.6E-12	2.7E-12	4.5E-12	1.3E-11	6.0E-11
^{125}Sb	3.3E-14	0.0	0.0	0.0	0.0	0.0	0.0
^{232}Th	0.0	0.0	0.0	0.0	0.0	0.0	6.2E-20
^{233}U	5.9E-15	9.8E-15	1.6E-14	2.7E-14	4.4E-14	1.2E-13	5.4E-13
^{234}U	3.5E-08	4.8E-08	6.4E-08	8.5E-08	1.1E-07	1.9E-07	4.4E-07
^{235}U	3.1E-10	4.6E-10	7.0E-10	1.0E-09	1.6E-09	3.5E-09	1.2E-08
Total Dose	6.2E-02	7.4E-03	9.3E-04	1.3E-04	3.6E-05	2.5E-05	3.2E-05
Radioactive Risk (HE/yr)							
	1.7E-08	2.1E-09	2.6E-10	3.8E-11	1.0E-11	6.9E-12	9.1E-12

Note: Analysis of this pathway is not applicable prior to 100 years because of assumed period of institutional control.

TABLE 64

Cumulative Release Over 1,000-Year Period to the Savannah River for the Waste Removal and Closure Option

Radionuclide	Total Release (Ci)
^{14}C	3.1E-03
^{60}Co	9.4E-05
^{134}Cs	1.7E-09
^{137}Cs	1.0E-01
^{3}H	1.1E+04
^{129}I	1.8E-06
^{59}Ni	1.3E-02
^{63}Ni	3.1E+02
^{238}Pu	3.8E-01
^{239}Pu	1.3E-01
^{241}Pu	2.5E-04
^{242}Pu	5.2E-06
^{87}Rb	1.2E-13
^{79}Se	1.6E-04
^{90}Sr	9.6E-02
^{99}Tc	2.0E+01
^{233}U	1.3E-03
^{234}U	8.0E-03
^{235}U	9.7E-04
^{236}U	1.8E-04
^{238}U	6.4E-02
^{90}Y	9.6E-02

Chemical	Total Release (kg)
Cadmium	4.0E+00
Lead	3.0E+03
Mercury	1.0E+01
Naphthalene	5.3E+02
Toluene	1.8E+03
Trimethylbenzene	1.3E+03
Xylene	2.9E+03

TABLE 65

Cumulative Release Over 1,000-Year Period to the Savannah River for the No Waste Removal and Closure Option

Radionuclide	Total Release (Ci)
^{14}C	6.4E-03
^{60}Co	9.4E-05
^{134}Cs	1.7E-09
^{137}Cs	1.0E-01
^{3}H	1.1E+04
^{129}I	1.8E-04
^{59}Ni	1.3E-02
^{63}Ni	3.1E+02
^{238}Pu	3.8E-01
^{239}Pu	1.3E-01
^{241}Pu	2.5E-04
^{242}Pu	5.6E-06
^{87}Rb	2.2E-12
^{79}Se	8.4E-04
^{90}Sr	9.6E-02
^{99}Tc	2.0E+01
^{233}U	1.3E-03
^{234}U	8.0E-03
^{235}U	9.7E-04
^{236}U	1.8E-04
^{238}U	6.4E-02
^{90}Y	9.6E-02

Chemical	Total Release (kg)
Cadmium	4.0E+00
Lead	3.0E+03
Mercury	1.0E+01
Naphthalene	3.3E+03
Toluene	1.1E+04
Trimethylbenzene	8.5E+03
Xylene	1.8E+04

TABLE 66

Cumulative Release Over 1,000-Year Period to the Savannah River for the No Action Option

Radionuclide	Total Release (Ci)
^{14}C	6.5E-03
^{60}Co	4.1E-04
^{134}Cs	1.4E-08
^{137}Cs	1.5E-01
^{3}H	2.6E+04
^{129}I	1.8E-03
^{59}Ni	1.3E-02
^{63}Ni	3.5E+02
^{238}Pu	4.4E-01
^{239}Pu	1.3E-01
^{241}Pu	5.5E-04
^{242}Pu	5.6E-06
^{87}Rb	1.8E-11
^{79}Se	4.6E-03
^{90}Sr	1.4E-01
^{99}Tc	2.0E+01
^{233}U	1.3E-03
^{234}U	8.0E-03
^{235}U	9.7E-04
^{236}U	1.8E-04
^{238}U	6.4E-02
^{90}Y	1.4E-01

Chemical	Total Release (kg)
Cadmium	4.0E+00
Lead	3.0E+03
Mercury	1.0E+01
Naphthalene	4.0E+03
Toluene	1.3E+04
Trimethylbenzene	1.3E+04
Xylene	2.1E+04

TABLE 67

Comparison of Maximum Risks and Dominant Constituents

Pathway	Peak Year Since 1985	Dominant Constituent	Radioactive Risk (HE/yr)	Noncarcinogenic Risk (EPA Hazard Index)
		Waste Removal and Closure		
Groundwater to well at 1 m	100 1,000	Lead ^{237}Np	- 1.1E-08	4.9E-01 -
Groundwater well at at 100 m	100 1,000	Lead ^{237}Np	- 5.7E-09	7.1E-01 -
Groundwater to river	48 110	^{3}H Lead	2.8E-10 -	- 9.4E-05
Reclaimed farmland	100 100	^{90}Sr, ^{90}Y, ^{137}Cs Mercury	6.8E-12 -	- 3.9E-06
Direct gamma	100	^{60}Co	5.0E-34	-
		No Waste Removal and Closure		
Groundwater to well at 1 m	100 1,000	Lead ^{237}Np	- 1.0E-06	6.1E-01 -
Groundwater to well at 100 m	100 1,000	Lead ^{237}Np	- 7.9E-07	8.1E-01 -
Groundwater to river	48 110	^{3}H Lead	2.8E-10 -	- 9.4E-05
Reclaimed farmland	100 100	^{90}Sr, ^{90}Y, ^{137}Cs Mercury	6.5E-10 -	- 3.6E-04
Direct gamma	100	^{60}Co	1.9E-16	-
		No Action		
Groundwater to well at 1 m	200 1,000	Cadmium ^{237}Np	- 7.4E-06	2.2E+00 -
Groundwater to well at 100 m	100 1,000	Xylene ^{237}Np	- 1.8E-06	1.2E+00 -
Groundwater to river	35 92	^{3}H Lead	7.0E-10 -	- 9.6E-05
Reclaimed farmland	100 100	^{90}Sr, ^{90}Y, ^{137}Cs Mercury	1.6E-06 -	- 1.4E+00
Direct gamma	100	^{137}Cs, ^{60}Co	1.7E-08	-

mercury), while the calculated risks for this pathway are low for the other closure options (maximum radioactive risk of 6.5E-10 HE/yr and noncarcinogenic risk of 3.6E-04 ADI fraction). The calculated population risk for the direct gamma pathway is low for all closure options (with maximum radioactive risks in Year 100 of 1.7E-08 HE/yr for the no action option, 1.9E-16 HE/yr for the no waste removal and closure option, and 5.0E-34 for the waste removal and closure option).

Tritium is assumed to be completely leached out of the waste zone prior to excavation, thus, the various closures do not affect the calculated groundwater concentrations. The no waste removal and waste removal and closure options are significantly better than the no action option with respect to the reclaimed-farmland pathway, reducing radioactive risk below 1.0E-06 HE/yr and noncarcinogenic risk below 1 ADI fraction. The calculated risks are also highest for the no action option for the groundwater pathways. The peak risks for the no action option at the well at 1 m are greater than 1E-06 HE/yr (radioactive) and greater than 1 EPA Hazard Index (noncarcinogenic), while the more rigorous closures result in calculated risks below these thresholds.

Atmospheric Pathway

Estimates of public risk attributable to exposure of atmospherically transported contaminants resulting from the postulated closure options at the Radioactive Waste Burial Grounds have been calculated. As discussed earlier, the general pathways for exposure to atmospherically dispersed chemical or radioactive constituents are inhalation of polluted air, ingestion of contaminated foodstuffs, and direct gamma radiation. The data, assumptions, and models discussed previously were used to estimate the quantities of airborne contaminants released from the waste site and to quantify public exposure and risk via the inhalation, ingestion, and gamma radiation pathways.

The chemical and radionuclide constituents selected for this environmental analysis of risk were identified by Looney et al. (1987a) as discussed previously. Soil inventory profiles for each closure option for the estimates of disposed mass and radioactivity were determined using a four-layer soil model (SESOIL). These concentration profiles for the Radioactive Waste Burial Grounds were determined for each constituent of concern for each site cleanup option. Tables 68 and 69 contain these data. For the waste removal and closure option, the tables also list the volume of soil and mass of each constituent that would be excavated from the site.

TABLE 68

Soil Inventory Profile for Radionuclide Constituents at the Radioactive Waste Burial Ground[a]

Layer Number	Thickness (m)	Constituent Inventory (Ci) ^{241}Am	^{243}Am	^{14}C	^{244}Cm	^{248}Cm	^{60}Co	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu	^{3}H
Waste Removal and Closure												
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.07E-06
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.31E-03
3	6.4	2.97E-03	1.76E-06	1.73E-05	5.64E-03	3.65E-10	1.06E+02	3.87E-03	1.64E-01	3.89E-03	1.96E-04	2.07E+03
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.18E+04
	Inventory excavated	2.94E-01	1.74E-04	1.71E-03	5.58E-01	3.61E-08	1.05E+04	3.83E-01	1.62E+01	3.85E-01	1.94E-02	2.05E+05
No Waste Removal and Closure												
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.07E-04
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.31E-01
3	6.4	2.97E-01	1.76E-04	1.73E-03	5.64E-01	3.65E-08	1.06E+04	3.87E-01	1.64E+01	3.89E-01	1.96E-02	2.07E+05
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.18E+04
No Action												
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.07E-04
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.31E-01
3	6.4	2.97E-01	1.76E-04	1.73E-03	5.64E-01	3.65E-08	1.06E+04	3.87E-01	1.64E+01	3.89E-01	1.96E-02	2.07E+05
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.18E+04

Note: The waste removal and closure option includes excavating 3.0E+06 m^3 of contaminated soil.

TABLE 68, Contd

Layer Number	Thickness (m)	Constituent Inventory (Ci) ^{129}I	^{59}Ni	^{63}Ni	^{237}Np	^{147}Pm	^{238}Pu	^{239}Pu	^{241}Pu	^{242}Pu	^{87}Rb	^{106}Ru
Waste Removal and Closure												
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6.4	4.16E-07	5.21E-04	2.38E+01	1.40E-04	1.80E-02	4.51E-01	5.35E-02	8.85E-03	2.01E-06	4.13E-08	2.29E-03
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Inventory excavated	4.12E-05	5.16E-02	2.36E+03	1.39E-02	1.78E+00	4.46E+01	5.30E+00	8.76E-01	1.99E-04	4.09E-06	2.27E-01
No Waste Removal and Closure												
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6.4	4.16E-05	5.21E-02	2.38E+03	1.40E-02	1.80E+00	4.51E+01	5.35E+00	8.85E-01	2.01E-04	4.13E-06	2.29E-01
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action												
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6.4	4.16E-05	5.21E-02	2.38E+03	1.40E-02	1.80E+00	4.51E+01	5.35E+00	8.85E-01	2.01E-04	4.13E-06	2.29E-01
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: The waste removal and closure option includes excavating 3.0E+06 m^3 of contaminated soil.

TABLE 68, Contd

Layer Number	Thickness (m)	Constituent Inventory (Ci)											
		^{125}Sb	^{79}Se	^{151}Sm	^{90}Sr	^{99}Tc	^{228}Th	^{232}Th	^{233}U	^{234}U	^{235}U	^{238}U	^{90}Y
Waste Removal and Closure													
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.07E-06	0.0
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.31E-03	0.0
3	6.4	1.90E-04	1.34E-03	6.12E-03	8.71E+00	1.61E-02	1.41E-08	7.74E-06	1.34E-04	1.26E-05	7.62E-05	1.18E-02	8.72E+00
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.18E+04	0.0
	Inventory excavated	1.88E-02	1.33E-01	6.06E-01	8.62E+02	1.59E+00	1.40E-06	7.66E-04	1.33E-02	1.25E-03	7.54E-03	1.17E+00	8.63E+02
No Waste Removal and Closure													
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.07E-04	0.0
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.31E-01	0.0
3	6.4	1.90E-02	1.34E-01	6.12E-01	8.71E+02	1.61E+00	1.41E-06	7.74E-04	1.34E-02	1.26E-03	7.62E-03	1.18E+00	8.72E+02
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.18E+04	0.0
No Action													
1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.07E-04	0.0
2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.31E-01	0.0
3	6.4	1.90E-02	1.34E-01	6.12E-01	8.71E+02	1.61E+00	1.41E-06	7.74E-04	1.34E-02	1.26E-03	7.62E-03	1.18E+00	8.72E+02
4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: The waste removal and closure option includes excavating 3.0E+06 m^3 of contaminated soil.

TABLE 69

Soil Inventory Profile for Chemical Constituents at the Radioactive Waste Burial Grounds

Layer Number	Thickness (m)	Constituent Inventory (kg)						
		Cadmium	Lead	Mercury	Naphthalene	Toluene	Trimethyl-benzene	Xylene
Waste Removal and Closure								
1	0.5	0.0	0.0	0.0	1.10E-05	9.24E-03	3.89E-03	2.45E-02
2	0.7	0.0	0.0	0.0	9.88E-04	6.31E-02	3.85E-02	1.40E-01
3	6.4	2.16E+00	1.02E+01	1.59E-02	4.76E+00	1.50E+01	1.61E+01	2.49E+01
4	7.4	0.0	0.0	0.0	5.54E+01	2.25E+02	1.13E+02	2.82E+02
	Inventory excavated	2.14E+02	1.01E+03	1.57E+00	4.71E+02	1.49E+03	1.60E+03	2.48E+03
No Waste Removal and Closure								
1	0.5	0.0	0.0	0.0	1.10E-03	9.24E-01	3.89E-01	2.45E+00
2	0.7	0.0	0.0	0.0	9.88E-02	6.31E+00	3.85E+00	1.40E+01
3	6.4	2.16E+02	1.02E+03	1.59E+00	4.76E+02	1.50E+03	1.61E+03	2.49E+03
4	7.4	0.0	0.0	0.0	5.54E+01	2.25E+02	1.13E+02	2.82E+02
No Action								
1	0.5	0.0	0.0	0.0	1.10E-03	9.24E-01	3.89E-01	2.45E+00
2	0.7	0.0	0.0	0.0	9.88E-02	6.31E+00	3.85E+00	1.40E+01
3	6.4	2.16E+02	1.02E+03	1.59E+00	4.76E+02	1.50E+03	1.61E+03	2.49E+03
4	7.4	0.0	0.0	0.0	5.54E+01	2.25E+02	1.13E+02	2.82E+02

Note: The waste removal and closure option includes excavating 3.0E+06 m^3 of contaminated soil.

Because containerized wastes were also disposed at this site, the source term estimation methods described earlier were modified to account for the containers. The modification involved using unsaturated zone modeling to estimate the upper soil layer contaminant concentration attributable to contaminants that leak out of the containers. The leak rate of containerized constituents into the soil was assumed to be constant, and all the containerized materials were assumed to leak into the soil after 340 years. The upper soil layer concentration attributable to containerized waste was added to the time-dependent upper soil layer constituent concentration attributable to already free waste. This summed concentration was used to estimate the air source term.

For nonmobile, nonvolatile species, all disposal mass was assumed to be in Layer 3 for all three options. For dibutylphosphate, n-dodecane, naphthalene, toluene, tributylphosphate, trimethylbenzene, and xylene--which are all mobile and volatile--unsaturated zone modeling was used to calculate the time-dependent inventory profiles for each closure option. Inventory profiles for tritium, which is also mobile and volatile, were also calculated by using unsaturated zone modeling. Based on risk data for the inhalation route of exposure, cadmium was modeled as both a carcinogen and a noncarcinogen.

Nonradioactive Constituents

Twenty-four 1-year assessments were performed to span the 1,000-year period. Analyses were performed for every year for the period 1986-1990, for every 5th year for the period 1990-2035, and for every 100th year for the period 2085-2985. Doses and risks for the population and for a maximum exposed individual were estimated. The risks associated with carcinogens and noncarcinogens were analyzed separately by closure option. Carcinogenic risks from nonradioactive constituents were low--the results show risks of 8.22E-08 HE (population) and 1.46E-12 HE/lifetime (maximum individual) for the waste removal option in the year of excavation and zero risk for the other evaluated options. Figure 45 is a graph of noncarcinogenic risk versus time for all closure options. The starting time for the graph is Year 1. All noncarcinogenic risks (EPA Hazard Index) are less than one.

The waste removal and closure and no waste removal and closure options include the installation of a low-permeability cap over the site. For these options, it is assumed that the cap would remain intact for the first 100 years and that volatile contaminants would not escape to the atmosphere. After 100 years, it is assumed that homesteaders would destroy the integrity of the cap. Accordingly, volatile contaminant releases were estimated for ensuing years.

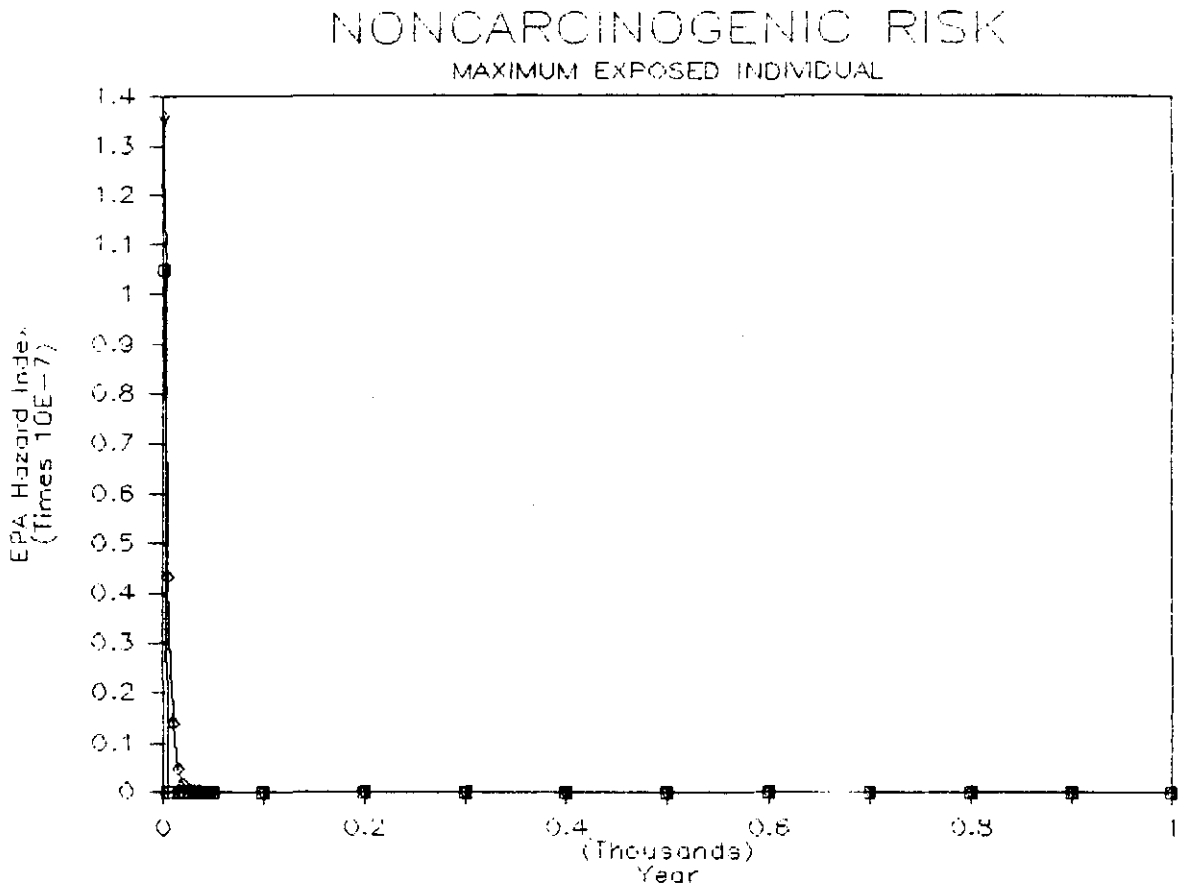


FIGURE 45. Noncarcinogenic Risk for the Exposed Individual Due to Atmospherically Released Noncarcinogens

From Year 1 through Year 99, the location of the maximum exposed individual is assumed to be approximately 8 km from the center of SRP in a northwest direction. Consequently, the risk posed to this individual varies directly with the source term strength; as the source term strength declines due to leaching, so does the risk to the maximum exposed individual. Thus, an exponential decay in the maximum individual risk from Year 1 to Year 99 is calculated. At Year 100, SRP is assumed to be occupied by homesteaders, and the location of the maximum exposed individual shifts much closer to a location directly east of, and adjacent to, the waste site. Consequently, the risk increase at this time (a step increase) and then decreases with succeeding years as the source strength decays.

Tables 70 and 71 show carcinogenic and noncarcinogenic risks for three selected years--1, 100, and 1,000. For carcinogens, the risk associated with waste removal in Year 1 is higher than the other closure options due to the large amount of dust generated from excavation. For noncarcinogens, the risk associated with no action is higher than that for the other closure options in Year 1. The major contributor to noncarcinogenic population risks in Year 1 for the waste removal and closure option is lead. The major contributors to noncarcinogenic population risks in Year 1 for the no action option are xylene and toluene. Mercury, due to volatilization and movement to the surface, is the dominant contributor to noncarcinogenic risk in later years. Note that in all cases, public risks from atmospheric transport are very low; the maximum calculated carcinogenic risk is 3.7E-11 (HE/yr) (maximum individual) and 2.1E-06 HE (population), and the maximum sum of ADI fractions is 3.4E-05 (which is $<<1$).

Radioactive Constituents

Atmospheric dust terms were estimated for 35 radionuclide contaminants for each of the closure options at the Burial Grounds. The results are presented in Table 72. Nonzero source terms were calculated for excavation and small releases due to tritium volatilization. In the waste removal and closure option, the source is associated with the excavation of the site during the first year and is near-zero thereafter due to capping of the site. Other sources include tritium volatilization and resuspension at the site under the assumption of no benefit from vegetative cover. Tritium source terms decrease in later years due to downward movement of contamination and radioactive decay.

The dose to the maximum exposed individual at the SRP boundary, as a consequence of contaminated dust moving from the Burial Grounds, is presented in Table 73. The doses are based upon

TABLE 70

Risks Due to Atmospherically Released Chemical Carcinogens for Years 1, 100, and 1,000 for the Closure Options

	Chemical Carcinogenic Risk					
	Waste Removal and Closure		No Waste Removal and Closure		No Action	
Contaminant	Population (HE)	Maximum Exposed Individual (HE/lifetime)	Population (HE)	Maximum Exposed Individual (HE/lifetime)	Population (HE)	Maximum Exposed Individual (HE/lifetime)
			Year 1			
Cadmium	8.22E-08	1.46E-12	0.0	0.0	0.0	0.0
			Year 100			
Cadmium	0.0	0.0	0.0	0.0	0.0	0.0
			Year 1,000			
Cadmium	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 71

Risks Due to Atmospherically Released Noncarcinogens for Years 1, 100, and 1,000 for the Closure Options

Chemical	Noncarcinogenic Risk (ADI fraction) Waste Removal and Closure	No Waste Removal and Closure	No Action
	Year 1		
Lead	1.03E-07	0.0	0.0
Mercury	1.35E-09	0.0	5.25E-17
Naphthalene	7.93E-11	0.0	1.61E-12
Toluene	2.25E-10	0.0	5.72E-08
Trimethylbenzene	1.10E-10	0.0	1.65E-09
Xylene	2.71E-10	0.0	7.69E-08
EPA Hazard Index	1.04E-07	0.0	1.36E-07
	Year 100		
Lead	0.0	0.0	0.0
Mercury	2.41E-17	2.41E-15	2.41E-15
Naphthalene	5.41E-15	5.41E-15	5.41E-15
Toluene	8.32E-13	8.32E-13	8.32E-13
Trimethylbenzene	1.98E-12	2.04E-12	2.04E-12
Xylene	4.07E-12	4.07E-12	4.07E-12
EPA Hazard Index	6.88E-12	6.94E-12	6.94E-12
	Year 1,000		
Lead	0.0	0.0	0.0
Mercury	1.90E-17	1.90E-15	1.90E-15
Naphthalene	0.0	0.0	0.0
Toluene	0.0	0.0	0.0
Trimethylbenzene	0.0	0.0	0.0
Xylene	0.0	0.0	0.0
EPA Hazard Index	1.90E-17	1.90E-15	1.90E-15

TABLE 72

Radionuclide Atmospheric Source Terms Used to Assess Public Risk for Years 1, 100, and 1,000 for the Closure Options

Radionuclide (Ci/yr)	Waste Removal and Closure			No Waste Removal and Closure			No Action		
	1	100	1000	1	100	1000	1	100	1000
^{3}H	1.84E+01	2.68E-22	0	0	2.68E-20	0	9.57E-04	2.68E-20	0
^{14}C	1.54E-07	0	0	0	0	0	0	0	0
^{60}Co	9.45E-01	0	0	0	0	0	0	0	0
^{59}Ni	4.64E-06	0	0	0	0	0	0	0	0
^{63}Ni	2.12E-01	0	0	0	0	0	0	0	0
^{79}Se	1.20E-05	0	0	0	0	0	0	0	0
^{87}Rb	3.68E-10	0	0	0	0	0	0	0	0
^{90}Sr	7.76E-02	0	0	0	0	0	0	0	0
^{90}Y	7.76E-02	0	0	0	0	0	0	0	0
^{99}Tc	1.43E-04	0	0	0	0	0	0	0	0
^{106}Ru	2.04E-05	0	0	0	0	0	0	0	0
^{125}Sb	1.69E-06	0	0	0	0	0	0	0	0
^{129}I	3.71E-09	0	0	0	0	0	0	0	0
^{134}Cs	3.45E-05	0	0	0	0	0	0	0	0
^{137}Cs	1.46E-03	0	0	0	0	0	0	0	0
^{147}Pm	1.60E-04	0	0	0	0	0	0	0	0
^{151}Sm	5.45E-05	0	0	0	0	0	0	0	0
^{154}Eu	3.46E-05	0	0	0	0	0	0	0	0
^{155}Eu	1.75E-06	0	0	0	0	0	0	0	0
^{228}Th	1.26E-10	0	0	0	0	0	0	0	0
^{232}Th	6.89E-08	0	0	0	0	0	0	0	0
^{233}U	1.20E-06	0	0	0	0	0	0	0	0
^{234}U	1.12E-07	0	0	0	0	0	0	0	0
^{235}U	6.78E-07	0	0	0	0	0	0	0	0
^{238}U	1.05E-04	0	0	0	0	0	0	0	0
^{237}Np	1.25E-06	0	0	0	0	0	0	0	0
^{238}Pu	4.01E-03	0	0	0	0	0	0	0	0
^{239}Pu	4.77E-04	0	0	0	0	0	0	0	0
^{241}Pu	7.88E-05	0	0	0	0	0	0	0	0
^{242}Pu	1.79E-08	0	0	0	0	0	0	0	0
^{241}Am	2.65E-05	0	0	0	0	0	0	0	0
^{243}Am	1.57E-08	0	0	0	0	0	0	0	0
^{244}Cm	5.02E-05	0	0	0	0	0	0	0	0
^{248}Cm	3.25E-12	0	0	0	0	0	0	0	0

Note: Units are in Ci/yr.

TABLE 73

Summary of Public Risk from Atmospheric Transport of Radionuclides

	Dose								
	Waste Removal and Closure			No Waste Removal and Closure			No Action		
	1	100	1000	1	100	1000	1	100	1000
Maximum individual (mrem)	7.0E-01	3.0E-26	0.0	0.0	7.0E-24	0.0	1.8E-08	7.4E-24	0.0
Population (person-rem)	2.5E+01	1.0E-25	0.0	0.0	1.2E-23	0.0	4.7E-07	1.2E-23	0.0

	Radioactive Risk								
	Waste Removal and Closure			No Waste Removal and Closure			No Action		
	1	100	1000	1	100	1000	1	100	1000
Maximum individual (HE/yr)	2.0E-07	8.4E-34	0.0	0.0	2.0E-30	0.0	5.1E-15	2.0E-30	0.0
Population (HE)	7.0E-03	2.8E-29	0.0	0.0	3.4E-27	0.0	1.3E-10	3.4E-27	0.0

XOQDOQ and GASPAR calculations. These calculations include inhalation of suspended dust and radionuclides deposited to the ground entering the human food chain.

The total dose from the waste removal and closure option for the Burial Grounds is 0.703 mrem during the first year. Minor dose is expected thereafter because of the installation of a clay cap and backfilling of the site. Most of the dose is due to ^{239}Pu, ^{238}Pu, ^{60}Co, and ^{137}Cs, with a small contribution from ^{237}Np, ^{241}Am, and ^{90}Sr.

There is a minor offsite atmospheric dose associated with no waste removal and closure because the site would be capped with low-permeability clay. Minor levels of tritium would eventually volatilize. Capping of the site would eliminate the potential suspension of the nonvolatile radionuclides.

In the no action option, the total dose is 1.81E-08, 7.41E-24, and 0.0 mrem for the 1st, 100th, and 1,000th years, respectively. The maximum individual dose is lower in Year 100 than Year 1 even though it is assumed that the site will no longer be controlled by the DOE and will be occupied by the surrounding population, bringing parts of this population into closer proximity to the source of the radionuclides. All of the potential offsite exposure is due to minor levels of tritium volatilizing from the site.

Table 73 also summarizes the dose calculations and presents an estimate of total health effects to the exposed population surrounding the Savannah River Plant for the closure options. Calculated health effects do not exceed 7.00E-03 (25 person-rem). This is an extremely small calculated absolute health effect to the affected population of about 585,000 (1986 estimate) in the vicinity of the Savannah River Plant. The population results can be placed into proper perspective relative to exposure to background radiation. For the exposed population of 585,000 (1986 estimate) surrounding the Savannah River Plant, the average individual receives 93 mrem of background radiation corresponding to a population dose of 5.42E+04 person-rem of radiation exposure, resulting in an estimate of 15 absolute health effects to the exposed population over a lifetime due to natural background radiation.

Capping of the sites would decrease calculated health effects to near-zero due to the elimination of suspendable atmospheric source terms. For radionuclide atmospheric pathways, the risk of offsite exposure does not exceed acceptable criteria for any closure option for the Burial Grounds.

Occupational Exposure

Cleanup of the sites under the waste removal and closure option would expose workers to airborne radioactive and nonradioactive contaminants. Approximately 3.0E+06 m^3 of soil would be excavated if waste removal and closure is the cleanup option selected; therefore, the site excavation would require approximately 15,625 days using one crew of nine workers (Table 74). With ~60 work crews working, the site could be excavated in ~260 days. Approximately 4.32E+05 kg of contaminated dust would be generated as a result of excavation activities. Respiratory protection (reducing inhalation risk by a factor of 50) and shielding are assumed for all constituents.

Nonradioactive Constituents

The calculated nonradioactive risks for the waste removal and closure option, assuming an average individual works at the site for 8 hr each day, are summarized in Tables 75 and 76. (Note that the average worker and maximum exposed worker are the same in this model for worker risk.) These results indicate that cadmium is the only contributor to excess cancer risk via inhalation. Total chemical carcinogenic risk due to excavation operations for a worker is 3.8E-12 HE/lifetime. For the noncarcinogen contaminants modeled, the average worker is exposed to an EPA Hazard Index of 3.8E-07.

While the results presented herein are for an average individual worker excavating the site, they can be easily translated to worker population risks. Excavating the Radioactive Waste Burial Grounds is estimated to require an average of 540 workers for 260 days. Thus, for workers the chemical carcinogenic risk associated with the inhalation of carcinogens released during the excavation of this site is 1.5E-09 HE.

Radioactive Constituents

For each of the three closure options considered (no action, no waste removal and closure, and waste removal and closure), 34 radioactive constituents were analyzed to estimate occupational exposure and risk attributable to closure activities for the Radioactive Waste Burial Grounds. Radiation exposures from the following pathways were considered: internal dose (from inhalation) to personnel directly involved in cleanup activities, external dose to personnel directly involved in cleanup activities, and external dose to personnel involved in transportation of contaminated waste. External dose is calculated only for radionuclides. Table 77 summarizes the inhalation exposure for the waste removal and closure option.

TABLE 74

Parameters for the Assessment of Occupational Exposure

Work crew composition	One supervisor One health physics technician One crane operator One loader operator Two handlers Three truck drivers
Work day	8 hours for crew 4 hours for drivers
Truck volume	12 metal boxes per trip 2 m^3 per box
Loading rate	8 truckloads (192 m^3/day)
Volume of material removed	3.0E+06 m^3
Exposure time	15,625 work days
Distance waste is transported	16 km (one way)
Transport speed	32 km/hr
Number of crews	60

TABLE 75

Occupational Risk Due to Atmospherically Released Carcinogens for the Waste Removal and Closure Option

Constituent	Source Term ($g/m^2/s$)	Inhalation Dose (mg/kg/day)	Exposure Time (days)	Chemical Carcinogenic Risk (HE/lifetime)
Cadmium	3.26E-12	1.72E-09	260	3.8E-12
Total Risk				3.8E-12

TABLE 76

Occupational Risk Due to Atmospherically Released Noncarcinogens for the Waste Removal and Closure Option

Constituent	Source Term ($g/m^2/s$)	Inhalation Dose (mg/kg/day)	Exposure Time (days)	Noncarcinogenic Risk (ADI fraction)
Lead	1.54E-11	8.13E-09	260	3.8E-07
Mercury	2.39E-14	1.26E-11	260	5.0E-09
Naphthalene	7.16E-12	3.79E-09	260	2.9E-10
Toluene	2.27E-11	1.20E-08	260	8.3E-10
Trimethylbenzene	2.43E-11	1.29E-08	260	4.0E-10
Xylene	3.77E-11	2.00E-08	260	1.0E-10
EPA Hazard Index				3.8E-07

TABLE 77

Internal Dose to Each Crew Worker Due to Inhalation

Radionuclide	Inhalation Dose Factor (mrem/μCi)	Air Concentration (μCi/m³)	Total Intake (μCi) (260 days)	Dose Commitment (mrem)
^{3}H	9.5E-02	1.5E-05	3.8E-02	3.7E-03
^{14}C	2.4E-02	1.3E-13	3.2E-10	7.7E-12
^{60}Co	1.5E+02	7.8E-07	2.0E-03	3.0E-01
^{59}Ni	1.3E+00	3.8E-12	9.5E-09	1.3E-08
^{63}Ni	3.1E+00	1.8E-07	4.3E-04	1.4E-03
^{79}Se	8.9E+00	9.9E-12	2.5E-08	2.2E-07
^{87}Rb	3.3E+00	3.0E-16	7.5E-13	2.5E-12
^{90}Sr	1.3E+03	6.4E-08	1.6E-04	2.0E-01
^{90}Y	8.2E+00	6.4E-08	1.6E-04	1.3E-03
^{99}Tc	7.5E+00	1.2E-10	3.0E-07	2.2E-06
^{106}Ru	4.4E+02	1.7E-11	4.2E-03	1.8E-05
^{125}Sb	9.8E+00	1.4E-12	3.5E-09	3.3E-08
^{129}I	1.8E+02	3.1E-15	7.7E-12	1.4E-09
^{134}Cs	4.7E+01	2.8E-11	7.2E-08	3.3E-06
^{137}Cs	3.2E+01	1.2E-09	3.0E-06	9.7E-05
^{147}Pm	2.7E-02	1.3E-10	3.3E-07	8.8E-09
^{151}Sm	2.9E+01	4.5E-11	1.1E-07	3.3E-06
^{154}Sm	2.6E+02	2.9E-11	7.2E-08	1.8E-05
^{155}Eu	3.9E+01	1.4E-12	3.7E-09	1.4E-07
^{228}Th	3.1E+05	1.0E-16	2.7E-13	8.0E-08
^{232}Th	1.6E+06	5.7E-14	1.4E-10	2.3E-04
^{233}U	1.3E+05	9.9E-13	2.5E-09	3.2E-04
^{234}U	1.3E+05	9.3E-14	2.3E-10	3.0E-05
^{235}U	1.3E+05	5.6E-13	1.4E-09	1.8E-04
^{238}U	1.2E+05	8.7E-11	2.2E-07	2.7E-02
^{237}Np	4.9E+01	1.0E-12	2.5E-09	1.3E-07
^{238}Pu	4.6E+05	3.3E-09	8.3E-06	3.8E+00
^{239}Pu	5.1E+05	3.9E-10	9.8E-07	5.0E-01
^{241}Pu	1.0E+04	6.5E-11	1.6E-07	1.6E-03
^{242}Pu	4.8E+05	1.5E-14	3.7E-11	1.8E-05
^{241}Am	5.2E+05	2.2E-11	5.5E-08	2.8E-02
^{243}Am	5.2E+05	1.3E-14	3.2E-11	1.7E-05
^{244}Cm	2.7E+05	4.1E-11	1.0E-07	2.8E-02
^{248}Cm	1.9E+06	2.7E-18	6.7E-15	1.3E-08
			Total	4.8E+00

Note: The total dose in subsequent tables is assumed to be reduced by a factor of 50 using standard respiratory protection.

The majority of radionuclides are located approximately 1.2 m below the ground in a 6.4-m-thick layer. Tritium is the only radionuclide that is assumed to exist below this 6.4-m-thick layer of debris, extending another 7.4 m into the ground. Additionally, the same assumptions related to number of workers and dust suspension were employed for radioactive and nonradioactive constituents.

For the waste removal option, external dose rates were calculated for the exposed contaminated material after uncontaminated overburden is removed, leaving the buried debris as the top layer of soil. External dose rates vary as a function of depth between 7.3E-01 mrem/hr above the top layer and 124 mrem/hr after 45 cm of buried debris have been removed. This exposure rate is approximately constant throughout the 6.4-m-thick layer of contaminated waste.

It is evident that a dose rate of 124 mrem/hr to workers is not acceptable under routine conditions and that a significant reduction in exposure would be needed before the site could be excavated. This reduction could be implemented through shielding, use of remote control technology, or permitting further decay of the primary contributors to occupational exposures. For this assessment, it is assumed that exposures would be limited through either one or a combination of these methods to no more than 2 mrem/hr. This dose rate would result in an annual dose to a worker of 4 rem/yr, which is less than the limit prescribed in 10 CFR 20 (1985).

The calculated external dose rate for a crew worker is given in Table 77. The total calculated external exposure to a crew worker is 4.2E+03 mrem. Truck drivers are assumed to remain in vehicles during the work day; therefore, their dose due to inhalation is assumed to be insignificant. Exposure to drivers results from external irradiation from contaminated waste being transported from the site to the permanent storage facility. The total time of exposure for each driver is assumed to be 4 hr/day or 6.25E+04 hr total for the cleanup period. The 4-hr period accounts for time the driver spends in the truck waiting for it to be loaded and off-loaded.

A conservative estimate is made assuming the dose rate to the driver during transport is constant and equals the highest predicted external exposure rate at 1 m above ground. This assumption results in a dose rate to drivers of 124 mrem/hr. The maximum allowable Department of Transportation limit for exposure in the occupied cab is 2 mrem/hr unless the driver is wearing dosimeters under a radiation protection program (CFR, 1984). Since the estimated dose rate is greater than the 2 mrem/hr limit, it is assumed that shielding would be used to reduce driver exposure to 2 mrem/hr during cleanup.

The total dose due to external exposure to drivers is calculated by assuming they are exposed for 4 hr/day for 260 days. This yields a total external dose to drivers of 2.2E+03 mrem.

It is assumed there will be no release of radioactive materials from the metal boxes during transport. Further, since the material is being transported within the boundary of the Savannah River Plant, it is assumed there will be no exposure to the public and no significant exposure to employees onsite involved in activities not related to the cleanup of this area.

Table 78 lists the total estimated exposures to the work crew and to truck drivers. Total worker dose due to internal and external exposure is 1.89E+06 person-mrem, resulting in a combined total risk to occupational workers (including truck drivers) of 5.3E-01 health effects.

It is assumed that the worker risk for the no waste removal and closure and no action options would be few since the Burial Grounds are currently covered with uncontaminated overburden and no further work is to be performed.

ECOLOGICAL ASSESSMENT

Surface Water Quality Impacts

Several nonradioactive constituents and a large number of radionuclides were identified earlier in this report as contaminant substances of potential ecological concern in the assessment of closure options for the Radioactive Waste Burial Grounds. Groundwater beneath the Burial Grounds is conservatively assumed to outcrop to the upstream, nonthermal reach of Four Mile Creek west of SRP Road 4. Simple dilution modeling of instream water chemistry of Four Mile Creek and outcropping of trace elements, organics, and radionuclides has resulted in calculated concentrations exceeding EPA drinking water standards for ^{3}H and ^{63}Ni at Year 100 following 1985 for all postulated options. Beyond Year 100, all nonradioactive and radioactive constituents (except ^{237}Np) outcropping from the Burial Grounds to Four Mile Creek are within applicable standards and criteria for all postulated closure options. The calculated concentration of ^{237}Np may exceed standards beyond the 1,000 year analysis period for the no action option.

Simple dilution modeling of trace elements, organics, and radionuclides in groundwater associated with the Burial Grounds closure options with existing Four Mile Creek water chemistry was completed according to

$$C_3 = \frac{Q_1 C_1 + Q_2 C_2}{Q_1 + Q_2}$$

TABLE 78

Summary of Occupational Exposure and Risk for the Waste Removal and Closure Option

Worker	Internal Dose Due to Inhalation (mrem)	External Dose (mrem)	Total Dose* (mrem)
Supervisor	0.1	4.2E+03	4.2E+03
Health physics	0.1	4.2E+03	4.2E+03
Crane operator	0.1	4.2E+03	4.2E+03
Loader	0.1	4.2E+03	4.2E+03
Handler #1	0.1	4.2E+03	4.2E+03
Handler #2	0.1	4.2E+03	4.2E+03
Driver #1	0.0	2.2E+03	2.2E+03
Driver #2	0.0	2.2E+03	2.2E+03
Driver #3	0.0	2.2E+03	2.2E+03
Total			1.89E+06 (person-mrem)

Note: Radioactive risk = 1.89E+06 mrem x 2.8E-07 health effects/mrem
= 5.29E-01 health effects.

* Total dose assumes 60 crews.

where

C_1 = instream water chemistry data (stream reach)

C_2 = outcrop water chemistry data (influent)

Q_1 = instream flow rate

Q_2 = influent flow from outcrops

C_3 = resultant mixed concentration (calculated mixture)

The groundwater migrating from the Burial Grounds is assumed to outcrop into Four Mile Creek southwest of SRP Road 4 (Figure 44). The mean Four Mile Creek flow rate is estimated at 1.1E+07 m^3/yr. The groundwater flux into the river within the flow path is approximately 3.0E+05 m^3/yr. The concentrations of chemical and radionuclide contaminants outcropping into Four Mile Creek have been calculated using the PATHRAE code.

Tables 79 and 80 employ this simple dilution equation for all pertinent trace elements, organics, and radionuclides for the no action, no waste removal and closure, and waste removal and closure options. Year 100 (no action and either closure option) was chosen for dilution modeling in Tables 78 and 79 because, of the years assessed, this year represents the time at which outcropping of all pertinent contaminants to Four Mile Creek would approach or reach a maximum concentration. The comparison criteria for chemicals are based on EPA ambient water quality criteria documents or upstream unimpacted measurements (whichever are greater). The comparison criteria for radionuclides are based on National Interim Primary Drinking Water Standards (EPA-570/9-76-003) for beta and gamma emitters (EPA, 1977). Comparison criteria for alpha emitters are based on the activity of the radionuclide yielding an effective dose equivalent rate of 4 mrem/yr.

The results of the postulated modeling of outcropping of trace elements, organics, and radionuclides from groundwaters encompassing the Radioactive Waste Burial Grounds (Tables 79 and 80) indicate that the existing water chemistry of Four Mile Creek is not adversely impacted for any of the closure options offered for most of the pertinent contaminants. However, calculated mixtures for tritium and ^{63}Ni (all options) exceed EPA drinking water standards. The exceedance of the drinking water standard for tritium in Tables 79 and 80 is a result of instream conditions upstream of burial ground outcrops (i.e., results from other facilities). The existing instream concentration of ^{63}Ni is not known but is believed to be small compared to the comparison criterion of 50 pCi/L. By Year 200 (after 1985) the calculated concentration of ^{63}Ni in Four Mile Creek would be below the comparison criterion for all options.

TABLE 79

Four Mile Creek Water Quality Impacts for the Waste Removal and Closure and No Waste Removal and Closure Options

Parameter	Units	Stream Reach	Calculated Mixture	Comparison Criterion	Criterion Exceeded
Cadmium	µg/L	0.46	0.46	3	No
Lead	µg/L	3.1	5.5	15	No
Mercury	µg/L	<0.05	<0.05	0.1	No
Naphthalene	µg/L	<10	<10	NS	--
Toluene	µg/L	<10	<10	NS	--
Trimethylbenzene	µg/L	NA	NA	NS	--
Xylene	µg/L	NA	NA	NS	--
^{3}H	pCi/L	9.4E+04	9.8E+04	20,000	Yes
^{14}C	pCi/L	NA	NA	2,000	--
^{59}Ni	pCi/L	NA	NA	300	--
^{63}Ni	pCi/L	NA	2.6E+02	50	Yes
^{60}Co	pCi/L	0.46	0.46	100	No
^{79}Se	pCi/L	NA	NA	NS	--
^{90}Sr	pCi/L	<4.2	<4.2	8	No
^{90}Y	pCi/L	<4.2	<4.2	60	No
^{99}Tc	pCi/L	<100	<120	900	No
^{129}I	pCi/L	<1	<1	1	No
^{137}Cs	pCi/L	<33	<33	200	No
^{233}U	pCi/L	<0.1	<0.1	20	No
^{234}U	pCi/L	<0.1	<0.1	21	No
^{235}U	pCi/L	<0.1	<0.1	22	No
^{238}U	pCi/L	<0.1	<1.6	24	No
^{238}Pu	pCi/L	<0.1	<0.52	14	No
^{239}Pu	pCi/L	<0.1	<0.21	13	No
^{241}Pu	pCi/L	<0.1	<0.1	640	No
^{242}Pu	pCi/L	<0.1	<0.1	13	No

Note: This model run represents Year 100 following 1985.
NA = not available. NS = no standard.

TABLE 80

Four Mile Creek Water Quality Impacts for the No Action Option

Parameter	Units	Stream Reach	Calculated Mixture	Comparison Criterion	Criterion Exceeded
Cadmium	µg/L	0.46	0.46	3	No
Lead	µg/L	3.1	5.6	15	No
Mercury	µg/L	<0.05	<0.05	0.1	No
Naphthalene	µg/L	<10	<10	NS	--
Toluene	µg/L	<10	<10	NS	--
Trimethylbenzene	µg/L	NA	NA	NS	--
Xylene	µg/L	NA	NA	NS	--
^{3}H	pCi/L	9.4E+04	1.0E+05	20,000	Yes
^{14}C	pCi/L	NA	NA	2,000	--
^{59}Ni	pCi/L	NA	NA	300	--
^{63}Ni	pCi/L	NA	2.7E+02	50	Yes
^{60}Co	pCi/L	0.46	0.46	100	No
^{79}Se	pCi/L	NA	NA	NS	--
^{90}Sr	pCi/L	<4.2	<4.2	8	No
^{90}Y	pCi/L	<4.2	<4.2	60	No
^{99}Tc	pCi/L	<100	<120	900	No
^{129}I	pCi/L	<1	<1	1	No
^{134}Cs	pCi/L	<33	<33	80	--
^{137}Cs	pCi/L	<33	<33	200	No
^{233}U	pCi/L	<0.1	<0.1	20	No
^{234}U	pCi/L	<1.1	<1.0	21	No
^{235}U	pCi/L	<0.1	<0.1	22	No
^{238}U	pCi/L	<1.1	<1.6	24	No
^{237}Np	pCi/L	<0.1	<0.1	0.14	No
^{238}Pu	pCi/L	<0.1	<0.55	14	No
^{239}Pu	pCi/L	<0.1	<0.21	13	No
^{241}Pu	pCi/L	<0.1	<0.1	640	No
^{242}Pu	pCi/L	<0.1	<0.1	13	No

Note: This model run represents Year 100 following 1985.
NA = not available. NS = no standard.

A summary of the calculated incremental increase in instream water quality associated with the outcropping water from the Radioactive Waste Burial Grounds for eight time scenarios up to 1,000 years following 1985 for the various closure options are given in Tables 81 through 82. Under all postulated options, the maximum incremental concentration increases are low--the most significant increases are for lead, ^{3}H, ^{63}Ni, and ^{99}Tc. The fluxes from the no action option are higher than those from the other closure options.

Aquatic and Terrestrial Impacts

For the aquatic and terrestrial impacts assessment, four pathways through which waste-site constituents can reach the environment were identified: (1) biointrusion, (2) surface erosion of waste constituents due to water and subsequent transport to surface waters, (3) movement of waste constituents through the unsaturated zone to the groundwater and subsequent transport to a surface outcrop, and (4) consumption of contaminated basin waters and, at some sites, aquatic plants.

The exposure concentrations were screened by comparing them to various ecological benchmark criteria. The first benchmark for each constituent, a lower screening level, represents an ecologically protective concentration (SAIC, 1987) and is based on EPA Water Quality Criteria for the Protection of Aquatic Life or equivalent numbers from the technical literature. Any constituent that exceeded the lower screening level by more than a factor of 10 was compared to additional ecological benchmarks to define further the extent (if any) of the potential ecological effects. These additional benchmarks are based on either (1) LC-50s and EC-50s for taxa specific to the SRP ecosystem to assess effects on the aquatic community; (2) the EPA National Interim Primary Drinking Water Standards (DWS) and, if the DWS are exceeded, chronic no-effect concentrations of metals and organics (except volatile solvents) in mammalian diets to screen for possible effects from consumption of surface waters by terrestrial wildlife; or (3) dietary concentrations shown to be toxic to birds and mammals to assess consumption of contaminated aquatic biota. For those waste sites with radionuclide constituents, EPA National Interim Drinking Water Standards were used as first-level benchmarks for comparison of potential exposure concentrations in surface waters. For tritium, no-effect concentrations in fish were used as second-level benchmarks. Benchmarks for soil are based on the Department of Energy's Threshold Guidance Limits (DOE, 1985) as presented in Looney et al. (1987a). These soil and water criteria are based on human health concerns and so are conservative. The various quotients (comparing calculated concentrations to benchmarks) form the basis for quantification of potential ecological impacts from each waste site.

TABLE 81

Instream Ecological Effects in Four Mile Creek for the Waste Removal and Closure and No Waste Removal and Closure Options

Parameter	Units	Existing Four Mile Creek Concentration*	Incremental Increase in Concentration for Years Since 1985							
			0	100	200	300	400	500	700	1000
Cadmium	µg/L	0.46	1.5E-05	4.2E-03	8.4E-04	7.8E-06	2.4E-08	5.4E-11	1.1E-12	5.7E-08
Lead	µg/L	3.1	1.1E-02	3.6E+00	6.5E-01	5.7E-03	1.8E-05	3.8E-08	1.1E-13	0.0
Mercury	µg/L	<0.05	3.8E-05	1.2E-02	2.1E-03	1.9E-05	6.1E-08	1.3E-10	0.0	0.0
Naphthalene	µg/L	<10	1.9E-08	2.7E-01	5.3E-01	5.3E-01	5.3E-01	5.3E-01	5.3E-01	5.3E-01
Toluene	µg/L	<10	1.1E-04	1.5E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00
Trimethylbenzene	µg/L	NA	0.0	8.5E-02	1.0E+00	1.5E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00
Xylene	µg/L	NA	2.0E-06	1.8E+00	2.8E+00	2.8E+00	2.8E+00	2.8E+00	2.8E+00	2.8E+00
^{3}H	pCi/L	9.4E+04	2.6E+03	6.5E+03	8.1E+00	2.8E-04	0.0	0.0	0.0	0.0
^{14}C	pCi/L	NA	1.1E-06	2.4E-03	2.5E-03	2.5E-03	2.1E-03	3.4E-04	2.8E-08	0.0
^{59}Ni	pCi/L	NA	4.9E-05	1.5E-02	2.7E-03	2.5E-05	7.7E-08	0.0	0.0	0.0
^{63}Ni	pCi/L	NA	2.2E+00	3.9E+02	4.0E+01	1.9E-01	3.3E-04	3.7E-07	0.0	0.0
^{60}Co	pCi/L	0.46	3.6E-04	1.9E-06	0.0	0.0	0.0	0.0	0.0	0.0
^{79}Se	pCi/L	NA	0.0	0.0	0.0	0.0	0.0	2.2E-06	2.9E-04	7.3E-03
^{90}Sr	pCi/L	<4.2	3.0E-03	1.1E-01	2.4E-03	2.0E-06	0.0	0.0	0.0	0.0
^{90}Y	pCi/L	<4.2	3.0E-03	1.1E-01	2.4E-03	2.0E-06	0.0	0.0	0.0	0.0
^{99}Tc	pCi/L	<100	7.7E-02	2.3E+01	4.1E+00	3.8E-02	1.2E-04	2.6E-07	0.0	0.0
^{129}I	pCi/L	<1	0.0	2.7E-06	2.4E-05	3.2E-05	3.4E-05	3.4E-05	3.4E-05	3.4E-05
^{137}Cs	pCi/L	<33	2.9E-03	1.2E-01	2.9E-03	2.8E-06	0.0	0.0	0.0	0.0
^{233}U	pCi/L	<0.1	2.7E-06	8.1E-04	1.5E-04	1.3E-06	0.0	0.0	0.0	0.0
^{234}U	pCi/L	<1.1	2.5E-07	7.7E-05	1.4E-05	1.3E-07	0.0	0.0	0.0	0.0
^{235}U	pCi/L	<0.1	1.5E-06	4.5E-04	8.5E-05	7.7E-07	0.0	0.0	0.0	0.0
^{238}U	pCi/L	<1.1	2.4E-04	7.3E-02	1.3E-02	1.2E-04	3.7E-07	0.0	0.0	0.0
^{238}Pu	pCi/L	<0.1	4.1E-03	6.5E-01	5.7E-02	2.4E-04	3.4E-07	0.0	0.0	0.0
^{239}Pu	pCi/L	<0.1	5.3E-04	1.6E-01	2.9E-02	2.6E-04	8.1E-07	0.0	0.0	0.0
^{241}Pu	pCi/L	<0.1	4.5E-05	1.6E-04	2.8E-07	0.0	0.0	0.0	0.0	0.0
^{242}Pu	pCi/L	<0.1	0.0	6.5E-06	1.2E-06	0.0	0.0	0.0	0.0	0.0

Note: In vicinity of outcrop (Looney & Holmes, 1987). NA = not available.

TABLE 82

Instream Ecological Effects in Four Mile Creek for the No Action Option

Parameter	Units	Existing Four Mile Creek Concentration*	Incremental Increase in Concentration for Years Since 1985							
			0	100	200	300	400	500	700	1000
Cadmium	µg/L	0.46	1.5E-04	4.9E-03	3.8E-04	2.4E-06	6.5E-09	1.3E-11	1.2E-11	6.5E-07
Lead	µg/L	3.1	1.1E-01	3.6E+00	2.8E-01	1.8E-03	4.9E-06	9.7E-09	2.7E-14	0.0
Mercury	µg/L	<0.05	3.8E-04	1.2E-02	9.3E-04	6.1E-06	1.6E-08	3.3E-11	0.0	0.0
Naphthalene	µg/L	<10	2.0E-07	2.7E+00	2.9E+00	1.7E+00	2.4E-01	1.5E-02	2.0E-05	3.6E-10
Toluene	µg/L	<10	1.2E-03	1.5E+01	1.0E+01	1.1E+00	2.3E-02	2.1E-04	7.7E-09	0.0
Trimethylbenzene	µg/L	NA	0.0	8.9E-01	9.7E+00	6.5E+00	5.3E+00	2.1E+00	1.1E-01	2.6E-04
Xylene	µg/L	NA	2.0E-05	1.9E+01	6.1E+00	6.1E+00	4.9E-01	1.7E-02	7.3E-06	2.8E-11
^{3}H	pCi/L	9.4E+04	2.6E+04	8.1E+03	3.8E+00	8.9E-05	0.0	0.0	0.0	0.0
^{14}C	pCi/L	NA	1.1E-05	7.3E-03	1.8E-03	2.6E-05	1.3E-07	0.0	0.0	0.0
^{59}Ni	pCi/L	NA	4.9E-04	1.5E-02	1.2E-03	7.7E-06	2.1E-08	0.0	0.0	0.0
^{63}Ni	pCi/L	NA	2.1E+01	4.1E+02	1.8E+01	6.1E-02	8.9E-05	9.7E-08	0.0	0.0
^{60}Co	pCi/L	0.46	3.6E-03	3.2E-06	0.0	0.0	0.0	0.0	0.0	0.0
^{79}Se	pCi/L	NA	0.0	0.0	0.0	0.0	2.9E-07	2.6E-05	2.4E-03	3.2E-02
^{90}Sr	pCi/L	<4.2	3.0E-02	1.3E-01	1.1E-03	6.5E-07	0.0	0.0	0.0	0.0
^{90}Y	pCi/L	<4.2	3.0E-02	1.3E-01	1.1E-03	6.5E-07	0.0	0.0	0.0	0.0
^{99}Tc	pCi/L	<100	7.7E-01	2.4E+01	1.9E+00	1.2E-02	3.3E-05	6.5E-08	0.0	0.0
^{129}I	pCi/L	<1	0.0	2.7E-05	2.4E-04	3.2E-04	3.4E-04	3.4E-04	3.4E-04	3.4E-04
^{134}Cs	pCi/L	<33	1.1E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{137}Cs	pCi/L	<33	2.9E-02	1.4E-01	1.3E-03	8.5E-07	0.0	0.0	0.0	0.0
^{233}U	pCi/L	<0.1	2.6E-05	8.5E-04	6.5E-05	4.1E-07	0.0	0.0	0.0	0.0
^{234}U	pCi/L	<1.1	2.5E-06	7.7E-05	6.5E-06	3.9E-08	0.0	0.0	0.0	0.0
^{235}U	pCi/L	<0.1	1.5E-05	4.9E-04	3.8E-05	2.4E-07	0.0	0.0	0.0	0.0
^{238}U	pCi/L	<1.1	2.4E-03	7.3E-02	6.1E-03	3.7E-05	1.0E-07	0.0	0.0	0.0
^{238}Pu	pCi/L	<0.1	4.1E-02	6.9E-01	2.6E-02	7.7E-05	9.3E-08	0.0	0.0	0.0
^{239}Pu	pCi/L	<0.1	5.3E-03	1.7E-01	1.3E-02	8.1E-05	2.3E-07	0.0	0.0	0.0
^{241}Pu	pCi/L	<0.1	4.5E-04	2.0E-04	1.3E-07	0.0	0.0	0.0	0.0	0.0
^{242}Pu	pCi/L	<0.1	2.1E-07	6.5E-06	5.3E-07	0.0	0.0	0.0	0.0	0.0

Note: In vicinity of outcrop (Looney & Holmes, 1987). NA = not available.

Of the four pathways considered, the groundwater transport to a surface outcrop and biointrusion pathways are applicable at this site and would remain under the no action option. Implementation of either the waste removal and closure or no waste removal and closure options would remove the biointrusion pathway.

The potential exists for adverse effects on the aquatic biota for Four Mile Creek and adjacent wetlands under all closure options. The levels of groundwater outcrop contamination predicted by the PATHRAE model for Year 100 for lead, mercury, tritium, and ^{238}Pu exceed the benchmark criteria by factors ranging from 1.2 (^{238}Pu) to 232 (lead) under the no action option, indicating the potential for adverse effects on the aquatic biota in the relatively unmixed waters of wetlands adjacent to the groundwater outcrop, primarily due to elevated lead concentrations. Dilution of the contaminated groundwater outcrop by Four Mile Creek yields contaminant concentrations for lead, mercury, and tritium that exceed the criteria by factors ranging from 5.4 (tritium) to 35 (lead). Dilution modeling indicates that the input of the contaminated groundwater outcrop into Four Mile Creek will elevate the existing stream concentrations for lead, mercury, and tritium.

An examination of the second level toxicity benchmarks for tritium reveals that the tritium concentrations in the groundwater outcrop and diluted stream are well below the no-effect concentration for developing fish embryos, which are the most sensitive life stage of aquatic biota to radiation effects. A comparison of the groundwater outcrop and diluted stream concentrations for lead with second-level toxicity benchmarks for zooplankton (Daphnia) and bluegill (Lepomis macrochirus) indicates that the lead concentrations are sufficient to affect zooplankton populations adversely, but are not expected to affect bluegill populations adversely. In general, slight decreases in the levels of groundwater contamination are realized under the implementation of the waste removal and closure option or the no waste removal and closure option as compared to the no action option.

The groundwater outcrop concentrations for lead, tritium, and ^{238}Pu exceed the drinking water standards under all closure options, indicating the potential for effects on wildlife consuming the undiluted groundwater at the outcrop. However, any such effects should be negligible in view of the conservative nature of human drinking water standards when applied to wildlife and the low probability of significant numbers of wildlife consistently drinking water in the area of the undiluted groundwater outcrop.

Based on the calculated radioactivity concentrations in the disposed waste, the potential exists for limited terrestrial impacts such as reduced plant growth, increased plant mortalities, and food chain transport to herbivorous wildlife under the no

action option via the biointrusion pathway. Terrestrial impacts would be limited to the general area (approximately 1,985 acres) occupied by the Burial Grounds.

Endangered Species

No endangered species have been identified in the vicinity of the Radioactive Waste Burial Grounds from previous endangered species surveys at SRP. The habitats in the vicinity of this waste site are not suitable for any federally endangered species that have been identified at SRP, including the American alligator, the red-cockaded woodpecker, the wood stork, and the shortnose sturgeon (Dukes, 1984; Gladden et al., 1985). Therefore, none of the actions postulated for this site would have any effect on endangered species or their critical habitats.

Wetlands

Wetlands found within 1,000 m of the Burial Grounds are summarized in Table 83 (Mackey et al., 1985; Shields et al., 1982). The bottomland hardwoods occur along small drainages to and within the floodplain of Four Mile Creek (Figure 46). Seepage from this waste site has discharged to these wetlands. Outcrop pathways have been identified from tritium in monitoring wells at this waste site.

Remedial actions should improve the water quality of these environments. Also, remedial actions should use appropriate erosion control techniques to eliminate potential runoff and sedimentation to these wetland environments.

TABLE 83

Wetlands Within 1,000 m of the Radioactive Waste Burial Grounds

Type of Wetlands (acres)	Distance to Wetlands (m) 0-200	201-400	401-600	601-800	801-1000
Open water	0	0	0	0	0
Cypress/tupelo	0	0	0	0	0
Emergent marsh	0	0	0	0	10.5
Scrub/shrub	0	0	0	0	0
Bottomland hardwood	4.0	6.3	6.1	60.9	106.2
Total	4.0	6.3	6.1	60.9	116.7

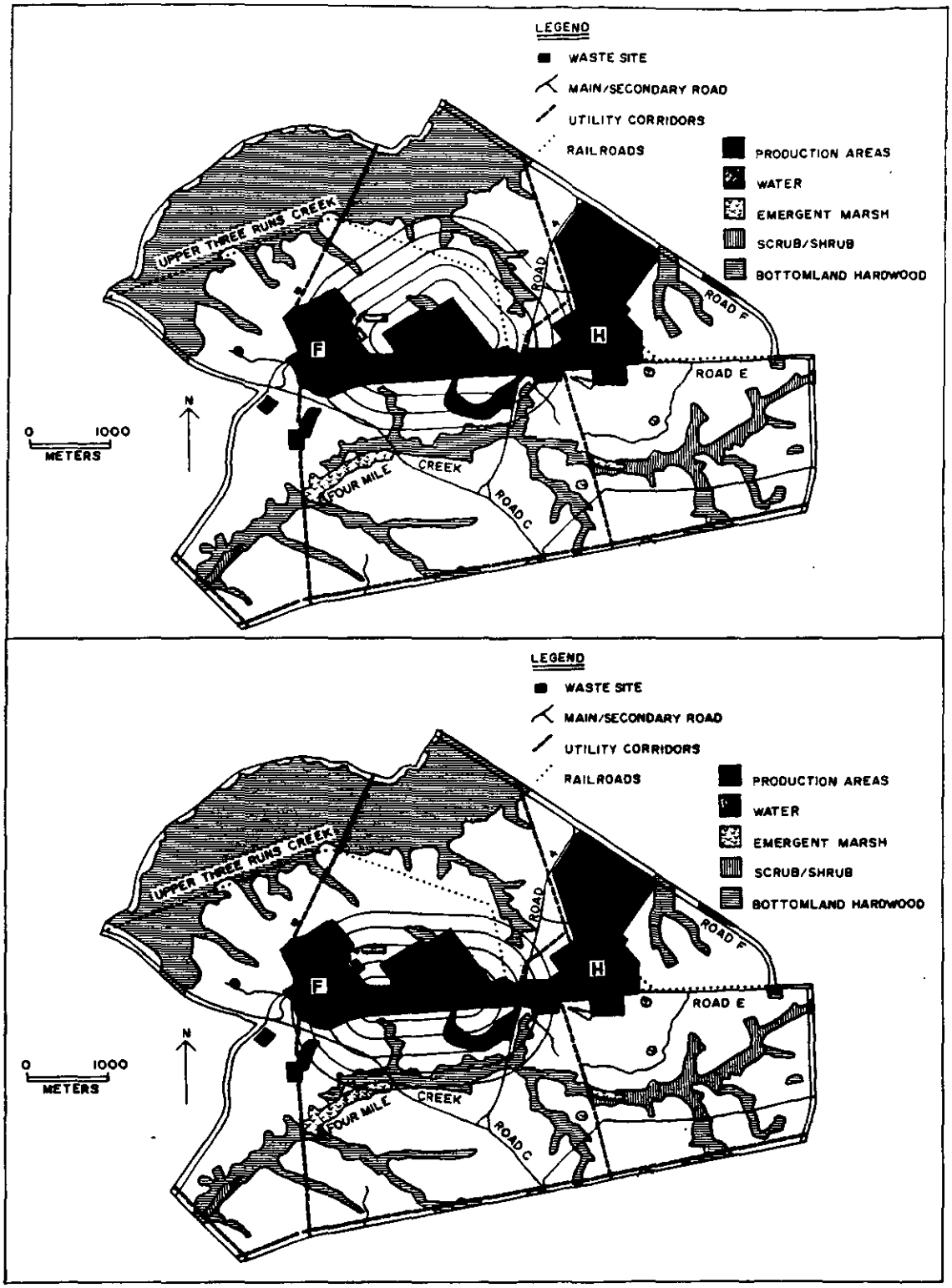


FIGURE 46. Location of Wetlands Within 1,000 m of the Radioactive Waste Burial Grounds

ACCIDENT ANALYSIS

The environmental impacts and risk of potential accidents occurring during the closure options for the Radioactive Waste Burial Grounds have been analyzed. The selected closure option would be implemented in such a manner that the risk to the public and to workers from accidental releases of or exposure to site materials/contaminants would be minimal.

Pertinent environmental and safety documents were reviewed to identify potential accidents. The potential accidents and consequences associated with each waste site closure option are related to the materials at the site. The accident scenarios are based on the hazards associated with these materials. The Radioactive Burial Grounds, 743-G, 743-7G, and 743-28G, are the SRP central storage facilities for solid radioactive waste. The areas received a variety of solid radioactive waste including contaminated equipment (tanks, pipes, jumpers), reactor hardware and resins, spent lithium-aluminum targets, drummed oil containing absorbent material, shipments from offsite DOE facilities, incidental laboratory and production waste (spent air filters, gloves, clothes, etc.), and steel cans containing mercury-filled, 1-L polyethylene bottles. The work for the closure and remedial options involves primarily excavating, earthmoving, and backfilling.

The accidents considered for the closure options are natural events such as earthquakes, tornadoes, and straight winds and industrial accidents such as injuries, fires, cave-ins, and container spills. The natural events were analyzed using historical data on probability and severity. Industrial accidents were analyzed using man-hour estimates based on construction industry cost-estimating handbooks and industrial accident rate tabulations. The number of construction labor man-days required to accomplish the postulated options was estimated. This estimate was used to calculate the frequency of each potential accident. The contaminants considered in accident analysis are those selected for this site in Looney et al. (1987a).

Tables 84 through 86 identify the potential accidents germane to the site. For the Radioactive Waste Burial Grounds the greatest potential consequences would result from the accident initiators--tornadoes and fire. The potential dispersion of contaminants off of the site by fire suggests further analysis. This concern arises because some transuranic and low-level waste has been stored in dry form in containers. The puncture or rupture of these containers is probable because these containers would be handled by remotely controlled equipment or equipment with shielded cabs. Sources of ignition are equipment fire, sparks from friction between equipment and containers, and spontaneous combustion. Based on analysis of

these ignition sources and dry combustible type material disposed of in the Burial Grounds, the frequency of a fire is estimated at 4.84E-01 for the waste removal and closure option.

The liklihood of puncture or rupture of a container is greater during the excavation option of this site than other SRP waste sites because of the number of buried containers and because of the intention to use remotely controlled equipment or equipment with shielded cabs. The frequency of puncture or rupture of a waste container was calculated in a standard manner and then multiplied by two to account for these additional concerns.

Also, employee injury was estimated to be a serious risk during waste site closure activities. The accident scenarios of fire, container puncture, equipment accidents, employee injuries, and tornadoes were further analyzed and the results presented in a separate report (Palmiotto & Comiskey, 1986).

TABLE 84

Accident Analysis for the Waste Removal and Closure Option

Initiator	Accident	Frequency	Consequences
Natural Events			
Tornado	High winds disperse soil during excavation.	1.40E-03	Dispersion of soil off waste site.
Straight winds	High winds disperse wet.	1.01E-02	Dispersion of soil off of waste site.
Earthquake	Failure of walls.	N/A	N/A
Industrial Events			
Container puncture	Waste containers in site punctured.	1.60E-02	Release of contents at waste site. Potential for serious or fatal injury to personnel.
Equipment collision	Mobile equipment collides. Possible puncture of waste boxes.	2.81E-00	Potential for serious injury to personnel. Releases confined to the immediate area of the site.
Large equipment toppling	Failure of equipment.	1.55E-00	Potential for serious injury to personnel. Dispersion of waste material at site.
Employee injury	Falls/equipment-related injuries.	4.20E+01	Potential for serious injury to personnel.
Contamination	Inadvertent contamination to workers at site.	3.21E+01	Potential for minor injury to personnel.
Drop & breach	Waste box dropped and puncture or lid opening occurs.	6.07E-01	Potential for minor injury to personnel. Release of waste at site. Cleanup initiated.

Note: N/A = not applicable because of the nature of the closure option or the waste site.

TABLE 84, Contd

Initiator	Accident	Frequency	Consequences
Equipment fire	Fuel or hydraulic fluid catches fire.	4.84E-01	Onsite fire team response. Potential for serious or fatal injury to personnel. Equipment damaged.
Cave-In	During excavation of material with equipment.	4.82E-02	Possible fatality.
Waste truck accident and fire	Accident resulting in fire.	4.32E-03	Onsite Fire Department response. Potential for serious injury to personnel Damaged equipment.
Waste truck accident and spill	Waste truck accident during transport. Waste box damaged and breached.	2.58E-01	Waste release confined to accident site. Cleanup initiated. Potential for serious injury to personnel.
Waste truck accident and fatality	Truck accident while in transit to disposal area.	1.37E-01	Fatality to driver.
Waste box falls off truck	Rigging or driving error results in spillage of waste box contents.	6.86E-01	Release of waste to site of accident. Cleanup initiated.
Fill truck accident	Fill truck and another vehicle collide, or single vehicle accident occurs.	3.56E-00	Potential for serious injury to personnel. Fill material released at accident site. Cleanup initiated.
Fatal construction accident	Construction accident resulting in fatality.	3.07E-03	Fatality.

TABLE 85

Accident Analysis for the No Waste Removal and Closure Option

Initiator	Accident	Frequency	Consequences
Natural Events			
Tornado	High winds disperse soil during excavation.	N/A	N/A
Straight winds	High winds disperse wet soil during excavation.	N/A	N/A
Earthquake	Failure of walls.	N/A	N/A
Industrial Events			
Container puncture	Waste containers in site punctured.	N/A	N/A
Equipment collision	Mobile equipment collides. Possible puncture of waste containers.	6.34E-01	Potential for serious injury to personnel. Waste materials confined to site.
Large equipment toppling	Failure of equipment.	N/A	N/A
Employee injury	Falls/equipment-related injuries.	9.53E-00	Potential for injury to personnel.
Contamination	Inadvertent contamination to workers at site.	1.88E-00	Potential for employee contamination.
Drop & breach	Waste box dropped and puncture or lid opening occurs.	N/A	N/A
Equipment fire	Fuel or hydraulic fluid catches fire.	1.10E-01	Potential for minor injury to personnel. Damage to equipment.

Note: N/A = not applicable because of the nature of the closure option or the waste site.

TABLE 85, Contd

Initiator	Accident	Frequency	Consequences
Cave-In	During excavation of material with equipment.	N/A	N/A
Waste truck accident and fire	Accident resulting in fire.	N/A	N/A
Waste truck accident and spill	Truck accident during transport. Waste box damaged and breached.	N/A	N/A
Waste truck accident and fatality	Truck accident while in transit to disposal area.	N/A	N/A
Waste box falls off truck	Rigging or driving error results in spillage of waste box contents.	N/A	N/A
Fill truck accident	Truck with fill and another vehicle collide, or single vehicle accident.	1.69E-00	Potential for serious injury to personnel. Fill material released at accident site. Cleanup initiated.
Fatal construction accident	Construction accident resulting in fatality.	6.96E-04	Fatality.

Note: N/A = not applicable because of the nature of the closure option or waste site.

TABLE 86

Accident Analysis for the No Action Option

Initiator	Accident	Frequency	Consequences
Natural Events			
Tornado	High winds disperse soil during excavation.	N/A	N/A
Straight winds	High winds disperse wet soil during excavation.	N/A	N/A
Earthquake	Failure of walls.	N/A	N/A
Industrial Events			
Container puncture	Waste containers in site punctured.	N/A	N/A
Equipment collision	Mobile equipment. Possible puncture of waste boxes.	N/A	N/A
Large equipment toppling	Failure of equipment.	N/A	N/A
Employee injury	Falls/equipment-related injuries.	N/A	N/A
Contamination	Inadvertant contamination to workers at site.	N/A	N/A
Drop & breach	Waste box dropped and puncture or lid opening occurs.	N/A	N/A
Equipment fire	Fuel or hydraulic fluid catches fire.	N/A	N/A

Note: N/A = not applicable because of the nature of the closure option or the waste site.

TABLE 86, Contd

Initiator	Accident	Frequency	Consequences
Cave-In	During excavation of material with equipment.	N/A	N/A
Waste truck accident and fire	Accident resulting in fire.	N/A	N/A
Waste truck accident and spill	Truck accident during transport. Waste box damaged and breached.	N/A	N/A
Waste truck accident and fatality	Truck accident while in transit to disposal area.	N/A	N/A
Waste box falls off truck	Rigging or driving error results in spillage of waste box contents.	N/A	N/A
Fill truck accident	Truck with fill and another vehicle collide or single vehicle accident.	N/A	N/A
Fatal construction accident	Construction accident resulting in fatality.	N/A	N/A

Note: N/A = not applicable because of the nature of the closure option or the waste site.

ARCHEOLOGICAL AND HISTORICAL SURVEY

Archeological surveying and testing of the Radioactive Waste Burial Grounds have been performed by the University of South Carolina's Institute of Archeology and Anthropology (Brooks, 1986). The areas were surveyed by visual inspection and their conditions documented by general area photographs. One hundred percent of the areas was disturbed by burial-related activities. The survey located no archeological or historical sites. Therefore, no further archeological work is warranted or required as part of the closure options for the Radioactive Waste Burial Grounds. It is recommended that a request be made to the South Carolina State Historic Preservation Officer for concurrence with this determination of no effect.

UNAVOIDABLE/IRREVERSIBLE IMPACTS

Environmental impacts that cannot be avoided by reasonable mitigation measures are described in this section. These impacts are based upon the alternative closure options developed for the Radioactive Waste Burial Grounds. Also assessed are the irreversible and irretrievable commitments of resources, short-term land uses, and long-term environmental implications for the alternative closure options considered.

Many of the unavoidable adverse impacts expected from the closure of the Radioactive Waste Burial Grounds have already been experienced during past use of the land. One impact is the loss of alternative land uses while the subject area (approximately 790,000 m^2) remains under the control of the Department of Energy. Application of the no action option would require some future action (i.e., site preparation) before alternative land uses such as agriculture could be implemented. The potential exists for field personnel and equipment to be exposed to significant levels of radiation if closure activities such as excavation and transport of contaminated materials are implemented. However, the use of standard SRP work practices as well as personal and special protective equipment (i.e., remote controlled or shielded excavation machinery) should protect workers from this exposure. Contaminated equipment that cannot be decontaminated will be disposed of in a waste storage/disposal facility. Other adverse environmental impacts may include minimal wildlife habitat loss during revegetation of the site and temporary air pollution associated with activities such as fieldwork (i.e., excavation, backfilling, grading) and transportation of materials to and from the site.

Energy, raw materials, and other resources would be used for the closure of the Radioactive Waste Burial Grounds. Resources that would be irreversibly or irretrievably committed during closure actions include (1) materials that cannot be recovered or recycled (i.e., backfill material) and (2) materials consumed or reduced to unrecoverable forms (i.e., energy).

Closure of the site would involve land area already committed. Disposal of soils and other materials from the site (approximately 3,000,000 m^3) would require use of additional land at a waste storage/disposal facility. Other committed resources would include backfill and capping materials, clean topsoil, and packaging materials (i.e., metal boxes). Irretrievable energy loss would result from the use of machinery to work the site, transport materials, and process wastes at the disposal facility. Continued grounds maintenance and groundwater monitoring of the subject area would require a 100-year commitment of manpower and other resources.

In the short term, implementation of site closure options would minimally impact local wildlife habitat and natural productivity. The long-term impact of these effects would be no greater than the impacts of existing land use. Following closure actions, the site would probably revert to its natural state and productivity with minimal long-term effects. Implementation of the no waste removal and closure and no action options, however, may necessitate dedication of the area for continued waste management.

CONTROL AND SECURITY

Access to the Savannah River Plant is controlled at primary roads by permanently manned barricades. Other roads entering the site are closed to traffic by gates or other barriers. The plant, except along the Savannah River, is fenced. Additionally, the site is posted against trespass under South Carolina and federal statutes. Operating areas are separately fenced and continuously patrolled by armed security personnel.

The Radioactive Waste Burial Grounds are located off SRP Road 4, between the F- and H-Area separations facilities. The Burial Grounds are protected by a chain-link security fence. Access to the site is controlled, and the area is frequently patrolled by plant security personnel. Current controls and security will continue throughout the period of institutional control and be extended as required. The Waste Management Operations Department is responsible for the care and maintenance of the Radioactive Waste Burial Grounds.

COST ANALYSIS

The relative costs for each of the postulated closure options for the Radioactive Waste Burial Grounds have been estimated. The Du Pont Engineering Department has prepared Venture Guidance Appraisal (VGA) cost estimates for each option.

SCOPES OF WORK

Scopes of work based upon the various closure options described earlier in this document have been developed and are detailed below. The specific details of the commitments to maintenance, monitoring, and cap design in this section were selected primarily for the purpose of deriving reasonable and consistent relative cost estimates.

Waste Removal and Closure

Under the waste removal and closure option, waste and soil would be excavated along known trench lines with the excavation extending beyond and below the original trench. Temporary shelters would be erected over the areas where excavation is taking place to prevent rainwater from contacting the excavated wastes. Excavating machines would either be remotely operated or have shielded cabs. Waste materials and contaminated soils (approximately 3,000,000 m^3) would be transported in metal boxes to a waste storage/disposal facility. The excavation would be backfilled (approximately 1,841,112 m^3) to 1.5 m below original grade and a low-permeability clay cap placed over the site. Topsoil would be added and the area compacted and seeded to prevent erosion. The cap would extend approximately 3 m beyond the existing fenceline around the burial sites, encompassing a total area of approximately 809,400 m^2. A new perimeter fence would be constructed after installation of the cap. The existing 125 groundwater monitoring wells within the subject area would be sampled and analyzed annually for the next 100 years. Site maintenance would be provided for the entire 100-year period.

No Waste Removal and Closure

Under the no waste removal and closure option, no waste material would be removed. A low-permeability cap as noted in the waste removal and closure option would be installed on top of the existing grade. Environmental monitoring and site maintenance would be the same as in the previous option.

No Action

Under the no action option, burial sites would be left as is. Environmental monitoring and site maintenance would be the same as in the waste removal and closure option.

VENTURE GUIDANCE APPRAISAL COST ESTIMATES

Cost estimates are provided below for the site closure options previously described (Moyer, 1987). The costs are in fourth quarter 1985 dollars.

	Closure Option Costs ($ Millions)		
Estimate Categories	Waste Removal and Closure	No Waste Removal and Closure	No Action
Site preparation and waste treatment	1,100	100	--
Waste disposal*	9,000	--	--
Monitoring and maintenance	25	25	38
Total	10,125	125	38

* Based on $\$3,000/m^3$ of waste disposed to a storage/disposal facility.

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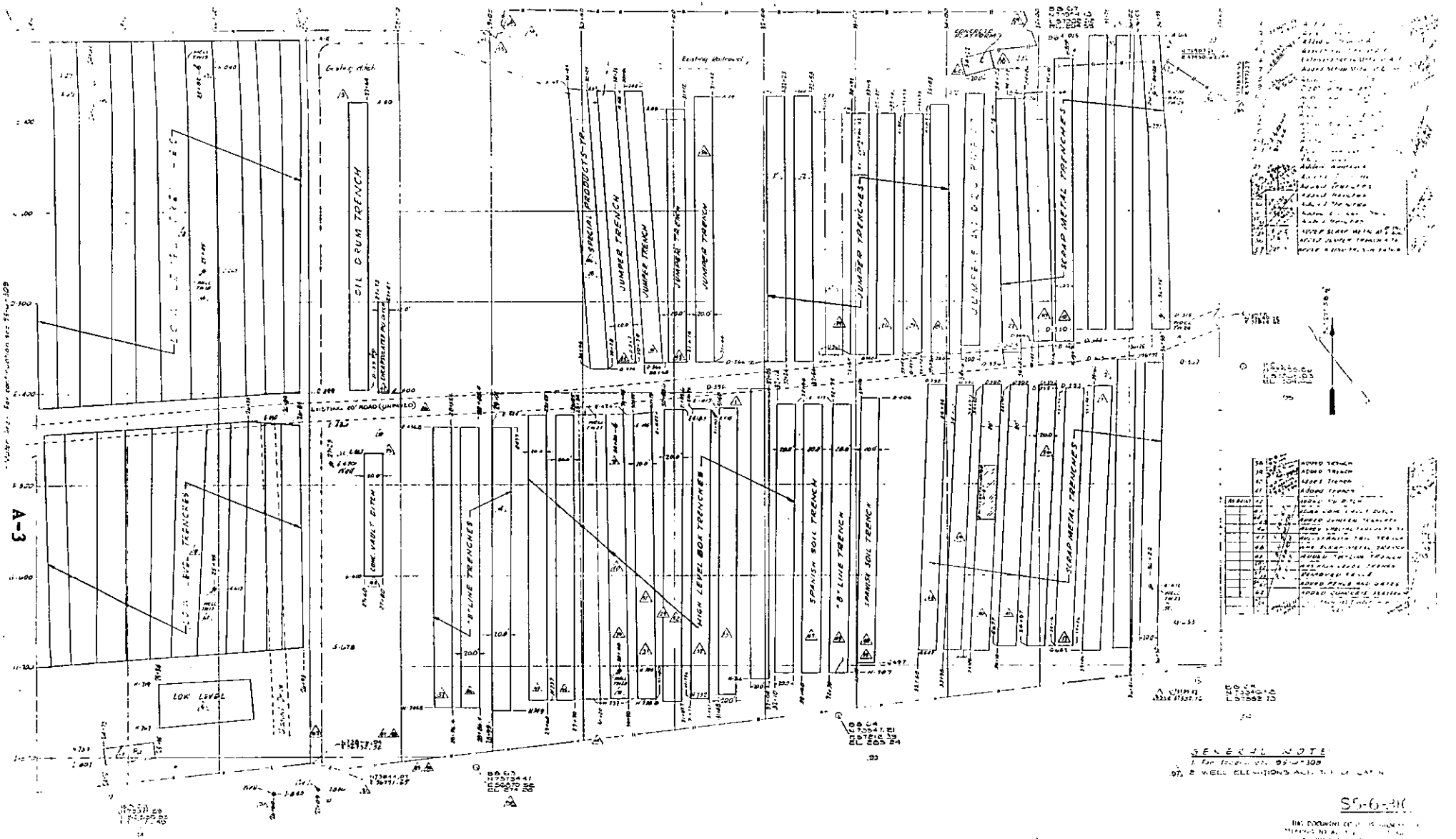
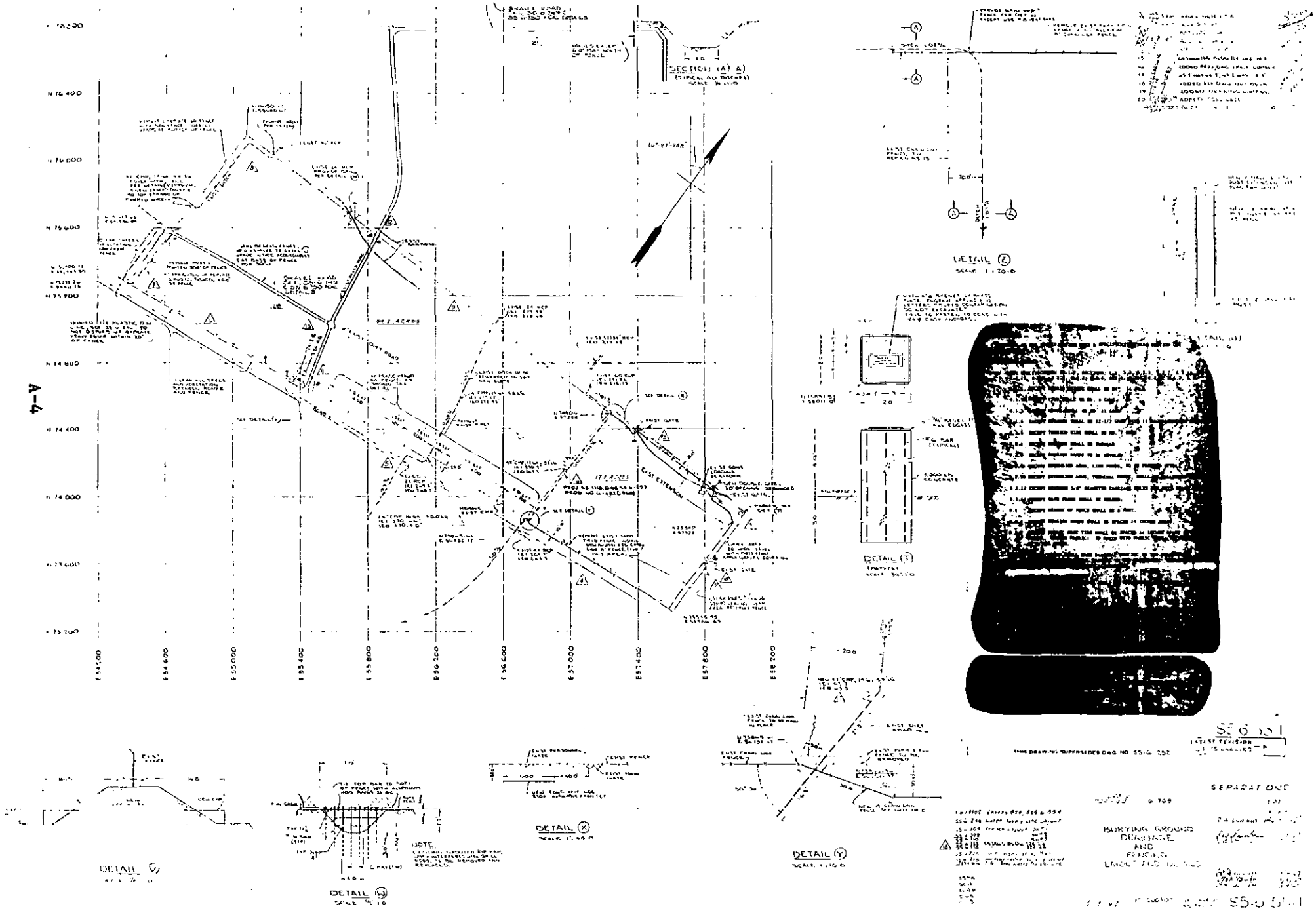
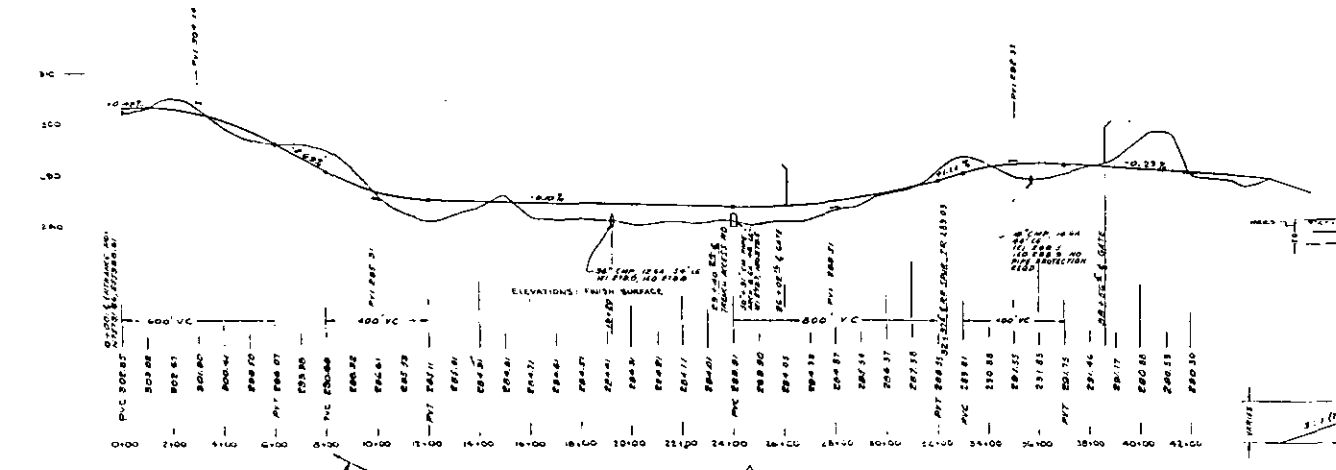
APPENDIX A

ENGINEERING DRAWINGS OF THE RADIOACTIVE WASTE BURIAL GROUNDS


BURIAL GROUND
TRENCH LAYOUT
SHEET No 2
S5 6 309
S5·6·309
GENERAL NOTE
SP-235
B-LINE
Scrap Metal
GRAPHITE TRENCH
Existing 10' Road (Unpaved)
High level scrap metal waste
High level dump metal waste
High level box waste
Underground Tanks
BURNING PIT
Existing ditch
Old Inert Trenches
Plutonium
A-2

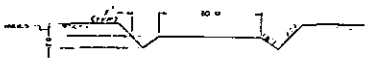

OIL DRUM TRENCH
SPECIAL PRODUCTS TRENCH
JUNIPER TRENCH
JUNIPER TRENCH
JUNIPER TRENCH
JUNIPER TRENCHES
SCRAP METAL TRENCHES
SCRAP METAL TRENCHES
EXISTING 20' ROAD (UNPAVED)
LOW LEVEL DITCH
LOW LEVEL TRENCHES
"B" LINE TRENCHES
HIGH LEVEL BOX TRENCHES
SPANISH SOIL TRENCH
"B" LINE TRENCH
SPANISH SOIL TRENCH
LOW LEVEL
A-3
GENERAL NOTE
BURIAL GROUND
TRENCH LAYOUT


A-4
SECTION (A) A
DETAIL (Z)
DETAIL (T)
DETAIL (X)
DETAIL (Y)
DETAIL (W)
BURYING GROUND
DRAINAGE
AND
FENCING
SEPARATE ONE



PROFILE SOUTH ROAD

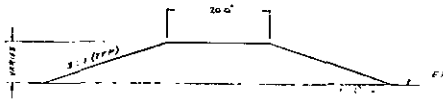
SCALE: 1"=10' VERT. 1"=200' HOR'S



CUT SECTION

(SOUTH PERIMETER ROAD)

SCALE 1"=10'



FILL SECTION

(SOUTH PERIMETER ROAD)

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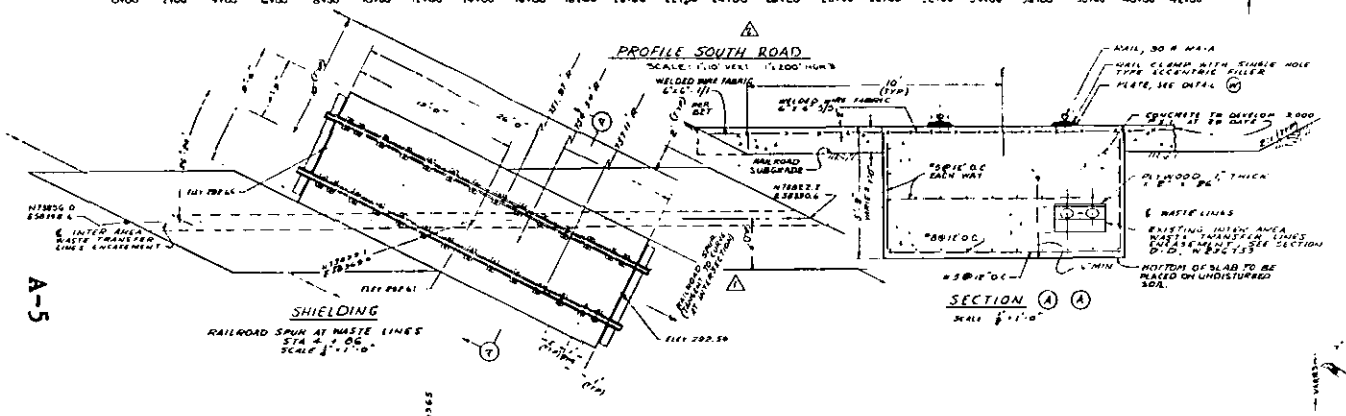


SHIELDING

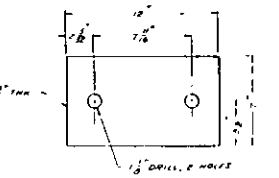
RAILROAD SPUR AT WASTE LINES

STA 4 + 06

SCALE 1"=1'-0"

SECTION (A) (A)

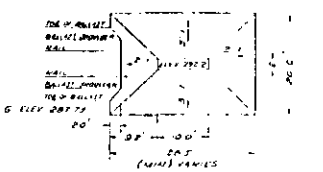
SCALE 1"=1'-0"



DETAIL (W)

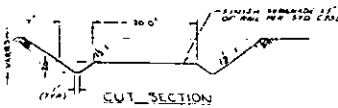
MATL STEEL A500 GR B

SCALE 1"=1'-0"



EARTH BUNKER

SCALE 1"=10'

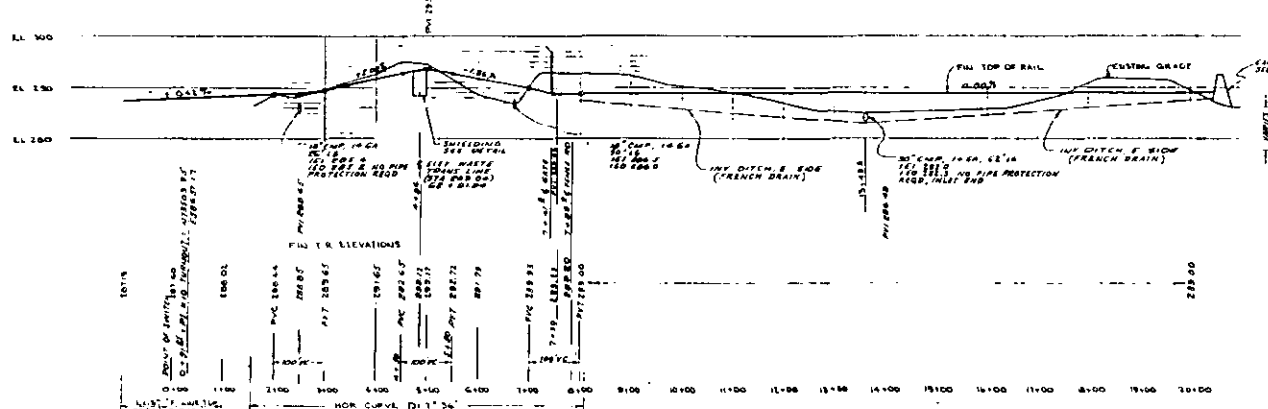


CUT SECTION

(RR SPUR, STA 0 TO STA 8)

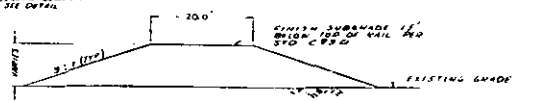
EXCEPT OMIT ROADBED DITCH, BOTH SIDES, STA 4+82.72 P + 30

SCALE 1"=10'



PROFILE R.R. SPUR

SCALE 1"=10' VERT 1"=100' HOR'S



FILL SECTION

(RR SPUR, STA 0 TO STA 8)

SCALE 1"=10'

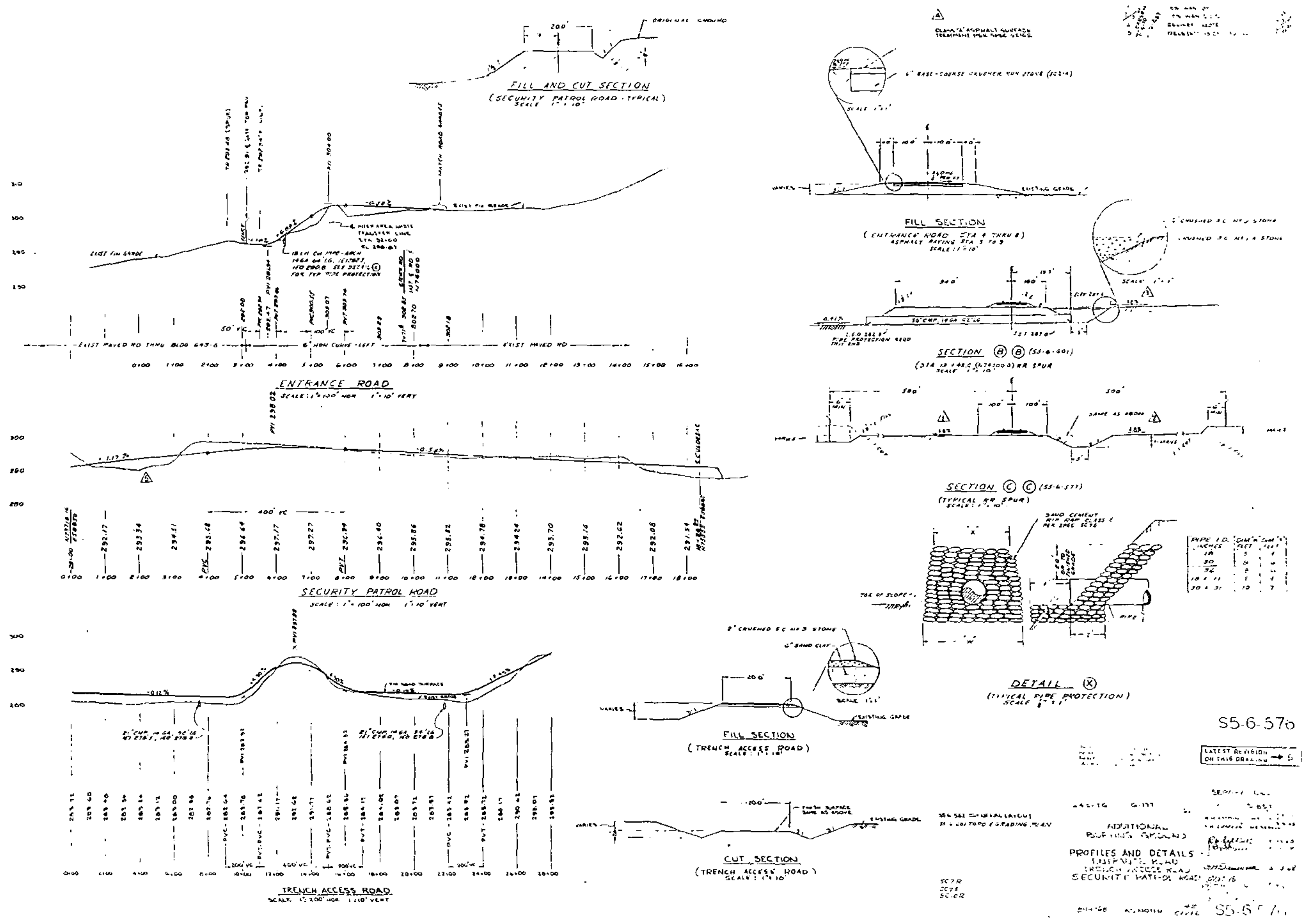
LATEST REVISION ON THIS DRAWING → (3)

ADDITIONAL ISSUED FOR GROUND

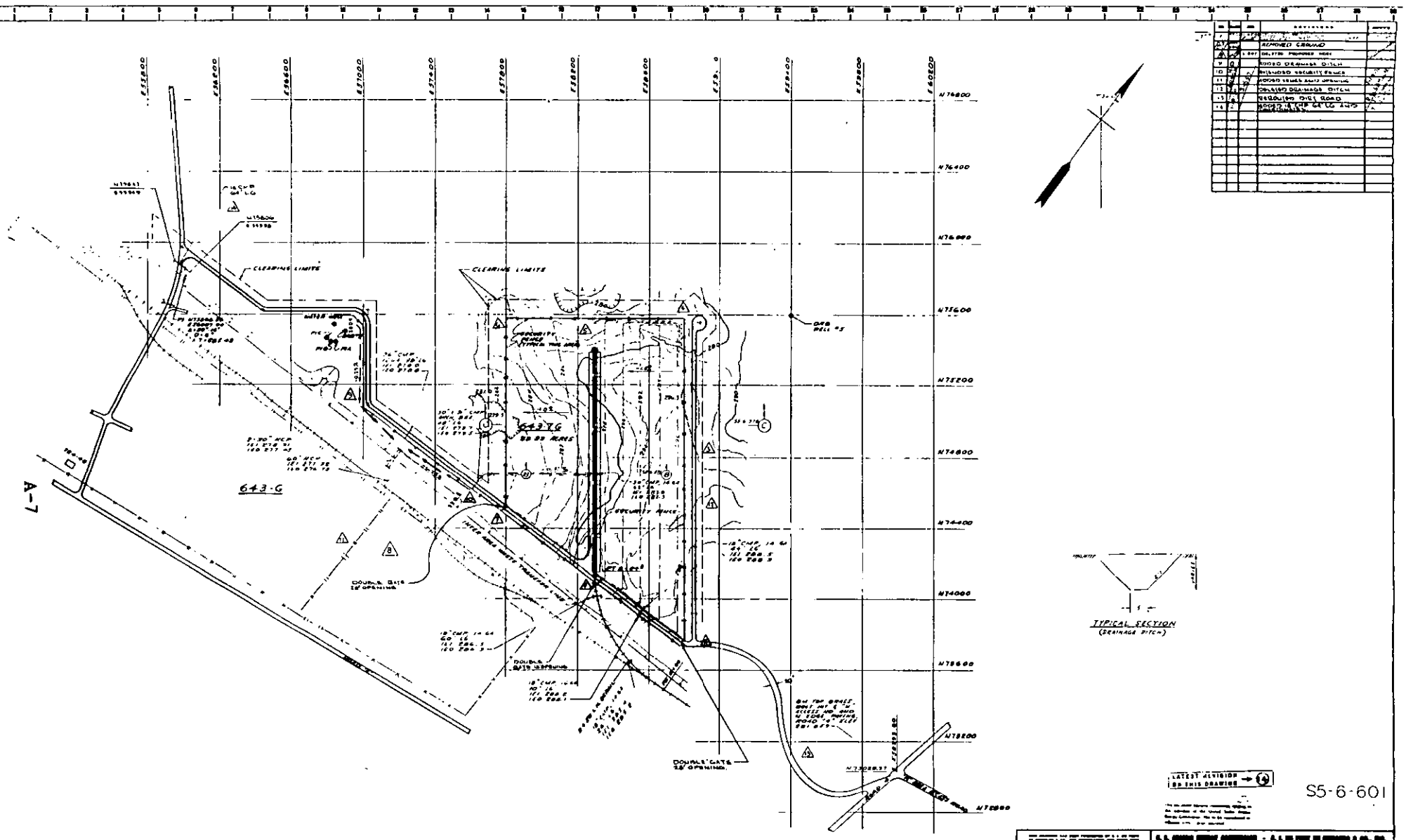
PROFILES AND DETAILS SOUTH ROAD RR SPUR

A-5

S5-6-571



FILL AND CUT SECTION
(SECURITY PATROL ROAD - TYPICAL)
ORIGINAL GROUND
ENTRANCE ROAD
EXIST PAVED RD THRU BLDG 643-G
EXIST PAVED RD
SECURITY PATROL ROAD
TRENCH ACCESS ROAD
FILL SECTION
(TRENCH ACCESS ROAD)
CUT SECTION
(TRENCH ACCESS ROAD)
EXISTING GRADE
VARIES
FILL SECTION
(ENTRANCE ROAD STA 4 THRU 8)
SECTION (B) (B) (S5-6-601)
SECTION (C) (C) (S5-6-577)
(TYPICAL RR SPUR)
DETAIL (X)
(TYPICAL PIPE PROTECTION)
TOE OF SLOPE
PIPE
S5-6-576
LATEST REVISION ON THIS DRAWING
ADDITIONAL
PROFILES AND DETAILS

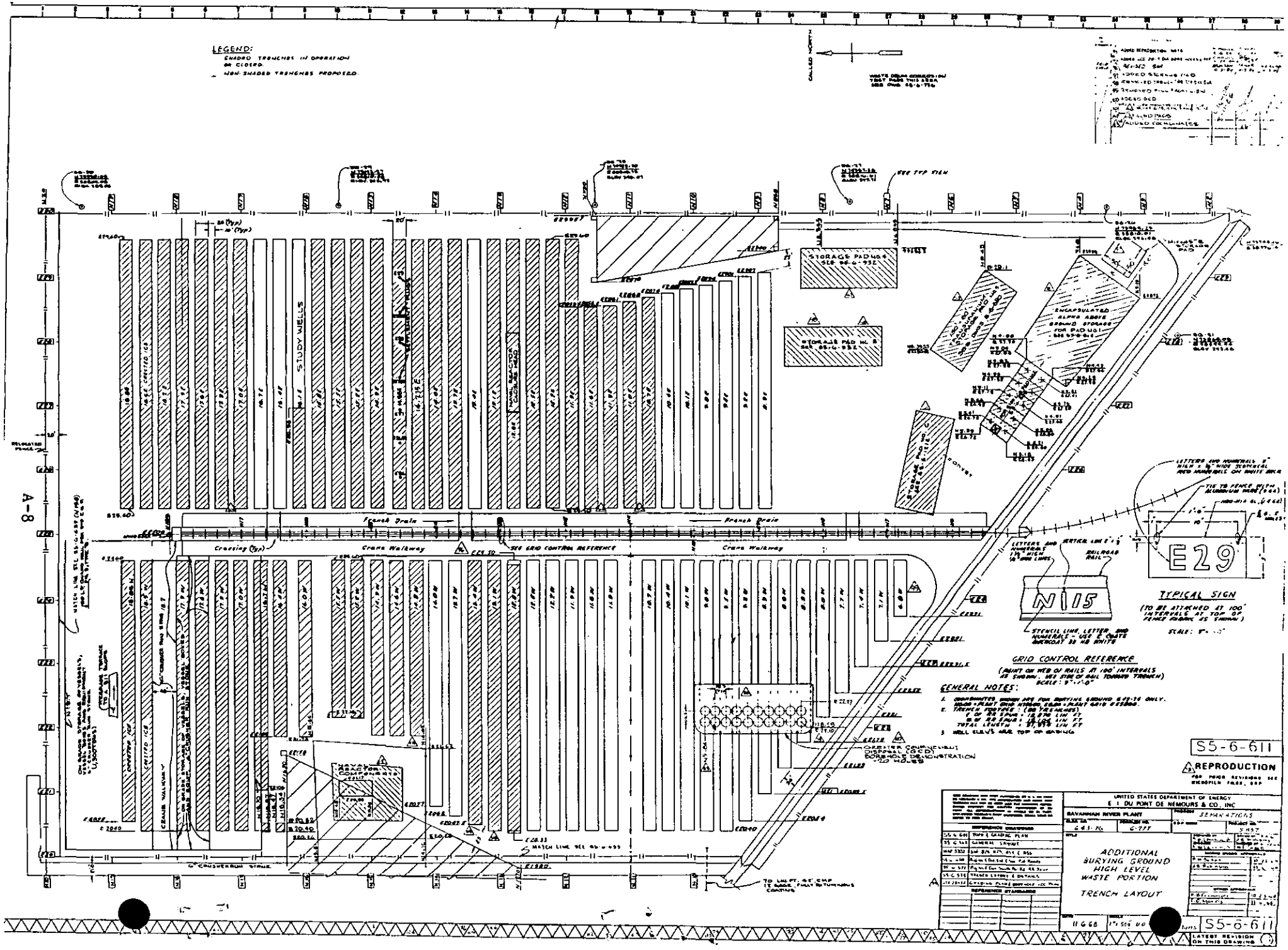


S5-6-601

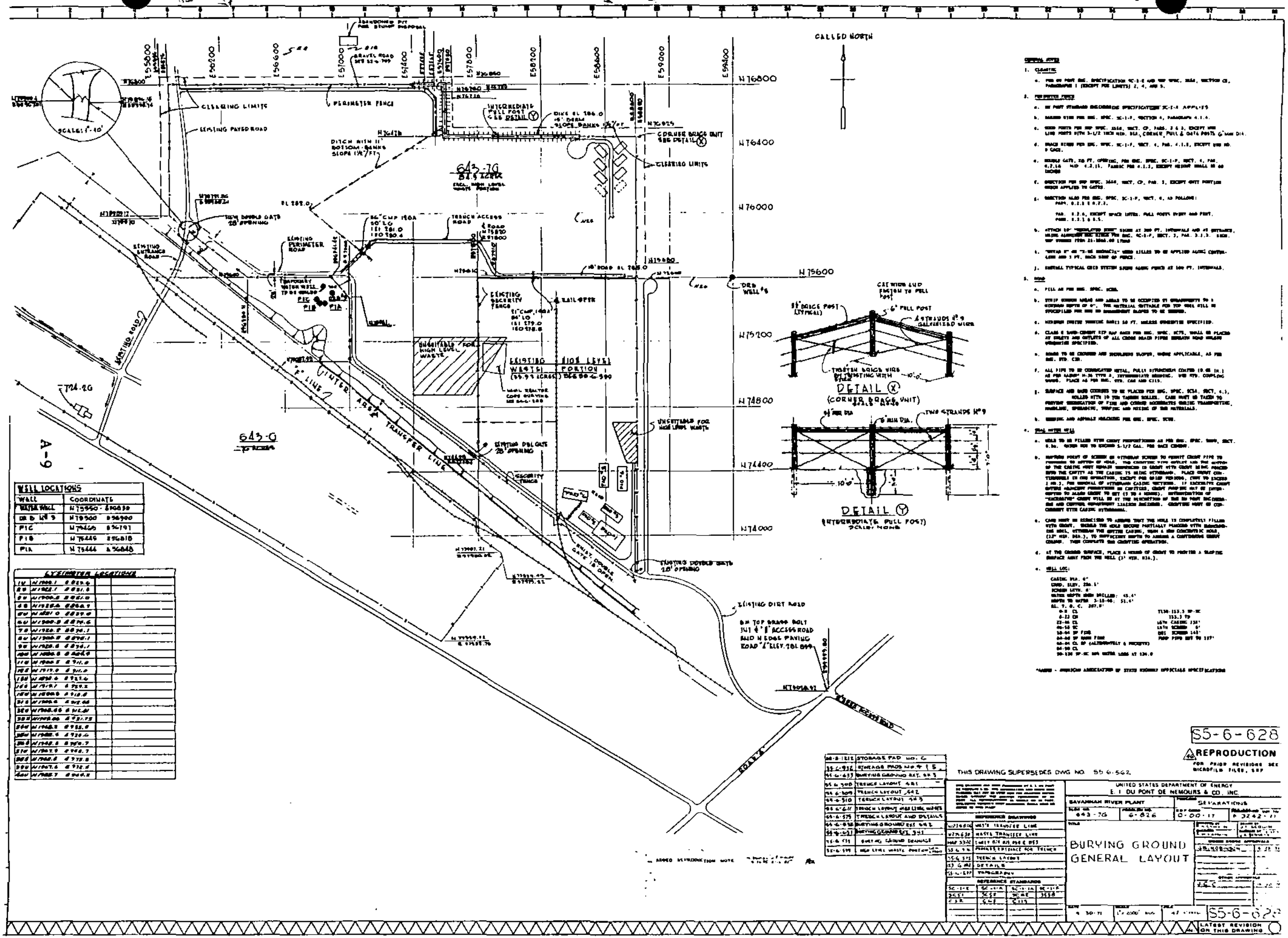
SAVANNAH RIVER PLANT

ADDITIONAL BURYING GROUND HIGH LEVEL WASTE PORTION TOPOGRAPHY AND GRADING PLAN

S5-6-601

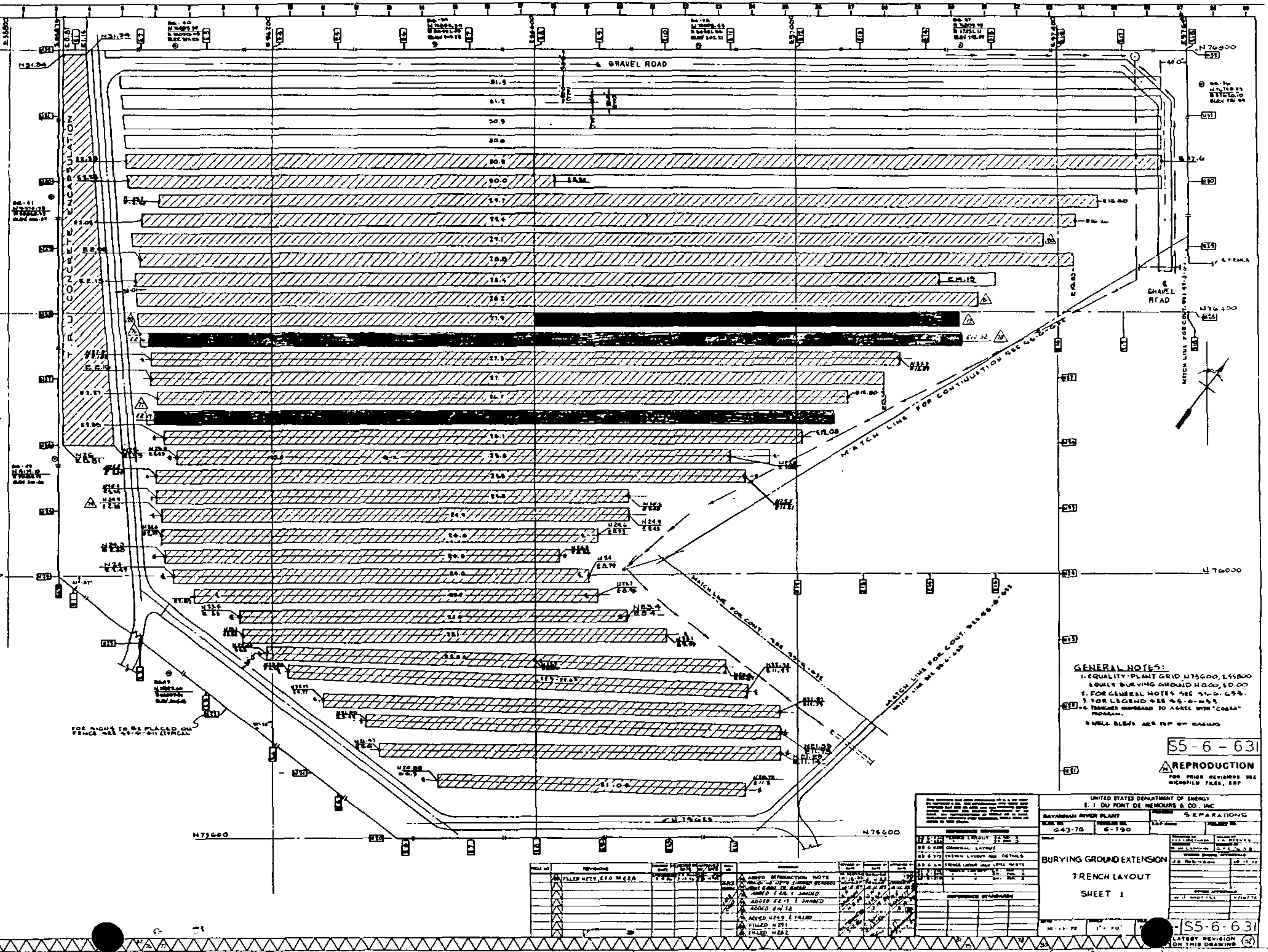

LEGEND:
SHADED TRENCHES IN OPERATION OR CLOSED.
NON-SHADED TRENCHES PROPOSED.
STORAGE PAD NO 4
STORAGE PAD NO. 5
STUDY WELLS
French Drain
Crane Walkway
SEE GRID CONTROL REFERENCE
CRUSHED STONE
CRUSHED ICE
CRANE WALKWAY
ENCAPSULATED ALPHA ABOVE GROUND STORAGE
E29
N15
TYPICAL SIGN
GRID CONTROL REFERENCE
GENERAL NOTES:
S5-6-611
REPRODUCTION
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC
SAVANNAH RIVER PLANT
ADDITIONAL SURVING GROUND HIGH LEVEL WASTE PORTION
TRENCH LAYOUT
S5-6-611
LATEST REVISION ON THIS DRAWING

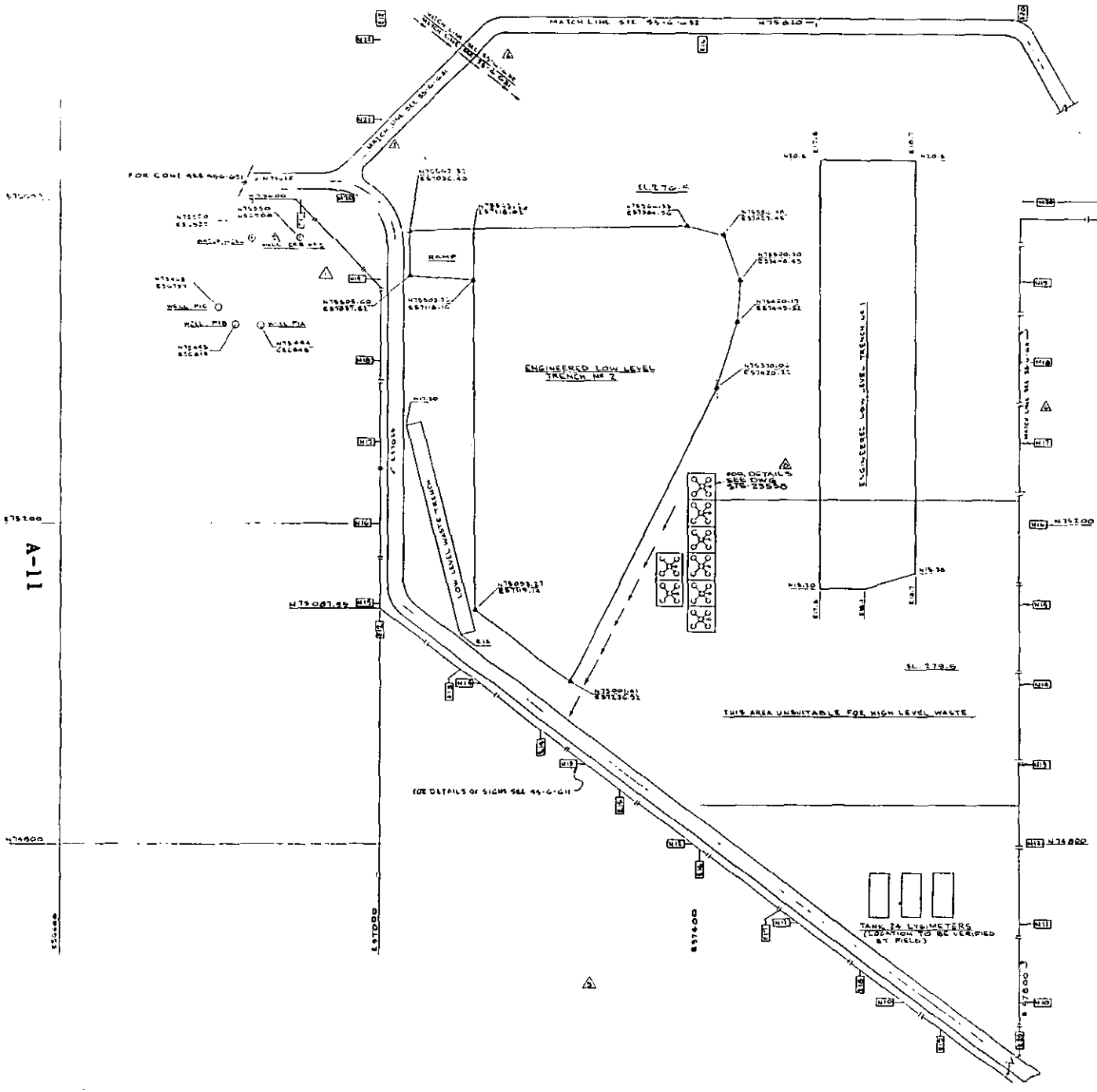
A-8



CALLED NORTH
CLEARING LIMITS
PERIMETER FENCE
EXISTING PAVED ROAD
SCALE: 1"=10'
643-7G
643-G
EXISTING HIGH LEVEL WASTE PORTION
UNSUITABLE FOR HIGH LEVEL WASTE
INTER AREA TRANSFER LINE
EXISTING SECURITY FENCE
EXISTING PERIMETER ROAD
TRENCH ACCESS ROAD
EXISTING DIRT ROAD
EXISTING ROAD
NEW DOUBLE GATE 28' OPENING
EXISTING DOUBLE GATE 20' OPENING
DETAIL X (CORNER BRACE UNIT)
DETAIL Y (INTERMEDIATE PULL POST)
WELL LOCATIONS
WELL | COORDINATE
WATER WELL | N 75950 - E56030
DR B WELL 9 | N 75500 E 56900
P1C | N 75465 E 56797
P1B | N 75445 E 56818
P1A | N 75444 E 56848
LYSIMETER LOCATIONS
THIS DRAWING SUPERSEDES DWG NO. S5-6-562
S5-6-628
REPRODUCTION
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO. INC.
SAVANNAH RIVER PLANT
SEPARATIONS
643-7G
BURYING GROUND GENERAL LAYOUT
REFERENCE DRAWINGS
REFERENCE STANDARDS
LATEST REVISION ON THIS DRAWING

A-9


GRAVEL ROAD
GRAVEL ROAD
CONCRETE ENCAPSULATION
MATCH LINE FOR CONTINUATION SEE S5-6-632
MATCH LINE FOR CONT. SEE S5-6-632
MATCH LINE FOR CONT. SEE S5-6-633
N76800
N76400
N76000
N75600
GENERAL NOTES:
1. EQUALITY - PLANT GRID N75600, E55800 EQUALS BURYING GROUND N0.00, E0.00
2. FOR GENERAL NOTES SEE S5-6-653.
3. FOR LEGEND SEE S5-6-653
FOR SIGNS TO BE PLACED ON FENCE SEE S5-6-611 (TYPICAL)
S5-6-631
REPRODUCTION
FOR PRIOR REVISIONS SEE MICROFILM FILES, SRP
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.
SAVANNAH RIVER PLANT
SEPARATIONS
643-7G
6-790
BURYING GROUND EXTENSION
TRENCH LAYOUT
SHEET 1
GENERAL LAYOUT
TRENCH LAYOUT AND DETAILS
REFERENCE DRAWINGS
REFERENCE STANDARDS
REVISIONS
ADDED REPRODUCTION NOTE
ADDED E 14.1 SHADED
ADDED E 21.3 SHADED
ADDED E N 32
ADDED N 24.9 E FILLED
FILLED N 29.1
FILLED N 28.2
FILLED N 27.9, E 8.0 N 28.6
LATEST REVISION ON THIS DRAWING
S5-6-631



GENERAL NOTES:

1. EQUALITY - PLANT GRID N73600, E55800 EQUALS BURYING GROUND N0.000, E0.000.
2. FOR GRID CONTROL REFERENCE SIGNS SEE S5-6-G-11
3. FOR COORDINATE MARKERS SEE DETAIL 1 S5-6-G-75

S5-6-633

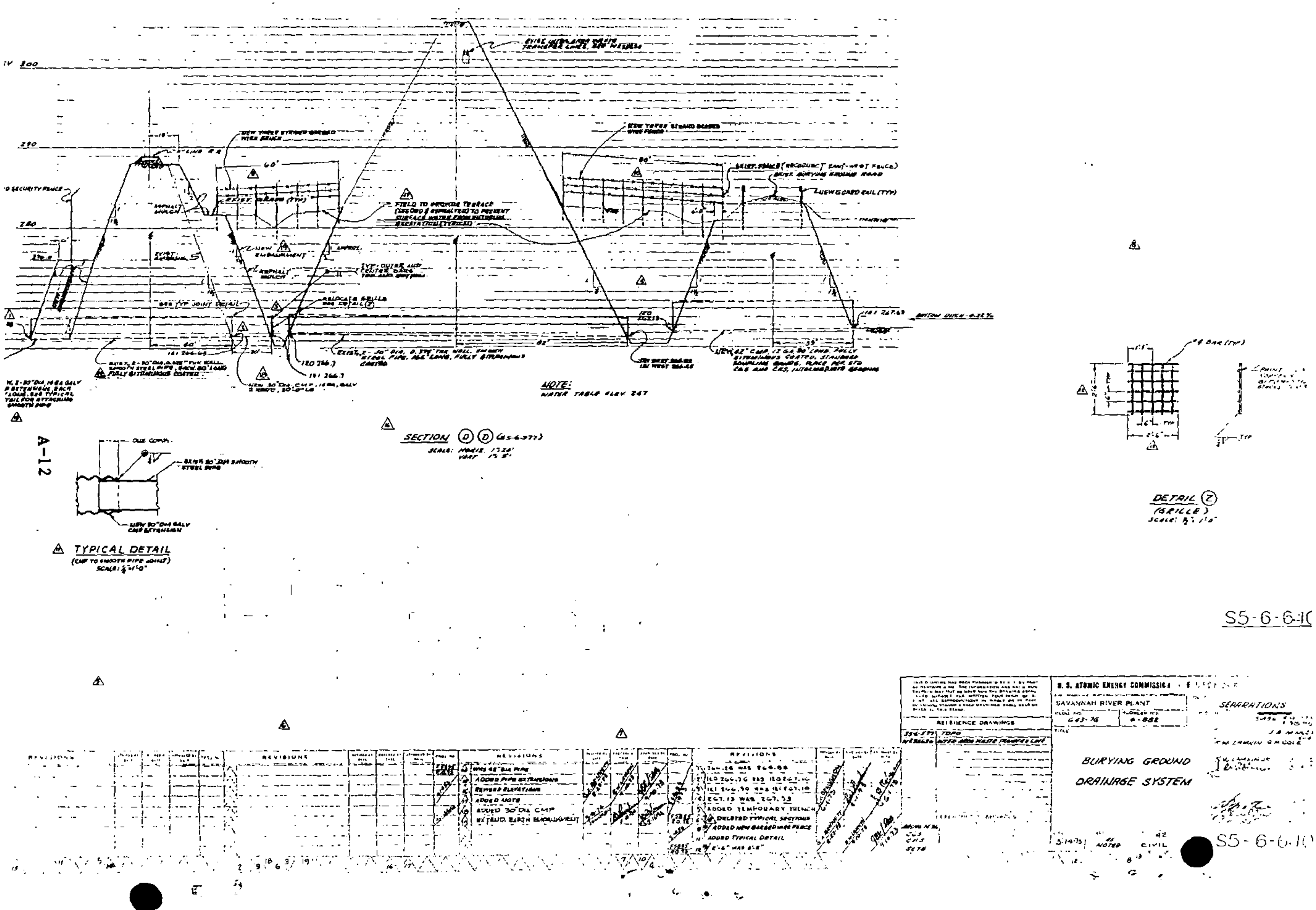
SEPARATION

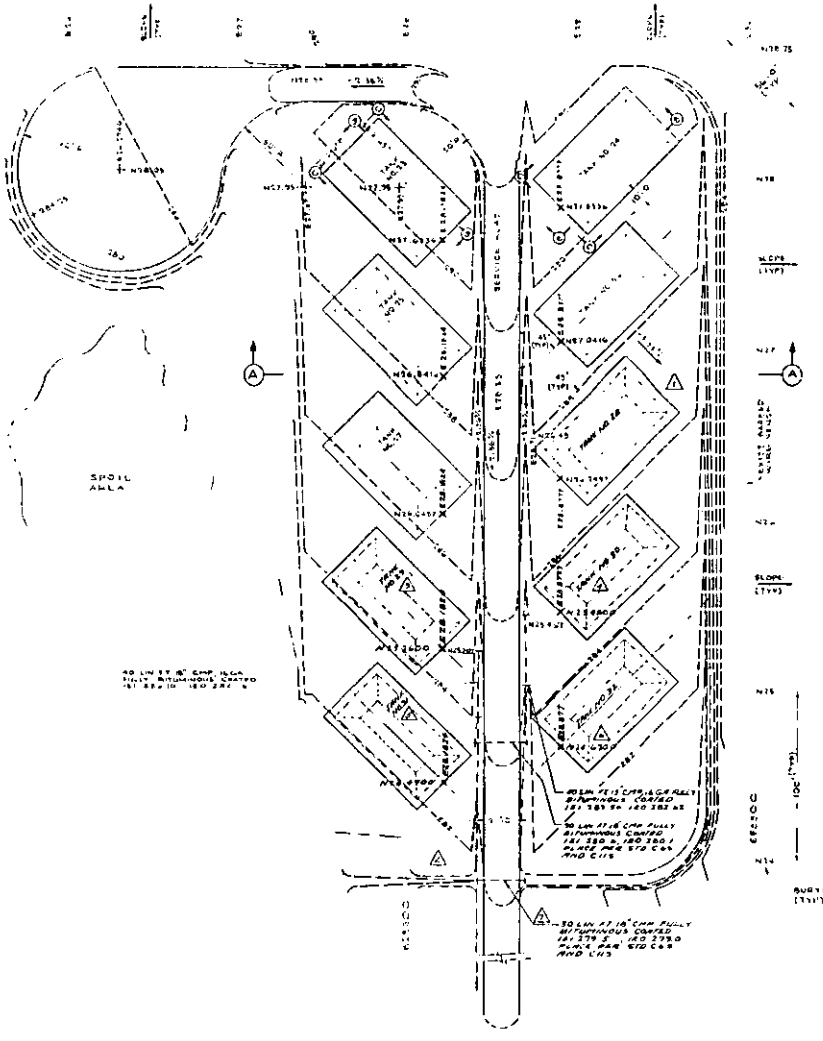
BURYING GROUND EXTENSION

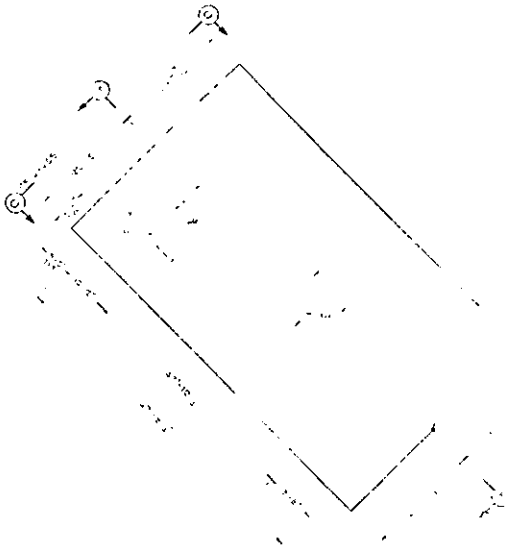
TRENCH LAYOUT

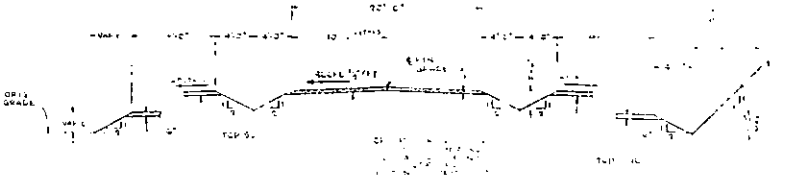
SHEET 5

S5-6-633


SECTION D D (S5-6-577)
NOTE:
WATER TABLE ELEV 247
TYPICAL DETAIL
(CMP TO SMOOTH PIPE JOINT)
DETAIL Z
(GRILLE)
S5-6-6-10
U. S. ATOMIC ENERGY COMMISSION
SAVANNAH RIVER PLANT
643-7G
REFERENCE DRAWINGS
REVISIONS
BURYING GROUND
DRAINAGE SYSTEM
SEPARATIONS
CIVIL
S5-6-6-10

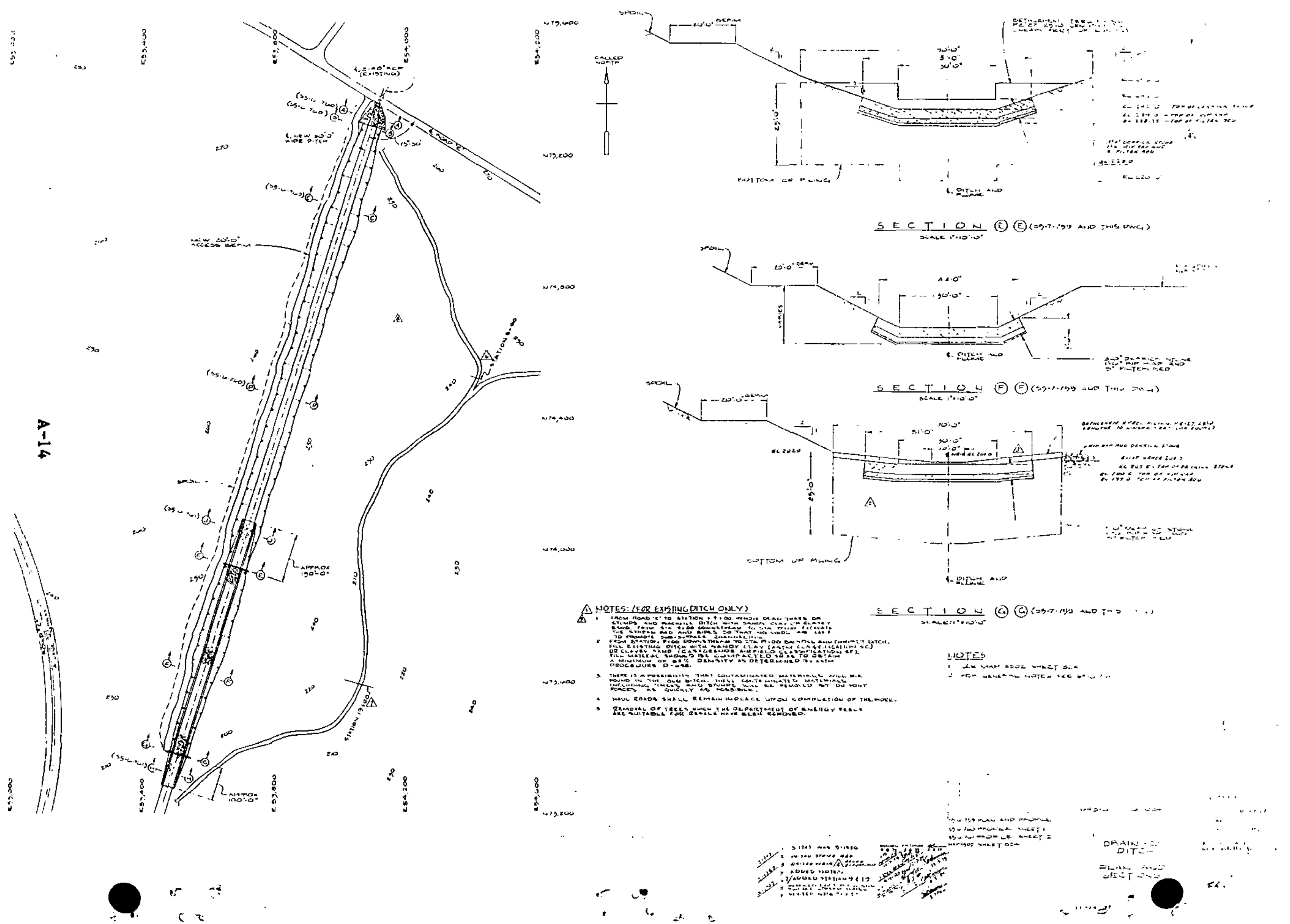


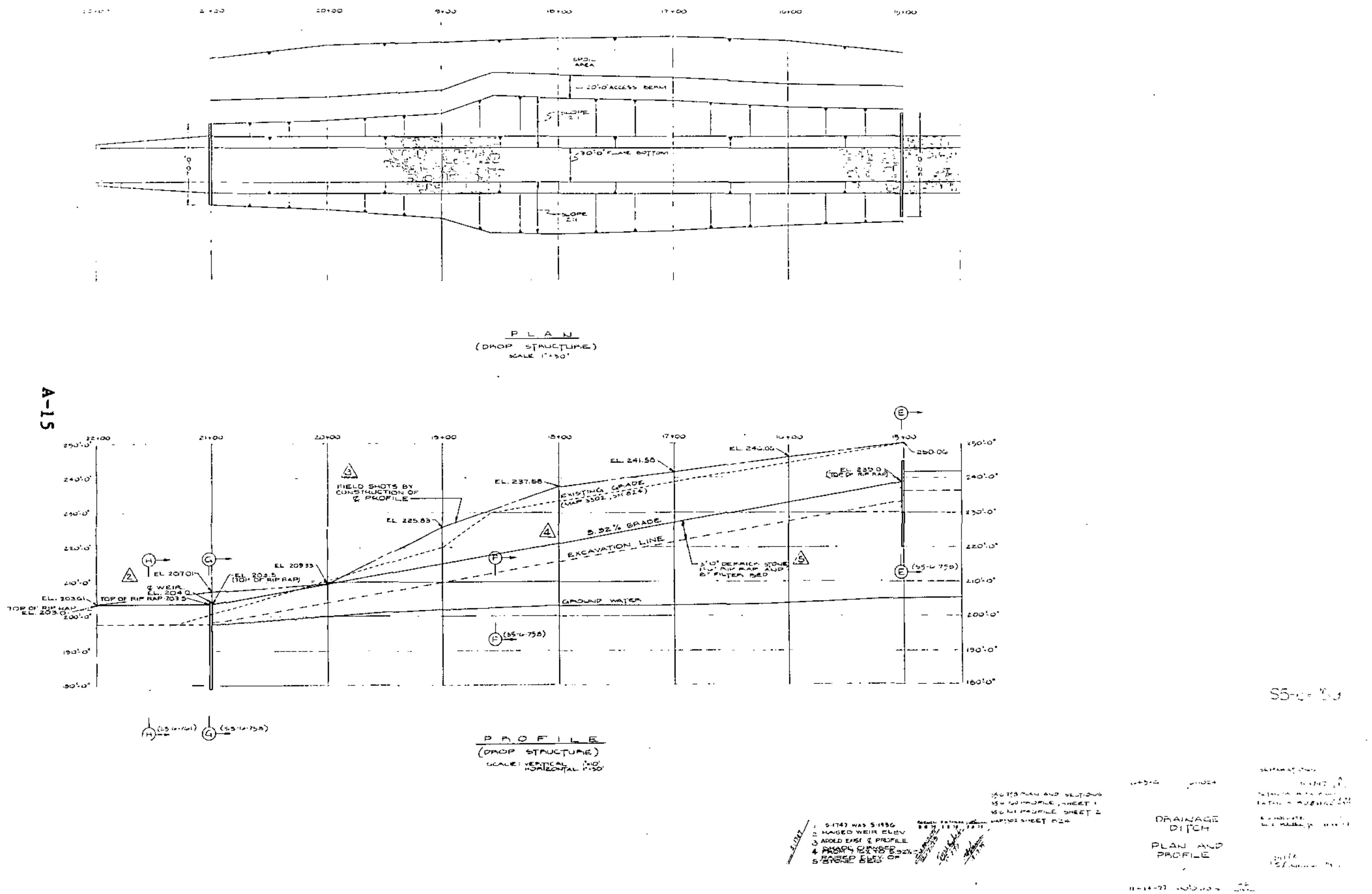


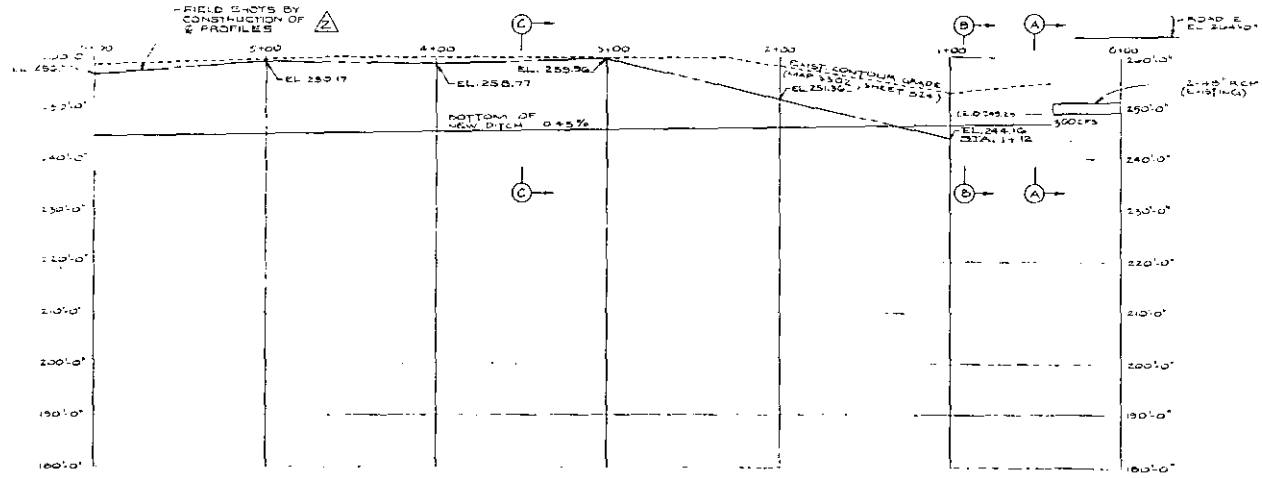


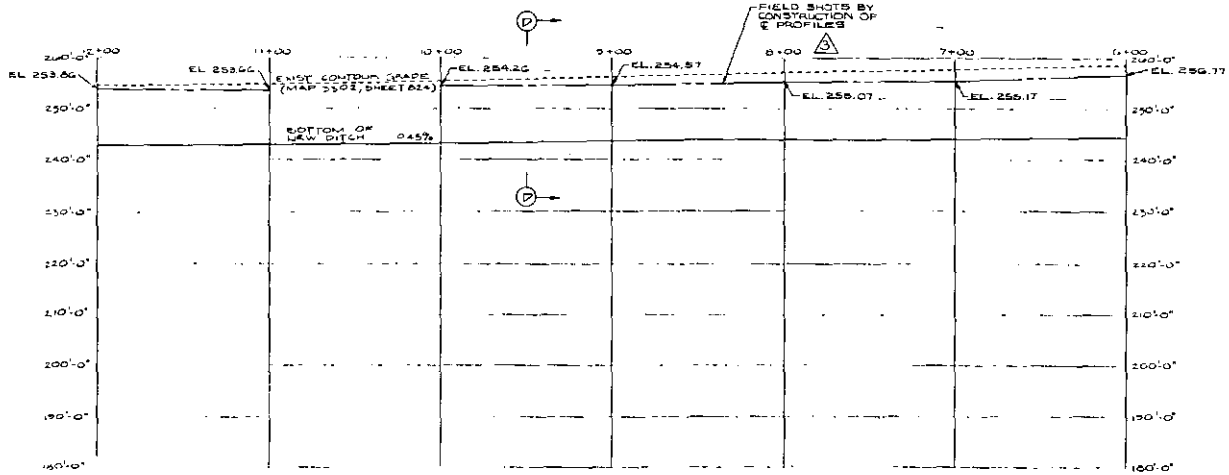
A-13

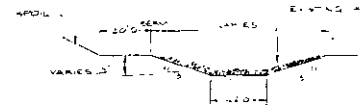
S5-6-65.1


CALLED NORTH
NEW 20'-0" ACCESS BERM
SPOIL
APPROX 150'-0"
APPROX 100'-0"
SECTION E (55-7-159 AND THIS DWG)
SECTION F (55-7-159 AND THIS DWG)
SECTION G
BOTTOM OF PILING
NOTES: (FOR EXISTING DITCH ONLY)
4. HAUL ROADS SHALL REMAIN IN PLACE UPON COMPLETION OF THE WORK.
5. REMOVAL OF TREES WHICH THE DEPARTMENT OF ENERGY FEELS ARE SUITABLE FOR RESALE HAVE BEEN REMOVED.
NOTES
DRAINAGE DITCH
PLAN AND SECTIONS

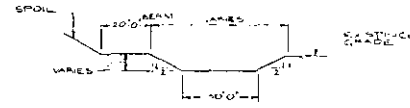

PLAN
(DROP STRUCTURE)
SCALE 1"=30'
SPOIL AREA
20'0" ACCESS BERM
SLOPE 2:1
30'0" FLUME BOTTOM
PROFILE
(DROP STRUCTURE)
SCALE: VERTICAL 1"=10' HORIZONTAL 1"=30'
EL. 241.50
EL. 240.06
250.06
EL. 237.66
EL. 235.0 (TOP OF RIP RAP)
EXISTING GRADE (MAP 3302, SH 624)
5.32% GRADE
EXCAVATION LINE
GROUND WATER
FIELD SHOTS BY CONSTRUCTION OF & PROFILE
EL. 225.83
EL. 209.33
EL. 207.01
EL. 204.5 (TOP OF RIP RAP)
℄ WEIR EL. 204.0
TOP OF RIP RAP 203.5
EL. 203.61
TOP OF RIP RAP EL. 203.0
3'0" DERRICK STONE, 1'0" RIP RAP AND 6" FILTER BED
DRAINAGE DITCH
PLAN AND PROFILE
1 S-1747 WAS S-1936
2 RAISED WEIR ELEV
3 ADDED EXIST. & PROFILE
4 GRADE CHANGED FROM 4% TO 5.32%
5 RAISED ELEV. OF STONE BED



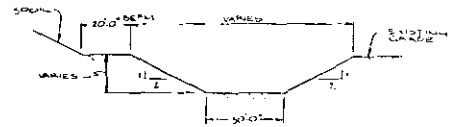




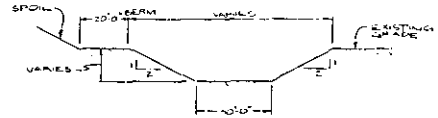
SECTION (A) (A) (55-6-753 AND THIS PAPER)
SCALE: 1"=20'-0"



SECTION (B) (B) (55-6-753 AND THIS PAPER)
SCALE: 1"=20'-0"



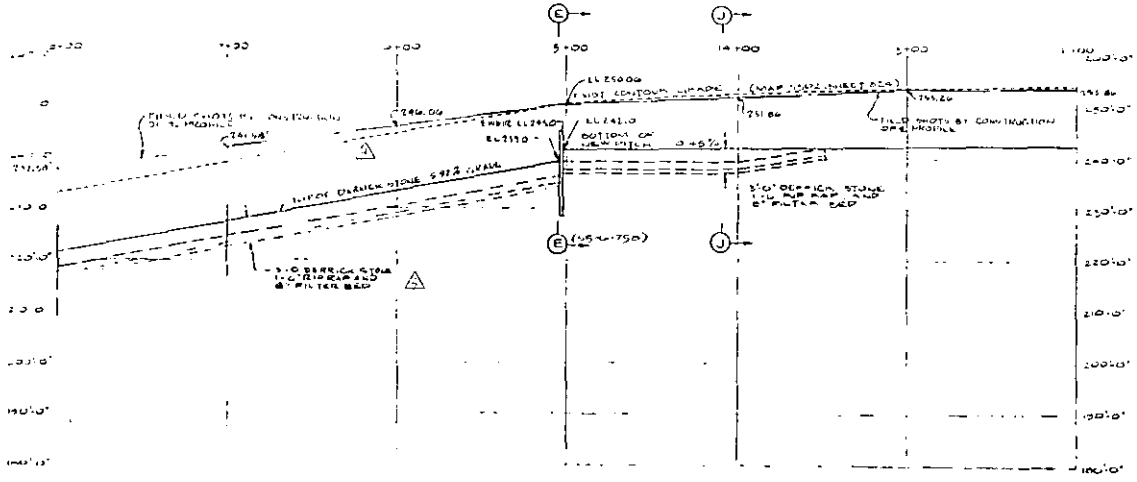
SECTION (C) (C) (55-6-753 AND THIS PAPER)
SCALE: 1"=20'-0"

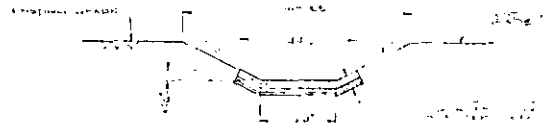


SECTION (D) (D) (55-6-753 AND THIS PAPER)
SCALE: 1"=20'-0"

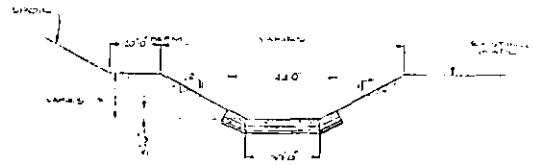
55-6-760

A-16

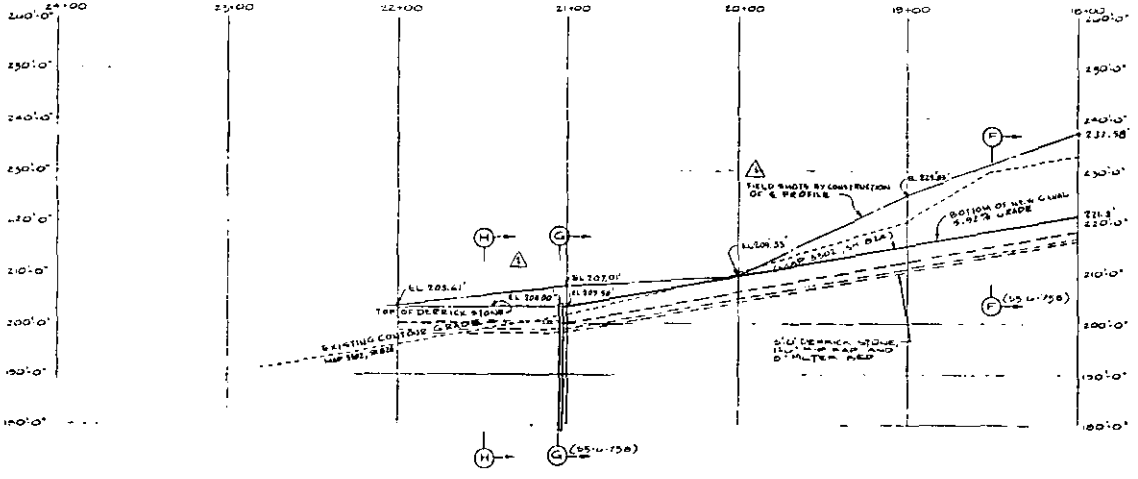




SECTION ⑪ ⑪

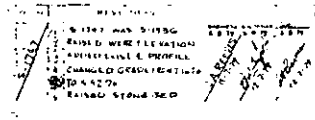


SECTION ⑨ ⑨



GENERAL NOTES:

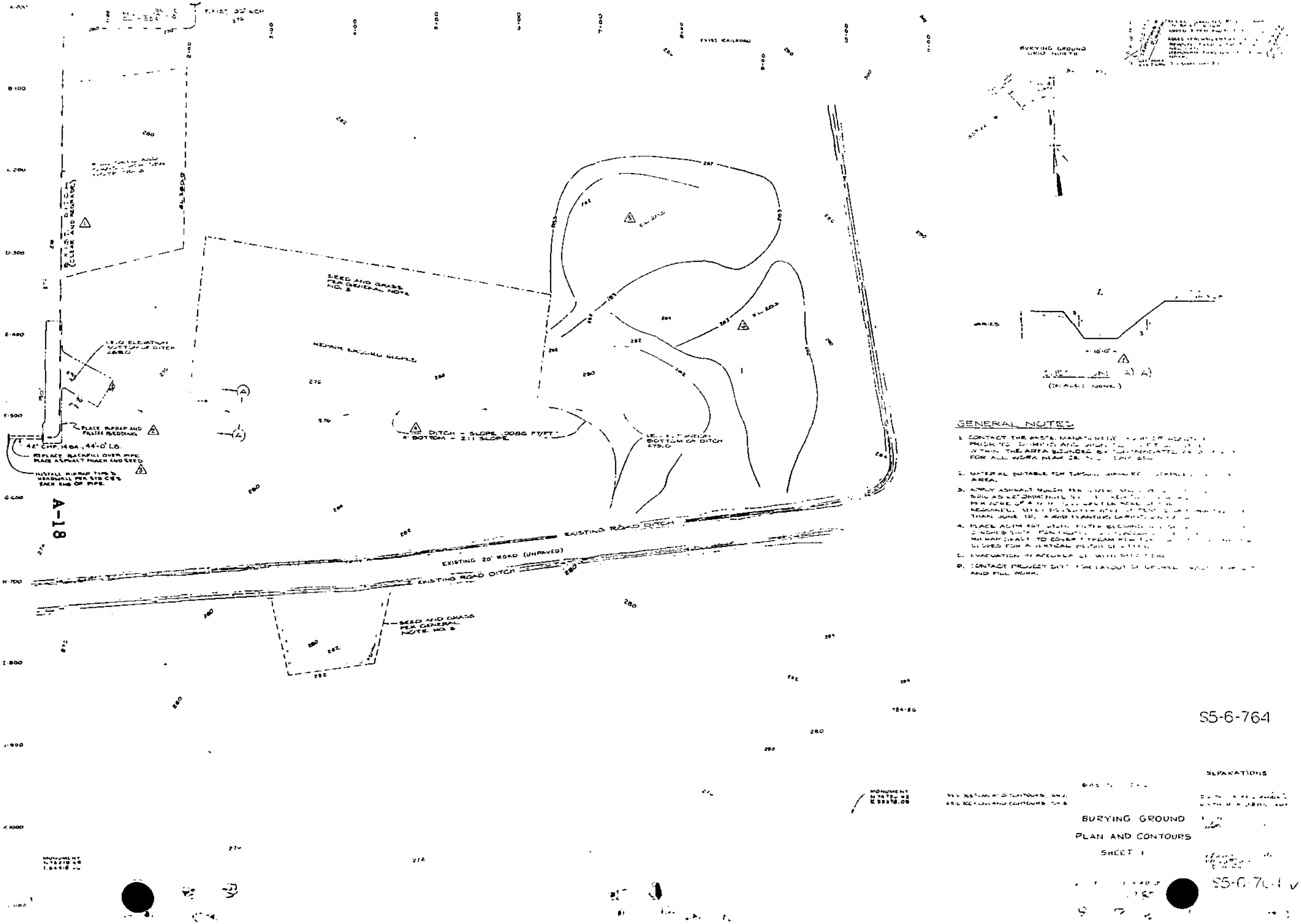
1. EXCAVATION PER ENGINEERING STD SCALE
2. CLEARING AND GRUBBING PER ENGINEERING STD SCALE
3. FILL STANDARD CONSTRUCTION PER ENGINEERING STD SCALE
4. RIP RAP PER ENGINEERING STD SIZE
5. SEEDING PER ENGINEERING STD SCALE
6. SPOIL TO BE SMOOTHED TO FORM GENTLE CONTOUR.

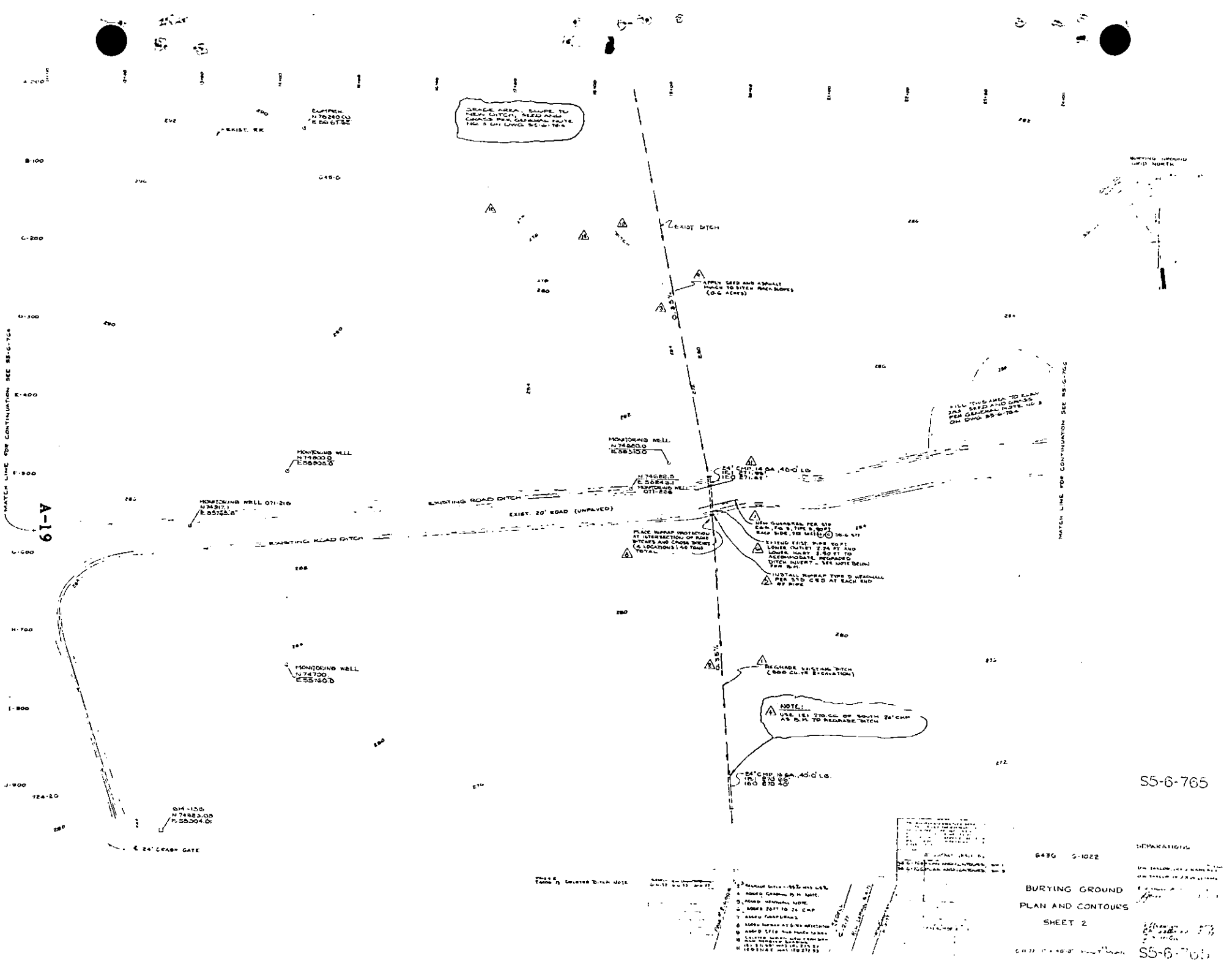


DRAINAGE DITCH PROFILE SHEET 2

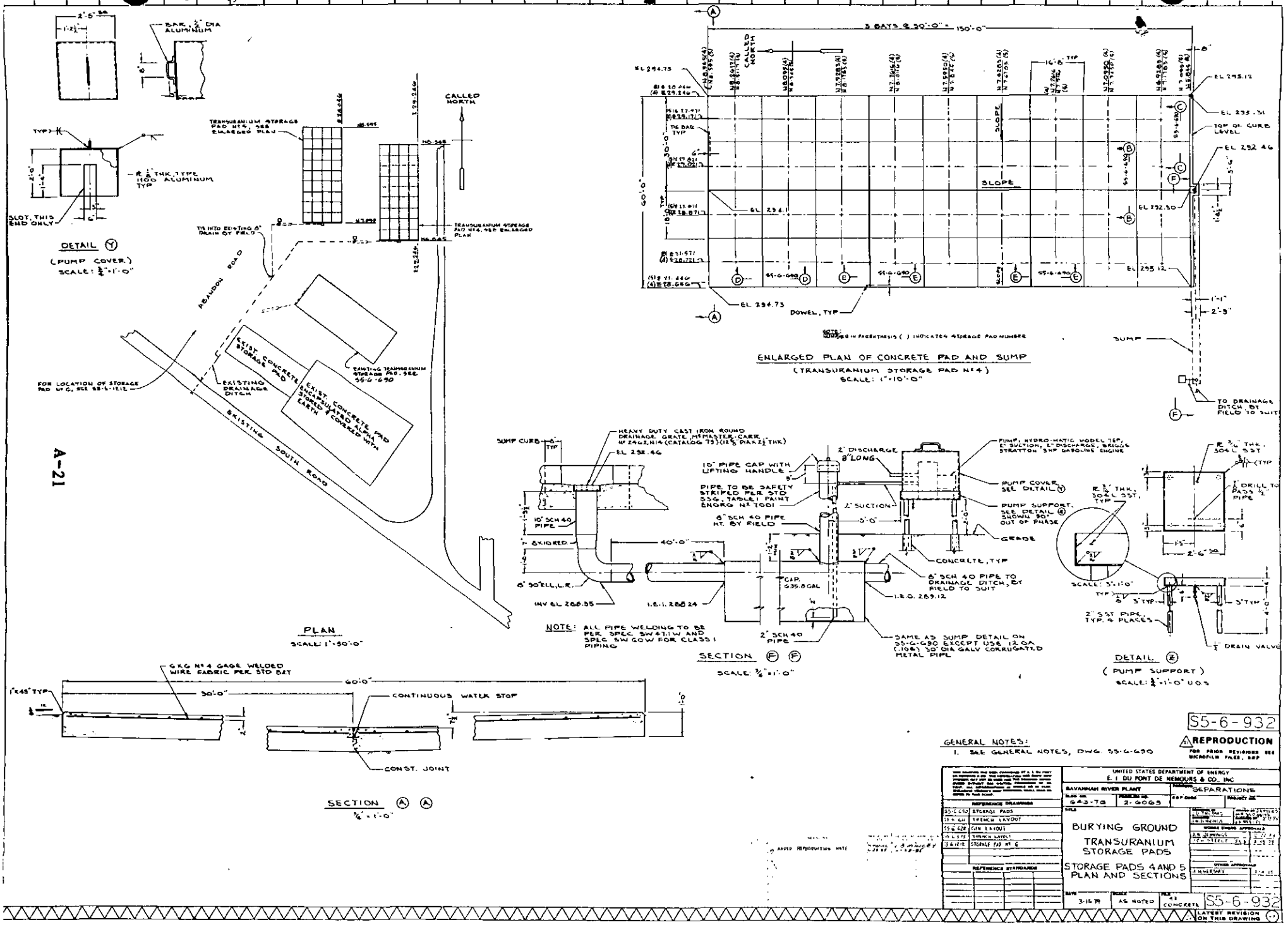
S5-0-701

A-17


BURYING GROUND
PLAN AND CONTOURS
SHEET 1
S5-6-764
SEPARATIONS
A-18
EXIST. RAILROAD
BURYING GROUND GRID NORTH
EXISTING ROAD DITCH
EXISTING 20' ROAD (UNPAVED)
EXISTING ROAD DITCH
SEED AND GRASS PER GENERAL NOTE NO. 3
REPAIR EROSION DAMAGE
DITCH - SLOPE .0086 FT/FT. 4' BOTTOM - 2:1 SLOPE
BOTTOM OF DITCH 275.0
PLACE RIPRAP AND FILTER BEDDING
42" CMP, 14GA., 44'-0" LG.
REPLACE BACKFILL OVER PIPE PLACE ASPHALT MULCH AND SEED
INSTALL RIPRAP TYPE D. HEADWALL PER STD C-E'S EACH END OF PIPE.
EXIST. DITCH (CLEAR AND REGRADE)
SEED AND GRASS PER GENERAL NOTE NO. 3
(SCALE: NONE)
GENERAL NOTES
MONUMENT N 74732.42 E 53278.08
MONUMENT
282
280
276
272


EXIST. RR
EXIST DITCH
EXISTING ROAD DITCH
EXIST. 20' ROAD (UNPAVED)
MONITORING WELL
MONITORING WELL 071-216
MONITORING WELL 071-226
MONITORING WELL
MONITORING WELL
24" CMP
24" CMP
24' CRASH GATE
A-19
MATCH LINE FOR CONTINUATION SEE S5-6-764
MATCH LINE FOR CONTINUATION SEE S5-6-766
NOTE:
BURYING GROUND
PLAN AND CONTOURS
SHEET 2
S5-6-765

EXISTING RAILROAD
CONCRETE PLATFORM
EXISTING 20' ROAD (UNPAVED)
EXISTING ROAD DITCH
EXISTING ROAD DITCH
DITCH - 1.00%
SEED AND GRASS GRADE PER GENERAL NOTE #3 ON DWG 55 C-1024
DITCH BOTTOM @ SLOPE 0.020 FT/FT SIDE SLOPE 3:1, SEE GENERAL NOTE #4 FOR RIPRAP ON DWG 55 C-1024
A-20
S5-6-766
BURYING GROUND PLAN AND CONTOURS
SHEET 2
S5-6-766



S5-6-932

GENERAL NOTES:

1. SEE GENERAL NOTES, DWG. 55-6-690

REPRODUCTION

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC
SAVANNAH RIVER PLANT
SEPARATIONS
E.D.W. NO. 643-78
PROJECT NO. 2-6065

REFERENCE DRAWINGS

55-6-690	STORAGE PADS
55-6-691	TRENCH LAYOUT
55-6-628	GEN. LAYOUT
55-6-695	TRENCH LAYOUT
55-6-1212	STORAGE PAD NO 6

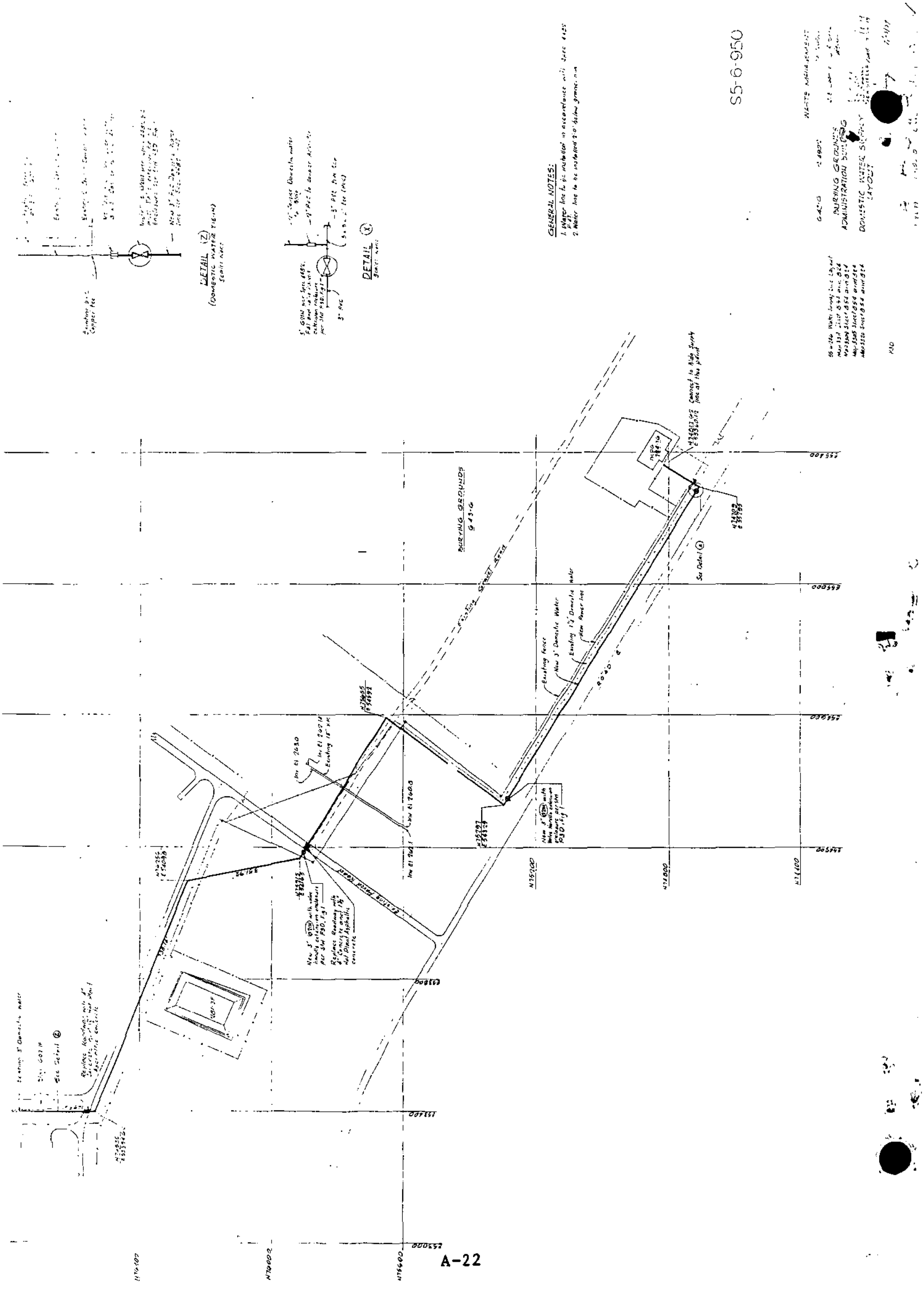
REFERENCE STANDARDS

TITLE
BURYING GROUND
TRANSURANIUM
STORAGE PADS
STORAGE PADS 4 AND 5
PLAN AND SECTIONS

DRAWN 3-15-79
SCALE AS NOTED
FILE NO 43 CONCRETE

S5-6-932

LATEST REVISION ON THIS DRAWING


S5-6-950
GENERAL NOTES:
DETAIL (Z)
DETAIL (X)
BURYING GROUNDS
643-G
Existing Gravel Road
Existing Fence
Road "C"
N74000
N75200
N75800
N76400