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Remedial Investigation Report on Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

Volume 3
Appendix B: Technical Findings and Conclusions

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PREFACE

This Remedial Investigation Report on Waste Area Grouping (WAG) 5 at Oak Ridge National Laboratory (DOE/OR/01-1326&D2/V1, DOE/OR/01-1326&D2/V2, DOE/OR/01-1326&D2/V3, and DOE/OR/01-1326&D2/V4) was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for reporting the results of a site characterization for public review. This work was performed under Work Breakdown Structure 1.4.12.6.1.05.40.02 (Activity Data Sheet 3305, "WAG 5"). Publication of this document meets a Federal Facility Agreement milestone of March 31, 1995. This document provides the Environmental Restoration Program with information about the results of investigations performed at WAG 5. It includes information on risk assessments that have evaluated long-term impacts to human health and the environment. Information provided in this document forms the basis for decisions regarding the need for subsequent remediation work at WAG 5.

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ACRONYMS

AEC	Atomic Energy Commission
ASEMP	Active Sites Environmental Monitoring Program
ASL	analytical support laboratory
ATDL	Atmospheric Turbulence and Diffusion Laboratory
BMAP	Biological Monitoring and Abatement Program
CEC	cation exchange capacity
CH	contact-handled
CSL	Close Support Laboratory
D&D	decontamination and decommissioning
DOE	Department of Energy
EP	extraction procedure
EPA	Environmental Protection Agency
ESD	Environmental Sciences Division
ESP	ORNL Environmental Surveillance Program (or procedure)
FSP	field sampling plan
GWOU	groundwater operable unit
HELP	Hydrologic Evaluation of Landfill Performance
HSPF	Hydrological Simulation Program—FORTRAN
IDW	investigation-derived waste
ILW	intermediate-level waste
LLW	low-level waste
MCL	maximum contaminant level
MUSLE	Modified Universal Soil Loss Equation
NHF	New Hydrofracture Facility
NPDES	National Pollutant Discharge Elimination System
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
ORNL/ER-DMG	Environmental Restoration-Data Management Group
ORR	Oak Ridge Reservation
PVC	polyvinyl chloride
PWSB	Process Waste Sludge Basin
RAP	Remedial Action Program
RCRA	Resource Conservation and Recovery Act
RFA	RCRA facility assessment
RH	remote-handled
RI	remedial investigation
SC	special case
SDID	Shared Data Initiative Distribution
SDWA	Safe Drinking Water Act
SWIMS	solid waste information management system
SWMU	solid waste management unit
SWSA	solid waste storage area
TAL	Target Analyte List
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids

ACRONYMS (continued)

TOC	total organic carbon
TRU	transuranic
TVA	Tennessee Valley Authority
USRADS	ultrasonic ranging and data system
VCP	vitrified clay pipe
VOC	volatile organic compound
WAG	waste area grouping
WIPP	Waste Isolation Pilot Plant

B1. ENVIRONMENTAL SETTING

Sections B1.1 through B1.4 present an overview of the environmental setting of Waste Area Grouping (WAG) 5, including location, population, land uses, ecology, and climate, and Sects. B1.5 through B1.7 give site-specific details (e.g., topography, soils, geology, and hydrology). The remedial investigation (RI) of WAG 5 did not entail an exhaustive characterization of all physical attributes of the site; the information presented here focuses on those most relevant to the development and verification of the WAG 5 conceptual model. Most of the information presented in this appendix was derived from the RI field investigation, which was designed to complement the existing data base from earlier, site-specific studies of Solid Waste Storage Area (SWSA) 5 and related areas.

B1.1 SITE LOCATION AND DESCRIPTION

WAG 5 is part of Oak Ridge National Laboratory (ORNL), located on the Department of Energy's (DOE) Oak Ridge Reservation (ORR) in Roane and Anderson Counties (Fig. B1.1.1). The site lies southeast of Haw Ridge in Melton Valley, a prominent northeast-southwest-trending valley typical of landforms in the Valley and Ridge Physiographic Province. The ridge tops on either side of Melton Valley range in elevation between 1040 (Haw Ridge) and 1350 ft above mean sea level (msl) (Copper Ridge). A line of lower hills with crest elevations of approximately 850 ft msl occurs near the center of Melton Valley; WAG 5 is within this hilly area.

WAG 5 comprises approximately 80 acres, about 30 acres of woods and the balance in grassed fields (Fig. B1.1.2). Ground surface elevations range from a low of 756 ft along White Oak Creek and Melton Branch to a topographic high of 865 ft in the northeast corner of SWSA 5 South. Topographic slopes are variable and range from relatively flat to 80%. Average slopes for the grassed fields and wooded hillsides are about 10 and 20%, respectively.

The western and southern boundaries of WAG 5 are contiguous with the WAG 2 area that includes White Oak Creek and Melton Branch and associated floodplains. (The administrative boundary between WAG 5 and WAG 2 was drawn at the eastern and northern edges of the White Oak Creek and Melton Branch floodplains, respectively.) Two principal drainages (D-1 and D-2) transport surface water from WAG 5; each is associated with a forested drainage swale (or valley) that extends from the WAG interior to White Oak Creek (D-1) or Melton Branch (D-2). Elevations within the stream channels are typically 1 to 4 ft below the surrounding topography. Drainage D-3 is a small side tributary along the eastern WAG boundary that discharges into a larger tributary of Melton Branch. (Note: Although D-3 is outside the WAG 5 administrative boundary, it drains a portion of the site and was therefore included in the scope of the RI.) Immediately downstream of the site, Melton Branch flows into White Oak Creek, which discharges at the ORR boundary into the Clinch River (a tributary to the Tennessee River).

Comparison of historical (preoperational) maps and photographs with recent ones reveals that burial ground operations and other activities at the site have not significantly altered the overall drainage patterns or slope configuration. Small-scale modifications have been made, however,

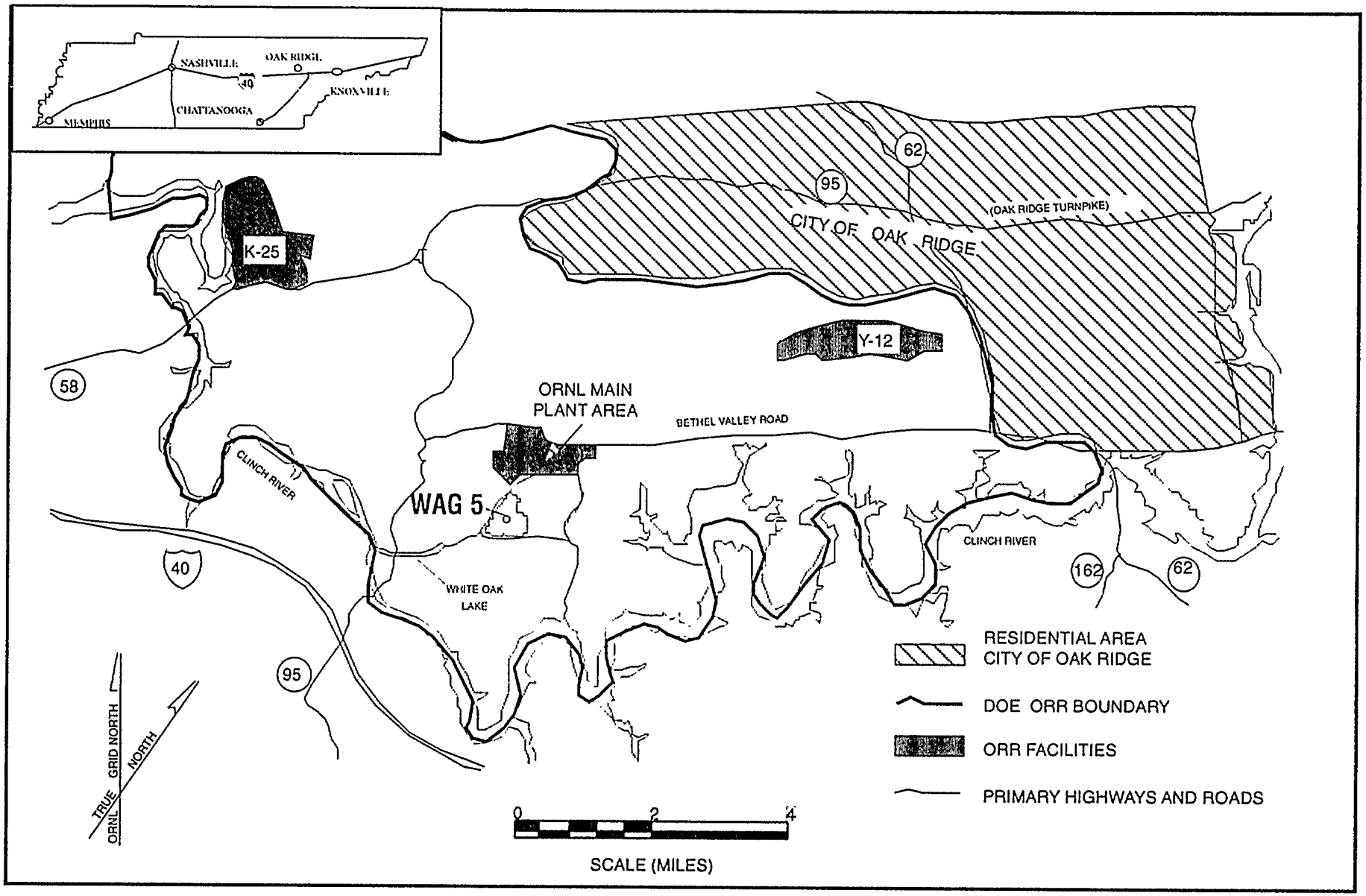

Fig. B1.1.1. DOE Oak Ridge Reservation.

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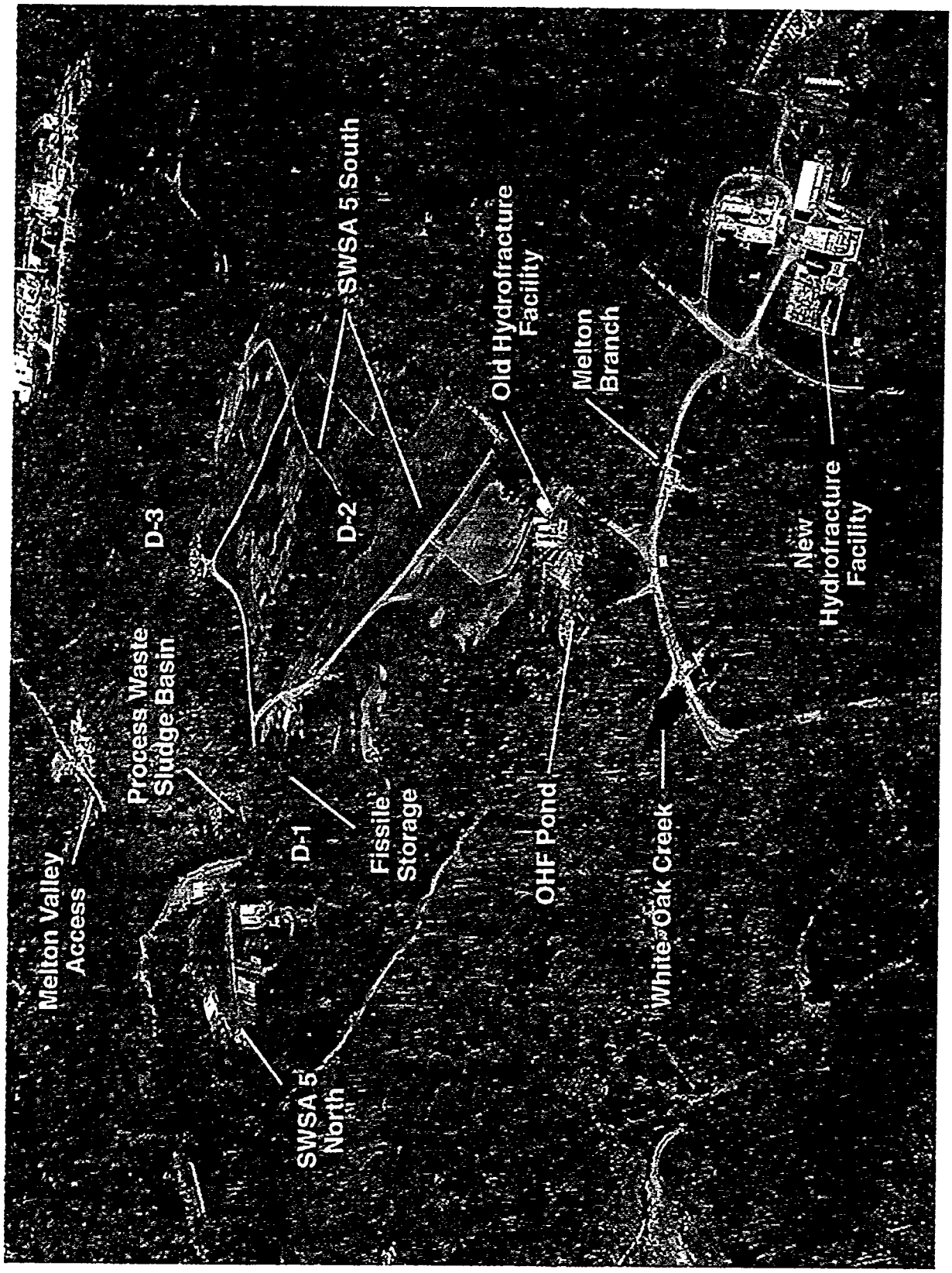

Fig. B1.1.2. WAG 5 surface features (1988).

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primarily to minimize rainfall infiltration into trenches (Duguid et al. 1977). These post-burial modifications to the SWSA 5 land surface have included

- surface contouring,
- filling of depressions caused by subsidence of trench wastes and backfill materials, and
- installation of concrete surface water diversion ditches to intercept and channel surface water away from the trench areas (most were removed in 1993).

Man-made surface features (e.g., buildings, tanks, paved areas) at WAG 5 are concentrated in three areas: the Old Hydrofracture Facility (OHF), New Hydrofracture Facility (NHF), and the transuranic (TRU) waste storage area (SWSA 5 North). The site includes two small surface impoundments [OHF pond and the process waste sludge basin (PWSB)], a system of interconnecting paved and gravel roads with culverts at stream intersections, a perimeter boundary fence and electrified deer fence, numerous groundwater monitoring wells, and remnants of the concrete diversion ditches described above. Surface debris from past disposal activities is present in several areas, including the dump area, the landfill, and at the head of drainage D-2. A temporary waste storage pad with full and empty concrete casks is located in the northeast corner of SWSA 5 South. The rest of the site is covered by either trees or grassed fields; the latter are mowed during the growing season.

A decontamination facility and investigation-derived waste (IDW) consolidation and storage areas were constructed to support the RI field investigation. Other surface modifications to support data collection included

- construction of flumes for monitoring and sampling surface water from drainages D-1, D-2, and D-3;
- construction of 12-ft scaffolding to allow for water level monitoring and sampling of artesian wells 0461, 0462, and 0463 with extended casing; and
- completion of limited surface improvements to the riser casings of 27 existing wells.

An E-size drawing identifying WAG 5 surface features is included in the back of Volume 2 (Plate 1).

B1.2 NEARBY POPULATIONS AND LAND USE

Access to WAG 5 is limited through security measures such as fencing, gates, and posting. The area surrounding the ORR is predominantly rural with the exception of the City of Oak Ridge, which abuts the northern perimeter of the ORR. Census data from 1990 indicate that the population of Oak Ridge is 27,310. Small towns (population <10,000) in the vicinity of the ORR include Oliver Springs (7 miles northwest), Kingston (7 miles southwest), Harriman (8 miles west), and Clinton (10 miles northeast). The nearest metropolitan area, Knoxville, is 25 miles to the east; Knoxville's 1990 census data indicate a population of approximately 200,000. Local and regional population distributions are shown in Figs. B1.2.1 and B1.2.2.

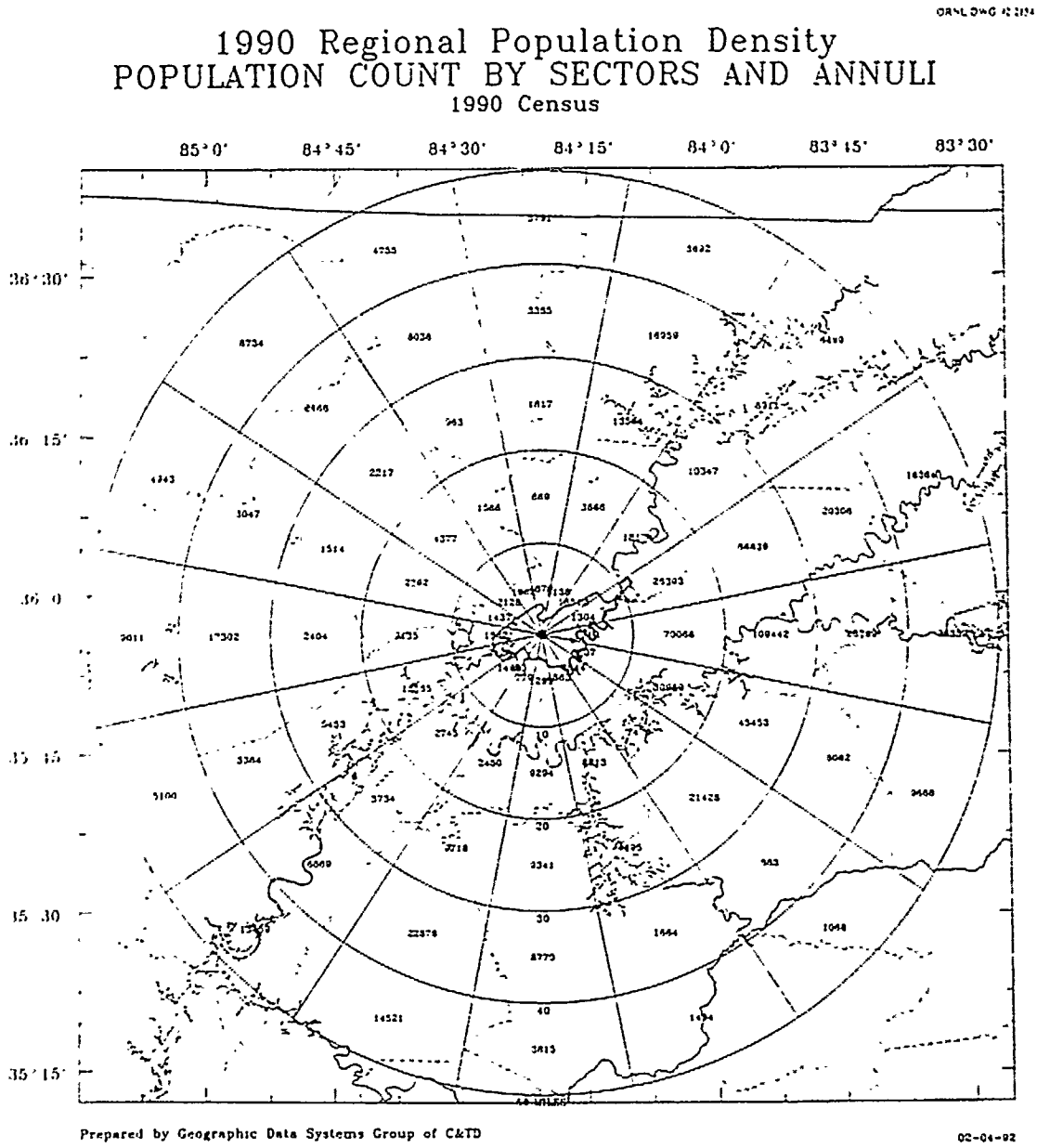

Fig. B1.2.1. 1990 regional population density.

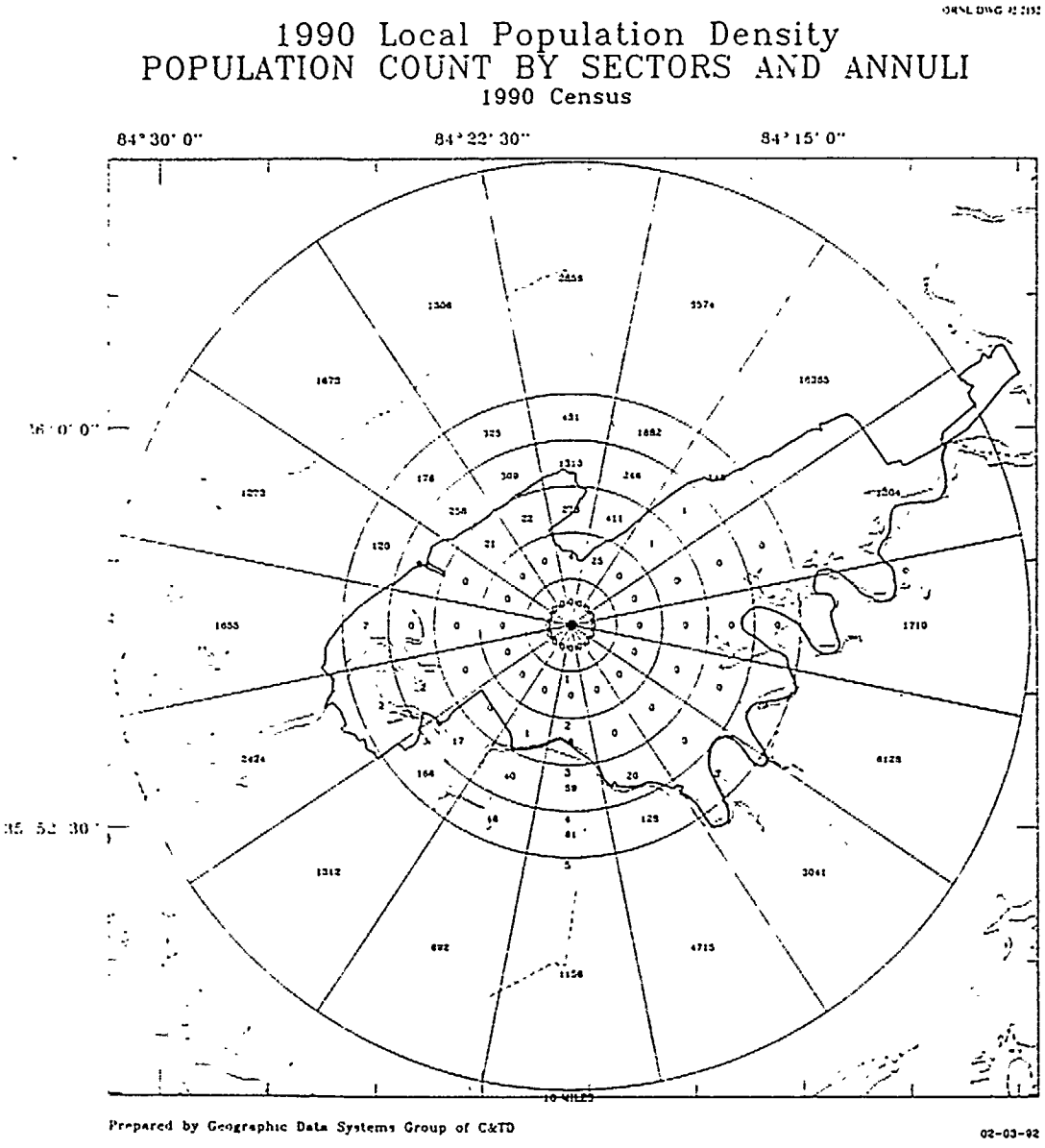

Fig. B1.2.2. 1990 local population density.

Given the predominance of surface water as the primary release, migration, and exposure pathway associated with WAG 5, the population most likely to be affected by offsite release of contaminants includes residents along (and recreational users of) the lower Clinch River and the Tennessee Valley Authority's (TVA) Watts Bar Reservoir in Roane, Rhea, and Meigs Counties. Both the Clinch River and Watts Bar (which impounds both the Clinch and Tennessee Rivers) are popular areas for water-based recreation, including fishing, swimming, water skiing, and waterfowl hunting. Sport fishing for game fish such as striped bass, largemouth bass, white bass, sauger, walleye, crappie, and catfish constitutes a major use of the reservoir and has a significant economic impact on the surrounding communities (marinas, bait shops, convenience stores, etc.). The population of the downstream areas fluctuates due to the seasonal variability in recreation and the numerous weekend/vacation homes along the reservoir.

Other potentially affected populations include those whose domestic (potable) water supplies are drawn from surface water downstream of WAG 5. Domestic water supply users in this category include the K-25 Site (part of the ORR), TVA's Kingston Steam Plant on the Clinch River, and the communities of Kingston, Rockwood, and Spring City, which obtain water supplies from Watts Bar. Farther downstream, Chattanooga and a number of smaller towns obtain water supplies from the Tennessee River.

B1.3 CLIMATE

The Oak Ridge area has a temperate climate with warm, humid summers and mild, cool winters. The climate is moderated by the Blue Ridge Mountains to the east and the Cumberland Plateau to the west, resulting in a milder climate than is normally associated with areas of similar latitude. The mountains and plateau also divert the more severe weather phenomena and, consequently, tornadoes and high-velocity wind storms are rare. The mean annual temperature for the Oak Ridge area is 58°F. Summer temperatures average 77°F and occasionally reach into the 100°F range; in winter, temperatures average 38°F and occasionally dip below 0°F (Webster and Bradley 1988). The average frost-free period is 196 days, from April 11 through October 24.

The 30-year mean annual precipitation for the Oak Ridge area is 54.2 in. Annual rainfall typically ranges from 51 to 55 in. and occasionally exceeds 70 in. Although precipitation is seasonally distributed throughout the year, the highest monthly accumulations occur during winter (December–March) and the lowest during late summer/early fall (September–October). Summer thunderstorms produce short-duration, high-intensity rains. Average annual snowfall, approximately 10 in., is not a significant contributor to precipitation. (Note: Site-specific precipitation data are presented in Sect. B1.5.)

Prevailing winds are controlled by the ridge and valley topography, which has a tendency to direct the winds up valley (northeast) during the day and down valley (southwest) at night. According to the Atmospheric Turbulence and Diffusion Laboratory (ATDL) in Oak Ridge, the average wind speed for the ORR is reported to be about 4.5 mph; a maximum of 59 mph was recorded in January 1959.

B1.4 GEOLOGY AND SOILS

The geology and soils of WAG 5 are key components of the site conceptual model and exert considerable influence over hydrologic processes, including those associated with the release, transport, and environmental fate of site-specific contamination. An understanding of the relevant geologic and soils characteristics is therefore a prerequisite for verifying this conceptual model, interpreting the current distribution of contamination, and developing viable predictions regarding future contaminant migration.

B1.4.1 Regional Geology

WAG 5 is situated in the Valley and Ridge Province, part of the Appalachian fold and thrust belt. Mountain-building processes during the Permian-Pennsylvanian period (approximately 250 million years ago) produced a succession of northeast-trending thrust faults that duplicate the Paleozoic-age sedimentary rock sequences, transposing older rocks above younger rocks in a shingled effect. Differential erosion resulted in a series of alternating valleys and ridges that parallel the surface traces of the thrust faults. Rocks resistant to weathering (sandstones and dolomite or chert units) generally form the ridges, and rocks that are more readily weathered (shales and shaley carbonates) typically underlie the valley floors. The geology is influenced by structural features at all scales, including regional and local thrust faults, normal and tear faults, local folding, and widespread fracture development.

B1.4.2 Bedrock Geology

The bedrock geology of WAG 5 controls the development of soil and saprolite in the overburden as well as the occurrence and hydraulic properties of the intermediate and deeper groundwater zones. Specific attributes of the geology to be discussed here include

- depth to rock and configuration of bedrock surface: information about soil/overburden thickness and the interface between regolith and rock, which influences the nature of shallow groundwater flow (e.g., through porous vs. fractured media) and groundwater circulation patterns;
- stratigraphy: a description of the vertical sequence and types of strata beneath the site, which influences weathering and saprolite and soil formation as well as fracture development and other hydraulic parameters affecting groundwater flow; and
- structural features: primarily fractures, which control groundwater movement (and contaminant transport) in the bedrock.

Geologic data were obtained from geophysical surveys, coring and logging of three 500-ft multizone wells, and previous investigations. The boundary between WAG 5 and the groundwater operable unit (GWOU) occurs at an elevation approximately equivalent to the base of local streams (maximum elevation 750 ft); the site-wide GWOU has primary responsibility for assessing the presence and movement of groundwater contamination (DOE 1994). The discussion of site geology focuses on the shallow subsurface, where impacts from WAG 5 contaminant sources are more significant. (Note: Sect. B1.6 discusses the GWOU and its relationship to WAG 5.) Information pertaining to deeper conditions is provided where necessary to support the discussion of shallow geology.

Depth to rock and configuration of bedrock surface

Existing well data were combined with the results of seismic refraction surveys to delineate the top of bedrock (Fig. B1.4.1); depth to competent (as opposed to weathered) bedrock at the site varies from a few feet to 40 ft. The bedrock surface generally reflects topography, and the highest elevations occur northeast of the undefined trench area (825 ft msl) and in the TRU waste storage area (805 ft msl). The bedrock surface varies locally due to variations in weathering related to changes in the composition, porosity, permeability, and structural attitude (i.e., dip) of the rock. The surface is most variable where thin, more resistant limestone beds occur as discontinuous lenses or where stratigraphy has been displaced significantly by local structural alterations.

Predominant features of the bedrock surface include structural lows or "channels" associated with thicker development of overburden materials and therefore having a potentially significant role in the movement of groundwater (and contamination) in the subsurface. With one prominent exception, these bedrock channels generally correspond to WAG 5 surface drainages. Drainage D-2 is west of the axis of the major south-trending channel in the bedrock surface below SWSA 5 South. Historical photos and maps suggest that the offset is probably not related to alteration of site drainage patterns by burial ground activities. The bedrock channel here underlies a large portion of the undefined trench area and provides a potential conduit for fluid (and contaminant) migration southward to Melton Branch.

Past construction, backfilling, and/or cut-and-fill operations related to waste disposal activities have masked several minor bedrock channels that at one time may have been associated with surface drainage features. These channels include one in the vicinity of seep area C, two in the southeast corner of SWSA 5, and one just to the west of the miscellaneous trenches in SWSA 5 North. Appendixes B2 and B3 examine in greater detail the potential role of these bedrock channels in the transport of contamination.

Stratigraphy

WAG 5 is underlain by sedimentary shales and limestones of the Conasauga Group. The Conasauga includes several different formations, all of which are exposed in a series of linear, northeast-southwest-trending belts that are the result of folding and thrust fault motion along the Copper Creek thrust fault. This fault is exposed on the northwest side of Haw Ridge, dips to the southeast under Melton Valley, and quickly reaches a depth of several hundred feet below the ground surface at WAG 5. The Conasauga strata above the fault also dip to the southeast, at an approximate angle of 35°. Locally, near-vertical dips (90°) were measured from rock core recovered from the 500-ft Westbay wells at WAG 5. In descending order, formations within the Conasauga include the Nolichucky Shale, Maryville Limestone (identified as the Dismal Gap Formation in Hatcher et al. 1992), Rogersville Shale, Rutledge Limestone (Friendship Formation in Hatcher et al. 1992), and Pumpkin Valley Shale. Figure B1.4.2 is a generalized geologic map of the site.

Most of WAG 5 is underlain by the Maryville Limestone, and drilling and coring activities typically encountered a variable sequence of thinly interbedded shales, siltstones, and limestones. The limestones, protected by the more prevalent shaley beds, generally form more resistant horizons, and most power auger refusals were attributed to limestones beds. The Maryville has been divided

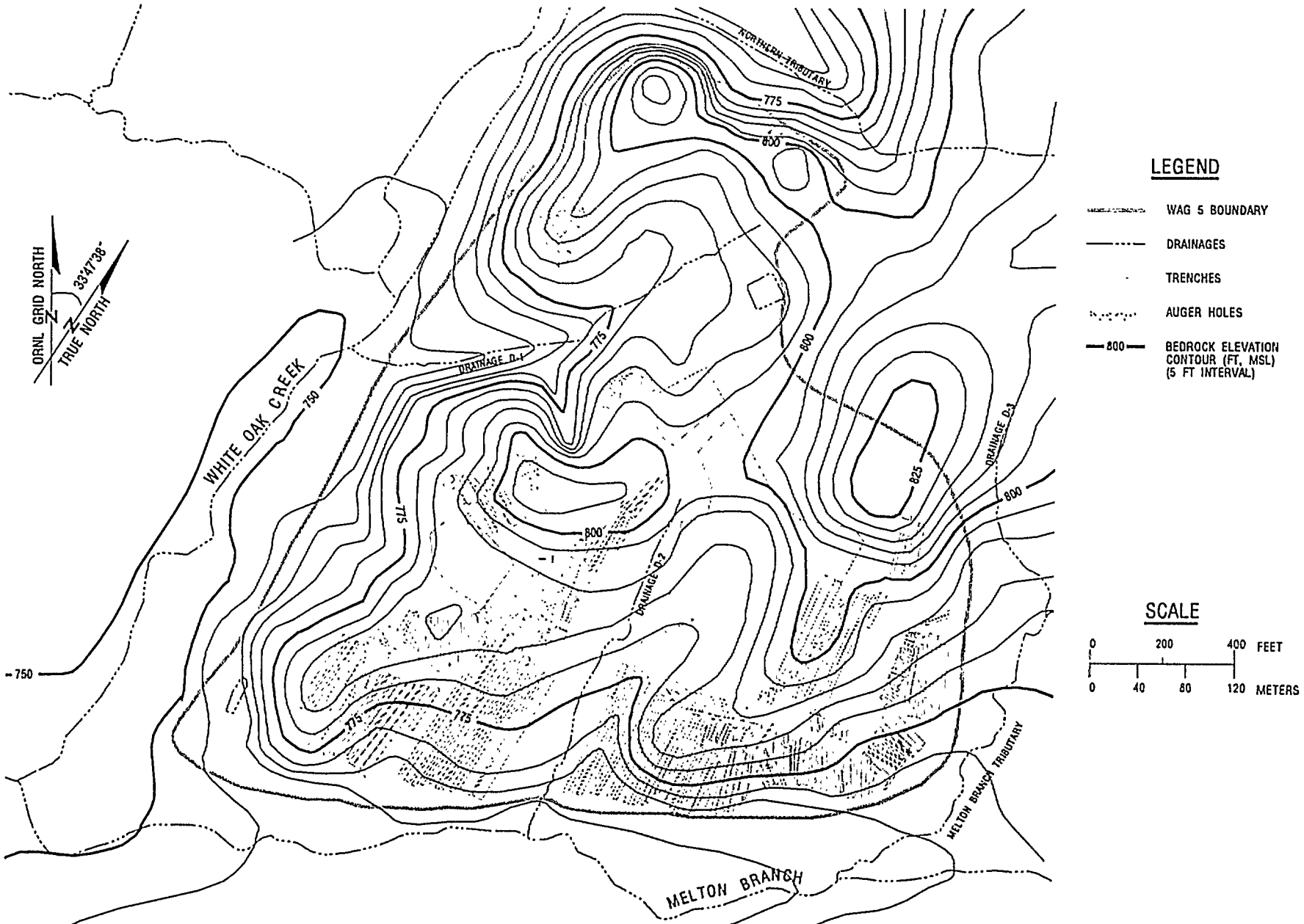

Fig. B1.4.1. Bedrock surface contour map.

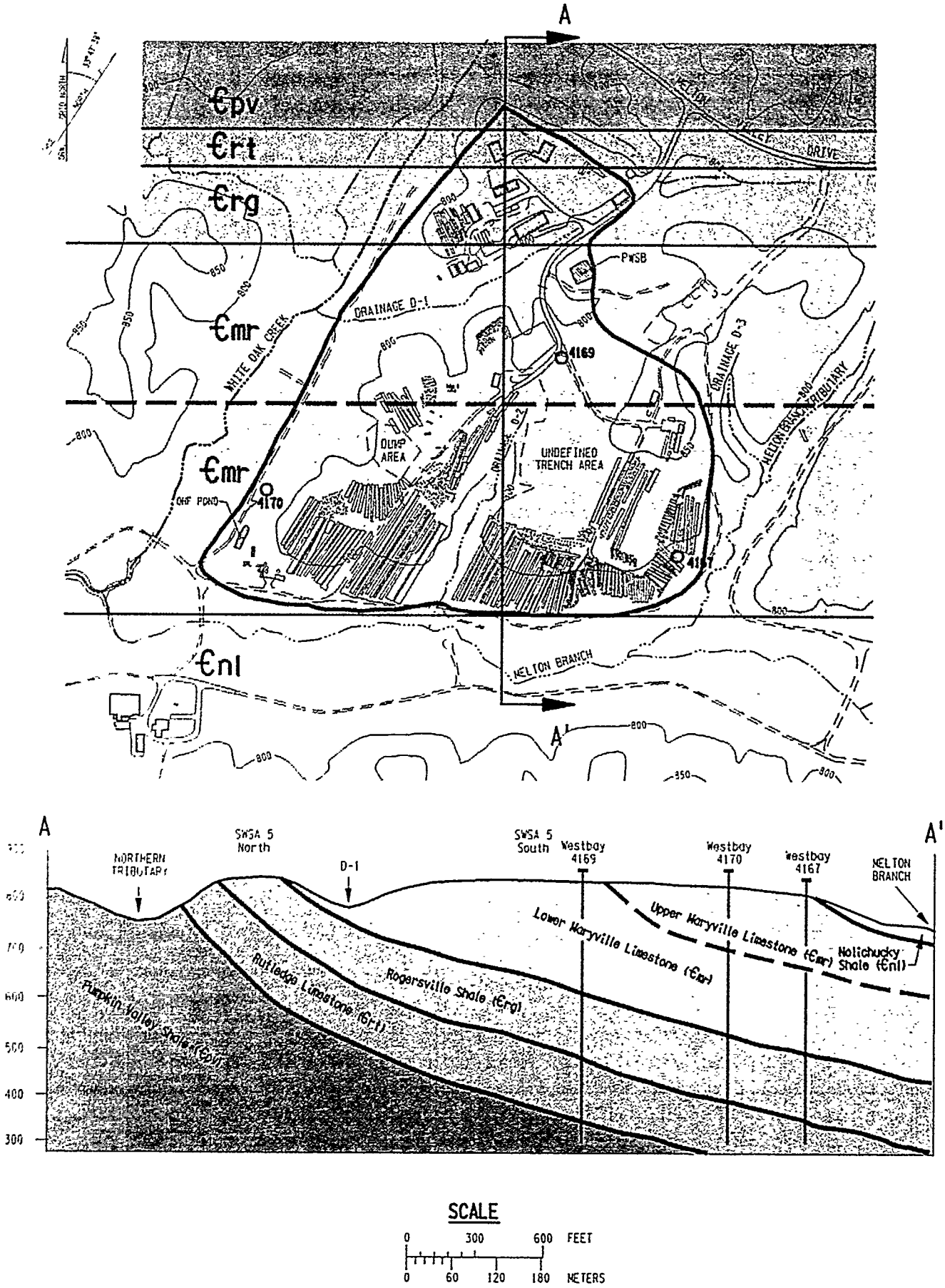

Fig. B1.4.2. WAG 5 generalized geologic map.

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into upper and lower units. The upper unit, present in the southern portion of the site, typically has a greater proportion of shale. Coring, logging, and flow testing of the multizone wells indicated that the upper zone is also more likely to have greater numbers of fractures and hydrologically active zones. The Nolichucky Shale, present in the Melton Branch floodplain, contains minor amounts of limestone. The Rogersville and Pumpkin Valley Shales, present in the northern part of WAG 5, are mostly shale with interbedded lenses of siltstone and limestone.

Further details concerning the appearance, lithology, and physical properties of stratigraphic units at WAG 5 are presented in "Multizone Well Installation at WAG 5" (Bechtel 1994).

Structural features

Melton Valley and the Valley and Ridge Province in general are dominated by thrust faulting and the resultant displacement of thick sequences of sedimentary rocks. At the mesoscopic scale, geologic structures in the area consist of inclined, faulted, and folded bedding; and fractures. Hatcher et al. (1992) describe fractures as the most important structural feature in the ORR because, along with bedding and local karst, they form the conduit system that controls groundwater movement. According to Hatcher et al. (1992), the general characteristics of Conasauga Group fractures are that

- fracture strikes are predominantly oriented along north-northwest/south-southwest, north-south, and northeast-southwest trends; and
- fracture spacing ranges from about 1 to 18 in. overall (generally higher for limestone and lower for shale and siltstone).

Within WAG 5, the most important structural features controlling groundwater flow are probably related to the bedrock surface and to fractures in the shallow bedrock and saprolite. Because the Melton Valley stratigraphy is inclined, exposing several Conasauga units, this structural setting may also affect groundwater movement either at a specific location or along a northeast-southwest trend where the strike exposure of each unit occurs across the WAG. Surface seeps are known to be discrete contributors of groundwater discharge at WAG 5 and may be an example of one or more of these characteristics that contribute to groundwater movement. However, in general, studies of the ORR have concluded that fractures are the major pathway for groundwater movement in bedrock because rock matrix porosity and hydraulic conductivity are comparatively low (Smith and Vaughan 1985; Olsen et al. 1986; Dreier et al. 1987 [as referenced in the *Status Report on the Geology of the ORR* by Hatcher et al. 1992]).

At WAG 5, the shallow bedrock was not cored, but samples from greater depths (100 to 500 ft) showed localized folding, fracturing (bedding plane and vertical), and joint sets. No solution cavities were identified during coring, drilling, or logging. Only a few scattered fractures were found to be hydraulically active below the 100 ft depth at which coring began; most were healed with calcite. Most active fracture flow occurs in the shallower bedrock and saprolite where relict fractures are enlarged from chemical weathering of the bedrock.

Information related to the interconnectedness of bedrock fractures was indirectly obtained from analysis of well hydrographs by assuming that hydraulic connection between wells is caused by fracture interconnection. Continuous water level data from well clusters with shallow (25 to 50 ft),

intermediate (100 to 150 ft), and deep (200 to 400 ft) wells indicate that the degree of hydraulic connection in wells varies both vertically and areally. Rapid response to storm events at some intermediate and deeper wells indicates a vertical connection to the shallow system via fractures. However, this does not necessarily mean that groundwater is more actively flowing from the shallow system to significant depths—only that the hydraulic head is more quickly distributed after a rainfall event. In general, the response attenuates with depth, which may indicate less interconnection with depth. The extent of lateral connection was shown through hydraulic responses in wells up to 100 ft away when water was withdrawn from the 500-ft-deep multiport wells. The magnitude of this hydraulic response in the vicinity of the multiport wells also varied across the site. Fracture interconnectedness is examined in greater detail in Sect. B1.6 and Appendix B3.

B1.4.3 Regolith (Soil, Saprolite, and Fill)

Most WAG 5 contaminant sources are buried within the regolith or lie on the ground surface, and most contaminants moving within or being released from the site do so via pathways within, through, or over the soil, saprolite, and fill materials that constitute the regolith. Verification of the conceptual model requires definition of key characteristics of the regolith, including the type and distribution of component materials and engineering properties, and measurement of selected parameters needed to evaluate contaminant fate and transport. These data are needed to define the regolith-related components of the conceptual model with regard to

- the influence of regolith composition and geotechnical and geochemical properties on contaminant release and migration, and
- the extent to which regolith type and thickness controls or influences hydrologic processes, including infiltration and downward percolation, development of active stormflow zones, and hydraulic properties of water table aquifers that occur within the regolith.

The types and distribution of regolith components were determined on the basis of split spoon sampling and/or examination of auger cuttings from 33 soil borings. All of the borings were drilled to competent bedrock (defined as power auger refusal), thereby providing regolith thickness data. Thickness data were also obtained from the seismic refraction survey discussed in Appendix A2 and from previous well installations at the site.

Type and distribution

Data from the drilling, sampling, and geophysical surveys indicate that WAG 5 regolith has three basic units:

- soil material, composed of residual soil, alluvium, and colluvium;
- saprolite, composed of chemically weathered (oxidized and leached) bedrock; and
- fill materials, consisting predominantly of imported soils from construction sites and borrow areas elsewhere at ORNL or the ORR.

The thickness of the regolith varies from a few feet at the southern boundary near Melton Branch to 40 ft in the interior and higher topographic locations. Within the regolith, soil thickness varies from less than 1 to as much as 6 ft; in most undisturbed areas, the soils are less than 2 ft thick.

Saprolite thickness varies from a few feet to several tens of feet. The vertical transition from soils to saprolite is generally sharp, and the transition from saprolite to unweathered ("fresh") rock is highly gradational in most areas.

Residual soils (generally a silty clay material having visible soil horizons, texture, and appearance) are generally found in the forested areas that were not disturbed during site operations. Excluding wooded areas, the original soil section over most of the WAG was effectively destroyed through construction, waste disposal, and backfilling operations. Interior drainages D-1, D-2, and D-3 and the floodplains of Melton Branch and White Oak Creek contain alluvial deposits associated with stream channels and low-lying areas.

The residual soil composition and thickness are related to underlying parent rock and topographic locality. Soils overlying limestones are more clay-rich; those overlying shales and siltstones tend to be more loamy. Soil thickness ranges from a few inches to several feet; the thickest accumulations are in low-lying and wooded areas and around the PWSB. Average site-wide thickness of residual soil, where present, is approximately 5 to 6 ft. Field descriptions of surface soils characterize them as being typically soft, moist, containing 20–30% shale fragments, and light colored.

Saprolite, encountered in 28 soil borings, represents the transition zone between soil and bedrock. Saprolite has the appearance of weathered, friable bedrock that retains much of the original bedding and structural features. These remnant structures are important because they provide preferential flowpaths for groundwater and contaminant migration. In addition to relict structures, characteristics of the saprolitic zone include increased clay content, greater strength (high blow counts) than the overlying soils, and an abundance of variably weathered and decomposed siltstone and shale fragments.

Site preparation, trenching, augering, backfilling, and surface contouring have resulted in significant alteration of the original soil-saprolite profile within the regolith, particularly in SWSA 5 South. The regolith in much of this area and OHF, NHF, SWSA 5 North (TRU storage area), and the area surrounding the PWSB has a significant fill component. Fill materials include soils and saprolite excavated from the trenches, imported soil from construction sites or borrow pits elsewhere on the ORR, and contaminated soils and debris. In general, the imported soils and saprolitic material appear to be similar to native regolith materials, with the addition of chert fragments.

Noncontaminated material was periodically brought in to fill voids created by trench subsidence (Duguid et al. 1977). Fill material also was brought in to construct a perimeter road around the southern boundary of the WAG during installation of the 900-series compliance wells. Contaminated soils (and debris) from the main ORNL plant area and other WAGs also were brought on site; in some cases these materials were dumped into a specific location (e.g., at the head of drainage D-2 or in the head of the former drainage swale now identified as the dump along the western edge of SWSA 5 South), while at other times they were apparently used to fill subsidence at various locations.

Table B1.4.1. Selected geotechnical and geochemical properties of WAG 5 regolith

Sampling			Sieve Analysis - (% by weight)			USCS	Liquid	Plastic	Plasticity		Specific		Wet	Dry		Soil
ID No.	Location	Interval (ft)	Gravel (3" - #4)	Sand (#4 - #200)	Silt/Clay (< #200)	(1)	Limit	Limit	Index	CEC (meq/100g)	Gravity (g/cm^3)	Moisture (%)	Density (lb/ft^3)	Density (lb/ft^3)	pH	Resistivity (ohms/cm)
SB002	SWSA 5N	4-6	4.6	47.7	47.7	SC	36	23	13	24.7	2.70	16.3	123.7	106		
SB008	SWSA 5S	0-1								21.93					6.82	
		2-4	0.0	19.4	80.6	CL-ML	26	19	7	11.6	2.69	28.6	121.1	95.4		
SB022	OHFT	4-6													4.82	200000
		6-7.3	15.6	54.8	29.6	SM	39	27	12	23.3	2.54	18.6	99.84	84.1		
		12-14	14.7	60.1	25.2	SM	NP	NP	NP	11.8	2.51	20.4	124.3	102.5	6.08	222000
SB025	OHFT	4-5.5	16.2	45.2	38.6	SM	38	25	13	26.2	2.54	23.0	127.3	103.5		
		6-7.7	15.6	48.4	36.0	SM	37	27	10	28.95	2.62	26.3	115	91		
		8-9													5.27	10000
		14-15.2	6.6	45.3	48.1	SM	NP	NP	NP	28.04	2.30	33.1	109.6	82.4		
		16-17	17.8	69.1	13.1	SM	NP	NP	NP	28.71	2.60	21.4	124	102.1		
		18-19													2.87	39000
SB030	PWSB	8-12.9	11.5	69.1	19.4	SM	NP	NP	NP	23.3	2.72	14.3	NM	NM		
SB046	SWSA 5S	0-1								18.8					7.64	
SB049	SWSA 5S	0-1								20.62						
SB057	SWSA 5S	0-1								23.73						
SB062	SW-3	0-1								21.44						
SB063	SWSA 5SW	0-1								30.09						

Notes:

1) The Unified Soil Classification System symbol is based on the grain size sieve analysis and Atterberg limits (liquid limits & plasticity index).
2) Soil boring locations provide in Volume II, Section A2, Fig. (A2.5 through A2.8).
3) Abbreviations:

CEC - Cation exchange capacity
meq/g - milli equivalent/gram
NP - Nonplastic
NM - Not measured
OHFT - Old Hydrofracture Facility tanks
PC - Plasticity chart
SB - Soil boring
SWSA - Solid waste storage area
USCS - Unified Soil Classification System

Physical/chemical properties

Geotechnical analyses of regolith materials were completed on samples collected at five soil boring locations across the WAG (Table B1.4.1). Grain size sieve analyses on samples from both the soil and saprolitic horizons indicate an average grain size distribution for the regolith of

- 11% gravel (3 in. to #4 sieve),
- 51% sand (#4 to #200 sieve), and
- 38% silts and clays (< #200 sieve).

No significant grain size variations between the soil and saprolite horizons were apparent. Using the Unified Soils Classification System, these soils are classified as silty and clayey sands (SM to CL-ML). The Plasticity Chart (Plasticity Index vs. Liquid Limit) further classifies the fine-grained portion (i.e., smaller than a #40 sieve) as sandy silts and clays (ML and CL). Field classification of cores from 62 sampling locations characterized soils across the site as sandy silts. An increasing clay content with depth was attributed to the presence of weathered shales and siltstones.

Geochemical measurements of soils were limited to pH, cation exchange capacity (CEC), and total organic carbon (TOC) (Table B1.4.1). Surface soils pH ranged from 4.82 to 7.64, with an average value of 6.13. A pH of 2.87 was measured in a saprolite sample from SB025 near the OHF waste storage tanks. This sample was collected at a depth of 18–19 ft, which correlates with the bottom of the tanks. Because the pH of the wastes in these tanks is slightly to highly alkaline, the pH of the saprolite does not indicate a release from the tanks. The value is important in a consideration of the corrosion potential of the soil. The saprolites formed from weathering of the Conasauga (and most other rocks on the ORR) produce an acidic material due to oxidation and leaching of the carbonate content (Hatcher et al. 1992; Carroll 1961).

TOC measurements were performed on 40 soil, saprolite, and fill samples from WAG 5 regolith (see Fig. B1.4.3). The data indicate a range of 81 to 39,300 mg/kg with a median of 661 mg/kg and a geometric mean of 1239 mg/kg. TOC concentrations were generally higher in surface soils (0–1 or 0–0.5 ft) and decreased with depth.

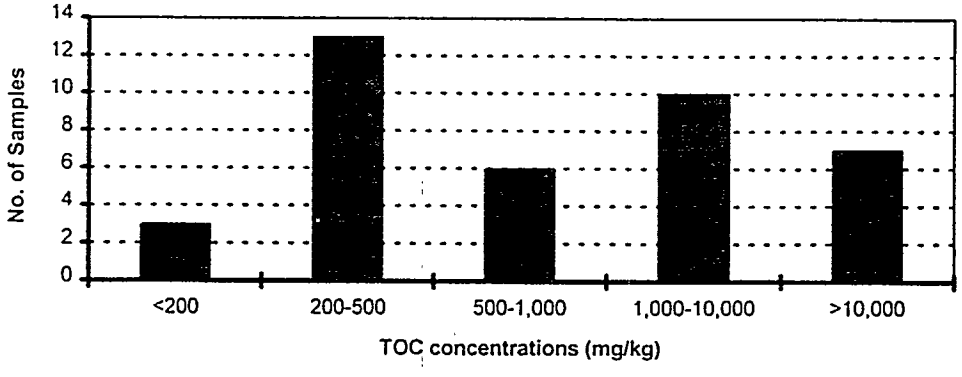

Fig. B1.4.3. TOC concentrations in WAG 5 regolith.

CEC values for the regolith are mostly a function of the clay mineralogy of the soil and saprolite material. Regolith derived from the Conasauga typically contains illite and vermiculite as principal clay minerals and is characterized by a relatively high CEC (Webster 1976a). Results from

CEC analyses for 15 samples from WAG 5 show a range of 11.6 to 30.09 meq/100 g, typical of illitic clays. The CEC does not measure the ability of the clay minerals to adsorb ionic species onto the surface of the clay particles or into the lattice structure of the mineral; determination of these properties requires partitioning tests to determine the distribution or partitioning coefficient. Studies by Webster (1976b) indicate that distribution coefficients for Cs and Sr (major contaminants at the site) ranged from 370 (Sr) to 180,000 (Cs). The higher coefficient for Cs indicates that this element is much more likely to be adsorbed than Sr by the illitic clays in the Conasauga-derived regolith. Adsorption and CEC are examined in greater detail in Appendix B3.

B1.5 SURFACE WATER HYDROLOGY

The hydrologic model developed during the scoping phase of the RI identified surface water as the principal conduit for contaminant migration from WAG 5 source areas to WAG 2 and other offsite areas, including downstream areas off the ORR. Surface water also constitutes an important exposure point for human and ecological receptors. The hydrologic model identified the interior drainages, surface impoundments, seeps, and receiving waters along the WAG perimeter (i.e., White Oak Creek and Melton Branch) as the principal components of the surface water system. Better delineation of this system allows for determination of flow contributions from the drainage basins and source areas and the relative significance of the flow pathways (e.g., groundwater discharge/seeps, runoff) in the context of total discharge from the site. Because hydrologic fluxes drive contaminant fluxes, an understanding of the surface water system is essential to an accurate definition of contaminant flux and determination of the influence of flow patterns, storm events, and other hydrologic phenomena.

This section summarizes the surface water hydrology at WAG 5 and contiguous reaches of the adjacent receiving waters. Topographic data and man-made surface water controls (e.g., concrete drainage ditches in SWSA 5 South) were used to divide the site into discrete drainage subbasins within the larger White Oak Creek and Melton Branch drainage basins as shown in Fig. B1.5.1. For both the White Oak Creek and Melton Branch drainage basins, the following discussion focuses on a general description of basin features (including impoundments), receiving waters, seeps, and surface water quality (contamination is discussed in Appendix B2).

B1.5.1 White Oak Creek Drainage Area

WAG 5 lies within the White Oak Creek watershed and near the confluence of White Oak Creek and Melton Branch, the principal White Oak Creek tributary in Melton Valley. Because many of the drainage subareas include land both within and adjacent to the administrative WAG 5 boundary (shown in Fig. B1.8), the total drainage area associated with WAG 5 is 113.7 acres (the total area within the administrative boundary is 69.5 acres). Fifty-three percent of this area (about 61 acres) discharges into White Oak Creek above its confluence with Melton Branch; the remaining 47% (53 acres) discharges to Melton Branch above its confluence with White Oak Creek. The subareas discharging into White Oak Creek are listed below (see Fig. B1.5.1 for locations).

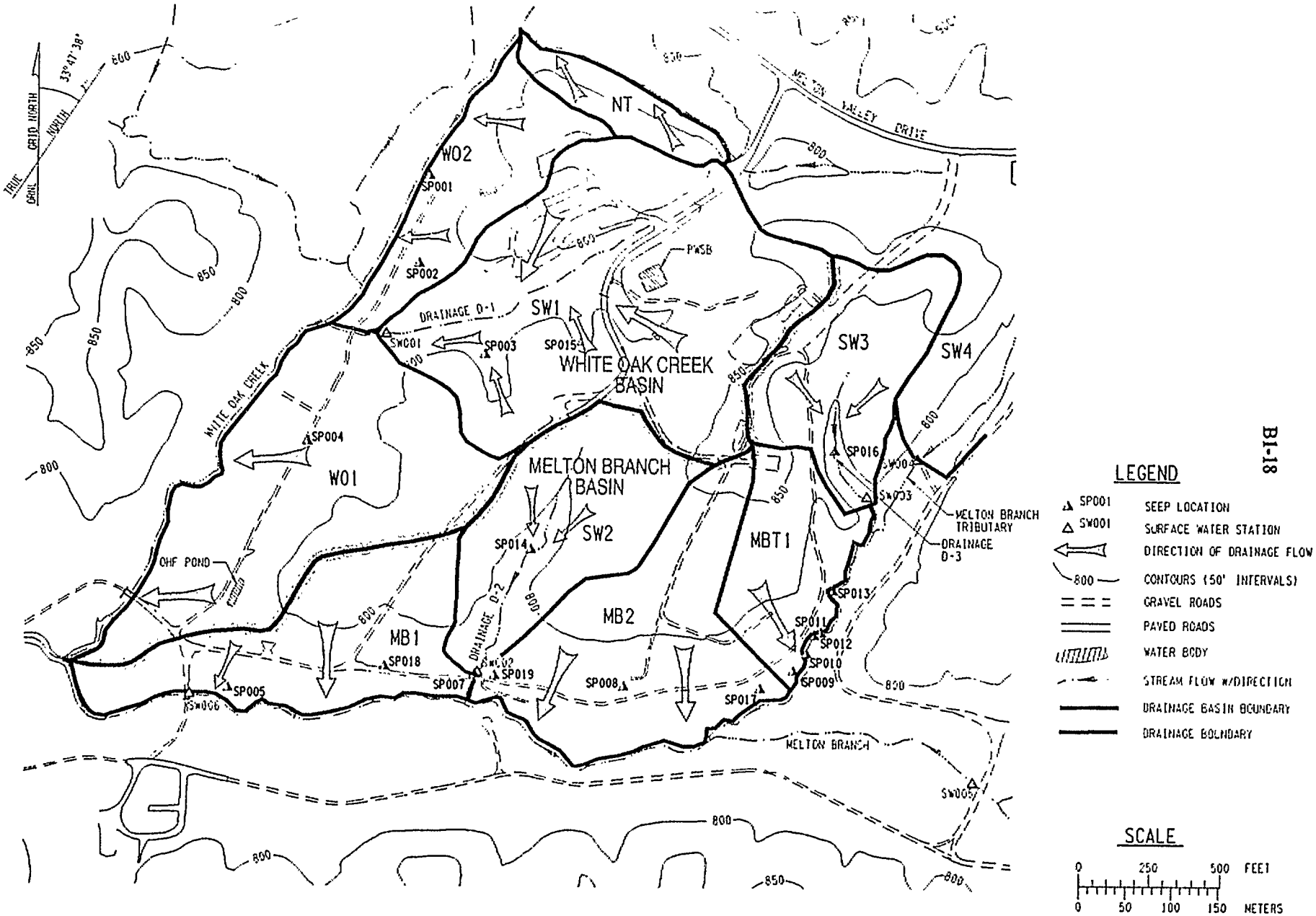

Fig. B1.5.1. Surface water drainage areas.

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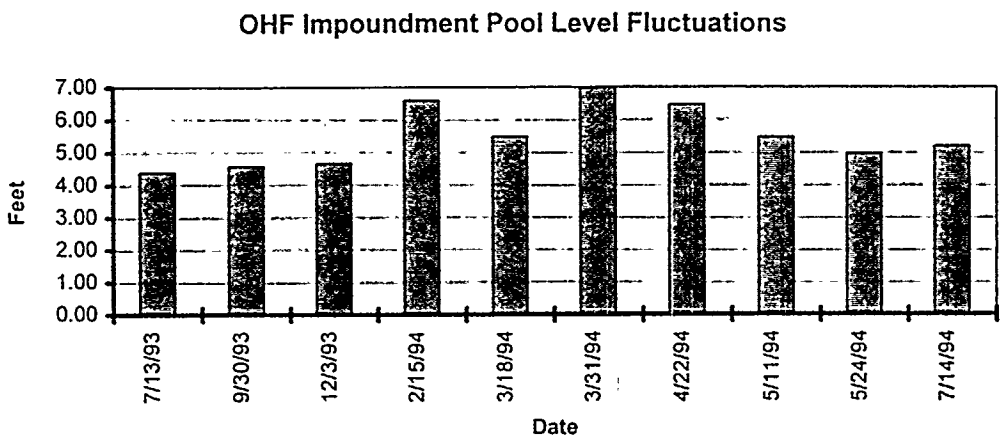
WHITE OAK CREEK DRAINAGE	
Subarea	Area (acres)
WO1	21.5
SW1	27.9
WO2	8.2
North Tributary	3.2
Total area	60.8

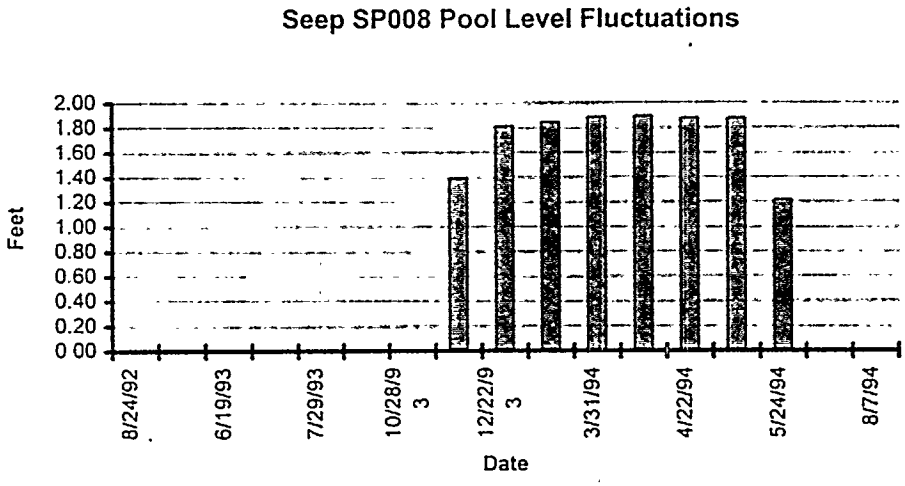
The White Oak Creek area contains all of SWSA 5 North, the northern half of the OHF facility, the PWSB, the fissile material storage area, and the northwestern portion of SWSA 5 South (including several trenches and groups of auger holes and the dump area). The area is predominantly forested but includes 14 acres used for waste management activities, a relatively significant (from a hydrologic perspective) portion of which is impervious (buildings, pavement, and roads). Average topographic slopes for the drainage area are approximately 10%.

The White Oak Creek basin on WAG 5 has one main drainage course, D-1, running east to west along the southern perimeter of SWSA 5 North. The D-1 drainage area is 27.9 acres, which represents 46% of the WAG 5 White Oak Creek basin. Flow in D-1 is gauged via an H-flume installed for the RI field investigation. The North Tributary, north of the WAG 5 boundary between SWSA 5 North and Melton Valley Drive, receives runoff and other surface water discharges from approximately 5% of the White Oak Creek basin. The remaining 49% consists of areas along the eastern side of SWSA 5 North and south of the D-1 drainage area and drains directly into White Oak Creek. None of the flow from the White Oak Creek drainage area outside of the D-1 catchment is gauged.

Both of the WAG 5 impoundments are in the White Oak Creek drainage basin. The PWSB has a total storage capacity of about 970 m^3 (257,000 gal), dimensions of 85 × 85 ft, and a maximum depth of 7.8 ft. The impoundment, constructed with a PVC liner, was used to decant sludges from the Process Waste Treatment Plant from 1976 to 1980 and currently has a 4-ft-thick layer of sludge in its bottom. Elevation at the top of the berms surrounding the impoundment is 809 ft msl. Runoff from the vicinity or overflow from the PWSB (if it occurs) flows into Drainage D-1, approximately 180 ft to the west. A staff gauge was installed in the PWSB in March 1994, and discrete readings were made through July 1994 (Fig. B1.5.2).

The OHF pond, constructed in 1964, measures 20 × 100 ft in area with a maximum depth of 6 ft and a storage capacity of about 380 m^3 (100,000 gal). The sides of the pond are lined with limestone riprap. A construction drawing (ORNL-DWG No. 540002-A-002-0) indicates that liquid asphalt was to be sprayed on the pond bottom to control erosion; however, the presence of the liner has not been confirmed. The elevation of the bottom of the pond is 764 ft msl, and the elevation of the berms on the downhill side is 771 ft msl. The topography slopes towards White Oak Creek, approximately 400 ft to the west. Staff gauge measurements were taken at the OHF pond between July 1993 and July 1994.





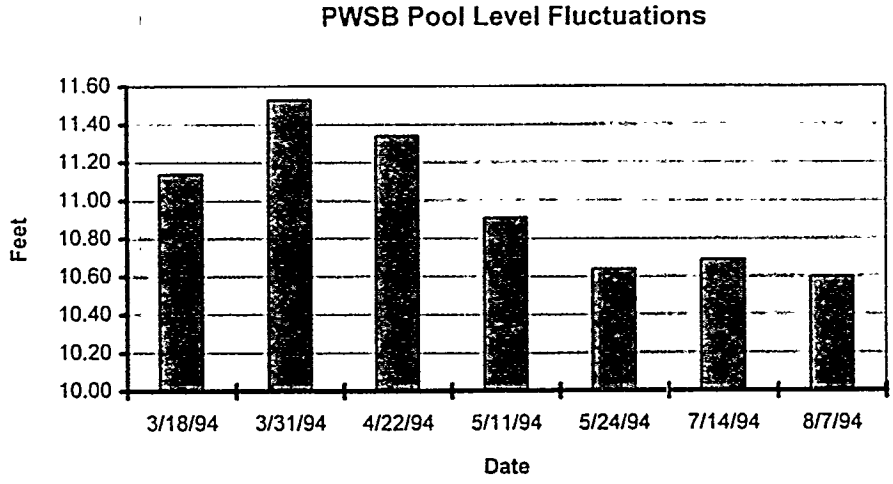


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Fig. B1.5.2. Staff gauge measurements.

Drainage D-1

D-1 is a small tributary to White Oak Creek that drains the northern portion of WAG 5, including most of SWSA 5 North, the northwest portion of SWSA 5 South, the fissile material storage area, and the PWSB. D-1 corresponds to the WAG 5 South Tributary as used in sampling and analysis activities for the WAG 2 RI and Active Sites Environmental Monitoring Program (ASEMP) in SWSA 5 North. The channel extends 1250 ft from its headwaters near the entrance to SWSA 5 North to its discharge point into White Oak Creek. The D-1 drainage catchment is primarily forested except for the paved and built-up areas in SWSA 5 North and the grassed areas associated with the SWSA 5 South, fissile storage, and PWSB areas. Seven percent of the D-1 drainage area is impervious (mostly from the pavement and buildings in SWSA 5 North).

Continuous flow measurements in D-1 were made at surface water station SW001, 150 ft above the confluence with White Oak Creek, between April 1993 and June 1994. Average daily flows are shown in Fig. B1.5.3. D-1 is typically dry during summer and fall with an average flow of only 0.11 cfs (based on the 1993–1994 flow data). In general, the D-1 drainage course receives little contribution from baseflow and reacts quickly to storm events. Most of the area is undisturbed (in contrast to the Melton Branch drainage area), and thus precipitation is more likely to be discharged through runoff and stormflow. The impervious areas contribute disproportionate runoff and cause relatively higher peak flows during storm events (as shown on the hydrographs from SW001 in Fig. B1.5.3).

The Hydrological Simulation Program—FORTRAN (HSPF) computer model was used to simulate long-term discharge in drainage D-1. HSPF is a deterministic, physically based (as opposed to stochastic, statistically based) model that performs a continuous simulation of stream discharge using rainfall and potential evapotranspiration as input data. HSPF calculates the stream discharge by dividing the flow into three separate components: surface runoff, interflow, and shallow groundwater discharge into the streams. Surface runoff is the water that travels over the ground surface into the channel. Interflow is analogous to stormflow and describes that component of flow associated with a transient, perched water table at the approximate depth of the root zone. Water within the stormflow zone is transmitted laterally (downslope) until it reaches the stream channel. Groundwater discharge (and resulting baseflow) occurs when the water table intersects the stream channel and the hydraulic potential causes groundwater to discharge into the stream.

The model was calibrated by matching the measured flow at SW001 by adjusting the physical parameters describing the soils, vegetation, and topography. After the physical parameters were determined, streamflow in D-1 was simulated for a 41-year period using hourly precipitation data recorded at the ATDL from 1953 through 1993. The average annual water balance components for D-1, based on the 41-year HSPF simulation, are summarized below.

COMPONENT	VOLUME (in.)
Precipitation	53.9
Evapotranspiration	26.1
Total discharge	27.8
Surface runoff	7.6 (2.3%)
Interflow	8.5 (30.6%)
Groundwater	11.7 (42.1%)

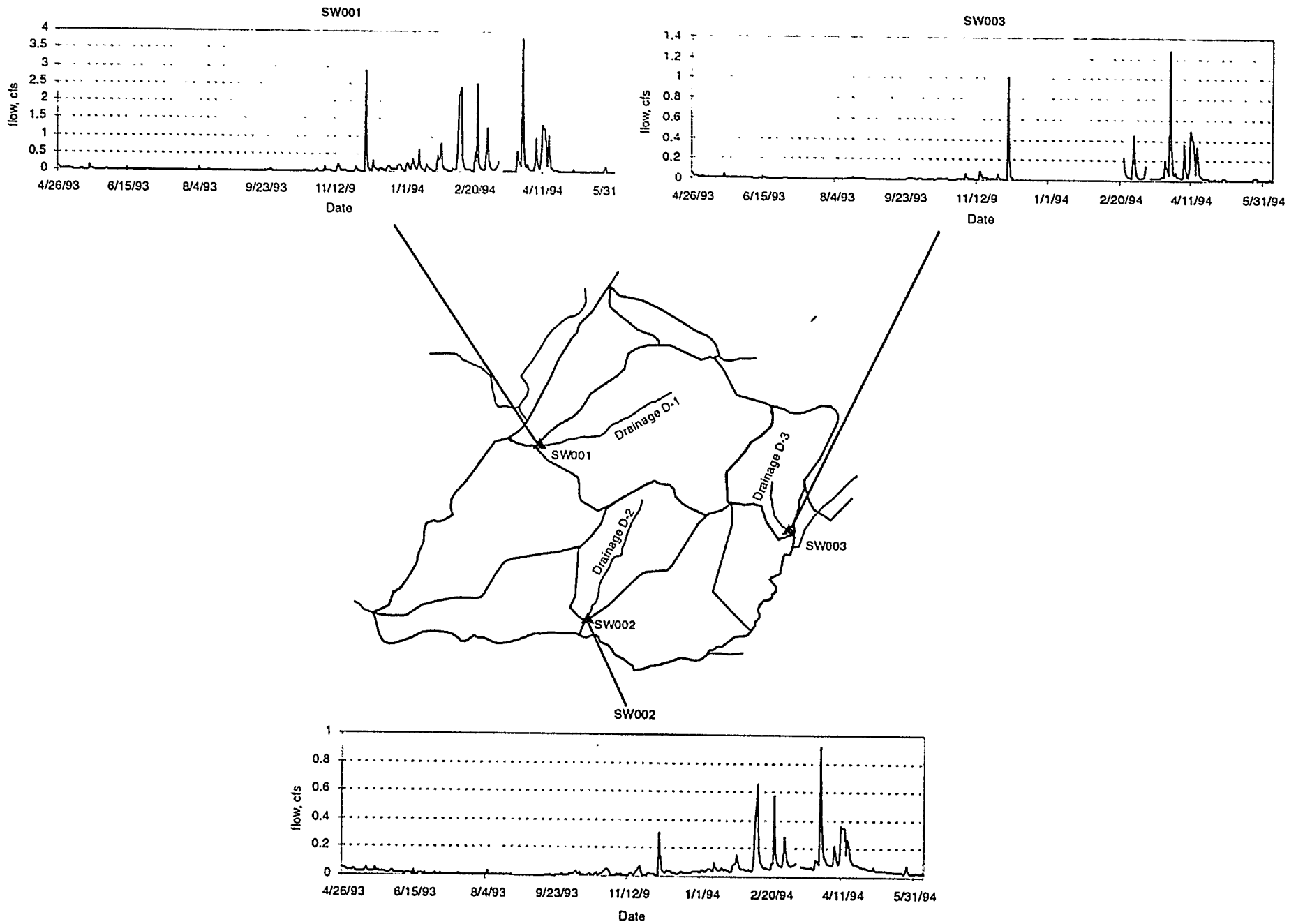

Fig. B1.5.3. Daily flows for D-1, D-2, and D-3.

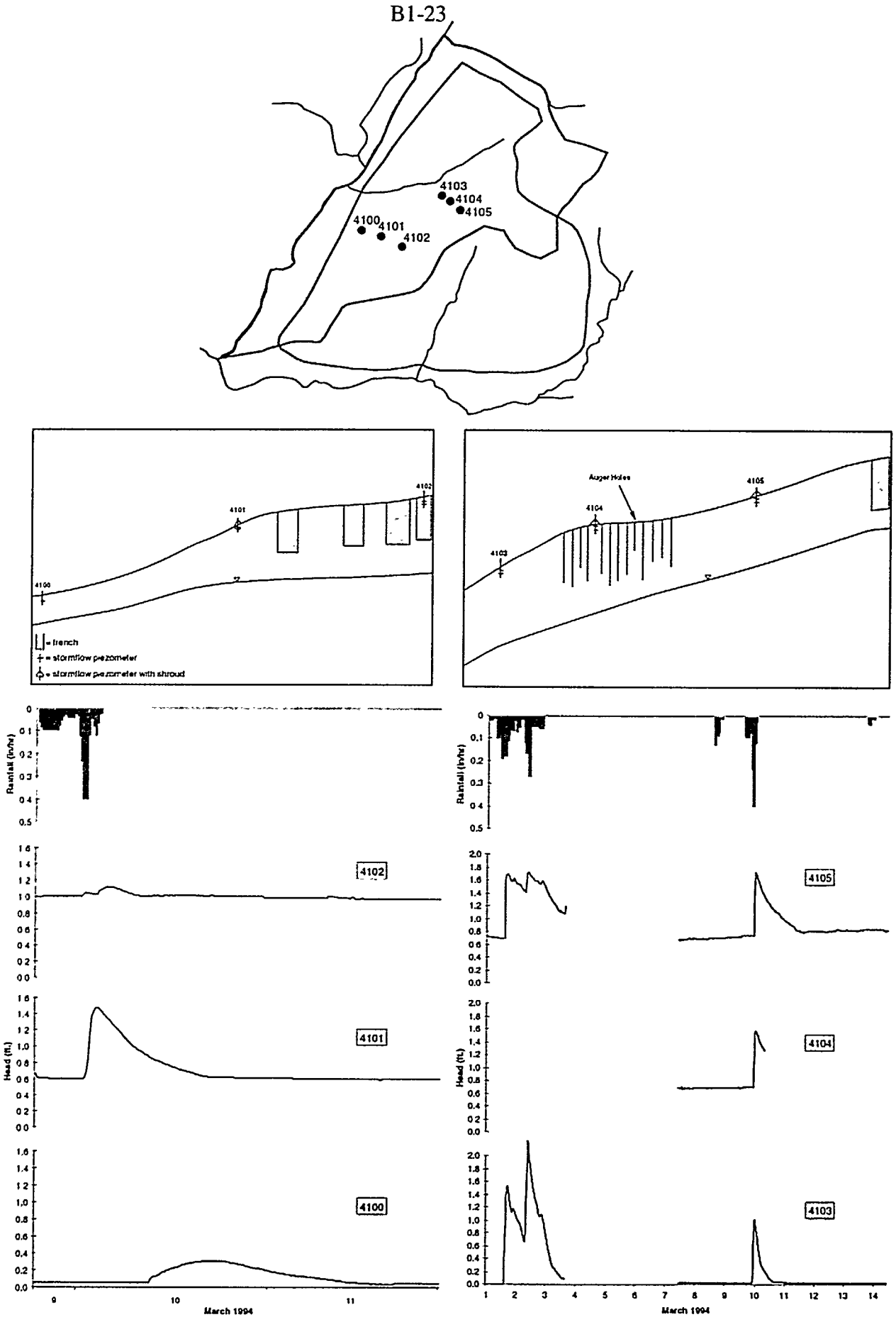

Fig. B1.5.4. White Oak Creek shallow stormflow piezometer hydrographs.

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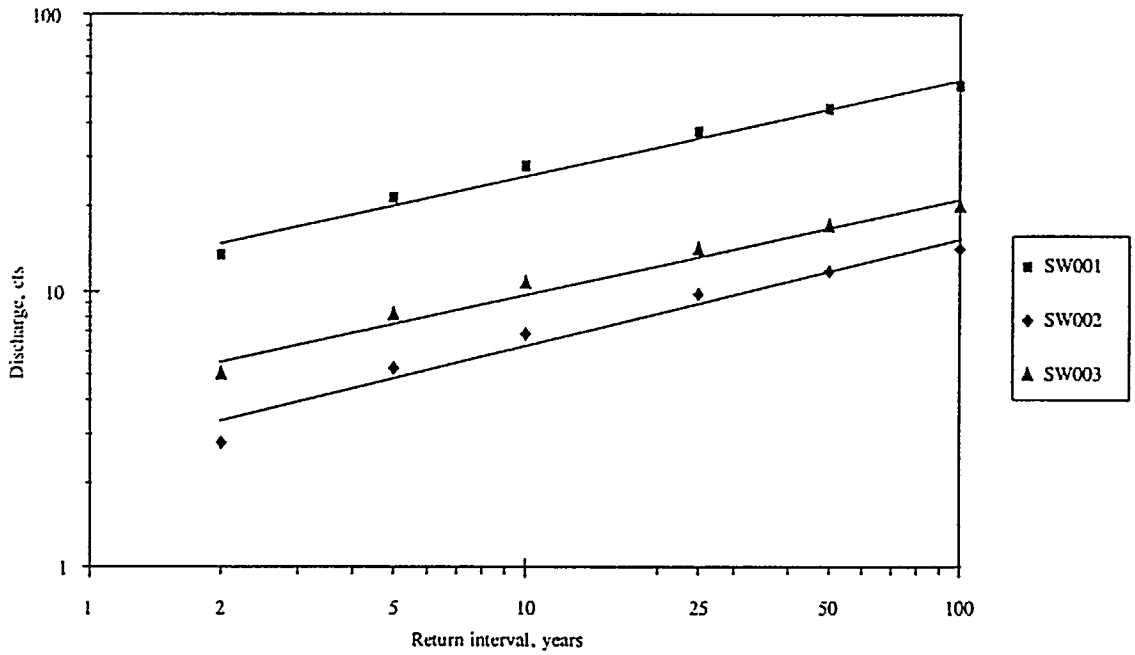
Interflow in D-1 was observed during spring 1994 at stormflow piezometers 4100 through 4105 (Fig. B1.5.4), which are screened from a depth of 0.5 to 2.0 ft and designed to monitor the flow in the shallow soil zone. A 6-ft^2 piece of plastic was placed on the ground and sealed around the riser to prevent infiltration in the immediate area around each piezometer. In this way, only lateral subsurface flow was captured. Continuous water level recorders were temporarily installed in each piezometer to observe response during a storm event.

The 2-, 5-, 10-, 25-, 50-, and 100-year return period annual maximum hourly discharges (i.e., what would occur during storms) were calculated from the simulated 41-year flow at SW001 using the log-Pearson Type III distribution. The calculated discharges are plotted in Fig. B1.5.5 and summarized below.

RETURN PERIOD (yrs)	MAXIMUM HOURLY DISCHARGE (cfs)
2	13.5
5	21.8
10	28.4
25	37.9
50	45.9
100	54.6

The average flow in D-1 for the 41-year period of simulation was 0.09 cfs.



Note: Data are based on HSPF simulation.

Fig B1.5.5. Annual maximum hourly discharge for SW001, SW002, and SW003.

White Oak Creek

White Oak Creek is the receiving body for all surface water from this drainage area, whether directly (through runoff or discharge of interflow and groundwater) or indirectly (through runoff and discharge into D-1). The total drainage area for White Oak Creek is 6.5 mi^2 within Melton Valley and Bethel Valley. White Oak Creek drains into White Oak Lake, an impoundment approximately 4000 ft downstream of the confluence of White Oak Creek and Melton Branch. White Oak Lake was created in 1943 to serve as a settling basin for effluents from ORNL. White Oak Dam, located at the point where Highway 95 passes over White Oak Creek, has been modified a number of times to better control water and sediment discharge from White Oak Lake; it currently maintains an elevation of 745 ft msl and creates a standing pond of 17 acres. The White Oak Creek Embayment extends 0.6 miles from White Oak Dam to its confluence with the Clinch River at Clinch River Mile 20.8.

Continuous flow measurements are made at two stations on White Oak Creek downstream of WAG 5 as part of the National Pollutant Discharge Elimination System (NPDES) ambient surface water monitoring program (Clapp 1992). Station MS3 is at the southwest corner of WAG 5 just upstream of the White Oak Creek and Melton Branch confluence, and station MS5 is at White Oak Dam. The mean daily flows at MS3 and MS5 for October 1989 to December 1993 show average flow in White Oak Creek at MS3 to be 11.3 cfs and average flow at White Oak Dam to be 14.8 cfs.

The total discharge into White Oak Creek from the WAG 5 White Oak Creek drainage area was estimated by assuming that the ungauged areas are hydrologically similar to D-1. Using this approach, the average discharge from the WAG 5 White Oak Creek area during October 1989 to December 1993 was 0.19 cfs, which represents 1.7% of the total flow in White Oak Creek at MS3 and 1.3% of the total flow at MS5 (White Oak Dam).

Seeps

Five seeps were identified in the White Oak Creek drainage of WAG 5 (Fig. B1.5.1). Most were visible areas of groundwater discharge, either as discrete water flows or diffuse wet areas, mostly at the base of slopes or floodplain/stream channel margins. It is likely that the visible seeps represent only a small portion of the total groundwater discharge that occurs into White Oak Creek and D-1 along the western side of WAG 5.

All five of the seeps were sampled during the RI and flow measurements were made periodically between August 1992 and March 1994. Only seep SP015, in a swale northeast of the fissile material storage area, flowed year-round; the rest dried up during the summer. At least one seep (SP004) corresponded with a seep sampled in 1973 by Duguid (1975). In addition, seeps SP001, SP002, SP003, and SP004 correspond to seeps sampled for the WAG 2 Phase I RI activities in 1992. Table B1.5.1 summarizes the description, location, seep flow data and, where possible, the seep designations used in the WAG 2 RI.

Table B1.5.1. Seep summary

Seep ID No.	WAG 2 Designation	Drainage Basin	Description of Seep Flow Measurement Location	Discharge Type		No. of Measurements	No. of Months Flowing	Avg. Flow Rate (gpm)	Max Flow	
				Discrete	Diffuse				Rate (gpm)	Date
SP001	5NW-2	WOC	Small drainage catchment 25-ft east of WOC, west of SWSA 5 North	X		8	8	0.4	1	Sep-93, Nov-92
SP002	5NW-1	WOC	Intermittent saturated area 100-ft east of WOC, southern boundary of SWSA 5 North		X	8	6	0.3	1.7	Mar-94
SP003	SW5-1	WOC	Head waters of a small tributary to drainage D-1, 150-ft south of D-1, northwest boundary of SWSA 5 South	X		8	9	0.4	2.5	Mar-94
SP004	SW5-2	WOC	Catchment for small drainage 250-ft east of WOC, along WAG 5 boundary	X		8	6	0.2	1.1	Mar-94
SP005	SW5-3	MB	Catchment in low lying area 75-ft north of MB, eastern Area D		X	8	6	0.1	0.7	Mar-94
SP006	SW5-4	MB	Hill slope discharge 20-ft north of flume in Area C near MB	X		15	12	0.06	0.4	May-93
SP007	SW5-5	MB	Bank discharge on west bank of D-2, 100-ft above confluence with MB	X		9	12	0.2	1	Dec-93
SP008	SW5-11	MB	Catchment (300-400 gal) of ponded water 20-ft south of trench T-117 in eastern Area B		X	7*	7	--	--	
SP009	SW5-6	MB	Catchment in floodplan 25-ft west of MBT, along southern bondary of Area A		X	8	9	0.1	0.9	May-93
SP010	SW5-7	MB	Creek bank discharge along MBT in southeastern Area A	X		7	9	0.007	0.03	Sep-93
SP011	SW5-8	MB	Creek bank discharge along MBT in southeastern Area A	X		8	12	0.09	0.3	Apr-93
SP012	SW5-9	MB	Creek bank discharge along MBT in southeastern Area A	X		8	11	0.2	0.4	May-93
SP013	--	MB	Creek bank discharge along MBT 50-ft east of Area A boundary	X		6*	7	--	--	Mar-94
SP014	--	MB	Head waters for drainage D-2 just south of well 0149.	X		7	12	0.05	0.3	May-93
SP015	--	WOC	Head waters of a small tributary to Drainage D-1, 250 ft southeast of D-1, northern boundary of SWSA 5 South	X		7	12	0.3	0.5	Apr-93
SP016	--	MB	Head waters of a small side drainage (D-3), 300-ft above confluence with larger MBT	X		5	12	1.7	4	Sep-93
SP017	--	MB	Catchment within a marshy floodplan 150-ft north of MB, 50-ft south of southeastern WAG 5 boundary		X	5*	12	--	--	Mar-94
SP018	--	MB	Catchments for bathtubbing trenches just south of trenches 105 and 83 in Area C		X	2*	2	--	--	Mar-94
SP019	--	MB	Discharge from shale outcrop 50-ft east of D-2 in western Area B	X		2	5	0.01	0.2	Mar-94
SP00D	SW2-5	MB	Creek bank discharge along MB in western Area D	X		4	>8	0.4	0.6	Dec-93

Notes: * Flow present but could not be measured.

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Water quality

The Tennessee Water Quality Control Board has classified White Oak Creek as suitable for fish and aquatic life, recreation, irrigation and livestock watering, and wildlife (TDEC Rules, Chap. 1200-4-4). Surface water quality in WAG 2 (White Oak Creek and Melton Branch) generally meets NPDES permit requirements and Environmental Protection Agency (EPA) water quality criteria for freshwater aquatic life (WAG 2 RI Work Plan, November 1990). Water quality samples were taken at SW001 during high and low base conditions and storm events in October 1993 and March 1994, and water quality analyses are also conducted regularly as part of the NPDES ambient surface water monitoring program. These results did not identify any water quality problems apart from those associated with radionuclides. Samples from SW001 indicate that surface water in D-1 is generally calcium carbonate with elevated concentrations of sulfate, magnesium, and chloride. Concentrations of calcium and sulfate were similar.

Water quality results from seep sampling (spring 1993) indicate that the water chemistry of seeps in the White Oak Creek drainage is similar to that of surface water. Discharging groundwater is primarily calcium carbonate, with lesser amounts of magnesium and sodium. SP015 had typical concentrations of calcium carbonate, but elevated concentrations of magnesium, sodium, chloride, and sulfate.

OHF pond and PWSB waters are highly contaminated with radionuclides and would not be considered suitable habitat for aquatic or other wildlife. Both impoundments support vegetation (e.g., cattails and various weeds), and the PWSB also supports a population of frogs and turtles based as observed during the RI field investigation. The OHF pond has barriers to limit access by waterfowl and other birds due to the high beta-gamma emissions; the PWSB has no such barriers. Appendix A4 summarizes the water quality data for surface impoundments, seeps, and surface water.

B1.5.2 Melton Branch Drainage Area

The Melton Branch drainage area consists of approximately 53 acres, representing 47% of the total WAG 5 drainage area. The area is defined as those portions of the site where surface flow discharges directly into Melton Branch along the southern perimeter of the site or indirectly to Melton Branch via the Melton Branch tributary that partially bounds the eastern portion of WAG 5. The Melton Branch drainage area and subareas are shown on Fig. B1.5.1 and summarized below.

DRAINAGE SUBAREA	AREA (acres)
SW3 (D-3)	9.3
MBT1	7.0
MB2	13.7
SW2 (D-2)	10.6
MB1	12.3
Total area	52.9

The Melton Branch drainage area contains all of SWSA 5 South, the southern half of the OHF facility, the landfill in the northeast corner of the site, and the D-3 catchment basin. Most of the drainage area consists of the grass-covered slope of SWSA 5 South used for disposal of wastes in

trenches and auger holes. Forested areas are present along the WAG 5 perimeter and along the interior drainages (D-2 and D-3). The average land slope for the Melton Branch area is 12%.

The drainage area has two main drainage courses, D-2 and D-3, both of which are gauged via H-flumes constructed for the RI. D-2 runs north to south, bisecting SWSA 5 South. The drainage subarea associated with D-2 is 10.6 acres, representing 20% of the area. D-3 is along the eastern boundary of WAG 5 and drains an area of 9.3 acres, representing 18% of the area. The remaining 62% is ungauged and discharges directly into either Melton Branch or its unnamed tributary.

Drainage D-2

D-2 is a small tributary to Melton Branch that drains the south-central portion of WAG 5 and corresponds with the "Mid Drain" designation used for WAG 2 sampling activities. The D-2 drainage catchment is 10.6 acres and consists primarily of grassed-over SWSA 5 South trench areas with wooded areas along the stream channel. The 1100-ft-long channel discharges into Melton Branch.

Continuous flow measurements were made at surface water station SW002, 100 ft upstream of the confluence with Melton Branch, from April 1993 until June 1994 (Fig. B1.5.3). Average flows in D-2 are low (0.05 cfs based on 1993–1994 data) but typically occur year-round due to a relatively large contribution from baseflow (discussed below). In contrast to D-1, baseflow is recognizable from mid-fall through the beginning of summer. Higher baseflow in D-2 was attributed to the fact that most of the drainage area has been disturbed by trenching and drilling of auger holes and disturbed areas typically have higher infiltration rates and more poorly developed stormflow zones.

HSPF was used to simulate the long-term runoff in D-2. The model was calibrated with the 1993–1994 measured flow at SW002 in a manner similar to that described for SW001 and run for a 41-year simulation using the Oak Ridge precipitation data. The average annual water balance components for D-2 based on the 41-year HSPF simulation are given below.

COMPONENT	VOLUME (in.)
Precipitation	53.9
Actual evapotranspiration	24.7
Total discharge	29.2
Surface runoff	2.0 (6.9%)
Interflow	8.3 (28.4%)
Groundwater	18.9 (64.7%)

The HSPF simulations show that baseflow from groundwater discharge to D-2 is more than twice the contribution from interflow and an order of magnitude greater than runoff. The presence of an active stormflow zone (interflow) in the D-2 catchment was confirmed during spring 1994. Each of eight shallow stormflow piezometers (4099 and 4106–4112) had continuous water level recorders temporarily installed to observe the piezometers' response during a storm event. Figure B1.5.6 plots the hydrograph for each piezometer.

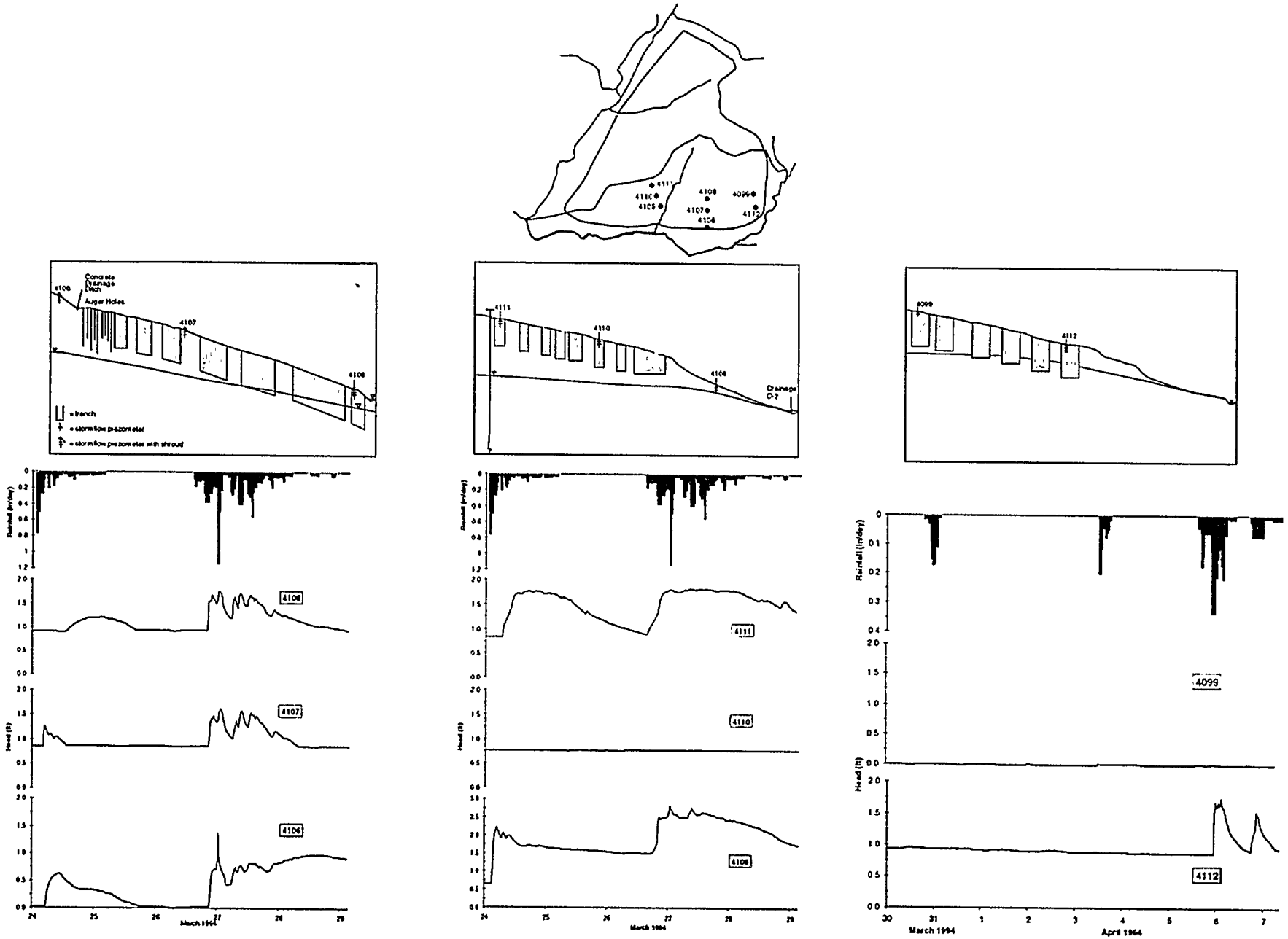

Fig. B1.5.6. Melton Branch shallow stormflow piezometer hydrographs.

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The 2-, 5-, 10-, 25-, 50-, and 100-year return period annual maximum hourly discharges were calculated from the simulated 41-year flow at SW002 using the log-Pearson Type III distribution. The calculated discharges are shown in Fig. B1.5.5 and summarized below.

RETURN PERIOD (yrs)	MAXIMUM HOURLY DISCHARGE (cfs)
2	2.8
5	5.1
10	7.0
25	9.6
50	11.8
100	14.1

The average flow in D-2 for the 41-year period of simulation was 0.04 cfs, approximately one-half of that predicted for D-1.

Drainage D-3

D-3 has a 9.3-acre drainage catchment on the northeastern side of WAG 5. Most of the area lies outside the WAG 5 administrative boundary, but the catchment does receive runoff and other flow from the eastern portion of the WAG, including the landfill. In addition, D-3 is downgradient of the WAG 5 decontamination and IDW consolidation areas. Almost all of the drainage area is forested; a small fraction of the area is grass-covered. The D-3 drainage channel is 800 ft long and discharges into the Melton Branch tributary.

Continuous flow measurements were made in D-3 from April 1993 until June 1994 at station SW003, 50 ft upstream of the confluence with the unnamed tributary of Melton Branch (no data were collected for December, January, and most of February due to instrument problems). Average daily flows are shown in Fig. B1.5.3. Average flows in D-3 are the lowest of the three WAG 5 interior drainages. The drainage is mostly dry from late spring to mid-fall with an averaged flow of 0.03 cfs based on 1993–1994 data. Almost all of the area is undisturbed and would be expected to have a relatively well-developed stormflow zone. The hydrographs support this assumption and show that most precipitation is discharged via either stormflow or runoff. Appreciable baseflow occurs only during the winter and early spring.

HSPF was used to simulate the long-term runoff in D-3. The model was calibrated with the measured flow at SW003, and a 41-year flow simulation was performed similar to that completed for D-1 and D-2. The average annual water balance components for D-3, based on the 41-year HSPF simulation, are given below.

COMPONENT	VOLUME (in.)
Precipitation	53.9
Evapotranspiration	27.4
Total discharge	26.5
Surface runoff	4.9 (18.5%)
Interflow	9.1 (34.3%)
Groundwater	12.5 (47.2%)

Results from the HSPF model support interpretations based on analysis of the D-3 flow hydrograph that the catchment has a lower groundwater recharge and baseflow contribution because the area has remained relatively undisturbed. The surface runoff in D-3 is relatively low because the basin does not contain any impervious areas.

The 2-, 5-, 10-, 25-, 50-, and 100-year return period annual maximum hourly discharges were calculated from the simulated 41-year flow at SW003 using the log-Pearson Type III distribution. The calculated discharges are shown in Fig. B1.5.5 and summarized below.

RETURN PERIOD (yrs)	MAXIMUM HOURLY DISCHARGE (cfs)
2	4.9
5	8.1
10	10.6
25	14.1
50	17.0
100	20.2

The average flow in D-3 for the 41-year period of simulation was 0.03 cfs.

Melton Branch

Melton Branch is the receiving body for surface water from the Melton Branch drainage area. The total drainage area is 1.51 mi^2, all of which is in Melton Valley. Melton Branch drains into White Oak Creek opposite the southwest corner of WAG 5, at a point that coincides with the southwest corner of the WAG 5 drainage area. Flow and water quality are monitored at station MS4 (also identified as X13 and Melton Branch-1), a weir that is approximately 600 ft upstream of the Melton Branch and White Oak Creek confluence. Continuous flow measurements from MS4 for the period October 1989 through December 1993 indicate a mean daily flow of 3.1 cfs.

The total discharge into Melton Branch from WAG 5 (i.e., the Melton Branch drainage area) was estimated by assuming that the ungauged drainage areas had characteristics similar to D-2 (data from the D-3 drainage basin were used only for that subarea). Using this approach, the average discharge from WAG 5 into Melton Branch from October 1989 to December 1993 was 0.18 cfs, which represents 5.8% of the total flow in Melton Branch at MS4 and 1.2% of the total flow at MS5 at White Oak Dam. Combining the White Oak Creek and Melton Branch drainage areas, the total discharge from WAG 5 during 1989–1993 was approximately 2.5% of the flow at White Oak Dam (Fig. B1.5.7).

Seeps

Most of the 15 seeps at WAG 5 were identified in the Melton Branch drainage area: [SP00D, and SP005 through SP019 excluding SP015 (Fig. B1.5.1) correspond to ones sampled for the WAG 2 RI and possibly earlier investigations (e.g., Duguid 1975)]. A notable exception was SP018, which was attributed to overflowing (bathtubbing) trenches in SWSA 5 South during the unusually wet winter and spring of 1994. Most of the seeps were visible areas of groundwater discharge, either as discrete water flows or diffuse wet areas, mostly at the base of slopes or floodplain/stream channel margins. It is likely that the visible seeps represent only a small portion of the total groundwater discharge associated with the Melton Branch drainage area of WAG 5.

All 14 of the WAG 5 Melton Branch drainage area seeps were sampled for the RI, and flow was measured periodically between August 1992 and March 1994. Seeps SP006, SP007, SP011, SP016, and SP017 flowed year-round; the rest dried up during the summer. Table B1.5.1 summarizes the description, location, seep flow data and, where possible, the seep designations used in the WAG 2 RI.

Water quality

The Tennessee Water Quality Control Board has classified Melton Branch as suitable for fish and aquatic life, recreation, irrigation and livestock watering, and wildlife (TDEC Rules, Chap. 1200-4-4). Surface water quality in Melton Branch generally meets NPDES permit requirements and EPA water quality criteria for freshwater aquatic life (WAG 2 RI Work Plan, November 1990). Water quality samples were taken at SW002 and SW003 during high- and low-base conditions and storm events in October 1993 and March 1994, and water quality analyses are conducted regularly as part of the NPDES ambient surface water monitoring program at station MS4. These results did not identify any water quality problems apart from those associated with radionuclides. Samples from SW002 and SW003 indicate that surface water in D-1 is generally calcium carbonate; SW002 had elevated concentrations of sulfate and chloride.

Seep sampling water quality results (spring 1993) indicate that seeps in the Melton Branch drainage are primarily calcium carbonate with lesser amounts of magnesium and sodium. Appendix A4 summarizes the water quality data for seeps and surface water.

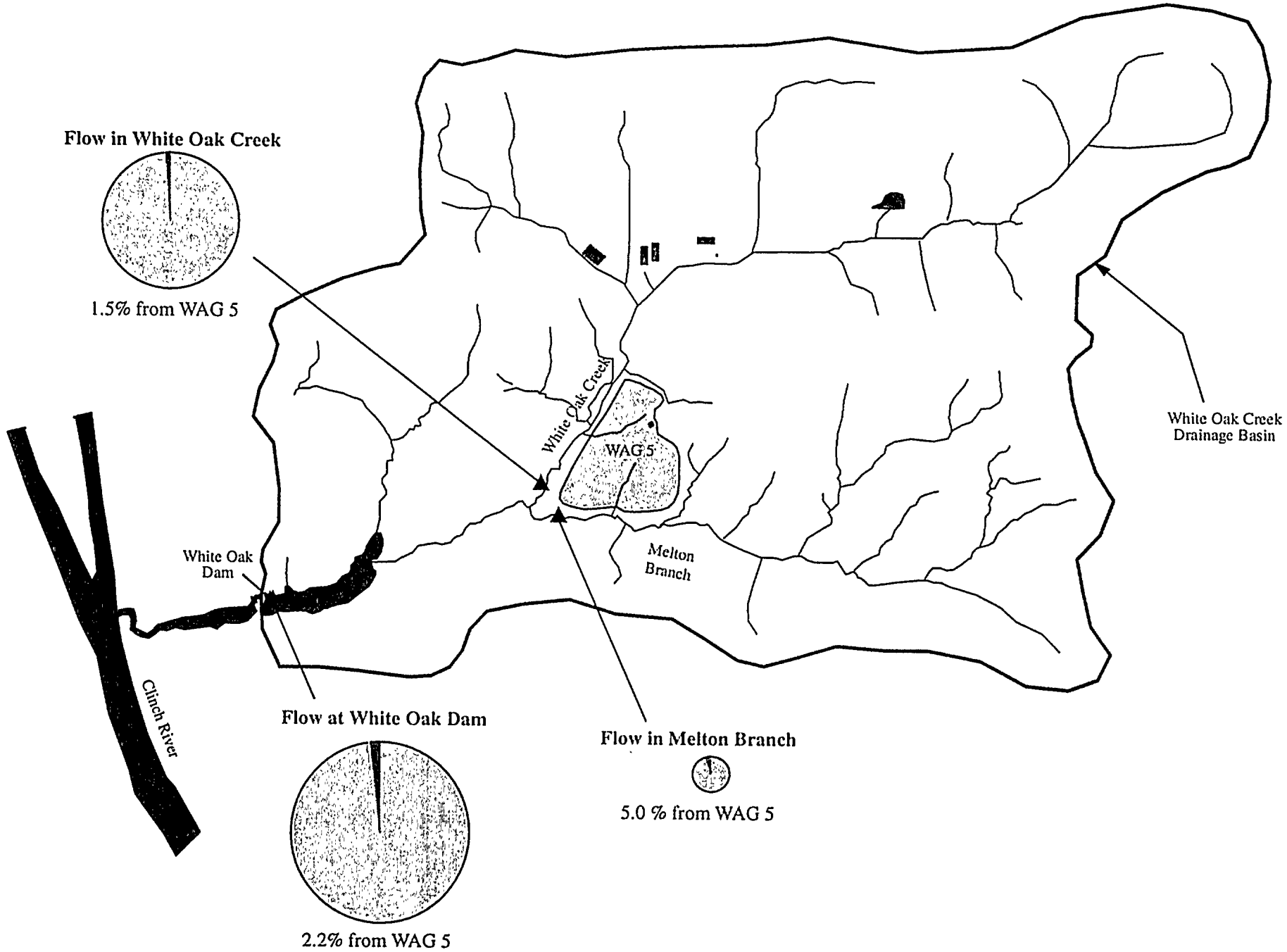

Fig. B1.5.7. Relative discharge in White Oak Creek, Melton Branch, and White Oak Dam.

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B1.5.3 Precipitation Patterns and Site Rainfall Data

Precipitation is an important component of the hydrologic system because it controls the quantity of discharge from WAG 5. The precipitation gauge with the longest period of record in the Oak Ridge area is the ATDL monitoring station approximately 7 miles to the north of WAG 5. The long-term hourly rainfall record (1953–1990) was analyzed for seasonal variations and extreme occurrences (National Climatic Data Center 1990).

The average annual precipitation is 53.6 in.; average monthly precipitation volumes recorded at ATDL are listed below.

MONTH	VOLUME (in.)
January	4.73
February	4.75
March	5.59
April	4.12
May	4.34
June	4.21
July	5.11
August	3.75
September	3.77
October	3.02
November	4.49
December	5.73

Assuming a 6-h period of no precipitation to divide storm events, the rainfall time series was separated into storm events. Based on the 38-year period, 116 storms are expected in an average year. The average number of storms varies from month to month; the maximum (12.2 storms) occurs in July and the minimum (6.9 storms) occurs in October. The annual average storm duration is 7.2 h; average monthly storm duration varies from approximately 4 h in the summer to approximately 11 h in December and January. The average annual storm volume is 0.46 in., and the average dry period between storm events is 75.5 h.

A frequency analysis was performed on the maximum rainfall amounts for various durations (1 to 24 h) for the 38-year rainfall record. A log-Pearson Type III distribution was fitted to ranked data points. Figure B1.5.8 shows the derived rainfall depth-duration-frequency relationships for each the duration and for return periods from 1.003 to 500 years.

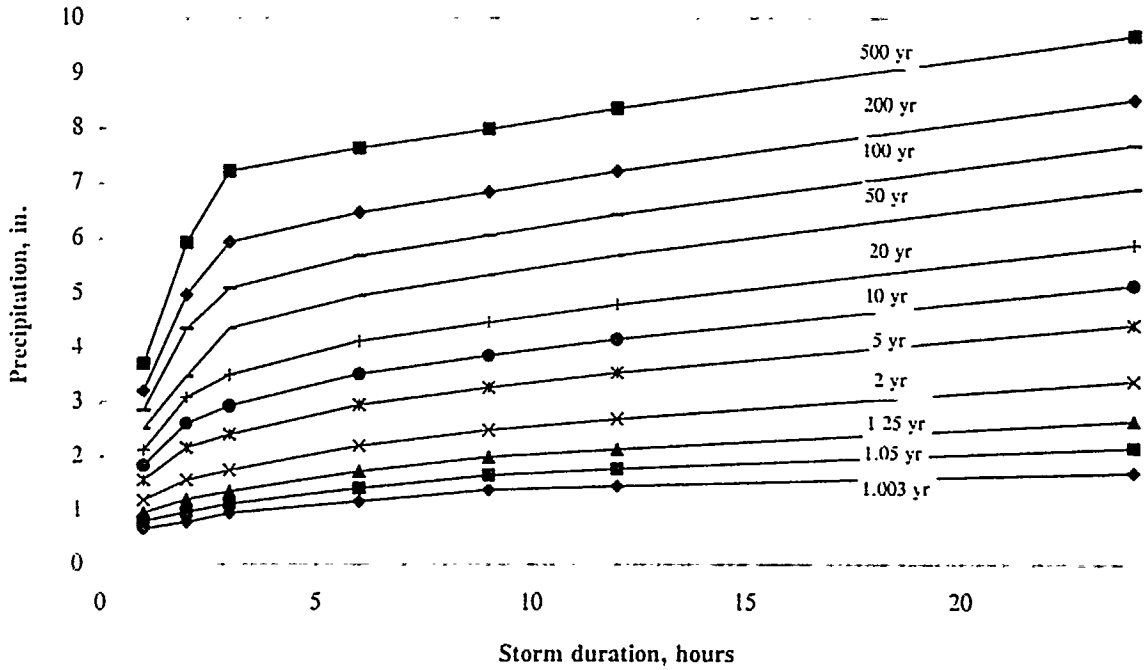


Fig. B1.5.8. Oak Ridge rainfall depth-duration-frequency.

The closest precipitation gauge to WAG 5 is at SWSA 4. The station is maintained by Energy Systems, and the data are recorded in breakpoint format. Figure B1.5.9 shows the monthly and maximum daily rainfall recorded from January 1993 to April 1994.

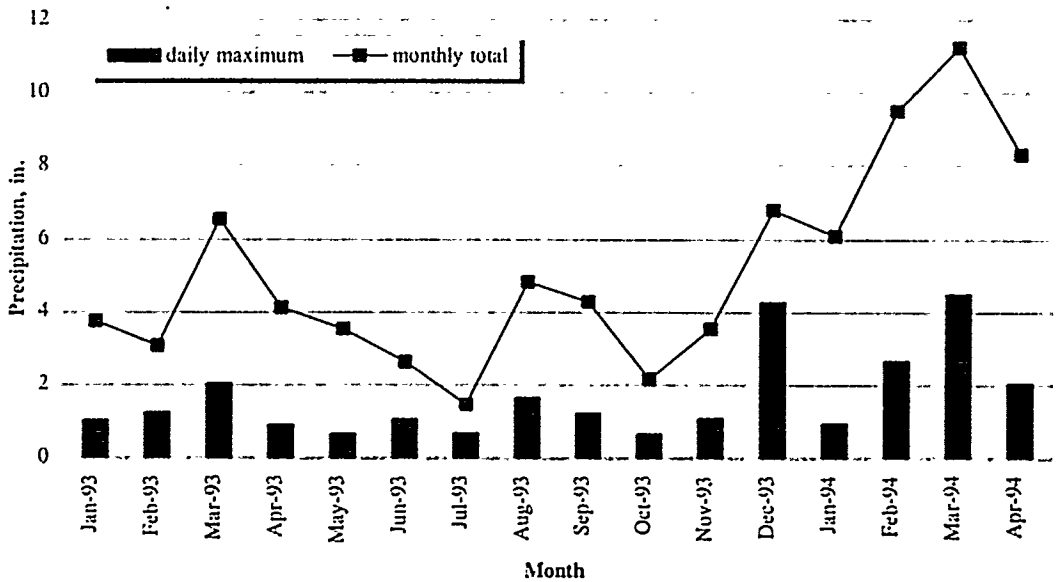


Fig. B1.5.9. SWSA 4 monthly and maximum daily precipitation.

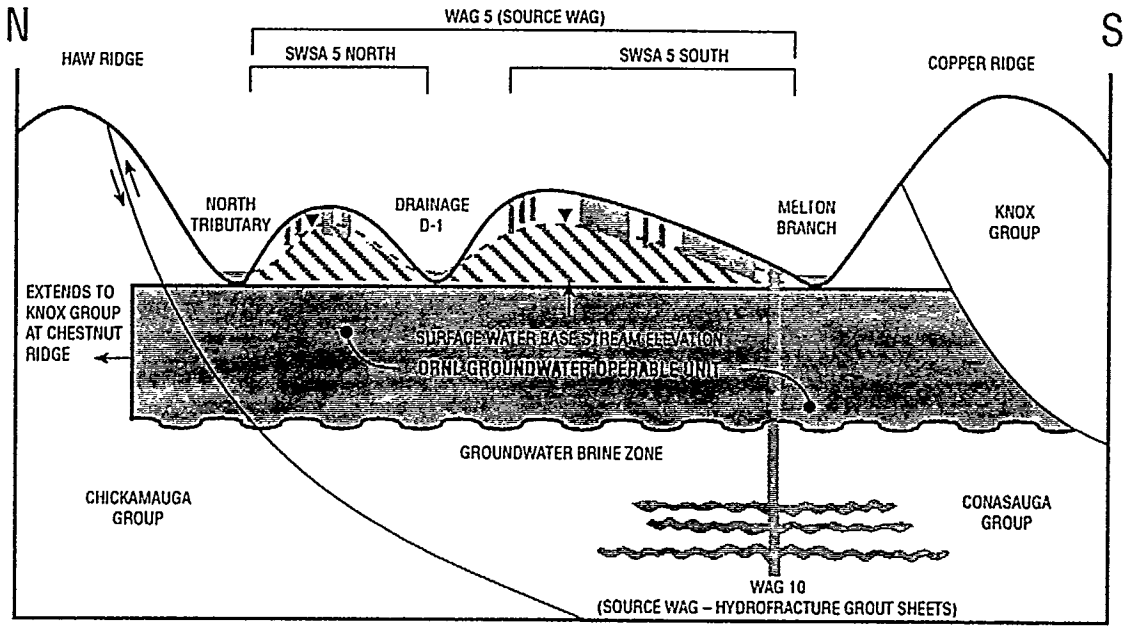
B1.6 GROUNDWATER HYDROLOGY

Shallow groundwater at WAG 5 is a primary release mechanism and contaminant migration pathway linking buried wastes in the source areas to nearby surface waters in WAG 2 (primarily Melton Branch) and thus downstream areas, including areas off the ORR. Groundwater also constitutes a potential exposure pathway for the residential land use scenario evaluated for the baseline human health risk assessment. The hydrogeology of Melton Valley (and the ORR in general) has been examined in great detail by others (e.g., Moore and Toran 1992; Solomon et al. 1992; Webster and Bradley 1988). These documents contain a detailed analysis of the Melton Valley groundwater system and formed the basis of the WAG 5 hydrologic model developed during the scoping phase of the RI. This model, which identified the stormflow zone, vadose zone, water table interval, and deeper groundwater as the principal components of the groundwater system at the site, is described in the Technical Summary (Volume 1). The primary zones of interest for the WAG 5 RI are the water table interval and stormflow zone. Deeper groundwater, defined as that below the base level of the surrounding streams (White Oak Creek and Melton Branch), will be addressed as part of the Melton Valley GWOU. The relationship between shallow groundwater at WAG 5 and the deeper groundwater in the GWOU is schematically depicted in Fig. B1.6.1.

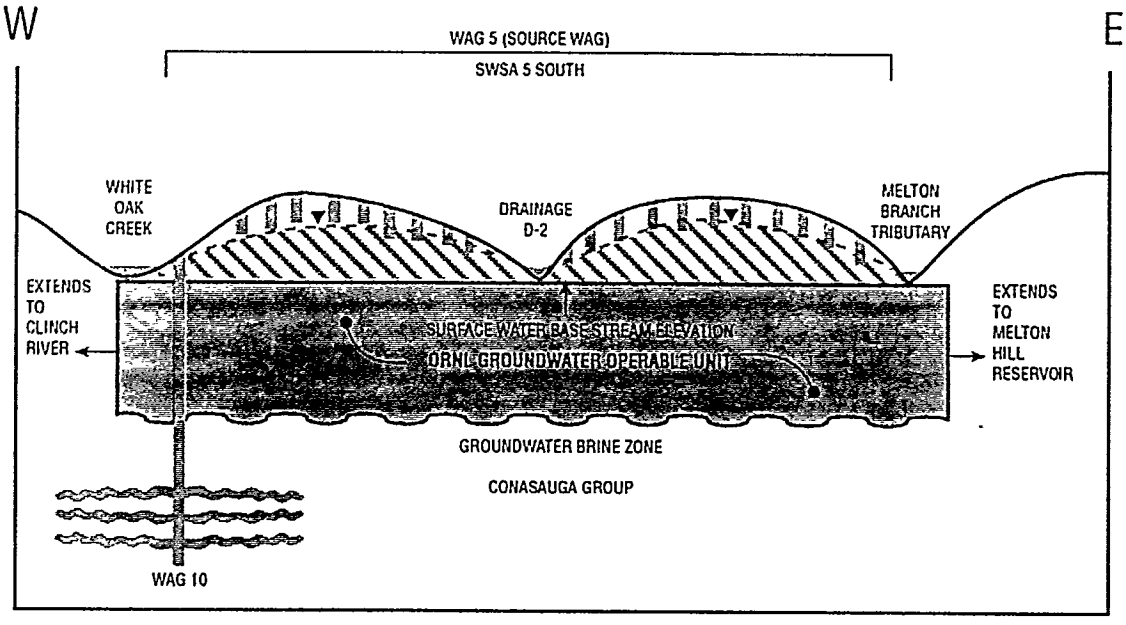
The following section discusses groundwater components of the hydrologic model as they relate to the release, migration, and discharge of contaminants from WAG 5 source areas and presents site-specific data concerning the physical, chemical, and hydraulic characteristics of the stormflow zone, vadose zone, and water table. Water level data were used to define groundwater circulation pathways (vertical and horizontal) and the relative significance of the potential flow pathways in the context of total discharge (i.e., hydrologic flux attributed to groundwater) from the site. It is important to emphasize that this section was not intended to be a complete characterization of the hydrogeology of WAG 5 but rather a focused summary of those attributes of the groundwater system that are most significant from the perspective of the conceptual site model. A more thorough and detailed analysis of the groundwater system in Melton Valley is presented in Solomon et al. (1992) and Moore and Toran (1992) and references therein.

B1.6.1 Stormflow Zone

The stormflow zone is a shallow layer of relatively high permeability (both horizontal and vertical) that extends from just below the ground surface to the approximate base of the root zone. Depending on the type of vegetation, the zone may extend as deep as 6 ft or more. Areas with paving or otherwise lacking in vegetation do not have stormflow zones. Because the vertical permeabilities in the underlying vadose zone are typically much lower, the stormflow zone becomes saturated during large precipitation events and transmits water laterally (downslope) to surface water systems (Moore 1989). Solomon et al. (1992) reported that >90% of active subsurface water flow occurs in the stormflow zone.



a) North/south section through WAG 5



b) East/west section through WAG 5

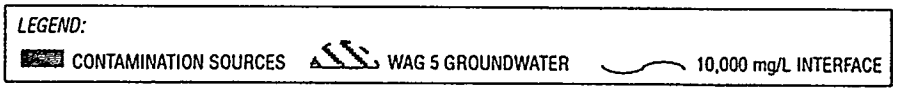


Fig. B1.6.1. Schematic description of the relationship between the source (WAG 5) and the integrator (GWOU).

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Occurrence

The occurrence and hydrologic significance of the stormflow zone was investigated through a variety of methods, including

- installation, sampling, and water level monitoring (discrete and continuous) of specially constructed stormflow zone piezometers (ORNL Nos. 4099–4112);
- evaluation of flow hydrographs from surface water monitoring stations; and
- modeling of the surface water system at the site.

Fourteen stormflow piezometers were installed in 2- or 3-well, downslope transects, as shown in Figs. B1.5.4 and B1.5.6. Locations included backfilled trenches, upland and hillside areas with disturbed soils, and hillside areas having apparently undisturbed soils. Monitoring of water levels and post-storm samples from stormflow piezometers indicate that the WAG 5 stormflow zone is active from late fall to spring when evapotranspiration is at a minimum and rainfall abundant.

Stormflow zone responses to precipitation events for selected piezometer transects are shown in Figs. B1.5.4 and B1.5.6. In general, an active stormflow zone is present over much of the site but is often disrupted in the backfill materials over trenches, most likely due to lateral variations in the vertical permeability of the backfill material. The result of these disruptions is that the stormflow zone does not constitute an uninterrupted pathway (to the downslope discharge point) for subsurface flow. When the stormflow encounters areas of higher vertical permeability in trench backfill, potentially significant quantities of additional water (i.e., beyond that which directly infiltrates) are introduced into the trenches.

Flow hydrographs from drainages D-1, D-2, and D-3 also indicate an active stormflow zone that contributes, on average, approximately 30% of the total discharge (flow) in these drainages. The piezometer and surface water flow data support the conclusion that the stormflow zone is not the primary pathway for subsurface water migration at WAG 5. The zone is probably of greater significance because of its role in the recharge of water to the trenches and the resulting mobilization/release of contaminants from trench wastes. This mechanism is highlighted in the conceptual model discussion in Volume 1.

Hydraulic parameters

The RI did not include measurements of hydraulic conductivity, porosity, specific discharge, or other hydraulic parameters for the stormflow zone; parameter values presented here were obtained from previous investigations considered relevant to subsurface conditions in WAG 5. McMaster (1967) showed that the vertical permeability of the stormflow zone is greater than the 1-h precipitation intensity in vegetated areas (3 in. for 100-year recurrence). Moore and Toran (1992) gave the mean infiltration rates for the stormflow zone as 3.6 ft/day and for grassland and forested areas as 28.9 ft/day. Kirkby (1988) states that both vertical hydraulic conductivity and porosity decrease with depth, which may be due to the concentration of roots in the upper soil layer. The hydraulic conductivity of the stormflow zone has been calculated to have a geometric mean of 28.9 ft/day near the top of the zone and 0.11 ft/day near the base (Moore 1989); however, this actual value may be halved due to air trapped in the pores as the water infiltrates (Bouwer 1978).

Moore and Toran (1992) give the average porosity of 0.4 with a specific yield of 0.035 for the stormflow zone. Watson and Luxmoore (1986) found that macropores and mesopores occupy only 0.2% of the soil volume but account for 96% of the infiltration. The effective porosity of macropores and mesopores for vertical and lateral flows is only about 0.002 (Moore 1989).

B1.6.2 Vadose Zone

The vadose zone at WAG 5 consists of the unsaturated interval between the stormflow zone or ground surface (where stormflow zone is absent) and the water table. Because the water table generally occurs near the bedrock/regolith interface, the vadose zone consists almost entirely of regolith, which is dominated at the site by fill materials, saprolite, and buried wastes.

Occurrence

A vadose zone is present beneath most of WAG 5; it is transient in nature where the water table rises up to the ground surface or where the stormflow zone and water table intersect (e.g., at the margin of the Melton Branch and White Oak Creek floodplains). The thickness of the vadose zone fluctuates seasonally with changing elevations of the water table, which in some areas may extend it into bedrock during low base conditions. Recharge through the vadose zone is episodic and typically is restricted to discrete features such as relict fractures in the saprolite. In contrast to the stormflow zone, the predominant direction of flow is vertical (downward) to the water table.

From a conceptual model perspective, the vadose zone is important because contamination released from upland trenches (i.e., those that do not become inundated) must travel through the vadose zone to reach the shallow groundwater. Interactions between the contaminants and matrix materials of the regolith have a significant influence on the type and magnitude of contamination that actually reaches the water table. Where these interactions entail the transfer of significant levels of contamination to the matrix, the process can result in the creation of secondary sources within the vadose zone.

Hydraulic parameters

Moore (1989) gave a geometric mean of hydraulic conductivity as 0.0062 ft/day. The total porosity of the vadose zone is probably the same as that of the stormflow zone (0.3–0.5; Solomon et al. 1992) with an average effective porosity of about 0.0042 (Moore 1989). The low effective porosity is consistent with the observation that most flow occurs through only a few permeable features (e.g., fractures). The average annual recharge through the water table has been calculated as approximately 0.78 in. (Solomon et al. 1992).

B1.6.3 Shallow Groundwater

The shallow groundwater interval at WAG 5 is the saturated interval in which most groundwater flow occurs and generally corresponds to the water table interval identified by Solomon et al. (1992). The designation usually is applied to the upper 10–30 ft of saturated material below the water table. The actual depth (and thickness) varies between locations depending on topography, degree and depth of weathering, and structure, especially fracture abundance, orientation, and interconnectedness. In most areas, the shallow groundwater interval is within the saprolitic regolith

materials, but it may extend upward into fill or natural soils and/or downward into the upper weathered portion of the bedrock.

Occurrence

The water table typically occurs within the regolith and usually within the saprolite, but at some locations may occur within the bedrock, particularly during the dry season. Moore (1989) and Solomon et al. (1992) identified a water table interval corresponding with the transition from regolith to bedrock (i.e., the top of weathered bedrock). As measured during the RI, the depth to the water table ranged from less than 1 ft to more than 40 ft. Shallow water tables were typically associated with WAG 5 drainages and the floodplains of White Oak Creek and Melton Branch; depth to water increased to a maximum at the topographically highest areas on the site. The water table is typically highest between February and April (high base conditions) and lowest between August and October (low base conditions).

Water table surface maps were contoured based on water level measurements during high and low base conditions (Figs. B1.6.2 and B1.6.3, respectively). These maps were generated using data from wells judged to be representative of water table conditions during high or low base conditions. These two contour maps show relatively constant hydraulic gradients with the water table surface mimicking site topography. Solomon et al. (1989, p. 3-18) observe this relationship by noting that

> Changes in saturated thickness with the inverse of hydraulic gradient from one topographic location to another explain the common observation that the water table is a subdued replica of land surface, because the product of transmissivity and hydraulic gradient is nearly constant at all locations along any flow path.

Figure B1.6.4 presents representative well hydrographs based on continuous water level data collected during 1993 and 1994. Water levels typically rose 4 to 8 ft in topographically higher areas and 1 to 4 ft in areas near drainages and White Oak Creek and Melton Branch. The maximum water level increases were approximately 14 ft measured at a topographically high well (0455) and also in wells 0453 and 1596 in area A.

Hydraulic parameters

The shallow groundwater system at WAG 5 is a heterogeneous, anisotropic aquifer dominated by fracture flow. Soil samples from below the water table indicate that some intergranular flow may also be present due to weathering and dissolution/leaching of bedrock materials. In addition, some saprolitic horizons have dense fracture networks that may approximate a porous medium for flow considerations. Porosity in the regolith was not measured for the WAG 5 RI but is probably in the range of 0.10–0.15 for granular regolith and 0.001–0.1 for saprolite (Moore 1989); however, much higher porosities are possible (e.g., 0.3–0.5) depending on the degree of weathering and lithology of parent bedrock material. Bedrock porosity is controlled by the aperture and spacing of fractures and is highly variable; Solomon et al. (1992) report effective porosity (i.e., that fraction of the rock volume that permits fluid flow) of about 0.00035. A tracer test at another burial ground in Melton Valley yielded a regolith porosity of 0.03 (Webster and Bradley 1988). Specific yields for the regolith, an indication of the storage capacity of the medium, average 0.0025 near the water table (Moore 1989).

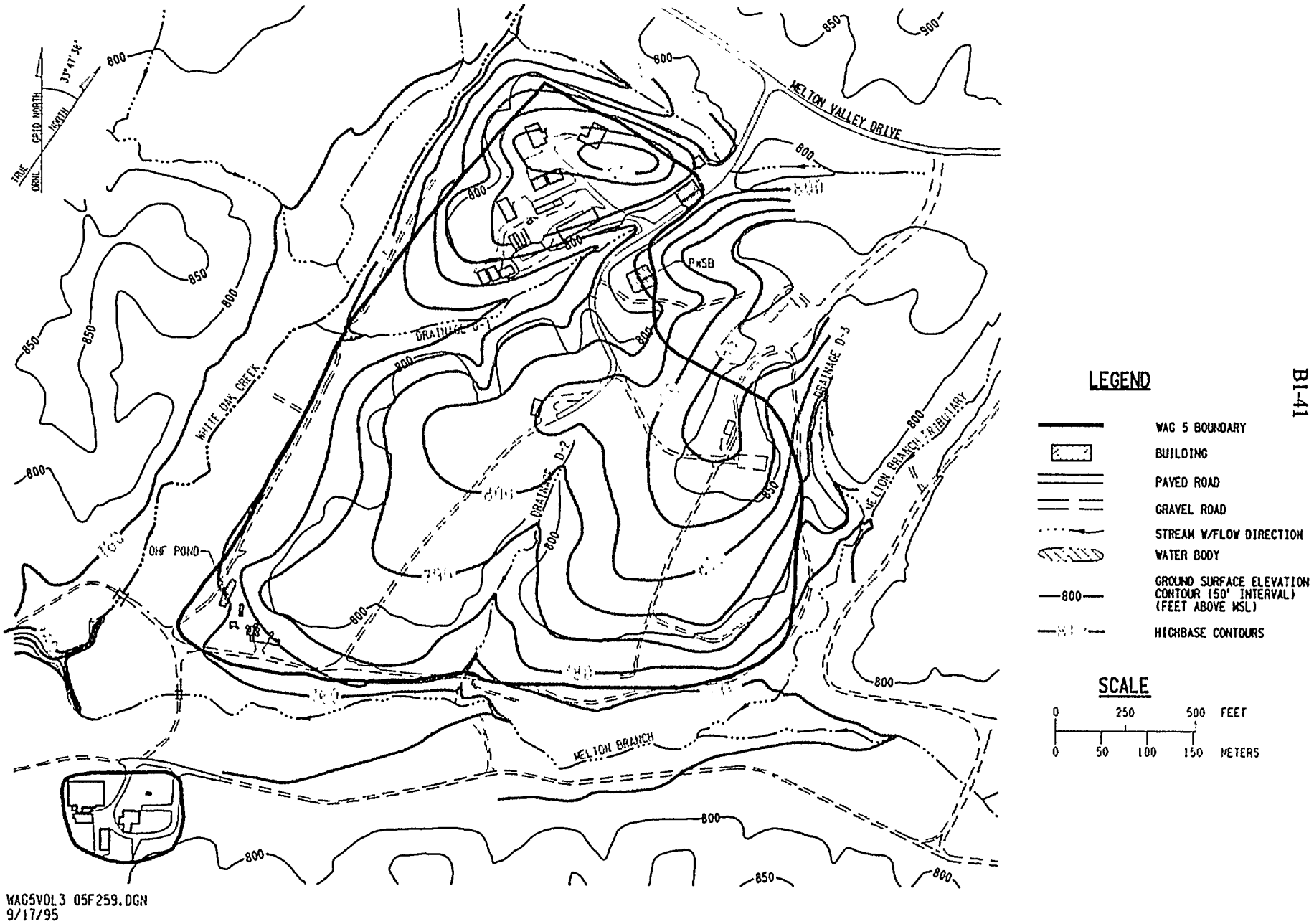


Fig. B1.6.2. Highbase groundwater table (March 23 - 25, 1993)

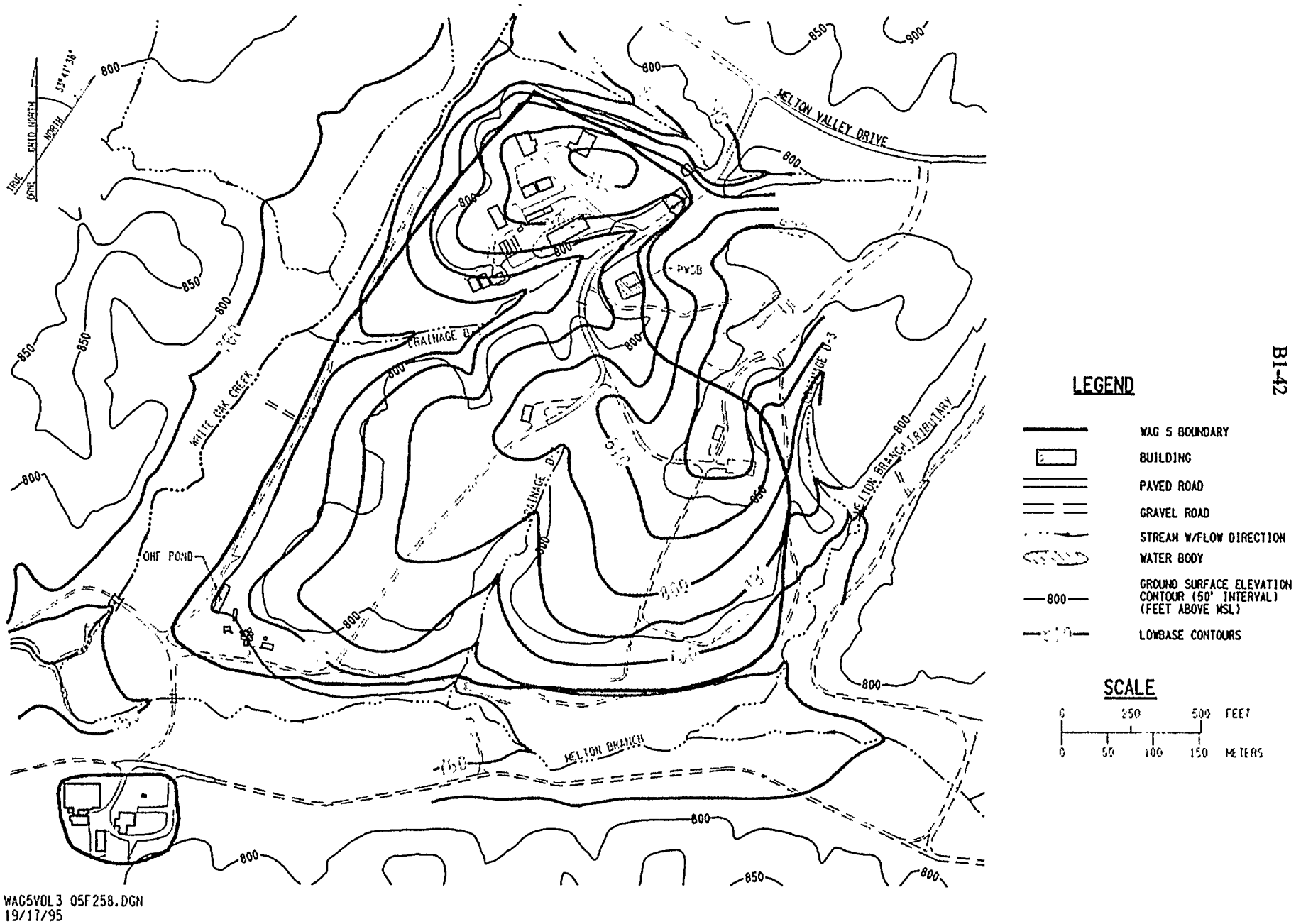
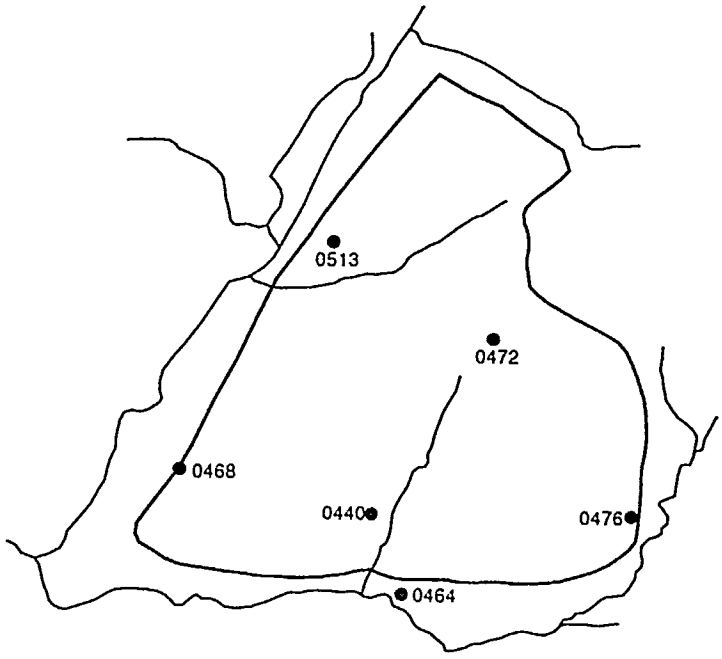


Fig. B1.6.3. Low base groundwater table (August 29-30, 1993).



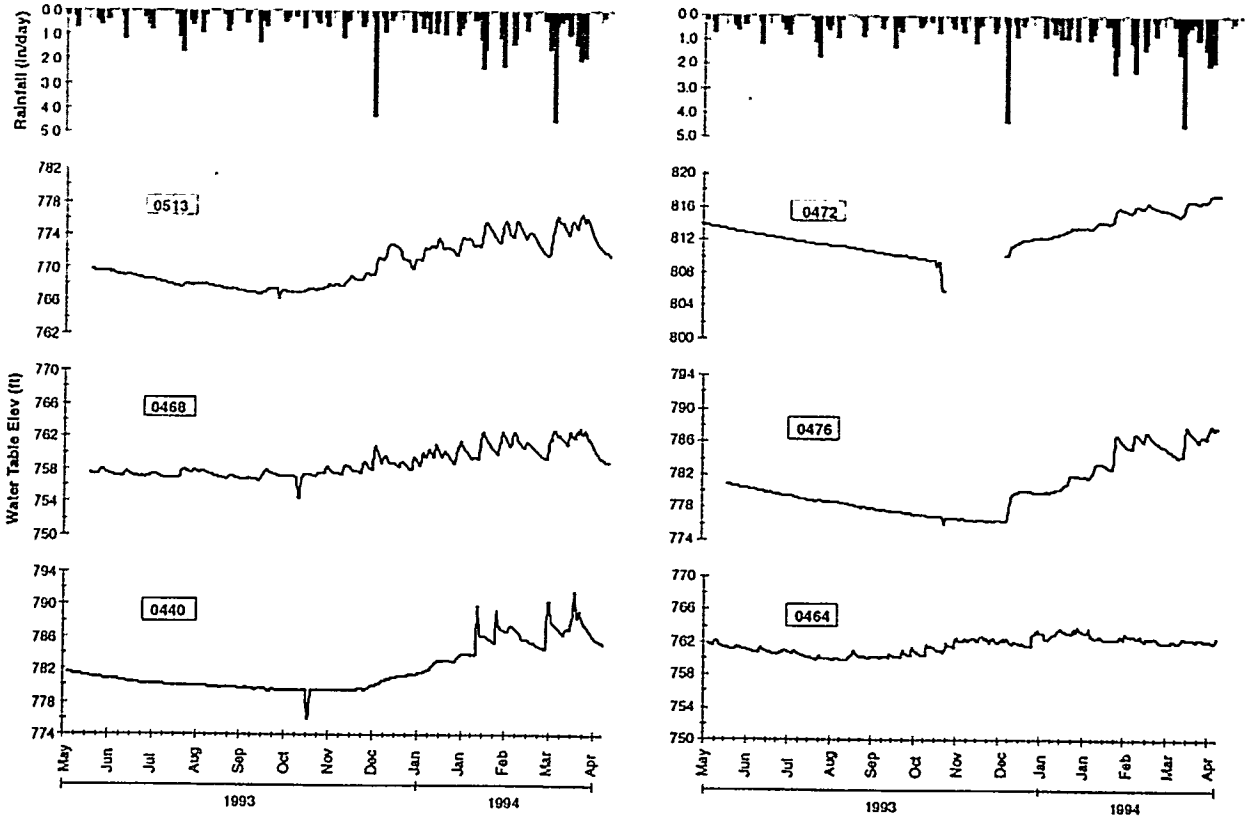


Fig. B1.6.4. Sample hydrographs for WAG 5 shallow wells.

Hydraulic conductivity values for the shallow, intermediate, and deep groundwater intervals were obtained from 90 single-well slug tests (including values for the 4 newly installed wells, 4113 through 4116). Test results (Fig. B1.6.5) show higher conductivity in the shallow zones (usually in saprolitic regolith) and much lower conductivity in the deep bedrock. Shallow groundwater has an average hydraulic conductivity (based on the geometric mean of 71 tests) of approximately 0.16 ft/day. These values correlate relatively well with slug-test-derived average conductivity values of 0.15 ft/day from Moore (1989) and 0.26 ft/day from Moore and Toran (1992).

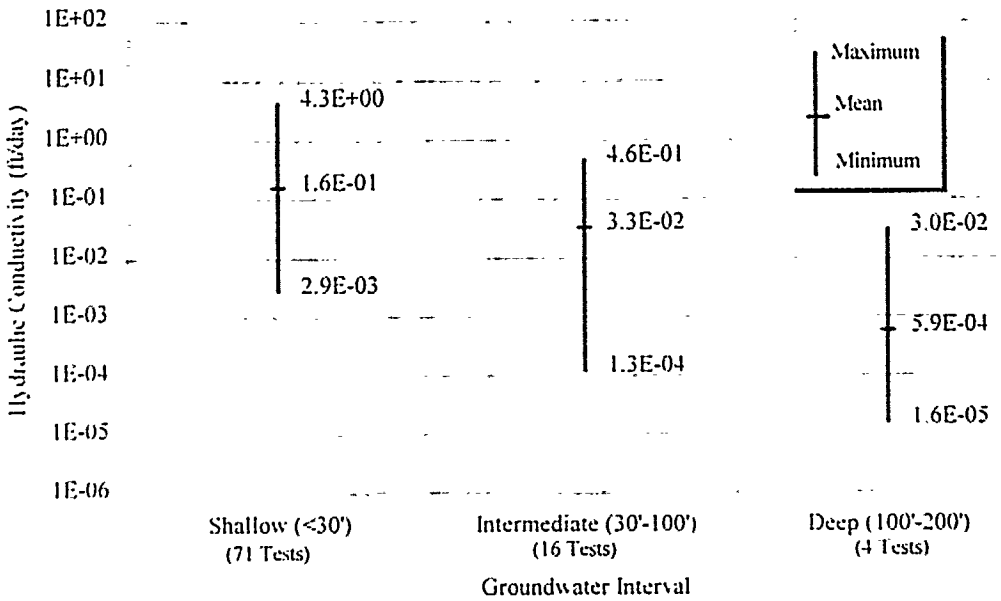


Fig. B1.6.5. Hydraulic conductivity as a function of groundwater depth.

Horizontal hydraulic gradients were calculated for wet and dry seasonal conditions using water level data from wells determined to be aligned along a given flowpath. Representative gradients for 10 shallow well pairs are summarized in Table B1.6.1. The horizontal gradients fluctuate considerably depending on topographic location, and steeper gradients are present where topographic slopes are also steep (as expected, given the relationship between water table surface and topography). The horizontal gradients decline during the dry season due to the greater seasonal fluctuations in water levels associated with higher elevations. Average horizontal hydraulic gradients average 0.07 during the wet season and 0.06 during dry conditions.

Vertical hydraulic gradients were calculated using the 1993 water level data from adjacent well pairs completed in the shallow and intermediate groundwater intervals (Table B1.6.2) for both wet (March 1993) and dry seasonal (September 1993) conditions. Gradients were computed using the midpoint elevations of the screened intervals for the upper and lower wells.

The computed vertical gradients ranged from 0.14 ft/ft (positive indicating upward potential) to -0.11 ft/ft. Downward vertical gradients (i.e., downward flow potential from shallow to intermediate zone) indicative of recharge areas generally existed at well pairs in upland locations and along the slopes, and upward gradients, indicating potential discharge, were found in the White Oak Creek and Melton Branch floodplain areas.

Table B1.6.1. Horizontal hydraulic gradients

Well Pairs	Study Area Location	Topographic Slope (%)	Distance (ft)	Wet Season		Dry Season		Gradient Variation from Wet to Dry Season
				Elevations	Gradient	Elevations	Gradient	
0451 0452	SWSA 5SE	3.5	275	810.78 802.83	0.029	801.80 794.94	0.025	0.004 ↓
0440 0439	SWSA 5SW	5.9	168	787.58 777.43	0.060	779.20 771.95	0.043	0.017 ↓
0666 0669	OHFP	12.0	277	780.33 757.14	0.084	774.98 754.89	0.073	0.011 ↓
0518 0519	SWSA 5N	9.7	190	807.56 790.97	0.087	802.37 787.91	0.076	0.011 ↓
0528 0526	PWSB	14.7	300	818.38 791.57	0.089	809.87 789.52	0.068	0.021 ↓
0432 0132	WOC	19.0	240	788.65 762.26	0.110	782.40 759.60	0.095	0.015 ↓
0518 0982	SWSA 5N	8.4	530	807.56 772.21	0.067	802.37 767.84	0.065	0.002 ↓
0447 0457	WOC	6.3	282	777.22 758.56	0.066	774.24 755.69	0.066	---
0452 0973	SWSA 5SE	10.0	442	802.83 771.02	0.072	794.94 767.89	0.061	0.011 ↓
0666 0977	OHFT	9.3	289	780.33 760.46	0.068	774.98 756.03	0.065	0.003 ↓

Table B1.6.2. Groundwater vertical gradients for wet and dry seasonal conditions

ONRL NO.	Location	Screened Interval	Screened Mid Point (ft)	Wet Season (Mar-93)	Vertical Gradient (+ upwards)		Dry Season (Sep-93)	Vertical Gradient (+ upwards)	
0472	Upland	15-19.4	17.2	814.75			810.84		
0471		89-98.1	93.55	806.23	-0.11	↓	802.82	-0.11	↓
0476	Slope	25-29	27	784.72			778.33		
0475		90-100.5	95.25	783.87	-0.01	↓	781.02	0.04	↑
0766	Slope	7.5-12.7	10.1	760.61			757.44		
0767		27-46.2	36.6	764.23	0.14	↑	760.64	0.12	↑
0770	WOC	4-14.9	9.45	758.41			755.27		
0771	Floodplain	37-43	40	758.23	-0.01	↓	755.10	-0.01	↓
0772	WOC	5.5-16.1	10.8	757.49			754.82		
0773	Floodplain	40-51.5	45.75	757.65	0.00	↑	754.42	-0.01	↓
0774	WOC	6-11.2	8.6	757.46			753.82		
0775	Floodplain	36-43.6	39.8	757.83	0.01	↑	754.02	0.01	↑
0776	Slope	9-19.9	14.45	765.59			760.66		
0777		38-49.3	43.65	760.18	-0.19	↓	756.50	-0.14	↓
0969	MBT	4-15.3	9.65	782.55			780.40		
0970	Floodplain	58-74.7	66.35	783.97	0.03	↑	781.22	0.01	↑
0973	Near	9.1-15.3	12.2	774.19			771.23		
0972	Floodplain	59-74.7	66.85	771.02	-0.06	↓	767.89	-0.06	↓
0975	Lower	16.5-28	22.25	771.66			768.02		
0976	Slope	63.2-83.9	73.55	769.60	-0.04	↓	765.19	-0.06	↓
0978	Slope	9-19.7	14.35	764.64			760.34		
0979		32.5-49.3	40.9	761.69	-0.11	↓	758.37	-0.07	↓
0981	D-1	8-19.7	13.85	761.93			756.74		
0980	Floodplain	33.6-49.7	41.65	760.44	-0.05	↓	758.41	0.06	↑
0983	Upland	8-24.7	16.35	785.46			782.12		
0984		58-79.7	68.85	781.98	-0.07	↓	779.53	-0.05	↓

Notes: 1) * High base water levels taken in Jan-93
2) Italic well ID numbers indicate locations inside WAG 5 boundary
3) Abbreviation: WOC - White Oak Creek MBT - Melton Branch Tributary D-1 - Drainage D-1

Continuous water level data were obtained from three 3-well clusters in WAG 5. Figure B1.6.6 shows the locations of the wells and water level hydrographs based on 1993–1994 monitoring data. The hydrographs for well cluster 461-463-464, in the southern portion of SWSA 5 South near the Melton Branch floodplain, show a persistent upward gradient, indicating potential discharge conditions. Farther uphill in SWSA 5, well cluster 440-460-458 shows a downward gradient, indicating recharging conditions. A more complex relationship involving alternating recharge and discharge conditions and changes in the directional component with depth was noted in well cluster 468-467-466. This well cluster, located in the southeastern corner of WAG 5 and just above the White Oak Creek floodplain, had an upward gradient between the deep and both intermediate and shallow zones; however, a downward gradient was apparent between the shallow and intermediate zones, which reversed during the wetter months of January–April 1994.

The continuous water level data provide further evidence of the complexity of the groundwater flow regime in WAG 5. Topographic locations are generally reliable indicators of vertical gradients, but conditions may vary significantly at a given location. The variability is probably due to the anisotropic, fracture-dominated flowpaths in both the saprolite and bedrock; hydraulic gradients (and flow potential) can vary significantly depending on which fractures or fracture zones are intercepted by the wells, even when such wells are only several feet apart.

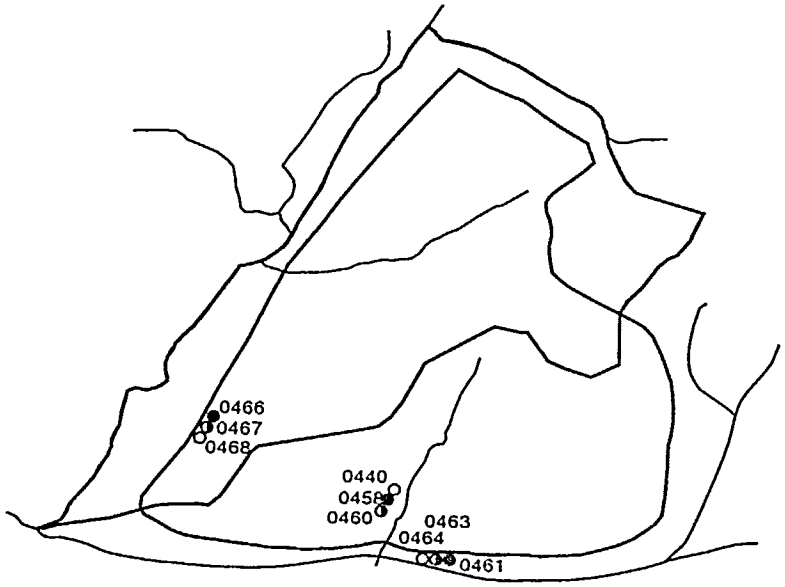
B1.6.4 Trench Hydrology

Trench hydrology has a significant role in the release and transport of contaminants from WAG 5 and thus is an important component of the site conceptual model. As illustrated in Figs. B1.6.7 and B1.6.8, inundation of the trenches is widespread in the downhill (southern) portion of SWSA 5 South and, during the wet season, in SWSA 5 North. Segments (or in some cases the entire length) of nearly half the trenches in SWSA 5 South are inundated during the wet season. The thickness of the saturated zone within the trench varies with topographic position and season, but during the wet season the water table rises to the point that many trenches are entirely filled with water.

Perched water tables are formed when the trenches fill with water derived from infiltration that has accumulated in the lower ends of the trenches (i.e., bathtubbing). Another source of recharge is where the trench intercepts the stormflow zone from upgradient/upslope areas (as discussed above). The point at which a trench is bathtubbing versus filled with water from a rising water table is not always readily discernible on the basis of water level data. Webster and Bradley (1988) also investigated the interaction of trench water and groundwater and reported similar conclusions.

After injecting water in trench 117, Spalding (1984) calculated the fractional void space as 0.41 and a saturated hydraulic conductivity of the formation defining the trench as 0.096 ft/day, which is similar to that of the surrounding overburden. Based on water level fluctuations during the injection in the same trench, Spalding (1984) also noted that the intrinsic conductivity in the trench is very high (>1E+3 ft/day).

Discharge of trench water may occur in several ways. For perched water tables (bathtubbing trenches), leakage through the trench bottom (and sides) may be a significant source of contaminated recharge to the water table. Webster and Bradley (1988) suggested that trench water may also overflow into the stormflow zone. Flow from trench to trench is also a potentially significant



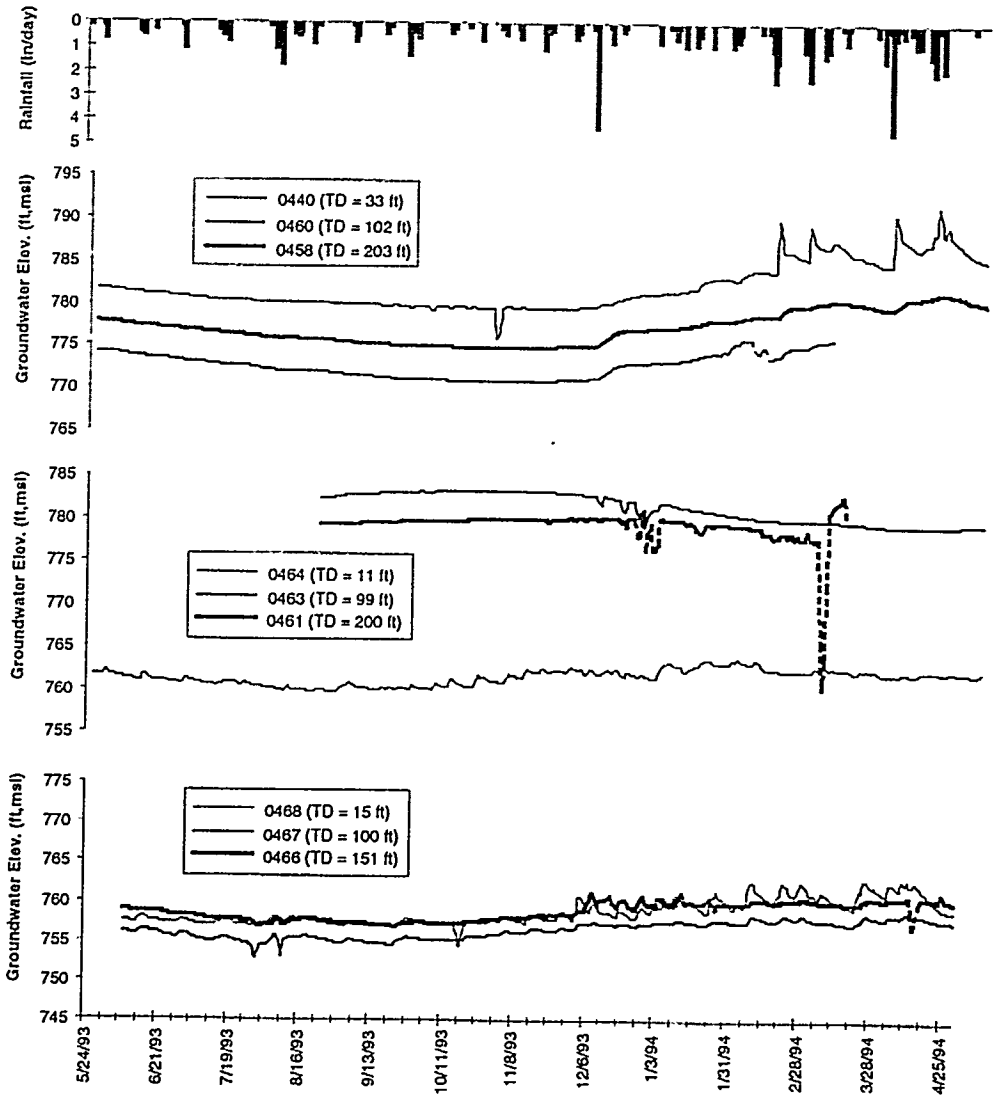


Fig. B1.6.6. Hydrographs for WAG 5 well clusters.

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Fig. B1.6.7. Trench inundation levels (August 1993).

Fig. B1.6.8 Trench inundation levels (March 1993).

pathway where trenches are in proximity. During the injection of water into trench 117, Spalding (1984) observed responses in a number of nearby trench wells and monitoring wells outside the trenches.

Continuous water level instrumentation was installed in clusters of trench drive points and water table monitoring wells to evaluate the response of trench water levels to precipitation events and compare this response to that observed in nearby water table wells. Instrumentation was installed in SWSA 5 areas A and C; in both areas, drive points were installed in the toes of the trenches that were inundated year-round (i.e., the water table was within the trenches).

There was only one rain event during the time the instruments were installed in area A. This event caused a 1- to 2-ft rise in the water table in wells 0453 and 2045, but had a negligible effect in trench drive points 4227 and 4231. Monitoring in area C was conducted over a period in which six precipitation events occurred. Rapid responses to the events were observed in water table wells 4303 and 0436. Water levels in the trenches also rose, but the overall response was much more subdued. When the water levels rose in the trenches, the water level remained elevated, and there was not an appreciable decline between precipitation events (Fig. B1.6.9).

As described above, Spalding (1984) reported that the conductivity and void space (porosity) of the trenches was similar to that measured for the overburden. The variations in water level response to precipitation between the trenches and adjacent regolith indicate that the hydraulic properties of the trenches may in fact be quite different from those of the regolith. Infiltration into the trenches, for example, should be more rapid due to the higher vertical permeabilities associated with the heterogeneous mixture of wastes and backfilled regolith materials. Higher infiltration rates should produce a more rapid response to precipitation than that observed for the water table within adjacent, undisturbed regolith. The fact that the opposite response was observed may be due to a much higher void space—and storage capacity—within the trench. Even with higher infiltration rates, filling of the these voids would require considerably more time (and volume) than needed to fill the pore space in the undisturbed regolith. In hydraulic terms, if the specific yield of the trenches were significantly higher than that of surrounding regolith, the volume of water required to raise the water table a unit length would be much larger than that associated with the regolith. For a given precipitation event, the combination of higher infiltration rates and specific yields may explain the subdued response to precipitation observed in the trench drive point wells.

Higher specific yields for the trenches would also explain why the water levels did not decline as rapidly as those in the undisturbed regolith. When this additional storage capacity of the trenches had filled with water, a much larger volume of water would have to be drained to achieve the same reduction in water level observed in the regolith. Because the drainage from the trenches is limited by the groundwater seepage velocities (specific discharge rates) of the underlying regolith and bedrock, the volume of water draining from them is more or less identical to that draining from undisturbed regolith. Because of the higher specific yields, drainage of this volume produces a measurable decline in the water table elevation within the regolith but has little to no effect within the trenches.

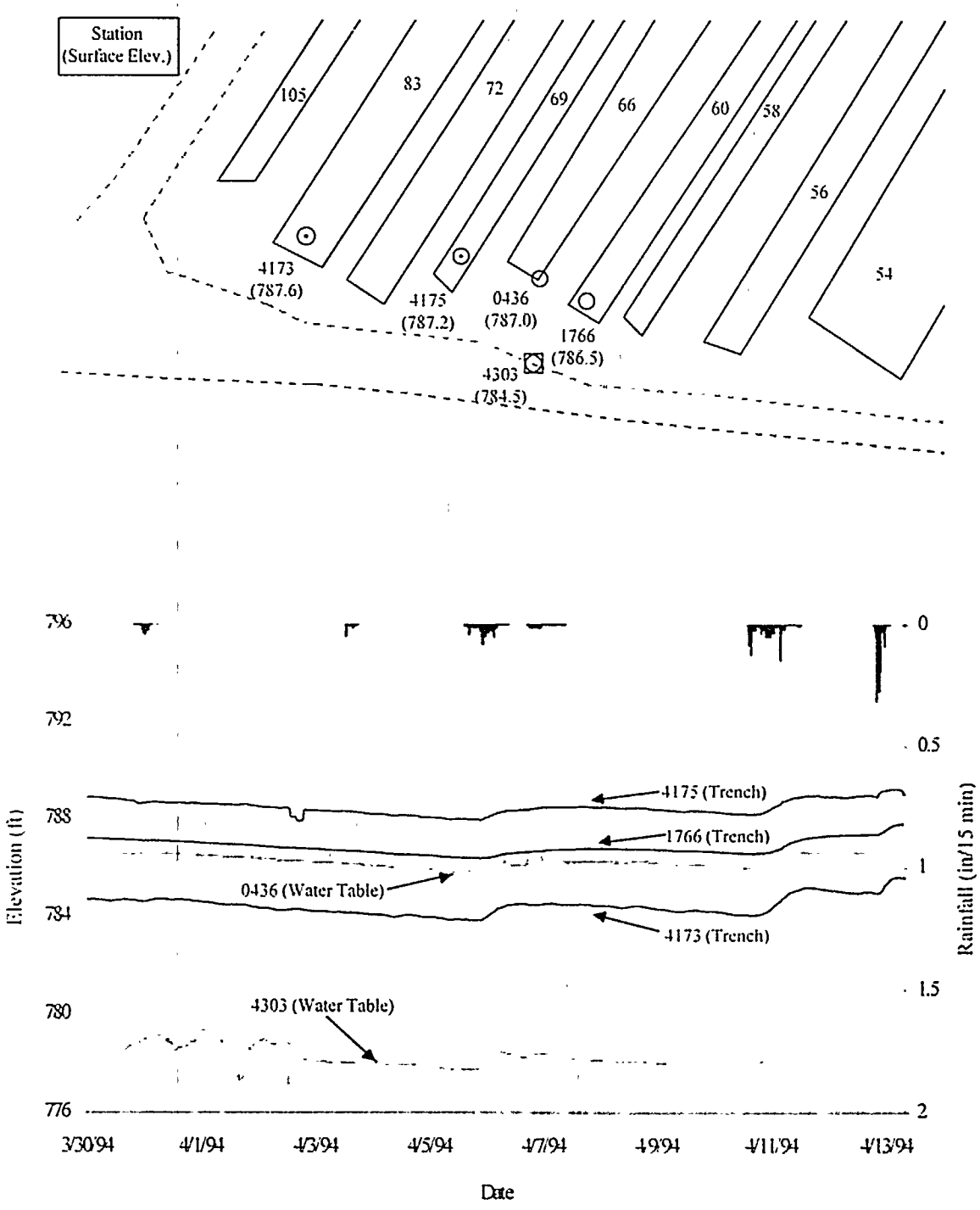

Fig. B1.6.9. Continuous hydrographs for wells in area C.

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B1.6.5 Deep Groundwater

The Melton Valley deep groundwater system is under confined conditions (Moore 1989) and has seasonal fluctuation of 1.5 to 14 ft (Webster 1976). Hydraulic conductivity values indicate that the deeper groundwater system begins at approximately 100 ft below ground surface. WAG 5 wells in the deep groundwater system had a geometric mean of hydraulic conductivity of 0.0013 ft/day for wells screened between 145 and 155 ft and 0.00038 ft/day for wells screened between 195 and 205 ft. Moore (1989) presented the geometric mean of hydraulic conductivity as 0.0014 ft/day for the deep system around ORNL. Based on 17 wells in Melton Valley, Solomon et al. (1992) reported a mean hydraulic conductivity of 0.0012 ft/day. The typical effective porosity and storativity were speculated to be in the range of 1×10^{-5} to 5×10^{-4} (Moore 1989).

As mentioned previously, the zone between 30 and 100 ft has vertical gradients based on topographical locations; however, the deeper zone from 100 to 150 ft has upward vertical gradients, indicating discharge to the shallower system. The zone from 150 to 200 ft has vertical gradients also based on topographical location [i.e., lower-lying wells have upward gradients (discharge), and higher-lying wells have downward gradients (recharge)].

The general flow pattern for the deeper system has water coming from shallower levels and eventually returning to shallow levels before being discharged to streams (Moore 1989).

B1.6.6 Groundwater Circulation Patterns and Specific Discharge

Circulation patterns in the shallow groundwater interval illustrate the close link between groundwater and surface water at WAG 5. The water table surface maps, hydraulic gradient data, seep monitoring data, and results of surface water modeling (using the HSPF code as described in Sect. B1.5) were used where possible to define and quantify the parameters related to circulation (direction and rate of flow, specific discharge, etc.). The WAG 5 water balance components derived from the HSPF simulation (calibrated using flow data from D-1, D-2, and D-3) include an average annual precipitation of 53.9 in., of which an average of 26.1 in. is lost to evapotranspiration, 4.8 in. becomes runoff, and the remainder (23 in.) infiltrates the soil. About 38% of this amount (8.3 in.) is removed via stormflow, while the rest (14.7 in.) percolates through the vadose zone and recharges the water table.

Stormflow follows topographic gradient, and maps of the surface topography can be used to illustrate potential flow directions. Because the zone is poorly developed or disrupted due to trench excavation and backfilling, roads, and other features, it is not possible to trace a continuous flow path from the point of infiltration to the point of discharge for most areas of the site. These disruptions also have the unintended consequence of increasing the net recharge of water through the trench wastes and probably explain the diminished stormflow component of WAG 5 in contrast to that described elsewhere for the ORR (e.g., Solomon et al. 1992).

Groundwater flow in the shallow zone accounts for most of the subsurface flow occurring at WAG 5. The shallow flow regime is complex due to the presence of discrete flow paths associated with fractures, which appear to be areally extensive and exhibit a relatively high degree of interconnection. As a result, movement of shallow groundwater is dominated by flow paths that conform to hydraulic gradients. Moore and Toran (1989) present a similar conclusion for the ORR hydrologic framework. At WAG 5, groundwater flow generally follows the topographic slope,

flowing from the upland areas toward seeps, springs, and other discharge points in the vicinity of the WAG 5 drainages, Melton Branch, and White Oak Creek. Figure B1.6.10 is a generalized depiction of this flow. Groundwater flow divides nearly coincide with surface water drainage divides such that most of the groundwater flow in the White Oak Creek and Melton Branch drainage basins is toward discharge points along White Oak Creek and Melton Branch, respectively.

The HSPF model assumed that all of the water entering the subsurface at WAG 5 is eventually discharged to Melton Branch or White Oak Creek. Some recharge of the intermediate and deeper groundwater zones may be occurring, but the total flux of water recharging these deeper zones is small (estimated to be <1 cm/year in Clapp and Watts 1993). Vertical gradient data show a mix of recharge and discharge between water table and zones at depth, but it is likely that most intermediate groundwater also discharges into Melton Branch and White Oak Creek. These interpretations are consistent with data presented in Moore and Toran (1992; p. 11) and Solomon et al. (1992) that attribute <2% of the estimated subsurface water flux to the intermediate zone and describe groundwater discharge from the intermediate zone into both cross-cutting tributary streams (e.g., D-2) and main valley streams (Melton Branch and White Oak Creek).

Travel times for groundwater, based on the length of time required to move between recharge and discharge points, are difficult to calculate accurately given the heterogeneity of flowpaths in the shallow groundwater interval, the presence of both intergranular and fracture flowpaths, and spatial variability with regard to location and topographic position of these recharge and discharge areas. A geochemical dating study completed by Poreda et al. (1988) assigned ages of 0.09 to 7.23 years for shallow groundwater at WAG 6. Assuming that a comparable situation exists at WAG 5, some groundwater circulation appears to be quite rapid, while at other areas (or depths) the rate is two orders of magnitude less.

Specific discharge (average linear velocity of groundwater) in the shallow groundwater system were estimated using minimum, maximum, and mean values for hydraulic gradient and hydraulic conductivity and an assumed effective porosity of 0.0025 (equivalent to the specific yield). Table B1.6.3 summarizes these estimates.

Table B1.6.3. Specific discharge (ft/day) matrix for WAG 5 shallow groundwater

PARAMETER	MINIMUM HYDRAULIC CONDUCTIVITY (0.0029 ft/day)	MAXIMUM HYDRAULIC CONDUCTIVITY (4.3 ft/day)	AVERAGE HYDRAULIC CONDUCTIVITY (0.16 ft/day)
Minimum hydraulic gradient (0.025)	0.029	43	1.6
Maximum hydraulic gradient (0.11)	0.13	189	7.0
Average hydraulic gradient (0.07)	0.08	120	4.5

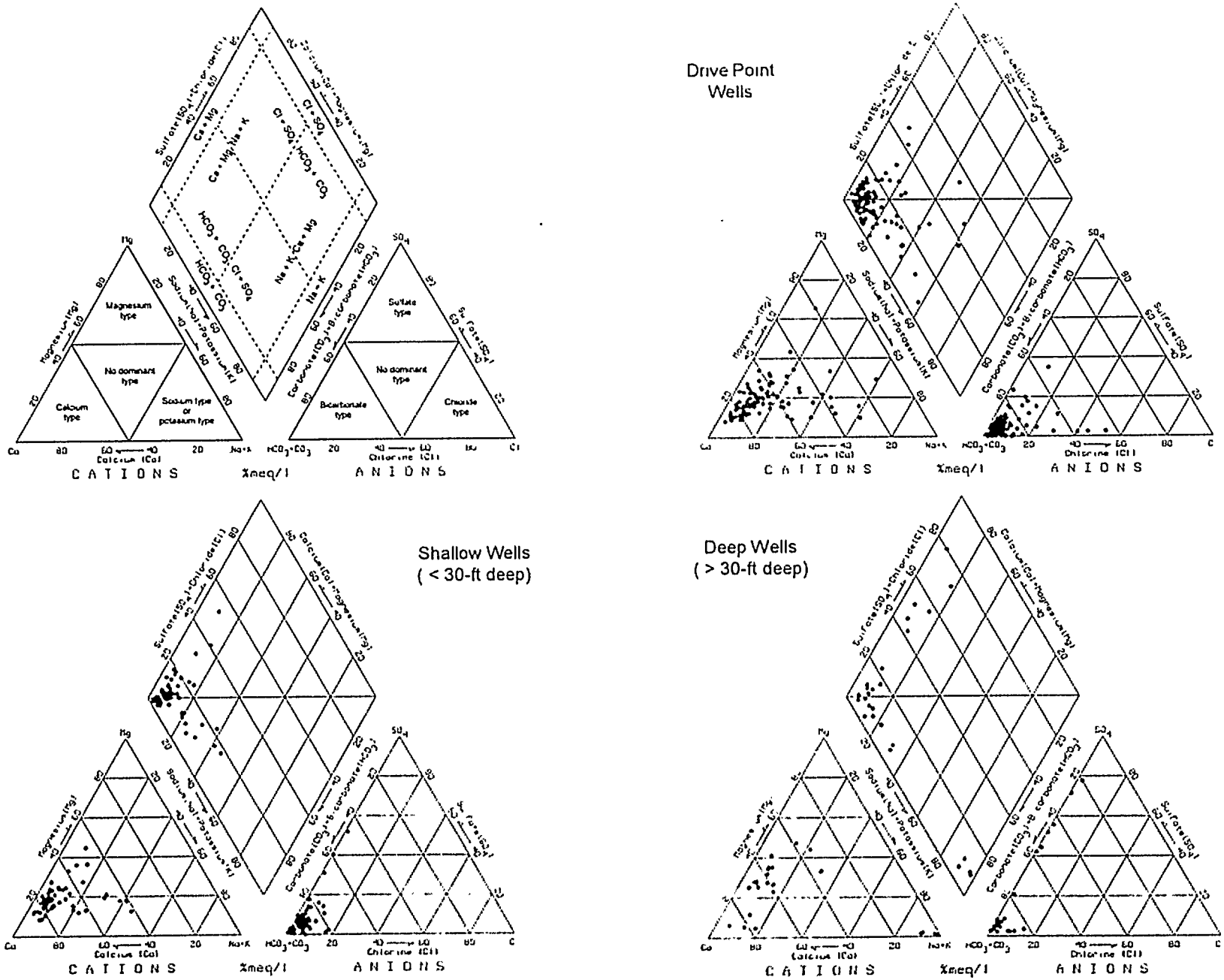


Fig. B1.6.10. Trilinear diagrams by well type.

Variability in the computed groundwater velocities for the shallow groundwater interval reflects the heterogeneity in the composition and structure of aquifer matrix (regolith) and its resulting impact on hydraulic properties. For example, groundwater flowing through enlarged, closely spaced, and interconnected fractures has a much higher velocity than that flowing through widely spaced or filled fractures. It is important to note that the estimate of effective porosity (0.0025) is based on hydrograph analyses in the headwaters of Melton Branch as reported by Moore (1989). Effective porosities in WAG 5 may be much higher due to the large amount of fill and waste materials in the subsurface, and these higher porosities could reduce groundwater seepage velocities by one to two orders of magnitude. Solomon et al. (1992) report specific discharge for the water table interval of ORR aquitards of 5.1 m/year (0.046 ft/day).

B1.6.7 Groundwater Geochemistry

WAG 5 groundwater geochemistry was evaluated to characterize non-contaminant- related water quality and to obtain information concerning groundwater flow and circulation patterns. The evaluation was based on dissolved ion concentration data for major anions and cations. Total dissolved solids (TDS) in WAG 5 groundwater ranged from 217 to 3361 mg/L with an average (arithmetic) of 470 mg/L. Moore and Toran (1992) report that groundwater TDS concentrations typically are less than 500 mg/L. WAG 5 data indicate that 53 of the 197 samples analyzed for TDS exceed this value, indicating fairly widespread water quality impacts (which is obvious from contamination data).

WAG 5 groundwater is dominated by the calcium-carbonate-type waters (Fig. B1.6.10) characteristic of the underlying Maryville Limestone. Shallow well samples were predominantly calcium type with bicarbonate the major anion and lesser amounts of sulfate. Drive points show a wider variety of cation type, with calcium carbonate still predominant and more noticable equivalents of sodium and chloride. Deeper well waters were also grouped as calcium bicarbonate type; however, wells that were screened in different geologic units (e.g., shale) have higher concentrations of sulfate. Individual areas that significantly depart from calcium bicarbonate areas are discussed below.

Area B in SWSA 5 South had widespread areas with higher values of sodium and chloride. Trench drive points 4202 and 4203 contained the highest levels of chloride and also had elevated sodium. Downgradient floodplain drive points had elevated concentrations similar to those of 4202 and 4203, and the drive points (4244 and 4243) closest to Melton Branch and farthest from the trenches had the highest chloride concentrations of the floodplain drive points. Other samples collected from the vicinity of Melton Branch and White Oak Creek have shown higher chloride. These samples include groundwater from shallow piezometers in the White Oak Creek floodplain downgradient of WAG 5 in 1987 (Clapp et al. 1993) and seep samples collected during construction of the interceptor trench and treatment system for seep area D in September 1994. As a group, these results support the interpretation of artesian (upward) leakage from deeper groundwater. The limited number of samples having elevated chloride indicates that this leakage occurs along discrete flow paths that have not been well defined. An alternative explanation—that the higher chloride concentrations indicate a direct pathway between the trenches and Melton Branch—is also feasible.

Drive point 4211 (trench 117) yielded a sample with elevated levels of sodium and alkalinity, both of which were also elevated in downgradient (floodplain) drive points (e.g., 4245 and 4251). Variations in water chemistry in this area are most likely due to in situ treatability studies conducted at trench 117 (Spalding 1984). The study involved injection of a sodium-based agent to raise the pH and cause precipitation of strontium. Four separate injections were made with caustic soda (NaOH), soda ash (Na_2CO_3), caustic soda (NaOH), and lime ($Ca(OH)_2$)/soda ash (Na_2CO_3), respectively .

Drive points 4269 through 4274 in SWSA 5 South, area C, had geochemical characteristics different from nearby drive points. Sulfate and sodium were detected at elevated levels in this area directly south of the OHF pump house. These differences may be due to previous contamination involved with the WAG 10 wells. Field measurements and radiological analyses of drive points from this area indicate high levels of contamination (e.g., strontium-90).

Well 1108, downgradient of the OHF pond, had outlier geochemical characteristics as shown in Table B1.6.4. Wells 1105, 1106, and 1107 had levels characteristic of the shallow groundwater. Well 1108 had lower alkalinity and calcium levels, with values of alkalinity and cations similar to those found in the OHF pond. Well 1108 also has been directly linked to the OHF pond by Stansfield and Francis (1986).

Wells in SWSA 5 North had higher concentrations of sodium and sulfate; this may be attributed to the underlying Rogersville and Pumpkin Valley shale formations. Moore and Toran (1992) attribute higher sulfate concentrations (30 to 300 mg/L) to dissolution of gypsum in the Conasauga Group. Well 0521 (total depth 85.2 ft) had the largest sulfate concentration at 852 mg/L.

The geochemistry of the deeper groundwater has been documented as sodium bicarbonate (Moore and Toran 1992). Most of the deeper wells sampled as part of the RI were predominantly sodium bicarbonate; however, some were calcium bicarbonate or sodium/calcium sulfate, depending upon the geologic unit in which the well was screened. No water quality samples were taken from the stormflow zone as part of the WAG 5 field investigation. Previous studies indicate that the stormflow water in Melton Valley is slightly acidic (mean pH of 5.8) and is calcium carbonate type (mean alkalinity concentration of 48 mg/L) with lesser amounts of magnesium, sodium, and sulfate. The spatial and temporal differences of chemical constituents in the stormflow zone are not presently well defined (Solomon et al., 1992).

Table B1.6.4. Comparison of water quality near the OHF pond[a]

Well No. Date	1105 10/93	1106 10/93	1107 10/93	1108 10/93	OHF Pond[a] 12/93
Ca	104	127	98	26	27
Mg	15	10	12	6.4	4.9
Na	11	15	33	25	4.5
K	1.2	1.3	1.6	2.1	3.5
Alkalinity as $CaCO_3$	412	349	325	110	6
Cl	11	16	11	6.1	0.81
SO_4	22	12	21	22	0.14
NO_3	3.2	3.7	6.3	1.2	14

[a]Units are mg/L.

B1.7 ECOLOGY

B1.7.1 Habitat Description

The 13 WAG 5 solid waste management units (SWMUs) are primarily covered with grass, concrete, gravel, or industrial structures. For the purposes of the ecological risk assessment, WAG 5 has been divided into six units: WAG 5 wide, SWSA 5, TRU Waste Storage Area, OHF, NHF, and PWSB (Fig. B1.7.1). White Oak Creek and Melton Branch border the SWMUs of WAG 5 on the west and south, respectively. These streams and most of their floodplains lie outside the defined boundaries of WAG 5.

The WAG 5 wide area is defined as the areas that are not included in the SWMUs and totals ~12 ha. The area includes the deciduous forest that fringes SWSA 5 South and the TRU waste storage area and three surface water drainages designated as D-1A, D-1, and D-2 (Sect. B1.7.2). Drainages D-1A and D-1 are tributaries flowing southwestward to White Oak Creek, which parallels the western border of WAG 5. Drainage D-2 is in the south-central area of SWSA 5 South and is a tributary to Melton Branch. Deciduous forested wetlands exist along the entire length of drainage D-1 and along drainage D-2 in an area extending 650 ft upstream from a point near where it exits WAG 5 (Rosensteel 1992a). The wetland hydrology is controlled by stream overflow and groundwater discharge (Rosensteel 1992b).

Drainage D-1A is on the northern edge of WAG 5 and runs roughly parallel to Melton Valley Drive. The drainage is surrounded by deciduous forested wetlands at the eastern area of the drainage just north of Building 7831A (Fig. B1.7.1). The wetland contains canopy species that include sycamore (*Platanus occidentalis*), sweetgum (*Liquidamber styraciflua*), red maple (*Acer rubrum*), and tulip poplar (*Liriodendron tulipifera*). The subcanopy is composed of all the canopy species except tulip poplar. The predominant shrub species present is witchhazel (*Hamamelis virginiana*), and japanese honeysuckle (*Lonicera japonica*) and greenbriar (*Smilax* sp.) are the vine species present. Additional wetlands, approximately 300 ft downstream of the above wetlands, are confined to a limited strip immediately adjacent to the tributary. The vegetation in this strip is predominantly herbaceous and contains canopy and subcanopy species similar to those on the east portion of the drainage. The remainder of the drainage area (nonwetland) is dominated by additional species including short-leaf pine (*Pinus echinata*), white oak (*Quercus alba*), beech (*Fagus grandifolia*), red elm (*Ulmus rubra*), buckeye (*Aesculus flava*), black walnut (*Juglans nigra*), and flowering dogwood (*Cornus florida*). Predominant ground cover includes nepal microstegium (*Microstegium vimineum*) and christmas fern (*Polystichum acrostichoides*). The northern slope above the drainage is cleared, and downed pine vegetation (*Pinus virginiana*) remains. The southern slope is dominated by beech and some buckeye (Rosensteel 1992a; Cook 1992).

Drainage D-1 is directly south of the TRU waste storage area (SWSA 5 North). This drainage is considered an ephemeral tributary, predominantly drying up during low base flow conditions (completely dry during a site visit on September 15, 1994, although some small dispersed standing ponds were present). The tributary channel is approximately 3 ft wide, has relatively high banks (3–4 ft), and has a streambed consisting of soft clay/mud substrate. During high flow conditions, habitat at D-1 may be suitable for some fish species including black-nose dace and creek chubs, which are found in White Oak Creek. Wetlands are present along all of drainage D-1 within the WAG 5 boundary. A short section at the crest of the drainage is relatively open with black willow (*Salix nigra*), sycamore saplings, and red maple saplings. The most common canopy species along the

tributary are sweetgum, red maple, sycamore, beech, pines (*P. echinata* and *P. virginiana*), and tulip poplar. The subcanopy is similar except that tulip poplar is absent and ironwood (*Carpinus caroliniana*) is present. Ground cover includes nepal microstegium, cattail (*Typha sp.*), seedbox (*Ludwigia sp.*), cane (*Arundinaria gigantea*), red maple saplings, and sedges (*Carex sp.*, *Scirpus sp.*, and *Cyperus* sp.) (Rosensteel 1992a; Cook Feb. 6, 1992).

Drainage D-2 is considered an ephemeral tributary, predominantly dry in most areas during low base flow conditions. A culvert within the drainage acts as a barrier for upstream migration of fish during low flow conditions. Although unlikely, upstream migration may be possible during extremely high flow conditions. The habitat for fish communities within this drainage is highly unfavorable, but fish may have the potential for upward migration from Melton Branch to the barrier.

Drainage D-3, outside the eastern WAG 5 boundary, flows into a small tributary flowing along the eastern boundary of WAG 5 to Melton Branch. During a survey on September 15, 1994, D-3 was primarily dry during base flow conditions but had intermittent small standing pools. The streambed consists of a silt/mud bottom that may have sufficient habitat to support fish communities during high flow conditions. The area adjacent to the drainage D-3 is dominated by sweetgum, tulip poplar, and white oak. Some sycamore and ironwood are also present. The number of sycamore and black willow increases appeared in the canopy near the head of the drainage.

The TRU waste storage area (SWMU 5.10) is south of drainage D-1A and north of drainage D-1 (Fig. B1.7.1). The TRU waste storage area covers 4 ha and consists primarily of burial grounds (trenches containing concrete casks) with have a maintained grass cover. Buildings 7823, 7826, 7834, 7827, 7829, and 7855 store stainless steel drums, metal boxes, or concrete casks containing waste are found throughout the area. Other buildings (7824 and 7804) house miscellaneous equipment and the Solid Waste Compactor Facility (7831). A classified burial ground surrounded by a secondary security fence is located in the southwest corner of SWSA 5 North (Bechtel 1988). The classified burial ground has not been maintained and currently has overgrown scrub brush vegetation within the fenced area.

The PWSB (SWMU 5.6) covers an area of approximately 0.1 ha and is within the northern part of the SWSA 5 South, next to surface drainages D-1 and D-1B (Fig. B1.7.1). The outside dimensions of the basin are 85 × 85 ft, with a depth of 7.8 ft. Prior to use, a polyvinylchloride (PVC) liner was placed on the compacted clay bottom of the basin. The basin perimeter is currently surrounded by overgrown vegetation (i.e., shrubs, grasses) and a fence. The basin contains standing water and approximately 4 ft of sludge/sediment on the bottom (Bechtel 1988). Outside the fence, the basin is surrounded by cut grass with deciduous forest to the south (drainage D-1B) and west (drainage D-1). Sycamore, sweetgum, and black willow are the dominant species, with pine (*P. virginiana*) along the fringe. The trees are small, which prevents a clear canopy-subcanopy distinction. Japanese honeysuckle is plentiful; however, other ground cover is sparse (Rosensteel 1992a).

SWSA 5 South (SWMU 5.7), south of drainage D-1, consists primarily of burial grounds (containing 230 trenches) and an undefined trench area and dump area (Bechtel 1988) covering an area of 14.5 ha. All burial grounds are maintained with a grass cover. The northwestern area of SWSA 5 South is fringed by a deciduous forest containing species similar to those described for areas surrounding drainage D-1. A thin strip of deciduous forest surrounds drainage D-2 in the south-central area of the burial grounds. The area of forest along the northern section of drainage

D-2 is not considered a wetland. The dominant tree species in the area are tulip poplar, sycamore, sweetgum, red maple, and red cedar (*Juniperua virginiana*). Nepal microstegium and japanese honeysuckle are both plentiful in the ground cover (Rosensteel 1992a).

A strip of wetlands is located along drainage D-2, from approximately 300 ft south of the head of the drainage to the WAG 5 boundary. The overstory here consists of sweetgum, sycamore, black willow, and red maple. The subcanopy is similar, with the addition of ironwood, dogwood (*Cornus amomum or C. stolonifera*), and brookside alder (*Alnus serrulata*). Dominant vine species include japanese honeysuckle and some crossvine (*Bignonia capreolata*). Nepal microstegium and cutgrass (*Leersia oryzoides*) are also found in the area. Watercress (*Nasturtium officinale*) may also be present in the tributary.

Many seeps are located within or surrounding SWSA 5 South. The condition and water flow from seeps varies throughout the year, with presence of pools during winter/early spring to dry conditions during late summer/early fall (personal communication, D.S. Hicks, August 19,1994). Most of the seeps possess wetland vegetation (i.e., black willow, sweetgum, sedges, and cattails) (Rosensteel 1992a; Cook 1992).

Most seeps (1, 5, 6, 7, 10, 11, 12, and 19) are bank discharge points contributing to contaminant input into White Oak Creek, Melton Branch, or the drainages. These seeps are immediately diluted with surface water upon entry of the stream; thus, biotic communities (e.g., fish) are not directly exposed to undiluted concentrations of contaminants. The seep proper does not provide habitat for aquatic life.

Seeps 3, 15, 14, and 16 discharge at the headwaters of drainages D-1, D-2, or D-3. Dilution does occur in the drainage, but the point of dilution is unknown. The headwater area of the drainage is narrow with unknown habitat size.

Seeps 2, 4, 8, 9, and 18 are located at distances from a stream or drainage. Most were collection reservoirs that are ephemeral and dry during base flow conditions. Because of the ephemeral nature of these seeps, distance from a tributary, and size, it is unlikely that they seeps are suitable habitat for fish and other aquatic life. However, seep 8 contains approximately 300 to 400 gal of water from December to April. Fish would not have the potential for direct exposure to contaminants released from these seeps.

OHF covers an area of 0.57 ha and consists of the impoundment (SWMU 5.2) and the site surface facilities (SWMU 5.3). The impoundment, east of Service Road and west of the T-4 waste pit at the south-west boundary of WAG 5 (Fig. B1.7.1), was used as an emergency storage basin for grout during the hydrofracture operation. The bottom dimensions are 20 × 100 ft, the sides slope at 1 vertical to 1.5 horizontal, the depth is slightly greater than 5 ft at the low (west) side, and the capacity is 100,000 gal. The sides are lined with limestone riprap varying in diameter from approximately 6 to 12 in. The basin has a sediment bottom that averages approximately 11 in. in thickness (1950 ft^3 of sediment). The impoundment has an emergency spillway provided by a concrete standpipe at the north end that is connected with a drain pipe that goes through the bottom of the pond and extends 50 ft to the west toward the White Oak Creek floodplain (Bechtel 1988).

The OHF site surface facilities are east of the impoundment and approximately 390 ft to the northeast of the confluence of White Oak Creek and Melton Branch (Fig. B1.7.1). They include

Buildings 7852 and 7853, T-4 waste pit, pump house, and all the above-ground tanks and bins. A valve pit covered with metal plates is also located at the southwest corner of the pump house (Bechtel 1988). This area is primarily covered with concrete, has small areas of grass cover, and (with the exception of the OHF impoundment) lacks surface water resources. Therefore, the current state of the OHF site surface facilities provides minimal habitat for terrestrial wildlife.

NHF (SWMU 5.4), southwest of the OHF on the south side of Melton Branch (Fig. B1.7.1), is a 1-ha area enclosed by a chain-link fence. This facility includes Building 7860, an emergency waste storage tank, two large bulk solid storage tanks, three mobile solid storage tanks, and the low-level waste concentrate waste storage tanks (Bechtel 1988). Buildings and storage tanks are predominantly surrounded by gravel and dirt surfaces. Deciduous forests are found outside the fence beyond the WAG 5 boundary. The current state of the NHF site, lacking vegetation and surface water resources, provides little habitat for terrestrial wildlife. Additionally, the chain-link fence may limit wildlife access (i.e., deer).

B1.7.2 Wetland Assessment

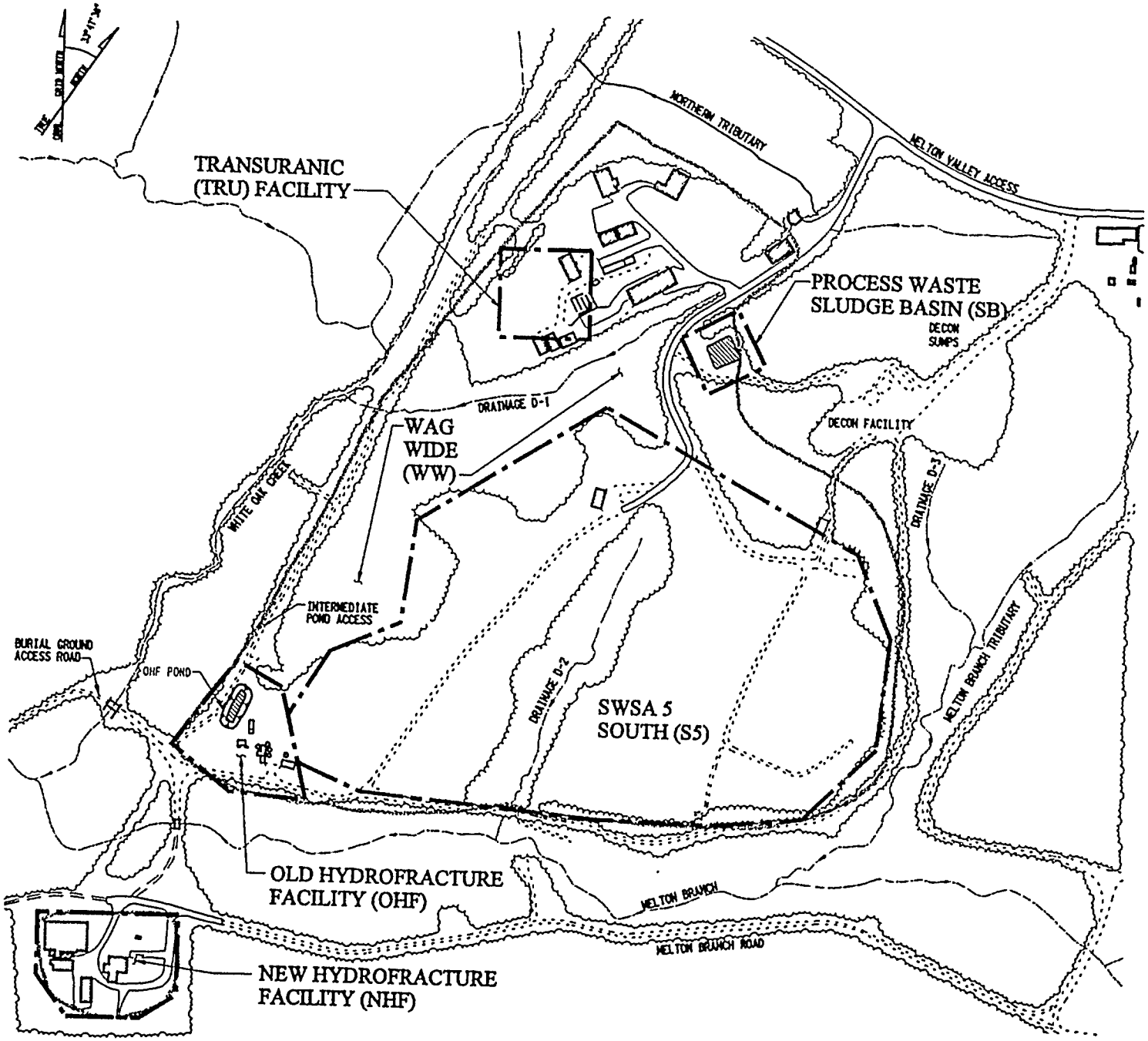
Executive Order 11988, Floodplain Management, and the National Environmental Policy Act of 1969 (Public Law 91-190; 91Stat. 852; 42USC 4321-4347) require each federal agency to ensure that any action taken in a floodplain or wetland is evaluated and that impacts are minimized. To meet this requirement, a wetlands survey and assessment were prepared to describe proposed actions, discuss the effects of those actions on the floodplain and wetlands, and consider possible alternatives to potential wetland and floodplain disturbance.

A wetland survey of WAG 5 conducted in two phases in the spring of 1992 included a preliminary survey and a wetlands delineation survey. The results of the preliminary survey indicated that wetlands were likely to be present along all three of the tributaries draining WAG 5. The locations and approximate boundaries of these wetland areas are shown in Fig. B1.7.2 and are designated as D-1, D-1a, D-1b, D-2, and D-2a. The wetlands are in stream floodplain areas and are controlled hydrologically by stream overflow and groundwater discharge. (Rosensteel 1992b).

The second survey was conducted to delineate the boundaries of wetland areas within the WAG. Deciduous forested wetlands were delineated along the entire length of drainage D-1 and along drainage D-2 in an area extending 650 ft upstream from a point near the exit of drainage D-2 from the WAG (Rosensteel 1992a).

The preliminary survey also indicated that there are probably wetlands around each of the eight seeps along the southern border of WAG 5. However, a definitive evaluation of the plant communities was not conducted because the seeps are in an area with high contaminant levels (Rosensteel 1992a).

The wetlands are characterized by a dominance of hydrophytic vegetation, hydric soils, and characteristic wetland hydrology. Vegetation present in each wetland area is identified and associated with a wetland classification regional indicator in Table B1.7.1.



NOTES

1. TREE LINES ARE APPROXIMATE.

LEGEND

- WAG 5 BOUNDARY
- BUILDING
- PAVED ROAD
- GRAVEL ROAD
- TREE LINE
- STREAM W/FLOW DIRECTION
- WATER BODY
- OPERABLE UNIT BOUNDARY

Fig. B1.7.1. Base map for ecological risk assessment with six divisional units.

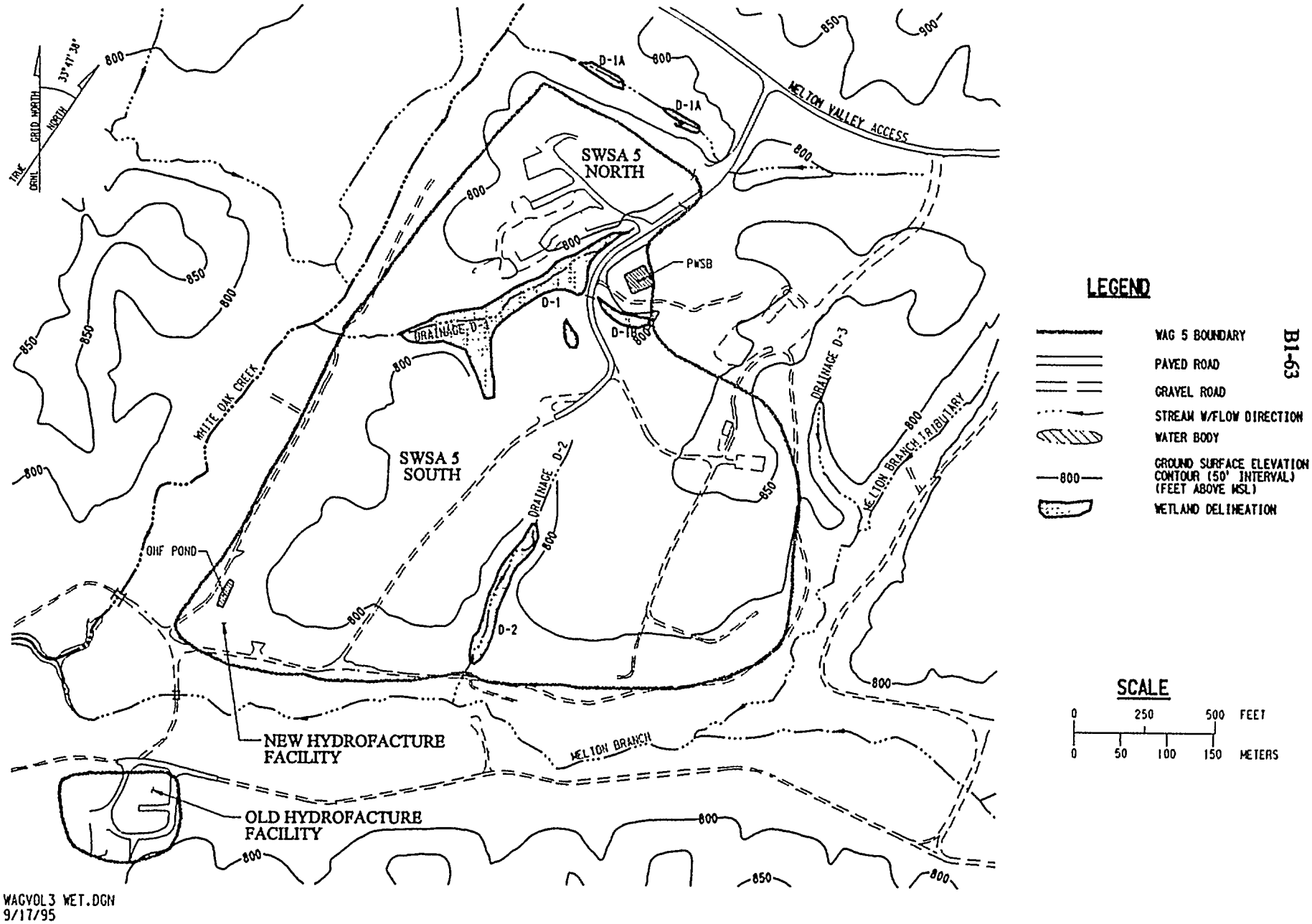


Fig. B1.7.2. Map of wetlands present within the WAG 5 boundary.

B1.7.3 Endangered Species Survey

Results of the threatened and endangered animal surveys indicate that no threatened or endangered animal species (aquatic and terrestrial invertebrates and vertebrates) or critical habitat of listed (or proposed to be listed) species by the U.S. Fish and Wildlife Service are known to be present on WAG 5 (Ashwood et al. 1992). However, the endangered Indiana bat (Myotis sodalis) is a possible summer resident along East Fork Poplar Creek and therefore may occur in the area of WAG 5.

Surveys for rare plants (Rosensteel 1992b) and animals of concern identified no species in WAG 5 (Ashwood et al. 1992). However, several animal (Ashwood et al. 1994, Kroodsma 1987, Hatcher 1990, and TWRC 1990) and plant (Ashwood et al. 1994) species listed by the state of Tennessee as threatened (T), endangered (E), or in need of management (INM) are known to occur on the ORR (Tables B1.7.2 and B1.7.3). These animals may occur outside the boundaries of WAG 5 and could potentially occur on WAG 5 if suitable habitat became available. Any proposed project that would affect habitats in these locations would be expected to affect these species.

B1.7.4 Biomonitoring Data

Biological monitoring data collected within WAG 5 are limited to media toxicity testing (Sect. C2.3.2) and earthworm bioaccumulation studies (Sect. C2.3.3.1). Additional biomonitoring data have been obtained for the streams that border, but lie outside, WAG 5 (i.e., fish and benthic macroinvertebrate community data). The Biological Monitoring and Abatement Program (BMAP) has monitored White Oak Creek and Melton Branch since 1985. Since contaminants are transported off of WAG 5 into WAG 2, impacts may occur on the biotic communities inhabiting White Oak Creek and Melton Branch. Biological survey data for fish communities (Sect. C2.3.3.2) include fish community surveys, fish bioaccumulation studies, and fish bioindicators. The benthic macroinvertebrate communities in Wnite Oak Creek and Melton Branch have also been evaluated (Sect. C2.3.3.3). The biological survey data for fish and benthic macroinvertebrates are derived from the 1994 BMAP annual report (Ashwood 1994).

Table B1.7.1. Wetland vegetation and classification regional indicator in wetland areas in WAG 5

Wetland Area	Species Name	Wetland Classification Regional Indicator
AREA D-1		
Canopy	sweetgum (*Liquidambar styraciflua*)	FAC+
	red maple (*Acer rubrum*)	FAC
	sycamore (*Platanus occidentalis*)	FACW
	tulip poplar (*Liriodendron tulipifera*)	FAC
Subcanopy	sweetgum	FAC+
	red maple	FAC
	sycamore	FACW
	black willow (*Salix nigra*)	OBL
	ironwood (*Carpinus caroliniana*)	FAC
Ground cover	nepal microstegium (*Microstegium vimineum*)	FAC
	cattail (*Typha sp.*)	OBL
	sedges (*Carex sp.*, *Scirpus sp.*, and *Cyperus sp.*)	primarily OBL and FACW
	seedbox (*Ludwigia sp.*)	OBL
	red maple saplings (*Acer rubrum*)	FAC
	cane (*Arundinaria gigantea*)	FACW
AREA D-1A		
Canopy	sycamore	FACW
	tulip poplar	FAC
	sweetgum	FAC+
	red maple	FAC
Subcanopy	all canopy species with exception of tulip poplar	
	witchhazel (*Hamamelis virginiana*)	FACU
Ground cover	common pawpaw (*Asimina triloba*)	FAC
	japanese honeysuckle (*Lonicera japonica*)	FAC
	greenbriar (*Smilax* sp.)	
	sedge (*Cyperus* spp.)	most are FACW
AREA D-1b		
Subcanopy	sycamore	FACW
	sweetgum	FAC+
	black willow saplings	OBL
Ground cover	sedges	primarily OBL and FACW
	rushes (*Juncus* spp.)	
	cattails	OBL

Table B1.7.1 (continued)

Wetland Area	Species Name	Wetland Classification Regional Indicator
AREA D-2		
Canopy	black willow	OBL
	red maple	FAC
	sycamore	FACW
	sweetgum	FAC+
Subcanopy	ironwood	FAC
	dogwood (*Cornus amomum* or *C. Stolonifera*)	FACW
	brookside alder (*Alnus serrulata*)	FACW+
Ground cover	japanese honeysuckle	FAC
	nepal microstegium	FAC
	cutgrass (*Leersia oryzoides*)	OBL
	crossvine (*Bignonia capreolata*)	FAC
water	watercress (*Nasturtium officinale*)	OBL

Source:

National List of Plant Species that occur in Wetlands: Tennessee. May 1988 Biological Report, Reed Porter Jr., U.S. Fish and Wildlife Service, NERC-88/18.42.

Notes:

(1) OBL: Obligate wetland (occur almost always; estimated probability > 99% under natural conditions in wetlands)

FACW: Facultative wetland (usually occur in wetlands; estimated probability 67% to 99%, but occasionally found in nonwetlands)

FAC: Facultative (equally likely to occur in wetlands or nonwetlands; estimated probability 34% to 66%)

FACU: Facultative upland (usually occurs in nonwetlands; estimated probability 67% to 99%, but occasionally found in wetlands; probability 1% to 33%)

(2) A positive or negative sign was used with the facultative indicator categories to more specifically define the regional frequency of occurrence in wetlands. The positive sign indicates a frequency toward the higher end of the category (more frequently found in wetlands), and a negative sign indicates a frequency toward the lower end of the category (less frequently found in wetlands).

Table B1.7.2. Animal species on the ORR that are threatened, endangered, or in need of management

Common Name	Trophic Category[a]	Special Status[b]
Birds		
Red-Headed Woodpecker	ArI	INM
Golden Eagle	LC	SE
Northern Harrier	LC	ST
Cooper's Hawk	LC	ST
Red-Shouldered Hawk	LC	INM
Sharp-Shinned Hawk	LC	ST
Barn Owl	LC	INM
Black Vulture	LC	INM
Grasshopper Sparrow	LH	ST
Henslow's Sparrow	LH	FC
Lark Sparrow	LH	INM
Vesper Sparrow	LH	INM
Double-Crested Cormorant	P	INM
Black-Crowned Night Heron	P	INM
Bald Eagle	P	SE, FE
Osprey	P	SE
Mammals		
Eastern Small-Footed Bat	FI	FC, INM
Gray Bat	FI	FE, SE
Indiana Bat	FI	FE, SE
Rafinesque's Big-Eared Bat	FI	FC, INM
Long-Tailed Shrew	GI	FC, INM
Masked Shrew	GI	INM
Smokey Shrew	GI	INM
Southeastern Shrew	GI	INM

Table B1.7.2 (continued)

Common Name	Trophic Level[a]	Special Status[b]
Mammals cont.		
Cougar[c]	LC	FE
River Otter[d]	LC	ST
Southern Bog Lemming	SH	INM
Meadow Jumping Mouse	SO	INM
Woodland Jumping Mouse	SO	INM
Amphibians and Reptiles		
Cumberland Slider	AqH	INM
Hellbender	AqI	FC, INM
Six-Lined Racer	GI	INM
Slender Glass Lizard	GI	INM
Tennessee Cave Salamander	GI	FC, ST
Green Salmander	GI	FC, INM
Northern Pine Snake	LC	FC, ST
	Fish	
Tennessee dace	Dtr	INM

[a] AqI = aquatic invertebrate feeder; ArI = arboreal invertebrate feeder; GI = ground invertebrate feeder; LC = predators and scavengers with ORR-wide populations; LH = herbivores with ORR-wide populations; LO = omnivores with ORR-wide populations; P = piscivores; SH = herbivores with populations restricted to source OU-scale; SO = omnivores with populations restricted to source OU-scale; Dtr = Detritivores;.

[b] FC = candidate for federal listing; FE = federally listed as endangered; INM = state listed as in need of management; SE = state listed as endangered; ST = state listed as threatened.

[c] Reported sightings, but probably does not occur on a regular basis.

[d] Not yet sighted on the ORR, but introduced to area streams, and suitable habitat exists on the ORR.

Table B1.7.3. Habitats and rarity status of plant species listed by state or federal agencies that occur on the ORR[a]

Species	Common Name	Habitat on ORR	Status[b]
Aureolaria patula	Spreading false-foxglove	River bluffs	C1, T
Carex gravida	Gravid sedge	Varied	S
Cimicifuga rubifolia	Appalachian bugbane	River slopes	C2, T
Cypripedium acuale	Pink lady-slipper	Dry to rich woods	E*
Delphinum exaltatum	Tall larkspur	Barrens, woods	C2, E
Diervilla lonicera	Northern bush-honeysuckle	River bluffs	T
Elodea nuttallii	Nuttall waterweed	Ponds, embayments	S
Fothergilla major	Mountain witch-alder	Woods	T
Hydrastis canadensis	Golden seal	Rich woods	T
Juglans cinerea	Butternut	Slopes near streams	C2, T
Lilium canadense	Canada lily	Moist woods	T
Liparis loeselii	Fen orchid	Forested wetland	E
Panax quinquifolius	Ginseng	Rich woods	3C, T
Platanthera flava var. *herbiola*	Tuberculed rein-orchid	Forested wetland	T
Platanthera peramoena	Purple fringeless orchid	Wet meadow	3C, T
Saxifraga careyana	Carey saxifrage	River bluffs, sinks	C3, T
Spiranthes ovalis	Lesser ladies tresses	Moist to dry woods	S

[a] Other similar lists for ORR include *Lilium michiganense*. It is excluded here because it is not definitely known to be currently on the ORR.

[b] Status codes:
- C1 - Candidate for federal listing. Proposed listing considered likely.
- C2 - Candidate for federal listing. More information needed to determine status.
- C3 - Taxa no longer considered for federal listing. Subcategories indicate reason.
- 3C - Taxa more widespread or abundant than previously thought, or taxa not subject to immediate threat.
- E - Endangered in Tennessee.
- E* - Endangered in Tennessee due to commercial exploitation.
- T - Threatened in Tennessee.
- S - Special concern in Tennessee.

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B2. NATURE AND EXTENT OF CONTAMINATION

B2.1 OBJECTIVES, APPROACH, AND ORGANIZATION

B2.1.1 Objectives

The objectives of the data analyses and presentations in this section are to

- define and quantify (when possible) the hydraulic processes associated with existing or potential release and movement of contamination within WAG 5;
- describe the nature and extent of WAG 5 contamination in light of the hydrologic processes and discuss observed or potential effects on WAG 2 and downstream White Oak Creek contaminant concentrations; and
- refine and quantify the WAG 5 conceptual model to reflect as accurately and completely as possible the principal contaminant types and sources, release mechanisms, transport media and routes, and intermedia transfers so that the model can be used to identify current and potential exposure routes, locations, and receptors.

Accomplishing these objectives will serve to summarize the current knowledge of WAG 5 contaminant dynamics and provide a framework for analyzing risk and planning general response actions.

B2.1.2 Approach and Organization

WAG 2 is hydrologically tied to WAG 5 (Appendix B1), and therefore increasing contaminant fluxes along the portion of WAG 2 adjacent to WAG 5 may indicate migration of contaminants from WAG 5. Sampling results for WAG 2 are summarized first so that WAG 5 results can be presented in the context of measured or potential effects on WAG 2.

Varied source characteristics and burial techniques and the site geology made it necessary to divide WAG 5 into smaller study areas. Divisions generally follow water drainage because most of the release mechanisms and transport media are water-based. Divisions were also influenced by previously established solid waste management unit (SWMU) designations and knowledge of source characteristics and/or containment techniques.

The primary site division runs approximately northeast-southwest and constitutes the Melton Branch/White Oak Creek drainage divide, as shown in Fig. B2.1.1. Within each drainage, the dashed lines outline "study areas," which usually contain at least one contaminant "source area" (Table B2.1.1). The order of the presentations and conclusions in this appendix mirrors this organization.

- Available, pertinent information on the operational history and/or characteristics of the study area and its contaminant sources is summarized.
- When available, historical and concurrent investigation data are summarized to further characterize the area.

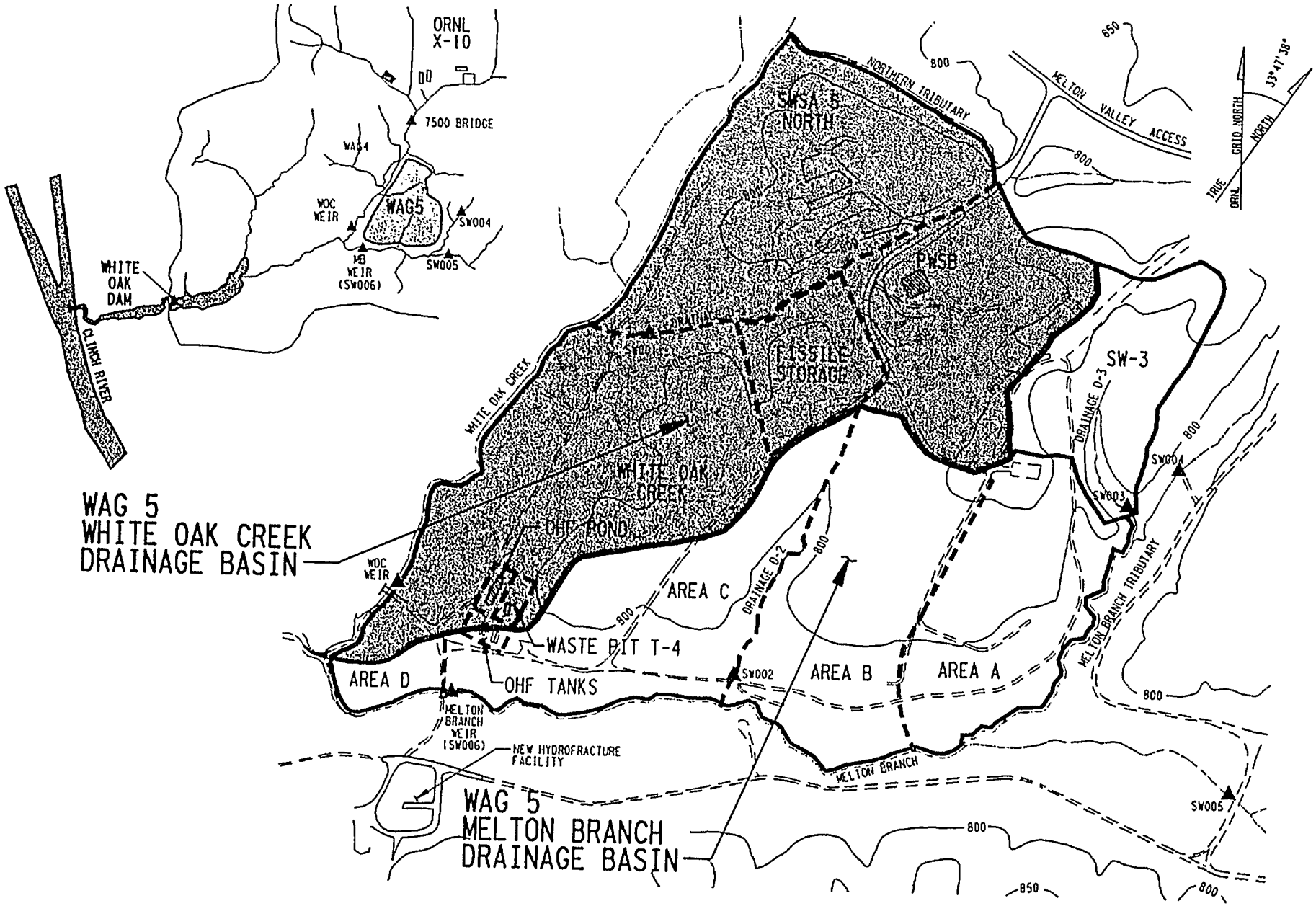

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Fig. B2.1.1 WAG 5 drainages and study areas.

Table B2.1.1. WAG 5 study areas and contaminant sources

WAG 5 Study Areas	Potential Sources of Contamination
Process Waste Sludge Basin	Surface water Sediment (sludge)
SWSA 5 North	10 TRU trenches w/boxed RH-TRU waste 17 TRU trenches w/RH-TRU waste in concrete casks 8 stainless-steel-lined auger holes Bldg. 7831A drain field and seepage trench
Fissile Storage	151 auger holes 3 trenches Ravine landfill
White Oak Creek	110 auger holes 12 trenches Dump area TRU storage vaults (8 lined auger holes)
OHF Area	Waste pit T4 OHF waste storage tanks OHF impoundment (sediment and surface water)
SW-3	Northern landfill/hillside dump
SWSA 5 South, Area A	121 auger holes 23 upland trenches 56 inundated trenches
SWSA 5 South, Area B	177 auger holes 27 upland trenches (undefined trench area) 47 inundated trenches
SWSA 5 South, Area C	344 auger holes 44 upland trenches 13 inundated trenches
Area D	WAG 5 upland trenches and auger holes WAG 10 grout sheets

- WAG 5 sampling efforts are summarized.

- At least one model is constructed for each identified contaminant source within a study area. These models are cross sections through contaminant source areas and parallel to the predominant or most likely contaminant migration path. Each model extends to the nearest WAG 2 or on-site drainage (D-1, D-2, D-3) discharge point. The models, when possible, also identify and quantify primary release mechanisms and intermedia transfers and present the annual water budgets for individual flow pathways.

- Analytical results (WAG 5, historical, Energy Systems monitoring) pertinent to describing the nature and extent of contamination within a study area's sources and potentially affected surrounding media are presented and discussed in terms of the models. Data tables present the detections for analytes of concern in all media. The analytes of concern for a given study area are those identified by risk analyses (Appendix C) *and* detected at 2 times mean background (when background values are available) in at least one medium. When background results are

not available, all detections of that analyte are included in the table. As a note, background values traditionally refer to concentrations of chemicals or radionuclides that are naturally occurring and uninfluenced by human activities. For this report, background values represent concentrations of chemicals or radionuclides that are present on the ORR but are uninfluenced by site waste management practices (anthropogenic levels). Background values were compiled from a variety of sources: soils from the *Final Report on the Background Soil Characterization Project at the Oak Ridge Reservation* (ORNL 1993); groundwater from data collected as part of ORNL's Environmental Protection and Surveillance Database (EPSD); and sediment and surface water from the WAG 6 RI. The objectives and sources for the background reference data are described further in Volume 2, Appendix A5.

- Analytical results and hydrological models are combined into a study-area-specific conceptual model that summarizes contaminant occurrence, migration pathways, and principal release mechanisms. The model also presents the results of flux calculations performed for primary analytes (i.e., gross alpha, gross beta, tritium, ^{60}Co, ^{90}Sr, and ^{137}Cs). Flux calculations are pathway specific (i.e., surface runoff, interflow, and groundwater) and are based on the average annual flow rate and the average concentration detected in that pathway (if available). Flux calculations for surface runoff are based on average soil concentrations, erosion potential, and sediment/soil transport in surface runoff.
- Repeating this process for each study area allows for construction of a drainage-wide model and a summary of the nature and extent of contamination.

Each drainage summary (Sects. B2.3 and B2.4) includes a condensed conceptual model based on the individual models presented for each study area. Repeating these steps for both White Oak Creek and Melton Branch produces an overall drainage summary. In addition, fluxes from each study area are combined with the WAG 2 information to determine overall contributions of major contaminants released by surface water from WAG 5 and other off-site sources (e.g., WAG 4 and WAG 1). Section B2.5 summarizes WAG-wide contamination by media, focusing more on the on-site extent of contamination than on the off-site contaminant releases presented in the individual drainage area summaries.

B2.2 WASTE DISPOSAL OPERATIONS

The WAG 5 Melton Branch drainage area includes most of SWSA 5 South and, thus, most of the contaminant sources and contaminated media at the site. The western- and northern-most portions of SWSA 5 South lie in the White Oak Creek drainage basin and are grouped into the SWSA 5-White Oak Creek and fissile storage study areas discussed in Sect. B2.3. The Melton Branch drainage area occupies about 42 acres, extending from the White Oak Creek-Melton Branch drainage divide to its southern perimeter along Melton Branch and to the eastern boundary along Melton Branch tributary.

To simplify the interpretation and presentation of data, the SWSA 5-Melton Branch drainage area was subdivided into five study areas (Fig. B2.1.1): areas A, B, C, and D, and SW-3. Study areas A through D are consistent with the "seep areas" delineated for the WAG 5 source area investigation as documented in Bechtel (1994b) and the subsequent removal actions in areas C and D. The boundaries of Areas A through D were expanded on the basis of the location of divides for

surface water and groundwater flow (the primary mechanisms for contaminant transport in SWSA 5), with some consideration for the distribution and orientation of burial sites and the type of burial (auger hole or trench). Area SW-3 was added to account for the D-3 drainage catchment in the eastern portion of WAG 5.

The following sections summarize the nature and extent of contamination in each study area by evaluating contamination in steps of increasingly larger perspective, from area-specific through WAG-wide. This introductory section presents an integrated summary of the SWSA 5 South source term (including those portions of SWSA 5 South that are included in the White Oak Creek drainage basin). Information concerning burial ground practices, waste types and sources, packaging and disposal (burial) methods, contaminant types, and estimated inventories was collected from a variety of ORNL and external sources. The ORNL ER Program Support Section, Database Management Group (ORNL/ER-DMG) has an ongoing effort to identify and assemble all available information pertaining to historical waste disposal activities. These efforts have yielded a large quantity of information relevant to SWSA 5 South and other portions of WAG 5, and this information has been integrated into the WAG 5 RI Report.

B2.2.1 Description

SWSA 5 is one of the major burial grounds used for disposal of low-level radioactive solid waste at ORNL. Waste disposal operations began in 1959 after an extensive siting study, as reported in Cowser (1958). Waste disposal methods were consistent with standard practices of the time and entailed shallow land burial in excavated trenches and drilled auger holes. Several small landfills were also created, and in some cases debris and other wastes were dumped on hillsides or into drainage valleys and left exposed. When the TRU storage facilities were opened in 1970, the SWSA 5 trench and auger hole disposal areas became known as SWSA 5 South, and the TRU storage area was designated SWSA 5 North. Appendix B4 presents historic photographs that document many of these activities.

Waste disposal operations in SWSA 5 South continued through 1973, and over 220 unlined trenches and nearly 1000 unlined auger holes were used for disposal of approximately 3 million ft^3 (85,000 m^3) of solid waste containing an estimated 210,000 Ci of radioactivity. Table B2.2.1 presents the breakdown of waste units (trenches and auger holes) in each study area (including those in the White Oak Creek drainage area).

Waste types

SWSA 5 received a large and diverse quantity of solid wastes, both radioactively contaminated and not, packaged in a variety of containers and unpackaged; some wastes were well documented, but most were not. Based on available historical records, most of SWSA 5 can be classified into one of five categories:

1. **Low-level radioactive wastes**, also referred to as routine or general radioactive wastes/radwaste, comprise those wastes with <200 mR/h surface exposure. Includes materials contaminated with fission and activation (induced activity) products (mostly β-γ emitters such as ^{90}Sr, ^{137}Cs, and ^{60}Co), uranium-thorium decay series radionuclides (^{23X}U, $^{23X/22X}Th$, ^{22X}Ra, etc.), and tritium.

Table B2.2.1. Summary of SWSA 5 study areas

AREA	SURFACE AREA[a] (ac.)	DISPOSAL UNIT	NO. UNITS	DISPOSAL VOL.[b] (M^3)	PERCENT OF TOTAL VOL.[c]
A	9.5	Trenches	78	15,260	20
	0.53	Holes - augered	121	24	11
B	15.8	Trenches	47	18,143	24
		Trenches - undefined	27	9,531[d]	13
	0.27	Holes - augered	177	35	15
C	14.3	Trenches	57	28,755	38
	0.87	Holes - augered	344	69	30
	-	Holes - Yankee	5	unknown	-
		Holes - Vault	8	16	7
White Oak Creek	22.1	Trenches	12	3164	4
	0.13	Holes - augered	120	24	11
Fissile Storage	4.6	Trenches	3	494	<1
	0.13	Holes - augered	151	59	26
D	1.9	None	-	-	-

[a] *Auger hole area estimated from average surface area for each clustered group of holes.*

[b] *Trench volume based on the mapped trench surface area and an assumed average trench depth of 15 ft and 50% void space at the time of placement. Auger hole volume based on average 1-ft diameter and 17.5-ft depth and 50% void space at the time of placement.*

[c] *Volume percentages calculated as percent of total "trench" volume and percent of total "holes" volume.*

[d] *Area and volumes of undefined trenches are unknown — estimates shown are based on average volume of 353 m^3 for all dimensioned trenches multiplied by 27.*

Duguid et al. (1977) reported that low-level wastes comprised as much as 96% of the total volume of solid wastes placed in the burial grounds.

2. **High activity β-γ wastes** exhibiting >200 mR/h surface exposure required shielding and other precautions for burial. Consists mostly fission products and induced activity radionuclides. **TRU wastes** contain actinide elements above uranium in the periodic table (Z>92). By definition, TRU waste is composed of transuranium isotopes with half-lives greater than 20 years and total activity greater than 100 nCi/g of waste material. (Prior to 1984, when SWSA 5 was in operation, TRU waste classification was based on a threshold of 10 nCi/g.) Consists of by-products of fuel assembly, weapons fabrication, and reprocessing operations. The most common TRU constituents placed in SWSA 5 include $^{23X/24X}$Pu, ^{241}Am, and ^{24X}Cm. Under certain circumstances, ORNL also manages ^{233}U as a TRU waste (other times it is managed as a fissile waste).

3. **Fissile wastes** are those wastes containing 1 g or more of fissionable material regardless of concentration or >1 g/ft^3 regardless of quantity; mostly used for wastes with ^{235}U but may include other fissionable isotopes such as ^{239}Pu and ^{233}U. Concentration limits, restrictions on the quantity of material per container type, and disposal spacing criteria (e.g., auger holes at least 3 ft apart) were used for criticality control.

4. **Special case wastes** have unusually high activity or other distinct characteristics. Examples include the Yankee Atomic Energy control rods placed in concrete storage vaults in SWSA 5 South area C.

SWSA 5 also received wastes contaminated with organic and inorganic chemicals, including volatile and semivolatile organic compounds, beryllium, mercury and other heavy metals, PCBs, laboratory chemicals, cleaning agents, water treatment chemicals, and inorganic salts. In many cases, these chemically contaminated materials also had radioactivity associated with them. Overall, the nonradiological SWSA 5 wastes are not well documented.

The ORNL/ER-DMG database currently contains several thousand burial records that span most of the SWSA 5 disposal period. Based on waste descriptions at the time of burial, ORNL/ER-DMG has labeled many individual trenches by primary waste category (e.g., biological, low activity, TRU). Figure B2.2.1 identifies the location and distribution of this general waste classification by trench and area.

Off-site waste sources

Between 1959 and 1964, ORNL was the Southern Regional Burial Ground for the Atomic Energy Commission (AEC), a precursor agency to DOE. In some years (e.g., 1963, 1964), wastes received from off-site sources exceeded the volume generated by ORNL. ORNL/ER-DMG found burial ground logbooks that document the daily receipt of significant quantities of off-site waste for disposal at SWSA 5. The logbooks contain information concerning shipper, volume, number and type of container, and sometimes burial location, but do not identify type of waste, isotope, or curie count. As a result, little is known about the composition or inventory of these wastes. Photographs from the period show shipments of off-site wastes—including drums, concrete casks, metal cans, and miscellaneous small containers—being unloaded from railroad cars and trucks.

According to information compiled by ORNL/ER-DMG through review of logbooks, burial authorizations (UCN Form 2822), and other records, burial ground activities were a major operation, with dozens of shipments and hundreds or even thousands of containers of waste received each week. Appendix B4 presents historical photos showing the scale of operations associated with the receipt of wastes in railroad cars; other wastes were shipped mostly by truck. An example of a "typical" week in early 1961, based on the "Off Area Logbook" as recorded by Bill Felknor, is shown in Table B2.2.2.

The information collected by ORNL/ER-DMG also identified several off-site (but local) research centers engaged in biological research that apparently shipped significant quantities of biological waste to SWSA 5. These facilities included the Oak Ridge Institute for Nuclear Science (ORINS), the University of Tennessee, and Building 9207 at Y-12 (administratively part of ORNL). Wastes included animal carcasses, animal remains, bedding, animal waste, and miscellaneous trash; much of this waste was containerized in fiber drums and cardboard boxes. Shipment of biological wastes continued after ORNL was no longer the AEC Southern Regional Burial Ground.

Another potentially significant source of off-site waste disposed of in SWSA 5 is the Y-12 Plant: ORNL/ER-DMG identified a limited number of waste records, primarily from burial ground logbooks that detail shipments of Y-12 waste from the early 1960s. One such logbook (also

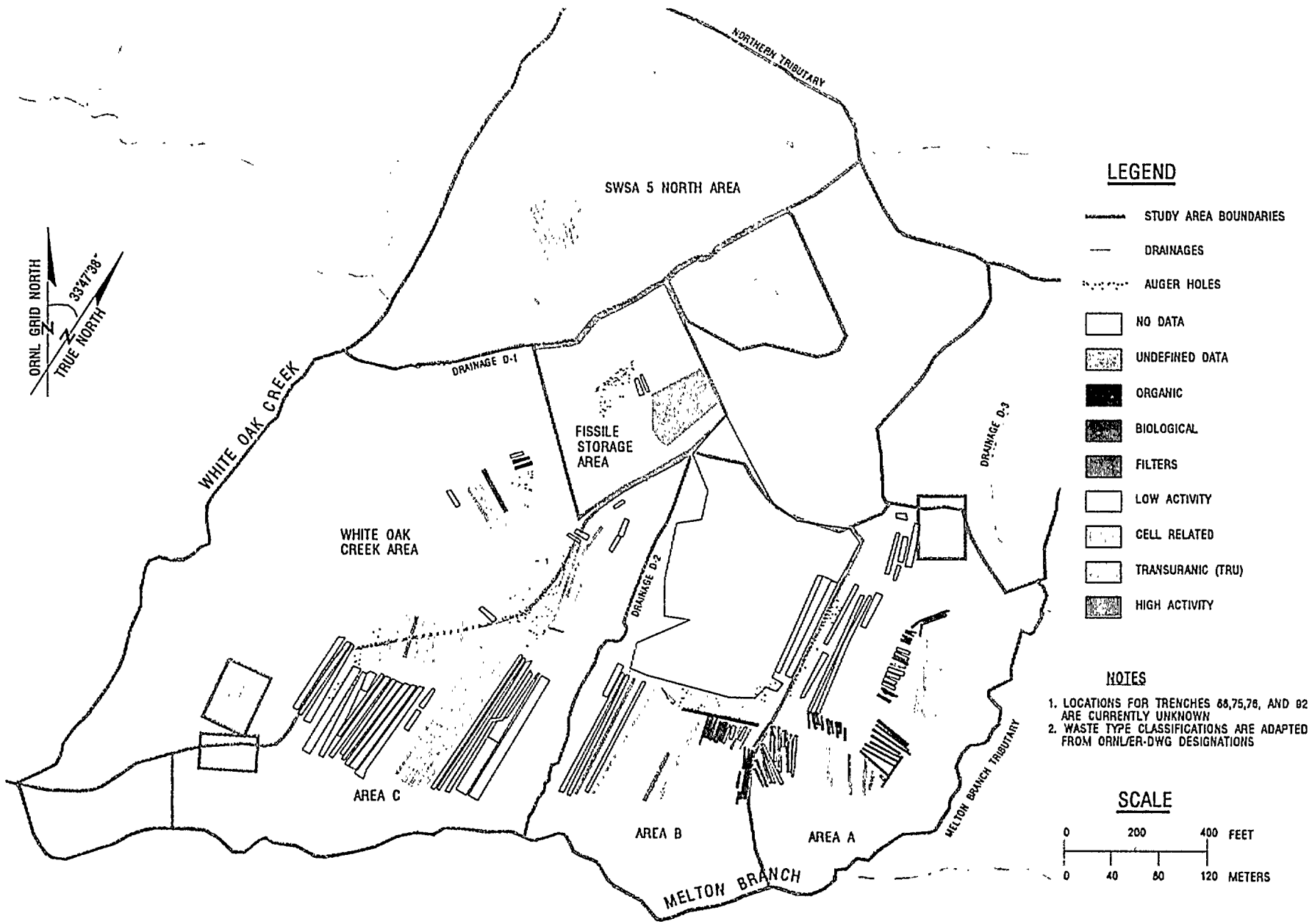


Fig. B2.2.1. Trench classification by waste type.

Table B2.2.2. Excerpt from "off area logbook" for SWSA 5, week of January 31–February 3, 1961

DATE	WASTE RECEIVED FROM	WEIGHT (LB.)	NO. OF CONTAINERS	VOLUME (FT^3)	DISPOSAL LOCATION
1-31-61	Bridgeport Brass Co.	13,024	28 (55 gal) drums	113	Section 2 Trench 17
1-31-61	Mallinckrodt Chemical Co. 6 RR carloads		730 (55-gal) drums 100 (30-gal) drums	5,300	Section 2 Trench 16
1-31-61	Gamma Industries		3 drums	21.3	Section 3 Trench 12
1-31-61	Westinghouse Electric		5 drums		Section 3 Trench 12
2-1-61	Nuclear Engr Co. Kerney, NJ		49 (55-gal) drums 30 (30-gal) drums 4 boxes	704.5	Section 2 Trench 16
2-2-61	Supply Office US Navy, Millington, TN	16	1 box	1	Section 3 Trench 12
2-2-61	Minnesota Mining & Manufacturing Co. (3M)	3,400	21 boxes	262	Section 3 Trench 12
2-3-61	Battelle Memorial Institute	15,000	4 boxes 40 (55-gal) drums	285	Section 2 Trench 17
2-3-61	National Lead Co 2 RR carloads	87,300 98,145	306 drums 282 drums		Ravine
2-3-61	U.S. Radium Corp.	1,670	4 (55-gal) drums 5 boxes	50	Section 3 Trench 12
2-3-61	Gamma Industries	475	3 drums	21.3	Section 3 Trench 12

authored by Bill Felknor) describes shipments between January 1961 and August 1962. During this time, Y-12 wastes were brought to SWSA 5 in dumpsters, pans, metal and fiber drums, cardboard and wooden boxes, and as loose debris. Waste materials included gloves and coveralls, piping, ductwork, gloveboxes, lab benches, and cabinets. The log also described various radionuclide contaminants, such as thorium, uranium, beryllium, plutonium, neptunium, fission products, ^{45}Ca, ^{89}Sr, and ^{32}P.

Much of the information concerning the composition, type, quantity, and disposal location of Y-12 wastes is classified due to the plant's role as a production facility for nuclear weapons components. Other off-site sources also sent classified waste, and any relevant portions of information pertaining to WAG 5, whether classified or declassified, will be factored into the decision-making for the selection and implementation of appropriate cleanup actions at WAG 5.

On-site waste sources

ORNL waste generators included radioisotope production facilities, reactors, hot cell operations, pilot plants, particle accelerators, and research laboratories (physical, biological, and chemical). Past programs that were major generators of radioactive waste at ORNL (as cited in NRC [1985]), include:

- ^{239}Pu production/separations development
- Naval reactors program
- ^{140}Ba-^{140}La production
- Systems for nuclear auxiliary power source development/production (^{90}Sr, $^{242/244}Cm$)
- High-enrichment fuel reprocessing development
- Aircraft nuclear propulsion program
- ^{3}H target development/fabrication
- Special radioisotope sources (^{60}Co, ^{3}H, ^{85}Kr, ^{241}Am)
- Low-intensity test reactor operations
- Uranium-thorium fuels development
- Radioisotope application development
- Reactor development
  - High-Temperature Gas Reactor,
  - Molten Salt Reactor Experiment,
  - Homogeneous Reactor Experiment.

Contaminants in ORNL wastes included fission products, elements of the uranium-thorium decay series, neutron activation products, tritium, and transuranic isotopes. It is likely that a significant fraction of the original radioactivity was associated with radionuclides with relatively short half-lives (<1 year), and thus the activity of SWSA 5 South wastes is currently dominated by the longer-lived fission products, uranium-thorium elements, and transuranics. ORNL wastes also included organic and inorganic chemicals such as metals, laboratory chemicals, and solvents; chemical waste characterization data are limited, however.

An early but by no means typical example of SWSA 5 disposal was the debris associated with the cleanup of the hot cell that exploded in Building 3019 in 1959. The explosion contaminated portions of the building with plutonium and other radionuclides. According to information collected by ORNL/ER-DMG, cleanup over the next 2 years included approximately 1500 Pu-contaminated cinder blocks that were placed in plastic-lined 55-gal drums and buried in SWSA 5. Other wastes included contaminated equipment and materials used in the cleanup operations (e.g., coveralls and gloves).

Most on-site wastes were low-level radioactive waste variously described as lab equipment, rags, paper, valves and piping, scrap metal, lumber, machinery, filters, soil, and miscellaneous trash. Not all of the wastes disposed of in SWSA 5 were contaminated, and most that were contaminated contained only low levels of radioactivity (Gilbert-Commonwealth 1980; National Academy of Sciences 1976; Duguid et al. 1977). As shown in the historical photos in Appendix B4, trench wastes included furniture, lumber, scrap metal, and other debris that in most cases probably does not represent a significant contaminant source.

Waste disposal methods

Trenches. Trench disposal in SWSA 5 consisted of excavating a trench, filling it with waste, and backfilling with regolith (soil), in some cases derived from excavation of an adjacent trench. Trenches range in length from several tens of feet to several hundred feet, from 4 to 30 ft in width, and up to 15 ft in depth. The most well-documented trench design was described in Cowser et al. (1961) for two trenches in the northeast corner of SWSA 5 South that were used for disposal of

drummed, alpha-contaminated wastes from Y-12. This modified design consisted of a sloped, gravel-covered trench bottom leading to an asphalt-coated sump from which a corrugated metal standpipe extended to the surface. After wastes were placed in the trench, a cover was constructed of compacted shale and a thin layer of asphalt. The design was intended to allow for improved monitoring. It is not known whether any additional trenches were so constructed.

Some wastes were buried in metal, wood, plastic, or concrete containers; larger debris, lumber, piping, furniture, and equipment, were simply dumped into trenches. Historical photos of trench-filling activities and trench waste materials provide the best information concerning disposal methods in SWSA 5 (see Appendix B4). These photos show dumpsters being dumped into trenches, drums stacked or dumped haphazardly into trenches, stacked wooden and concrete boxes, and variations thereof. Larger contaminated items such as glove boxes or contaminated building debris were either buried in trenches or placed in small landfills in several of the ravines at the site (discussed below). In general, it appears that most waste containers (when used) would provide minimal initial containment, and nearly all would have questionable integrity within a few years.

During the early portion of SWSA 5 operations, trenches with alpha-contaminated wastes were reportedly covered with concrete. The only confirmed location where this occurred was in a trench used for disposal of TRU waste casks. Other trenches with alpha wastes covered by concrete, if they exist, would most likely be found in the undefined trench area in SWSA 5 South (Study Area B).

Auger holes. Unlined auger holes were used to dispose of biological wastes, higher-activity beta-gamma wastes, and fissile wastes. Auger hole dimensions varied, but most were apparently 1 to 3 ft in diameter and 15 ft deep. Holes were spaced a minimum of about 3 ft apart (edge to edge). After filling, the holes typically were capped with concrete.

Historical photos in Appendix B4 show auger holes being drilled and filled with waste, as well as the concrete caps on holes already filled. Shielded containers of higher-activity wastes were brought to the burial ground, and the contents were emptied directly into the auger holes. Information collected by ORNL/ER-DMG indicates that the earlier auger holes in SWSA 5 were designated "animal tissue wells" and used solely for biological wastes. Other materials placed in the holes included boxes, drums, cans, and stainless steel containers.

A modification of the auger hole disposal method was used for special burials, the most noteworthy of which was the below-ground disposal of control rods from the Yankee Atomic Energy facility in five concrete-lined silos (Appendix B4). Eight additional concrete-lined auger holes ("vaults") were used to dispose of wastes from Building 3019. It is likely that wastes in these holes were analogous to remote-handled TRU wastes (i.e., TRU wastes with high beta-gamma content) disposed of in later years in SWSA 5 North, which were typically capped with concrete.

Landfills. SWSA 5 South contains several areas defined as small landfills. In the western part of the study area, landfills were constructed in the headland portion of incised drainage valleys leading to D-2 or White Oak Creek (see Fig. B2.2.2). The southernmost of these is the "dump area"; the one to the north was called the "ravine" during burial ground operations [the ravine also corresponds to trench 36 (fissile storage study area)]. A third landfill is located in the northeast corner of SWSA 5 South (landfill study area) on the slope leading eastward to drainage D-3. All three landfills are described in more detail in Sect. B2.3.

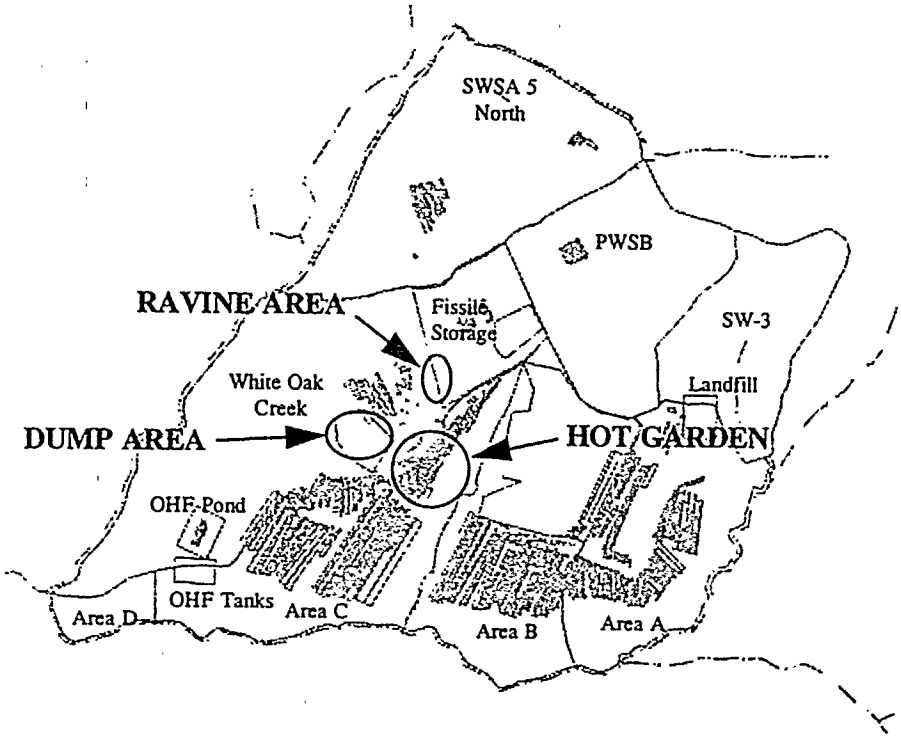


Fig. B2.2.2. SWSA 5 South historic areas.

Disposal methods in all three landfills were as follows: initially, wastes consisting of contaminated and uncontaminated debris, trash, and equipment were placed in these areas and covered with soil; later on, or perhaps concurrently, larger debris was dumped over the sides of the hill and in most cases rolled at least part of the way down the hill. No attempt was made to cover these wastes, and it is likely that in most cases they were uncontaminated. An exception to this occurred at the northeast landfill, where contaminated debris was dumped over the hillside and remains exposed (see Section B2.3.4).

Waste Inventory. The inventory of radioactive and chemical wastes in SWSA 5 South is poorly defined. Various estimates of radionuclide inventory have been proffered over the years (e.g., Gilbert-Commonwealth 1980; NRC 1985; Grizzard 1986). The consensus among these sources is that the total radioactivity at the time of emplacement was about 210,000 Ci. An unknown but potentially significant component of this radioactivity may have been related to short-lived radionuclides such as ^{106}Ru (1 yr half life), ^{144}Ce (285 day half life) and other fission and activation products. Most of the SWSA 5 wastes were disposed of more than 25 years ago, and it is likely much of the radioactivity in the wastes placed in SWSA 5 may have decayed to stable daughter products. Sampling results for the RI indicate that activity in SWSA 5 South currently is dominated by isotopes with half lives of at least several years; these include:

- fission products such as ^{90}Sr, (28.6 yrs) and ^{137}Cs (30 yrs)
- uranium-thorium decay series radionuclides (parent half-lives in the thousands or millions of years)

- transuranium radionuclides with half-lives of hundreds or thousands of years (with some exceptions, such as ^{244}Cm [18 yrs])
- activation products such as ^{60}Co (5.3 yrs) and ^{3}H (12.3 yrs).

The absence of reliable inventory data for SWSA 5 complicates efforts to predict future contamination trends or risk for WAG 5. Since information regarding the distribution, quantities, and containment of contaminants of concern in the majority of the buried waste at WAG 5 is limited, no quantitative model of future contaminant migration that provides exposure concentrations for use in future land use scenarios was developed for the RI. Instead, equilibrium conditions are assumed to derive exposure concentrations for groundwater and surface water in the future land use scenarios. This situation leads to the primary uncertainty associated with the risk assessment results presented in Volume 1, Section 3 figures, which is that the results are based on a combination of current exposure concentrations and future exposure conditions. The risks are based on the decay and ingrowth of radionuclides in the environmental media, assuming a steady state baseline condition for contaminant releases. Realistically, the various future land use scenarios presented in the risk assessment will not occur for some time in the future, and the media concentrations at that time will have changed.

B2.2.2 Operational History

Information collected by ORNL/ER-DMG provides an overview of the operational history of SWSA 5 South. This information included open and close dates for most of the 224 numbered trenches in SWSA 5 South (and SWSA 5 North); these dates were used to develop Fig. B2.2.3, which is a color-coded map based on the average open and close date for each trench. Figure B2.2.4 is a chart depicting the yearly volumes of wastes disposed of in SWSA 5 South from both on-site and off-site sources as well as the total and cumulative volumes. The chart has a color key and study area-specific breakdown of trenches used during each time period and was designed for use with the trench map (Fig. B2.2.3). For further reference, Fig. B2.2.5 shows the date range for individual trenches by area. Information concerning the fill dates for auger holes is less complete and is not included on either figure.

Operations in SWSA 5 South began in 1959 with disposal in the undefined trench area (the area was so designated in the early 1960s after records documenting the locations of individual trenches were lost). Between 1959 and 1962, 27 trenches were excavated and filled in this area. The undefined area received plutonium-contaminated wastes from the Building 3019 cleanup and large amounts of off-site waste, including biological wastes. (The undefined trench area lies in SWSA 5 South Area B as delineated for the RI.)

Waste disposal operations continued to the east of the undefined trench area (i.e., in SWSA 5 South area A) in an area designated on early ORNL drawings as the "Y-12 Uranium Salvage" area; opening and filling of these trenches (numbers 28–30) occurred in 1961. Trenches 29 and 30 were of the experimental design described in Cowser et al. (1961), and both received alpha-contaminated wastes from Y-12. Trench 35, also in this area, was reportedly filled with sludges from on-site and off-site sources in 1962–63.

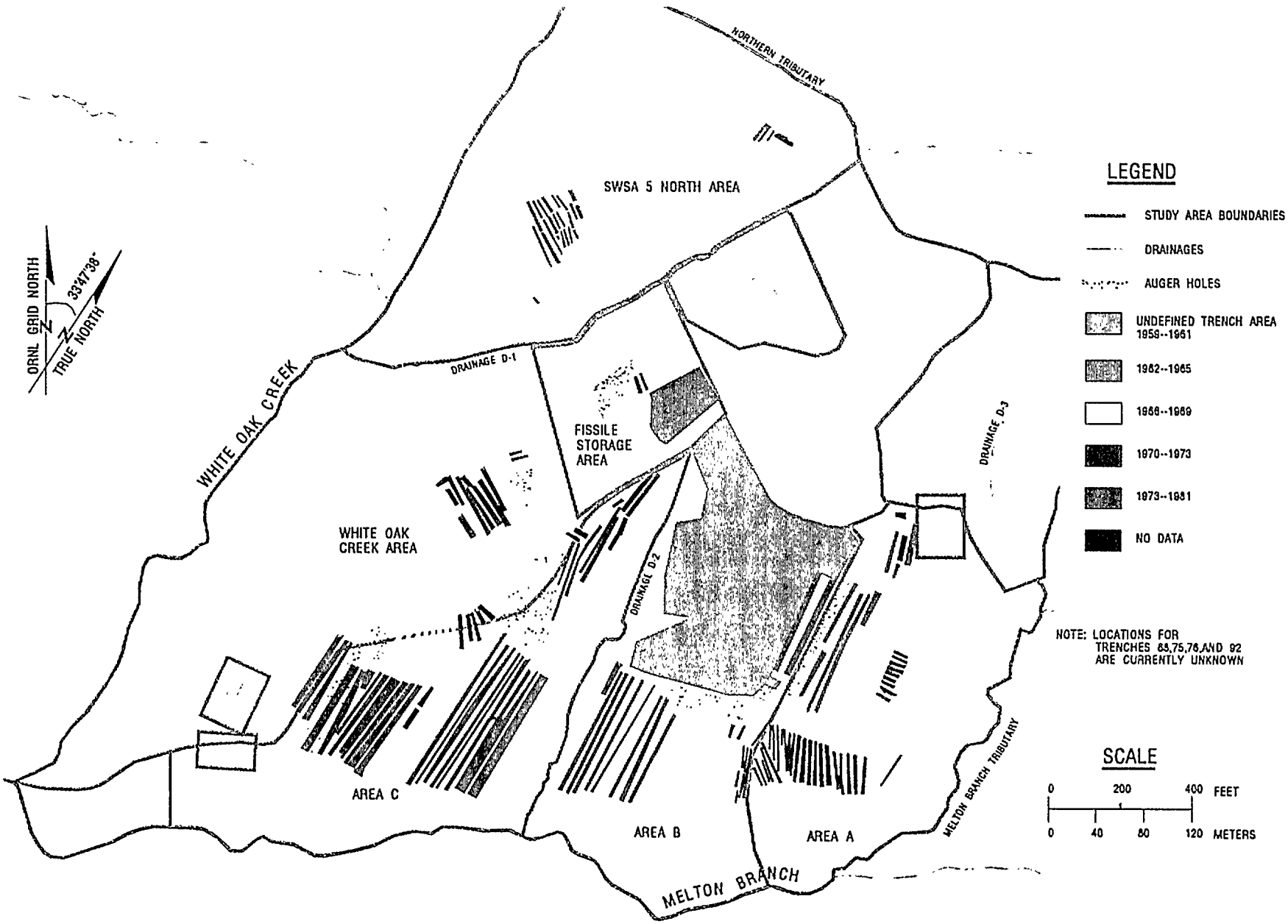
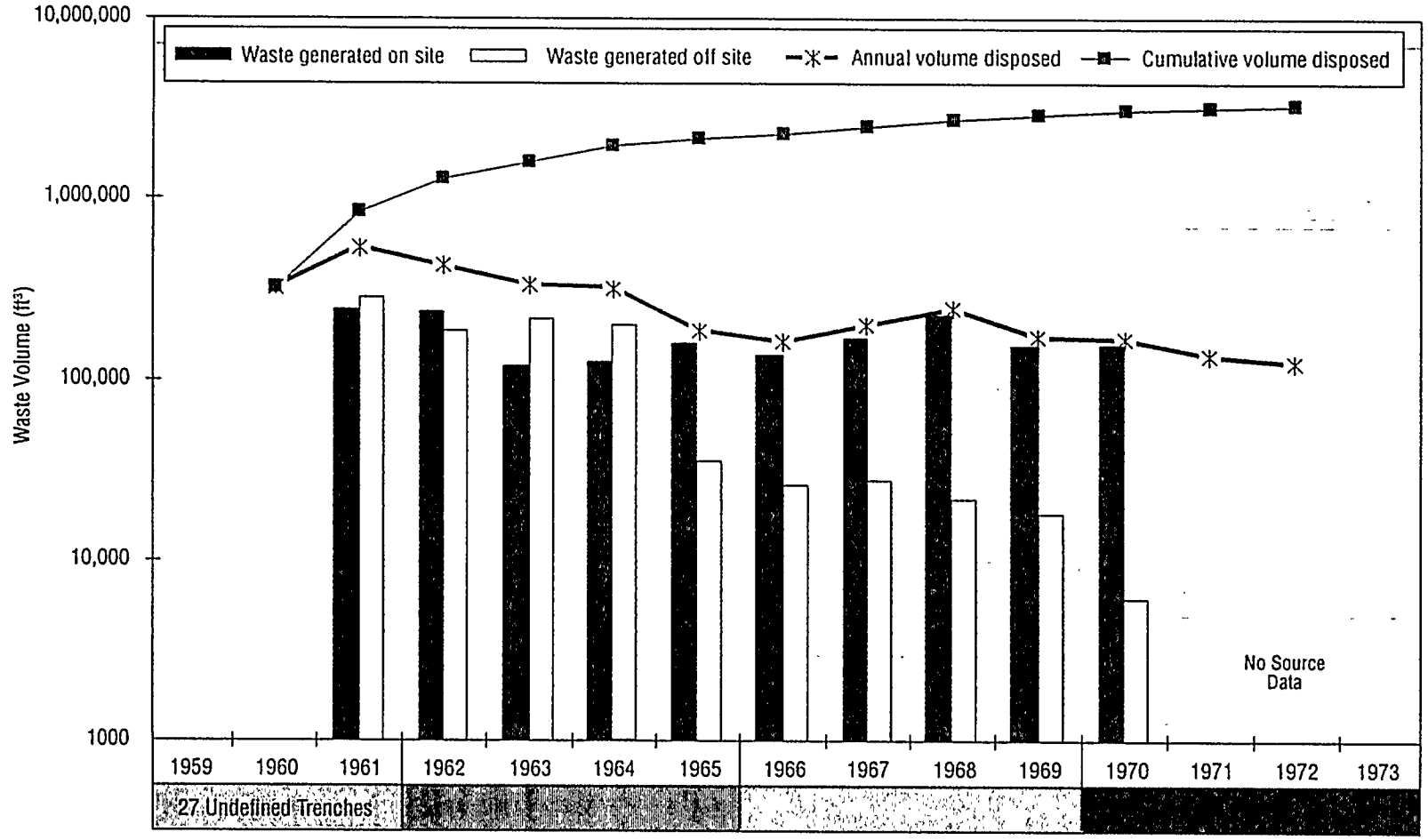


Fig. B2.2.3. Average open/close dates for trenches.



Area	Number of Trenches In Use (Based on average open/close date)			
A	—	6	36	34
B	27	12	27	6
C	—	23	15	12
SWSA 5 WOC	—	2	1	8
Fissile Storage	—	1	0	2
4 Unknown Trenches	—	2	2	—
Total	*27*	*46*	*81*	*62*

Fig. B2.2.4. SWSA 5 south trench disposal summary. *Sources:* Waste disposal data from Burch, 1972; trench data from ER-DMG database.

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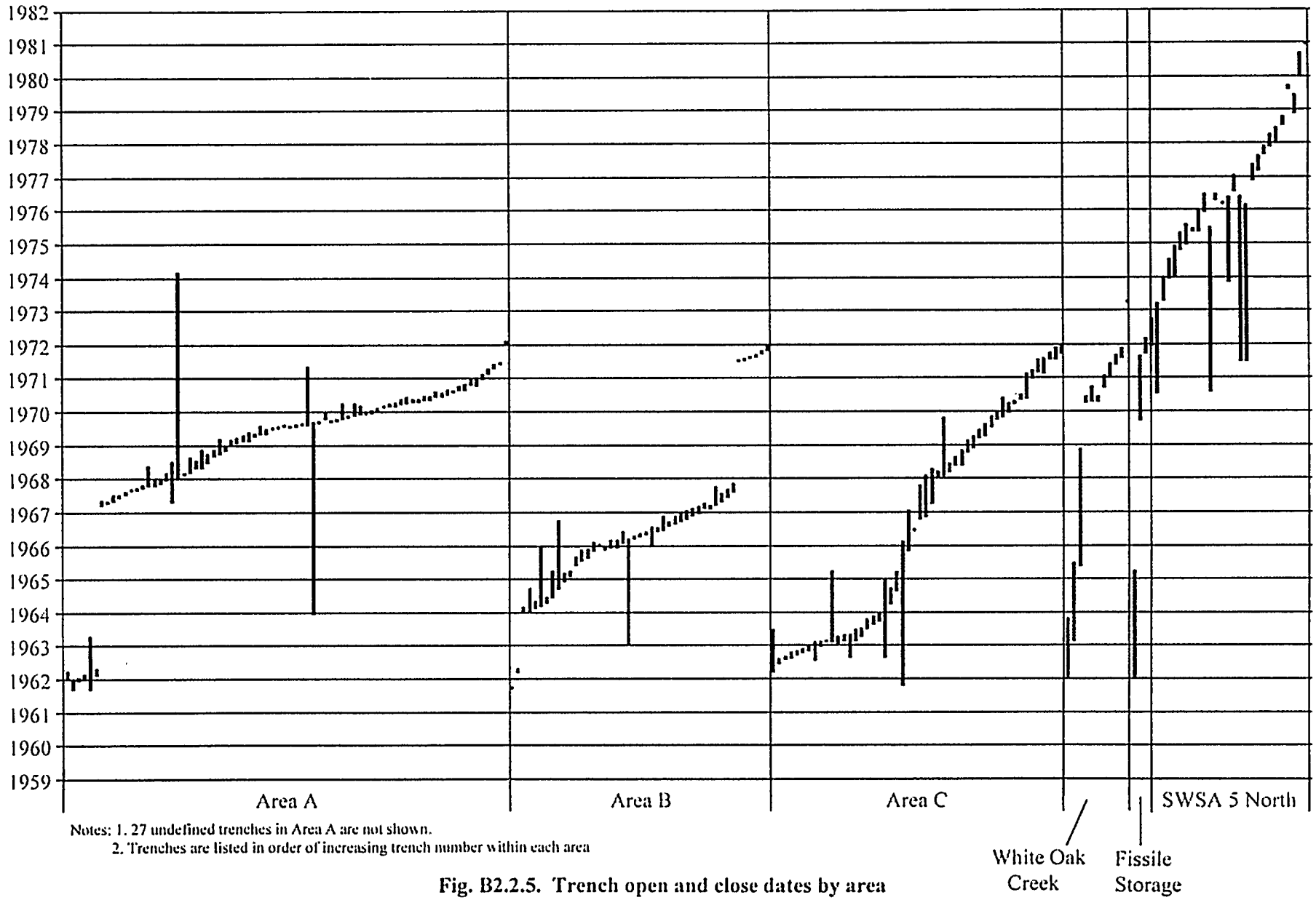


Notes: 1. 27 undefined trenches in Area A are not shown.
2. Trenches are listed in order of increasing trench number within each area

Fig. B2.2.5. Trench open and close dates by area

B2 F2_5.PPT

Between 1962 and 1965, 45 trenches in widely scattered locations across the burial ground were used. No information describing the waste types or sources was available, but it is likely that these trenches contain significant quantities of off-site wastes.

Some of the earliest auger holes used in SWSA 5 are in area A along the eastern and southern perimeters of the undefined trench area. These include approximately 110 holes to the east (between trenches 38 and 39) and 160 along the southern boundary (near trench 79). These holes were used for disposal of mostly biological wastes between 1962 and 1965. Disposal of biological wastes in auger holes was apparently terminated in 1965 because of the large quantities of biological waste being received.

After 1965, trench disposal activities were concentrated in areas A and B, during which time most of the biological waste trenches were filled. Eighty-one trenches were used during the period 1966 through 1969. The first used solely for biological waste was trench 79 (opened in November 1965 and closed in March 1966), located in area B along the southern margin of the undefined trench area. Also in 1965, the first auger holes in what would become the "hot garden" were used for disposal of high-activity wastes. The "hot garden" is in the central portion of area C (Fig. B2.2.2) and contains about 150 auger holes. Associated with this grouping are the special case wastes in the Yankee Atomic Energy control rod silos and concrete vaults discussed above. Disposal of these wastes occurred prior to 1965.

Between 1970 and 1973, the final years of routine burial operations at SWSA 5 South, 62 trenches in the western part of area A, the northern part of area C, and the White Oak Creek portion of SWSA 5 South were filled. The trenches in area A contain mostly low-activity wastes; those in area C contain TRU and high-activity wastes, while in the White Oak Creek portion both TRU and low-level (cell-related) wastes were buried. During the final years of operation, a group of approximately 50 auger holes in the White Oak Creek section of SWSA 5 South were used to dispose of radiologically contaminated organic wastes.

Beginning in October 1969, fissile wastes were buried in the fissile storage area in the northern part of SWSA 5 South. Disposal operations in this area, mostly in auger holes but including two trenches, continued through 1973.

B2.3 WAG 5 WHITE OAK CREEK DRAINAGE AREA

B2.3.1 WAG 2 Data Summary

Historical data from White Oak Creek studies are summarized to enhance understanding of the contamination in the creek and suggest reaches where WAG 5 may be contributing to this contamination. The Environmental Restoration Monitoring and Assessment activity in the WAG 2 Site Investigation Program provided most of the White Oak Creek data; other studies, such as the data collected by ASEMP [Ashwood and Marsh (1994)] and the stream bed gravels study by Cerling and Spalding (1981), provide peripheral information.

WAG 2 RI data

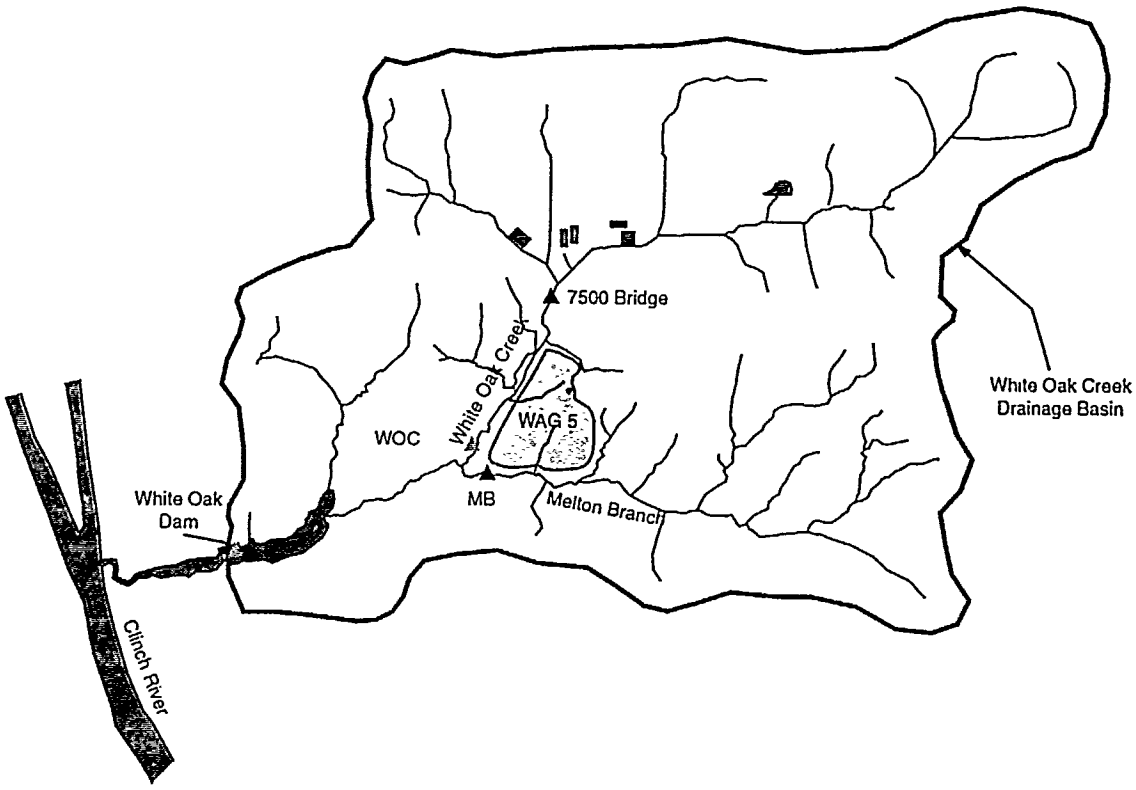
As part of the environmental monitoring and compliance program at ORNL, surface water quality is monitored at four locations in the vicinity or downstream of WAG 5: White Oak Dam, White Oak Creek weir, Melton Branch weir, and the 7500 bridge (Fig. B2.3.1). Each station is monitored continuously with a flow proportional sampler. Samples are collected monthly at each station except at White Oak Dam, where samples are collected weekly. Radiological analyses on these samples include ^{90}Sr, ^{3}H, and gamma scan. Samples from White Oak Dam are also analyzed for gross alpha and gross beta.

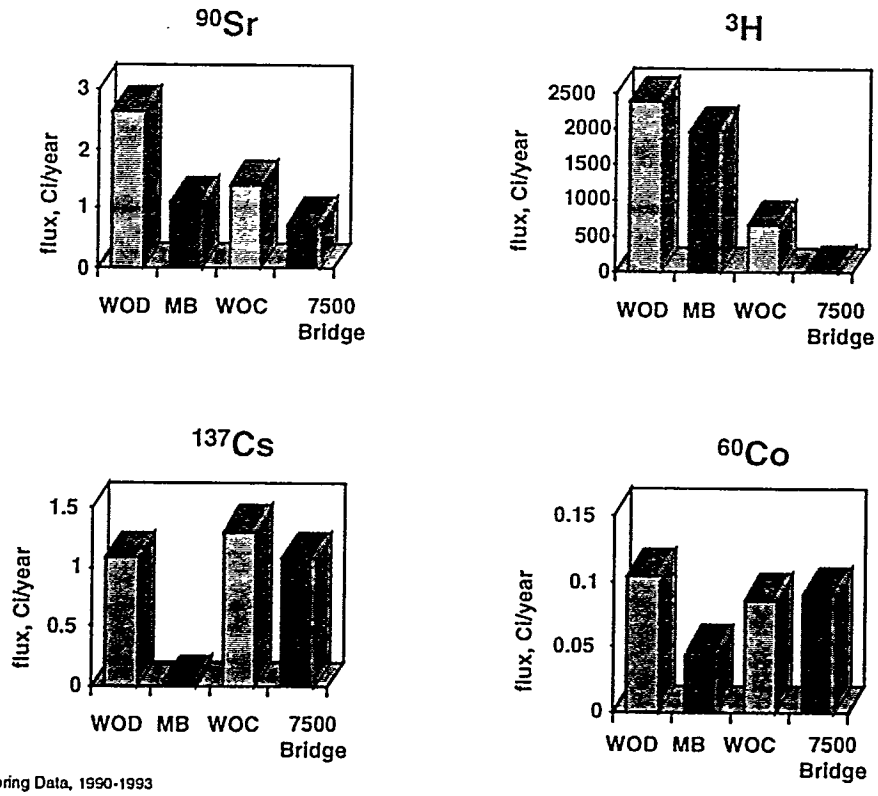
Figure B2.3.1 shows the average annual fluxes for 1990 through 1993 of ^{60}Co, ^{137}Cs, ^{3}H, and ^{90}Sr. The reach between the 7500 bridge and the White Oak Creek weir receives drainage from WAG 4 and the White Oak Creek drainage area of WAG 5 (i.e., SWSA 5 North, PWSB, fissile storage area, SWSA 5 White Oak Creek area, and OHF). Fluxes of ^{137}Cs, ^{90}Sr, and tritium increased in this reach of White Oak Creek, while the ^{60}Co flux remained unchanged. Strontium-90 showed the greatest flux increase (almost 50%), and the ^{137}Cs flux increased approximately 20%. Approximately 25% of the ^{3}H flux measured at the White Oak Creek weir entered the stream downstream of the 7500 bridge.

To better quantify the sources of the contamination entering the White Oak Creek system, WAG 2 field investigation personnel began collecting surface water samples at stream transects in 1992. Samples were collected at intervals along the stream channel to determine exact locations where contamination is entering the system. Figures B2.3.2 and B2.3.3 show the maximum, minimum, and average concentrations of gross alpha, gross beta, tritium, and ^{90}Sr at transects in White Oak Creek adjacent to WAG 5. Strontium-90 concentrations remained relatively constant between 100 and 200 pCi/L, but tritium concentrations increased steadily from 1,100 to 450,000 pCi/L, with the greatest increase occurring downstream of the confluence with Melton Branch. Gross alpha and gross beta followed similar patterns with an increase immediately after drainage D-1, followed by a general decrease to the confluence with Melton Branch.

Based on these transect samples, average fluxes were calculated from average concentrations and estimated average flow at each sampling transect. The average flow was determined using the flow data collected between 1990 and 1993 at the White Oak Creek weir and at the 7500 bridge. Flow at each transect location was found by interpolating between upstream flow and downstream flow on the basis of the drainage area upstream of each transect point. Figures B2.3.4 and B2.3.5 show the average flux of gross alpha, gross beta, tritium, and ^{90}Sr at transects along White Oak Creek. All of the contaminants show an increase in flux immediately downstream of the discharge from WAG 4 and drainage D-1. Farther downstream, gross alpha, gross beta, and ^{90}Sr fluxes decrease, which may be due to deposition of contaminants in the stream channel. Figures B2.3.4 and B2.3.5 show that similar or higher fluxes of ^{90}Sr, tritium, gross alpha, and gross beta exist in Melton Branch as indicated by the sampling points upstream and downstream of the White Oak Creek and Melton Branch confluence.

During 1992, stream transect sampling events corresponded to wet season baseflow and dry season baseflow. Flux over White Oak Dam from sampling stations on White Oak Creek was determined on the basis of this sampling (Clapp and Watts 1993): 32–37% of the ^{90}Sr and 2–4% of





Source: Environmental Monitoring Data, 1990-1993

Fig. B2.3.1. Average annual radionuclide flux (1990-1993) in White Oak Creek basin.

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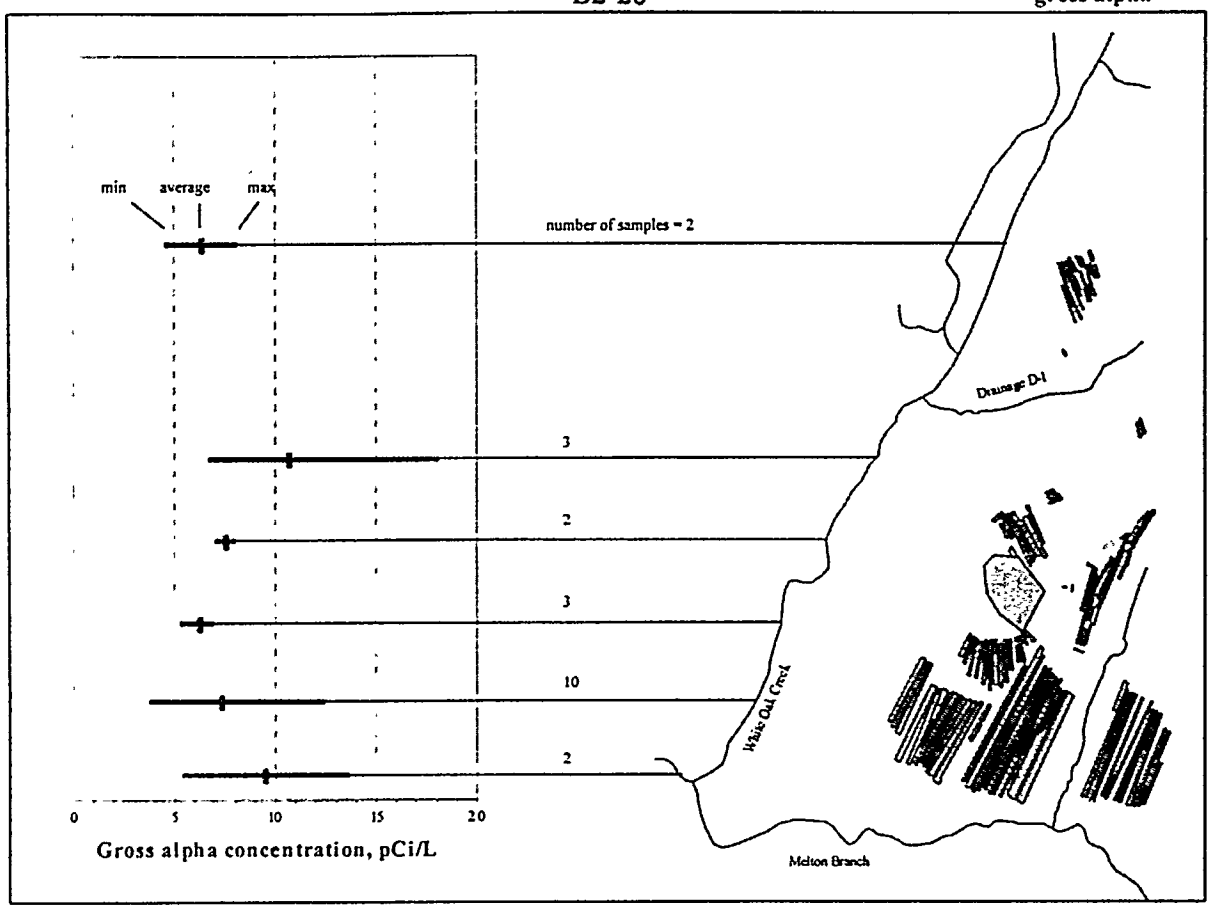
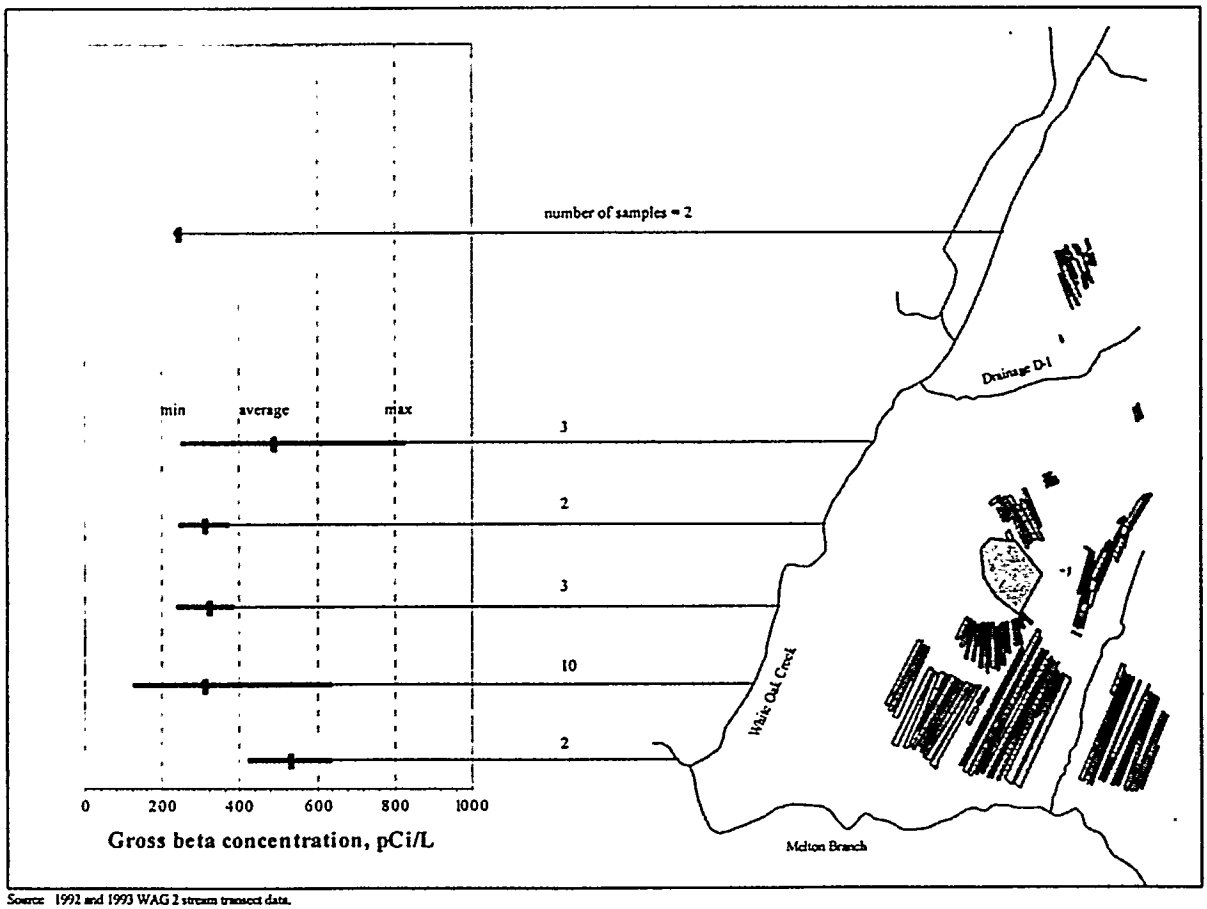
gross alpha



gross beta

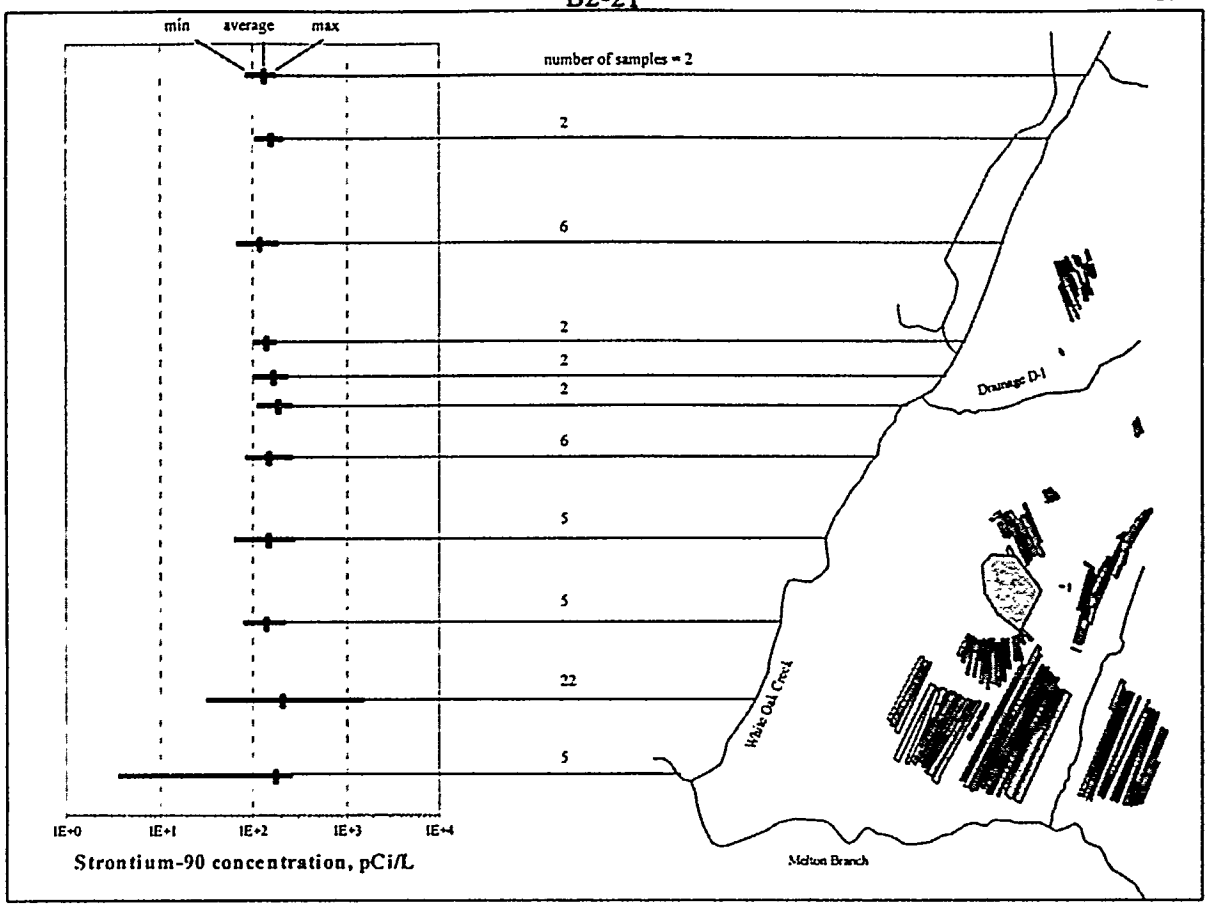


Source: 1992 and 1993 WAG 2 stream transect data.

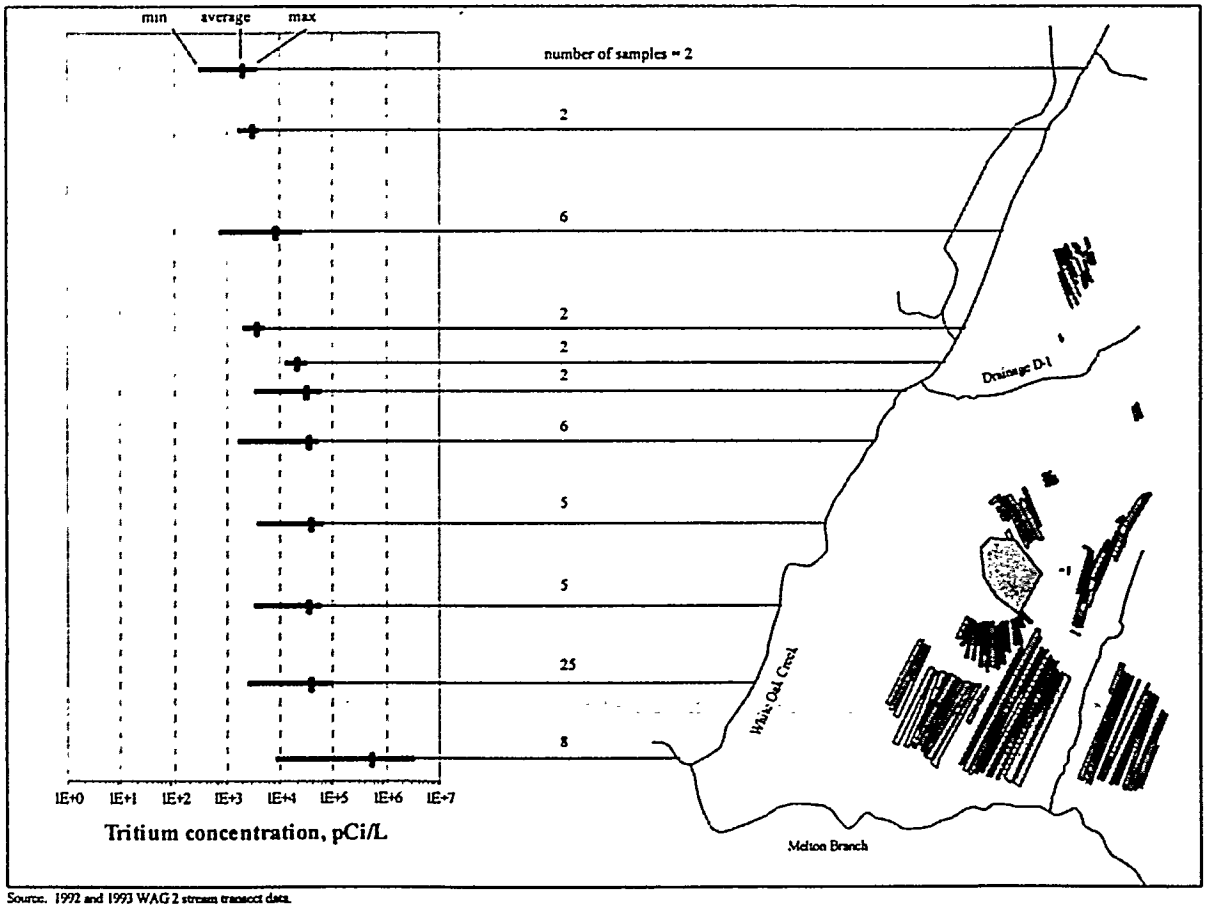
Fig. B2.3.2. Gross alpha and gross beta concentrations in White Oak Creek.

B2_F3_2.PPT

^{90}Sr



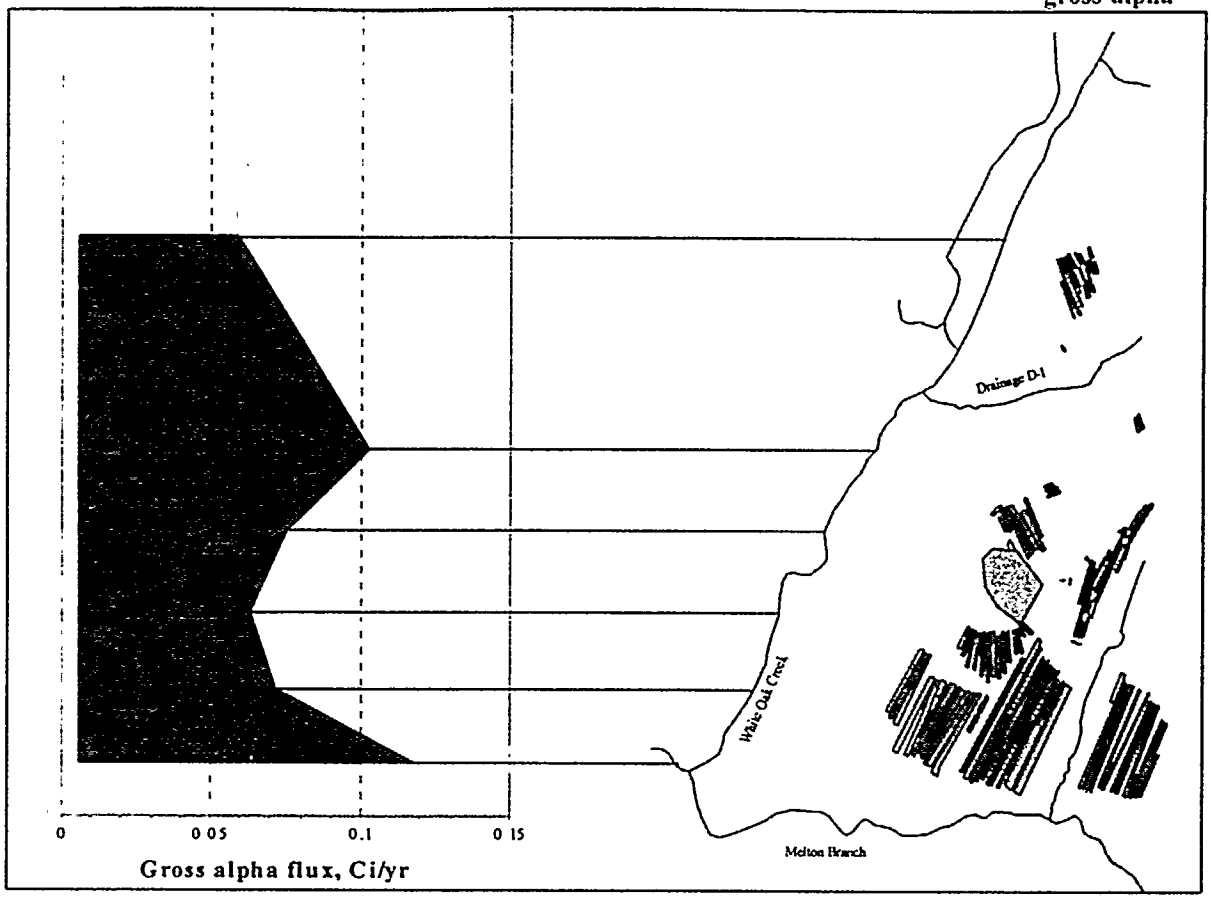
tritium



Source. 1992 and 1993 WAG 2 stream transect data.

Fig. B2.3.3. Strontium-90 and tritium concentrations in White Oak Creek.

B2_F3_2.PPT



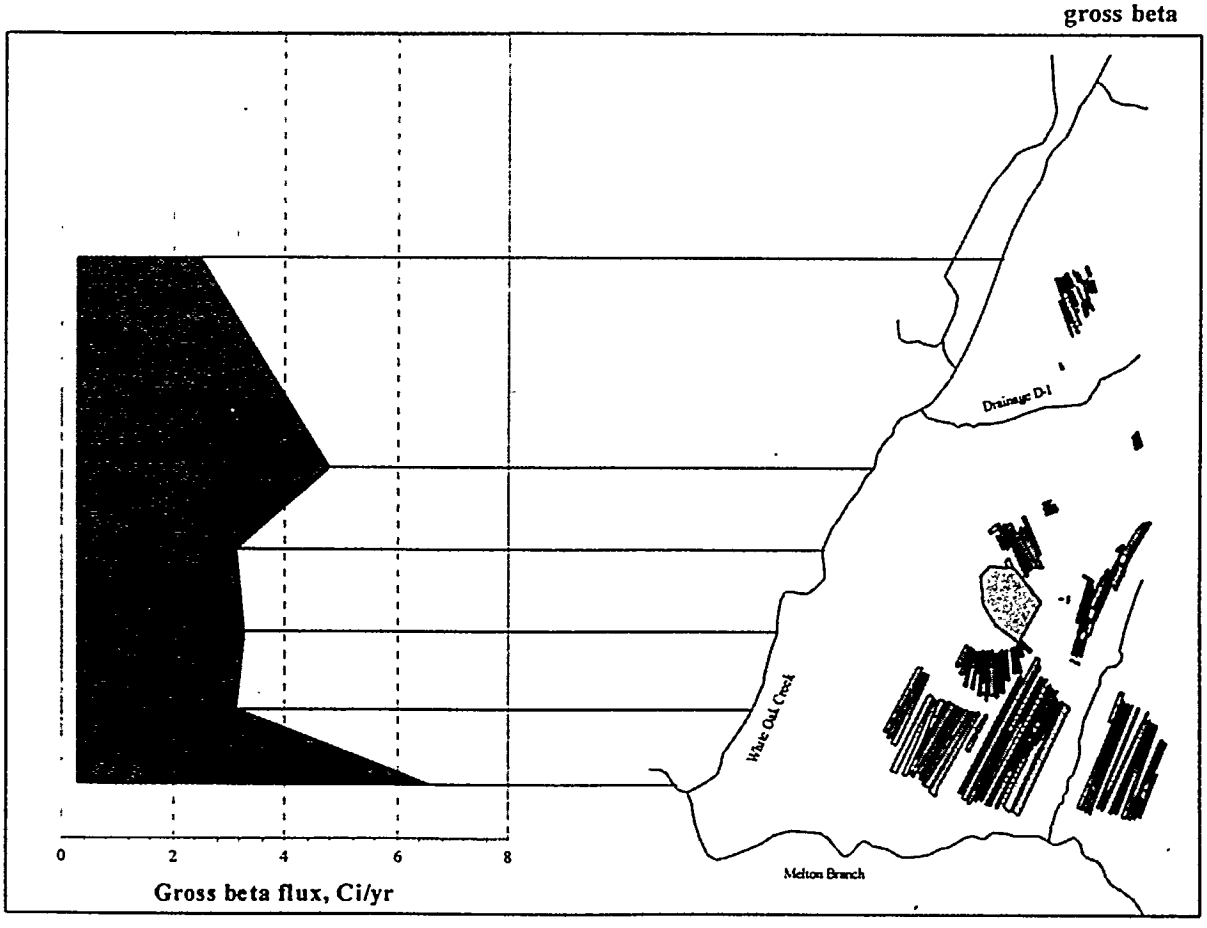
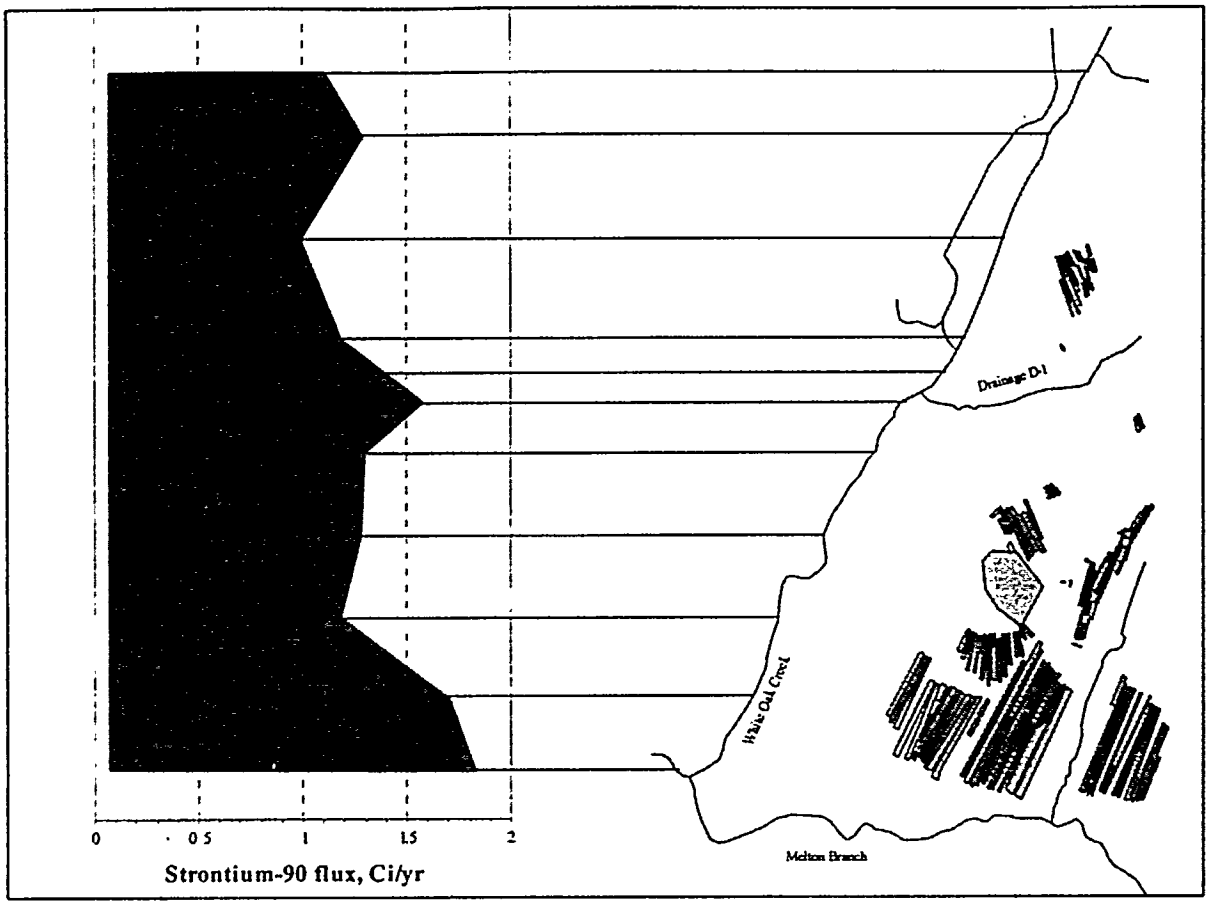


Fig. B2.3.4. Gross alpha and gross beta flux in White Oak Creek.

^{90}Sr



tritium

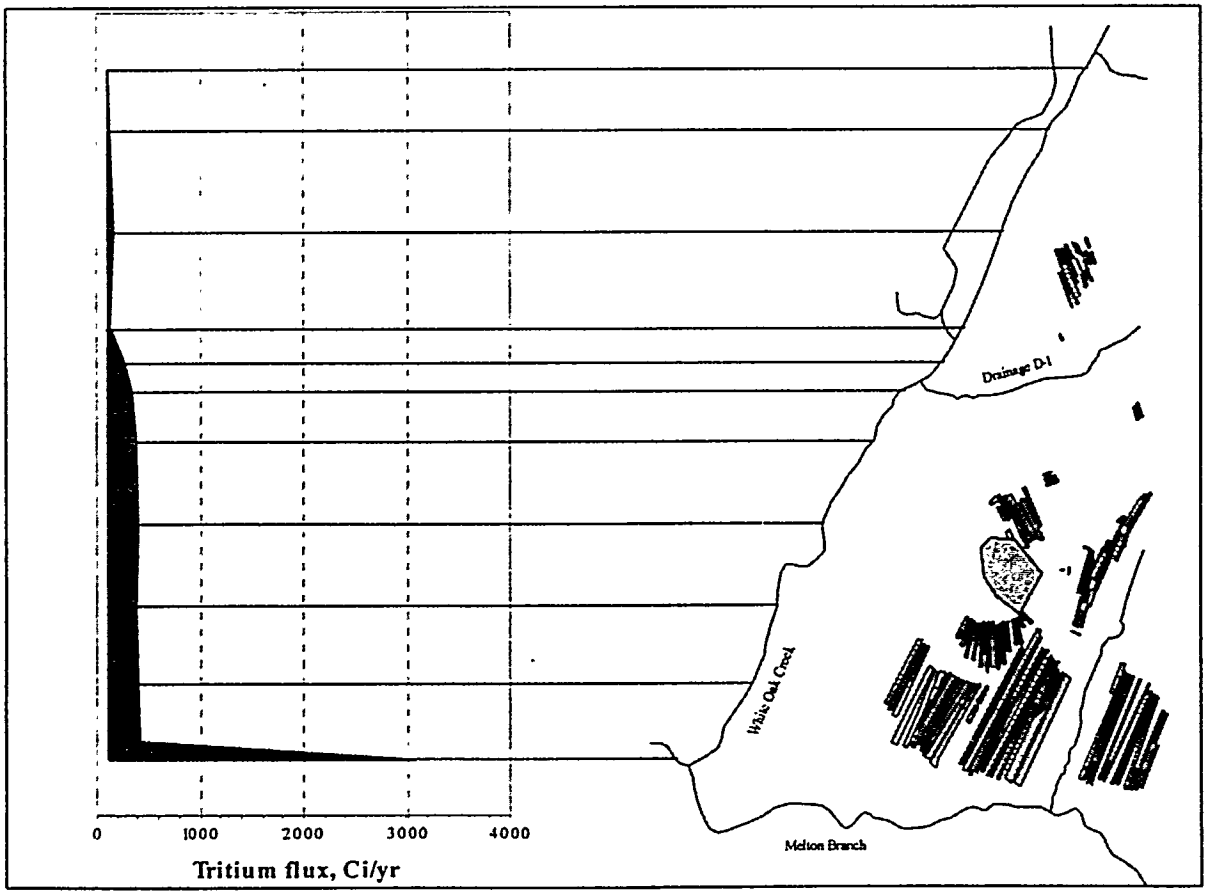


Fig. B2.3.5. Strontium-90 and tritium flux in White Oak Creek.

B2_F3_4 PPT

the tritium was observed at the 7500 bridge; 0–10% of the ^{90}Sr and 1–15% of the tritium at WAG 4; and 6–22% of the ^{90}Sr and 48% of the tritium at White Oak Creek weir.

ASEMP data

The ASEMP monitors both groundwater and surface water in and around SWSA 5 North and takes stream transect samples from White Oak Creek in the reach adjacent to SWSA 5 North. Figure B2.3.6 shows gross alpha and beta concentrations at the stream transects. Gross alpha was detected between 1 and 6 pCi/L, less than the background reference value of 9 pCi/L (2 times the mean background), and did not show any significant increase along this reach. Gross beta also showed no significant increase in this reach; results varied between 90 and 150 pCi/L, over 10 times greater than the background reference of 8 pCi/L, with the main beta emitter being ^{90}Sr.

Stream bed gravels data

Stream bed gravels were extensively surveyed to determine the areal concentration of ^{60}Co, ^{137}Cs, and ^{90}Sr in the White Oak Creek system (Cerling and Spalding 1981). The study collected sediment samples at approximately 35-m intervals along the stream channel. Gravels were collected from the upper 10 cm of streambed sediment and wet-sieved to retain the coarse sand and fine gravels. Only the sand and gravel were analyzed because previous studies found that these sediment particles had higher concentrations of radioactivity and were more resistant to downstream movement.

Figure B2.3.7 plots the concentrations of ^{60}Co, ^{137}Cs, and ^{90}Sr; the distributions of the contaminants are similar throughout the stream reach. Concentrations are fairly constant in the upper reaches, with typical concentrations of ^{60}Co, ^{90}Sr, and ^{137}Cs at 40, 4, and 400 pCi/g. Concentrations tend to increase along the reach between the area directly west of the "dump area" and the confluence of White Oak Creek with Melton Branch. The highest concentration of ^{60}Co occurred directly behind White Oak Creek weir at 100 pCi/g, and ^{90}Sr and ^{137}Cs concentrations peaked at 15 and 1400 pCi/g just upstream of the weir.

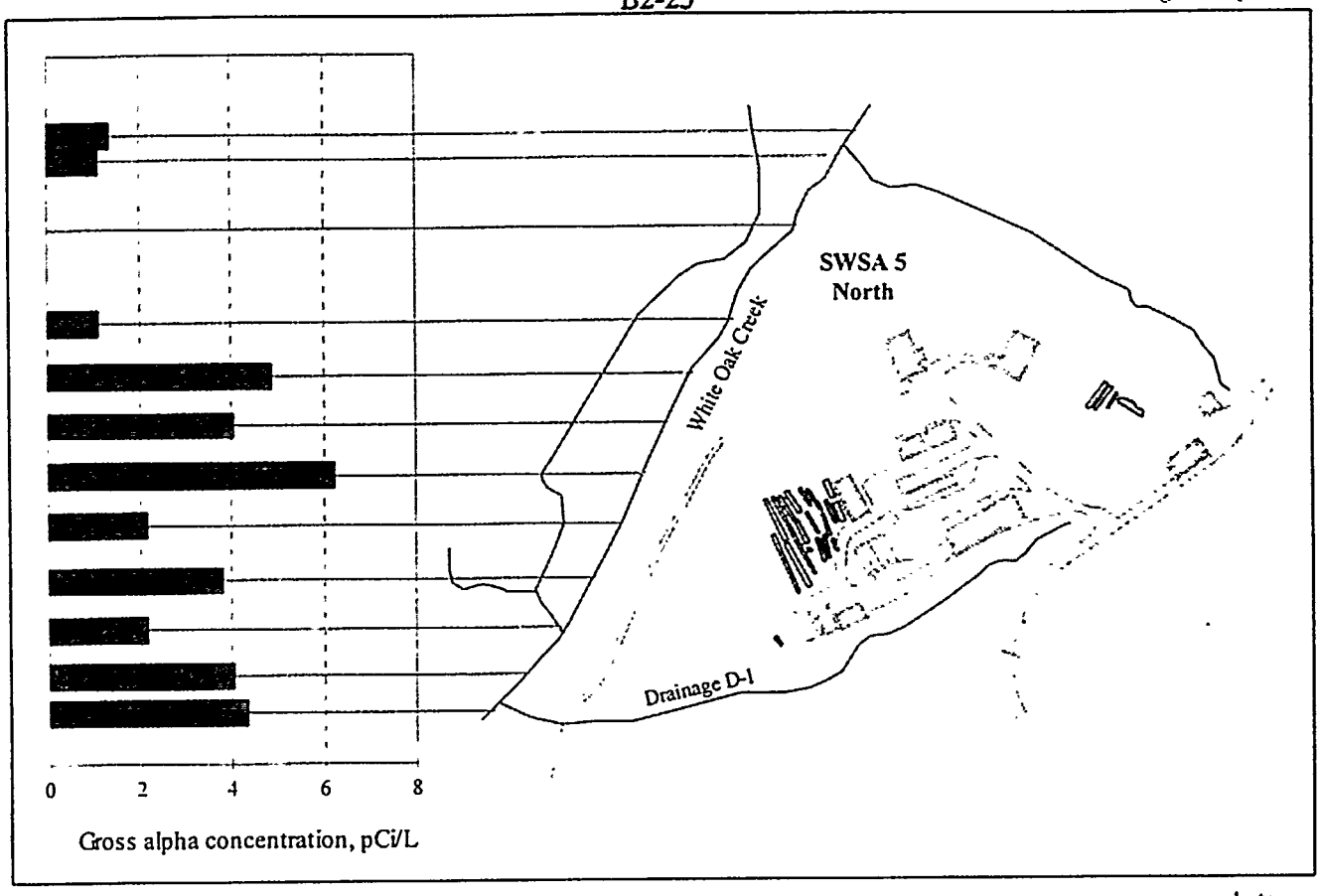
B2.3.2 White Oak Creek Surface Water/Drainage Summary

Drainage D-1

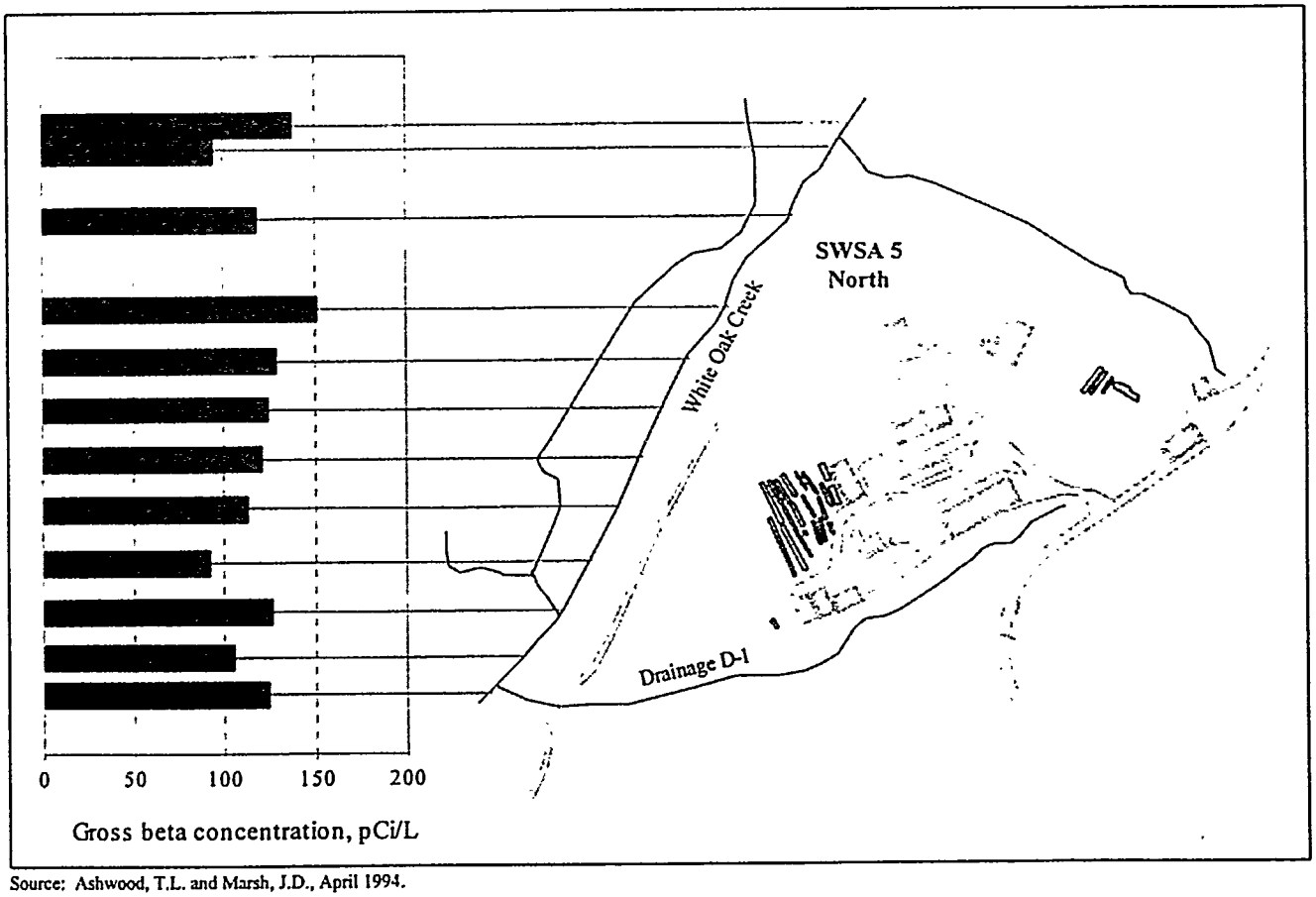
Introduction. Drainage D-1 receives runoff from an area of 27.9 acres in the northern portion of WAG 5, shown in Fig. B2.3.8. Study areas within drainage D-1 include the PWSB, the fissile storage area, 40% of SWSA 5 North, and 12% of the SWSA 5–White Oak Creek study area. The drainage basin is primarily forested except for developed areas in SWSA 5 North and the PWSB. Section B1.5 provides a more complete description of the hydrology and physical characteristics.

Previous investigations. As part of a study to determine ^{90}Sr flux to White Oak Creek, Duguid (1975) sampled surface water from a location near RI sediment sampling location SD002. Results (^{90}Sr concentrations at 9 pCi/L) indicated that no appreciable amount of ^{90}Sr was leaving drainage D-1.

gross alpha



gross beta



Source: Ashwood, T.L. and Marsh, J.D., April 1994.

Fig. B2.3.6. Gross alpha and gross beta in White Oak Creek adjacent to SWSA 5 North.

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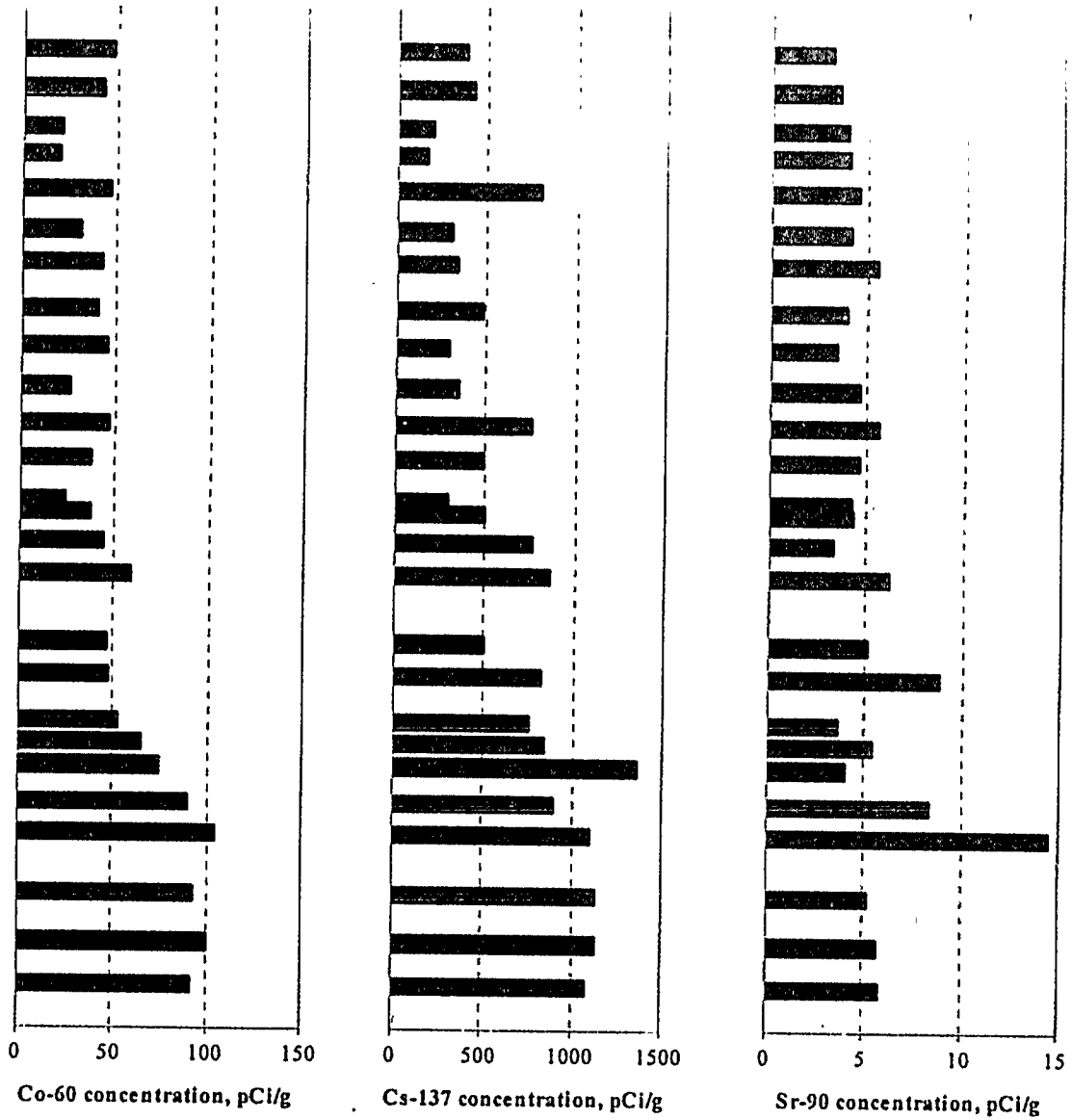
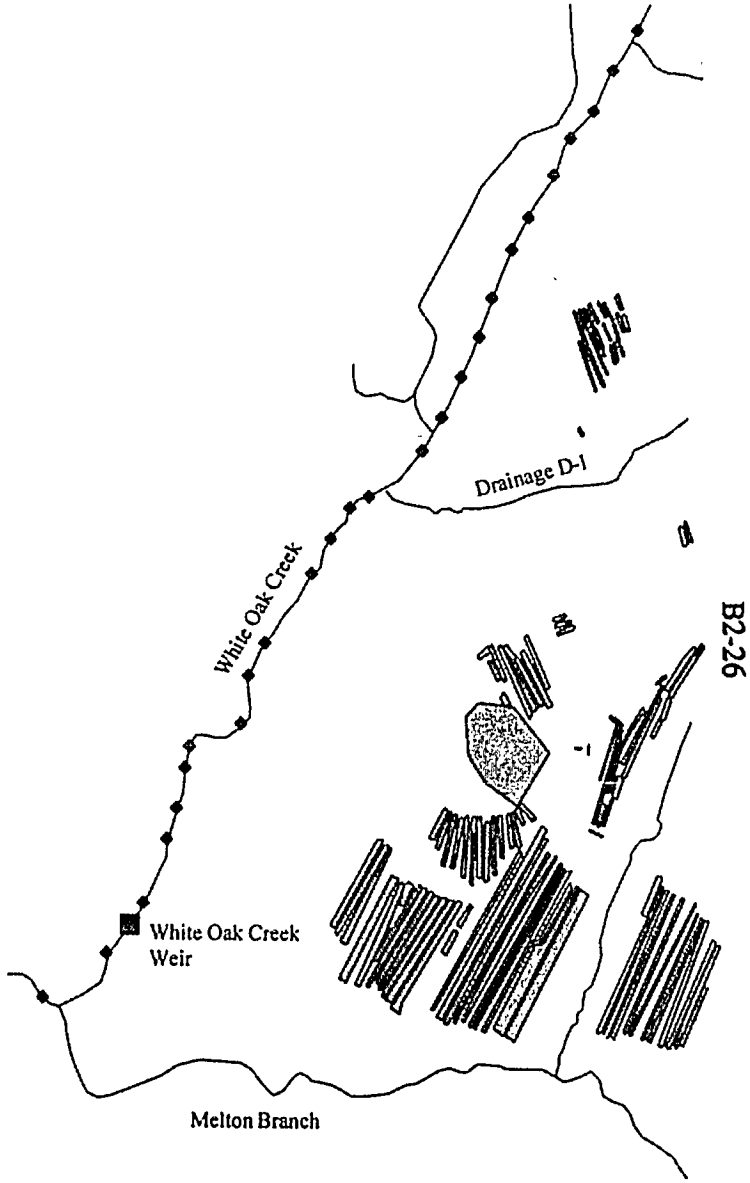




Source: Cerling, T.E. and Spalding, B.P., 1981

B2_F3_7.PPT

Fig. B2.3.7. Co-60, Cs-137, and Sr-90 concentrations in streambed gravels in White Oak Creek.

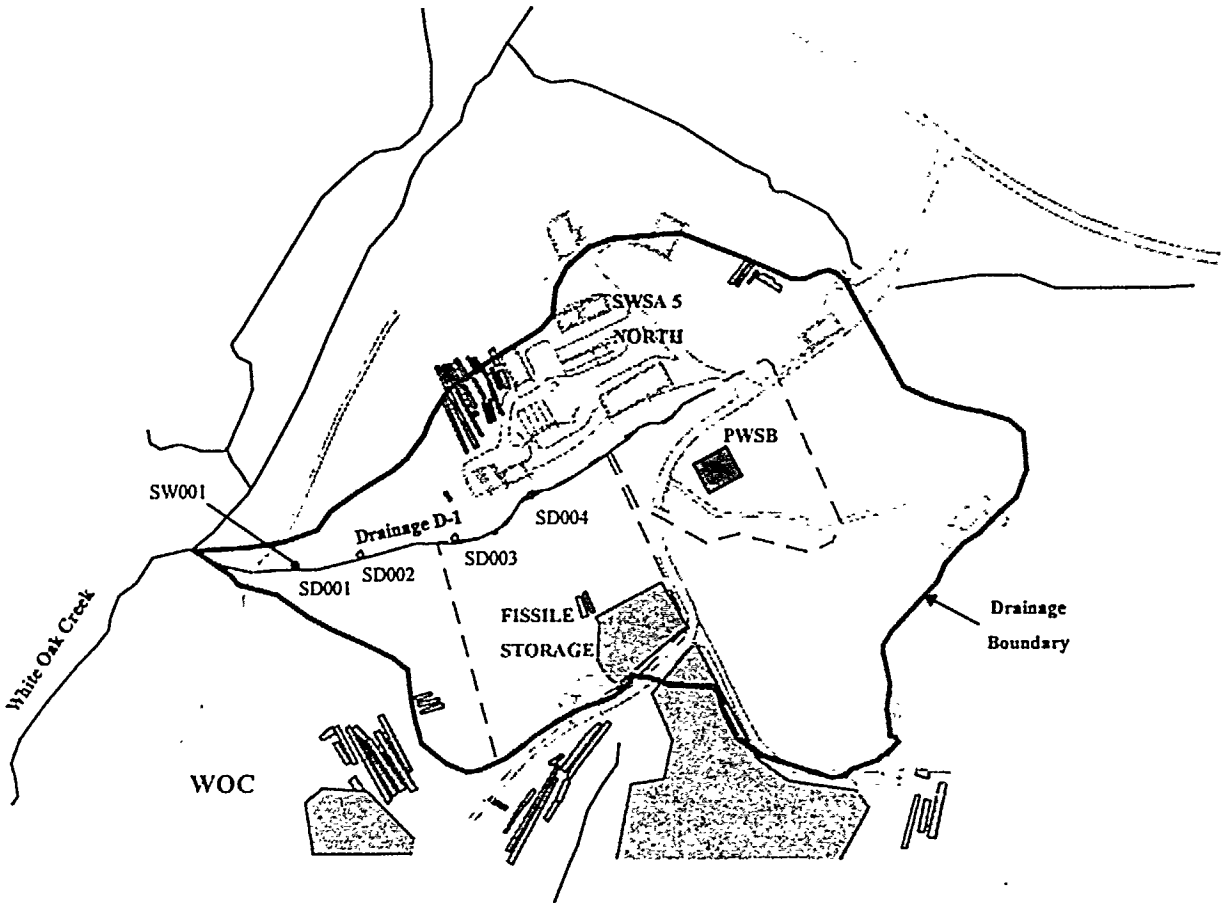


Fig. B2.3.8. Boundary and sampling locations for drainage D-1.

During the WAG 2 RI sampling (ORNL 1993), surface water samples were taken from SW001 (identified as 5NST in the WAG 2 RI) during the wet (April) and dry (September) seasons. Analyses included tritium (detected at 77,000 and 65,000 pCi/L) and ^{90}Sr (detected at 59 and 77 pCi/L).

As part of the ASEMP, quarterly surface water samples were taken from SW001 beginning in March 1990 (Ashwood and Marsh 1994). Analyses included gross alpha, gross beta, ^{241}Am, ^{244}Cm, ^{60}Co, ^{137}Cs, and tritium. Drainage D-1 frequently contained measurable quantities of gross alpha (10–120 pCi/L filtered). Alpha concentrations were not attributable to ^{241}Am or ^{244}Cm except in one sample taken in June 1993. Gross beta concentrations were generally around 200 pCi/L.

RI sample summary. Surface water samples were collected from SW001 during wet and dry seasonal conditions (June and October 1993) and during four storm events between May 1993 and March 1994; the dates and times are shown in relation to the flow hydrographs in Fig. B2.3.9. Storm samples were analyzed at the Close Support Laboratory (CSL), and base flow samples were analyzed at the off-site laboratory (see Appendix A2 for a complete sample summary). One set of sediment samples was collected from drainage D-1; the four locations are depicted in Fig. B2.3.8.

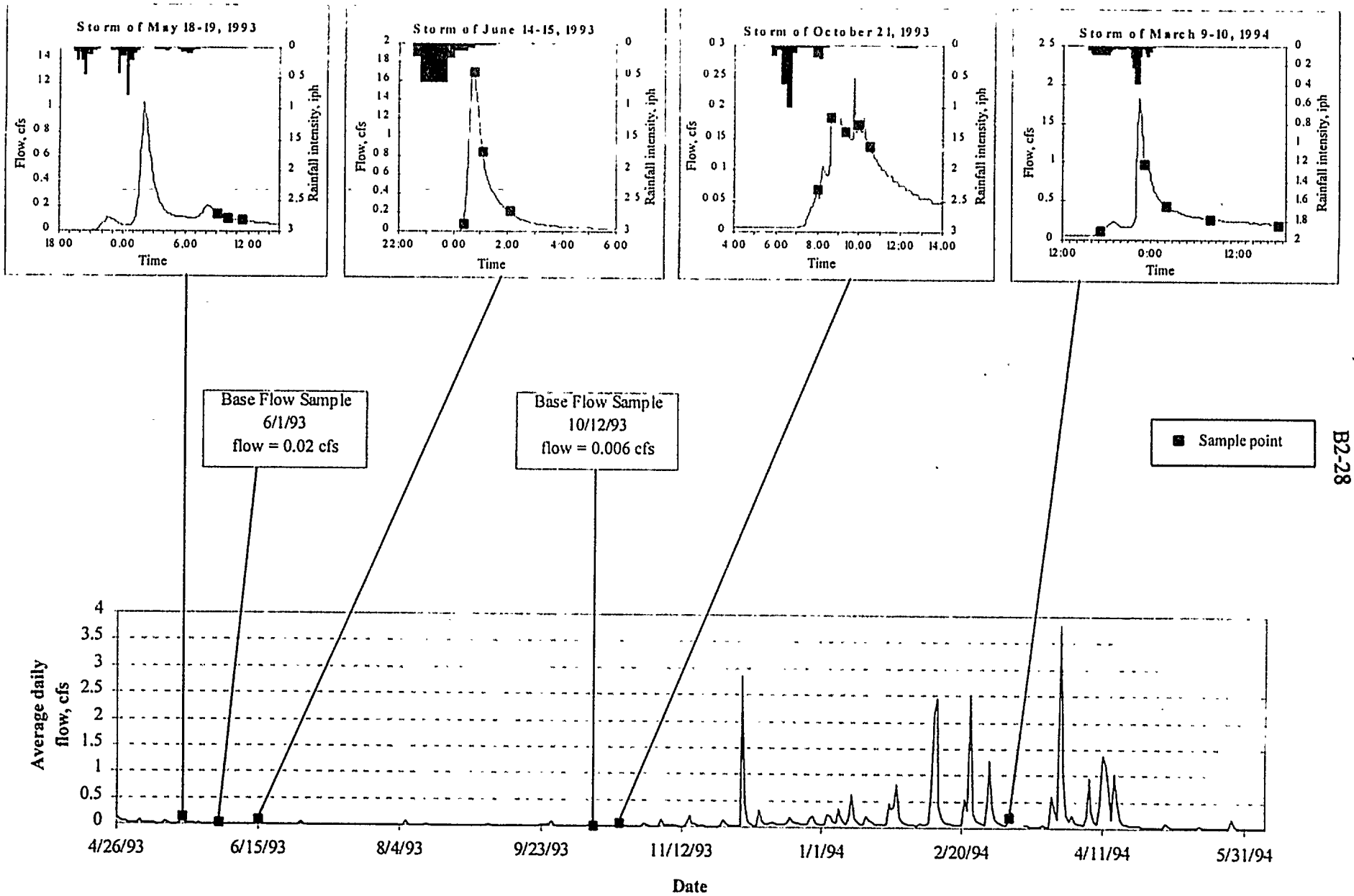


Fig. B2.3.9. Surface water sampling events at SW001.

B2_F3_9 PPT

Nature and extent of contamination. Sampling of the surface water and sediment in drainage D-1 identified a number of contaminants of concern: ^{241}Am, ^{137}Cs, $^{239/240}$Pu, ^{90}Sr, tritium, $^{233/234}$U, ^{235}U, and ^{238}U. Table B2.3.1 presents sample-specific results for the RI and historical data. The following paragraphs summarize the analytical findings.

Tritium, ^{90}Sr, $^{233/234}$U, ^{235}U, and ^{238}U were detected in all samples in which they were analyzed for. Americium-241 and $^{239/240}$Pu were detected only during the March 1994 storm. Also, concentrations of $^{233/234}$U, ^{235}U, and ^{238}U were significantly higher during the March 1994 storm than in any other sampling event. Strontium-90 concentrations were around 25 pCi/L, about 25 to 50% less than those found during the WAG 2 RI.

Sediment in drainage D-1 had $^{233/234}$U and ^{238}U concentrations approximately two to five times greater than the background reference levels. The corresponding gross alpha levels, however, were at or below background levels. Strontium-90 and ^{137}Cs concentrations were generally at or below background levels, as were the corresponding gross beta results. No general patterns (i.e., increasing or decreasing concentration with location) could be discerned.

Flux calculations. Figures B2.3.10 and B2.3.11 present gross beta transport at SW001 during two storm events. The June 14–15, 1993, event was a typical summer storm with high-intensity rainfall of short duration (0.79 in. in less than 3 h). The March 9–10, 1994, storm is more typical of winter storms with low-intensity rainfall and longer durations (0.75 in. in 9 h).

Runoff from these two storms shows similar patterns of concentration and discharge. The concentration at the beginning of the storm increases significantly as the contaminants in the stream channel are mobilized by increased flow. As the flow increases, the concentration decreases due to dilution from surface runoff. The flux or rate of transport increases as contamination in the subsurface pathways becomes mobilized. As the flow decreases, groundwater makes up a higher percentage of the overall flow, causing the concentration to increase.

The average contaminant flux in the quickflow (which is comprised of both surface runoff and interflow) and in the baseflow was estimated at SW001 by separating the storm hydrographs into baseflow and quickflow. An average concentration was assumed for both baseflow and quickflow, and a contaminant flux was calculated based on the assumed average concentrations. The total contaminant flux was then compared with the actual flux calculated from the measured concentrations and the flow at the time the sample was taken. A trial-and-error method was used to find the best fit of the flux calculated with the assumed quickflow and baseflow concentrations and the measured flux.

The average annual fluxes in the quickflow and baseflow were then calculated using the average annual discharge generated from the HSPF model (described in Appendix B1). The average concentrations and the resulting average annual contaminant fluxes from D-1 are shown in Table B2.3.2.

Table B2.3.1. Analytical data summary for selected radionuclides in drainage D-1

Sample ID	Date	Time	(β) Gross Beta		(β) Tritium		(β) Sr-90		(β-γ) Cs-137		(α) gross alpha		(α) U-233/234		(α) U-235		(α) U-238		(α) Pu-239/240		(α) Am-241	
SURFACE WATER (pCi/L)																						
Background Reference			8		1620				40		9		2				2					
SW001	5/19/93	09:08	62.2	66.2	50389	46527				71.4	90.9	75.7										
SW001	5/19/93	10:08	109.7	81.6	54712	51044					82	76										
SW001	5/19/93	11:28	63.5	2864	54932	50859		27.3			70.1	27.6										
SW001	6/1/93	10:45	99	65	55000	60000	24	25	-	-	47	64	27	22	1.7	1.1	45	37	-	-	-	-
SW001	6/4/93	08:56	56.2	36.1	89652	89219					65.8	63.2										
SW001	6/15/93	00:24	184.9	70.2	24098	22993	18.7		19.9		48.7	14.7										
SW001	6/15/93	00:44	40.8	16	12089	12128			25.8	22.4	20.5	9.3										
SW001	6/15/93	01:04	82.6	-	9490	10192	1241				41.5	10.4										
SW001	6/15/93	02:04	61.5	42.8	26344	28191					27.9	18.6										
SW001	10/12/93	09:38	81.6	87.7	117000	115000	29.9	24.7	-	-	15.8	23.7	10.4	7.2	0.8	-	18.5	12.1	-	-	-	-
SW001	10/21/93	08:00	146.4	200.3	106529	59996	22.1		55.7		197.2	86.2										
SW001	10/21/93	08:40	146.1	101	61536	91091	16.4				86	42.1										
SW001	10/21/93	09:20	148.5	62.9	35838	34839	80	95			39.5	29										
SW001	10/21/93	10:00	116.4	230	40289	38896	12.8	63.4			37	34										
SW001	10/21/93	10:30	63.5	59.7	28300	30100		17.6	-	-	17.9	15.5	10.6	8.88	0.683		17.2	12.9	-	-	-	-
SW001	3/9/94	17:14	131	360.1	52434	51353		207.3	58.6	824	102.7	95.5										
SW001	3/9/94	23:14	108.2	192.2	18707	18287			847		75.4	68.8										
SW001	3/10/94	02:14	148.2	145.7	26914	26290			684	146	137.1	120.7										
SW001	3/10/94	08:14	138	124.5	35006	35223			111	116	128.5	105.4										
SW001	3/10/94	18:01	101	93.2	25000	24700	16.3	15.3	-	-	60.3	56.1	51.4	58.4			81.1	95.6	0.075	0.094	0.111	0.085
Historical Samples																						
(a) 5NST	4/2/92				76566		59		-													
(a) 5NST	9/17/92				64823		77		-													
(b) S. Trib.	3/90-6/93		432		20500				3		351										0.51	
SEDIMENT (pCi/g)																						
Background Reference			54		100		1.34		0.82		44		2.6				2					
SD001	6/23/93		49.2		74		0.84		0.71		21		4		0.12		5.4				0.49	
SD002	6/23/93		89.3		101		1.5		0.76		28.3		6.4		0.24		10.2				0.65	
SD003	6/23/93		90.8		19		0.61		2.1		35.5		9.4		0.38		12.7					
SD004	6/28/93		48		2340		0.74		0.96		43		5.9		0.18		10		-			

Notes: 1. Historical Samples:
(a) Data taken from WAG 2 Phase I RI (ORNL, 1993)
(b) Data taken from Active Sites Environmental Monitoring Program (Ashwood and Marsh, 1994). Values reported are the maximum detected (out of 10 sam
2. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
3. Abbreviations: U/F = Unfilter/Filtered - = not detected (α,β,γ) = Alpha,beta,gamma emitter

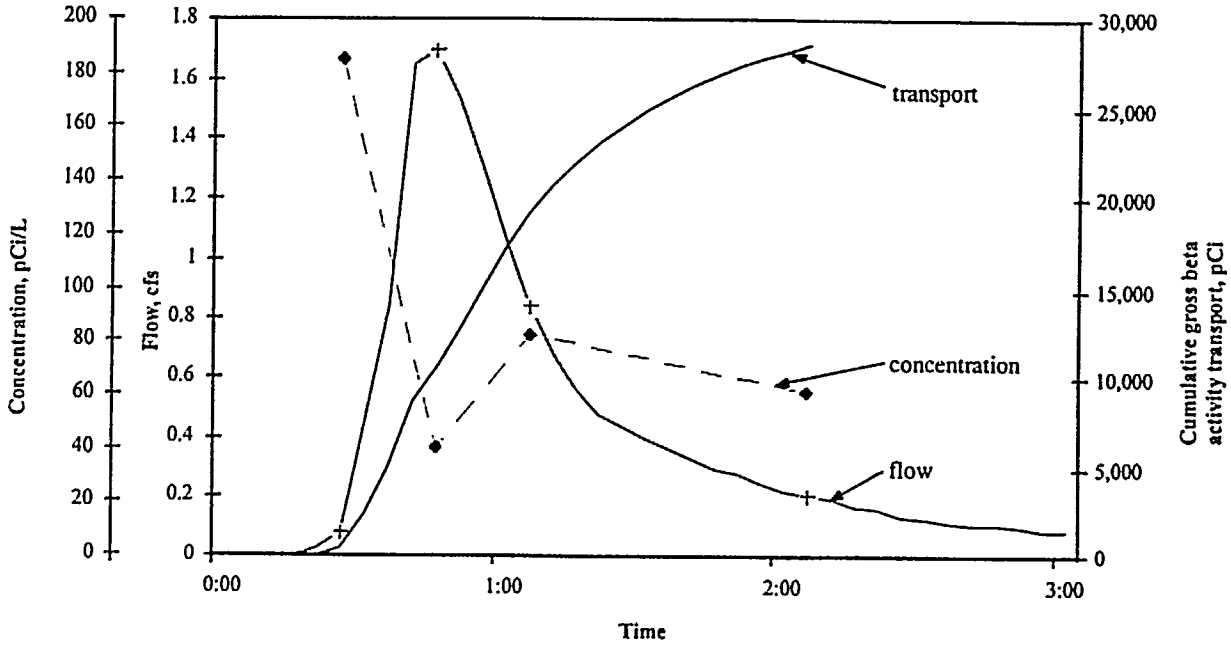


Fig. B2.3.10. Gross beta transport at SW001 during the June 1993 storm.

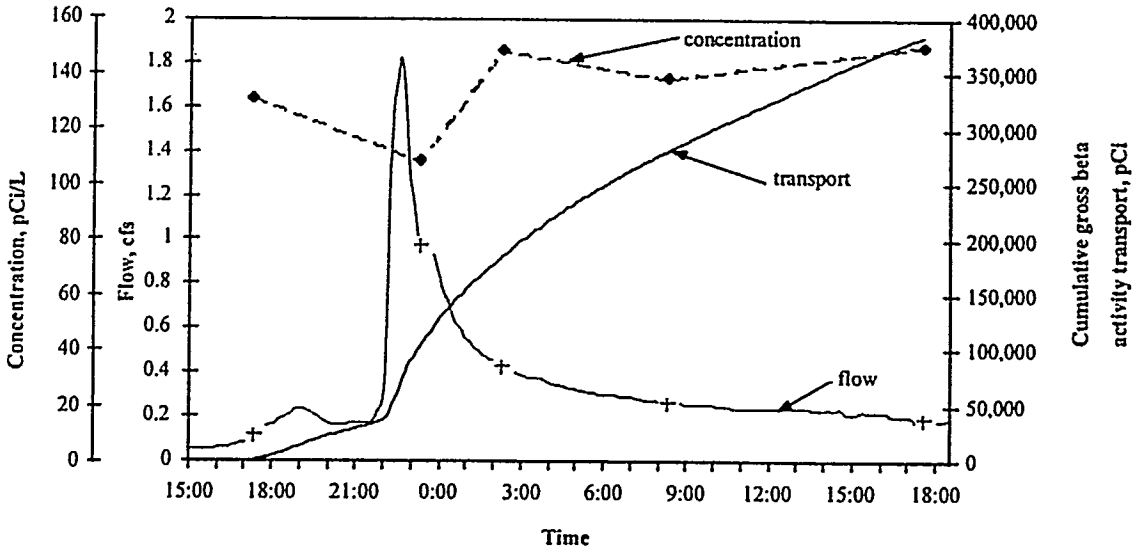


FIG B2.3.11. Gross beta transport at SW001 during the March 1994 storm.

Table B2.3.2. Average concentrations and fluxes of selected analytes at SW001

Analyte	Concentration (pCi/L) Quickflow	Concentration (pCi/L) Baseflow	Flux (mCi/yr) Quickflow	Flux (mCi/yr) Baseflow	Total Flux (mCi/yr)
Gross Alpha	23	152	1.1 (17 %)	5.1 (83 %)	6.2
Gross Beta	32	119	1.5 (27 %)	4.0 (73 %)	5.5
Tritium	2,290	51,025	106 (6 %)	1,712 (94 %)	1,818
^{90}Sr	19	17	0.9 (61 %)	0.6 (39 %)	1.5
$^{233,234}U$	0	47	0 (0 %)	1.6 (100 %)	1.6
^{235}U	0.7	0.6	0.012 (18 %)	0.056 (82 %)	0.05
^{238}U	0	74	0 (0 %)	2.5 (100 %)	2.5

B2.3.3 Process Waste Sludge Basin

The PWSB is in the northern part of SWSA 5 South, southeast of the drainage D-1 headwaters (Fig. B2.1.1). The impoundment is within a fenced area of approximately 0.25 acres, but the study area boundary was drawn to include areas outside the fence, primarily on the basis of the availability of monitoring/characterization data and consideration of overland drainage patterns. Figure B2.3.12 is a photograph of the pond reflecting conditions in November 1994.

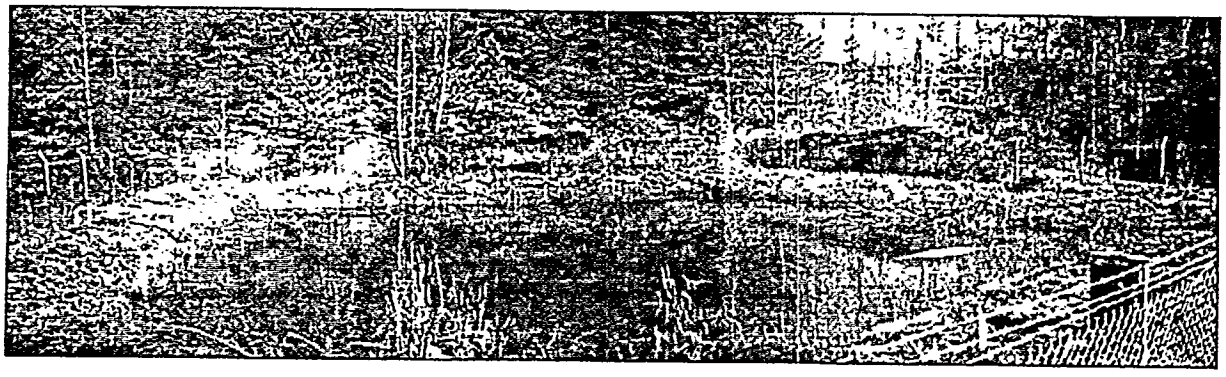


Fig. B2.3.12. Photograph of Process Waste Sludge Basin.

Description and history

Engineering drawings for the basin show dimensions of 85 by 85 by 7.8 ft. A PVC liner rests on a compacted clay bottom and is covered by a sand layer designed to protect the integrity of the liner. The design life for the liner is unknown. The basin was designed and built between 1974 and 1975 and used from 1976 to 1981 for the storage and decantation of sludge produced by a water-softening process at the Process Waste Treatment Plant. Sludge constituents were primarily ferrous sulfate and ferric hydroxide but included mixed fission products and minor quantities of TRU radionuclides. A subgrade line used to pump the process waste to the basin and, after settling, transport the supernatant back to the treatment plant, is still in place; however, the flow valves have been closed. Currently, the basin is exposed to the environment and typically contains 1 to 2 ft of standing water over approximately 4 ft of sludge. ORNL site personnel say that the water level in the

basin has been observed to rise and decline in response to precipitation patterns but has not been observed to dry up or overflow.

The primary contaminant sources in this study area are the surface water and sludge within the basin. The underlying sand layer is also contaminated and is grouped together with the sludge as PWSB "sediment." Table B2.3.3 presents a source characterization matrix that summarizes relevant attributes for PWSB surface water and sediment. Soil and groundwater sampling during the RI and previous investigations did not encounter any evidence that would indicate the presence of secondary sources such as contaminated vadose zone soils beneath the impoundment or contaminated surface soils around the impoundment.

Table B2.3.3. PWSB source characterization matrix

Source	Area/ Dimensions	Waste Types & Contaminants of Concern	Disposal Methods & Packaging	Waste Volume	Inventory	Dates
Surface Water	Basin Surface Area ~ 0.17 acres Typ. 1 to 2 ft of water	Relatively low activities of ^{90}Sr, ^{60}Co, ^{137}Cs, TRU	Designed & operated as treatment/ storage facility; wastes open to environment	~ 220 m^3	2 mCi ^{90}Sr 0.03 mCi ^{60}Co 0.01 mCi ^{137}Cs *(Bechtel RI data)*	1975-1981
Sediment *Bulk Density: 1.1 g/cm³* % Water: 91	Sludge Surface Area ~ 55 by 55 ft Max. depth of 4 ft	Ferrous sulfate, ferric hydroxide, and mixed fission products. High concentrations of ^{90}Sr, ^{137}Cs, ^{60}Co Minor conc. of: TRU isotopes	Sludge is on liner consisting of (descending order): • 6-in. sand • 30-mil PVC liner • compacted clay	~ 960 m^3	15 Ci ^{90}Sr 4 Ci ^{137}Cs <1 Ci ^{60}Co *(Francis and Sealand 1987)* 8 Ci ^{90}Sr 4 Ci ^{137}Cs <1 Ci ^{60}Co *(Bechtel RI data)*	1975-1981

Previous investigations

Francis and Sealand (1987) analyzed a composite of six surface sediment samples (Fig. B2.3.13) and estimated that approximately 20 to 30 Ci of total activity was contained within the basin, the dominant radionuclide being ^{90}Sr (and ^{90}Y), with lesser amounts of cobalt and cesium isotopes. In addition, they analyzed the sediment for Resource Conservation and Recovery Act (RCRA) toxicity characteristics by the RCRA-extraction procedure (EP) waste leaching test and studied the leachability characteristics of ^{137}Cs and ^{90}Sr in sediment core samples. The metal concentrations extracted during the RCRA-EP test were well below the RCRA limits; mercury was <0.002 mg/L and silver, arsenic, barium, cadmium, chromium, lead, and selenium were all <1.0 mg/L. The leachability tests demonstrated that although ^{137}Cs adsorbs readily to the PWSB sediment, ^{90}Sr is easily leached out and therefore has a higher migration potential.

The PWSB study area includes two WAG 5 perimeter monitoring wells (0965 and 0966) that were sampled annually beginning in 1990 by the ORNL Environmental Surveillance Program (ESP). In 1993, the sampling was coordinated with the WAG 5 RI, and the wet season RI sampling event was substituted for the annual perimeter monitoring sampling by the ESP.

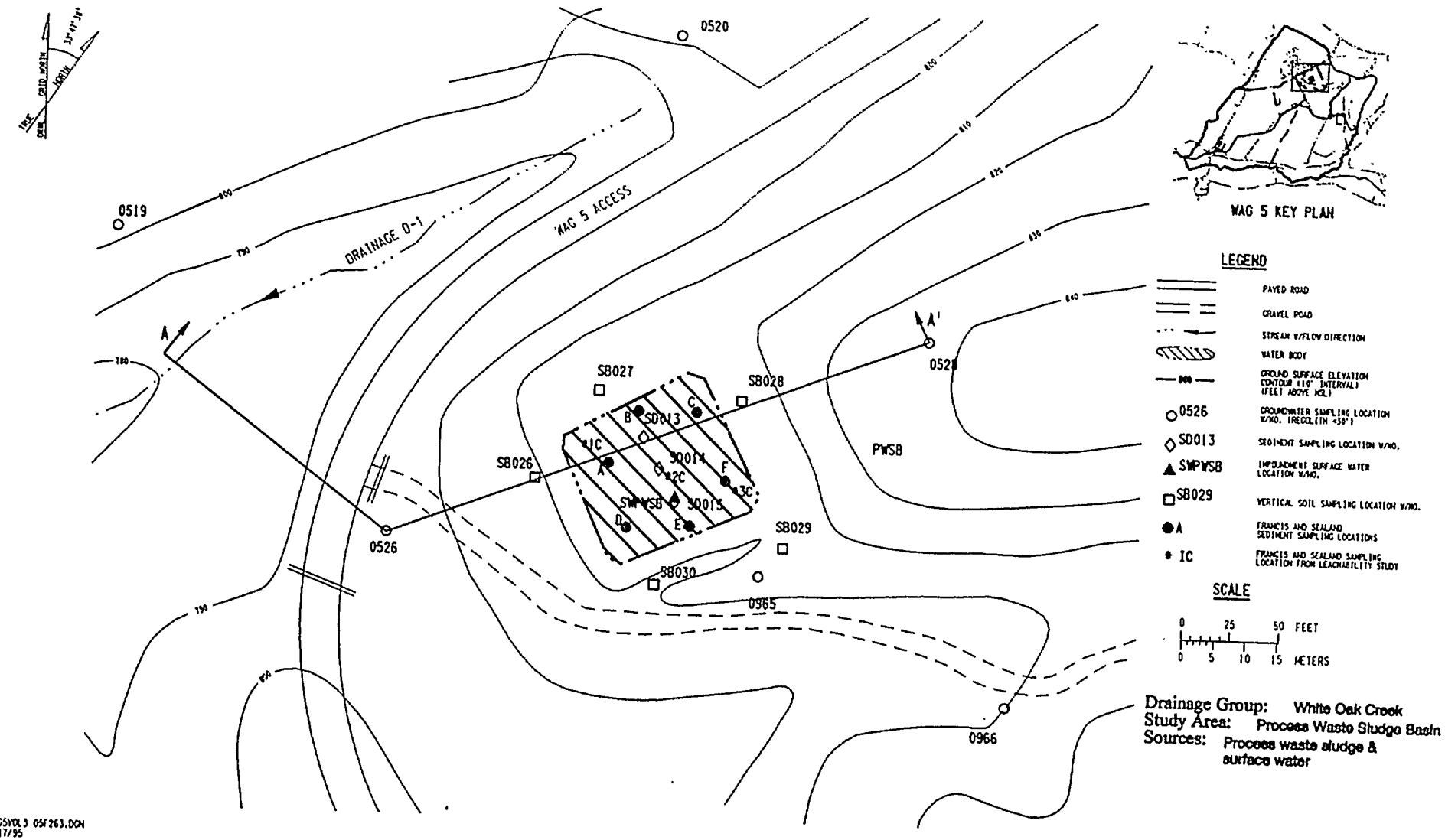


Fig. B2.3.13. Process waste sludge basin plan view.

RI sampling summary

Figure B2.3.13 shows the RI sampling locations and cross-section location used to depict the hydrologic model for the area. RI sediment from the PWSB are depth-discrete, areal composites representative of 1-ft intervals from each of the three 4-ft sediment cores. For example, the 0 to 1-ft interval from each core was composited to make sample PWSB1C. The soil boring samples taken from around the basin were composites also, extending from the surface to approximately 6 ft deep with an additional composited interval of 6 to 11.4 ft taken from SB027. All soil samples were analyzed for radiological and chemical analytes. Groundwater encountered during collection of soil samples from boring SB028 was sampled (SB028 GW).

Groundwater samples were collected from the two perimeter monitoring wells (0965 and 0966) and piezometer 0526. A CSL screening sample was collected from 0526 in 1992; in 1993, all three wells were sampled during both dry season (low base) and wet season (high base) conditions. The samples were analyzed for a full suite of radiological and chemical analytes.

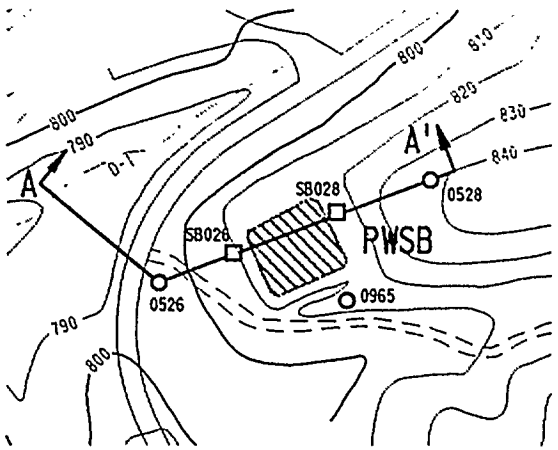
Hydrologic model

Based on the HSPF modeling effort, the average annual cumulative water discharge for the PWSB study area is 33,600 m^3 (Table B2.3.4). The PWSB area receives runoff, stormflow, and groundwater flow from upgradient areas, mostly forested land not apparently used for any WAG 5 or SWSA 5 activities. Surface runoff from upgradient areas flows southwestward but is diverted around the pond itself by surface contouring completed when the pond was constructed; the pond does not receive any surface runoff from these areas. Runoff from the study area eventually enters a ditch along the eastern side of the WAG 5 access road and flows southward to a culvert that leads to the western side of the road and an ephemeral tributary of drainage D-1.

Table B2.3.4. Annual water balance summary for the PWSB study area

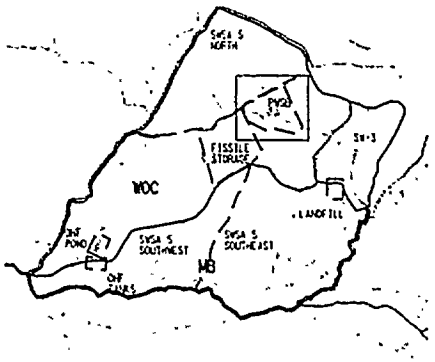
	Percent of Flow	Annual Discharge (m^3/year)
Surface Runoff	27	9,200
Interflow	31	10,300
Groundwater Flow	42	14,100
Total	100	33,600

Groundwater flow in the PWSB area is predominantly southwestward, as determined from the 1993 water level data. Section view A-A' (Fig. B2.3.14) shows that during wet weather conditions, the water table is projected to intersect the impoundment. It is unlikely that there is any hydraulic connection because of the clay and PVC liner beneath the basin. However, if the liner were to fail due to age or other causes, a direct connection with the water table would be a significant release mechanism and provide a direct pathway for contamination of the shallow groundwater.



LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0526 — WELL, WELL NO., SCREEN SECTION
- PROCESS WASTE SLUDGE
- SB026 — SOIL BORING LOCATION W/NO.



WAG 5 KEY PLAN

WATER BUDGET	FLUX TO D-1
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	9,140 m³/yr
Storm flow	10,223 m³/yr
Shallow GW	14,071 m³/yr

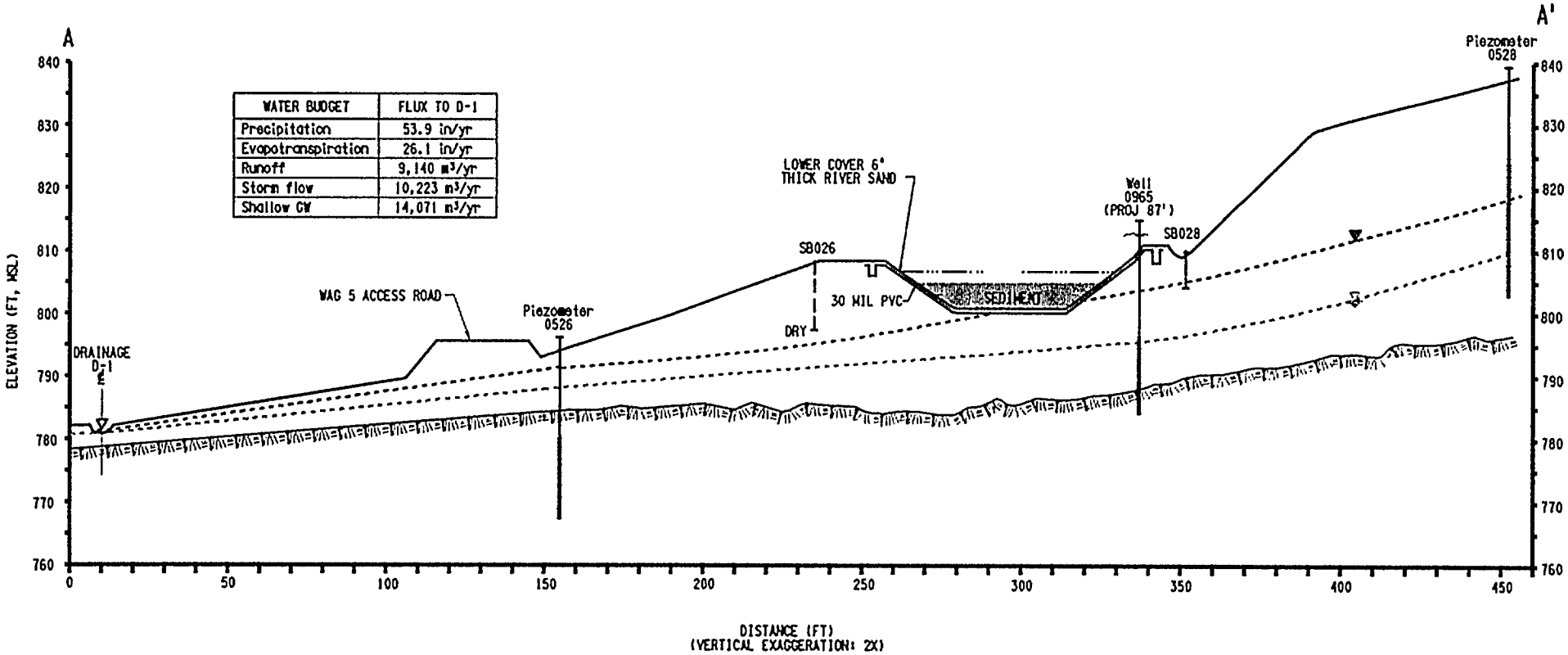


Fig. B2.3.14. Hydrologic model for the PWSB (Section A-A').

WAG5 OSF275.DGN
9/17/95

These HSPF estimates are based on measured flow in drainage D-3, which receives all of the discharge from the PWSB area. There have been no reports of overflow, and the available contamination data indicate that the impoundment is not leaking. Thus, the annual water balance distribution shown in the table is for the entire study area but does not include any direct contributions from the impoundment because of its hydrologic isolation caused by the liner. The rise and fall of water in the basin has been attributed entirely to precipitation and evaporation.

Nature and extent of contamination

Sampling of surface water and sediment (sludge) in the PWSB identified a large number of contaminants of concern in both media; fewer contaminants were detected, at much lower concentrations, in surrounding surface soil and groundwater (Table B2.3.5). Location- and/or sample-specific summaries are presented in Table B2.3.6.

Table B2.3.5. Contaminants of concern detected in the PWSB area

CONTAMINANT	SED[A]	SOIL	GW	SW[B]
^{241}Am	X	X		
$^{243/244}Cm$	X		X	
^{60}Co	X			
^{137}Cs	X	X	X	X
^{152}Eu	X			
^{154}Eu	X			
Tritium	X		X	X
^{238}Pu	X	X		
$^{239/240}Pu$	X			
^{90}Sr	X	X	X	X
^{99}Tc			X	
^{228}Th	X			
^{230}Th	X			
^{232}Th	X			
^{232}U	X			X
$^{233/234}U$	X			X
^{238}U	X			X
PCBs (Aroclors 1248/1254)	X			
Mercury	X			

[A] *Pond sediment.*
[B] *Pond surface water.*

Table B2.3.6. Analytical data summary for selected radionuclides in the process waste sludge basin

Sample	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Gross Beta	(β) Tritium	(β,γ) Co-60	(β) Sr-90	(β,γ) Cs-137	(α) Th-228	(α) Th-230	(α) Th-232	(α) U-233,234	(α) U-238	(α) Pu-238	(α) Am-241
PWSB SLUDGE (pCi/g)																
	Background Reference															
Basin	PWSB1C	11/19/93	0-1	2900	298000	79	6825	83500	4800	205	37	2	1900	41.7	123	77.4
Basin	PWSB2C	11/19/93	1-2	5870	328000	175	2598	93700	5790	323	19	2	2510	86	121	135
Basin	PWSB3C	11/19/93	2-3	14000	280000	278	1574	85200	5920	336	13	2.68	4760	138	115	241
Basin	PWSB4C	11/19/93	3-4	10400	325000	264	4424	110550	17700	388	43	5	2470	52.0	52.2	1110
	Historical Samples															
(a)	A thru F	1987	0-1			-	8910	153900	43200							-
PWSB SURFACE WATER (pCi/L)																
	Background Reference															
Basin	SWPWSB	11/16/93	0-1	384	13000	8860	127	5980	49.4	2	0.091	0.04	262	5	0.214	0.5
SOIL (pCi/g)																
	Background Reference				42	0.08	0.02	1.9	1.4	1.5	1.2	1.4		2.4	0.16	0.08
Perimeter	SB026	11/16/93	0-6			4.2		3.2	0.2							-
	SB026	8/10/93	1-2	14.5	55.5	5.0E46				1.9	0.7	0.7	0.6	0.3		
Perimeter	SB027	11/16/93	0-6	20.4	42.2	1.3		-	-	1.6	0.5	2.0	0.8	0.9	-	0.34
	SB027	11/16/93	6-11.4	-	52.4	0.8		0.8	-	1.7		1.8	0.4	0.7	-	1.05
Perimeter	SB028	11/16/93	0-6	19	26.1	8.9		-	-	1.2	1.0	0.9	0.7	0.8	4.15	0.3
Perimeter	SB029	11/16/93	0-6	16.7	53.5	-		-	-							-
Perimeter	SB030	11/16/93	0-6.6	9.9	46.6	-		0.3	0.1	1.8	0.67	0.87	0.8	0.7		-
GROUNDWATER (pCi/L)																
	Background Reference					2400	44	10.4	12.4							
Core	SB028GW	8/12/93	0-6			4681			45.2							
SEDIMENT (pCi/g)																
	Background Reference			44	54	100		1.3	0.8	2.6	2.0	2.4	2.6	2		
D1	SD004	6/28/93	0-0.3	43	48	5.3	0.4	0.7	0.96	2.6	3.5	2.4	5.9	10	-	

GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference			5.2	3.2	16	7.4	2400	1080	44	9.2	10.4	3.6	12.4	5.4										
UpGrdnt	0966	4/6/93	7.7-24.1	-	-	-	4.6	1100	1243	0.5	5.7	-	-	-	-					0.5	0.6	-	-	-	0.1
	0966	11/2/93	7.7-24.1	-	-	4.7	-	946	1160	-	-	0.8	-	-	-	-	-	-	-	-	-	-	0.1	-	0.1
	0965	4/6/93	16.2-28.3	-	-	-	-	1405	1405	-	-	-	-	-	-					0.5	0.5	0.1	0.2	-	-
	0965	11/2/93	16.2-28.3		-		-	1130	1090				-	-	-	0.4	0.6	-	-	0.1	-	0.3	0.3	0.2	-	-	0.1	0.2
DnGrdnt	0526	4/12/93	16-26	-	-	19.0	14.0	17000	18000			4.8	3.3	-	-										
	0526	10/14/93	16-26	-		8.8		-	-			1.2	-	-			-		-		0.9		0.6	-	-
	Historical Samples																								
(b)	0966	7/1/90	7.7-24.1								2.4		1.4		-										
(b)	0966	6/1/91	7.7-24.1							5.4	45.9	-	-	5.4	-										
(b)	0966	9/1/92	7.7-24.1							0.5	3.0	2.5	0.6	0.8	0.5										
(b)	0965	8/2/90	16.2-28.3						864.0		2.2		0.3		2.4										
(b)	0965	6/28/91	16.2-28.3					1566.0	1512.0	13.5	51.3	0.1	0.3	13.5	24.3										
(b)	0965	9/1/92	16.2-28.3					648.0	756.0	1.6	0.3	0.3	-	1.6	2.2										
Detected in Downgradient SW001?								X				X		X		X		X		X				X	X

Notes: 1) Historical Samples:
(a) Composite of 6 sediment samples taken from basin (Francis and Sealand, 1987)
(b) Data taken from ORNL Environmental Surviellance Program and Active Sites Environmental Monitoring Program
2) Blanks indicate analyte not analyzed for, Bold indicates detected over background reference (2x mean background)
3) Abreviations: U/F – Unfiltered/Filtered - - not detected (α,β,γ) - Alpha,beta,gamma emitter

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The RI sludge sampling results showed similar contaminants but at somewhat lower concentrations than the results from the Francis and Sealand (1987) study. Of the major contaminants (^{90}Sr, ^{137}Cs, ^{60}Co, $^{243/244}$Cm, ^{241}Am, and ^{228}Th) (Table B2.3.6), the concentrations of ^{90}Sr and ^{60}Co were approximately 50% of those found by Francis and Sealand (1987), and ^{137}Cs concentrations were approximately 20%. Because the RI samples spanned the total depth of the sludge layer (Francis and Sealand sampled only the upper few inches), they provide a more accurate characterization of the "sediment" horizon. Revised inventory calculations using the RI data indicate that the total curie content of the basin may be closer to 10 Ci than the 20 Ci estimated by Francis and Sealand (1987).

Contamination levels in PWSB surface water were typically one to two orders of magnitude less than those in sludge except for ^{3}H (Fig. B2.3.15). Another finding of interest is the relatively high concentration (262 pCi/L) of $^{233/234}$U (similar alpha energy levels prevent definitive identification of one isotope or the other). Most contamination in the basin lies in the sludge; unless the sludge is disturbed, an overflow of water would not be of the same magnitude as a release of (or directly from) the sludge layer.

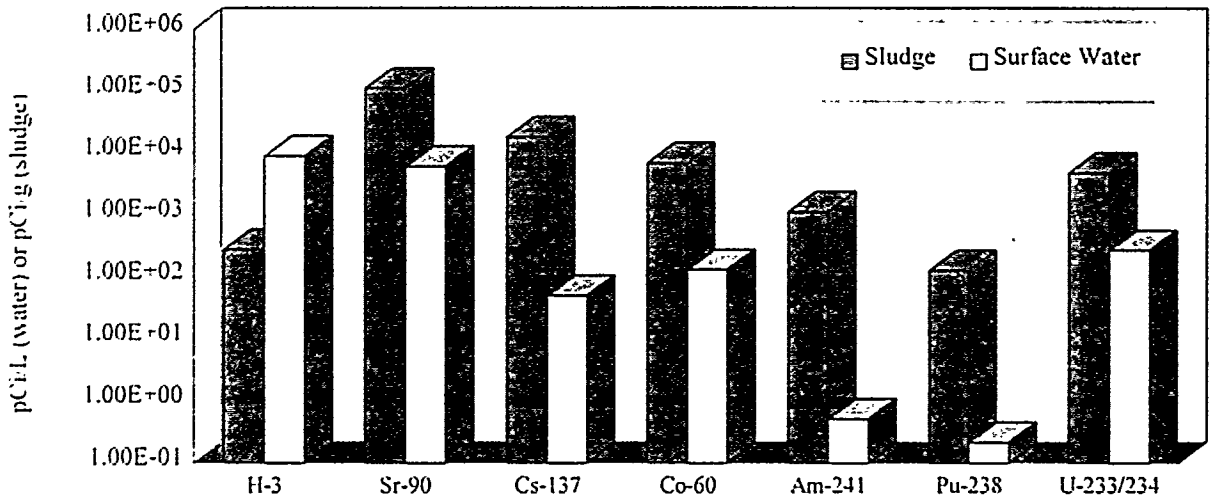


Fig. B2.3.15. Distribution of primary contaminants in PWSB.

There is little evidence of a contaminant release into the regolith or groundwater in the immediate vicinity of the PWSB or of any migration of sludge constituents to drainage D-1. One surface/near-surface (0 to 6-ft) sample from boring SB026 had a slightly elevated concentration of ^{90}Sr (3.2 pCi/g, compared to the twice background reference level of 1.9 pCi/g). The same interval in SB028 had ^{238}Pu in a concentration of 4.15 pCi/g, and ^{241}Am was detected in concentrations of 0.3–1.05 pCi/g in samples from borings SB027 and SB028. All other radiological constituents were either below or only slightly above background reference levels. The presence of these contaminants in the surface/near surface soils could be interpreted as evidence of a potential release from the sludge basin—^{90}Sr, ^{238}Pu, and ^{241}Am were detected in relatively high concentrations in the sludge samples. However, a more likely possibility is that the contamination is from small-scale spills or leaks associated with maintenance or other activities during operations. There have been no reports of the basin overflowing, and if it had, the most likely pathway for the overflow would be to

the west and south, toward boring locations SB026 and SB030. However, two of the three aforementioned borings (SB027, SB028) with minor levels of ^{90}Sr and TRU contamination are to the north of the basin.

Groundwater sampling results give further evidence of liner integrity and the conclusion that no release from the impoundment has occurred. Shallow groundwater in the vicinity of the impoundment, both upgradient and downgradient, generally shows little evidence of contamination, from the PWSB or any other source. Tritium was detected in the downgradient well (0526) in concentrations an order of magnitude greater than those observed in either the upgradient wells (0966 and 0965) or in the PWSB surface water. Given the contrast in ^{3}H concentrations between the basin and groundwater, this contamination cannot be attributed to the PWSB. Based on the relatively high concentrations and even distribution of ^{90}Sr within the sludge, its relatively high solubility, and its high leaching rates from PWSB sediments (Francis and Sealand 1987), ^{90}Sr should serve as a reliable indicator of a release from the PWSB. No ^{90}Sr exceeding background was detected in any of groundwater samples collected from the study area, including those collected in 1990–1992 by the ORNL ESP.

Summary and conceptual model

The PWSB contains approximately 10 Ci of radioactivity, mostly ^{90}Sr, ^{137}Cs, and ^{60}Co. Surface water and sediment samples collected for the RI and previous studies show no evidence of any release from the lined impoundment. Some minor amounts of contamination were detected in study area soils and groundwater, but the net contribution in terms of contaminant flux to D-1 and White Oak Creek is negligible.

A summary of the site conceptual model for the PWSB is presented in Table B2.3.7 and illustrated in Fig. B2.3.16. Because no release has occurred, the model depicts only potential release mechanisms, potential migration pathways, and potential downgradient exposure points. The principal exposure point for this study area is the basin itself, which has high levels of both beta-gamma and alpha emitting radionuclides.

Table B2.3.7. Conceptual model summary for PWSB area

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
Potential: Surface Water	• Overflow of basin • Direct leak (failure in liner)	• Shallow groundwater discharging to D-1 tributary • Surface runoff	*On site*: • Direct exposure from surface water *Off site*: • Downstream surface water and sediment
Potential: Sediment	• Inundation of sediment by shallow groundwater • Infiltration/percolation through sediment *(Based on the assumption that there is a liner failure)*	• Shallow groundwater and stormflow discharging to D-1 tributary	*On site* • Contact with sediment *Off site*: • Same as above

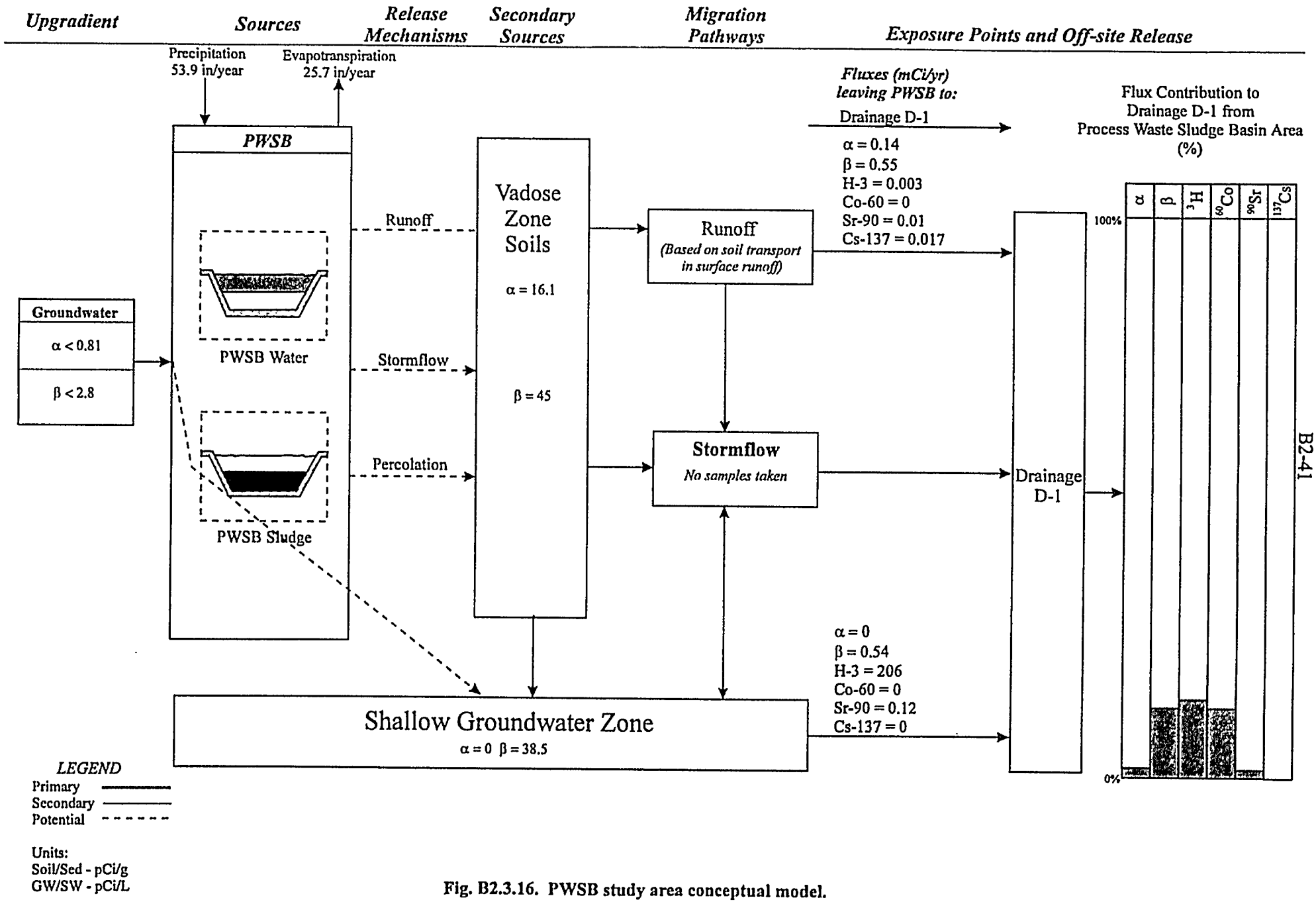


Fig. B2.3.16. PWSB study area conceptual model.

B2.3.4 SWSA 5 North

SWSA 5 North is currently used for the storage of alpha-contaminated LLW, other LLW, TRU waste, spent fuel materials, and special case (SC) wastes (ORNL 1993). (ORNL Waste Management Plan, Fiscal Year 1994, ORNL/TM-11433/R3.)] The principal constituents in the alpha-contaminated LLW are ^{233}U, ^{244}Cm, and ^{252}Cf. ORNL has managed much of its inventory of alpha-contaminated LLW as if it were TRU waste because of its uniqueness, difficulties in assay, and handling concerns (e.g., ^{233}U has fissile properties similar to ^{239}Pu, and ^{244}Cm and ^{252}Cf wastes are neutron sources). SC wastes are those that do not readily fit into the more typical waste categories and/or that would be difficult to process or to certify for disposal. Limited disposals of SC-TRU wastes and SC-alpha-contaminated LLW also occurred in SWSA 5 North (Baldwin et al. 1989). Figure B2.3.17 shows the SWSA 5 North storage and disposal areas evaluated for the WAG 5 RI.

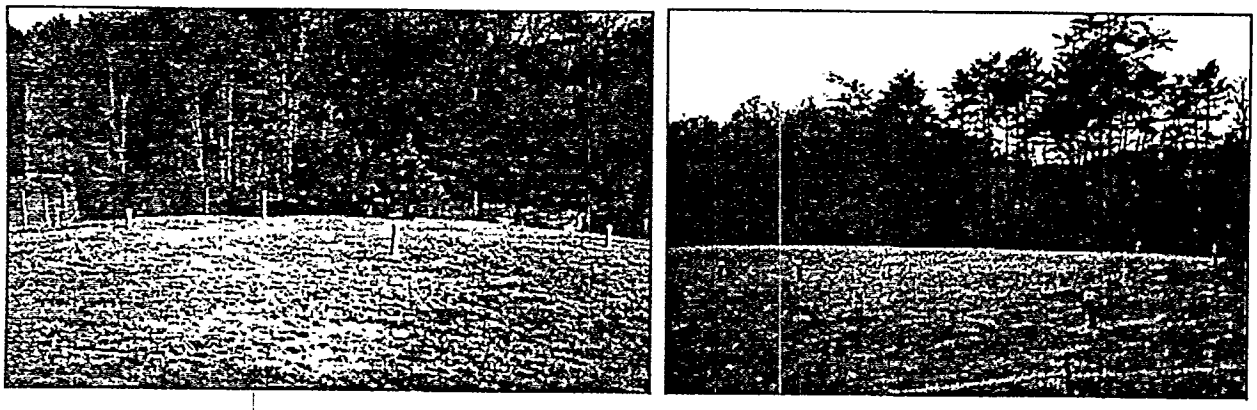


Fig. B2.3.17. Photographs of 7802N trenches (right) and TRU disposal trenches (left).

The principal operations in SWSA 5 North, both historical and current, have involved storage of alpha-contaminated wastes, a small fraction of which appear to be TRU wastes. Although TRU wastes are now defined [i.e., in the 1992 Land Withdrawal Act (LWA) for the Waste Isolation Pilot Plant (WIPP), by EPA in 40 CFR 191 regulations, and by DOE in proposed revisions to Order 5820.2A] as those containing alpha-emitting transuranium radionuclides with half lives >20 y and concentrations >100 nCi/g, this has not always been the case. Prior to 1970, there was no TRU waste classification. Radioactive waste contaminated with transuranium elements was classified as LLW and disposed of by shallow land burial. The dividing line between contact-handled (CH-) and remote-handled (RH-) wastes was (and still is) an external dose rate of 200 mrem/h.

In 1970, the U.S. Atomic Energy Commission established a TRU waste classification, and any solid waste contaminated with >10 nCi/g was to be segregated and stored, pending a disposal method that was yet to be determined. In 1982, the U.S. Nuclear Regulatory Commission changed the boundary between LLW and TRU waste from 10 nCi/g to 100 nCi/g. This definition of TRU wastes was not adopted by the DOE until 1984 (DOE Order 5820.2, Waste Management, February 6, 1984).

During the 1970 through 1981 period when wastes were stored or disposed of in trenches in SWSA 5 North, the TRU waste definition was based on a concentration >10 nCi/g. Thus, it is expected that some of these wastes would not classify as TRU wastes under the current definition,

even when the contaminants are alpha-emitting transuranium radionuclides with half lives >20 y (e.g., $^{238,239,240}Pu$, ^{241}Am), based on concentration alone.

Description and history of early storage and disposal sites in SWSA 5 north

RH-alpha-contaminated LLW (often simply—but not correctly—referred to as RH-TRU wastes) and some legitimate RH-TRU waste was emplaced for "storage" from April 1971 through April 1981 into 23 unlined trenches in one area of SWSA 5 North (7802N). SC-TRU wastes and alpha-contaminated LLW were disposed of in 4 additional trenches in the northeastern part of SWSA 5 North from 1970 through 1976. SC wastes, primarily nuclear fuel materials—sometimes included with the SC-TRU wastes—were placed in stainless-steel-lined wells (storage vaults) in the 7823A Area of SWSA 5 North during this period (Baldwin, Williams, and Massey 1989; Stewart et al. 1989; ORNL 1993). Figure B2.3.18 identifies the storage and disposal areas in SWSA 5 North. Disposals of RH-alpha-contaminated LLW and RH-TRU waste (contained in 108 concrete casks) also continued in 8 trench areas in SWSA 5 South during 1970 through 1974 (Stewart et al. 1989).

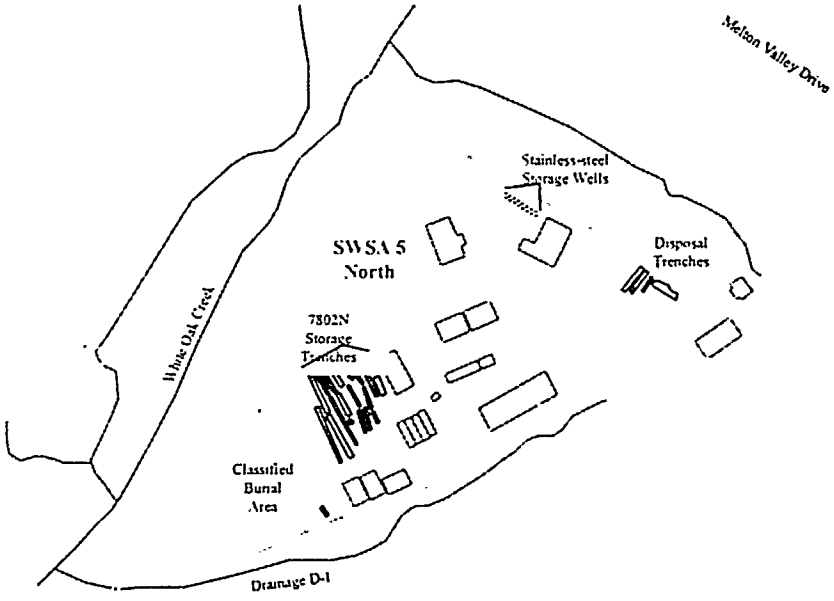


Fig. B2.3.18. Storage and disposal areas in SWSA 5 North.

In the past decade, ORNL has conducted several waste characterization studies to support programs for the retrieval, processing, certification, and disposal of TRU waste (Dickerson 1988; Stewart et al. 1989; Arakwa et al. 1994). Additional characterization studies are now ongoing. Certification that TRU wastes meet the Waste Acceptance Criteria (WAC) for the WIPP will be required for disposal. There are currently significant uncertainties associated with plans for (1) acceptance of RH-TRU wastes at the WIPP and (2) retrieval of RH-TRU wastes stored in the 7802N trenches. There are also major questions about the feasibility as well as the advisability of retrieval of the bulk of the materials emplaced in the 7802N trenches: RH-alpha-contaminated wastes containing neutron- and gamma-emitting radionuclides with relatively short half-lives. It is not clear that these materials could now be disposed of in the WIPP, even if retrieved, because the

materials do not appear to meet the TRU-waste definition in the WIPP LWA. The handling of the 7802N trench area is the subject of ongoing discussions between the DOE, the EPA, and the TDEC.

Monitoring of SWSA 5 North in accordance with DOE Order 5820.2A has identified ^{244}Cm and ^{241}Am in groundwater and in seeps discharging to White Oak Creek that indicate a probable release from the wastes in the 7802N trench area (Wickliff et al. 1991). Thus, the scope of the WAG 5 RI was expanded to evaluate the extent of contamination and potential impacts to human health and the environment through ongoing or future releases of radioactive constituents from selected storage or disposal areas in SWSA 5 North.

Details concerning the types, quantities, storage/disposal methods, and radionuclide inventory in (1) the SWSA 5 North trenches and (2) 8 stainless-steel lined vaults used for storage of SC-wastes and spent fuel materials were provided by Stewart et al. 1989 (see Table B2.3.8). Nearly 90% of the material in the 7802N trench area is RH-alpha-contaminated LLW and/or TRU wastes generated by the Radiochemical Engineering Development Center (REDC). These wastes were generated from production and separation of transplutonium isotopes (americium through fermium). The wastes in the 4-trench disposal area came from a variety of ORNL facilities. The Irradiated Fuel Examination Laboratory (Bldg 3525) was the primary source of the materials in the stainless-steel storage vaults.

The alpha-contaminated LLW and TRU wastes are heterogeneous solid wastes: glass, plastic, tubing, filters, pumps, protective clothing, metal cans/drums, gloveboxes, etc. Small quantities of liquids may be present in some of the containers. In addition to uranium and transuranium radionuclides, fission products (e.g., ^{106}Ru, ^{90}Sr, ^{125}Sb, ^{154,155}Eu, and ^{134,137}Cs) were also present. Many of the gamma and neutron-emitting radioisotopes are relatively short-lived (e.g., ^{106}Ru, ^{252}Cf), and thus some of the RH-wastes may now be CH-wastes because of radioactive decay over the 15- to 25-year period since these were placed into storage. Records also indicate that a small fraction of the wastes were CH- rather than RH-wastes when emplaced. The half-lives of radionuclides in the SWSA 5 North wastes based on data provided in Stewart et al. (1989) is presented in Table B2.3.9.

Alpha-contaminated LLW and TRU wastes stored or disposed of in SWSA 5 North trenches were packaged in three basic types of containers: concrete casks of varying wall thicknesses, wooden and metal boxes, and 55-gal drums. Concrete casks were cylindrical, approximately 7.5-ft high and 4.5-ft wide, with wall thicknesses of 4.5, 6, or 12 in., depending on the amount of shielding required. Some boxes were constructed entirely of wood and others were U.S. Air Force (aircraft engine) boxes that had wooden inner liners and metal exteriors. Most of the boxes had dimensions of 4 ft by 4 ft by 6 ft. The trenches in the 7802N area were 10-ft deep, 6-ft wide, and of variable length. Most of these trenches contain only concrete casks. However, three trenches contain only boxes, and one received two 55-gal drums only. The 4-trench disposal area (T-11, T-14, T-16, and T-17) received only boxes (59). The locations of the 274 waste containers stored or disposed of in the 27 trenches in SWSA 5 North (from Stewart et al. 1989) are shown in Fig. B2.3.19.

The containers in the 7802N area were placed in unlined trenches as shown in Fig. B2.3.20 and backfilled with excavated regolith materials. Trenches 1, 2, and 3 reportedly contain 2 layers of casks, and the bottom layer may have been encased in concrete to create a floor for the upper layer (Stewart et al. 1989). Boxes placed in the 4-trench disposal area were encased in concrete and then covered with soil (Baldwin, Williams, and Massey 1989). A bentonite-clay seal was placed over 14 of the 7802N trenches in 1977 to restrict infiltration of precipitation (Shoun 1977).

Table B2.3.8. SWSA 5 North source characterization matrix

Source Description	Area/ Dimensions	Waste Types & Contaminants Of Concern	Disposal Methods & Packaging	Waste Volume	Radionuclide Inventory	Waste Placement Dates
23 trenches in 7802N Area T1-10, T-12, T-13, T-15, T-18--27	Area: 0.7 acres Trench dimensions: length: 10 - 125 ft *avg. length: 50 ft* depth: 10 ft deep	RH-alpha-contaminated LLW and RH-TRU wastes: uranium and transuranium alpha- and neutron-emitting wastes in containers with surface exposure rate >200 mR/h at time of emplacement. Major isotopes: ^{239}Pu, ^{241}Am, ^{244}Cm, ^{252}Cf, ^{233}U, ^{137}Cs, ^{90}Sr Waste form: drums & gloveboxes, contaminated glass, metal, paper, plastic & cloth, incl. bottles, filters, pumps, racks, equipment, cardboard, gloves, bags, buckets, clothing, & wipes. Drums had pyrophoric wastes	200 reinforced concrete casks: sealed at point of origin & set upright in trench w/ crane internal dia = 27-42 in. wall thickness = 5-12 in. cask vol = 30-60 ft^3 13 boxes (wood/metal) placed in trenches; 75% had dimensions of: 4 × 4 × 6 ft = 96 ft^3 (*typ.*) 2 carbon-steel 55-gal drums	163 m^3 in casks *(assumes 50% void volume; 16 12-inch casks w/ waste volume of 15 ft^3 ea ; 184 4.5- & 6-in. casks w/waste volume of 30 ft^3 ea.)* 17 m^3 of waste in boxes *(based on typical box volume, 50% void ratio)* 0.2 m^3 (7.5 ft^3) of waste in drums	Isotope / Curies ^{239}Pu 5.3 ^{241}Am 10 ^{244}Cm 78 ^{252}Cf 23 ^{233}U 2.5 ^{232}Th -- Unident. 0.5 *Source:* Stewart et al. 1989	1971 -1981
4 Disposal Trenches near 7823 T-11, T-14, T-16, T-17	Area: 7500 ft^2 Trench dimensions: length: 20 - 65 ft *avg length: 47 ft* depth: 10 ft deep	SC-alpha-contaminated LLW and SC-TRU wastes packed in boxes due to physical size or composition, glove boxes, heating elements, calutron tanks & liners, other unspecified materials. Mostly used by small generators of TRU waste	59 wooden and combination wood/metal (USAF) boxes *(see dimensions above)* Containers in these 4 trenches were "filled" with concrete according to Stewart et al. (1989) and Baldwin et al. (1989)	80 m^3 of waste in boxes *(based on typical box volume, 50% void ratio as used on casks)*	See above Isotope / Curies ^{239}Pu 4.5 ^{241}Am 0.4 ^{244}Cm 63 Unident. 130 *Source:* Stewart et al. 1989	1970-1976
8 Stainless-steel storage wells (7823A)	Well dimensions: depth: 9 ft diameter: 17-39 in. spacing: 3 ft	High activity wastes, nuclear fuel material and SC wastes.	8-10 packages sealed inside 6-in.-dia. stainless steel tubes, sealed with metal gasket & bolt closure assembly. Auger holes lined w/ stainless steel & concrete w/18-in. concrete plug	4 m^3 (142 ft^3), assuming average vol of holes; range is from 3 ft^3 *(8-in dia hole)* to 44 ft^3 *(w/30-in dia)*	Isotope / Curies ^{239}Pu 17 ^{232}Th 3 Unident. 440 *Source:* Stewart et al. 1989	1970-1975
Bldg 7831A Drain field & seepage trench	Gravel-filled trench, 6 by 50 by 8	Decon fluids from decontamination of trucks/equipment using burial ground	Liquids drained directly into trench, followed by percolation into surrounding soils	Trench contents: Unknown qnty of contam. soil adjacent to trench	No information	1959-early 1960s

Table B2.3.9. Half-lives of isotopes in SWSA 5 North wastes

ISOTOPE	HALF-LIFE
^{227}Ac	21.8 years
^{110}Ag	250 days
^{241}Am	433 years
^{243}Am	7370 years
^{249}Bk	320 days
^{252}Cf	900 years
^{242}Cm	162 days
^{244}Cm	18.1 years
^{60}Co	5.3 years
^{137}Cs	30.2 years
^{237}Np	2.2×10^6 years
^{238}Pu	87.7 years
^{239}Pu	2.41×10^4 years
^{240}Pu	6560 years
^{241}Pu	14.1 years
^{226}Ra	1600 years
^{90}Sr	29.1 years
^{232}Th	1.39×10^{10} years
^{233}U	1.59×10^5 years
^{235}U	7.04×10^8 years
^{238}U	4.47×10^9 years

Source: Stewart et al. (1989).

Information concerning the highly radioactive wastes placed in the stainless-steel wells (see photo below) is also provided in Table B2.3.8. The wells have stainless steel liners with welded bottom plates inside a 4-in.-thick concrete collar. The wells are primarily used for storage of nuclear fuel materials from the Irradiated Fuel Examination Laboratory (Building 3525). Wastes are contained in either stainless-steel tubes or shielded carriers. Seven containers have uranium- and plutonium-containing fuel materials and have an ORNL Special Nuclear Materials number.

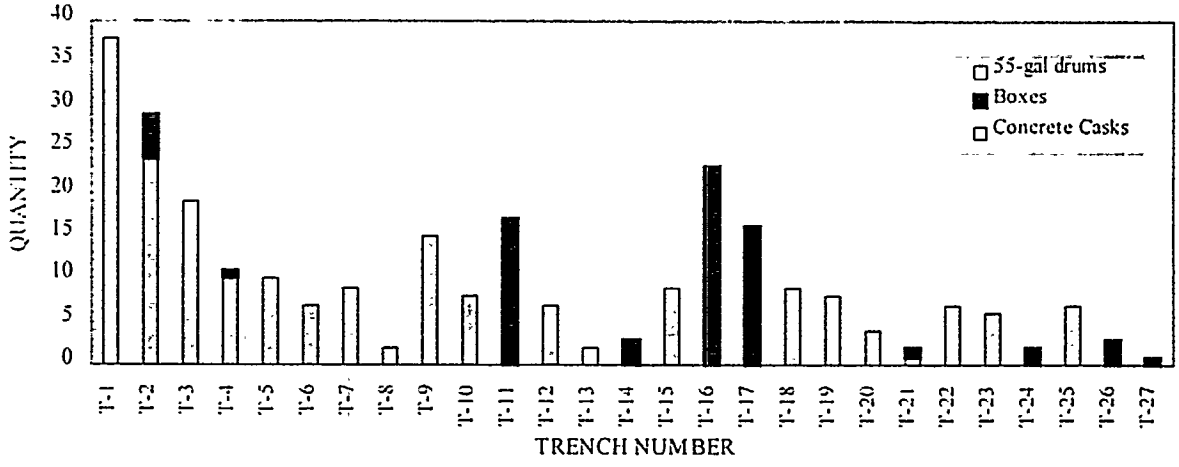


Fig. B2.3.19. Breakdown of contents in SWSA 5 North trenches.

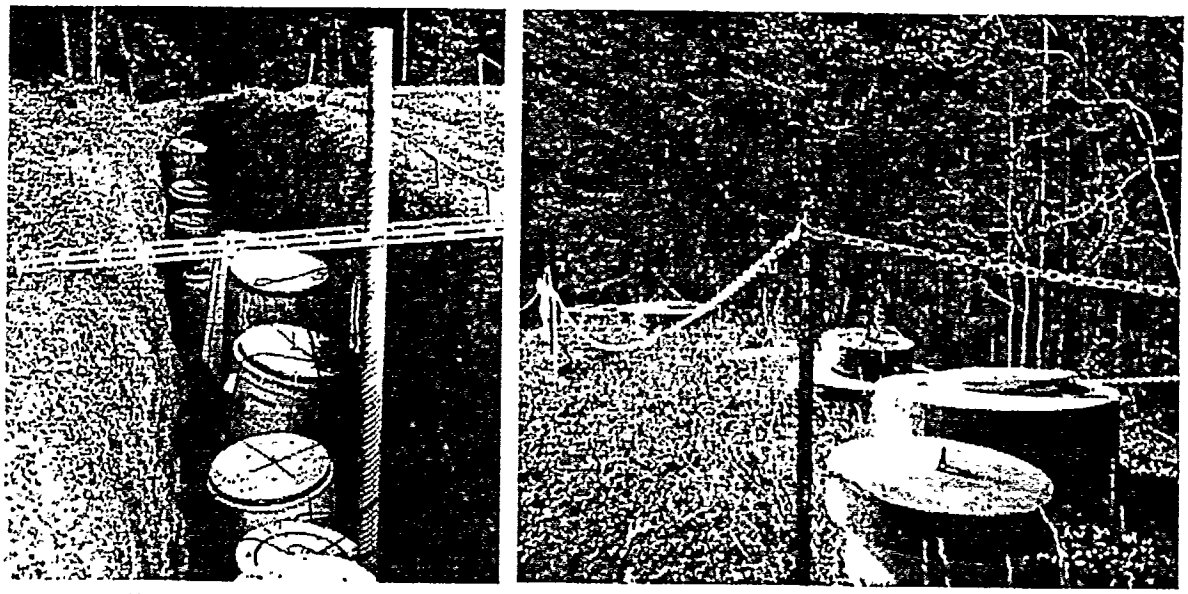


Fig. B2.3.20. Photographs of SWSA 5 North: (left) concrete casks in trench; (right) stainless steel storage wells.

Another potential source of contamination in the SWSA 5 North area is the drain field associated with Building 7831A near the entrance to WAG 5. The building contains a concrete pad with a center drain that was used for decontamination of burial ground equipment during the early years of SWSA 5 operations (late 1950s to early 1960s). Decontamination fluids were collected by the drain and conveyed via a buried pipe to a gravel-filled trench with dimensions of 6 ft wide by 50 ft long by 8 ft deep (Brill 1991). The trench and associated drain lines were not investigated or otherwise evaluated prior to the WAG 5 RI.

Previous and concurrent investigations

Groundwater monitoring in SWSA 5 North began in November 1989 as part of ORNL's ASEMP. Fifteen wells surrounding the TRU waste storage facilities were sampled quarterly through June 1993. ASEMP also sampled eight seep and stream locations; most of these are in or adjacent to White Oak Creek, but two are in the North Tributary and drainage D-1 (identified as the South Tributary in the ASEMP reports). In addition to the regular monitoring, a focused investigation was completed by ORNL Waste Management Division to further evaluate the contamination detected in well 0516 (Ashwood and Wickliff 1991). The focused investigation included additional sampling in White Oak Creek and selected wells in SWSA 5 North as well as an ongoing geochemical study of ^{244}Cm and ^{241}Am transport mechanisms (see Appendix B3). The WAG perimeter monitoring program has entailed annual sampling of the five 900-series wells in SWSA 5 North since August of 1990 (Clapp et al. 1992). Five soil borings, two rounds of groundwater sampling, and both baseflow and stormflow sampling of surface waters within and adjacent to SWSA 5 North were completed for the RI. Historical and RI sampling locations are shown in Fig. B2.3.21. Interpretations and conclusions relevant to the nature and extent of contamination are summarized below.

RI sampling summary

Figure B2.3.21 shows the sampling locations in the study area and the two cross-section locations used in the hydrologic models. Soil sampling consisted of a total of five vertical soil borings surrounding the 7802N waste storage trenches. These borings were completed to bedrock, and groundwater samples were obtained and screened at the CSL from borings that encountered groundwater. One medium to low exposure rate (USRADS) soil sample was collected behind the old decontamination building (7831A). During the summer of 1992, groundwater was collected from four piezometers in SWSA 5 North and screened at the CSL for radiological constituents. During wet and dry seasonal conditions in 1993, groundwater samples from SWSA 5 North were collected from 20 wells and piezometers for off-site analysis. Of these 20 sampling locations, 11 were part of ASEMP, 5 were RCRA compliance wells, and 4 were pre-RAP (Remedial Action Program) and RAP piezometers. Two surface water seeps were identified within SWSA 5 North during a WAG-wide field reconnaissance. CSL radiological screening was initially performed on samples collected at SP001 in the fall of 1992 (SP002 was dry at this time). Seeps SP001 and SP002 were then sampled during wet seasonal conditions (spring 1993).

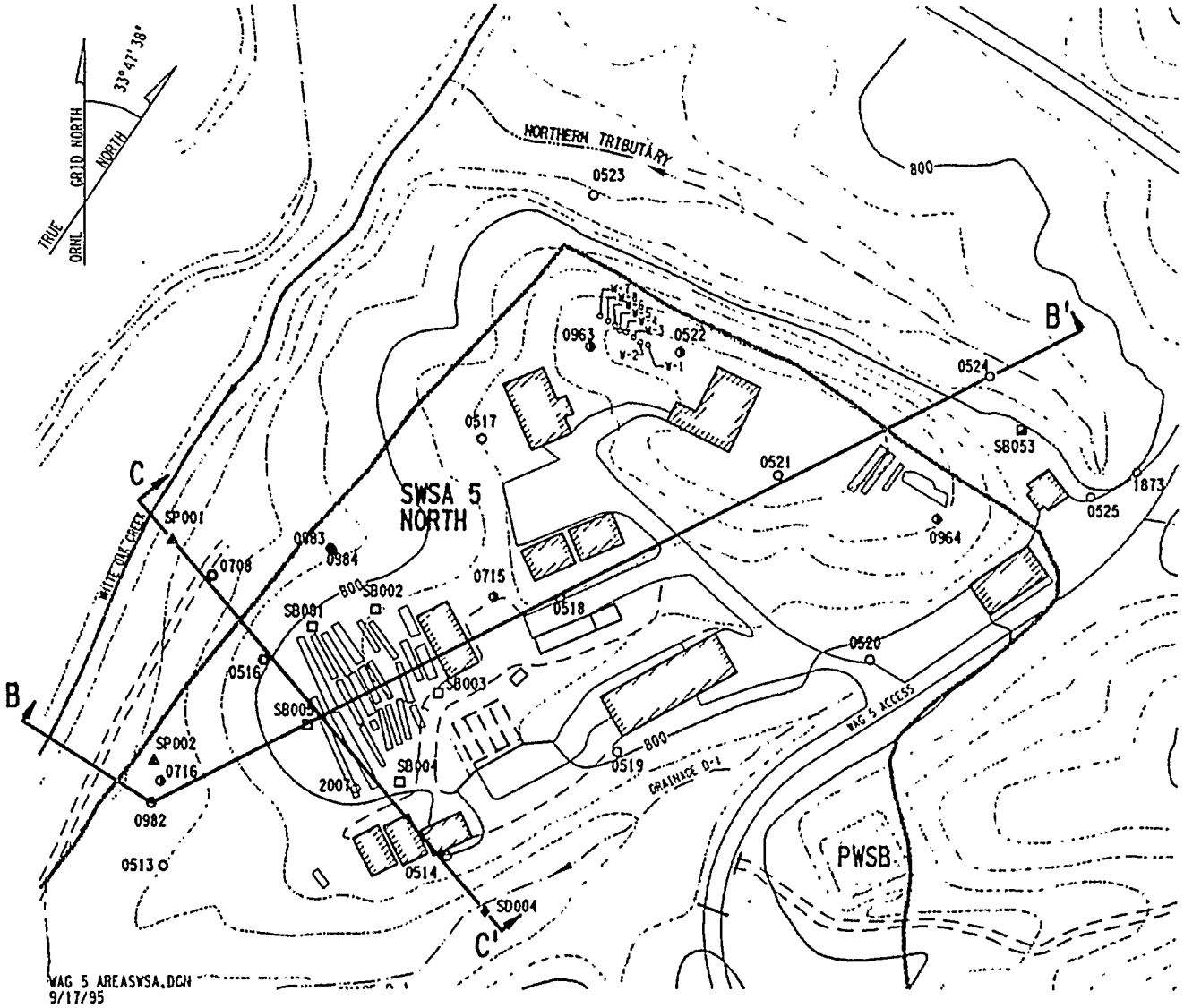
Hydrologic model

Figures B2.3.22(a) and (b) depict the hydrologic model for SWSA 5 North. Surface runoff, interflow (stormflow), and groundwater move radially from higher elevations toward discharge into D-1, North Tributary, and White Oak Creek. The water table generally occurs at depths of 5 to 40 ft below ground surface and is typically at or near the bedrock/regolith interface during the dry season and higher in the regolith during the wet season. Table B2.3.10 summarizes the annual water balance for the three pathways in SWSA 5 North (determined based on HSPF modeling). The flux through each pathway is similar, though shallow groundwater and interflow discharges slightly exceed the discharge calculated for surface runoff. Surface runoff is relatively high in SWSA 5 North because of the relatively extensive areas covered by buildings, roads, or pavement. Each pathway represents a potentially significant transport mechanism for the release of contamination from the area.

Table B2.3.10. Annual water balance summary for SWSA 5 North

		Annual Rate (m^3/yr)			
	Percent of Flow	White Oak Creek	Drainage D-1	North Tributary	Total
Surface Runoff	27	2,656	5,781	6,093	14,530
Interflow	31	2,971	6,466	6,815	16,252
Groundwater flow	42	4,089	8,900	9,381	22,370
Total	100	9,716	21,147	22,289	53,152

One significant feature shown in the hydrologic model is the location of the groundwater table relative to the 7802N retrievable storage trenches. Water level data collected in 1993 from in-trench standpipes and nearby monitoring wells show that most of the trenches in the 7802N area are at least partially inundated during the wet season. Wickliff et al. (1991) also reported wet season inundation of the 7802N trenches, indicating that the phenomenon is a fairly regular occurrence. Farther north (and uphill), transient 1993 water level data indicate that a perched water table (bathtubbing) occurred in the disposal trenches in the northeast corner of SWSA 5 North. The frequency of this bathtubbing could not be determined, but contamination data suggest it is a regular occurrence.



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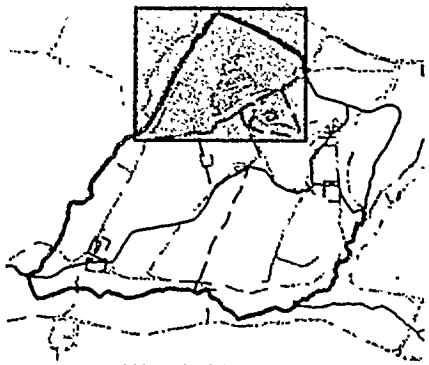


WAG 5 KEY PLAN

LEGEND

- WAG 5 BOUNDARY
- BUILDING
- PAVED ROAD
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- 0518 — GROUNDWATER SAMPLING LOCATION W/NO. (REGOLITH < 30')
- 0715 — GROUNDWATER SAMPLING LOCATION W/NO. (BEDROCK < 100')
- SD004 — SEDIMENT SAMPLING LOCATION W/NO.
- SP002 — SEEP LOCATION W/NO.
- SB001 — VERTICAL SOIL SAMPLING LOCATION W/NO.
- SB053 — SOIL SAMPLING LOCATION W/NO. (LOW TO MEDIUM EXPOSURE)
- AUGER HOLES W/NO.
- TRENCHES

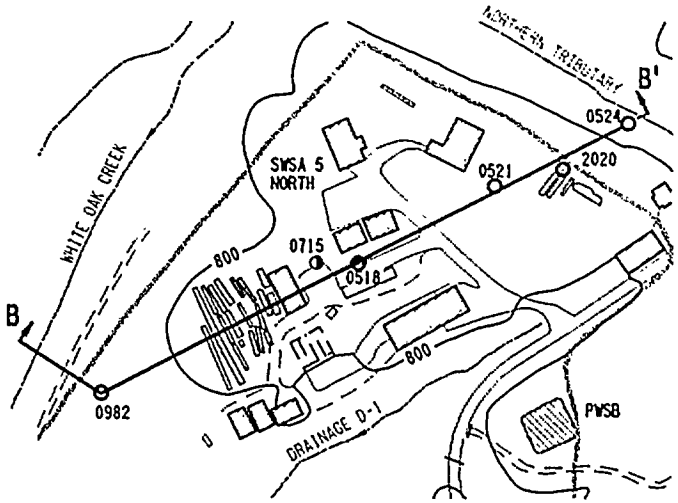
SCALE

0 100 200 FEET

0 20 40 60 METERS

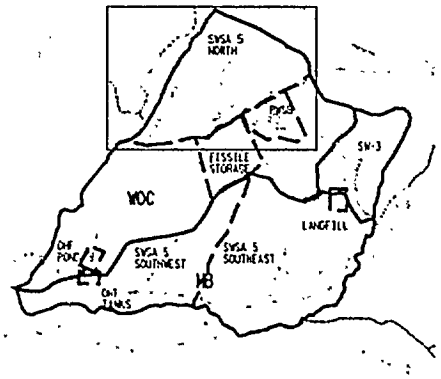
Drainage Group: White Oak Creek
Study Area: SWSA 5 North
Sources: RH-TRU waste storage trenches (15)
auger holes (8), miscellaneous trenches (5)

Fig. B2.3.21. SWSA 5 North plan view.

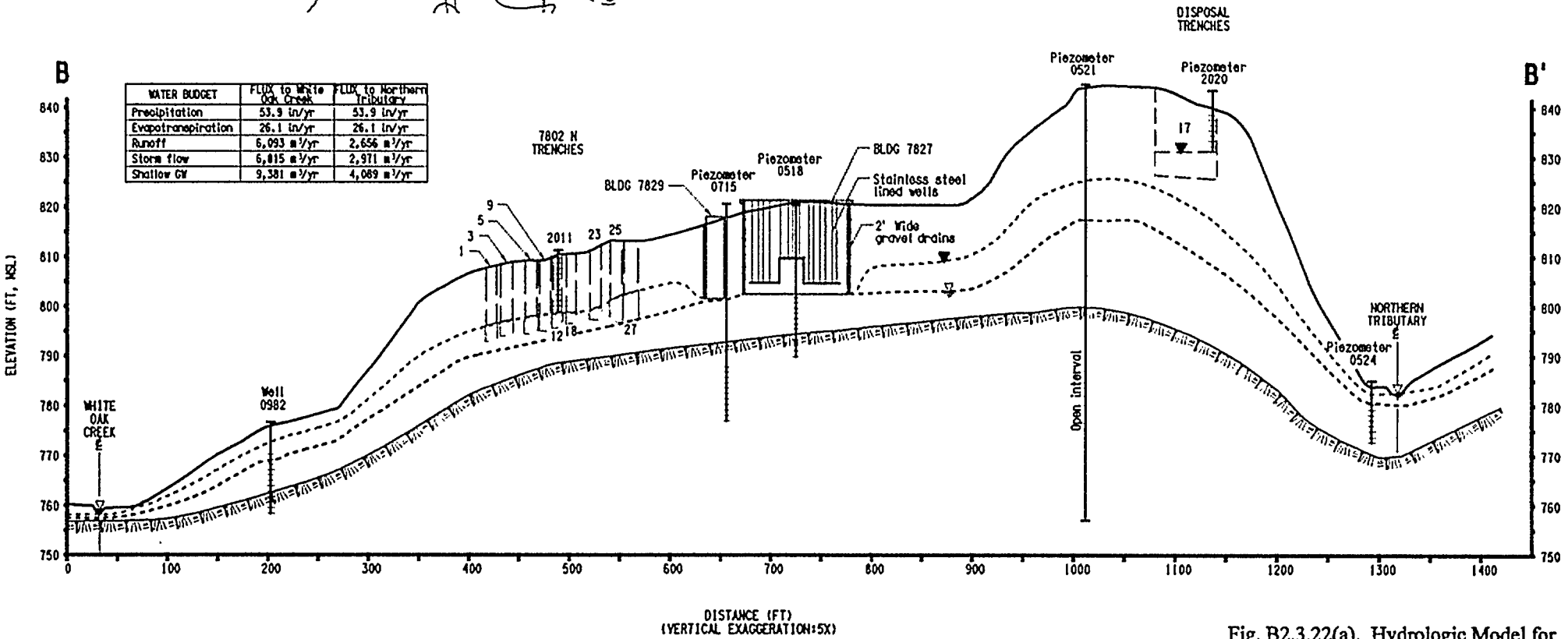


LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0524 — WELL, WELL NO., SCREEN SECTION
- 25 — APPROXIMATE TRENCH LIMIT W/NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX to White Oak Creek	FLUX to Northern Tributary
Precipitation	53.9 in/yr	53.9 in/yr
Evapotranspiration	26.1 in/yr	26.1 in/yr
Runoff	6,093 m^3/yr	2,656 m^3/yr
Storm flow	6,815 m^3/yr	2,971 m^3/yr
Shallow GW	9,381 m^3/yr	4,089 m^3/yr

Fig. B2.3.22(a). Hydrologic Model for SWSA 5 North (Section B-B').

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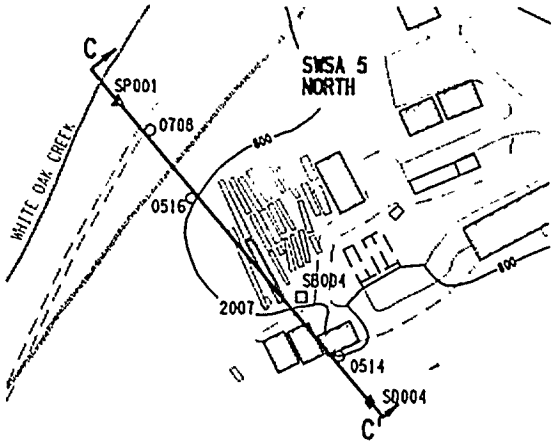
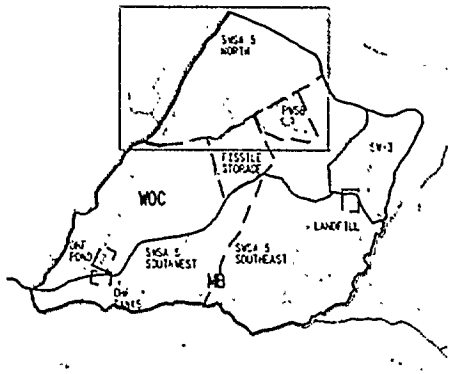


LEGEND

- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0516 — WELL, WELL NO., SCREEN SECTION
- T-1 — APPROXIMATE TRENCH BOUNDARY W/TRENCH NO.



WAG 5 KEY PLAN

WATER BUDGET	FLUX to White Oak Creek	FLUX to D-1
Precipitation	53.9 in/yr	53.9 in/yr
Evapotranspiration	26.1 in/yr	26.1 in/yr
Runoff	6,093 m^3/yr	5,781 m^3/yr
Storm flow	6,815 m^3/yr	6,466 m^3/yr
Shallow GW	9,381 m^3/yr	8,900 m^3/yr

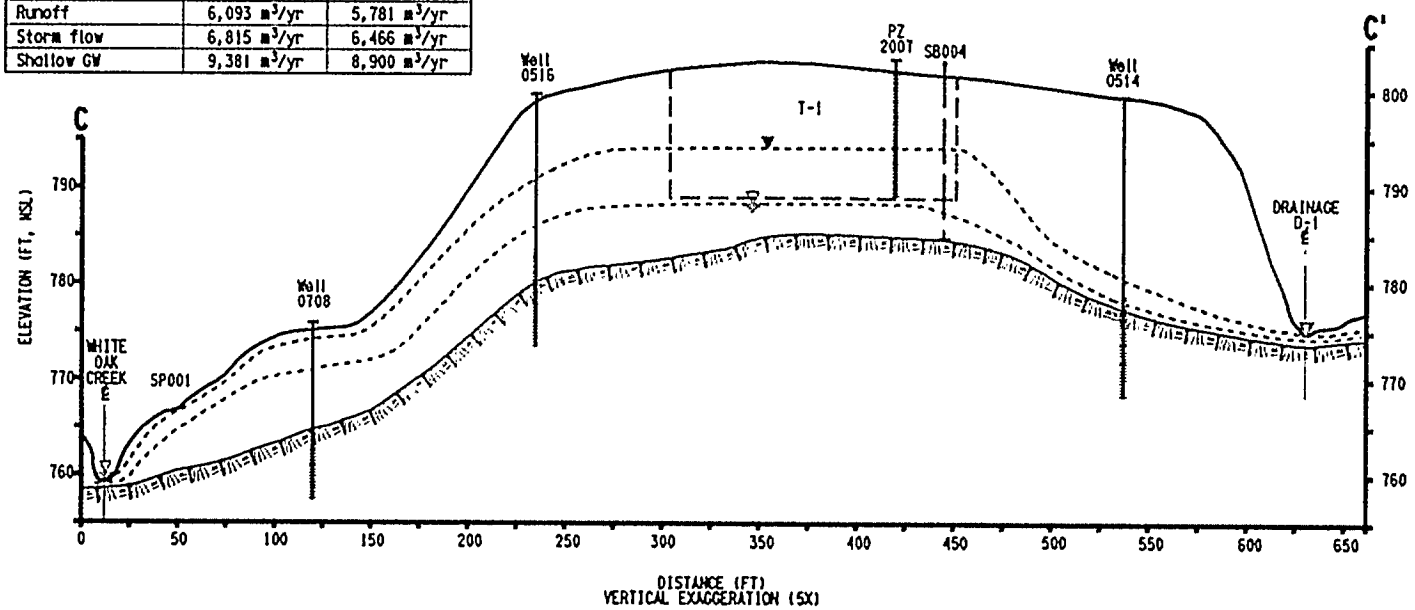


Fig. B2.3.22(b). Hydrologic model for SWSA 5 North (Section C-C').

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The water level data also show that the gravel drains installed to prevent inundation of wastes stored in Buildings 7826, 7827, and 7834 appear to be functioning as designed. During the wet season, these drains may actually create a localized reversal of the hydraulic gradient and groundwater flow. The downgradient limits of the drains' hydraulic influence (i.e., capture zone) is not known, but some (localized) reversal and/or stagnation of groundwater flow may result.

Nature and extent of contamination

Table B2.3.11 shows analytes of concern detected above background in the soils, surface water, groundwater, and sediment of SWSA 5 North; TRU constituents are shown in bold. Surface water and sediment results were based on sampling conducted in drainage D-1, White Oak Creek, and North Tributary; surface water samples include seeps. Table B2.3.12 summarizes results from RI and historical samples; due to the large number of samples, maximum detected results are presented for groundwater and surface water samples along with the detected ranges from soil boring samples.

Sampling results document a release of alpha-contaminated LLW and TRU waste constituents, primarily actinides, to shallow groundwater in SWSA 5 North. Americium and/or curium have been detected in all of the samples from well 0516 in concentrations ranging up to 5940 pCi/L. Curium and americium were detected at least once in 18 of the remaining 20 wells in SWSA 5 North, but typically in much lower concentrations (<1 to 3 pCi/L). Concentrations have varied over time (due in part to analytical variability and sampling methods), but there are sufficient confirmed detections to indicate that (1) pulses of actinide contamination have been released from the trenches and (2) certain pathways become active only under certain conditions (e.g., during inundation of trenches).

Table B2.3.11. Contaminants of concern detected above background in SWSA 5 North

CONTAMINANT	GW	SW	SED	SOIL
^{241}Am	X			
$^{243/244}$Cm	X			
^{212}Pb	X			
^{238}Pu	X			
^{226}Ra	X			
^{228}Ra	X			
^{99}Tc	X			
^{228}Th	X			
^{230}Th	X			
^{232}Th	X	X		
^{234}Th	X			
^{208}Tl				X
$^{233/234}$U	X			
^{238}U	X			
Lead	X			
Chromium	X			
Nickel	X			

Table B2.3.12. Analytical data summary for selected radionuclides in SWSA 5 North

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Gross Beta	(α) Ra-226	(β) Ra-228	(α) Th-228	(α) Th-230	(α) Th-232	(α) U-233/234	(α) U-238	(α) Pu-238	(α) Am-241	(α) Cm-243/244
SOIL maximums (pCi/g)															
Background Reference				9.9	42	1.44		1.5							
	SB001 (3)	4/6/93	0-9.4	23	55	0.83	2.1	1.3		2.1					
	SB002 (4)	4/7/93	0-17	31	55	0.95	2	2		1.9					
	SB003 (3)	3/29/93	0-11.7	24	53	0.75	1.3	1.7		1.3					
	SB004 (4)	3/30/93	0-16.2	33	31	0.91	1.8	1.6		1.8					
	SB005 (3)	4/5/93	0-6.9	29	46	0.71	2.4	1.5		2.4					
	SB053 (1)	3/2/93	0-2	-	49.2										

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha U	(α) Gross Alpha F	(β) Gross Beta U	(β) Gross Beta F	(α) Ra-226 U	(α) Ra-226 F	(β) Ra-228 U	(β) Ra-228 F	(α) Th-228 U	(α) Th-228 F	(α) Th-230 U	(α) Th-230 F	(α) Th-232 U	(α) Th-232 F	(α) U-233/234 U	(α) U-233/234 F	(α) U-238 U	(α) U-238 F	(α) Pu-238 U	(α) Pu-238 F	(α) Am-241 U	(α) Am-241 F	(α) Cm-243/244 U	(α) Cm-243/244 F
GROUNDWATER maximums (pCi/L)																											
Background Reference				5.2	3.2	16	7.4																				
(a)	0513 (16)	11/89-10/9	10-20	99.8	36.1	-	36	11.3	-			5.6		3.16		3.5		3.3	-	3.32	-	1.48	0.5	-	0.27		1.89
(a)	0514 (16)	11/89-10/9	20-30	17	4.59	27	12.4	0.47	-			-	-	-	-	0.14	-	-	-	-	-	-	-	-	0.3	-	0.62
(a)	0516 (18)	11/89-10/9	16-26	710	5670	77.9	405					1.02	-	0.57	-	0.68	-	0.4	0.3	0.29	0.23	0.79	-	1.12	189	180	5940
(a)	0517 (16)	11/89-10/9	22-31	66.9	18.9	143	35.9	0.31	-			2.2	-	2.38	-	1.56	-	1.28	-	1.13	-	2.24	-	0.67	0.24	-	0.24
(a)	0518 (16)	11/89-9/93	21-31	15.9	0.81	164	96.3	-	0.41			-	-	-	-	-	-		0.55		-			-	2.4	-	0.08
(a)	0519 (17)	11/89-10/9	15-25	104	20.4	165	164	9.1	-					7.8	-	9.17	-	8.6	0.38	7.58	0.46	-	3.17	1.39	0.81		0.24
(a)	0520 (17)	11/89-10/9	14-24	19.6	17.4	18.3	35.9	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	2.16	-	2.97
(a)	0521 (16)	11/89-9/93	18-87	11.2	22.7	33.9	37.8	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	2.16		8.1
(a)	0522 (15)	11/89-10/9	58-68	-	14.6	47.8	35.9	1.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.38		1.3
(a)	0523 (16)	11/89-10/9	5-10	21.8	14.6	60	51.3					-			-		0.1	5.15	0.71	5.05	0.32	-	-	0.75	0.43	0.18	0.49
(a)	0524 (16)	11/89-10/9	6-11	60.5	4.5	205	81	3.84	0.27	6	-	5.6	-	2.8	0.18	10.1	0.77	4.5	0.6	-	-	-	-	0.68	1.3		0.3
(a)	0525 (16)	11/89-10/9	19-29	36.1	17.5	110	35.9	5.17	0.31		19.2	0.72	-	0.18		0.36		-	-	0.27	-	0.34	-	-	0.46	-	0.38
(a)	0708 (12)	11/89-10/9	13-18	11.7	14.3	64.5	52.9	-	0.22			0.28	-	-	-	-	-	0.52	0.35	0.4	0.22	-	-	0.84	0.33		4.05
(a)	0715 (12)	11/89-10/9	31-41	-	-	757	3.9	5.44	-	48.6		4.8	-	3.5	-	4.2	-	10	-	9.88	-	-	0.34	-	0.35		0.49
(a)	0716 (13)	11/89-10/9	91-101	17.8	3.9	433	26.5	1.5	0.89	2.1	-	1.5	-	1.8	-	1.3	-	1.1	0.92	0.56	-	-	-	-	1.8		1.05
(b)	0963 (5)	4/93-11/93	56-95	32.7	41	3.5	4	-	-	-	-	-	-	0.1	-	0.06	-	0.46	0.55	-	-	-	-	-	-	-	-
(b)	0964 (5)	4/93-11/93	27-49	0.76	1.4	4.1	3.8	-		-	-	-	-	-	-	-	-	0.32	-	-	-	-	0.21	-	-	0.2	0.42
(b)	0982 (5)	4/93-11/93	5-16	51.3	34.8	13.2	6.2	-	-	-	-	-	-	0.24	-	-	-	0.32	0.68	-	0.27	0.05	-	0.21	0.17	18.1	15.9
(b)	0983 (5)	4/93-11/93	8-25	3.5	3	7	4.9	-	-	-	-	-	-	-	-	-	-	0.56	0.62	-	0.26	-	-	-	-	0.11	-
(b)	0984 (5)	4/93-11/93	58-80	19.4	183	10.7	24.4	0.22	-	0.12	0.12	-	-	0.27	0.1	-	-	0.68	0.54	-	-	0.19	-	-	0.13	-	0.14
	1873 (1)	7/92	187-205	128	28.9	410	98.9																				
SURFACE WATER maximums (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				9		8										2				2							
	SP002 (1)	5/5/93		-	-	9.7	6.9									29.1		-	-	0.97	0.33						
	SP001 (1)	5/5/93		23.4	18.4	8.9	16.4											-	-	-	-						
(a)	WOC 160 (11)	12/90-3/93		37.8		40.5																		1.5		0.38	
(a)	WOC 175 (7)	12/90-3/93		4.1		21.6																		0.16		0.24	
(a)	WOC 213 (3)	12/90-4/91		351		43.2																		19.4		351	
(a)	WOC 255 (10)	12/90-6/93		26.7		13.2																		1.08		21.3	
(a)	North Trib. (11)	3/90-6/93		10.6		48.6																		0.68		3.51	
(a)	South Trib. (11)	3/90-6/93		351		432																		1.27		3.78	

Notes.
1) Historical Samples.
(a) Includes data from ASEMP quarterly samples starting in Nov 1989 Filtered analyses included for Gross Alpha/Beta, Tritium, Am-241 and Cm-244
(b) Includes data from ESD yearly monitoring of RCRA perimeter wells Analyses include Gross Alpha/Beta and Tritium.
2) Number in parenthesis account for number of samples taken
3) Blanks indicate analyte not analyzed for; Bold indicates detected over background reference (2x mean background)
4) Abreviations: U/F = Unfiltered/Filtered - = not detected (α,β,γ) = Alpha,beta,gamma emitter

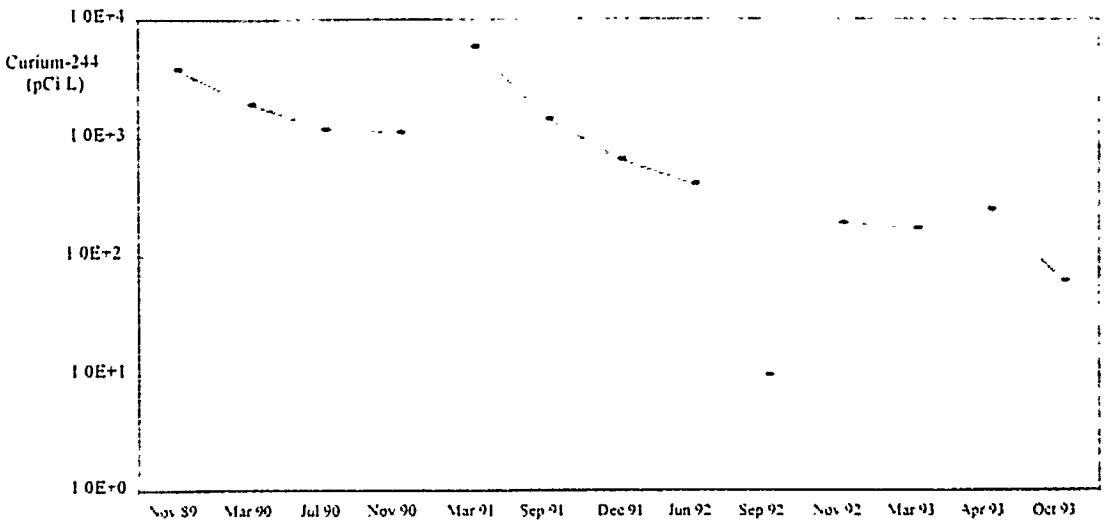


Fig. B2.3.23. Variations in ^{244}Cm concentrations in well 0516.

Figure B2.3.23 is a graph of ^{244}Cm concentrations from well 0516 (along the western edge of the 7802N trenches); concentrations show a general downward trend. Plots of other wells in the area are complicated due to the generally low levels of contamination and/or relatively significant errors associated with many of the analyses. In general, concentrations rise in the wetter months of winter and spring and decline during the drier summer and fall.

In addition to ^{244}Cm and ^{241}Am, ^{238}Pu has been detected in low concentrations (usually <1 pCi/L) in several wells. Other contaminants have also been detected, mostly radionuclides of the uranium-thorium decay series (e.g., ^{23X}U, ^{23X}Th, ^{22X}Ra). In contrast to groundwater elsewhere in WAG 5, concentrations of tritium and the principal fission products (^{90}Sr, ^{137}Cs) have, in most cases, been at or below background levels. Cobalt-60 has been detected infrequently in several wells but does not appear to be a major contaminant of concern in the area. Nonradiological contamination including lead, chromium, and nickel, has also been detected in several wells. In nearly every case, the elevated levels were detected in samples from wells 0516, 0524, and/or 0716. Stewart et al. (1989) reported that many of the wastes included materials constructed of or containing lead and mercury, but mercury was not detected in any of the groundwater samples. Specific sources for chromium and nickel are not known, but such materials would be expected in the heterogeneous waste mixture placed in the trenches.

Consistent with the hydrologic model showing shallow groundwater circulation in SWSA 5 North, the actinides ^{244}Cm and ^{241}Am were identified in seep samples collected in the downgradient groundwater discharge areas along White Oak Creek. Most of these seeps are seasonal, and none have particularly high water flows. Because of the dilution that occurs, only trace amounts of TRU contaminants have been detected on an infrequent basis within the surface waters of drainage D-1 and White Oak Creek. Ashwood and Wickliff (1991) used Mn_2O fibers (for preferential sorption of actinides from surface water) and reported the detection of both ^{244}Cm and ^{241}Am in White Oak Creek. Curium-244 and ^{241}Am were detected more frequently in the North Tributary, indicating either a greater contaminant flux or less dilution to the north.

Evaluation of soils data from the five soil borings completed along the perimeter of the 7802N trenches in SWSA 5 North did not identify significant levels of contamination. Most of these borings extended to the approximate depth of the trenches, and some extended to the water table but did not go below. Several radionuclides were present at levels greater than background, mostly members of the uranium-thorium decay series. The absence of TRU contamination in soils was determined to be the best indicator that soils were not contaminated. The presence of contamination in shallow wells near the soil borings but not in soil samples supports the general conclusion that contaminant migration pathways in the subsurface follow discrete pathways.

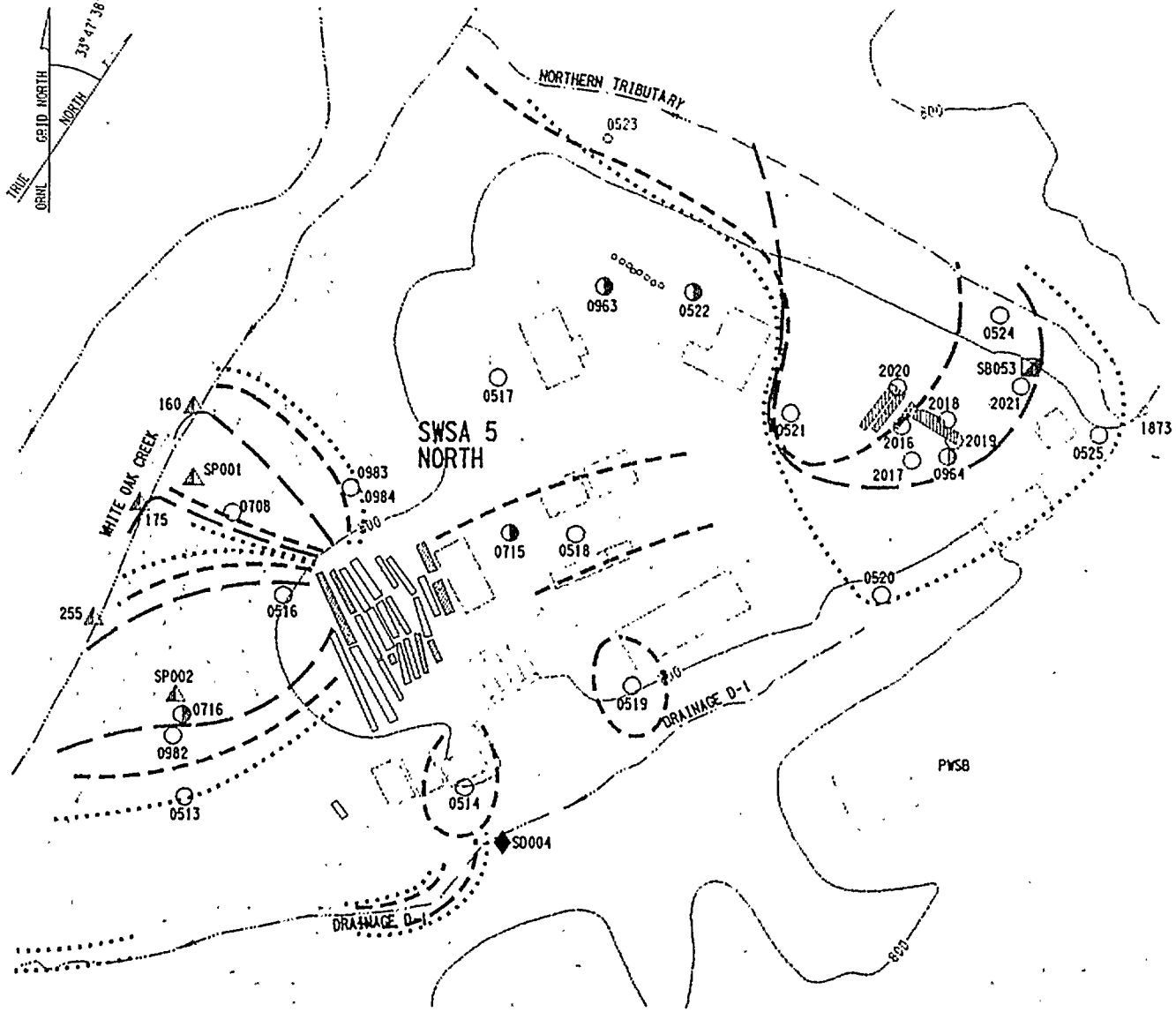
The ^{244}Cm and ^{241}Am data from wells, seeps, and surface waters associated with SWSA 5 North indicate that a relatively widespread release of contamination has occurred. The SC waste in the stainless-steel- and concrete-lined auger holes is not a likely source of the contamination detected in SWSA 5 North. These wastes are at least doubly contained in stainless steel, and hydrologic data show that the holes have not been inundated. Descriptions of the RH-alpha-contaminated and RH-TRU waste packaging and containers in Stewart et al. (1989) indicate that most of the wastes placed in the trenches consist of small items from hot cell operations that were placed in 1-gal metal paint cans, 5-gal metal cans, and 3-gal plastic buckets. These containers were sealed with a lid, heat-sealed in a polyethylene overpack, and then placed in concrete casks, which were also sealed prior to placement in the trenches. Even where these casks are inundated, the thickness and strength of the concrete, its resistance to corrosion, and the redundant levels of containment for interior waste packages probably prevent these casks from releasing contamination.

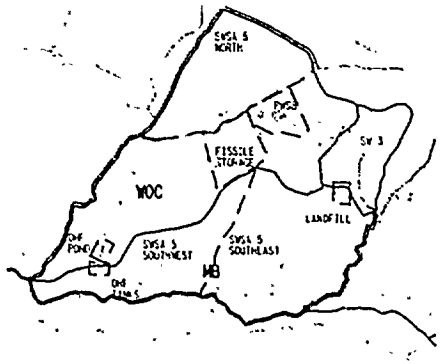
Another potential source that may account for the contamination detected in well 0524 is the drain field and seepage trench associated with Building 7831A. Samples from well 0524 contained a variety of contaminants not seen in any sample elsewhere in SWSA 5 North, including beryllium, lead, chromium.

Trench inundation (from a rising water table) or bathtubbing (formation of a perched water table) is the most likely mechanism to account for the release of contamination in SWSA 5 North, particularly when trenches containing wood or wood/metal boxes of alpha-contaminated LLW or TRU waste are inundated. As shown in Fig. B2.3.24, 72 boxes of waste were retrievably buried along with the casks in SWSA 5 North, most in the 4 disposal trenches in the northeast corner of the area. Table B2.3.13 summarizes the available trench-specific information associated with the boxed alpha-contaminated and TRU wastes. The integrity of these wood or wood and metal boxes after 20 years underground is not known, but it can be assumed that some deterioration of the containers has occurred and that the rate of deterioration would be accelerated where the container is at least partially inundated during the year.

The buried wastes in SWSA 5 North were generated by a wide variety of activities and processes and thus represent a heterogeneous source. Differences in the suite of contaminants found in samples from different wells indicate that multiple sources have been active. These differences include

- ^{238}U and ^{234}U in concentrations of 5 to 10 pCi/L in samples from wells 0715 and 0523 (most samples had <1 pCi/L of uranium isotopes);





WAG 5 KEY PLAN

LEGEND

STORAGE WELLS

TRENCHES W/ WASTES IN CASKS

TRENCHES W/ WASTES IN BOXES

TRU RELEASES AND ESTIMATED MIGRATION PATHS

1993

1992

1991

NOTE: SEE Fig. B2.3.21. FOR EXPLANATION OF SYMBOLS.

SCALE

0 100 200 FEET

0 20 40 60 METERS

Fig. B2.3.24. Spatial and temporal variations in actinide releases in SWSA 5 North.

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- beryllium (1.3 to 5.4 μg/L) in samples from wells 0516, 0524, and 0716 (not detected in any other wells);
- ^{238}Pu concentrations in wells 0517 and 0519 of 2 to 3 pCi/L, which were the highest concentrations detected in SWSA 5 North groundwater from the RI samples; and
- elevated lead concentrations in samples from well 0514 (47 to 118 μg/L)

In addition to variability in the types and magnitude of contamination, contaminant migration pathways change with time. Figure B2.3.24 identifies these migration pathways based on detection of ^{241}Am and/or ^{244}Cm in groundwater and surface water samples from the 1990–1993 ASEMP and 1993 RI sampling activities. The most frequently detected pathways are to the west, toward White Oak Creek (as evidenced by contamination in well 0516) and to the north, toward North Tributary. On an intermittent basis, contamination has flowed southeast toward drainage D-1 and toward the TRU storage buildings (7827 and 7834), possibly in response to the hydraulic effects associated with the perimeter drains that surround these buildings.

Contamination in well 0524 may also be due to release and migration of contamination from the Building 7831 drain field; however, the presence of ^{241}Am in several samples from this well indicates transport from TRU wastes in SWSA 5 North. This conclusion is based on information that the decon operations reportedly stopped in the early 1960s, by which time very little TRU waste had been disposed of in SWSA 5 (South). According to information provided in Williams (1987) and Stewart et al. (1989), most TRU wastes in WAG 5 were buried or stored after 1967. Given the unusual suite of contaminants detected in well 0524, it is likely that groundwater in that area has been impacted by contaminant releases from boxed SC-alpha-contaminated LLW and SC-TRU wastes in the disposal trenches in the northeast corner of SWSA 5 North with an additional contribution from the drain field associated with Building 7831A.

Table B2.3.13. Disposal of alpha-contaminated LLW and TRU wastes in boxes in SWSA 5 North

Trench	No. of Boxes	Date Placed	Comments
T-2	5	1972	Includes 4 boxes of wastes from Y-12 Isotopes Separation Facility
T-4	1	1974	
T-11	17	1973-1975	
T-14	3	1974-1976	Includes 2 boxes of wastes from Y-12 Isotopes Separation Facility
T-16	23	1973-1976	
T-17	16	1972-1976	Off-site wastes from New Brunswick National Lab and Y-12 Isotopes Separation Facility
T-21	1	1978	
T-24	2	1979-1980	
T-26	3	1980	
T-27	1	1981	
10 Trenches	*72 Boxes*	*9-yr period (1972-1981)*	

Source: Stewart et al. (1989).

Spatial variability in the type and magnitude of actinide contamination along downgradient flowpaths from probable source areas supports the interpretation that groundwater flow (and thus contaminant transport) in the water table interval follows discrete pathways. Contamination is not moving as a broad plume, but along preferential pathways related to the fracture distribution and orientation in the bedrock and saprolitic regolith. Well 0516 evidently intercepted one of these pathways, as evidenced by the persistence and strength of contamination detected in samples from the well. The prevalence of much lower levels of contamination is most likely due to the relatively low mobility of these actinide contaminants as well as dispersion and diffusion of contaminants through the aquifer matrix and into less-permeable fracture networks. Thus concentrations in a given well may not be representative of the total flux of contamination moving through the aquifer in that general area but are useful indicators that contamination is migrating in the groundwater. For these reasons, construction of a viable plume map with concentration gradients is not possible. It is important to note that Fig. B2.3.24 is an interpretive tool to illustrate contaminant migration pathways and should not be considered a plume map.

With the exception of well 0516, the magnitude of release of actinides from SWSA 5 North wastes has not been sufficient to cause significant contamination in either groundwater or surface water. The release is important, however, for several reasons. The source of the contamination is waste that has been "retrievably" buried. The ongoing release of alpha-contaminated and TRU waste constituents from boxes (or any containers) complicates eventual retrieval of the waste by (1) creating a large mass of alpha- and TRU-contaminated soil and (2) possibly transferring the contaminants from the waste containers to the soil, in which case the exhumed waste packages may not contain much in the way of alpha-contaminated LLW or TRU waste.

A second consideration is that release of alpha-contaminated and TRU wastes into the regolith and groundwater beneath SWSA 5 North is creating a potentially significant secondary source that may remain active for a long time. An increase in the release rate or overall flux of alpha and/or TRU waste constituents could have a measurable impact on downstream surface waters and associated human and ecological receptors. Long-term land uses for the SWSA 5 North area would be more restricted due to the secondary source, similar to that expected for SWSA 5 South, where the buried wastes would be much more difficult to retrieve.

Conceptual model

The site conceptual model for SWSA 5 North is summarized in Table B2.3.14 and illustrated in Fig. B2.3.25. This area-specific model integrates the hydrologic processes and contaminant data and forms the basis of the drainage basin and WAG-wide conceptual models presented in Volume 1. Briefly, the model can be summarized as follows: alpha-contaminated LLW and TRU wastes buried in boxes in 10 of the trenches in SWSA 5 North appear to be the primary sources of TRU contamination detected to date in groundwater and surface water. The principal release mechanism is inundation of the boxes (85% of the boxes are in trenches 2, 11, 16, and 17) either through a rising water table or formation of a perched water table (bathtubbing), both during the wetter portions of the year. Contaminants released to groundwater are transported in the water table interval to discharge points associated with White Oak Creek, North Tributary, and, to a lesser extent, drainage D-1 (South Tributary). Because the area is in a recharge zone, some downward transport of contaminants to intermediate depths in the fractured bedrock aquifer also occurs. Stormflow may

also have a significant role in contaminant transport from the miscellaneous trenches in the northeast corner of SWSA 5 North, but this has not been observed.

Uncertainty

There is a potentially significant level of uncertainty associated with the interpretations and data from SWSA 5 North. The principal cause for the uncertainty is the variability in the sampling and analytical program and resulting analytical data. For example, ASEMP sampling results do not have any validation or laboratory qualifiers attached to the data. Ashwood and Marsh (1994) do identify which results were "significantly greater than zero," but it is not clear if other ASEMP results not significantly greater than zero should be viewed as nondetects. Historical sampling of RCRA perimeter wells did not include TRU constituents.

For the RI sampling, the high base sampling round in April–June 1993 was mostly limited to americium and curium and the low base in September–October 1993 included the full suite of isotopic analyses. And lastly, only the RI data have been validated. The absence of validation does not preclude the use of the historical data (in fact, the comparability between the multiple sampling rounds from the ASEMP wells indicates these data should be viewed as highly reliable), but it does mean that false positives or false negatives may be included in the data set.

Table B2.3.14. Summary of conceptual model for SWSA 5 North

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
10 trenches w/ boxed wastes (alpha-contaminated LLW and TRU waste) • *active (primary) source*	Inundation of trenches from rising water table & perched water table (bathtubbing)	Shallow groundwater discharging to White Oak Creek, North Tributary, & D-1; stormflow zone may be important for transport from misc. trenches	*On site*: Wastes; contam. groundwater, surface water & sediment (D-1, North Trib., White Oak Creek), & seep area soils. *Off site*: White Oak Creek surface water & sediment
17 trenches w/alpha-contaminated LLW and TRU wastes in concrete casks • *inactive (potential) source*	Inundation of trenches	Same as above	Same as above
8 stainless-steel-lined storage wells with SC wastes • *inactive/unlikely source*	None expected; waste packages are doubly contained inside stainless-steel & concrete-lined auger holes	None expected	*On site*: Wastes *Off site:* None
Bldg. 7831A drain field & seepage trench • *active source*	Percolation of infiltration; inundation by rising water table	Shallow groundwater discharging to North Tributary & White Oak Creek	*On site*: Contam. materials in/adjacent to trench; contam. groundwater *Off site*: White Oak Creek surface water & sediment

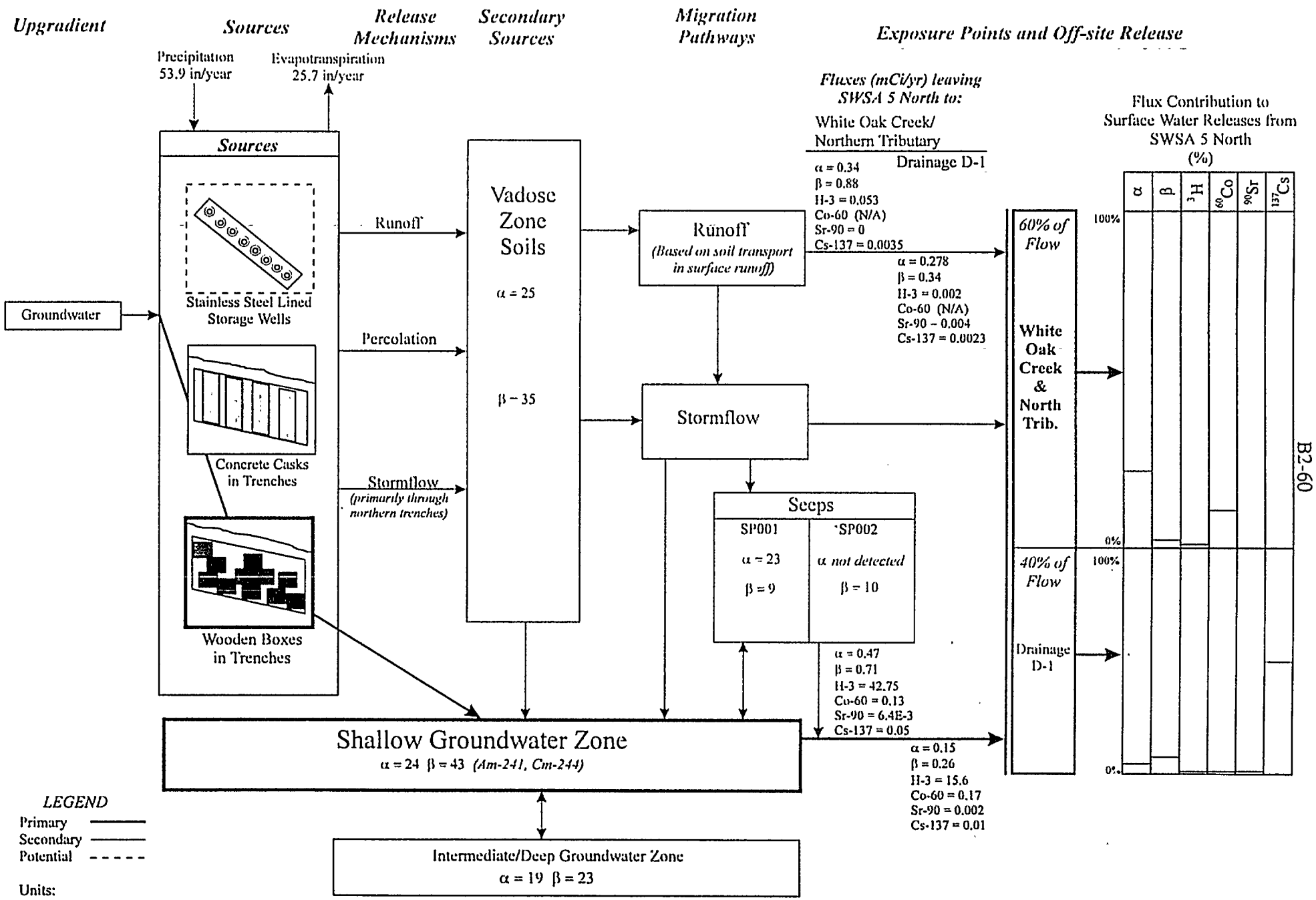


Fig. B2.3.25. SWSA 5 North area conceptual model.

B2.3.5 Fissile Storage Study Area

The 4.7-acre fissile storage study area is located in the northern portion of SWSA 5 South. Study area boundaries were drawn on the basis of a historical burial ground map. The area also extends to the approximate drainage divides for surface water to the east and south and to the inferred groundwater divide to the west. Figure B2.3.26 is a photograph of the area showing conditions as of November 1994.

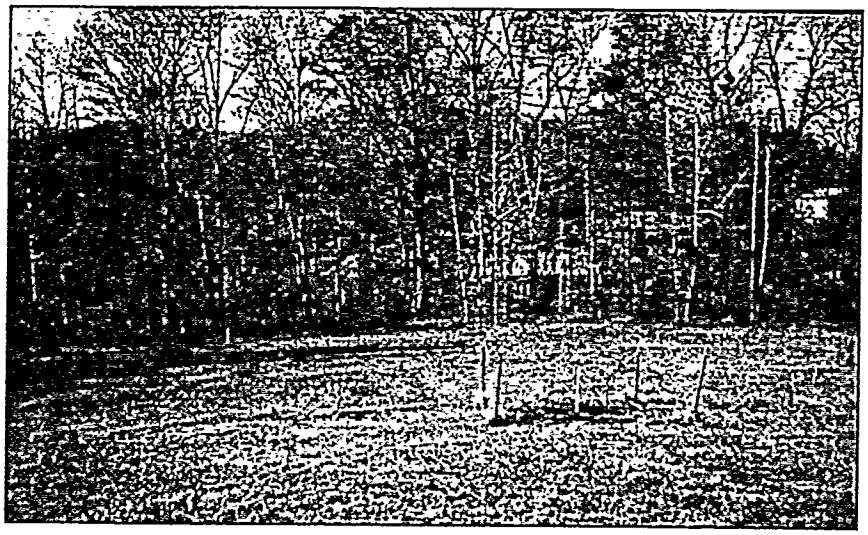


Fig. B2.3.26. Photograph of fissile storage study area.

Description and history

The fissile storage area consists mostly of an upland region bounded on the north by drainage D-1 and on the east and west by incised tributary valleys connected to D-1. Seeps have been identified in both of these small valleys, and during the wet season small tributaries flow into D-1. The buried wastes are mostly within a grass-covered area to the west/northwest of the WAG 5 access road. The open area ends at the top of the forested slopes leading downward to the drainages. Wastes have also been placed in the upper portion of each tributary valley; much of the waste has been buried, but some materials have been dumped onto the slopes.

The fissile storage area was used primarily for storage of fissile wastes, defined as wastes with greater than 1 g of fissionable material regardless of concentration or with a concentration greater than 1 g/ft^3 regardless of quantity. Table B2.3.15 summarizes the source characterization. Radionuclides in fissile waste consist mostly of ^{235}U but include ^{233}U, ^{239}Pu, and possibly other TRU isotopes (^{241}Am and ^{24X}Cm). The study area contains 2 types of contaminant sources: 3 waste trenches (36, 198, and 221) and 151 auger holes. Historic information on the fissile storage area indicates that it was part of a larger area set aside for disposal of higher-activity wastes (Cowser and Lomenick 1961). High-activity wastes were also buried in trenches and auger holes on the southern side of the WAG 5 access road, but it appears that most of the materials classified as fissile waste were disposed of to the north of the road. Designation of a separate fissile storage area apparently occurred around 1970 (based on the date of ORNL Drawing C-20923-EA-002-E).

Table B2.3.15. Fissile storage area source characterization matrix

Source	Area/ Dimensions	Waste Types & Contaminants of Concern	Disposal Methods and Packaging	Waste Volume	Estimated Inventory	Dates
151 Auger Holes	6 to 30-in. dia. 5 to 20-ft depth *[depth est. based on auger hole labels]*	**Fissile Waste** ^{235}U, ^{233}U *(based on available data)* May include ^{239}Pu and other transuranic isotopes	Wastes placed in unlined auger holes; some wastes containerized (drums); auger holes covered with soil, capped with concrete	50 m^3	Data for 23 auger holes show 2546.2 g of ^{235}U 1 auger hole has 26 g of ^{233}U in 1 auger hole *[no data for remaining holes]*	1971-1972
Trench 221	12x45x15 ft *(LxWxD)*	Same as above	Unknown; may be similar to T-198	115 m^3	Unknown	1972
Trench 198	10x50x15 ft *(LxWxD)*	Same as above	55-gal drums buried in unlined trenches; may have concrete cap	186 m^3 (83 drums)	>109.89 g ^{235}U *(Westinghouse shipment)*	1970-1971
Trench 36	200x120x10 ft *(LxWxD)*	Construction debris, equipment, possibly included sludge	Dumped into unlined trench; may have concrete cap in upper part	3,400 m^3	Unknown	1962-1965
Ravine Landfill Area	0.5 acres	Uncontaminated debris, trash & equipment from SWSA 3 and other sources; no data on contaminants in wastes	Wastes buried and dumped on hillside; large quantity of material remains visible at foot of landfill	Unknown	Unknown	1978-1979

Note: Waste volume estimates assume 50% of trench or auger hole volume is occupied by backfilled soil or void spaces

Trench 36, the first in the area (1962–1965), has also been categorized as a landfill and was used for disposal of construction debris, equipment, and other solid wastes; it also may have received sludge wastes, according to the Solid Waste Management Information Management System (SWIMS) data base. The placement of fissile wastes in this trench could not be documented. An impenetrable barrier was encountered at a depth of 0.5 to 1 ft during the boring of SB046 over trench 36 (several attempts were made over an area of several square meters). The barrier may be part of a concrete "cap" reported to have been placed over alpha-contaminated wastes during the early years of SWSA 5 operations (NAS 1976); conversely, it may have been debris dumped into the trench. If a cap is present, topography and vegetation suggest that it probably does not extend the full length of the trench. Trenches 198 and 221 were used in the early 1970s, probably solely for storage of fissile wastes. This conclusion is based on a set of records documenting the December 1971 disposal of 83 drums of "shop waste" from the Westinghouse Astronuclear Laboratory in Cheswick, Pennsylvania. Each 55-gal drum reportedly contained less than 5 g of ^{235}U, and the total quantity of ^{235}U disposed of in trench 198 from this shipment was 109.89 g.

Auger hole borings had 6- to 30-in. diameters and a maximum depth of 20 ft (Shoun 1987; Grizzard 1986). Wastes were placed in auger holes and covered with fill (typically 2 ft). This process was repeated to within 2 ft of the ground surface, when the hole was backfilled with concrete and tagged with an identification label. To avoid criticality, no more than 200 g of ^{235}U was placed in each hole unless prior authorization was given by the ORNL Criticality Committee. Identification labels found on nine auger holes used between March 1971 and June 1972 indicate that the amount of ^{235}U per hole ranges from 99.2 to 320.8 g; one of the holes had 26 g of ^{233}U. The total amount of fissile material disposed of in the nine holes was 1299.2 g. The only detailed information concerning the sources of the fissile wastes was derived from information concerning the disposal of 39 drums of material in a December 1971 shipment from the Westinghouse facility in Ohio. The shipment had a total of 537.33 g of ^{235}U and was placed in 15 auger holes; average fissile content per hole was approximately 35.8 g.

In the absence of additional data, it could not be determined whether the nine auger hole labels described the typical auger hole inventory or the assumed inventory associated with the Westinghouse shipment was more representative. Using the average per-hole inventory of 144 g based on the nine auger hole labels, the 151 auger holes could have as much as 21.8 kg of fissile material; using the value derived from the Westinghouse shipment (35.8 g/hole), an estimate of 5.4 kg of fissile material was obtained. It is likely, given the value and strategic importance of fissile material, that the total inventory in the 151 auger holes is the lower of these estimates; however, further evaluation of historical waste management data, including classified data, would be required to develop a more accurate estimate.

Another consideration is the method by which the fissile wastes were packaged. Evaluation of the disposal data for the Westinghouse shipment indicates that the wastes were taken out of the drums and dumped into the auger holes. (Disposal records for the waste identified the elevations between successive waste packages; since the difference in elevation was less than the diameter or height of the 55-gal drums in which the wastes were received, it was assumed that the waste packages inside the drums were placed in the holes rather than the entire drum.) Information concerning the types of packaging, if any, on the materials in the drums was not available. Assuming that the primary radiation hazard was alpha particles, the containers were probably much less durable than those for high level beta-gamma waste in other SWSA 5 auger holes. Capping the

holes with concrete may have slowed the degradation of the containers by minimizing direct infiltration, but some water is able to enter the holes and many of the containers have probably been breached.

An additional potential source area is the accumulation of buried and exposed waste in the drainage tributary west of the fissile waste auger holes and trenches. Information from the ORNL/ER Shared Data Initiative Distribution (SDID) indicates that this area received uncontaminated trash and debris after the official closing date (1973) of SWSA 5. Much of this waste was derived from the 1978–1979 cleanup of the aboveground wastes stored at SWSA 3. The landfill reportedly received some old vehicles as well. No information regarding the type and magnitude of contamination associated with these wastes was available.

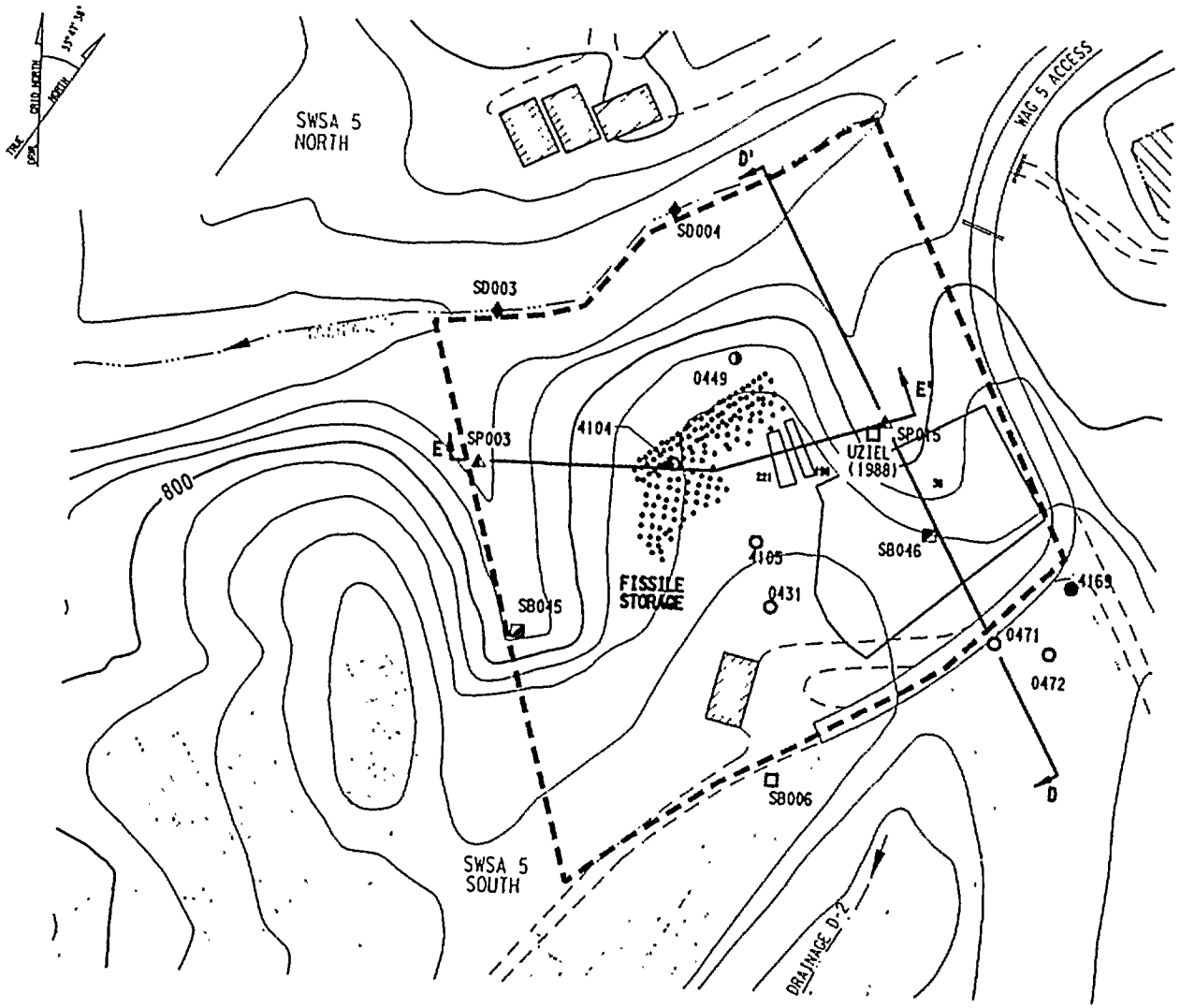
Previous investigations

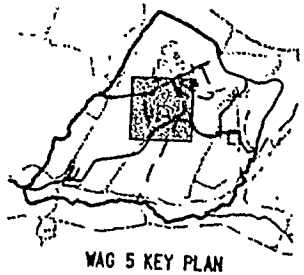
None of the earlier SWSA 5 studies or sampling activities specifically addressed the fissile storage study area. Uziel et al. (1989) did a surface radiological investigation of SWSA 5 South that identified elevated gamma exposure readings over trench 36 and around SP015. Three discrete areas with high gamma exposures were found in the upland portion of trench 36; the intensity of the gamma levels increased in the downslope direction toward SP015. Typical gamma exposure rates were between 80 and 650 mR/h. The open end of a steel pipe in the vicinity of SP015 had a gamma exposure rate of approximately 55,000 mR/h. The pipe (~3.5-in. dia) extended ~1 ft (vertically) out of the bank and contained standing water. The beta-to-gamma ratio at the side of the pipe was 240:1, indicating primarily beta contamination. A surface soil sample was taken at the base of the pipe.

RI sampling summary

Figure B2.3.27 shows the sampling locations in the study area and cross-section locations used in the hydrologic models. Results from an USRADS survey of SWSA 5 were used to select a high-exposure ("USRADS hot spot") soil sampling location (SB046) in the approximate center of trench 36 (Fig. B2.3.28) and a low/medium-exposure location (SB045) near seep SP003. Three surface soil samples were taken from SB045: a discrete sample from the staked USRADS location; an areal composite sample from several locations in the immediate vicinity of the stake; and a second discrete sample taken during the earthworm sampling event. Well 0449, downgradient of the auger holes and trenches, was dry during the low base (dry season) sampling event but was sampled during the wet season (high base) event; however, there was only enough water in the well to conduct CSL screening analyses. Well 0472, upgradient (southeast) of trench 36, was sampled during the CSL screening round in 1992 and during both wet and dry season sampling events in 1993. Grab samples were taken from shallow stormflow piezometers 4104 and 4105 during storms in December 1993, and three grab samples were taken from 4104 during a storm in March 1994.

Surface water samples were collected from seeps SP015 and SP003, located in the drainage tributaries to the east and west, respectively, of the fissile waste auger holes and trenches. During dry- and wet-season baseflow conditions and during several storm events, sampling was also conducted at downgradient surface water station SW001 on drainage D-1.





WAG 5 KEY PLAN

LEGEND

- APPROXIMATE STUDY AREA BOUNDARY
- BUILDING
- PAVED ROAD
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- WATER BODY
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- 0472 — GROUNDWATER SAMPLING LOCATION W/NO. (REGOLITH <50')
- 0449 — GROUNDWATER SAMPLING LOCATION W/NO. (BEDROCK <100')
- SD004 — SEDIMENT SAMPLING LOCATION W/NO.
- SP003 — SEEP LOCATION W/NO.
- SB006 — VERTICAL SOIL SAMPLING LOCATION W/NO.
- SB045 — SOIL SAMPLING LOCATION W/NO. (LOW TO MEDIUM EXPOSURE)
- SB043 — SOIL SAMPLING LOCATION W/NO. (HIGH EXPOSURE)
- UZIEL (1988) — SOIL SAMPLE TAKEN BY UZIEL et al (1988)
- AUGER HOLES
- TRENCHES W/NO.

SCALE

0 50 100 FEET

0 10 20 30 METERS

Drainage Group: White Oak Creek
Study Area: Fissile storage area
Sources: Auger holes and Trenches

Fig. B2.3.27. Fissile storage area plan view.

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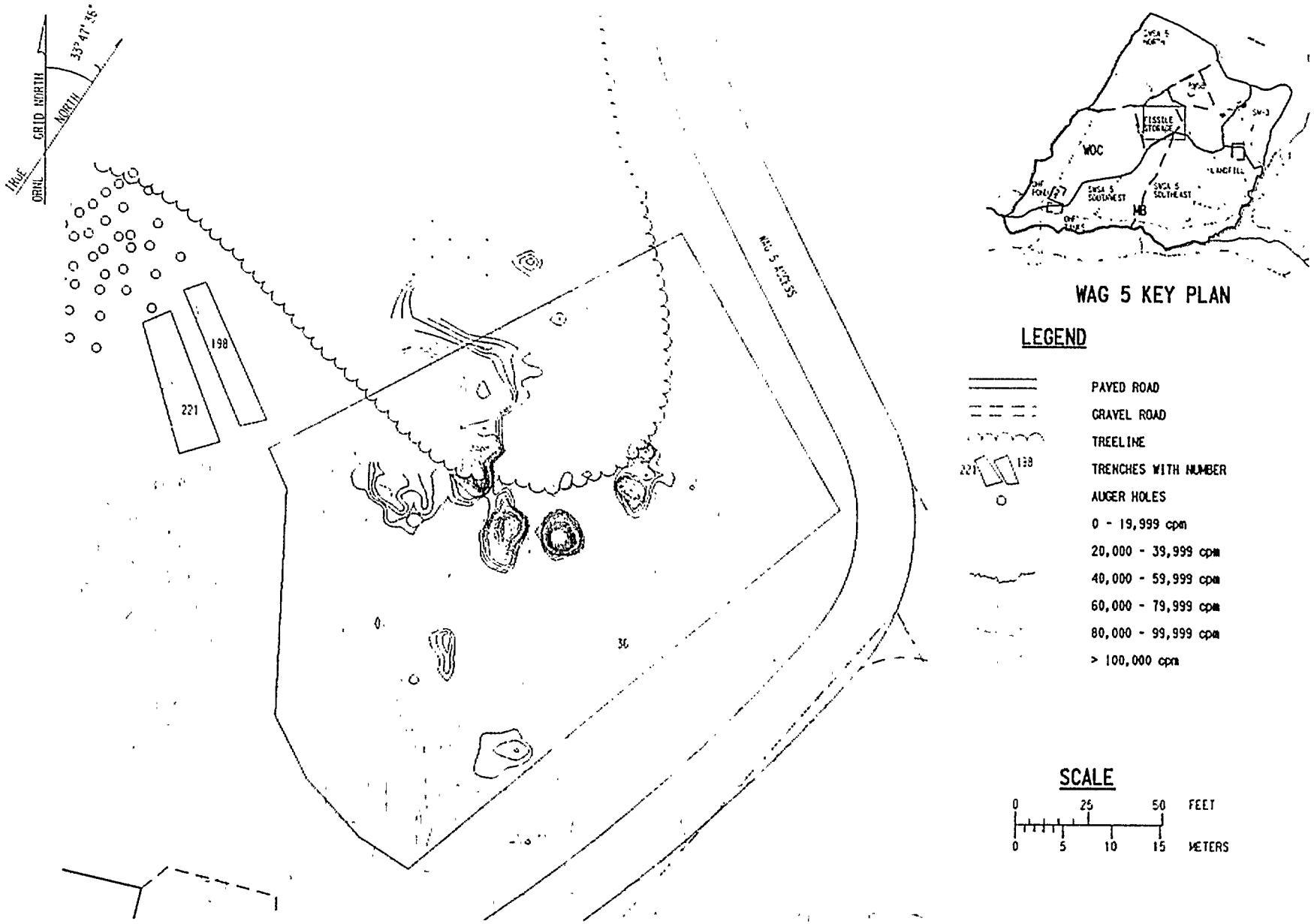


Fig. B2.3.28. USRADS results for fissile storage area (trench 36) cpm contours.

Hydrologic model

Figures B2.3.29 and B2.3.30 depict the hydrologic model based on different cross-sectional views through the fissile storage area. Surface and subsurface flowpaths from the fissile waste trenches and auger holes trend in a semiradial direction toward discharge points in the adjoining tributary valleys and drainage D-1. The upgradient boundary is more or less defined by the White Oak Creek and Melton Branch drainage divides. Runoff is mostly limited to areas within the defined fissile storage study area. The study area has an active stormflow zone, based on water level monitoring and sampling conducted in three shallow stormflow piezometers along a transect through the auger hole area. Some of the stormflow may originate in upgradient areas as far as the WAG 5 access road. Groundwater from upgradient areas includes a small but potentially significant contribution from the northwestern tip of the undefined trench area (discussed in Sect. B2.4.5).

Evidence of shallow groundwater circulation and discharge in the area included seeps SP015 and SP003, located in the tributary valleys to the northeast and southwest, respectively, of the fissile waste trenches and auger holes. Both seeps are active mostly during the wet season, and it is likely that they discharge both stormflow and shallow groundwater.

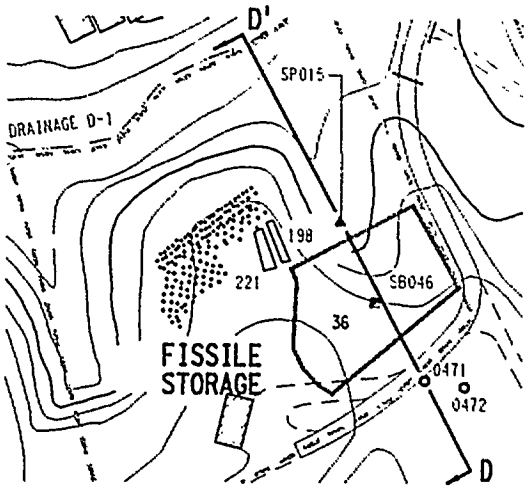
Table B2.3.16 summarizes the annual water balance (determined based on the HSPF modeling effort described in Appendix B1) for the three pathways in the fissile storage study area. Although the flux of water is dominated by subsurface flow—shallow groundwater and interflow (stormflow)—all three flowpaths are important. Surface runoff is probably lower than shown because the model was calibrated using D-1 flow data, influenced by the relatively extensive impervious areas in SWSA 5 North (i.e., areas covered by buildings, roads, or pavement).

Table B2.3.16. Annual water balance summary for the fissile storage area

	PERCENT OF FLUX (%)	ANNUAL FLUX (M^3/YEAR)
Surface Runoff	27	3,780
Interflow	31	4,160
Groundwater Flow	42	5,560
Total	100	13,500

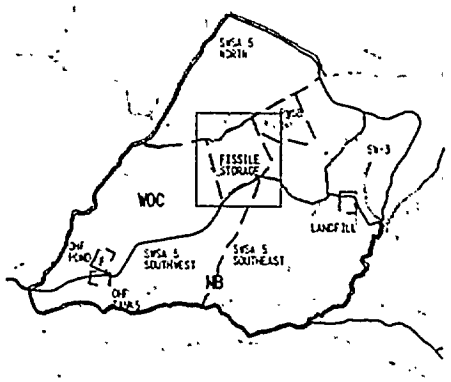
The cross sections show the role of groundwater in the potential release of contaminants from the buried wastes in the fissile storage area. Section D-D' (Fig. B2.3.29) shows that the downslope portions of trench 36 were inundated throughout 1993. Wastes in this portion of the trench are apparently inundated year-round, allowing shallow groundwater to mingle with the waste materials before discharging at SP015 (40 ft downgradient of the estimated trench limits) or farther downgradient in the tributary valley or drainage D-1. Groundwater flowing through trench 36 includes water that originated in the undefined trench area. If portions of the trench have a concrete cap, infiltration would be reduced but groundwater flow into the trench would not be affected.

Section E-E' (Fig. B2.3.30) shows a projected water table that (based on 1993 water level data) is 5 to 10 ft below the auger holes and trenches 198 and 221. It is highly unlikely that the water table ever rises and inundates the fissile wastes in these trenches or auger holes (the upland topography and depths to groundwater at this location was apparently one reason it was selected for storage of

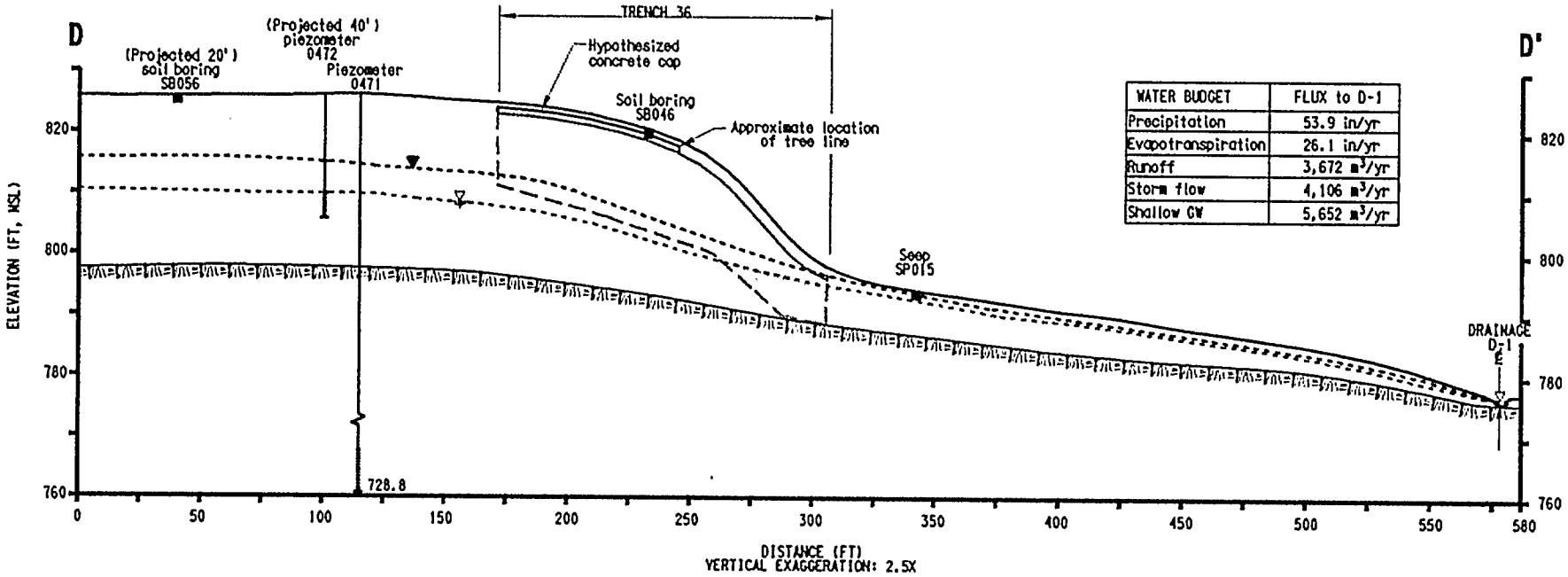


LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 36 APPROXIMATE TRENCH LIMIT W/NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX to D-1
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	3,672 m^3/yr
Storm flow	4,106 m^3/yr
Shallow GW	5,652 m^3/yr

Fig. B2.3.29. Hydrologic model for the fissile storage area (Section D-D').

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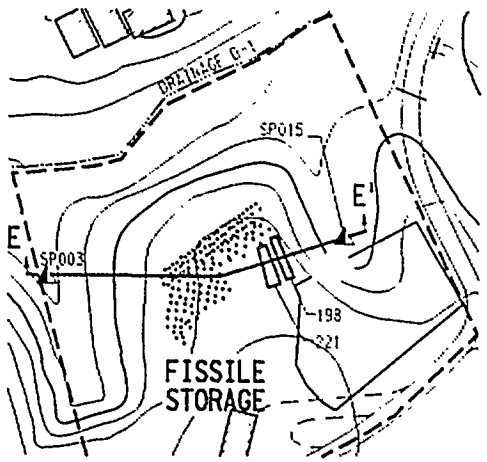
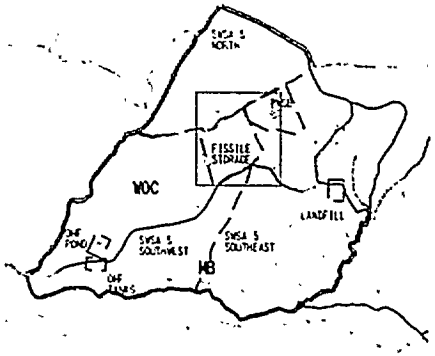
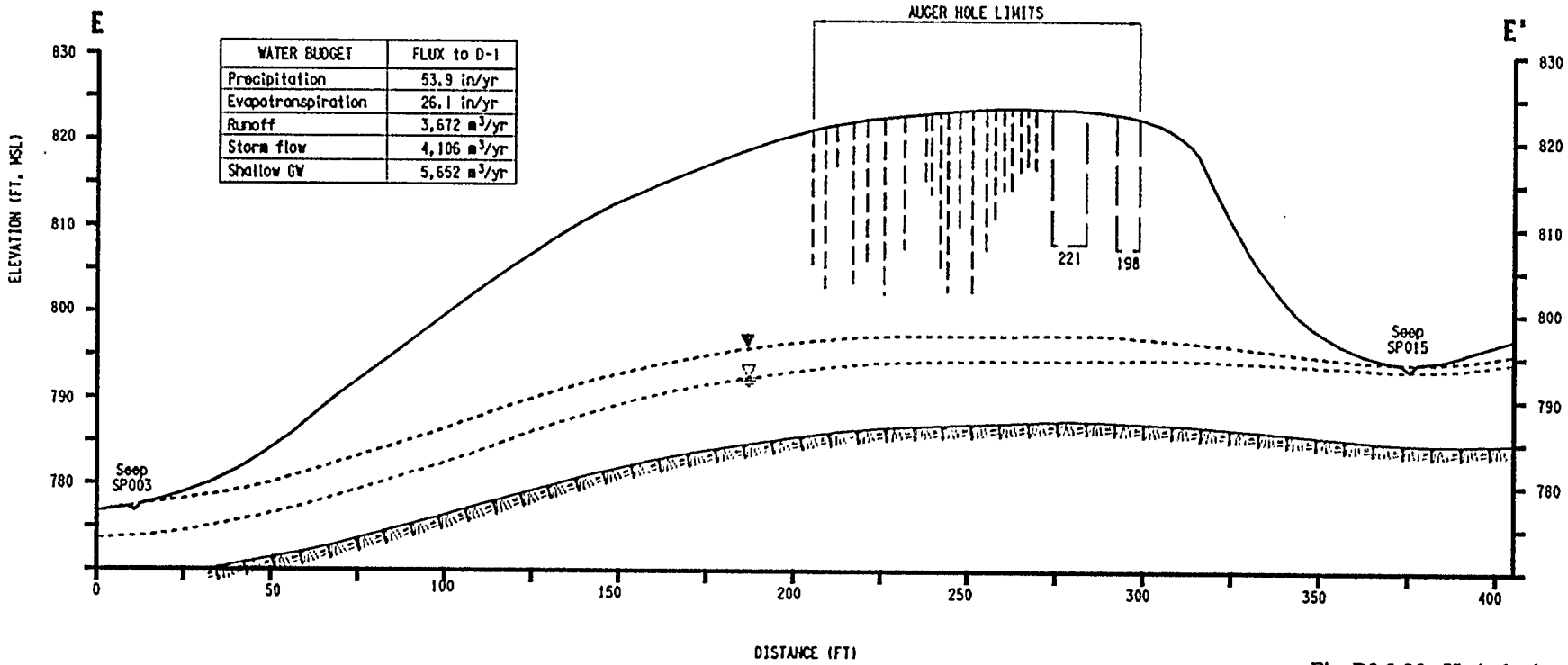


LEGEND

- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- APPROXIMATE TRENCH LIMITS W/NO.
- APPROXIMATE LOCATION/SIZE OF AUGER HOLES (MAX DEPTH OF 20', TYP; 3'-17' DEPTH)



WAG 5 KEY PLAN



WATER BUDGET	FLUX to D-1
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	3,672 m^3/yr
Storm flow	4,106 m^3/yr
Shallow GW	5,652 m^3/yr

Fig. B2.3.30. Hydrologic model for the fissile storage area (Section E-E').

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fissile wastes). The active stormflow zone in the area may introduce significant quantities of water into the auger holes and trenches because of the higher vertical permeabilities in the backfill and waste materials in the holes and trenches. Lateral seepage into the auger holes and trenches would also be expected from infiltrating waters percolating through the adjacent vadose zone. A period of prolonged or high-intensity precipitation could produce perched water tables (bathtubbing) in either trenches or auger holes; however, there was no direct evidence that this had occurred. Recharging waters from the stormflow zone and lateral seepage into the holes may be the most significant release mechanism for the fissile wastes in the auger holes. Infiltration and vertical percolation of precipitation through the wastes is probably a more important release mechanism for the trenches.

Nature and extent of contamination

Table B2.3.17 summarizes analytes of concern detected in the fissile storage area by medium; Table B2.3.18 presents sample-specific results for RI and historical data. Based on the available waste disposal records, the contaminants most likely to be released from the auger holes and trenches are ^{235}U and ^{233}U. Both were detected at SP015, indicating that a release of contamination from the area has occurred. The following paragraphs summarize the analytical findings and present interpretations regarding probable sources, release mechanisms, and contaminant migration.

Table B2.3.17. Contaminants of concern detected in the fissile storage area

CONTAMINANT	SOIL	GW	SED	SEEPS
^{241}Am	X			
^{60}Co	X		X	
^{137}Cs	X			
^{228}Ra		X		X
^{90}Sr	X	X		X
^{99}Tc				X
^{234}Th				X
Tritium	X	X	X	X
$^{233/234}U$				X
^{235}U				X
^{238}U	X			
Mercury	X			X

Seep sampling results showing ^{235}U in SP015 (54 pCi/L in a filtered sample) were the principal evidence that a release from the fissile waste trenches and/or auger holes has occurred. Uranium-235 was the major component of the fissile waste disposed of in the area and was determined to be the most reliable indicator of a fissile waste source. Uranium-235 was also detected in upgradient well 0472, although at much lower concentrations (0.99 pCi/L in a filtered sample). As noted, upgradient groundwater is derived from the undefined trench area, which historical documentation describes as being used for disposal of alpha-contaminated wastes. This area may be contributing some of the ^{235}U contamination detected in SP015, but it is unlikely that all of the contamination is derived from this area, given the proximity of the seep to the fissile wastes holes and the contrast in concentrations

Table B2.3.18. Analytical data summary for selected radionuclides in the fissile storage area

Sample Type	ID	Date	Ints (ft)	(α) Gross Alpha	(β) Gross Beta	(β) Tritium	(β) C-14	(β-γ) Co-60	(β) Sr-90	(β-γ) Cs-137	(α) U-233/234	(β) Th-234	(α) U-235	(α) U-238
SOIL (pCi/g)														
	Background Reference			9.9	22	0.084		0.02	1.94	1.4	2			2.4
	SB046 (d)	3/11/94	0-0.6	24	380	0.35	-	180	120	36	7.3		-	7
	SB046 (d)	4/25/94	0-0.6	22.4	1100	2.6		6.07	44.2	3900				
	SB046 (c)	3/11/94	0-0.6	5.3	111.6	4.6	-			17.2				
	SB045	3/9/93	0-2	6.0	75.4	0.75	-	0.604		22.7				
	Historical Sample													
(a)	Uziel et al	3/88		140	1100			5.9		650				
SEDIMENT (pCi/g)														
	Background Reference			44	54	100			1.34	0.82	2.6	2.2		2
	SD004	12/2/93	0-0.3	43	48	2340	-	0.37	0.74	0.96	5.9	11	0.18	10
	SD003	6/28/93	0-0.3	35.5	90.8	19.3	-	0.17	0.61	2.1	9.4		0.38	12.7

				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
GROUNDWATER (pCi/L)																									
	Background Reference			5.2	3.2	16	7.4	2400	1080			44	9.2	10.4	3.6	12.4	5.4								
	0472	6/18/92	15-20	175	338	1104	1168	2.5E+6	2.5E+6	-	-				852										
upgrd	0472	4/26/93	15-20	40	8.3	1100	850	1.5E+6	1.5E+6	130	-			440	360	-	-	8.4	-			-	1	-	-
	0472	10/20/93	15-20	39.4	23	889	943	1.1E+6	1.0E+6	482	387			322	417	-	-	6.38	2.43	173				5.36	2
	4105	12/2/93	1-2	57.5		134		13900		-															
	4104	12/2/93	1-2	41.8		154		4530		-															
	4104	4/15/94	1-2	10.8		65.9		555		-				66.6		354									
dwngrd	0449	4/15/93	30-40	256.6		1321		7220		-						174									
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference			9		8		1620								40				520				2	
	SP015	8/26/92		304	15.7	484	795.5	1.1E+6	1.0E+6	29900	28500				105										
	SP015	4/27/93		7100	4200	4000	4400	3.1E+5	2.5E+5	-	-			240	63	-	-	1100	1100	1100	1600	81	54	1900	2000
	SP003	8/18/92													111										
	SP003	5/6/93		14.6	-	167.2	125.8	1.5E+5	1.5E+5	873				43.3	33	-	-	4.2	5.5			-	-	2.7	3.1
	Historical Samples																								
(b)	SP003	3/2/92			15		196		4.3E+5				-		115		-								
(b)	SP003	9/17/92			3.7		138		7.1E+5				-		97		-								
Detected in Downgradient SW001?								X		X				X		X		X		na		X		X	

Notes: 1) Historical Samples:
(a) Uziel et al (1988) took a soil sample near SP015
(b) SP003 samples for 3-92 and 9-92 from WAG 2 Phase I RI report (ORNL, 1993)
2) SB046 had a composite (c) and discrete (d) sample from the USRADS sampling and a discrete (d) sample from the earthworm sampling.
3) Blanks indicate analyte not analyzed for; bold indicates detected over background reference (2x mean background)
4) Abreviations: U/F = Unfiltered/Filtered, - = not detected, (α, β, γ) = alpha, beta, gamma emitter, upgrd = upgradient, dwngrd = downgradient

(2 orders of magnitude) between the seep and well 0472. The seep is at the foot of trench 36, which may be the primary source of the ^{235}U contamination; however, the seep is also hydraulically downgradient of (and along geologic strike with) the fissile waste trenches and auger holes.

Baseflow and storm event sampling at downgradient surface water station SW001 also identified ^{235}U (0.68 to 1.7 pCi/L), indicating a small but measurable flux of ^{235}U in D-1. Given the low flow observed at SP015 (<1 gpm), not all of this flux can be attributed to discharge from SP015. Instead, a combination of seep discharge and the discharge of ^{235}U-contaminated groundwater into the ephemeral tributary below SP015 or directly into D-1 is apparently occurring. The high gross alpha detected in well 0449 (there was insufficient volume to complete isotopic analyses) may be related to ^{235}U contamination that is moving northward toward D-1 rather than eastward toward SP015.

Other contaminants detected in groundwater and seeps are members of the uranium decay series (i.e., ^{238}U, ^{234}Th, ^{234}U), ^{228}Ra, ^{90}Sr, ^{99}Tc, and ^{3}H. The uranium decay series elements were detected at both seeps, upgradient well 0472, and downgradient surface water station SW001. Relatively high concentrations of ^{238}U and $^{233/234}U$ (assumed to be ^{234}U given the similarities in concentrations with ^{238}U) were detected in SP015, indicating either a source of uranium contamination in trench 36 or other source units in the fissile storage area. Tritium, ^{90}Sr, and ^{228}Ra concentrations were also elevated in upgradient well 0472 and seeps SP015 and SP003, indicating widespread contamination in this portion of SWSA 5 South. The fissile storage area contributes to the net flux of ^{3}H and ^{90}Sr in D-1, but it is not clear how much of this contamination originates in upgradient sources.

Figure B2.3.31 compares selected results for upgradient well 0472 and seep SP015. The chart shows that some contaminants (e.g., ^{90}Sr, ^{3}H) detected in SP015 probably originated in upgradient areas, indicative of more widespread groundwater contamination, while others, particularly the uranium isotopes, are probably derived from a fissile storage area source. Given the complexities associated with groundwater transport in the water table interval (anisotropic flow patterns and preferential flow pathways), these interpretations must be qualified on the basis of the available data.

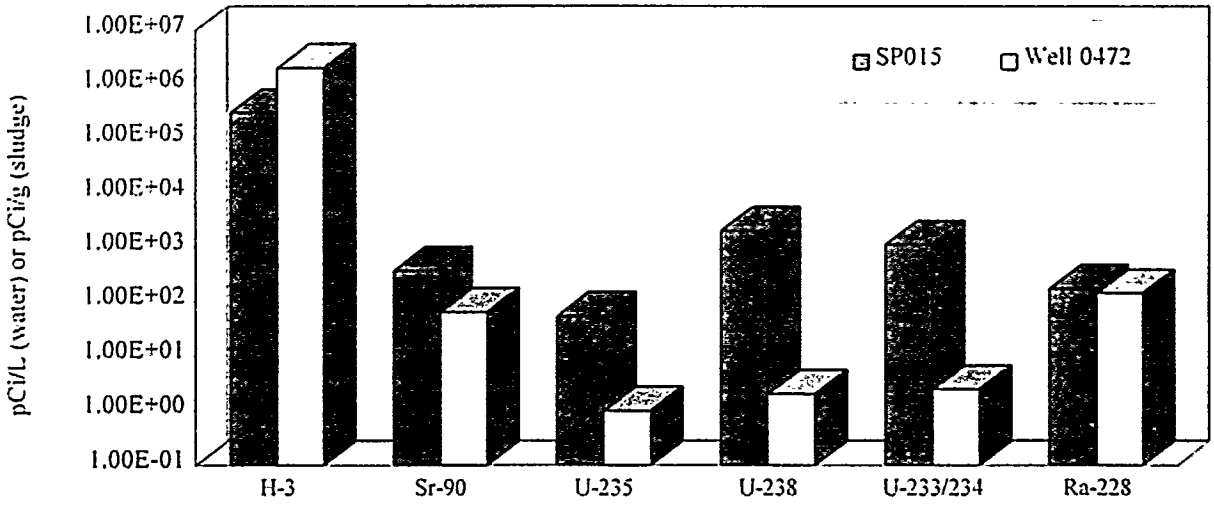


Fig. B2.3.31. Comparison of selected results from seep SP015 and well 0472.

Stormflow piezometer sampling identified ^{90}Sr and ^{137}Cs in concentrations greater than background reference levels, indicating a potentially important zone for contaminant transport in the fissile storage study area. The contamination moving through the stormflow zone is likely related to that detected in the USRADS hot spot (soil boring SB045) over trench 36. Analytical data from SB045 showed relatively high concentrations of ^{60}Co (180 pCi/g), ^{90}Sr (120 pCi/g), and ^{137}Cs (3900 pCi/g). In contrast, contaminant levels in SB046 were generally within background ranges. Combined with the data from nearby seep SP003, the soil sampling results from SB046 indicate that the "ravine" landfill is not likely a significant source of contamination in this study area or the WAG 5 White Oak Creek drainage basin.

A sample from SB046 also contained mercury in a concentration of 4.3 mg/kg. None of the other soil samples from the fissile storage area had mercury, and the concentration of 4.3 mg/kg was the highest detected in WAG 5 soils (most other detections were below 1 mg/kg). Mercury was also detected in upgradient well 0472 (0.32 mg/L unfiltered) and in SP015 (0.16 mg/L filtered), but was not detected in SW001, indicating that the total contribution of mercury to D-1 (and thus White Oak Creek) is negligible.

Conceptual model summary

A summary of the site conceptual model for the fissile storage area is presented in Table B2.3.19 and illustrated in Fig. B2.3.32. The fissile storage conceptual model can be summarized as follows. Source material containing fissile (^{235}U) and other, mostly undefined, radiological contaminants was buried in 151 unlined auger holes and 3 disposal trenches, including a large trench that may also have received sludges. In addition, a small landfill was created on an adjacent hillside. Most of the fissile wastes were disposed of in the final years of SWSA 5 operation (1970–1973). Uranium-235 and other radionuclides have been released from the buried wastes and detected in downgradient seeps and surface water.

Table B2.3.19. Conceptual model summary for fissile storage area

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
151 auger holes (active source)	• Interception of stormflow & lateral seepage into holes from percolating infiltration	• Shallow groundwater discharging to D-1 tributaries & seeps or directly into D-1	*On site:* • Seep discharge areas *Off site:* • Downstream surface water and sediment
3 Trenches [active (primary) source]	• Inundation of low-lying trench wastes *(T-36)* • Infiltration/percolation • Stormflow recharging trenches	• Shallow groundwater and stormflow discharging to D-1 tributaries & seeps or directly into D-1	*On site:* • Contaminated soil over trenches • Seep discharge areas *Off site same as above*
0.5-acre ravine landfill (active source)	• Infiltration/percolation through wastes • Stormflow • Inundation of lower portions of landfill	• Shallow groundwater and stormflow discharging to D-1 tributaries & seeps or directly into D-1	*On site:* • Contaminated soils in landfill area • Seep discharge areas *Off site same as above*

Groundwater data indicate that upgradient sources in the undefined trench area of SWSA 5 South are also contributing contamination detected in the fissile storage study area. The primary release mechanisms include inundation of trench wastes in trench 36 and percolation of infiltration

liquids through buried wastes in upland areas. An active stormflow zone may also be directing water into trenches and auger holes in the upland areas. Contaminants released to groundwater are transported short distances to discharge points in adjacent tributary valleys and drainage D-1. Discharges from the study area result in measurable fluxes of ^{235}U in D-1 and contribute to the overall ^{90}Sr and ^{3}H flux in D-1, but most of this contamination reflects upgradient contributions. The overall contaminant flux from the fissile storage area is not significant compared to the total WAG 5 contribution to White Oak Creek.

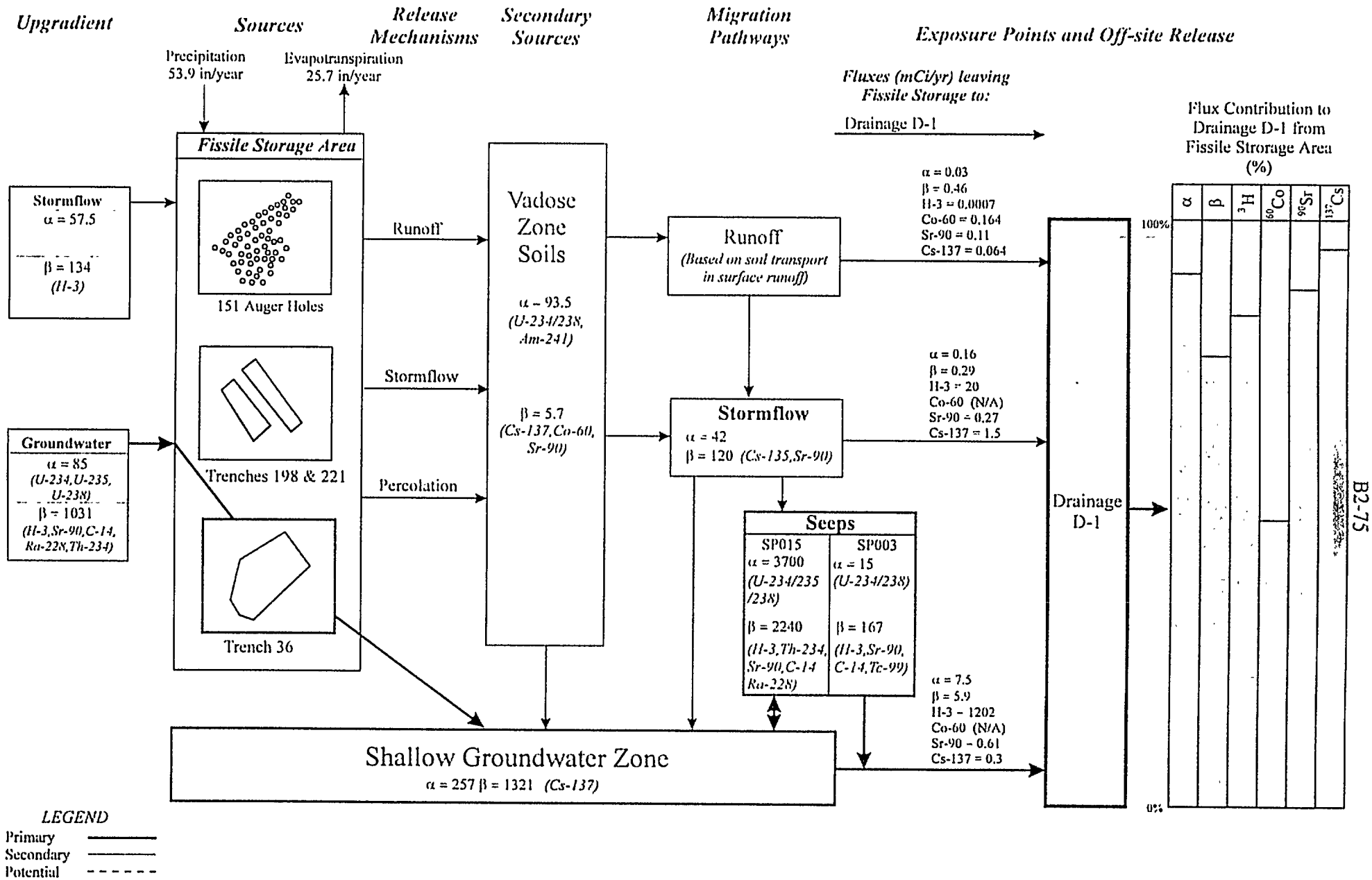


Fig. B2.3.32. Fissile storage area conceptual model

B2.3.6 SWSA 5 White Oak Creek Study Area

SWSA 5 South was divided into smaller sections on the basis of surface water drainage and groundwater flow divides. Most of SWSA 5 South drains into Melton Branch, but the western portion lies within the WAG 5 White Oak Creek drainage basin. This area (Fig. B2.1.1), designated the SWSA 5 White Oak Creek study area, is described below. Figure B2.3.33 is a photograph showing the conditions as of November 1994.

Description and history

The SWSA 5 White Oak Creek study area encompasses 22 acres in the western portion of SWSA 5 South. Approximately 5 acres were used for waste disposal in trenches, auger holes, and a small valley-fill-type dump area. This acreage lies in the upland portion of the study area that is maintained (through regular mowing) as cleared, grass-covered slopes. Most of the study area was not used for burial of wastes and remains forested; much of this area is within the White Oak Creek floodplain or associated with D-1 or other (unnamed) drainage swales. The lower (western) portions of the dump area evidently were not mowed regularly and have reverted to forest.

Fig. B2.3.33. Photo of SWSA 5 White Oak Creek study area looking northeast at upper trenches.

Available burial ground records indicate that wastes were disposed of in this portion of SWSA 5 between 1962 and 1973. The earliest trench (37) excavated in the area was reportedly used in 1962 for disposal of acid and sludges (ORNL Dwg E-52834, Rev. 1). Waste disposal in the area continued through the end of routine burial operations in SWSA 5 in 1973, with the bulk of the wastes being placed in this area after 1969. The first auger holes in the area, 53–58, were drilled and filled with waste in 1965. Placement of waste in the dump area began in 1966. Table B2.3.20 is a source characterization matrix that describes the waste types, contaminants of concern, disposal methods, and volume data for the SWSA 5 White Oak Creek study area.

Table B2.3.20. SWSA 5 White Oak Creek source characterization matrix

Source Description	Area/ Dimensions	Waste Types & Contaminants of Concern	Disposal Methods and Packaging	Waste Volume	Inventory	Waste Placement Dates
110 auger holes 66 holes west of road 44 holes east of road (some below road)	1-3 ft diameter 15-20-ft depth	Organic wastes-- solvents (Amsco, 2-ethyl hexanone), misc. chemicals; ^{3}H, ^{14}C, fission products, U/Th, ^{235}U; equipment & piping, misc. debris; historic data indicate auger holes used only for high-level (β-γ) or fissile (^{235}U) wastes	Wastes placed in unlined auger holes; some in metal/wood boxes, plastic containers; drums (incl. stainless steel); possible organic liquids; holes w/high β-γ and/or fissile wastes may have concrete caps	21 m^3 *[assuming avg dia. of 1 ft, avg depth of 17.5 ft, w/ void space of 50%]*	No inventory data available. Holes used for fissile waste had limit of 200 g ^{235}U per hole	1965-1973 *(based on available data)*
12 trenches 1 acid trench *(37)* 2 organic trenches *(59 & 78)* 2 high activity trenches *(180, 196)* 2 TRU trenches *(182, 184)* 3 low activity trenches *(202, 210, 217)* 2 misc. trenches *(224, 225)*	*Average*: 50x10x15 ft *[L x W x D]* *Range*: L: 35 to 190-ft W: 10 to 18-ft D: no data *[assumed 15 ft nominal depth]*	Solid low-level waste & debris: paper, glassware, scrap metal, filters, equip., depleted U, pumps/piping, furniture, etc. w/ mixed fission products, U/Th, ^{3}H, ^{15X}Eu, ^{137}Cs, ^{90}Sr, TRU; also: organic solvents in metal/plastic containers & drums, contam. w/ U/Th, fission products, ^{3}H; TRU wastes (^{238}Pu, ^{244}Cm, ^{24x}Am) and sludge (T-37 only)	Loose debris, dumpster contents, wooden/metal boxes, 55-gal metal & st-st drums, glass & plastic jugs, metal cans, etc. -- dumped into trench & covered with soil TRU waste in T-182 in 6-in. concrete cask	1,300 m^3 *[assuming avg trench dimensions & void space of 50%]*	No inventory data available. Activity probably dominated by ^{90}Sr and other fission product, U/Th decay series elements; TRU radionuclides [T-182 & T-184]	1962- 1973 *(based on available data)*
Dump Area	Actual Area: 35,860 ft^2 max. L = 240 ft W = 170 ft *[Assumed 15 ft nominal depth]*	Contaminated scrap material (steel tanks, scrap metal, equipment); contaminated soil w/ ^{137}Cs and ^{90}Sr	Waste materials dumped into excavation and covered with soil; small amt of surface debris remains	15,200 m^3 (total volume of fill area); 4600 m^3 of contam. soil	No inventory data available. Soil contamination levels (based on 1 sample) were 2300 pCi/g ^{137}Cs and 1900 pCi/g ^{90}Sr	1966-1970
TRU storage vaults 8 lined auger holes *(No. 96-103)*	20-ft deep 3 ft dia. *[assumed--based on SWSA 5 N wells]*	RH-TRU or other high-level (β-γ) waste. No specific data available	Stainless steel liner inside concrete collar; waste packages assumed to be stainless steel also	16 m^3 *[based on maximum hole dimension]*	No inventory data available. If fissile mat's, <200 g per hole	pre-1964

Trenches. The area contains 12 trenches representing 4 waste trench categories (ORNL/SDID 1994). Nine of the trenches were filled between July 1970 and July 1973. In addition to the acid/sludge trench identified above, there are two high-activity trenches, two organic trenches, three low-activity trenches, two TRU trenches, and two trenches that were not classified. Several of the trenches reportedly received only waste that was generated by ORNL, but the available data neither account for all waste materials placed in the trenches nor include any information concerning off-site sources (e.g., wastes from Y-12 or other users of the AEC Southern Regional Burial Ground).

Most of the wastes placed in the SWSA 5 White Oak Creek trenches consist of general radiological waste, variously classified as routine or low-level solid waste materials contaminated with mixed fission products, uranium-thorium decay series radionuclides, and transuranics. Materials apparently classified as TRU waste were placed in trenches 182 and 184. These trenches also contain low-level waste materials, and there is no indication that the wastes were segregated. Two of the trenches contain hot cell wastes that may have had relatively high levels of contamination. ORNL/SDID identified two trenches used for disposal of organic wastes, but the waste form and the magnitude of the radiological contamination associated with the organics is not known. Waste disposal practices were similar to those used elsewhere in SWSA 5: contaminated materials or containers holding contaminated materials (e.g., drums, boxes, cans) were dumped directly into the trenches, which were then backfilled with the soil excavated to make the trench.

Auger holes. SWSA 5 White Oak Creek study area has 110 auger holes used for waste disposal. Disposal records found for 24 of the holes (ORNL/SDID 1994) show that organic wastes contaminated with U/Th radionuclides, fission products, ^{14}C, and ^{3}H were disposed of in at least 22 of these holes. No description of the organic materials beyond "solvents, 2-ethyl Hexanol, Amsco (tributyl phosphate), and chemicals" was available; most of these wastes originated in the Building 4500 complex at ORNL. Most of the auger holes in this study area were drilled and filled with waste between 1970 and 1973.

Historical data (Coobs and Gissel 1986) indicate that auger holes were used for disposal of high-activity beta-gamma waste and fissile waste (>1 g/ft^3 of ^{235}U); there is no documentation concerning organic wastes. Study-area-specific data were not available, but auger hole diameters typically ranged from 1 to 3 ft; depths, depending on site-specific conditions, were 15 to 20 ft. The standard practice was to space the holes a minimum of 3 ft from edge to edge to minimize criticality concerns. Auger holes with high-level and fissile wastes were closed by backfilling with native soil to within approximately 2 ft of ground surface, adding 6 to 8 in. of concrete, and then completing the backfill with soil.

Dump area. The dump area was reportedly an excavated pit dug to 2 ft above the groundwater table (Lasher 1987). Historical data indicate that contaminated soil and scrap material from the White Wing Road Storage Area (WAG 11) were buried here (Grizzard 1986; Boegly and Moore 1988). The contaminated scrap material was brought to SWSA 5 between 1966 and 1970. No inventory of scrap material was found, but a list of material stored at WAG 11 included steel tanks, dump trucks, earth-moving equipment, glass-lined tanks, and assorted steel and aluminum material. In October 1970, about 6000 yd^3 of contaminated soil from the southern portion of WAG 11 (i.e., that portion used for storage of ORNL wastes) were disposed of in the dump area. A sample of the excavated soil had 2300 pCi/g of ^{137}Cs and 1900 pCi/g of ^{90}Sr. A more detailed inventory for the wastes was not available.

Previous investigations

Little work has been done that specifically focuses on the SWSA 5 White Oak Creek study area. Duguid (1975) sampled several wells and two seeps along the edge of the White Oak Creek floodplain (Fig. B2.3.34), downgradient of the dump area, trenches, and auger holes. Samples analyzed for ^{90}Sr showed nondetectable levels of contamination, which indicated either that (1) ^{90}Sr disposed of in the upgradient trenches had not yet migrated to the discharge areas or (2) the seeps sampled were not representative of all groundwater discharging from the area. Most of the wastes in SWSA 5 White Oak Creek were buried between 1970 and 1973; Duguid (1975) sampled the seeps in 1973, only a short time later. Uziel et al. (1989) performed a surface radiological investigation of SWSA 5 South that included the White Oak Creek drainage area. This survey identified elevated surface gamma exposure rates between 80 and 20,000 μR/h over the western end of the dump area and discrete "hot spots" with gamma rates between 80 and 1000 μR/h (background was 13 μR/h).

RI sampling summary

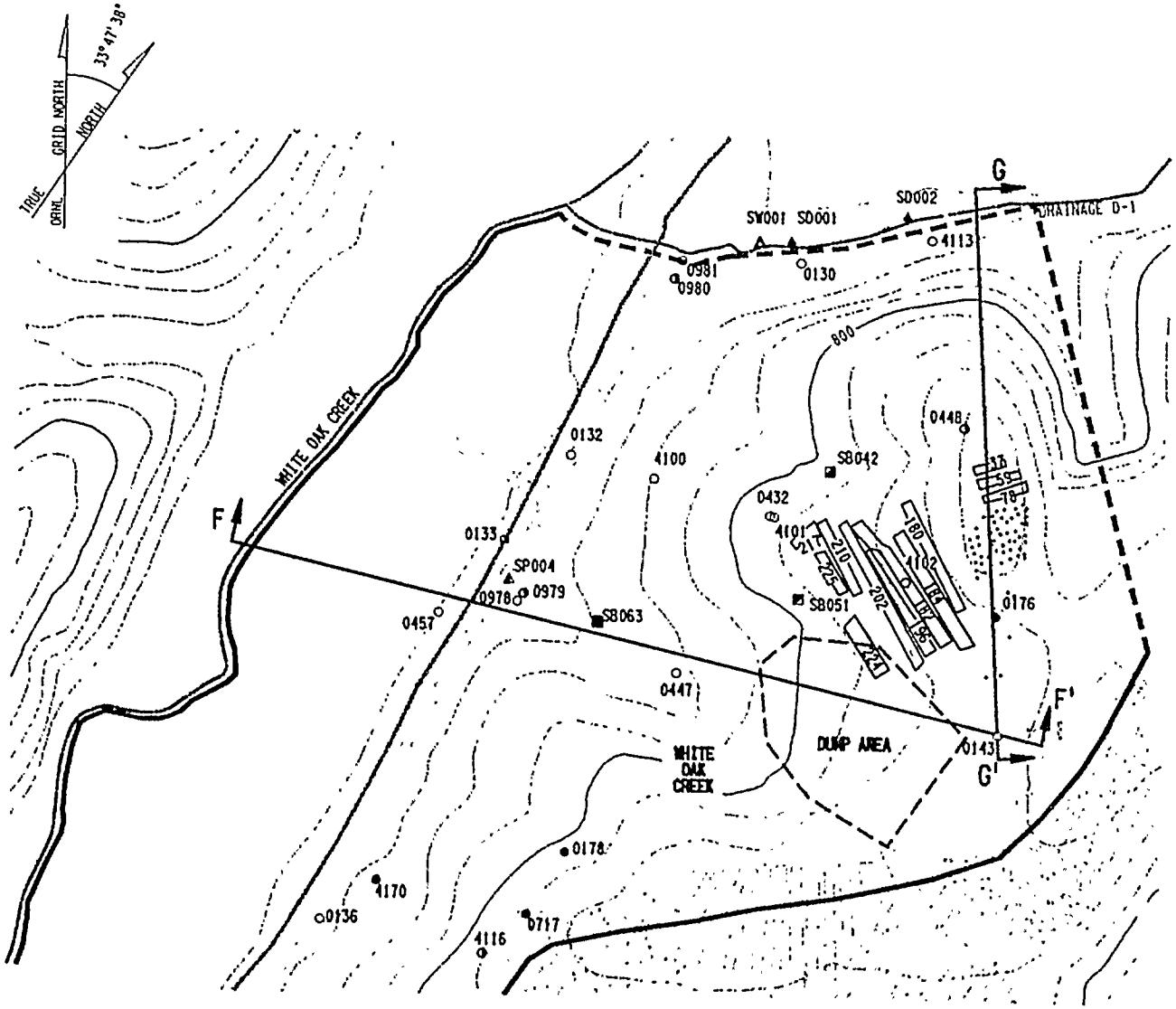
Figure B2.3.34 shows the sampling locations in the study area and cross-section locations used in the hydrologic models. Soil sampling involved two vertical soil borings completed to bedrock and three areal surface soil (0 to 2 ft) composites. The areal composites included a high-exposure USRADS location sample, a medium/low-exposure location sample, and a sample collected as part of the ecological risk assessment (earthworm studies). Seep SP004 was sampled for CSL screening in 1992 and sampled for a full suite of analyses during wet season conditions in 1993. This seep, which is active only during the wet season, is in the same general area as Duguid's (1975) S-2 seep.

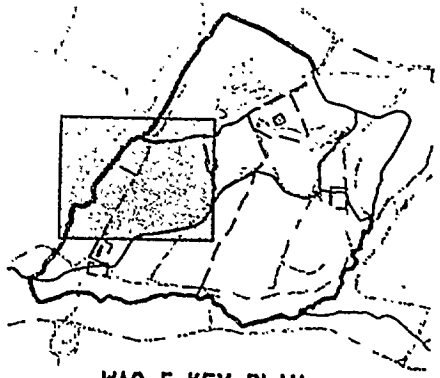
Hydrologic model

Figures B2.3.35 and B2.3.36 depict the hydrologic model for the SWSA 5 White Oak Creek study area. Most of the study area (88%) drains to White Oak Creek, and the balance (12%) drains to D-1. Surface water, interflow (stormflow), and groundwater flow either westward to White Oak Creek or northwest to drainage D-1. Table B2.3.21 summarizes the annual water balance (based on the HSPF modeling described in Appendix B1) for the three pathways in the SWSA 5 White Oak Creek study area. The flux of water through each pathway is similar, though shallow groundwater and interflow discharges slightly exceed the discharge calculated for surface runoff. Surface runoff is probably lower than shown because the model was calibrated using D-1 flow data, influenced by the relatively extensive impervious areas in SWSA 5 North (i.e., buildings, roads, or pavement).

Table B2.3.21. Annual water balance summary for SWSA 5 White Oak Creek study area

	Percent of Flow (%)	Discharge to White Oak Creek (M^3/year)	Discharge to Drainage D-1 (M^3/year)	Total Annual Discharge (M^3/year)
Surface Runoff	27	15,155	2,109	17,264
Interflow	31	16,950	2,359	19,309
Groundwater flow	42	23,331	3,247	26,578
Total	100	55,436	7,715	63,151





WAG 5 KEY PLAN

LEGEND

- APPROXIMATE STUDY AREA BOUNDARY
- WAG 5 BOUNDARY
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- SB042 — SOIL SAMPLING LOCATION W/NO. (USRADS MEDIUM TO LOW EXPOSURE RATE)
- SB051 — SOIL SAMPLING LOCATION W/NO. (USRADS HIGH EXPOSURE RATE)
- SB063 — AREAL COMPOSITE SOIL SAMPLING LOCATION W/NO.

GROUNDWATER WELL/PIEZOMETER LOCATION W/NO.

- 0132 — REGOLITH <30'
- 0448 — BEDROCK <100'
- 0178 — BEDROCK >100'
- SW001 — SURFACE WATER LOCATION W/NO.
- SP004 — SEEP SAMPLING LOCATION W/NO.
- SD002 — SEDIMENT SAMPLING LOCATION W/NO.
- TRENCHES W/NO.
- AUGER HOLES

SCALE

0 100 200 FEET

0 20 40 60 METERS

Drainage Group: White Oak Creek
Study Area: SWSA 5 White Oak Creek area
Sources: Auger holes, trenches, and dump area

Fig. B2.3.34. SWSA 5 White Oak Creek plan view.

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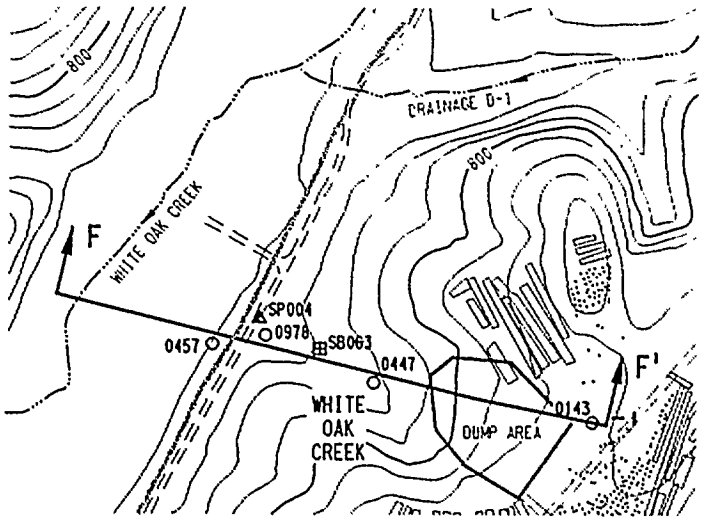
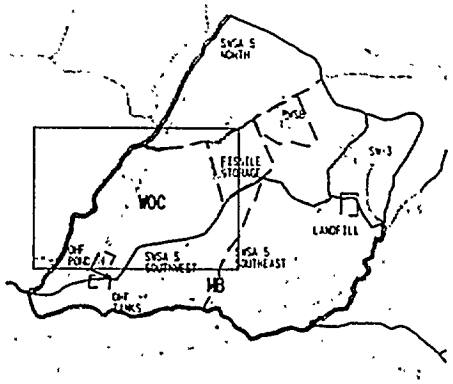
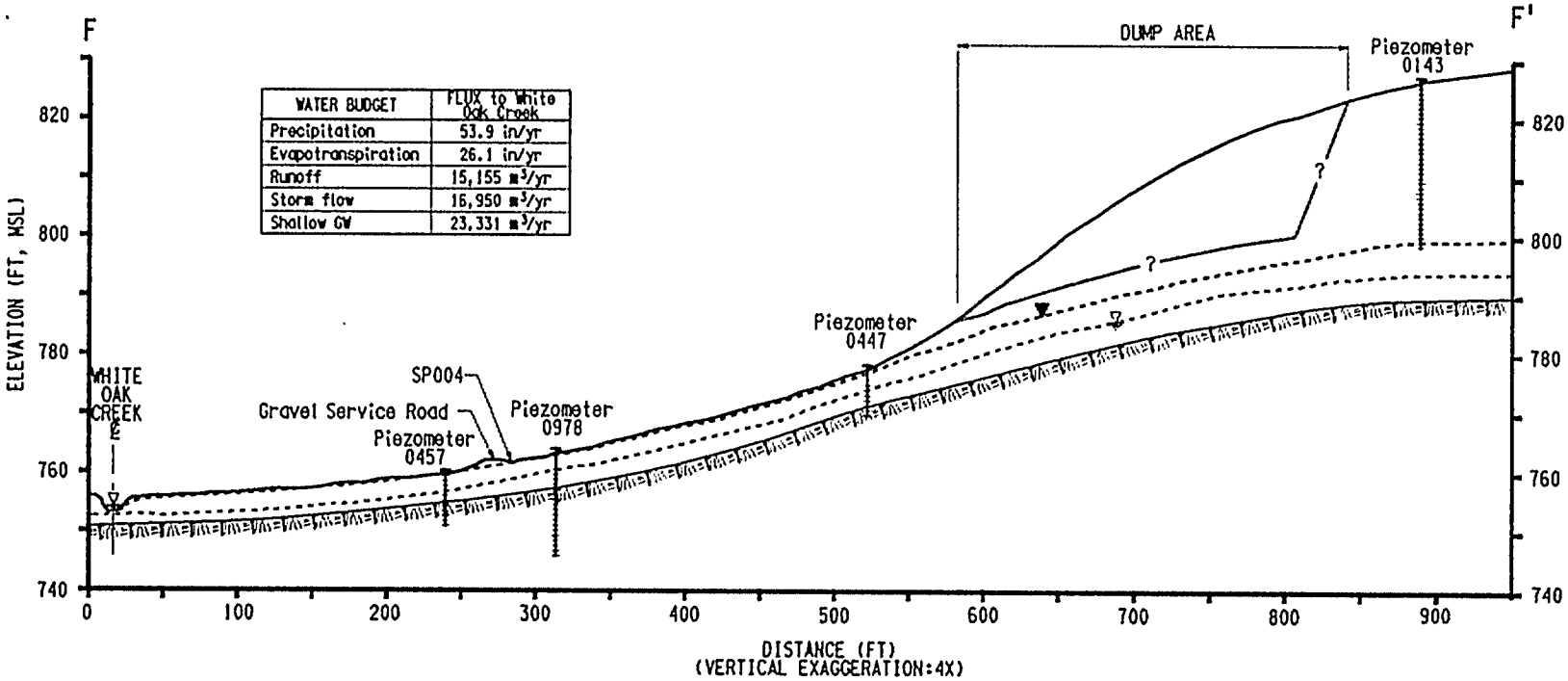


LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0526 — WELL, WELL NO., SCREEN SECTION
- —?— APPROXIMATE DUMP AREA LIMIT



WAG 5 KEY PLAN



WATER BUDGET	FLUX to White Oak Creek
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	15,155 m^3/yr
Storm flow	16,950 m^3/yr
Shallow GW	23,331 m^3/yr

Fig. B2.3.35. Hydrological model for SWSA 5 White Oak Creek (Section F-F').

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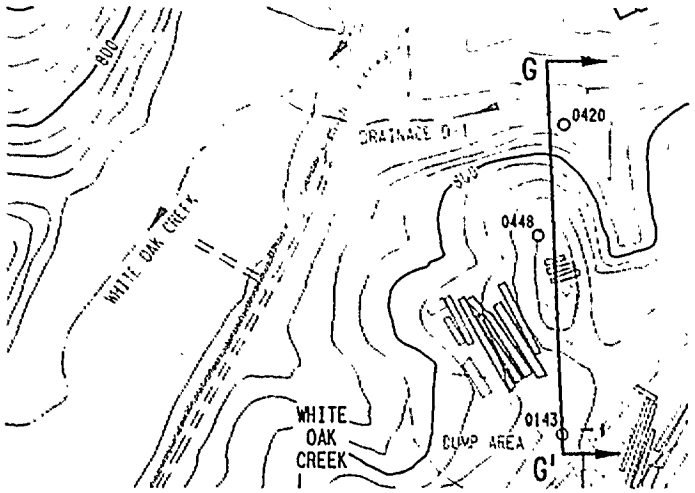
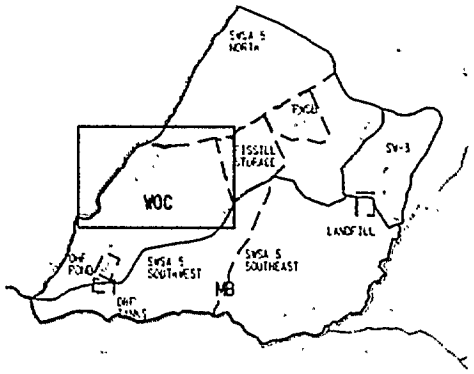


LEGEND

- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0448 — WELL, WELL NO., SCREEN SECTION
- 37 — APPROXIMATE TRENCH BOUNDARY W/ NO.



WAG 5 KEY PLAN

WATER BUDGET	FLUX D-1
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	2,109 m^3/yr
Storm flow	2,359 m^3/yr
Shallow GW	3,247 m^3/yr

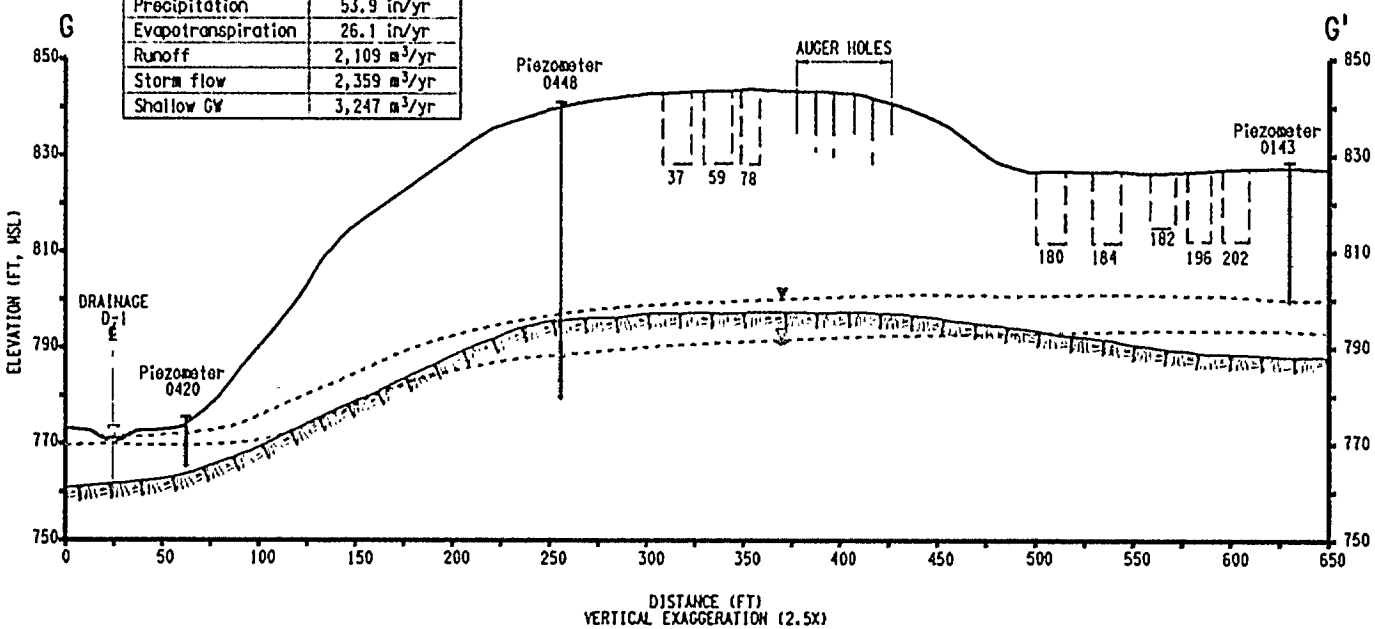


Fig. B2.3.36. Hydrologic model for SWSA 5 White Oak Creek (Section G-G').

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The hydrologic models depicted in sections F-F' and G-G' show that most of the trenches and auger holes in this area were above the water table throughout 1993. The vadose zone beneath the upland trenches (37, 59, and 78) is as much as 25 ft thick during wet conditions and even greater during the dry season. Farther to the west, the depth to water decreases to about 10 ft (see section G-G'). It is possible that some of the westernmost trenches (217, 220, 224, and 225) become partially inundated during the wet season; however, there were no direct observations of such conditions. Perched water tables (bathtubbing) may also occur in the upland trenches. The dump area was reported to have been excavated to within 2 ft of the water table, but its downslope (western) end may also become inundated during the wetter portions of the year. The most common release mechanism is the vertical percolation of rainwater through the wastes and vadose soils to the shallow groundwater, where the water is transported laterally and discharged primarily into White Oak Creek and (to lesser extent) drainage D-1. Inundation of the wastes with the shallow groundwater is a less likely release scenario, but one that may transport the greatest quantities of contaminants during unusual storm conditions.

Nature and extent of contamination

Table B2.3.22 summarizes contaminants of concern detected in the White Oak Creek study area, and Table B2.3.23 presents the quantitative results for each major contaminant.

Table B2.3.22. Contaminants of concern detected in the SWSA 5 White Oak Creek study area

CONTAMINANT	SOIL	GW	SEEP
^{60}Co	X		X
^{137}Cs	X	X	
^{212}Pb		X	
^{226}Ra		X	
^{228}Ra		X	
^{90}Sr		X	
^{99}Tc	X		X
^{228}Th		X	
^{230}Th		X	
^{232}Th		X	
^{234}Th		X	
Tritium		X	
^{238}U		X	
Nickel		X	
1,2-Dichloroethene (total)		X	X
Benzene		X	
Vinyl chloride		X	

Radiological contaminants. The USRADS walkover survey identified three major areas of surface gamma contamination within the study area (Fig. B2.3.37); all three areas corresponded to those found by Uziel et al. (1989). The highest and most widespread gamma activity was directly

Table B2.3.23. Analytical data summary for selected radionuclides in SWSA 5 White Oak Creek area

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Gross Beta	(β) Tritium	(β-γ) Co-60	(β) Sr-90	(β) Tc-99	(β-γ) Cs-137	(α) Th-228	(α) Th-230	(α) Th-232
SOIL (pCi/g)													
	Background Reference			9.92	42	0.084	0.02	1.94	2.2	1.4	1.5	1.24	1.42
	4113	3/3/93	6-7.4	-	50	6.36							
	4113	3/3/93	0-6	9.7	27.7	4.41		-		-			1.63
	4116	3/4/93	0-2	47	38	1.7		-		1.3	2.2		1.8
	4116	3/4/93	0-6	-	39	3.33							
	4116	3/4/93	6-10.9	-	32.6	-		-		0.31		-	1.42
	SB042	3/10/93	0-2	-	43.7	3.97				2.55			
discrete	SB051	3/10/93	0-2	370	6200	0.75	36	380	0.92	6800			
comp.	SB051	3/10/93	0-2	-	136	-	36.9			6.28			
	SB052	3/2/93	0-2	-	43.5	11				919			
	SB063	5/24/94	0-0.5	4.63	51.5	2.53	0.09	9.75		6.24			

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha U	(α) Gross Alpha F	(β) Gross Beta U	(β) Gross Beta F	(β) Tritium U	(β) Tritium F	(β-γ) Co-60 U	(β-γ) Co-60 F	(β) Sr-90 U	(β) Sr-90 F	(β) Tc-99 U	(β) Tc-99 F	(β-γ) Cs-137 U	(β-γ) Cs-137 F	(α) Th-228 U	(α) Th-228 F	(α) Th-230 U	(α) Th-230 F	(α) Th-232 U	(α) Th-232 F
GROUNDWATER (pCi/L)																							
	Background Reference			5.2	3.2	16	7.4	2400	1080	44	9.2	10.4	3.6			12.4	5.4						
	0176	6/25/92	36-143	20.7	-	704.8	145.8	96296	95741				17.1										
	0178	6/6/92	42-152	-	-	39.6	-	4503	4433				2.8										
	0432	5/28/92	17-27	-	-	27.3	-	7152	7236								1050						
	0447	5/26/92	3-8	-	-	38	33.7	34123	39756				12.3										
	0448	5/21/92	50-60	-	-	-	-	2316	2436														
	0455	6/3/92	26-36	-	-	35.8	74.9	-	-				19.5										
	0468	4/29/93	10-15	1.7	2.8	164.5		740	7700			5.9	-			-	-						
	0468	10/19/93	10-15	28.7	-	53.5	4.4	6800	6731			1.35	2.05	17.2	-	-	-	3.77	-	3.88	-	2.79	-
	0717	7/2/92	136-148	-	-	80.5	59.3	1276	1416				-										
	0978	4/20/93	9-19.7	-	-	21.4	15.1	56800	56800	32.4	23.8	-	-			-	-						
	0978	11/4/93	9-19.7	-	-	18.5	15.1	64800	62100	36.5		-	-	-	-	-	-	-	-	-	-	-	-
	0979	4/19/93	32.5-49.3	1.11	1.54	83.8	-	24324	24324	15.9	12.2	-	-			-	1.6						
	0979	11/10/93	32.5-49.3	-	-	14.5	11.3	32300	31600	17.3		0.636	0.57	-	-	-	-	-	-	-	-	-	-
	0980	4/16/93	33.6-49.7	-	-	-	-	-	-	-	-	-	-			-	-						
	0980	11/10/93	33.6-49.7	109.9	56.4	-	-	-	-			-	-	-	-	-	-	-	-	-	-	-	-
	0981	4/14/93	8-19.7	-	-	-	-	43243	40540	-	-	-	-			-	-						
	0981	11/9/93	8-19.7	50.9	4.74	4.87	23.3	63200	55700			-	-	-	-	-	-	2.59	0.807	0.322	-	-	-
stf	4100	12/6/93	0.5-3	29.6		110		7669															
stf	4101	12/2/93	0.5-1	28		53.1		2510															
stf	4102	12/6/93	0.5-1	128.7		140.2		4464															
	4113	4/19/93	2.8-14.4	12	1.3	9.4	3.5	110000	98000			2.5	-			-	-	32	-	24	-	35	-
	4113	10/19/93	2.8-14.4	-	6.5	58	17.1	87958	84983			-	-	14	-	-	-	3.9	-	1.3	-	3.1	-
	4116	4/27/93	30-49	4.5	2.9	13	4.6	84000	92000			-	2.3	-	3.1	-	-						
	4116	10/15/93	30-49	18.7	-	90.9	12.9	251844	230091			-	-	4.97	-	-	13.37	2.57	-	2.42	-	1.59	-
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference			9		8		1620				7.2		7.8		40		2		4.2		2	
	SP004	9/18/92	SW							95.7	87.3		419.1										
	SP004	5/6/93	SW	-	-	664.5	647.6	28600	29240	33.8	25.4	211.8	200.3	19.6	-	-	-	-	-	-	-	-	-

Notes: 1) Blanks indicate analyte not analyzed for; Bold indicates detected over background reference (2x mean background)
2) Abreviations: U/F = Unfiltered/Filtered - = not detected (α,β,γ) = alpha, beta, gamma emitter *stf* = stormflow piezometers

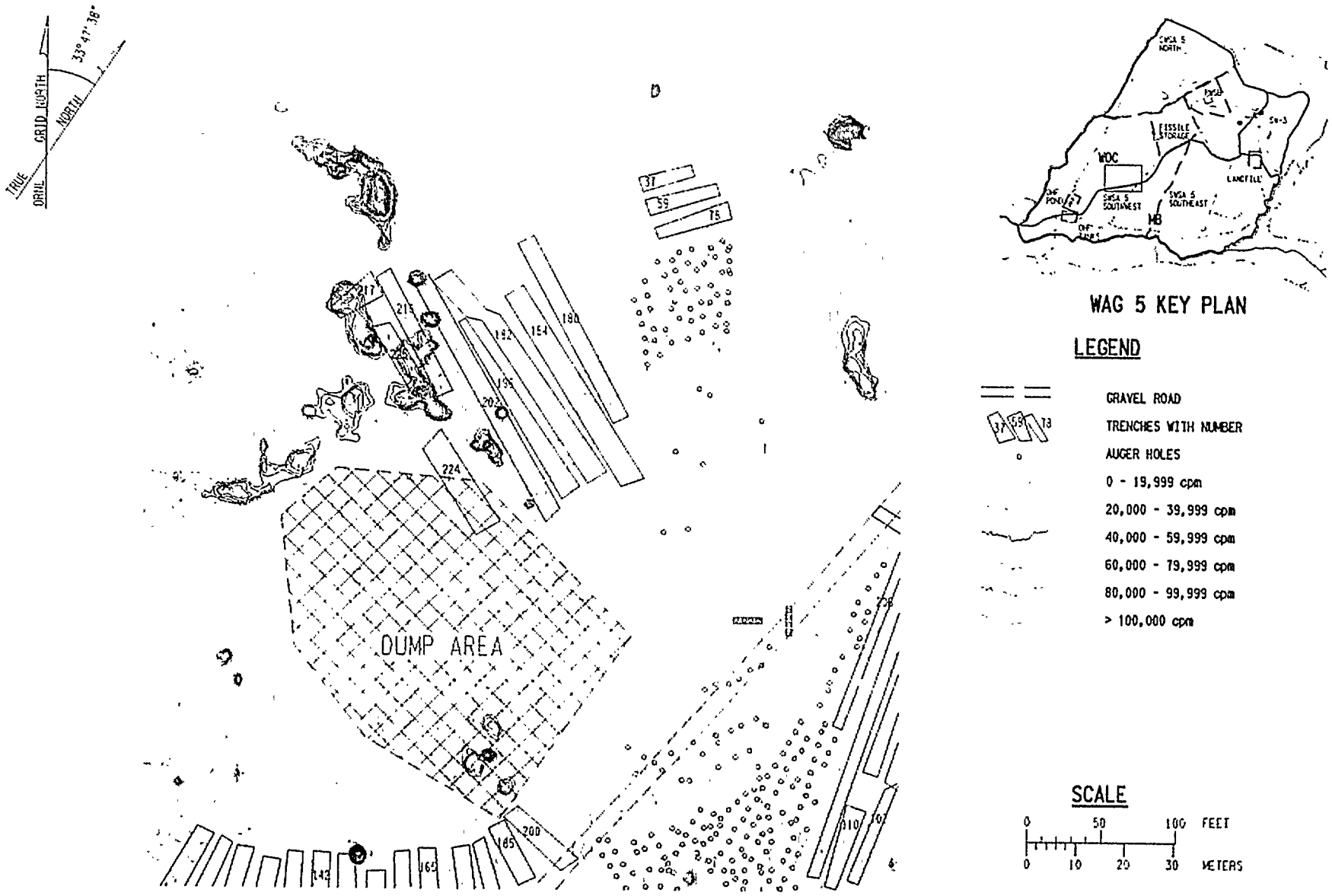

Fig. B2.3.37. USRADS results for SWSA 5 White Oak Creek study area - cpm contours.

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over and to the west of trenches 210, 217, and 225. Off-site analysis of surface soils collected in the hot spot showed relatively high levels of ^{137}Cs (6800 pCi/g), ^{90}Sr (380 pCi/g), and ^{60}Co (36 pCi/g). A surface soil sample from a second USRADS sampling location, in an area of low to medium exposure, had ^{137}Cs at 919 pCi/g but no cobalt, suggesting that ^{60}Co is the primary driver for the surface gamma exposures measured by USRADS in this area. Cesium-137 is also a contributor but has a much lower gamma emission energy (0.7 MeV) than ^{60}Co (1.1 to 1.3 MeV). The southeastern corner of the dump area and a discrete area between the auger holes and access road also had elevated gamma exposure levels but were not sampled. These areas probably have levels of cobalt and cesium contamination in the surface soils comparable to those detected in SB051. Soil sampling in support of the ecological risk assessment at SB063 (immediately downgradient of the dump area) had ^{90}Sr and ^{137}Cs at levels only slightly higher than background. Sampling of surface soils associated with wells 4116 (near OHF) and 4113 (near D-1) did not encounter any significant levels of radiological contamination.

A number of radiological contaminants were detected in groundwater from the study area (Table B2.3.22) but for the most part at concentrations significantly below those observed in the eastern (Melton Branch) portions of SWSA 5 South. For example, concentrations of ^{90}Sr were all less than 20 pCi/L, and the maximum concentration of ^{3}H was only 251,844 pCi/L. Cobalt-60 and ^{90}Sr were both detected at relatively high concentrations (87 and 419 pCi/L, respectively) in samples from seep SP004. Upgradient of the seep, ^{60}Co was detected at comparable levels in samples from perimeter wells 0978 and 0979 (Fig. B2.3.38). Strontium-90 was not detected in either of these wells but was identified in samples from wells farther upstream, although at levels only slightly higher than the background/reference values. Duguid (1975) reported similar results. The relationship between seep and upgradient groundwater concentrations is evidence of the discrete nature of contaminant transport in the water table interval throughout WAG 5. The presence of similar levels of ^{60}Co contamination in both wells in the 0978/0979 perimeter well pair (screened intervals of 9 to 20 ft and 33 to 50 ft, respectively) indicates that these discrete pathways may also have a vertical component. Differences involving other contaminants [primarily volatile organic compounds (VOCs)] suggest the presence of multiple contaminant-specific pathways. For this well pair, the shallow well (0978) intercepted both the ^{60}Co and VOC pathway; the deep well intercepted only the ^{60}Co pathway.

Some localized, downward transport of radionuclides to the deeper groundwater zones may have occurred, as evidenced by low levels of ^{90}Sr contamination in wells 0176 (completion depth of 36 to 143 ft) and 0178 (42 to 152 ft). Because of the extensive open intervals associated with these wells, however, the samples collected from them are not representative of deeper groundwater in the study area. The presence of contamination in these wells is probably due to the well design and cannot be used to infer large-scale migration (recharge) of contaminants to the intermediate or deeper groundwater zones.

Samples collected in the study area stormflow piezometers showed elevated gross alpha and gross beta (unfiltered only). The highest alpha activity was in a sample from well 4102, located directly above trench 182, used for disposal of TRU wastes. Isotopic analyses were not performed for these samples, and the radionuclides contributing to the alpha activity could not be determined. If the alpha contamination was TRU-related, its presence in the stormflow zone indicates this zone is a potentially significant pathway for migration of contaminants from the trenches.

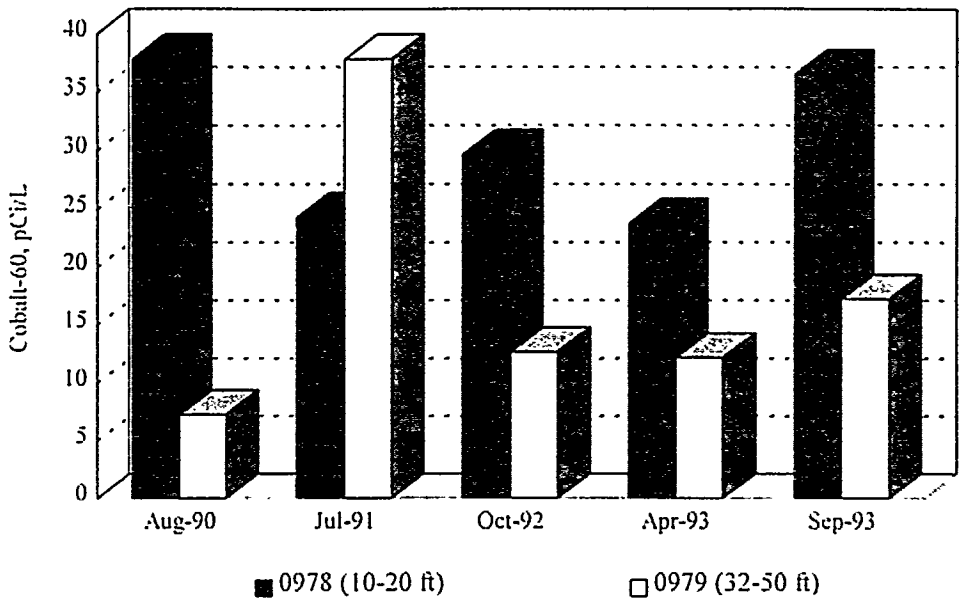

Fig. B2.3.38. Cobalt-60 in perimeter well pair 0978/0979.

Volatile organic compounds. Seep SP004 and perimeter well 0978 had the highest concentrations of VOCs detected in WAG 5 (Table B2.3.24). A similar suite of compounds was detected in SP004 and well 0978, indicating that 0978 intercepts at least one of the flow pathways transporting contamination from the source areas to the seep discharge on the margin of the White Oak Creek floodplain. Lower concentrations in the seep sample were attributed to volatilization losses that occur when the groundwater emerges onto the ground surface. Further volatilization and dilution of VOCs occurs when the discharged seepage water flows into White Oak Creek. Concentrations of VOCs in White Oak Creek have generally been below detection limits.

Table B2.3.24. VOC contamination in SP004 and well 0978

COMPOUND	SEEP SP004 (µg/L)	PERIMETER WELL 0978 (µg/L)
Trichloroethene	76	6-27
1,2-dichloroethene	180	1,600-3,300
1,1-dichloroethene	3	1-5
1,1-dichloroethane	Not detected	1
vinyl chloride	2	2,700-4,000
benzene	*14*	6-8
xylene (*total*)	Not detected	2

Note: Values in italics are based on CSL results; all others ASL

CSL analyses detected VOCs in several additional wells in the study area, including 0176 (DCE, TCE, benzene, and toluene), 0432 (TCE), 0448 (TCE), and 4116 (carbon tetrachloride). In most cases, concentrations of VOCs were below 100 µg/L. An exception was 0176, which had 1000 µg/L of TCE and several unidentified VOCs in concentrations as high as 800 µg/L. The source of the VOCs is most likely the trenches and auger holes used for disposal of organic wastes, which are being released to the water table and are migrating westward to discharge areas along the White Oak

Creek floodplain. The dump area may also be a source area of VOCs, due to its upgradient location; however, no historical evidence has been found to support the disposal of organic wastes here.

Conceptual model summary

The site conceptual model for SWSA 5 South White Oak Creek study area is summarized in Table B2.3.25 and illustrated in Fig. B2.3.39. This area-specific model integrates the hydrologic processes and contaminant data and forms the basis of the drainage basin and WAG-wide conceptual models presented in Volume 1.

Briefly, the model can be summarized as follows: Source material containing radiological and chemical contaminants was buried in trenches, auger holes, and a small landfill (dump area), much of it in the final years of SWSA 5 operation (1970–1973). Volatile organics and various radionuclides have been released from the buried wastes and detected in nearby and downgradient groundwater and seeps. The primary release mechanism involves percolation of infiltration liquids through buried wastes; stormflow recharge of trenches and auger holes intercepting the stormflow zone and episodic, partial inundation of wastes in lower elevations (or bathtubbing) may also be important during the wet season.

Contaminants released to the groundwater are transported in the water table interval to nearby discharge points along the eastern margin of the White Oak Creek floodplain. Discharges from the study area do not have a significant impact on water quality in White Oak Creek because most of the volatiles are lost due to volatilization and the flux of radionuclides is dwarfed by the flow and upstream contaminant input in White Oak Creek.

Table B2.3.25. Conceptual model summary for SWSA 5 White Oak Creek study area

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
110 auger holes	• Infiltration/percolation through wastes	• Shallow groundwater discharging to White Oak Creek	• Seep discharge areas • Downstream surface water and sediment
12 trenches	• Infiltration/percolation • Stormflow recharging trenches • Partial, episodic inundation by water table	• Same as above	• Contaminated soil over trenches • Seep discharge areas • Downstream surface water and sediment
Dump area	• Infiltration/percolation • Stormflow • Inundation of lower portions	• Same as above	• Contaminated surface soils on dump area • Seep discharge areas • Downstream surface water and sediment

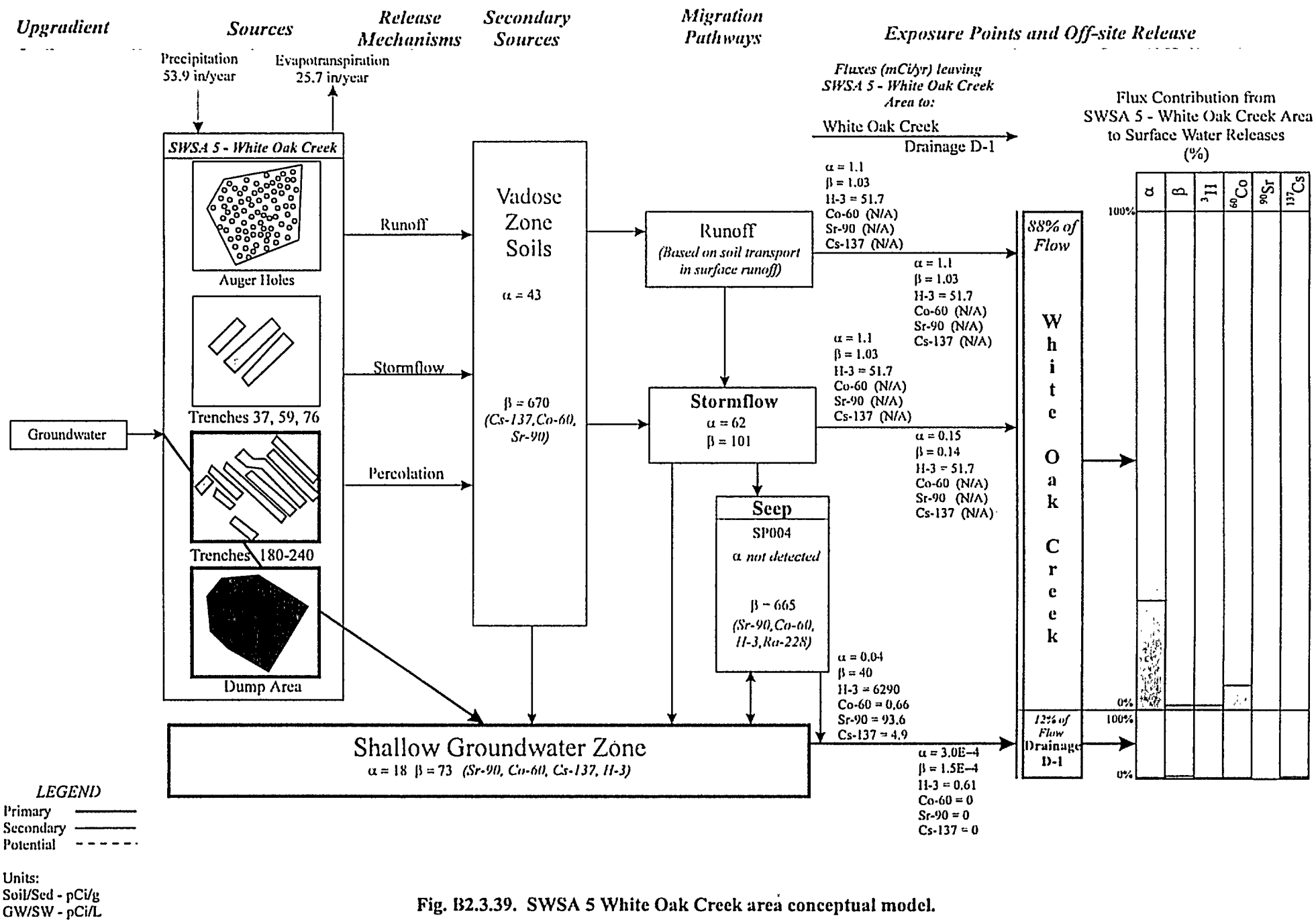

Fig. B2.3.39. SWSA 5 White Oak Creek area conceptual model.

B2.3.7 OHF Area

The OHF site is in the southwest part of SWSA 5 approximately 390 ft to the northeast of the confluence of White Oak Creek and Melton Branch (Fig. B2.1.1). From 1964 to 1979, OHF was used for disposal of liquid radioactive waste in shale formations at depths between 780 and 950 ft. More than 8 million liters of an intermediate-level waste (ILW) and grout mixture with over 2×10^4 TBq (0.6 MCi) of ^{137}Cs and 1×10^3 TBq (40 kCi) of ^{90}Sr were injected along with smaller quantities of alpha-emitting and other radionuclides. Contaminated structures remain at the site (Fig. B2.3.40). Releases to surrounding soils and groundwater have occurred, but on a much smaller scale. Contaminants detected in the area reflect the ratios present in the waste materials handled at the facility: ^{137}Cs, ^{90}Sr, and ^{60}Co, with traces of uranium and transuranic radionuclides.

Identifying the significance and characterizing contaminant sources and migration patterns in the OHF was complicated for a number of reasons; these include:

- The known source areas are relatively close to each other and include waste in various forms and types of containment.
- The entire area is immediately downgradient of a large, contaminated area (SWSA 5 South).
- Records associated with contamination events are sometimes incomplete and/or inconsistent.
- "Shine" from OHF features emanate particularly high radiation and reduce the ability of surveys to distinguish between contaminated and uncontaminated areas.
- Incidental (small-scale) spills and leaks over the 15-year period of facility operations resulted in many discrete, localized areas of surface soil contamination.

The approach to analyzing the nature and extent of contamination and developing a detailed conceptual model for the area is slightly different than that used elsewhere at WAG 5. This approach is detailed below.

Summary of OHF SWMUs and areas of concern

The OHF site was divided into four SWMUs in the 1987 RCRA Facilities Assessment (RFA) for ORNL (ORNL 1987). Most of the SWMUs consisted of several potential sources of contamination, and in some cases separate components were given letter designations (e.g., the five buried waste tanks were designated SWMU 5.5a–5.5e). The RFA SWMU designations (Table B2.3.26) represented logical groupings of the site and were apparently developed on the basis of available documentation, containment method, location, contaminant type, and historical characterization results; Table B2.3.27 summarizes these attributes.

Table B2.3.26. OHF SWMU designations

SWMU DESIGNATION	DESCRIPTION
5.1a–b	LLW Lines and Leak Sites: (a) OHF, Release of Grout and (b) Building 7852, Hydrofracture Injection Area
5.2	OHF Pond
5.3	OHF Surface Facilities (Waste Pit T-4, Pump House, Misc. Bldgs)
5.5a–e	OHF Waste Storage Tanks: T-1, T-2, T-3, T-4, T-9

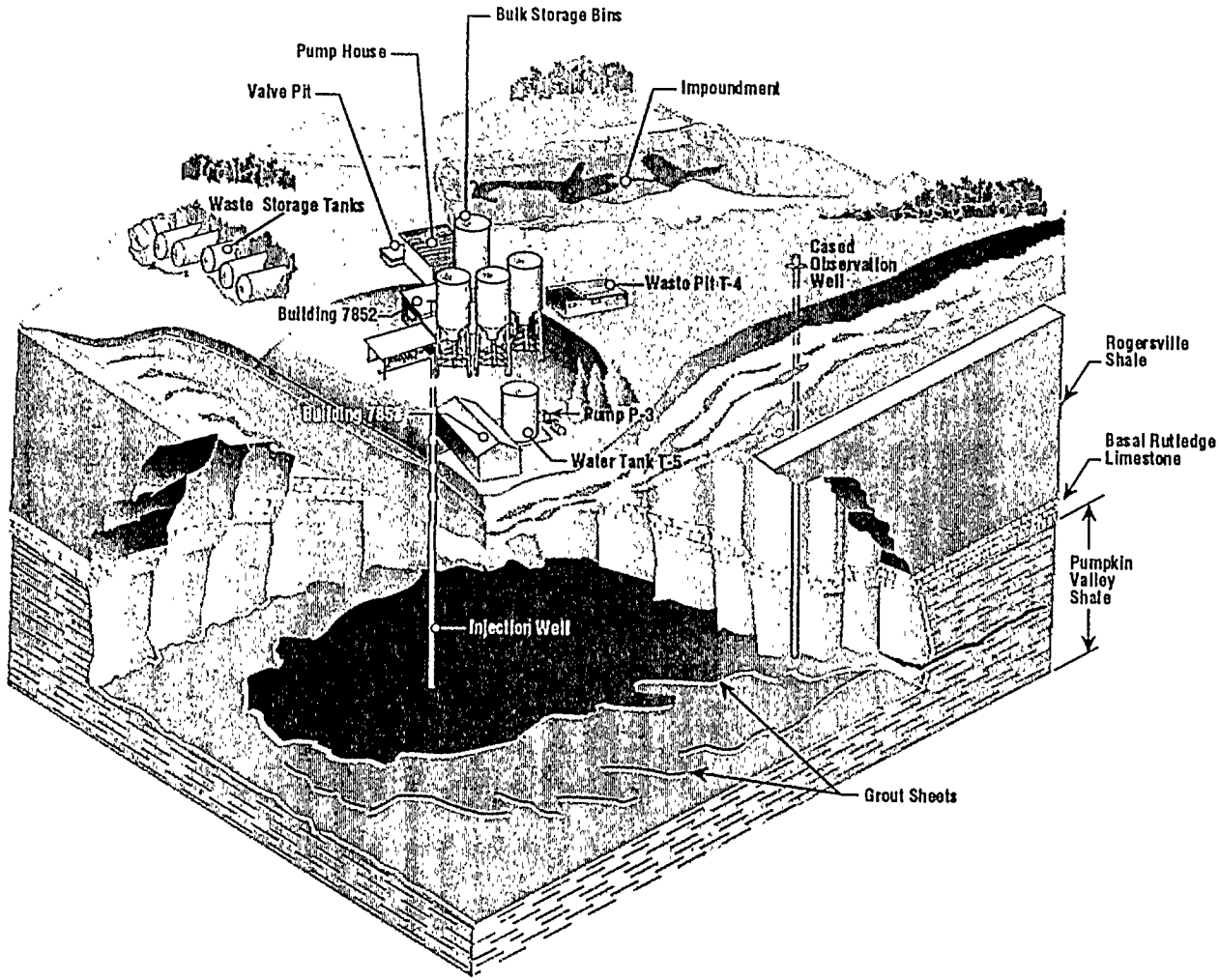

Fig. B2.3.40. Artist's rendering of OHF.

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After an extensive review of past and current characterization data and historical documents recounting facility operations and contamination events, it became apparent that of the many potential and known contaminant sources identified within the four SWMU groups, three areas stand out as sources and/or areas of concern: the OHF impoundment (SWMU 5.2), the five subsurface waste storage tanks (SWMU 5.5a–e), and waste pit T-4 (part of SWMU 5.3). SWMUs 5.1a–b and most of the components of SWMU 5.3 were determined to be either insignificant sources of contamination or part of the OHF facilities to be addressed through ongoing decontamination and decommissioning (D&D) activities. These areas were excluded from the detailed evaluation of OHF contamination for the following specific reasons.

SWMU 5.1a. The release of grout from an OHF observation well was originally described in Appendix II to the ORNL RFA (ORNL 1987). The description cited a release of 0.72 Ci of ^{90}Sr during the drilling of an observation well in 1968. ORNL coordinates were provided, but the well designation (well number) was not. Shoun (1987) reported that the spill involved a 1964 release of approximately 2 Ci of strontium from observation well S-100. A possible source of confusion was a report by de Laguna (1968) that discussed contaminated groundwater encountered during the drilling of well S-100 in 1964; however, no release of contamination occurred. Well S-100 is in the immediate vicinity of the RFA coordinates for SWMU 5.1a. Shoun's document was used as the basis for the 1988 WAG 5 RI work plan, and thus the WAG 5 field sampling plan developed and implemented an investigation designed to evaluate contamination associated with well S-100. After RI field activities ended, it was discovered that the spill actually occurred in 1968 from well S-220, approximately 100 ft downgradient of S-100 and 50 ft north of Melton Branch (Weinberg 1969; reauthored by Stow 1986).

As part of the WAG 5 RI, an USRADS survey of the S-100 area identified a "hot spot" of contamination near the wellhead. Sampling of surface soils from the hot spot area identified somewhat elevated ^{90}Sr (18.6 pCi/g) and ^{137}Cs (61 pCi/g). A downgradient surface soil sample from the S-220 vicinity was also analyzed, but no contamination was identified, and no direct characterization data were generated during the WAG 5 RI. Information concerning the nature and extent of contamination associated with well S-220 was obtained through drive point sampling in the vicinity of the spill area and evaluation of WAG 2 transect sampling results in Melton Branch (see Sect. B2.4.1).

SWMU 5.1b. The redirection of 2,300 gal of LLW grout due to a valve failure during an experimental injection at OHF reportedly resulted in a release of contaminated grout to the ground surface. Historical documents (Weeren 1980; Shoun 1987) state that the grout was accidentally routed to waste pit T-4 (due to the valve failure) and then included in the next injection (i.e., the wastes were pumped back out of the waste pit and injected underground). No mention of a release to the ground was made in the Weeren (1980) document, determined to be one of the more authoritative references for OHF operations data. Soil sampling and radiological surveys completed by Huang et al. (1984) and as part of this RI in the vicinity of the valve pit, tank T-4, and Building 7852 encountered only low levels of contamination that were not indicative of a release. Given the absence of documentation or actual soil contamination levels that show a release of contaminated grout at Building 7852, SWMU 5.1b is not given further consideration in this appendix (results from the soil sampling are evaluated in the discussion of waste pit T-4). This SWMU is also a candidate for no further action, as discussed in greater detail in Sect. 4 of Volume 1.

Table B2.3.27. Site characterization matrix for the OHF area

Source Description	Area/ Dimensions	Waste Types & Contaminants of Concern	Disposal Methods & Packaging	Waste Volume	Inventory	Dates
OHF Pond • *Sediment* • *Surface water*	100,000 gal capacity surface impoundment *100 X 20 ft,* *5-ft depth* Concrete standpipe at north end extends west into White Oak Creek floodplain Pond lined in rip-rap	Temporary holding basin for waste solutions, decon water from 1965-79; contaminated drill fluid & cuttings placed in pond in 1985 *Major contaminants* ^{137}Cs, ^{90}Sr, and ^{60}Co; smaller amounts of TRU, ^{234}U Max dose rate=100-300 mrad/h at 4-in. above pond water	Used for storage only; [any disposal was through inadvertent leakage through pond bottom]	*Sediment:* 1,938 cubic ft Avg. sediment thickness of 9 in. *Water:* Volume fluctuates seasonally; [design capacity 100,000 gal]	Sediment total of 78.6 Ci based on 1993 sampling: Isotope / Ci Cs-137 62.0 Sr-90 12.2 Co-60 0.1 Cm-244 4.6 Pu-238 0.02 Pu-239 0.01 Am-241 0.01 U-238 <0.01 U-233 0.03 Water activity <0.007	1964-1985
Waste Pit T-4 • *Hardened waste grout* • *Contaminated sediment* • *Contaminated water*	Partially buried concrete pit w/3 cells, each w/ dimensions of 14x14x9 ft (LxWxD) *orig. cell filled in 1965; 2 new cells of same size & construction added same year*	Routine/nonroutine, temporary storage of contaminated solutions during injection operations; original cell permanently filled when grout could not be removed Same primary contaminants as above	Designed for temporary storage of wastes; Base of pit constructed w/ 8-in. reinforced concrete; side walls w/ 10-in. concrete; structurally sound; Inflow was via underground pipelines	South cell holds 720 ft^3 [12x12x5 ft] of contam. grout Similar dimensions, much smaller volumes for 2 other cells	Huang et al. 1984 estimated inventory in all 3 cells: Cs-137 0.4.0 Sr-90 0.05 Co-60 0.007 Cm-244 0.022 Pu-238 0.001 Pu-239 0.006 Am-241 0.0006	1964-1979
OHF Waste Storage Tanks *T1* *T2* *T3* *T4* *T9*	Underground, carbon-steel storage tanks; piping connections to injection well cell, waste pit and OHF Pond;	Used for storage of wastes prior to blending and injection; injection of ILW from Gunnite tanks in main plant area of ORNL; avg. concentration of radionuclides in waste was 0.26 Ci/gal *Major Radionuclides* ^{137}Cs, ^{90}Sr, ^{60}Co, ^{244}Cm, ^{239}Pu, ^{238}Pu, ^{144}Ce	Designed & used for temporary storage of ILW; residual waste sludges remain in tank bottoms. Tanks had cathodic protection until early 1990s. No secondary containment	Approx. 100,000 gal of waste per injection or 2 million gals over the life of the facility. Residual sludge vol. Tank / Gal. Sludge T-1 800 T-2 1,210 T-3 2,030 T-4 1,330 T-9 490	Total Ci (Water and Sludge) from DOE/OR/01-1276&D2 (1994) Tank / Ci T-1 7,378 T-2 3,892 T-3 10,121 T-4 6,528 T-9 1,375	1964-1979

SWMU 5.3. Waste pit T-4 contains contaminated material and represents an active or future source of soil, surface water, and groundwater contamination in the OHF area. This unit was investigated as part of the WAG 5 RI and it has been evaluated in detail for this appendix. In addition to waste pit T-4, SWMU 5.3 includes a number of other OHF site surface facilities associated with storage, mixing, and injection of the grout/waste mixture. The valve pit, pump room, and underground piping are also grouped in this SWMU. Building 7852, the surrounding four bulk solids bins, water tank T-5, and the pump room are the focus of an ongoing D&D investigation and were not included in the scope of this RI. Though many of these structures contain radionuclide contamination, there is no evidence indicating they are current or potentially significant sources of contaminant migration. Building 7853 is currently used for storage of equipment and materials that are not sources of contamination and was not included in the scope of the WAG 5 RI.

Waste pit T-4.

Figure B2.3.41 shows the location of waste pit T-4 within the OHF area. The structure is approximately equidistant from the OHF impoundment and waste storage tanks. Figure B2.3.42 is a photo of the pit and surrounding area showing conditions as of November 1994.

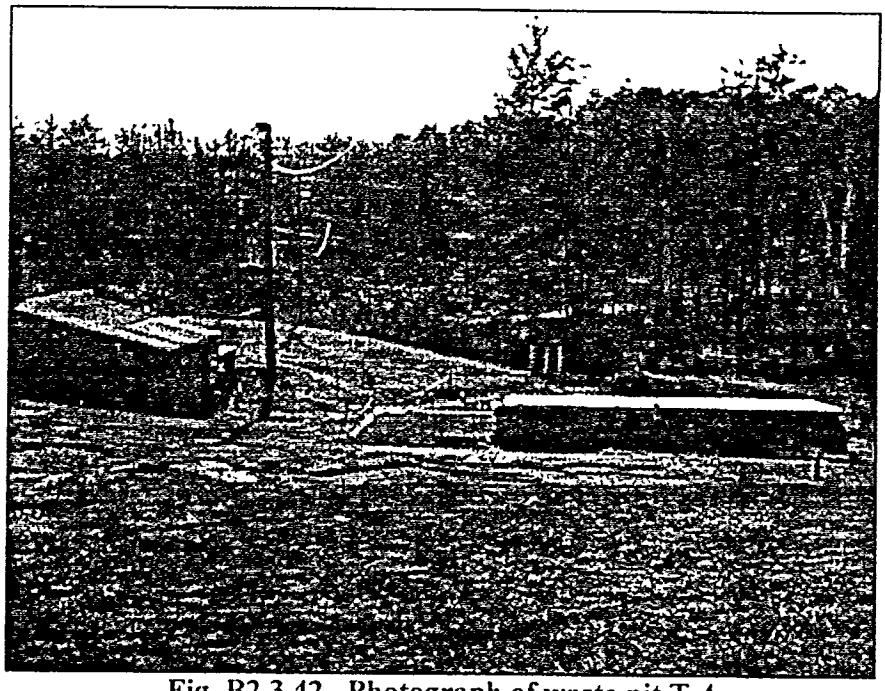
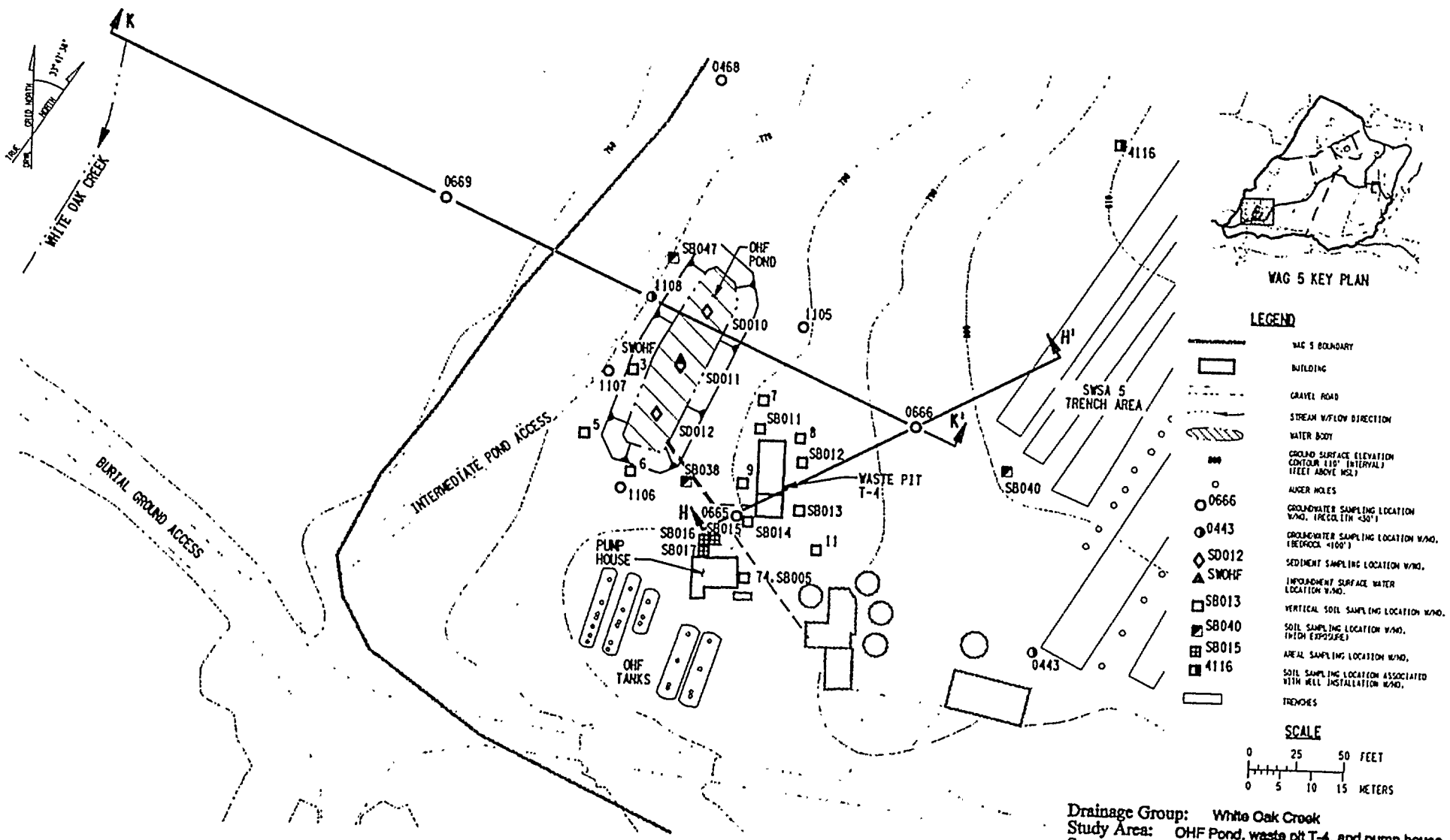


Fig. B2.3.42. Photograph of waste pit T-4.

Description and history. Waste pit T-4, which consists of three concrete compartments (cells) with approximate dimensions of 14 by 14 by 9 ft, was used for routine and nonroutine temporary storage of radioactive solutions during OHF injection operations. These solutions routinely included decontamination waste water used to flush pumps and piping after injections and sand mixtures generated from slotting the casing of the injection well; nonroutine solutions included radioactive grout diverted to the pits as a result of equipment failure or other operational problems (such as was described for SWMU 5.1b). The original pit (the southern cell) was filled with radioactive grout



Drainage Group: White Oak Creek
Study Area: OHF Pond, waste pit T-4, and pump house
Sources: Pond sediment, surface water, waste pit T-4, grout, discharge pipeline, and valve pit

Fig. B2.3.41. OHF pond, waste pit T-4, and pump house plan view.

during an experimental injection in May 1965 (de Laguna 1968). This batch of grout was not removed from the pit, which necessitated the construction of two additional cells to the north; use of these two cells continued until injections were discontinued in 1979. A 8-in.-diameter vitrified clay pipe that served as an emergency overflow connected the pit to the impoundment. There were no records indicating that this pipe had ever been used, but it was found to be contaminated.

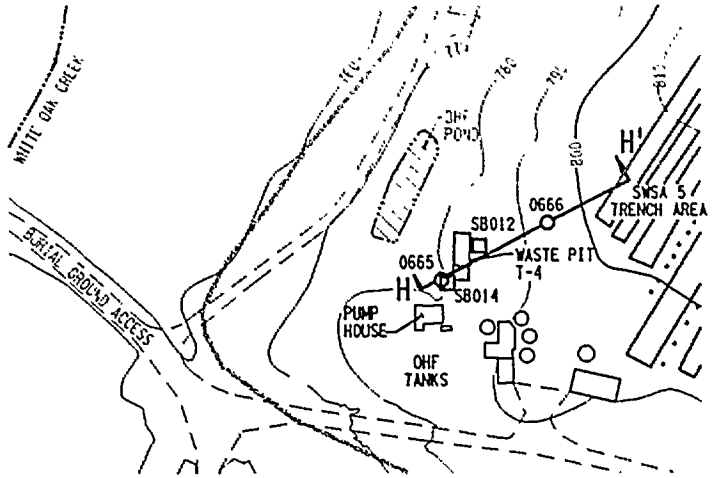
The waste pit received and is contaminated with the same radionuclides present in the injected ILW grout mixture. The southernmost cell contains a monolith of contaminated grout covered by a thin layer of concrete; the others contain contaminated water and sediments over a thin layer of hardened grout (Huang et al. 1984) and are covered with a corrugated plastic roof. The dimensions, design, volume and inventory estimates associated with waste pit T-4 are presented in Table B2.3.27.

Previous investigations. A comprehensive evaluation of OHF was completed by Huang et al. (1984). Work at waste pit T-4 included a walkover survey of the immediate area, collection and analysis of surface water and sediment samples from the open cells, and analysis of 28 soil samples from 3 cores drilled near the pit (Fig. B2.3.41). Huang et al. (1984) measured absorbed dose rates under the roof of the pit between 10 and 40 mrad/h and determined the radionuclide inventories listed on Table B2.3.36. The results of their soil sampling effort did not indicate any contaminant migration from the pit.

RI sample summary. Figure B2.3.41 shows the sampling locations associated with the waste pit and cross-section location used in the hydrologic model. Four soil borings were drilled around the perimeter of the pit and sampled to bedrock refusal. Soil borings SB012 and SB013 are on the upgradient side of the pit (from a surface drainage and groundwater flow perspective), and SB011 and SB014 are on the downgradient side. SB014 was drilled next to the 8-in.-diameter vitrified clay pipe connecting the pit to OHF. A broken section of this pipeline is exposed just outside the outer concrete wall of the original south cell of the waste pit. Field instrumentation indicated high contamination and moderate exposures at several inches from the broken pipeline. Three composite surface soil (0 to 2 ft) samples were collected from the north side of the pump house approximately 25 ft southeast of the waste pit. Although these samples were collected to investigate the alleged surface spill associated with the accidental transfer of radioactive grout to the waste pit (i.e., SWMU 5.1b), the samples provide useful data for evaluation of soil contamination in the vicinity of the waste pit (and elsewhere at OHF).

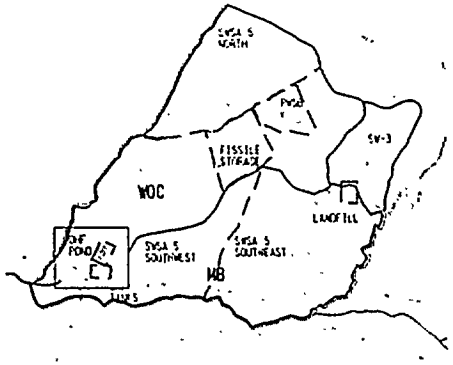
No monitoring wells are in the immediate vicinity of the waste pit other than piezometer 0666, located between the waste pit and the SWSA 5 trench area. This well was sampled during the 1992 CSL screening sampling event. The four 1100-series (CERCLA compliance) wells surrounding the OHF pond were also sampled for the RI; one of these, 1106, is approximately 75 ft downgradient of the waste pit.

Hydrologic model. Figure B2.3.43 depicts the hydrologic model (section H-H') for the waste pit. Surface water, stormflow, and shallow groundwater in the OHF area move generally from northeast to southwest toward discharge areas associated with White Oak Creek and its floodplain. In the immediate vicinity of waste pit T-4, flow has a more westerly direction due to surface features and hydraulic influence from the OHF pond (see below). Surface water drainage from the waste pit area passes to the south of the pond because of a diversion ditch designed to prevent run-on. Any



LEGEND

- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- VITRIFIED CLAY PIPE
- 0665 — WELL, WELL NO., SCREEN SECTION
- SB014 — SOIL BORING W/NO.
- APPROXIMATE TRENCH LIMIT W/NO.



WAG 5 KEY PLAN

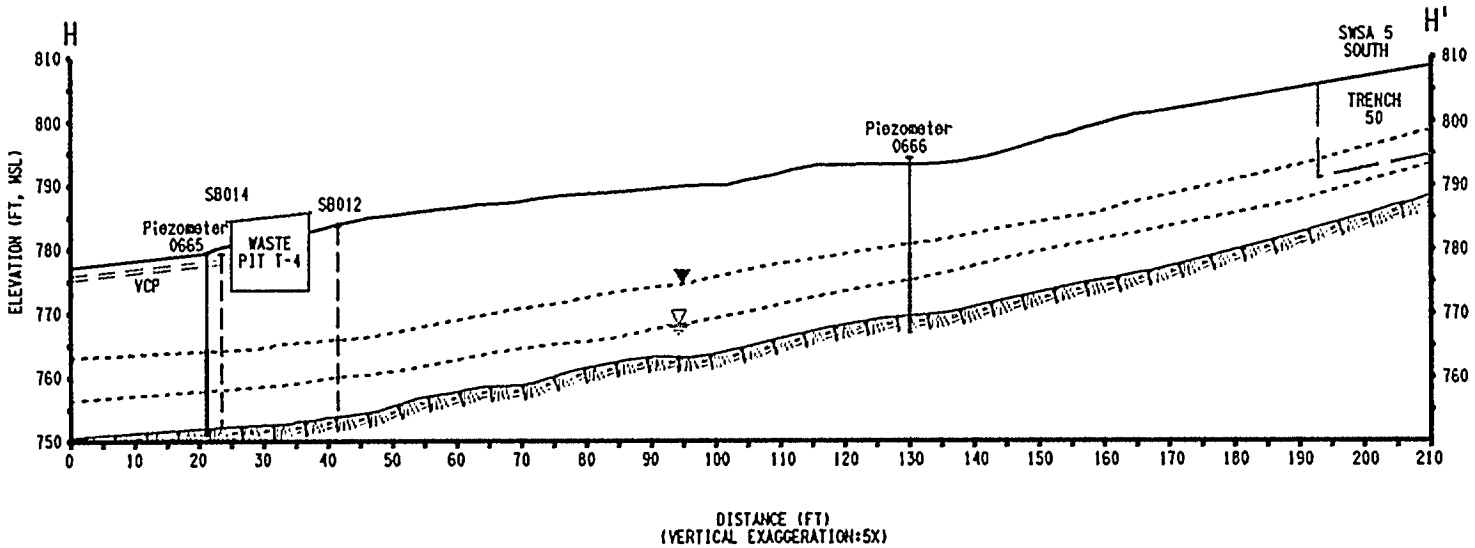


Fig. B2.3.43. Hydrologic model for OHF waste pit T-4 (Section H-H').

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release due to overflow from the pit would also flow westward, passing south of the pond to a culvert that discharges into the White Oak Creek floodplain on the other side of the gravel road that runs along the western side of the pond.

As determined from the 1993 water level data, groundwater is expected to follow a similar path in response to the hydraulic gradients. As shown in the section view, the depth to groundwater is about 15 ft during the wet season and greater than 20 ft during dry season. There is at least a 7- to 9-ft-thick vadose zone between the pit and the water table, and the small amount of water in the pit has no apparent hydraulic influence on the water table in the area. Any release from the sides or base of the pit would have to travel through this vadose zone to reach the water table, after which it would migrate westward toward White Oak Creek.

Nature and extent of contamination. Table B2.3.28 lists contaminants of concern detected in environmental media associated with waste pit T-4 (pit contents were not sampled); Table B2.3.29 presents a detailed summary of the RI and historical sampling results for the analytes of concern.

Table B2.3.28. Contaminants of concern detected in the waste pit T-4 area

	T-4 MEDIA	
CONTAMINANT	SOIL	GW
^{241}Am	X	
^{60}Co	X	
^{137}Cs	X	
^{212}Pb	X	
^{238}Pu	X	
^{90}Sr	X	X
Tritium	X	

Of the 19 soil samples collected from the 4 borings drilled around the waste pit, only 3 had obvious levels of contamination. In all cases, the principal contaminants detected were ^{90}Sr and ^{137}Cs. Two of these samples were from deeper intervals: one from a depth of 18 to 19 ft (SB013) and the other composited over the 12- to 18-ft interval (SB014). The depth to the water table in this area is about 18 ft during the wet season, and groundwater passing beneath the waste pit contains relatively high levels of contamination (^{3}H and ^{90}Sr) from the upgradient SWSA 5 South area. Filtered groundwater samples collected from boring SB014 and upgradient piezometer 0666 had high concentrations of ^{90}Sr (^{3}H was also present in 0666). The ^{90}Sr contamination detected in the deeper samples from these borings reflects partitioning of contaminants from the groundwater to the soil matrix. An alternate explanation involving a release from the waste pit was also considered, given that both borings were alongside the southern end of the waste pit, which contains the cell filled with hardened, contaminated grout. However, the configuration of the source (grout monolith sealed in concrete) and lack of viable release mechanisms, coupled with the absence of contamination at shallower depths from both borings, make it unlikely that the waste pit was the source of the deeper contamination.

Table B2.3.29. Analytical data summary for selected radionuclides in the OHF pump house and waste pit T-4 area

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Gross Beta	(β-γ) Co-60	(β) Sr-90	(β-γ) Cs-137	(α) Pu-238	(α) Pu-239/240	(α) Am-241	(α) Cm-243/244
SOIL (pCi/g)												
Background Reference				9.92	42	0.02	1.94	1.4	0.166	0.06	0.08	2.8
	SB011	11/11/93	0-6	12.7	44.7	0.116	3.65	13.1	0.07	-	0.04	0.26
	SB011	11/11/93	6-12	81.9	91.7							
	SB011	11/12/93	12-18	18.8	45.3							
	SB011	11/15/93	18-23	6.43	30.1	-	2.58	-	-	-	-	-
	SB012	11/1/93	0-6	68.4	56.6							
	SB012	11/2/93	6-12	-	22.9	0.09	2.89	0.03	0.06	0.04	0.08	-
	SB012	11/2/93	12-18	165.9	91.2							
	SB012	11/3/93	18-24	23.4	24.2							
	SB012	11/3/93	24-30	-	25.3		-	-	0.1	-	0.06	-
	SB013	11/30/93	0-6	14.6	32.4			0.5	-	-	0.47	-
	SB013	11/30/93	6-12	-	33.3							
	SB013	11/30/93	12-18	-	55.5							
	SB013	12/1/93	18-19	-	6828	0.52	2710	-	1.82	-	0.26	-
	SB014	12/27/93	0-6	175	3410	0.615	1420	1145	0.08	-	-	0.53
	SB014	12/27/93	6-12	-	1324	1.15		66.4				
	SB014	12/28/93	12-18	29.9	1930	1.33	1100	2.39	0.08	-	0.12	0.07
	SB014	12/28/93	15-16	101.9	22963	6.22						
	SB014	12/28/93	18-24	-	1457							
	SB014	12/28/93	24-27	-	461.8			3.26				
Pump House Soil Borings												
	SB015	2/10/93	0-2	5.07	102		50	22.8				
	SB016	2/26/93	0-2	-	135		103	76.7				
	SB017	2/11/93	0-2	-	295	0.75	247	223				
	74.SB005	4/25/94	0.8-3	11.3	175	0.03	65.7	32.3	0.89	0.052		
Historical Samples												
(a)	8	1983	16-18					-				
(a)	9	1983	0-1					1.35				
(a)	9	1983	2-4					15				
(a)	11	1983	22-24					-				

GROUNDWATER (pCi/L)			U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference			5.2	3.2	16	7.4			10.4	3.6	12.4	5.4						
	SB012	11/4/93	24	10.9		55.7												
	SB014	12/29/93	22						34447	4790								
	0666	6/2/92	14-25	-	-	18618	27198			23834								

Notes:
1. Historical sampling reference
   (a) S. F. Huang (Sept. 1984) "Preliminary Radiological Characterization of the Old Hydrofracture Facility (OHF) at Oak Ridge National Laboratory"
2. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
3. Abbreviations: U/F = Unfiltered/Filtered - = not detected (α,β,γ) = alpha, beta, gamma emitter

B2_T3_29.XLS

Surface soil contamination was also detected in the surface/near surface sample (0 to 6 ft) from boring SB013 on the southwest corner of the waste pit. Both ^{137}Cs and ^{90}Sr were detected in this sample (1,145 and 1,420 pCi/g, respectively). Contamination at this location was attributed to the discrete and/or localized areas of surface contamination resulting from incidental, *de minimis* releases that occurred during OHF operations. Such small-scale releases are common in process areas involving extensive piping networks and typically are due to leaking valves and fittings, small-volume incidental spills, or even splashing of liquids from tanks and pits. The contamination associated with these types of releases is not significant from a migration perspective (i.e., as secondary sources these areas of contaminated soil are insignificant), but from a risk perspective the areas may be of consequence under certain exposure scenarios. Figure B2.3.44 shows the distribution of contaminated surface soil in the OHF area.

OHF waste storage tanks

Figure B2.3.45 shows the location of the OHF waste storage tanks on the southwestern edge of the OHF area, approximately 75 ft from both the impoundment and waste pit T-4. Figure B2.3.46 is a photo showing aboveground conditions in the tank area as of November 1994.

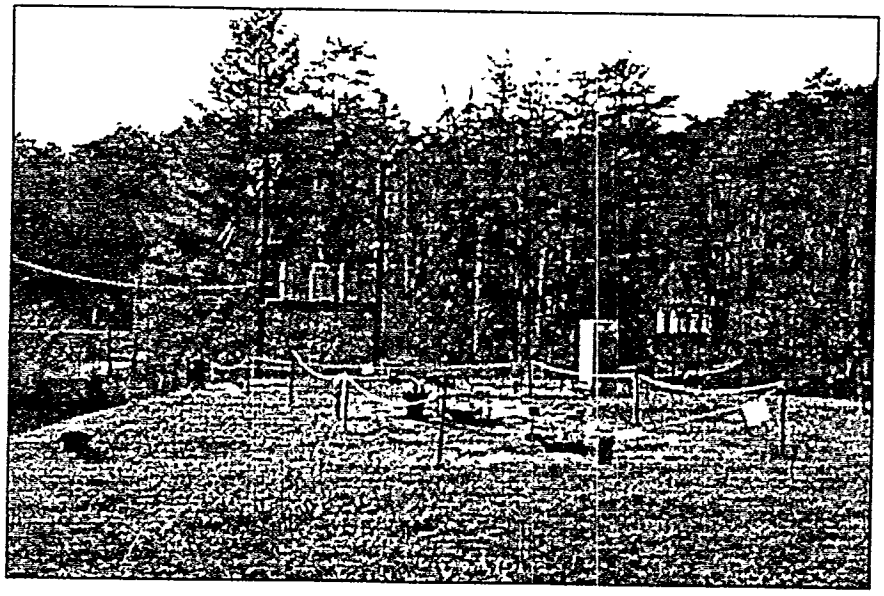
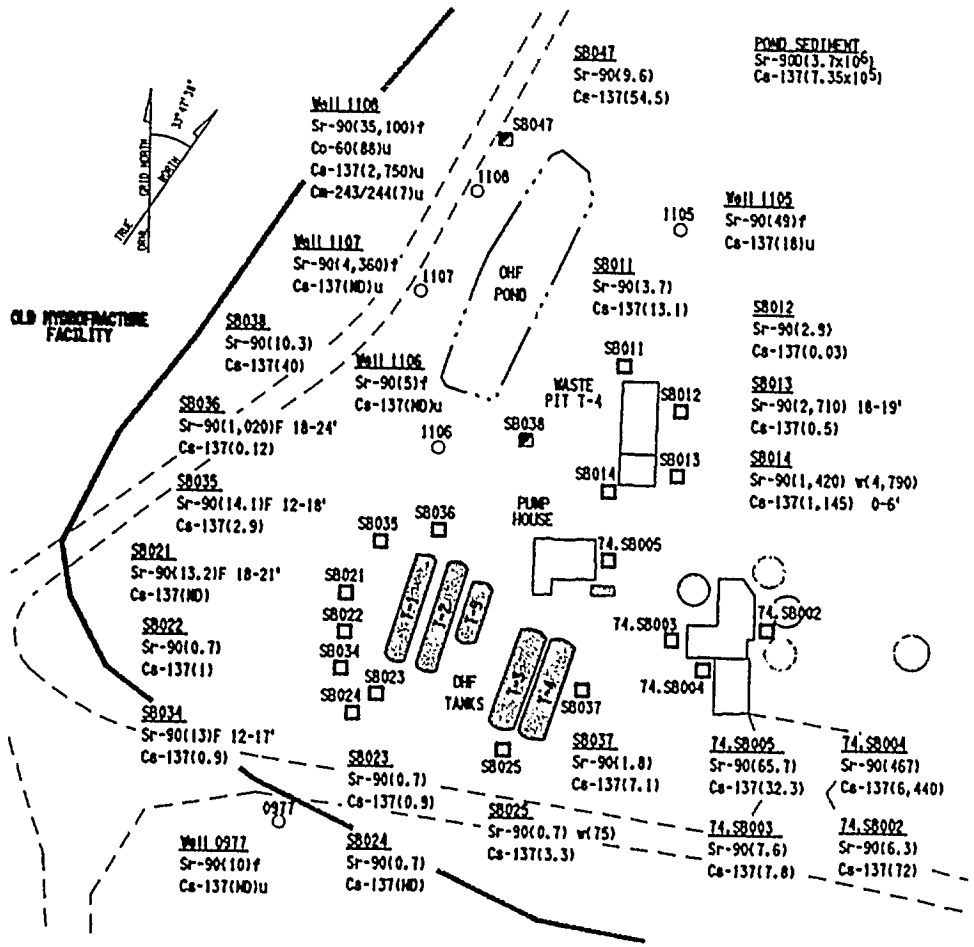
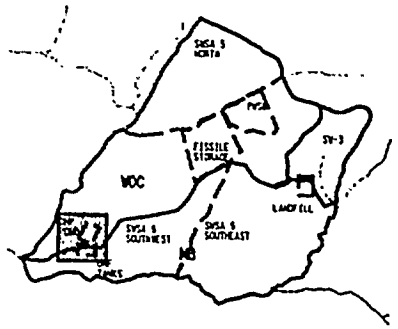


Fig. B2.3.46. Photograph of OHF waste storage tanks.

Description and history. The OHF tanks are underground storage tanks used during OHF operations to store liquid waste until it was ready to be blended with grout for hydrofracture injection. The tanks, designated T-1, T-2, T-3, T-4, and T-9, were used during both the experimental (1964–1965) and routine (1966–1979) waste injections. Table B2.3.30 summarizes the physical properties of each tank. The horizontal carbon steel tanks were placed in an open pit on a concrete pad at an approximate elevation of 768.5 ft msl. Crushed limestone was placed around the tanks to an approximate elevation of 775 ft msl, followed by compacted soil fill extending a minimum of 4 ft above the top of the tanks. Tanks T-1, T-2, and T-9 were installed in 1964, share a common pad, and are separated by 4-ft concrete walls. T-3 and T-4 were also installed on a common pad and separated by concrete walls. Each group of tanks was constructed with a specially-designed leak





WAG 5 KEY PLAN

LEGEND

- WAG 5 BOUNDARY
- GRAVEL ROAD
- SB011 — SOIL BORING WITH NUMBER
- SB047 — SOIL SAMPLING LOCATION W/ND. (HIGH EXPOSURE RATE)
- 1105 — WELL WITH NUMBER
- T-9 — TRENCH WITH NUMBER
- f — FILTERED WATER SAMPLE
- u — UNFILTERED WATER SAMPLE
- w — WATER
- ND — NOT DETECTED

SOIL CONCENTRATIONS - pCi/g

WATER CONCENTRATIONS - pCi/L

SCALE

0 25 50 FEET

0 5 10 15 METERS

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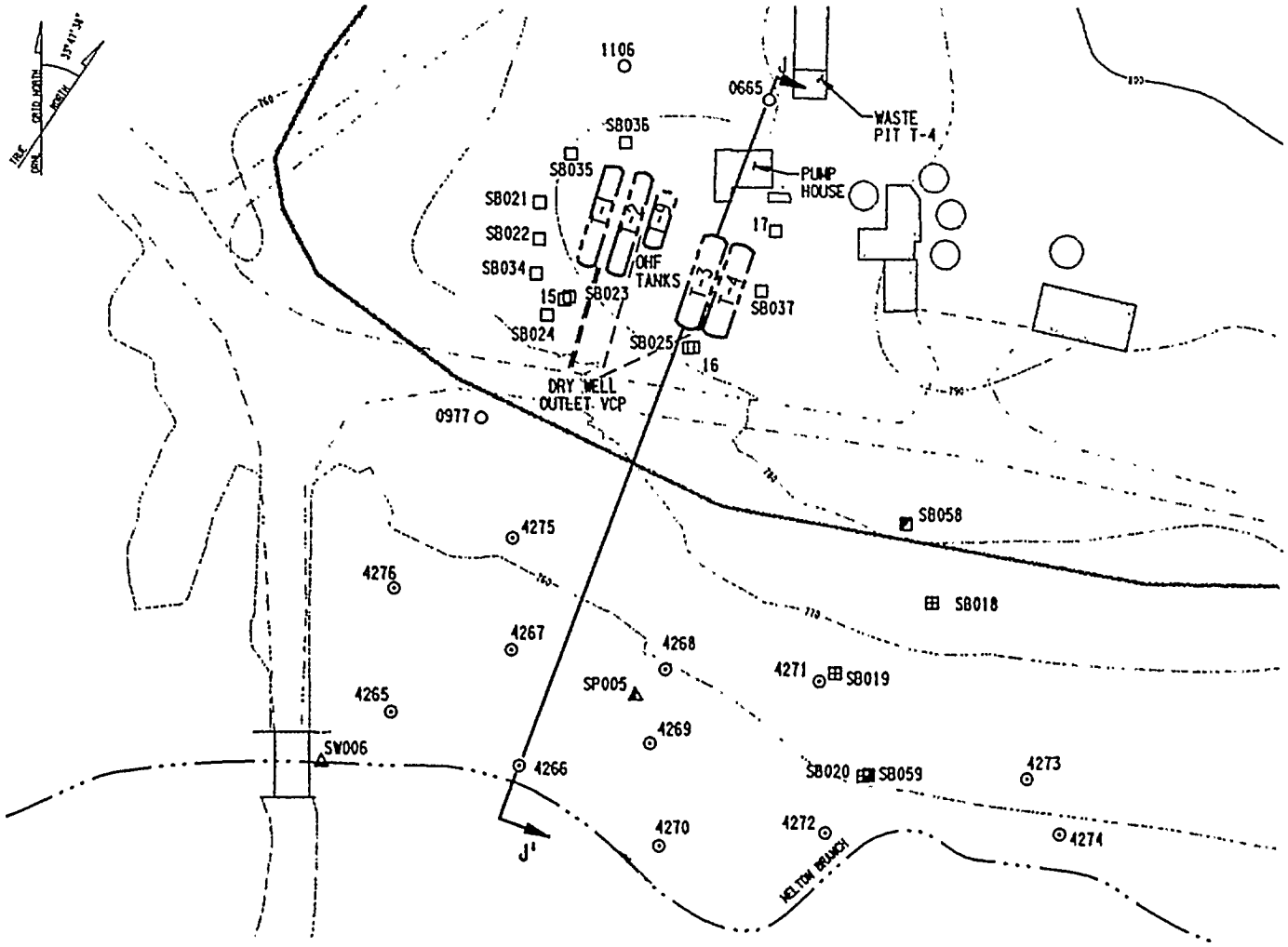
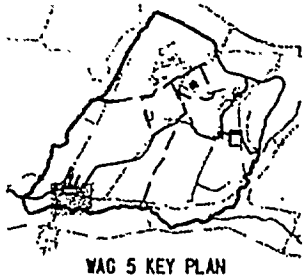
Fig. B2.3.44. Surface soil concentrations of Sr-90 and Cs-137 in the OHF area.





WAG 5 KEY PLAN

LEGEND

- WAG 5 BOUNDARY
- BUILDING
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- 1106 GROUNDWATER SAMPLING LOCATION W/NO (REGOLITH <30')
- SP005 SEEP SAMPLING LOCATION W/NO.
- SW006 SURFACE WATER LOCATION W/NO.
- SB013 VERTICAL SOIL SAMPLING LOCATION W/NO.
- SB059 SOIL SAMPLING LOCATION W/NO (MEDIUM TO LOW EXPOSURE RATE)
- SB058 SOIL SAMPLING LOCATION W/NO. (HIGH EXPOSURE RATE)
- SB018 AREAL SAMPLING LOCATION W/NO.
- 4272 DRIVE POINT SAMPLING LOCATION W/NO.
- OHF WASTE STORAGE TANKS W/NO.

Drainage Group: Melton Branch
Study Area: OHF Tanks
Sources: Tank leakage/contaminated soils

SCALE

0 25 50 FEET
0 5 10 15 METERS

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Fig. B2.3.45. OHF waste storage tanks plan view.

collection/leak detection system consisting of a perforated, horizontal pipe in the gravel leading to a dry well and extending up to the ground surface to allow for sampling. The tank excavations also have drain lines above the elevation of the leak detection pipe that prevent the pits from filling with water. These drain lines extend southwestward and terminate along the slope just above the gravel roadway directly south of OHF.

Table B2.3.30. OHF tank construction details

	T-1	T-2	T-3	T-4	T-9
Diameter (ft)	8	8	10.5	10.5	10
Length (ft)	44.1	44.1	42.1	42.1	23.8
Capacity (gal)	15,000	15,000	25,000	25,000	13,000
Liner	None	None	Rubber	Rubber	None
Depth to tank bottom (ft)	12	12	14.6	14.6	14

A complex system of piping and valves connects the tanks to the injection well and grout mixing facilities. In addition to waste fill and drain lines, the tanks are ventilated to the atmosphere through HEPA filters. A cathodic protection system designed to inhibit corrosion of the tanks was installed in 1968 and was working through at least 1990. A 1993 survey of the system (HARCO 1993) found that nine of the ten sacrificial anodes installed in the deep anode bed (a cased, 8-in.-diameter, 300-ft-deep hole 10 ft west of tank T-9) had been consumed. The remaining anode was still producing current but at a very low level; in effect, the corrosion protection system was no longer functioning. Soil sampling data from depths approximately equal to the base of the tank excavation did not encounter any contamination indicative of a large-scale leak from the tanks. Further evaluation of the OHF tanks is planned as part of the ORNL Inactive Tanks Remediation Program. This evaluation will address the need to reestablish cathodic protection in light of the decisions regarding the overall WAG 5 remedial action strategy (see Sect. 4 of Volume 1).

Wastes placed in the tanks after routine disposal operations commenced in 1967 were concentrated ILW solutions, primarily from the Gunite waste storage tanks in the ORNL main plant area (these tanks are being addressed as part of WAG 1). Radioactivity in the wastes was dominated by beta-gamma-emitting radionuclides, primarily ^{137}Cs and, to a lesser extent, ^{90}Sr; smaller amounts of other radionuclides, including ^{144}Ce, ^{60}Co, ^{106}Ru, and ^{198}Au were also present (de Laguna et al. 1971). Beginning in 1967, the injections also included alpha-emitting radionuclides, usually the transuranium isotopes ^{244}Cm and ^{239}Pu. Each injection involved a batch of waste with as much as 90,000 Ci of ^{137}Cs and 9,000 Ci of ^{90}Sr; TRU constituents, when present in the waste, were usually limited to quantities of less than 1 Ci, though occasionally much higher quantities were included (e.g., ILW injection 11 in 1972 contained 156 Ci of ^{244}Cm (ORNL/RAP-7 1987).

The tanks contain both aqueous and sludge components. Based on the 1988 sampling of the OHF tanks, a calculated total of 29,000 Ci (28,500 Ci sludge and 800 Ci in liquid) was determined to be present. Individual tank inventories for sludge are presented in Fig. B2.3.47.

Table B2.3.31. Waste characterization data for OHF waste storage tanks

Analytes	TANK LIQUIDS					TANK SLUDGES				
	T1	T2	T3	T4	T9	T1	T2	T3	T4	T9
Radionuclides (liquids: pCi/l, sludges: pCi/g)										
Cs-137	2.0E+9	3.8E+9	7.3E+9	8.1E+9	7.8E+9	1.1E+7	3.5E+7	3.5E+7	1.2E+7	1.1E+7
Co-60	<1.3E+6	<2.0E+6	9.7E+6	1.5E+6	1.6E+8	7.0E+6	1.7E+6	4.1E+6	1.6E+6	1.2E+6
Sr-90	9.2E+7	7.3E+7	8.1E+6	3.6E+7	9.7E+8	8.6E+8	3.2E+8	2.2E+8	5.9E+8	3.8E+8
Tritium	1.9E+6	5.7E+6	4.6E+6	3.0E+6	4.3E+6	7.0E+2	2.6E+3	2.1E+3	7.6E+2	9.2E+2
U-233	5.4E+6	4.9E+6	5.4E+4	6.6E+5	1.8E+7		2.2E+5	2.2E+5	1.9E+5	1.2E+5
Cf-252							4.9E+6	<5400		<5400
Pu-238						9.2E+5	8.4E+4	3.8E+5	5.9E+5	2.7E+5
Pu-239						1.8E+5	1.4E+5	1.4E+5	1.2E+5	1.2E+5
Cm-244							<5400	4.9E+6	5.7E+6	2.6E+6
Am-241									2.2E+5	
Th-228									1.6E+4	
Eu-152/154						2.5E+6	6.1E+5	1.4E+6	9.3E+5	5.9E+5
Metals (liquids: mg/l, sludges: mg/kg)										
Cr	0.24	0.44	14	12	0.4	134	184	69	102	<10
Hg	0.06	0.10		1.9	3.4	74	70	40	585	39
Pb	<1	<1	<0.5	<1	<1	863	354	295	512	543
pH	9.3	9.4	12.7	11.7	8.8	NA	NA	NA	NA	NA
Waste Classification										
RCRA Hazardous*			X	X	X	X	X	X	X	X
TRU						X	X	X	X	X

* *Based on total metals analysis*

Source: Autrey et al. 1989

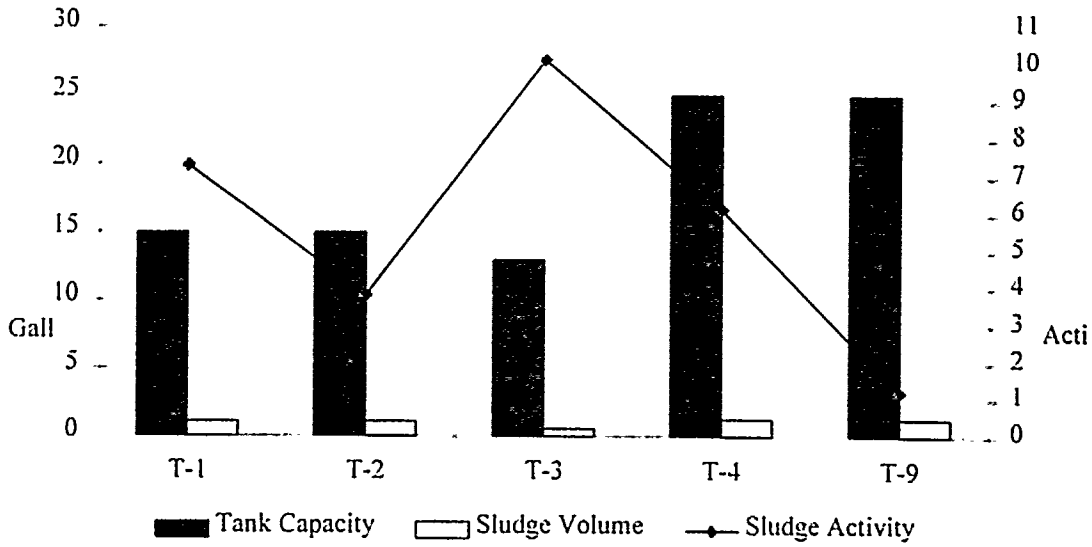


Fig. B2.3.47. OHF storage tanks inventory estimates.

Samples of aqueous liquids and sludge were obtained from the OHF waste storage tanks in 1988 as documented by Autrey et al. (1989). The results, summarized in Table B2.3.31, indicate that the sludges contain a variety of radiological and inorganic chemical constituents, including ^{137}Cs, ^{90}Sr, ^{60}Co, ^{233}U, ^{23x}Pu, ^{244}Cm, ^{241}Am, mercury, lead, and chromium. Analyses of tank liquids, all of which had a high pH (>9), identified chromium and mercury and low levels of a number of organic constituents, including chlorobenzene, toluene, TCE, and various phthalate esters (e.g., di-n-butyl phthalate, diethylphthalate). Based on the concentrations of curium, plutonium, and other TRU constituents, Autrey et al. (1989) stated that the sludges in all five tanks would be considered TRU waste. A determination that the sludges were RCRA characteristic waste was also provided, based on the total metals analyses for the sludges (extraction or TCLP tests were not conducted).

Previous investigations. The OHF characterization work completed by Huang et al. (1984) included a walkover survey of the storage tank area and collection of soil samples from three soil borings around the tanks with (sampling locations are shown in Fig. B2.3.45). The borings were continuously sampled to depths of 18 ft in two of the borings and 8 ft in the third. Four samples were selected for ^{137}Cs analysis based on gamma screening; the only subsurface sample, collected from a depth of 6 to 8 ft near tank T-4, had 8.9 pCi/g, higher than background but not indicative of a major spill or release. A deeper sample (16 ft) from the same location had elevated gamma but was not selected for isotopic analyses.

The dry wells installed for leak detection monitoring in the tank excavation have been periodically sampled. Ford (1991) summarized the results of monthly sampling conducted between September 1990 and March 1991; gross beta analyses showed activities ranging from 270 to 10,000 pCi/L. These data indicate potentially high levels of beta contamination in the dry wells and tank excavation. Without tank integrity (leak) testing, it is not possible to determine with confidence the source of the contamination. Although the tanks are a likely source, it is also possible that the dry well contamination is from residual contamination in the limestone and soil materials used to backfill the tank excavation. The source of this residual contamination is also speculative but may

include incidental spills or pipeline leaks during operations, overfilling of the tanks, or an unusually high water table (groundwater in this area has fairly high ^{90}Sr contamination).

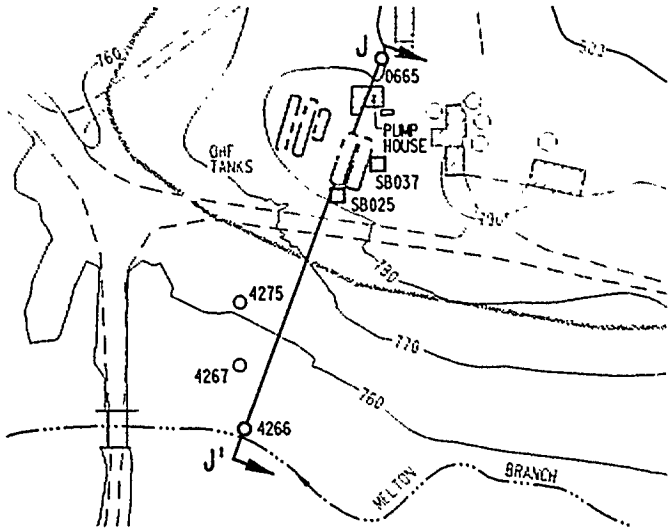
RI sampling summary. Figure B2.3.45 shows the RI sampling locations associated with waste tanks and the cross-section location used to depict the hydrologic model for the area. Nine soil borings were sampled to bedrock refusal along the perimeter of the OHF tank area. Two sample intervals (maximum of 6-ft composite of any interval selected) from each boring were selected for off-site TCL/TAL and radiological analyses. The remaining intervals were screened at the CSL for VOC, gross alpha, gross beta, ^{14}C, and tritium. Groundwater from four of the nine soil borings was sampled and analyzed at the CSL for radiological constituents.

The monitoring wells closest to the OHF storage tanks are 0977 (75 ft to the southwest) and 1106 (45 ft north). Both wells were sampled during the high and low base sampling rounds and were included in the monthly water level measuring activities. As part of the WAG 5 source area investigation (Bechtel 1994b), 12 drive points were installed and sampled in the Melton Branch floodplain south of OHF. Interpretations based on the hydrologic model for the area indicate that some of these drive points intercept groundwater that has passed beneath the OHF storage tanks.

Hydrologic model. Figure B2.3.48 depicts the hydrological model (Section J-J') for the OHF waste tanks. The tanks lie astride the surface water drainage divide between Melton Branch and White Oak Creek. Surface runoff drains from the tank area in a semiradial pattern to the north, west, and south. Runoff to the north is then directed westward and passes south of the OHF pond to a culvert that discharges to the White Oak Creek floodplain. Runoff to the south flows into Melton Branch. The presence of an active stormflow zone was not confirmed but may be significant along the south-facing slopes of the tank area. Given the presence of fill materials (and gravel) immediately above the tanks, higher infiltration rates are expected due to greater vertical permeabilities associated with these materials; an active stormflow zone immediately above the tanks is not likely.

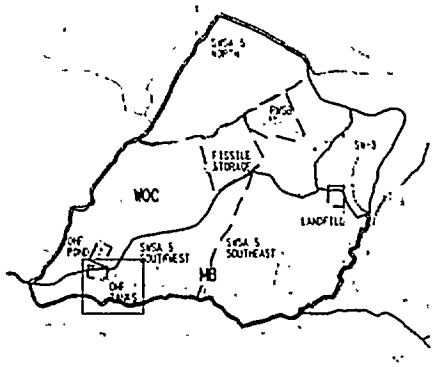
Groundwater is expected to follow a southwesterly flow path in response to the hydraulic gradients as determined from the 1993 water level data. As shown in the model, the depth to groundwater beneath the tanks ranged from a minimum of about 20 ft during the wet season to as much as 30 ft during the dry season. Consequently, there was at least a 5- to 7-ft-thick vadose zone between the base of the tank excavation and the water table. The tank excavation has drains to prevent ponding of water and thus would be expected (under present conditions) to have no hydraulic influence on the water table in the area. These drains also make it unlikely that the tank excavation would ever fill to the extent that a release to the stormflow zone could occur. Any release from the tanks would therefore be expected to migrate downward to the water table, after which it would migrate westward toward White Oak Creek.

Based on HSPF modeling, the average annual cumulative water discharge from the OHF tanks area is 3409 m^3. From a water balance perspective, groundwater comprises approximately 65% of the discharge, 28% is stormflow, and the balance is surface runoff. The stormflow contribution is probably somewhat smaller than indicated, given the extensive reworking of the OHF area soils due to construction activities; however, area-specific modeling was not conducted.

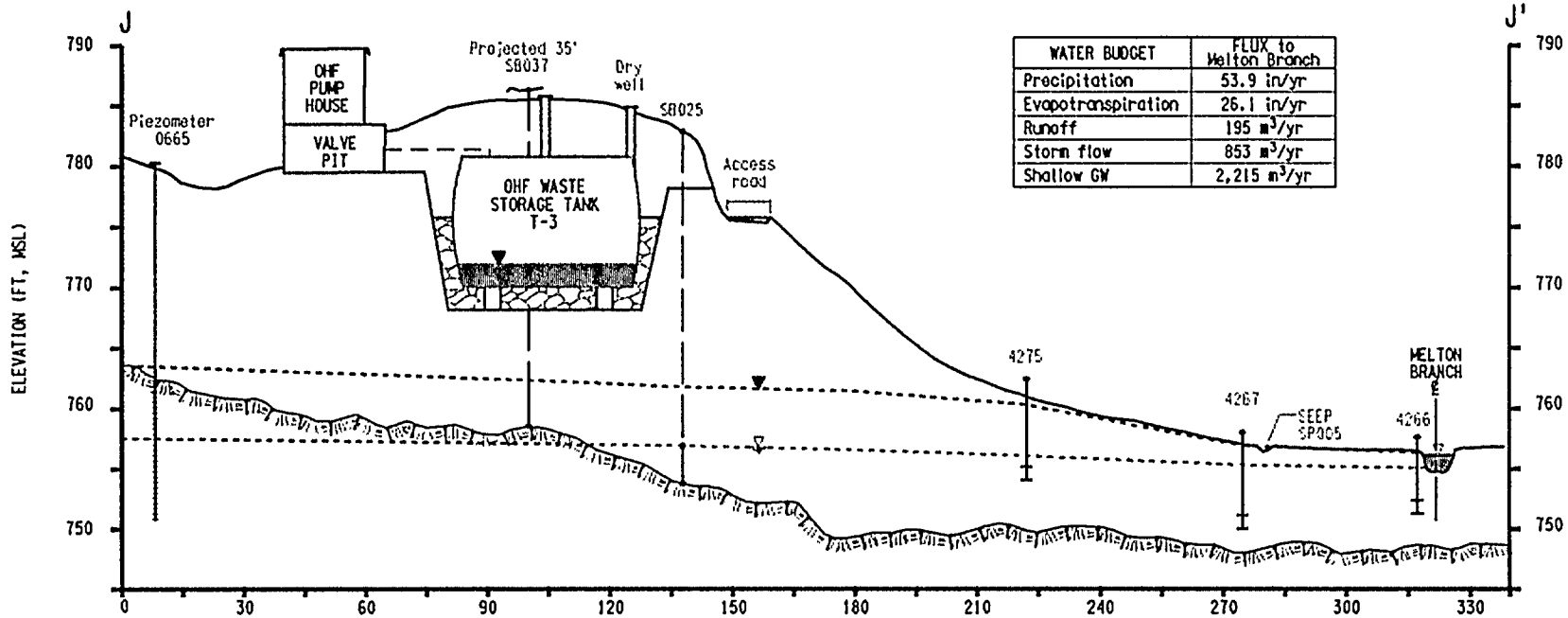


LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0526 — WELL, WELL NO., SCREEN SECTION
- LS GRAVEL
- SB026 — SOIL BORING LOCATION W/NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX to Melton Branch
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	195 m^3/yr
Storm flow	853 m^3/yr
Shallow GW	2,215 m^3/yr

DISTANCE (FT)
VERTICAL EXAGGERATION: 3X

Fig. B2.3.48. Hydrologic model for the OHF waste storage tanks (Section J-J').

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Nature and extent of contamination. Table B2.3.32 lists contaminants of concern detected in the soils and groundwater around the OHF tanks. The contaminants most likely to indicate a release from the tanks, based on the tank inventory data, are ^{137}Cs, ^{90}Sr, ^{60}Co, and transuranic isotopes. Of these, ^{137}Cs, ^{90}Sr, and ^{238}Pu were detected but only in isolated occurrences. The soil borings drilled around the tanks confirmed previous conclusions that there has not been a significant release of contamination from the tanks (Table B2.3.33). Soils data show that the backfill and native regolith materials in the vicinity of the tanks are cleaner than most of the soils elsewhere in the OHF area.

Contamination in the surface/near-surface soil samples was limited to three locations with slightly elevated ^{137}Cs (3 to 7 pCi/g) and one with ^{238}Pu at a concentration of 1.6 pCi/g. None of the surface/near-surface soils had elevated ^{90}Sr. Radium-226, ^{228}Ra, ^{228}Th, and ^{40}K were all detected in each soil sample at concentrations at or slightly above 2 times the mean background value and do not appear to indicate widespread tank leakage or risk. Similar to findings from borings adjacent to the waste pit and pump house, the presence of low-level, surface/near-surface soil contamination is probably due to *de minimis* spills during operations rather than any large-scale releases or areas of contamination.

Table B2.3.32. Contaminants of concern detected in OHF Tank area

	OHF TANKS	
CONTAMINANT	SOIL	GW
^{137}Cs	X	
^{212}Pb		X
^{238}Pu	X	
^{90}Sr	X	X
Tritium	X	X

Higher levels of soil contamination (mostly ^{90}Sr) were encountered in several of the borings at depths below 18 ft and in one instance from a sample collected over the 12- to 18-ft interval. All of these samples included soil (regolith) materials from below the water table. The correlation between depth of contamination in the regolith and the occurrence of the water table was also observed in the waste pit soil borings. Groundwater in the tank area has also been contaminated from the upgradient SWSA 5 South source area, and the contamination in these deeper soil samples was attributed to the partitioning of groundwater contaminants to the aquifer matrix materials rather than tank leakage.

Table B2.3.33. Analytical data summary for selected radionuclides in the OHF tanks area

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Gross Beta	(β) Tritium	(β) Sr-90	(β−γ) Cs-137	(β) Ra-228	(α) Th-228	(α) U-233/234	(α) Pu-238	(α) Am-241
SOIL (pCi/g)													
Background Reference				9.92	42	0.084	1.94	1.4		1.5	2	0.166	0.08
	SB021	12/14/93	0-6	16	53	9.4		0.5					
	SB021	12/15/93	6-12	6.2	45.2	1.6	0.57	-	2.1	1.35	0.97	-	0.25
	SB021	12/15/93	12-18	-	53	10.5							
	SB021	12/15/93	18-20.9	7.5	46.1	58.8	13.2	-	1.06	1.34	0.86	0.09	-
	SB022	11/17/93	0-6	7.5	21.4	1.4	0.75	1.03	1.2	1.33	1.07	-	0.05
	SB022	11/17/93	6-12		42.1	-							
	SB022	11/19/93	16-19.8	6.1	22	0.9	-	-	1.08	1.34	0.74	-	-
	SB023	12/3/93	0-6	18.4	35.7	3.07	0.7	0.94	2.4	1.54	0.63	1.6	0.42
	SB023	12/3/93	6-12	-	61.3	1.4							
	SB023	12/3/93	12-18	14.6	45	74.6	0.48	-	1.4	1.41	0.86	-	0.19
	SB024	12/6/93	0-6	-	37.6	8.08							
	SB024	12/6/93	6-12	10.5	56.2	58	0.76	-	1.9	1.98	0.43		0.22
	SB024	12/7/93	12-18	44.1	64.2	627							
	SB024	12/7/93	18-20	26.8	81.5	1625							
	SB025	12/9/93	2-8		34.3	5.6		3.27					
	SB025	12/9/93	8-14	9.4	32.1	2.9	0.72	0.28	-	1.45	0.77	-	0.59
	SB025	12/9/93	18-23.3	16.4	33.8	8.14	-	-	-	0.77	0.94	-	0.31
	SB034	11/22/93	0-6	5.5	26.6	1.35	0.56	0.91	1.22	1.17	1.21	-	- -
	SB034	11/23/93	6-12	54.4	86.6	-							
	SB034	11/23/93	12-17.7	6.4	50.2	56.5	13	-	1.07	1.05	0.71	-	-
	SB035	12/16/93	0-6	7	27.3	1.09	0.9	2.85	1.1	1.35	0.9	0.09	0.06
	SB035	12/17/93	6-12	-	30.5	-							
	SB035	12/17/93	12-17.4	5.7	24.8	0.6	14.1	0.03	1.02	1.3	0.88	-	0.04
	SB035	12/17/93	18-20	-	52								
	SB036	12/21/93	0-6	-	65	1.8							
	SB036	12/21/93	6-12	-	27.3	2.3							
	SB036	12/21/93	12-18	8	24.9	1.3	3.63	0.12	1	1.19	0.74	-	0.06
	SB036	12/21/93	18-24	9.6	1760	37.8	1020	-	1.03	1.09	0.79	-	-
	SB036	12/21/93	24-30	9.4	1150	62.4	681	-	1.2	1.45	1.15	0.08	-
	SB037	11/8/93	0-6	6.3	29.8	1.7	1.8	7.07	1.4	1.54	1.11	0.09	0.06
	SB037	11/8/93	6-12	13.9	43.4	1.4							
	SB037	11/8/93	12-18	-	60.1	2.9							
	SB037	11/9/93	18-24	-	48.2	2.6							

GROUNDWATER (pCi/L)			U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference			5.2	3.2	16	7.4	2400	1080	10.4	3.6	12.4	5.4								
	SB024	12/8/93	14		19603		1.1E+7													
	SB025	12/10/93	26	-	325.6		6.2E+5		252	75.1										
	SB036	12/22/93	24		5748		1.2E+6		15414	558	0.17									
	SB037	11/10/93	25		3551		9.4E+6													
	0977	4/20/93	3-19.8	2.56	-	26.2	22.4	4.6E+6	4.6E+6	11.1	9.73	-	-					0.76	-	-	-	-	-
	0977	11/6/93	3-19.8	14.4	-	23.9	20.1	5.4E+6	6.0E+6	7.7	8.33	-	-	-	-	-	-	-	-	-	-	-	-

Notes: 1. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfiltered/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emmiter

B2_T3_33 XLS

OHF impoundment (7852a)

Figure B2.3.41 shows the location of the OHF impoundment (pond) on the western edge of the OHF area, approximately 350 ft from White Oak Creek. Figure B2.3.49 is a photo showing general conditions at the impoundment in November 1994.

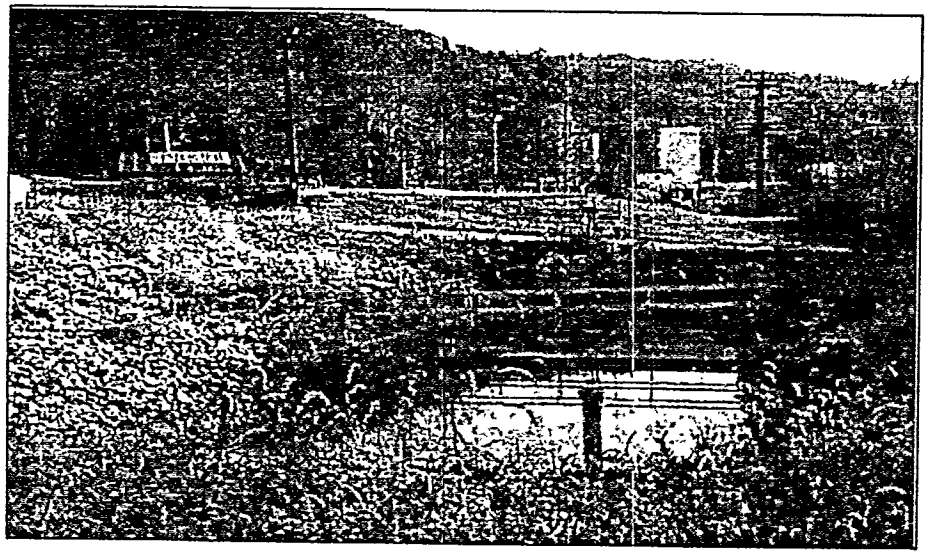


Fig. B2.3.49. Photograph of OHF impoundment.

Description and history. The OHF pond was constructed in 1963 with bottom dimensions of 20 by 100 ft, a depth of 5 ft, and a capacity of 100,000 gal. The sides are lined with limestone riprap (6 to 12 in. in diameter) at a slope of 1:1.5. Inflow to the impoundment was via two buried pipelines with outlets in the southeast corner. One of these is an 18-in.-diameter vitrified clay pipe (VCP) originating from the injection well cell; the other is an 8-in.-diameter VCP originating in waste pit T-4. The presence of an asphalt liner specified in engineering drawings was not observed during RI sampling activities or during previous investigations (Stansfield and Francis 1986; Huang et al. 1984). An overflow standpipe at the north end of the pond prevents over-topping of the impoundment berms. The drain consists of a vertical concrete pipe that extends downward through the bottom of the impoundment and then westward for a distance of approximately 50 ft to its termination at the edge of the White Oak Creek floodplain.

The OHF pond was used between 1965 and 1979 as a temporary holding basin for waste solutions during the initial experimental water and grout injections; for temporary storage of decontamination water from the cleanup of the injection pumps, piping, and other systems; and as a potential emergency storage receptacle for radioactive grout (this reportedly never occurred). In the winter of 1984–85, the impoundment received drilling fluid and drill cuttings from an exploratory core boring that penetrated radioactive grout sheets underlying the OHF site. Approximately 30 ft^3 of sediment from the 540-ft-deep exploration hole was also placed in the OHF pond. The total volume of the impoundment sediment has been calculated to be approximately 1,950 ft^3 based on a measured average thickness of 11 in. (Stansfield and Francis 1986).

The OHF pond has some of the highest external gamma exposures currently found on WAG 5, and both the surface water and sediment are contaminated. Most of this contamination is caused by high concentrations of ^{137}Cs, ^{90}Sr, and ^{60}Co in the sediment. Characterization data for the pond water and sediment were generated by several previous studies; these data are discussed below and summarized in Table B2.3.27.

Previous investigations. Huang et al. (1984) performed an in-depth walkover radiological survey of the pond area. Surface water and sediment samples were collected from five locations in the impoundment and used to calculate the radionuclide inventory presented in Table B2.3.34. The Huang et al. (1984) results showed that the water, sediment, and underlying clay layer in the impoundment are all contaminated with fission and activation products as well as alpha-emitting transuranics. Samples of algae from the impoundment contained ^{137}Cs concentrations up to 2 μCi/g of dried algae. In addition, Huang et al. (1984) analyzed several soil cores from the pond area (Fig. B2.3.41) and concluded that although ^{60}Co, ^{90}Sr, and ^{137}Cs concentrations were elevated in one 4- to 6-ft interval downgradient of the impoundment, there was little evidence of significant leakage.

In November 1984 and February 1985, Stansfield and Francis (1986) collected sediment samples from north, south, and central locations within the impoundment to confirm the Huang et al. (1984) radionuclide inventory calculations and determine whether the sediments possessed hazardous waste characteristics as defined by RCRA. The subsequent radionuclide inventory calculations did not differ greatly from Huang et al. (1984) (Table B2.3.34) and, when the analytical detection limits were low enough, the concentrations of the RCRA regulated constituents (via EP toxicity tests) were well below the RCRA maximum allowable concentrations.

In May 1985, Stansfield and Francis (1986) collected a single water sample (unfiltered) from the center of the impoundment and had it analyzed for heavy metals, herbicides/pesticides, PCBs, and radionuclides. The analyses indicated that arsenic, barium, cadmium, chromium, mercury, and lead, as well as pesticides and herbicides, were all below Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), which led them to conclude that in terms of nonradiological parameters, the impoundment water quality was surprisingly good. Like Huang et al. (1984), Stansfield and Francis (1986) found that in terms of total activity, ^{137}Cs and ^{90}Sr were the primary contributors, followed by ^{60}Co and, to a much lesser extent (<1%), ^{241}Am and $^{234/238}U$. Huang et al. (1984) also encountered a significant quantity of ^{154}Eu, which was not detected by Stansfield and Francis (1986).

To determine whether contaminants were migrating to the surrounding groundwater, groundwater samples were collected quarterly at the four 1100-series wells installed around the impoundment in 1985 (Francis and Stansfield 1986), again in 1987 (Francis and Sealand 1987), and then again in 1988 (Solomon et al. 1989) The analytical focus of the first two sampling rounds was on radionuclides, RCRA metals, and other constituents contained in EPA's primary drinking water standards; the 1988 round focused on hazardous organic compounds. Results of the sampling efforts all concluded that groundwater within the area has been contaminated with radionuclides, primarily ^{90}Sr, ^{137}Cs, ^{60}Co, ^{3}H, and ^{14}C. Several organic compounds were also detected; however, the presence of these contaminants was attributed to the upgradient SWSA 5 South trenches.

A tracer study performed by Solomon et al. (1989) revealed that ^{85}Sr added to the impoundment water was detected in downgradient groundwater well 1108 (on the northwest side of the

Table B2.3.34. Inventory estimates for OHF pond sediment

Primary Contaminants	Stansfield and Francis (1986)[A]		S.F. Huang (1984)[B]		WAG 5 RI (1993/94)[C]	
	Concentration (pCi/g)	Inventory (Ci)	Concentration (pCi/g)	Inventory (Ci)	Concentration (pCi/g)	Inventory (Ci)
^{134}Cs	<540	0.01	2700	0.22	--	--
^{137}Cs	3,375,000	64	4,860,000	388	3,720,000	62
^{154}Eu	<6,129	<0.01	10,530	1	--	--
^{234}U	<899.1	<0.01	--	--	--	--
^{238}U	<16,524	<1	6.21	<0.01	15.8	<0.01
^{241}Am	<540	<0.01	75.6	<0.01	882	0.01
^{60}Co	16,416	0.31	19,980	1.6	6,276	0.1
^{90}Sr	1,047,600	20	261,900	21	735,000	12.2
$^{243,244}Cm$	--	--	--	--	244,000	4.06
^{238}Pu	--	--	--	--	1,220	0.02
$^{239/240}Pu$	--	--	--	--	639	0.01
^{226}Ra	--	--	--	--	2,400	0.04
^{228}Ra	--	--	--	--	2,900	0.05
^{228}Th	--	--	--	--	174	<0.01
^{230}Th	--	--	--	--	309	<0.01
^{233}U	--	--	--	--	1,580	0.03
Total α		<1		<0.01		4.2
Total β–γ		84.3		411.8		74.4
Grand Total		85		411.8		78.6

Source: Adapted from R. R. Shoun (1987), "Environmental Data Package for ORNL Waste Area Grouping (WAG 5), Solid Waste Storage Area -5 (SWSA-5)."

[a] Sediment concentrations by R.G. Stansfield and C. W. Francis, in Francis and Stansfield (1986), are on dry-weight basis and represent a mean of three sediment samples taken from the north, center, and south sections of the impoundment. Inventory calculated by Stansfield and Francis was based on a total volume of sediment equal to 5.5×10^4 L, a wet bulk density of 1.2 kg/L, and a moisture content of 71%.

[b] Sediment concentrations by S. F. Huang are on a wet-weight basis and represent a mean of five sediment samples (except the Eu-154 analysis, which is from a single sediment sample) taken from the center of the pond from a southwest to northeast direction. Inventory calculated by Huang was based on a total volume of sediment equal to 3.7×10^4 L and a wet bulk density of 2.16 kg/L.

[c] Sediment concentrations by the WAG 5 RI are on the dry-weight basis and represent a composite of three sediment sampling locations from the north, center, and south sections of the impoundment. Inventory calculated by the RI Team was based on a total volume of sediment equal to 4.6×10^4 L (average calculated from Francis and Stransfield and Huang volumes), and a wet bulk density of 1.25 kg/L (measured in the field). No sediment moisture measurement was performed; therefore, a sediment moisture content of 71% obtained by Francis and Stransfield 1986 was used in the calculation.

Abbreviations: -- Not reported

impoundment) in approximately 50 days, with a peak concentration in about 100 days. The observed transport velocity was calculated to be on the order of 0.15 ft/day. Using a strontium retardation factor cited by Spalding and Munro (1984) for a similar soil, values of 5.4 ft/day and

0.018 ft/day were determined for seepage velocity and effective velocity (respectively). This indicated that ^{90}Sr was moving from the impoundment to surrounding groundwater (in addition to the release of ^{90}Sr to groundwater from the upgradient SWSA 5 South source areas). Contaminant migration was evidently occurring along preferential pathways, most likely fractures in the underlying saprolite and bedrock in the vicinity of well 1108.

The depth of ^{90}Sr contamination under the OHF pond was investigated by collecting samples from two angled cores drilled to bedrock beneath the impoundment (Francis and Hyder 1987). Results indicated that the bedrock beneath the impoundment was not significantly contaminated. Analysis of soil samples from the core again indicated that there has been seepage from the impoundment at the northwestern side and the greatest impact is on soils less than 20 ft deep.

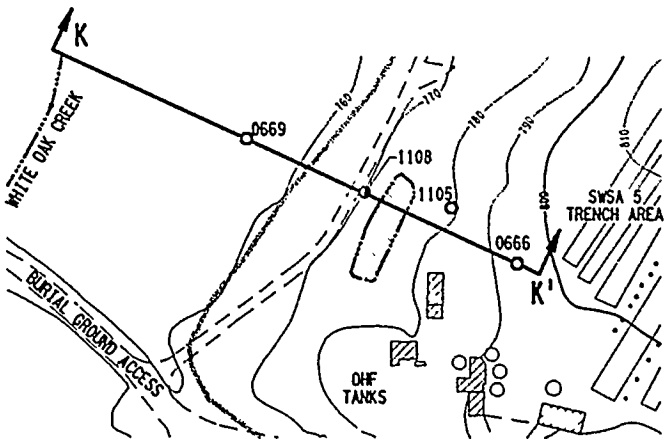
RI sampling summary. Figure 2.3.41 shows RI sampling locations associated with the OHF pond and the cross-section location used to depict the hydrologic model. RI samples from the impoundment included

- an initial radiological screening sediment sample collected at the southeast corner of the impoundment, adjacent to the pipelines leading to waste pit T-4 and the injection well cell;
- a surface water grab sample and discrete sediment sample from the center of the impoundment; and
- a composite sediment sample of the 0- to 6-in. interval taken from the northern, center, and southern portions of the impoundment.

Analyses were for TCL/TAL, toxicity characteristic leaching procedure (TCLP), and radiological constituents. Two near-surface (0 to 2 ft) USRADS soil samples (SB038 and SB047) were collected from the southeast and northwest rim corners of the OHF impoundment and analyzed for TCL/TAL and radiological constituents. Groundwater encountered during soil boring was sampled and analyzed for radiological contamination.

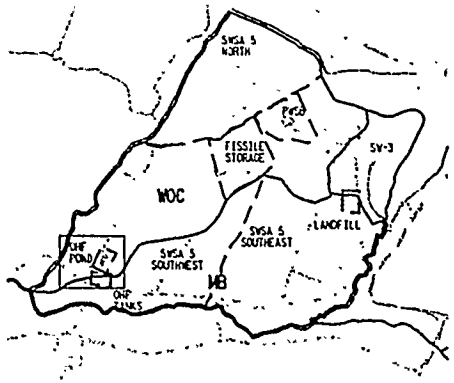
RI groundwater samples were collected during wet and dry seasonal conditions from the four 1100-series monitoring wells on the perimeter of the OHF pond (1105–1108). Groundwater sample analyses included both CSL screening and off-site TCL/TAL and radiological analyses (selected samples only).

Hydrologic model. Figure B2.3.50 depicts the hydrologic model (Section K-K') for the OHF impoundment and downgradient areas. The pond area receives runoff, stormflow, and groundwater flow from upgradient areas, including waste pit T-4 and portions of SWSA 5; however, the impoundment may be hydrologically isolated due to an asphalt liner that was designed (but never verified) to be sprayed along the bottom of the impoundment. Surface runoff from areas upgradient of the pond flows westward but is diverted around the pond itself via a perimeter diversion ditch.



LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 1105 — WELL, WELL NO., SCREEN SECTION
- IMPOUNDMENT SEDIMENT
- VITRIFIED CLAY PIPE



WAG 5 KEY PLAN

WATER BUDGET	FLUX to White Oak Creek
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	1,797 m^3/yr
Storm flow	2,010 m^3/yr
Shallow GW	2,766 m^3/yr

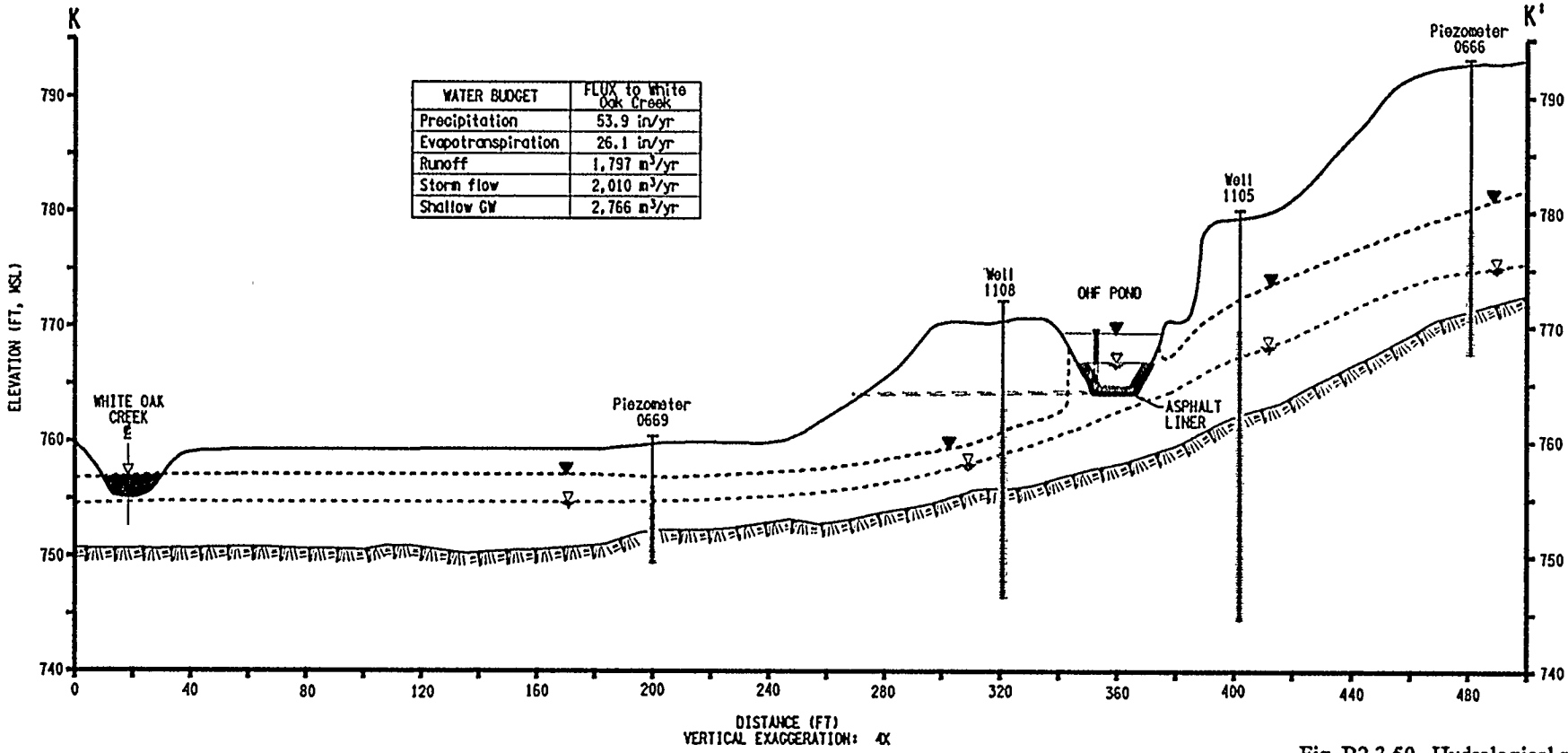


Fig. B2.3.50. Hydrological model for the OHF pond (Section K - K').

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Runoff eventually enters a culvert that leads to the western side of the road and White Oak Creek floodplain.

Although the stormflow zone in the vicinity of the OHF pond was not investigated during the RI, an active zone should be present in the up-slope areas (i.e., between the pond and SWSA 5 South trenches) and areas to the north and south of the pond. Some of the stormflow from upgradient areas may actually flow into the pond, depending on the depth of the zone and how much is intercepted by the pond's perimeter diversion ditch. The riprap along the pond slopes should not restrict discharge.

Groundwater flow in the OHF pond area is predominantly westward as determined from the 1993 water level data. The section view shows that during wet weather conditions, the water table intersects the impoundment. A longitudinal cross section through the impoundment parallel to gradient (not shown) indicates that only the north end of the impoundment is in direct contact with groundwater. This hydraulic connection has significant implications with regard to contaminant release and transport, given the high levels of contamination in the surface water and sediment of the pond. As discussed above, previous studies have attributed groundwater contamination in the vicinity of the pond to leakage from the northwest corner of the impoundment.

During drier seasonal conditions, the water table appears to drop below the impoundment. The absence of a direct connection was shown during a three-month period in 1993 (July–September). The impoundment elevation rose approximately 0.2 ft during this time, while water levels within the surrounding monitoring wells (1100-series) dropped an average of 0.9 ft. July–September were among the drier months of the year; the rise in water level in the pond was attributed to short-duration, high-intensity rainfall events. Away from the pond, this precipitation primarily served to replenish soil moisture and/or was lost to evapotranspiration.

Based on HSPF modeling, the average annual cumulative water discharge from the OHF pond area is approximately 6600 m^3; groundwater contributes approximately 42% of the discharge from the area, with stormflow and surface runoff each contributing about 30%.

Nature and extent of contamination. Sampling of surface water and sediment in the OHF pond identified a large number of contaminants of concern in the pond surface water and sediment as well as nearby groundwater and soils (Table B2.3.35). Table B2.3.36 (a and b) presents location and/or sample-specific summaries.

RI sampling results were consistent with the findings from previous investigations of the OHF pond area. The primary radiological contaminants detected within all media were ^{137}Cs, ^{90}Sr, and ^{60}Co; uranium and transuranics were detected less frequently and at lower concentrations. The primary source of contamination is the impoundment sediment, in which ^{137}Cs, ^{90}Sr, ^{60}Co, $^{243/244}Cm$, ^{241}Am, ^{238}Pu, $^{233/234}U$, and $^{239/240}Pu$ were all detected at high concentrations (Table B2.3.34).

The greatest levels of sediment contamination were detected in a discrete sample collected for CSL radiological screening analyses from the southeast corner of the impoundment, directly in front of the outlets for the drain lines originating in waste pit T-4 and the injection well cell. The ^{137}Cs concentration in this sample, 12,800,000 pCi/g, was the highest of any collected to date from the impoundment. The RI composite sample had a ^{137}Cs concentration of 3,700,000 pCi/g, comparable to historical sampling results from Stansfield and Francis (1986) and Huang et al. (1984). The CSL

Table B2.3.36a. Analytical data summary for selected alpha emitting radionuclides in the OHF impoundment

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Ra-228	(α) Th-228	(α) U-233/234	(α) Pu-238	(α) Pu-239/240	(α) Am-241	(α) Cm-243/244
IMPOUNDMENT SEDIMENT (pCi/g)											
Background Reference											
Sed Composite		2/15/94	0-0.5	80700	2900	174	1580	1220	639	882	24400
Sed Discrete		12/3/93	0-0.5	29491							
Historical Samples											
(b) Pond Center		2/20/85	0-0.5	918							
(b) North End		2/20/85	0-0.5	1134							
(b) South End		2/20/85	0-0.5	6483							
(b) Sed Composite		9/7/83	0-0.5					324	143	75.6	4320
IMPOUNDMENT SURFACE WATER				U F	U F	U F	U F	U F	U F	U F	U F
Background Reference				9	6	2	2				
Pond Water		12/3/93	0-1	6380 351	- -	0.88 1.07	102 101	0.316 0.33	0.506 -	0.392 0.226	16.2 8.6
Historical Sample											
(b) Pond Water		5/8/85	0-1	297				4.59	1.4	241	183.6
SOIL (pCi/g)											
Background Reference				9.92		1.5	2	0.166	0.06	0.08	2.8
SB038		12/16/93	0-2.0	9.11	1.12	1.41	0.83	0.12	0.06	0.04	0.365
SB047		12/3/93	0-2.0	12.2	1.11	1.48	0.87	-	-	0.08	-
GROUNDWATER (pCi/L)				U F	U F	U F	U F	U F	U F	U F	U F
Background Reference				5.2 3.2							
1105		5/5/93	9.5-29.2	- -							
1105		10/26/93	9.5-29.2	- -	- -	- -	- -	- -	- -	- -	- -
1106		5/3/93	6-22.3	- 2.5			- -	- -	- -	- -	- -
1106		10/26/93	6-22.3	- -	- -	- -	- 0.18	0.54 0.65	- -	- -	- -
1107		5/4/93	6-20.2	127 113							
1107		10/27/93	6-20.2	4.54 -	302 -	- -	- 0.35	- -	- -	- -	- -
1108		5/6/93	8-20.1	472 457.4							
1108		10/27/93	8-20.1	193 159	- -	0.93 0.55	14.1 1.17	0.23 -	0.23 0.47	0.19 -	7.08 -
Historical Samples											
(a) 1107		6/87	6-20.2	<54							
(a) 1108		6/87	8-20.1	<54							
(a) 1105		2/87	9.5-29.2	<27							
(a) 1106		2/87	6-22.3	<27							
(a) 1107		2/87	6-20.2	148.5							
(a) 1108		2/87	8-20.1	<54							

Notes:
1. Historical data references:
   (a) C. W. Francis & O. M. Sealand (July 1987) "Geohydrologic Investigations at the OHF and 3513 Impoundments"
   (b) Stansfield and Francis (Sept. 1986) "Characterization of the Old Hydrofracture Facility (OHF) Impoundment"
2. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
3. Abbreviations: U/F = Unfiltered/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emitter

Table B2.3.36b. Analytical data summary for selected beta emitting radionuclides in the OHF impoundment

Sample				(β) Gross Beta		(β) Tritium		(β) C-14		(β-γ) Co-60		(β) Sr-90		(β) Tc-99		(β-γ) Cs-137	
Type	ID	Date	Intv (ft)														
IMPOUNDMENT SEDIMENT (pCi/g)																	
	2x Mean Background																
	Sed Composite	2/15/94	0-0.5	7.9E+5		2		256		6276		735000				3.7E+6	
	Sed Discrete	12/3/93	0-0.5	2.4E+7		35		96.4		42100						1.3E+7	
	Historical Samples																
(b)	Pond Center	2/20/85	0-0.5	1.4E+6						9396		71010				1.6E+6	
(b)	North End	2/20/85	0-0.5	2.0E+6						11259		44820				2.7E+6	
(b)	South End	2/20/85	0-0.5	4.1E+6						28620		3.0E+6				5.8E+6	
(c)	Sed Composite	9/7/83	0-0.5							19980		261900				4.8E+6	
IMPOUNDMENT SURFACE WATER				U	F	U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference																
	Pond Water	12/3/93	0-1	2.0E+5	1.9E+5	20100	20000	-	86	152	148	90000	93600	43.2	12.7	25000	28800
	Historical Samples																
(b)	Pond Water	5/8/85	0-1	2.5E+5						729		118800				105300	
(c)	Pond Water	9/7/83	0-1							729		191700				783000	
SOIL (pCi/g)																	
	Background Reference			42		0.084		0.84		0.02		1.94		2.2		1.4	
	SB038	12/16/93	0-2.0	70.2		0.68		-		0.27		10.3		-		40	
	SB047	12/3/93	0-2.0	98.5		1.05		-		0.1		9.6		-		54.5	
	Historical Samples																
(c)	3	1983	0-1													10	
(c)	3	1983	1-2													1.08	
(c)	3	1983	2-4													3.24	
(c)	3	1983	4-6													78.3	
(c)	3	1983	6-8													5.4	
(c)	5	1983	0-1													2.43	
(c)	6	1983	0-1													5.4	
(c)	7	1983	0-1													29.7	
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference			16	7.4	2400	1080					10.4	3.6			12.4	5.4
	1105	5/5/93	9.5-29.2	101.6	95.6	1.4E+6	1.4E+6	-	-							-	-
	1105	10/26/93	9.5-29.2	127	112	2.1E+6	1.1E+6	-	381			45.3	48.7	-	-	-	-
	1106	5/3/93	6-22.3	480	390	1.8E+6	2.1E+6	570	880			6.1	5.3	4.9	13	-	-
	1106	10/26/93	6-22.3	16.7	18.7	1.5E+6	1.2E+6	1689	692			5.8	5.5	17.3	8.63	-	-
	1107	5/4/93	6-20.2	23463	24867	1.5E+6	1.6E+6	4861	5781	36	31.3					339	20.2
	1107	10/27/93	6-20.2	9590	8660	1.1E+6	1.6E+6	660	258	24.2		4440	4360	53.7	53.9	-	-
	1108	5/6/93	8-20.1	102222	88562	1.5E+5	142967	49044	45586	83.3	21.4					6970	196
	1108	10/27/93	8-20.1	68100	73600	5.5E+5	568000	199	-	88.5		41500	35100	31	9.78	2750	120
	Historical Samples																
(a)	1105	2/87	9.5-29.2													<5.4	
(a)	1106	2/87	6-22.3									<27				<5.4	
(a)	1107	2/87	6-20.2													<2.7	
(b)	1105	5/24/85	9.5-29.2							-							

Notes:
1. Historical data references:
   (a) C. W. Francis & O. M. Sealand (July 1987) "Geohydrologic Investigations at the OHF and 3513 Impoundments"
   (b) Stansfield and Francis (Sept. 1986) "Characterization of the Old Hydrofracture Facility (OHF) Impoundment"
   (c) S. F. Huang (Sept. 1984) "Preliminary Radiological Characterization of the Old Hydrofracture Facility (OHF) at Oak Ridge National Laboratory"
2. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
3. Abbreviations: U/F = Unfiltered/Filtered - = Not detected (α, β, γ) = alpha, beta, gamma emitter

screening sample also had higher ^{60}Co concentration (42,100 pCi/g) than the RI composite sample and historical samples. Field monitoring of the aliquots collected for the RI sample indicated that activity levels decreased with distance from the drain pipe outlets (i.e., from south to north).

Table B2.3.35. Contaminants of concern detected in OHF pond area

CONTAMINANT	SOIL	SED[A]	GW	SW[B]
^{241}Am		X		
$^{243/244}Cm$		X	X	
^{60}Co	X	X	X	X
^{137}Cs	X	X	X	X
^{212}Pb			X	
^{238}Pu	X	X		
$^{239/240}Pu$	X	X		X
^{228}Ra			X	
^{99}Tc			X	X
^{228}Th		X		
^{230}Th		X		
^{234}Th		X	X	
^{90}Sr	X	X	X	X
Tritium	X	X	X	X
^{232}U		X		X
$^{233/234}U$			X	X
PCBs		X		
Carbon Tetrachloride			X	

[A] *Pond sediment* [B] *Pond water*

Impoundment surface waters contained a similar suite of radiological contaminants at much lower concentrations (Fig. B2.3.51). Exceptions were tritium (3 orders of magnitude higher in the

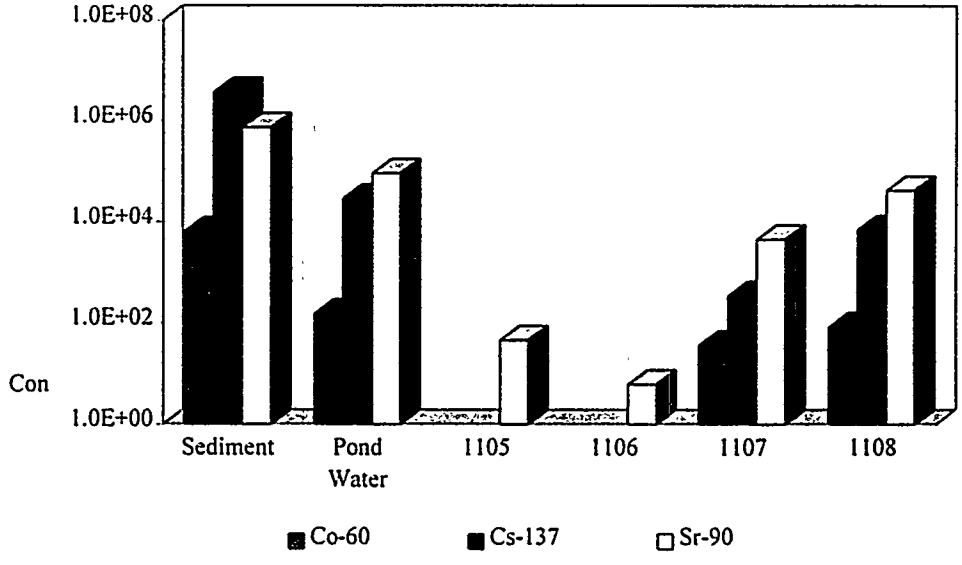


Fig. B2.3.51. Comparison of OHF pond and nearby groundwater.

water) and ^{99}Tc (not detected in the sediment). The surface water results were also notable for the high concentrations of ^{90}Sr and the apparent decline in concentrations from historical levels.

The sediment and surface water were also sampled for full TCL organics and TAL metals analyses. Consistent with a previous studies, only low concentrations of chemical compounds were detected within the sediment, including carbon tetrachloride and PCB Aroclors 1248, 1254, and 1260. Arsenic, chromium, and lead were detected in the sediment, generally at low levels. TCLP analyses confirmed the sediment is not a characteristic RCRA hazardous waste.

RI groundwater data provided further documentation that the pond is leaking along its northwest side, in the vicinity of well 1108. Similar conclusions were reached on the basis of the ^{85}Sr tracer tests (Francis 1980), the soil sampling results from deep soil cores near the pond (Francis et al. 1986), and previous groundwater sampling events (Stansfield and Francis 1986). Contaminant concentrations in well 1108 have been consistently higher during wet season conditions, when water level data indicate that the water table intersects the pond bottom. The groundwater at these times is serving as both a contaminant release and transport mechanism. Principal contaminants include ^{137}Cs, ^{90}Sr, ^{60}Co, ^{244}Cm, ^{238}Pu, and ^{233}U, all of which were identified at similar concentrations in the impoundment surface water sample. The presence of ^{233}U and ^{244}Cm in the groundwater was seen as a particularly strong indicator that the contamination was derived from the pond.

Further evidence of pond leakage, as opposed to the contamination being derived from other upgradient sources, was provided by groundwater and pond water geochemical data (Fig. B2.3.52). Relatively low (and similar) conductivity, calcium, and magnesium levels are present in the impoundment surface water and well 1108 water samples. The localized nature of these chemical changes (wells 1107 and 1108 are less than 50 ft apart) supports contamination- and hydrology-based interpretations that groundwater flow occurs along preferential pathways in the water table interval. At the OHF pond, the preferential pathways intercepted by well 1108 are conduits for contaminant migration from the pond toward eventual discharge into White Oak Creek.

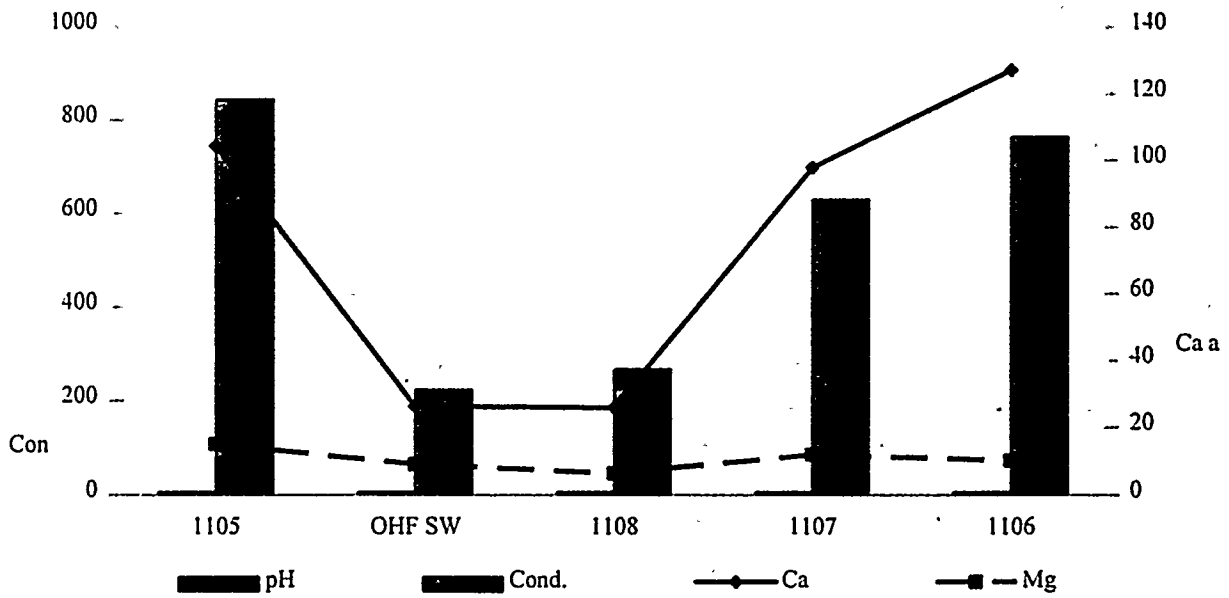


Fig. B2.3.52. Selected geochemical data for OHF impoundment surface water and wells.

The mechanism most likely to account for the release of contamination is the concrete standpipe that functions as an emergency overflow at the northern end of the pond. The pipe penetrates the pond bottom and connects to an 8-in. vitrified clay pipe that runs about 50 ft westward to an outlet near the margin of the White Oak Creek floodplain. Leakage may be occurring around the pipe or even into the pipe and back out into the groundwater (the western terminus apparently has been covered up and could not be located). The leakage rate is apparently small; otherwise the pond would drain during the dry season.

Other mechanisms may also account for the contamination, though determining the location and relative importance of other leakage points would be difficult. The pond reportedly has an asphalt liner, which may account for the poor correlation between the water table elevations and the water level in the pond. An incomplete or only transient hydraulic connection may also explain the lack of appreciable levels of contamination in wells 1106 and 1107. Together, these data suggest that some sort of boundary conditions exist for a large portion of the pond bottom.

OHF summary and conceptual model

The WAG 5 RI investigated three potentially significant sources of contamin ation in the OHF area: waste pit T-4, which contains a monolith of contaminated grout as well as contaminated sediment and water; the OHF waste storage tanks, which contain several hundred curies of radioactivity in waste sludges and liquids; and the OHF impoundment, which has highly contaminated sediment beneath a layer of somewhat less contaminated water. A relatively accurate inventory of all three of these waste units allowed for identification of releases and migration pathways with significantly greater confidence than most other areas of WAG 5. Principal contaminants in the three units are derived from the ILW disposed of using hydrofracture methods between 1965 and 1979; these include ^{90}Sr, ^{137}Cs, and ^{60}Co and lesser amounts of uranium and TRU radionuclides.

Except for a release to groundwater from the northwest side of the impoundment, contamination associated with the OHF facilities investigated for the WAG 5 RI is largely confined to the original source areas. Localized areas of shallow soil contamination resulting from incidental small-scale spills and leaks were also identified. These areas may have significance from an on-site risk perspective (depending on the exposure pathways), but the magnitude of contamination is not significant from a secondary source and contaminant migration perspective.

Soil contamination encountered at depth below waste pit T-4 and the OHF tanks was attributed to upgradient sources (i.e., waste trenches and auger holes) in SWSA 5 South. An examination of radionuclide concentrations in groundwater from well 1105 and piezometer 0666, both of which are located between OHF and SWSA 5 South, indicates that groundwater moving toward OHF has in some cases significant levels of ^{90}Sr and ^{3}H contamination derived from the SWSA 5 South sources. In the vicinity of the OHF pond, the ^{90}Sr component becomes highly elevated by the additional ^{90}Sr released from the pond. The only ^{3}H sources identified for OHF are the liquids in the waste storage tanks; there was no conclusive evidence that these tanks have been leaking.

The conceptual model for the OHF area is summarized in Table B2.3.37 and shown in Fig. B2.3.53.

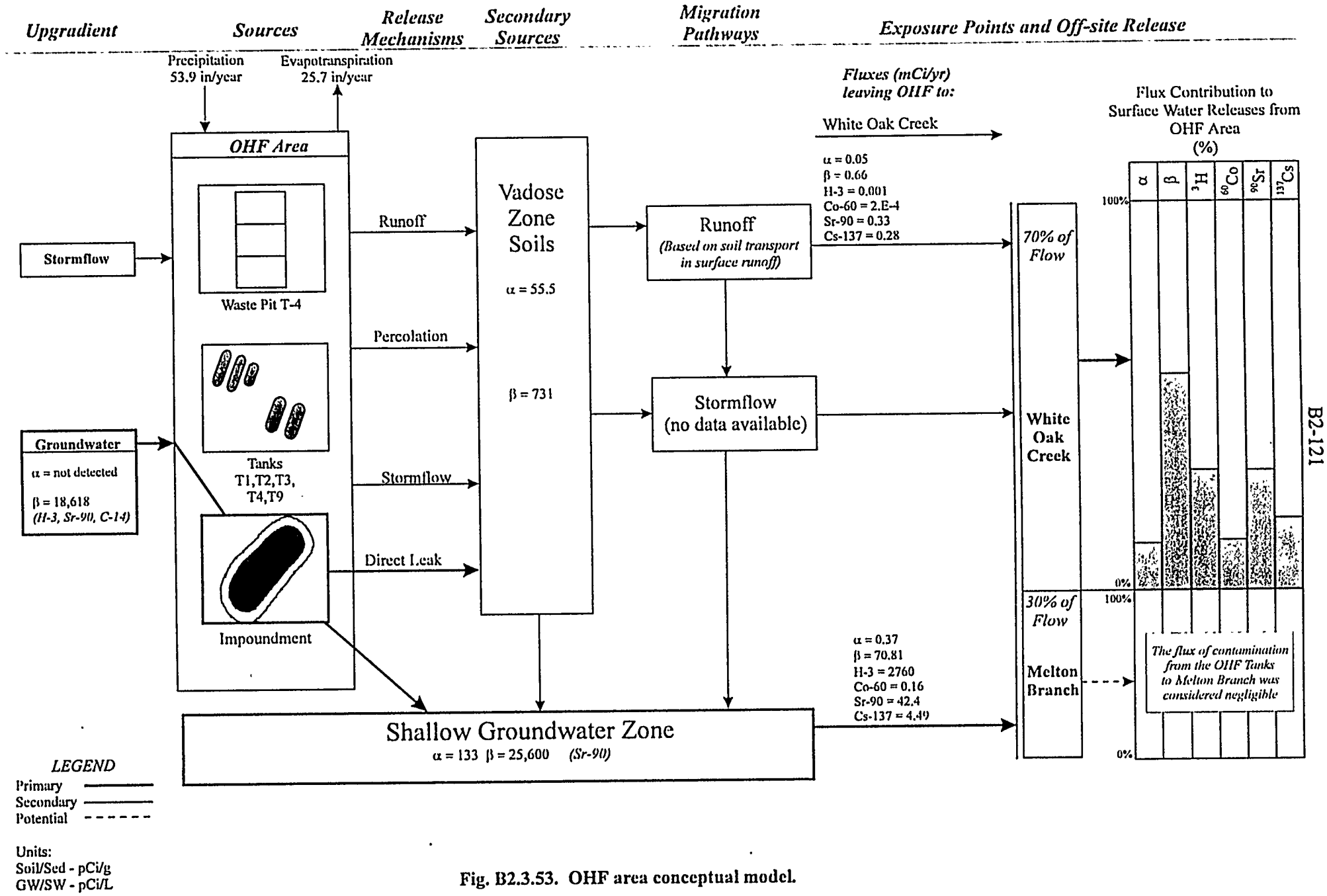


Fig. B2.3.53. OHF area conceptual model.

Table B2.3.37. Conceptual model summary for OHF area

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
POTENTIAL: Waste Pit T-4	• Leakage of cell liquids • Percolation of precip. through cell wastes/ underlying contaminated soils • Overflow of excess precip. from cells	• Stormflow zone to White Oak Creek floodplain Shallow groundwater discharging to White Oak Creek (floodplain and/or stream channel)	*On site*: • Vicinity of waste pit • Adjacent surface soils *Off site*: • White Oak Creek floodplain • Downstream surface water & sediment
POTENTIAL: OHF Waste Storage Tanks	• Leakage from tanks • Infiltration of precip. through contaminated backfill	• Shallow groundwater discharging to White Oak Creek or Melton Branch	*On site*: • Contaminated soils in tank area *Off site*: • Same as above
ACTIVE: OHF Impoundment	• Downward leakage through pond bottom • Overflow of pond	• Shallow groundwater discharging to White Oak Creek	*On site*: • Vicinity of pond *Off site*: • Same as above

B2.3.8 White Oak Creek drainage basin summary

The White Oak Creek drainage area of WAG 5 contains five study areas: PWSB, SWSA 5 North, fissile storage area, SWSA 5 White Oak Creek Area, and OHF area (Fig. B2.1.1). The total drainage area associated with WAG 5 (including the area beyond the administrative SWSA 5 Boundary) is 60.8 acres. Drainage D-1 is the main WAG 5 surface water contributor to White Oak Creek (46%); the tributary north of SWSA 5 North contributes lesser amounts (5%). Table B2.3.38 presents the annual water balance between surface runoff, interflow (stormflow), and groundwater for the WAG 5 White Oak Creek drainage area, based on the HSPF modeling effort.

Based on the results from the surface water modeling and the detailed interpretation of the sampling results, conceptual models were developed for each study area. Each model describes contaminant sources (*active and potential*) within the study area, release mechanisms, secondary sources, migration pathways, and exposures points. Table B2.3.39 summarizes the major findings from each of these models. The primary sources are the OHF and PWSB impoundments, the TRU storage facilities in SWSA 5 North, and the trenches and auger holes in the SWSA 5 White Oak Creek and Fissile Storage areas.

Primary contaminant types in these sources include TRU, fissile, mixed fission/activation products, and VOCs. While a number of waste disposal techniques have been applied (e.g., auger holes, trenches, landfills, and surface impoundments), the principal release mechanism is the inundation of trench wastes by shallow or perched groundwater. Contaminants are then transported through the shallow groundwater and discharged to seeps and surface waters (White Oak Creek, drainage D-1, Northern Tributary).

Table B2.3.38. Annual water balance for WAG 5White Oak Creek drainage basin

	PERCENT OF FLOW	ANNUAL DISCHARGE (m^3/year)
Surface Runoff	27	47,500
Interflow	31	53,100
Groundwater Flow	42	73,100
Total	100	173,700

Flux calculations

To determine the magnitude and extent of WAG 5 releases to White Oak Creek, contaminant fluxes (for gross alpha, gross beta, tritium, ^{60}Co, ^{90}Sr, and ^{137}Cs) from each study area were determined. These fluxes are pathway-dependent and are calculated based on the average annual flow rate (Table B2.3.38) and the average concentration found in that pathway during the RI sampling events (Note: The surface runoff pathway flux is based on erosion potential, sediment/soil transport in surface runoff, and average contaminant concentration in soil). Figure B2.3.54 presents the percentage flux contribution of contaminant by study area and pathway. These results show the dominance of the groundwater pathway in the transport of contaminants to White Oak Creek. The stormflow pathway is generally insignificant, and surface runoff of contaminated soil becomes an important contributor in areas where soil contamination has been identified (e.g., SWSA 5 White

Table B2.3.39. White Oak Creek conceptual model summary

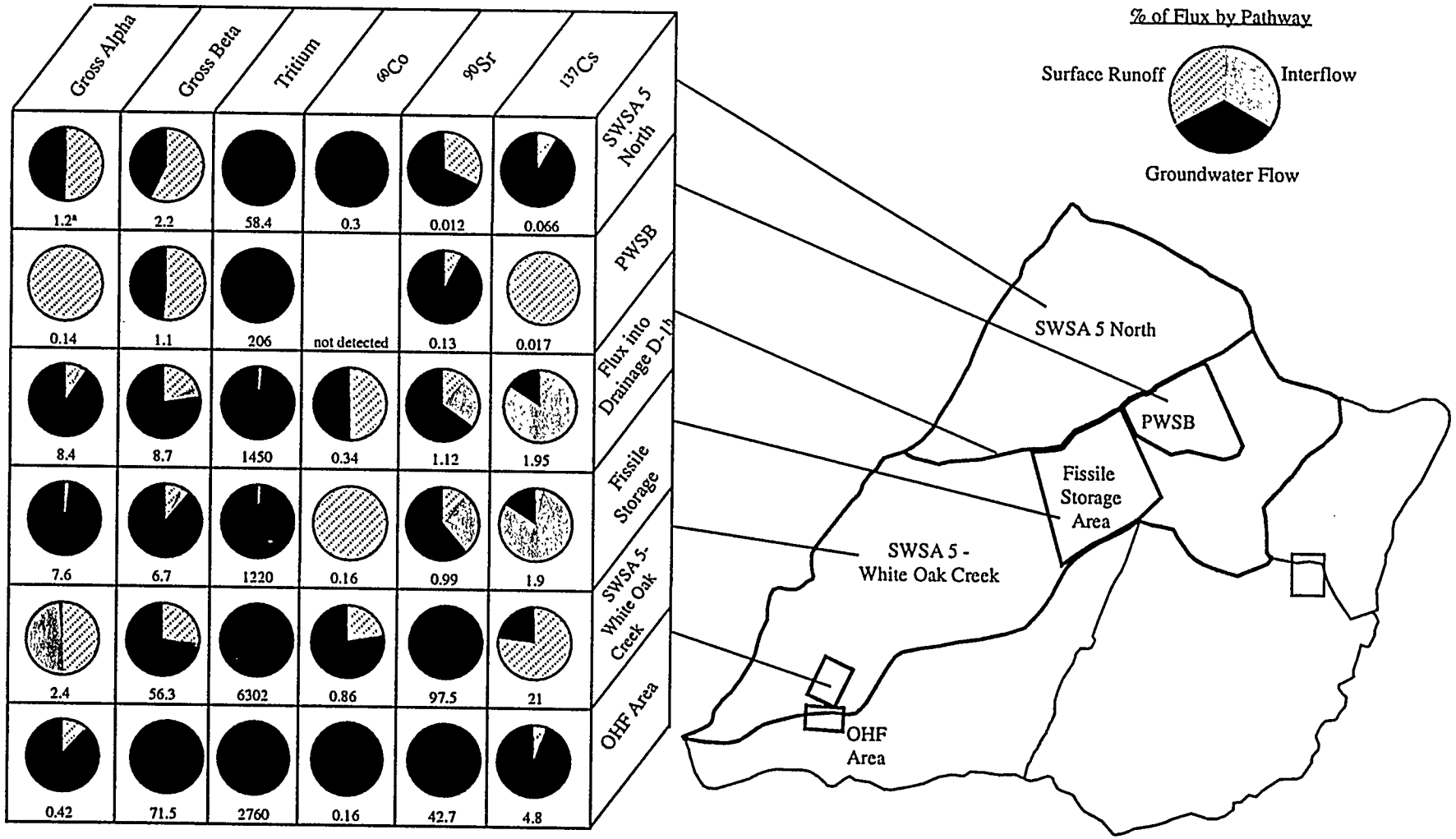
Study Area	Sources	Contaminant Types	Release Mechanisms	Secondary Source	Migrations Pathways	Exposure Points
Process Waste Sludge Basin	Active Sources: None Potential Sources: Basin sediment and water	Fission/Activation Products: ^{90}Sr, ^{137}Cs, ^{60}Co ^{241}Am, $^{243/244}Cm$ $^{233/234}U$, ^{238}U	No release to date: *potential mechanisms include overflow of basin or failure of liner system.*	None identified	*Shallow groundwater, surface runoff*	Basin surface water and sediment Drainage D-1
SWSA 5 North	Active Sources: 10 trenches w/ wood boxes Bldg 7831A drainfield Potential Sources: 17 trenches w/ conc. casks Inactive Sources: 8 stainless-steel-lined storage wells	Alpha-contaminated LLW and TRU wastes: ^{241}Am ^{244}Cm ^{239}Pu ^{233}U some with β–γ	Trench inundation and perched conditions in trenches with wooden boxes. In addition, infiltration and percolation through wastes.	Subsurface soils may contain sorbed alpha	Shallow groundwater Stormflow likely, but not yet documented	Seep discharge areas White Oak Creek Drainge D-1 Northern Tributary
Fissile Storage Area	Acvite Sources: 3 Trenches (primarily 36); 151 auger holes ravine landfill Potential Sources: none	Fissile: ^{235}U, minor ^{233}U Fission Products: ^{90}Sr ^{137}Cs	Inundation (trench 36 only). Percolation and stormflow.	Contaminated soils adjacent to trenches and auger holes Upgradient groundwater (from Undefined Trench Area)	Shallow groundwater and release to seeps; stormflow in topographically higher areas	Seep discharge areas Drainage D-1
SWSA 5 - White Oak Creek Area	Active Sources: Dump area 9 inundated trenches 110 Auger holes Potential Sources: upper 3 trenches Inactive Sources: 8 TRU storage vaults	Fission/Activation Products: ^{90}Sr, ^{137}Cs, ^{60}Co, ^{3}H VOCs	Inundation of trenches /Dump Area. Infiltration and percolation through wastes. Perched condtions in upper trenches.	Surface and subsurface soils adjacent to trenches and auger holes	Shallow groundwater with releases to surface seeps, minor contribution from stormflow	Contaminated soil above trenches Seep discharge areas White Oak Creek Drainage D-1
OHF Area	Active Sources: OHF Pond upgrdnt trenches in Area C Potential Sources: 5 underground tanks Waste Pit (*potential*)	Fission Products: ^{90}Sr, ^{137}Cs, ^{60}Co *Lesser amounts of TRU and U*	Direct leak of pond (near well 1108). Leakage of Tanks or percolation through Waste Pit T-4 potential but not likely.	Soils upgradient groundwater (from SWSA 5 South Area C)	Shallow groundwater directly to surface water *[upgradient groundwater also contaminated]*	OHF impoundment surface water/ sediment White Oak Creek

Oak Creek area). While a flow path in Fig. B2.3.54 may be active, the total flux contribution from this flow path may not be contributing to the overall contamination or risk. For example, both groundwater flow and surface runoff from the fissile storage area (contaminated area) and PWSB (noncontaminated area believed to represent background conditions on site) have been shown to be active contributors of contaminant flux to drainage D-1, but the magnitude of fluxes (also shown in Fig. B2.3.52) from the fissile storage area dwarfs the flux from the PWSB.

Table B2.3.40 and Fig. B2.3.55 present qualitative and pictorial summaries to better represent the relative difference in fluxes from each area. Table B2.3.40 summarizes the fluxes (and relative percentages) from each source, beginning with the study areas draining into D-1 and culminating with the total flux measured at White Oak Creek weir. Fluxes calculated from upgradient input (7500 bridge sampling station) and from WAG 4 are also presented in Table B2.3.40 (fluxes from these stations are based on analytical data collected as part of the WAG 2 RI and flow measurements collected by the ESD Surface Water Hydrology group). The results indicate a good correlation between calculated and observed fluxes, typically in the same order of magnitude. Differences between the two may be attributed to (but not limited to) assumptions in the surface water mathematical model; use of average concentrations of analytes in each pathway and homogeneous soil properties and flow paths; and neglecting the effects of contaminant retardation in the soil matrix or sediment deposition in the streambed.

Figure B2.3.55 presents the relative percent fluxes from each WAG 5 study area and non-WAG 5 contributors in a funnel representation. Fluxes calculated from individual areas are combined into three hydrologically distinct groups: WAG 5 study areas draining into D-1; WAG 5 study areas draining directly into White Oak Creek (including the SWSA 5 North basin, which drains into the Northern Tributary); and non-WAG 5 contributors. The groups are then combined to give relative percent contributions to the fluxes calculated at White Oak Creek weir. Figure B2.3.55 also presents the relative percent flux from the WAG 5 White Oak Creek drainage basin and White Oak Creek weir to the total flux at the White Oak Dam. For example, the OHF study area has a ^{90}Sr flux of 42.69 mCi/year (Table B2.3.40), which is approximately 30% of the total ^{90}Sr flux (138 mCi/year) leaving WAG 5 study areas draining directly in White Oak Creek. Combining the 138 mCi/year with the ^{90}Sr fluxes from drainage D-1 (1.45 mCi/year) and non-WAG 5 contributors (1840 mCi/year), the total ^{90}Sr flux calculated to leave from the White Oak Creek weir is around 1980 mCi/year. The OHF area therefore contributes 2% (42.69/1840) of the total ^{90}Sr flux over the White Oak Creek weir.

In summary, based on the flux calculations, the WAG 5 White Oak Creek drainage basin is contributing only a small percentage (less than 5%) of contamination to the total measured flux leaving White Oak Dam. Most contamination measured at White Oak Creek weir is from sources upstream of or adjacent to WAG 5 (i.e., WAG 1 upstream of the 7500 bridge and WAG 4).



[a] Calculated fluxes are in mCi/yr
[b] Drainage fluxes are based on contributions from study areas in D-1 drainage basin

Fig B2.3.54. Flux summary by study area and pathway for WAG 5 White Oak Creek drainage.

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Table B2.3.40. Flux contributions to drainage D-1 and White Oak Creek Weir

	Alpha Flux		Beta Flux		H-3 Flux		Co-60 Flux		Sr-90 Flux		Cs-137 Flux	
	(mCi/yr)	(%)	(mCi/yr)	(%)	(mCi/yr)	(%)	(mCi/yr)	(%)	(mCi/yr)	(%)	(mCi/yr)	(%)
Drainage D-1												
PWSB	0.14	(2%)	1.1	(13%)	206	(14%)	0.02	(1%)	0.13	(12%)	0.00	(0%)
SWSA 5 North	0.43	(5%)	0.6	(7%)	16	(1%)	0.01	(1%)	0.01	(1%)	0.17	(50%)
Fissile Storage	7.69	(91%)	6.7	(77%)	1222	(84%)	1.86	(95%)	0.99	(88%)	0.16	(49%)
SWSA 5 -WOC	0.19	(2%)	0.3	(4%)	8	(1%)	0.06	(3%)	0.00	(0%)	0.00	(1%)
Calculated total flux from Drainage D-1	8.45		8.7		1451		1.95		1.13		0.34	
Measured flux at Drainage D-1 (SW001)	6.16		5.5		1818		0.16		1.45		0.43	
White Oak Creek												
Non WAG 5 Sources												
7500 Bridge	80.11	(64%)	2870.7	(52%)	43291	(3%)	89.56	(99%)	761.35	(38%)	1080.68	(96%)
WAG 4	34.99	(28%)	2519.0	(46%)	1219968	(96%)	0.00	(0%)	1080.86	(55%)	20.30	(2%)
WAG 5 Sources												
SWSA 5 North -> N. Trib	0.04	(0%)	0.5	(0%)	8	(0%)	0.07	(0%)	0.00	(0%)	0.01	(0%)
SWSA 5 North -> WOC	0.76	(1%)	1.1	(0%)	35	(0%)	0.06	(0%)	0.01	(0%)	0.04	(0%)
Drainage D-1	6.16	(5%)	5.5	(0%)	1818	(0%)	0.16	(0%)	1.45	(0%)	0.43	(0%)
SWSA 5 WOC -> WOC	2.19	(2%)	56.0	(1%)	6312	(0%)	0.86	(1%)	94.76	(5%)	21.02	(2%)
OHF Pond	0.42	(0%)	71.5	(1%)	2761	(0%)	0.16	(0%)	42.69	(2%)	4.77	(0%)
Calculated total flux into White Oak Creek Wier	124.68		5524.2		1274192		90.87		1981.12		1127.26	
Measured flux at White Oak Creek Weir	70.45		3009.2		640047		84.89		1388.86		1305.95	

Notes:

1. (%) are based on the percentage of calculated total flux, not measured flux
2. WAG 5 data based on RI sampling and flow measurements
3. White Oak Creek weir, 7500 Bridge, and WAG 4 (T-2A weir) analytical data based on WAG 2 sampling, flow data collected by ESD Surface Water Hydrology group

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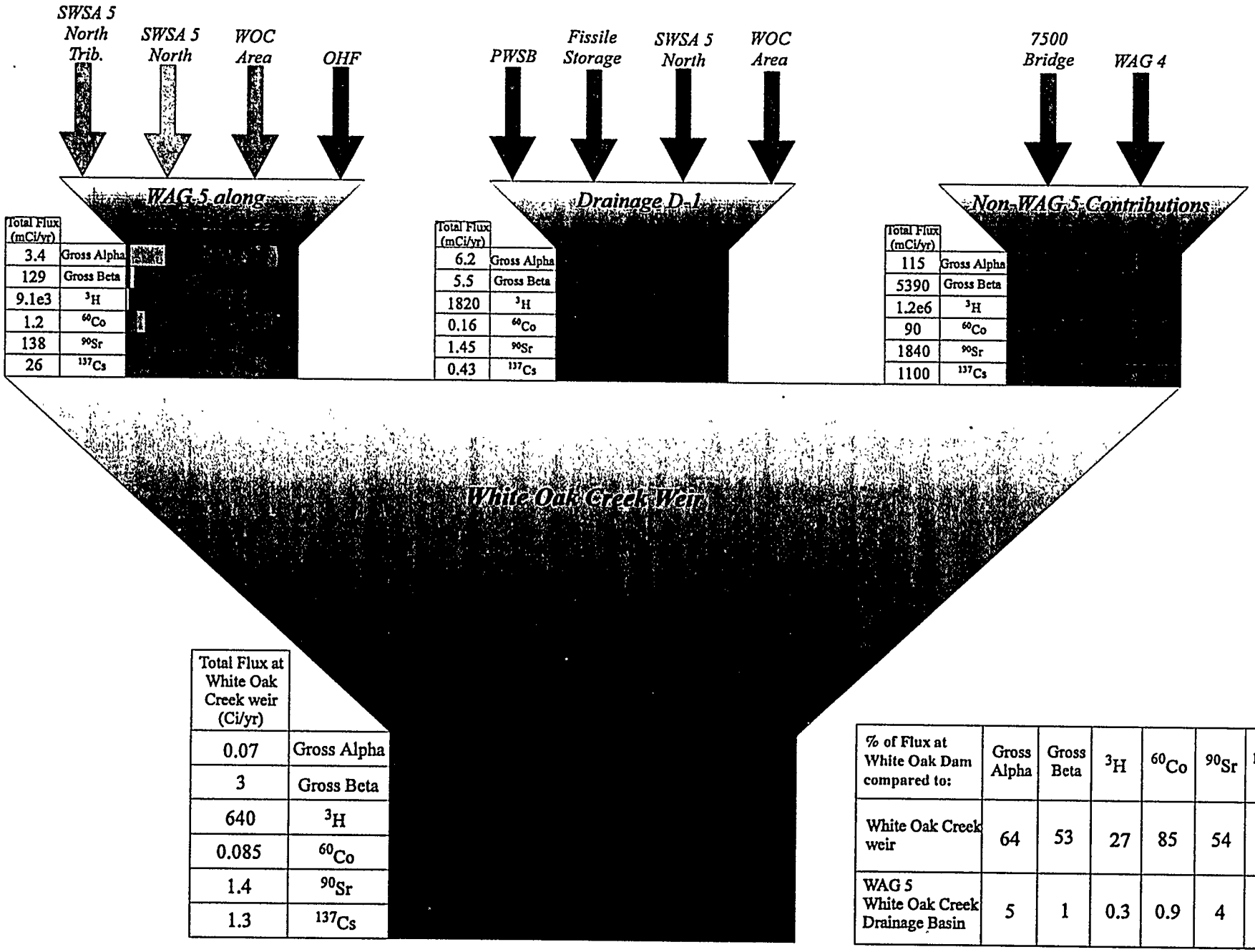


Total Flux (mCi/yr)	
3.4	Gross Alpha
129	Gross Beta
9.1e3	^{3}H
1.2	^{60}Co
138	^{90}Sr
26	^{137}Cs

Total Flux (mCi/yr)	
6.2	Gross Alpha
5.5	Gross Beta
1820	^{3}H
0.16	^{60}Co
1.45	^{90}Sr
0.43	^{137}Cs

Total Flux (mCi/yr)	
115	Gross Alpha
5390	Gross Beta
1.2e6	^{3}H
90	^{60}Co
1840	^{90}Sr
1100	^{137}Cs

Total Flux at White Oak Creek weir (Ci/yr)	
0.07	Gross Alpha
3	Gross Beta
640	^{3}H
0.085	^{60}Co
1.4	^{90}Sr
1.3	^{137}Cs

% of Flux at White Oak Dam compared to:	Gross Alpha	Gross Beta	^{3}H	^{60}Co	^{90}Sr	^{137}Cs
White Oak Creek weir	64	53	27	85	54	118
WAG 5 White Oak Creek Drainage Basin	5	1	0.3	0.9	4	2

Fig. B2.3.55. White Oak Creek contaminant flux summary.

B2.4 MELTON BRANCH DRAINAGE AREA

B2.4.1 Melton Branch WAG 2 Data Summary

Historical data from Melton Branch are summarized to provide an understanding of the contamination in this creek and to present possible reaches of Melton Branch where WAG 5 may be contributing to this contamination. The Environmental Restoration Monitoring and Assessment activity in the WAG 2 Site Investigation Program provided most of the White Oak Creek data; other studies, such as the shallow groundwater sampling performed by Spalding and Munro (1983) and the stream bed gravels study by Cerling and Spalding (1981), provided peripheral information.

WAG 2 RI data

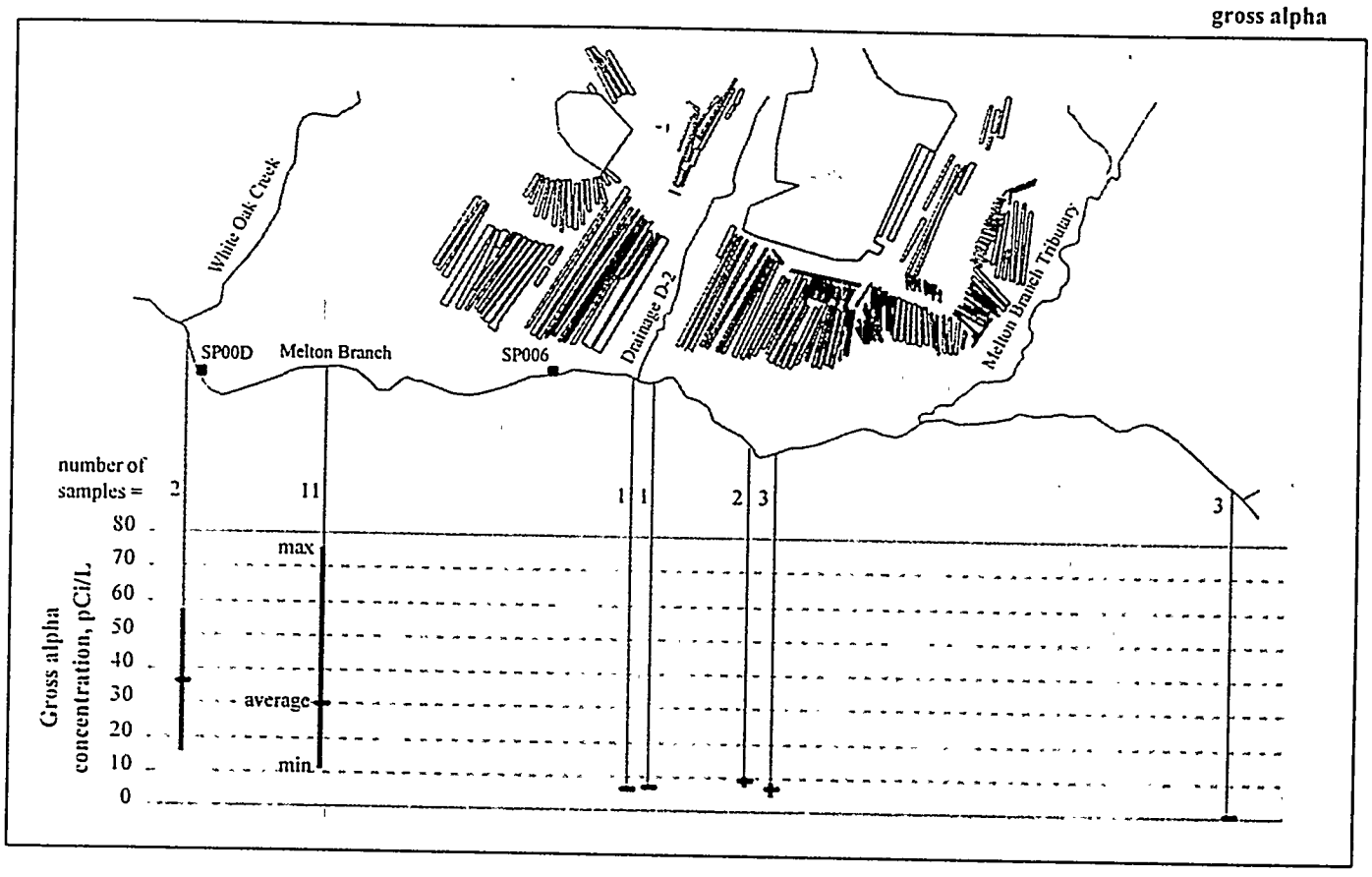
As in White Oak Creek, the WAG 2 field investigation began collecting surface water samples from Melton Branch at stream transects in 1992. Analyses typically consisted of gross alpha, gross beta, tritium, and ^{90}Sr; Figs. B2.4.1 and B2.4.2 show maximum, minimum, and average results for these analytes at the sampling transects in Melton Branch along the southern boundary of WAG 5. Gross alpha concentrations were below 10 pCi/L at the confluence with drainage D-2 and then increased to almost 40 pCi/L downstream of seep SP00D. Strontium-90 results were generally higher at seep SP006, below area C trenches; and seep SP00D, downstream of the Melton Branch weir. Tritium concentrations increased from 100,000 to over 1,000,000 pCi/L between the confluence of Melton Branch and Melton Branch Tributary and the confluence with drainage D-2, where tritium concentrations remained around 1,000,000 pCi/L.

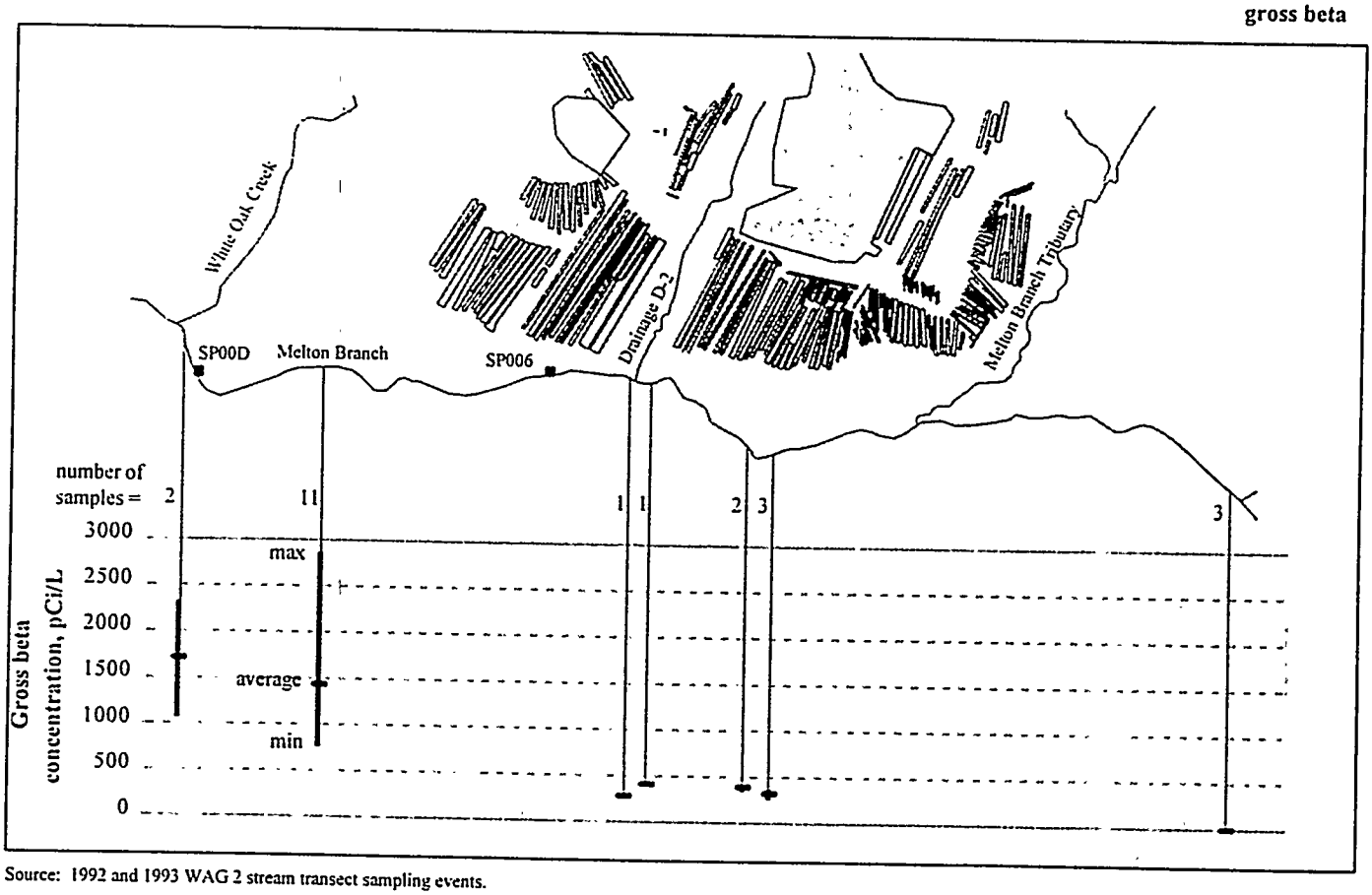
The average flux at each sampling location was calculated on the basis of the average concentration and estimated average flow. The average flow at the transect points is based on the average flow (1990–1993) at the Melton Branch weir. The average flow at the transects was assumed to be proportional to the drainage area above the transect point compared to the drainage area above Melton Branch weir. Figures B2.4.3 and B2.4.4 show the average flux of gross alpha, gross beta, ^{3}H, and ^{90}Sr at transects along Melton Branch. Generally, each contaminant increased in flux along the southern boundary of WAG 5. Gross alpha and gross beta have similar patterns of flux into Melton Branch. Less than 10% of each is from Melton Branch Tributary upstream of WAG 5; the primary WAG 5 contributions occur downstream of drainage D-2. Approximately 90% of the ^{90}Sr in Melton Branch is from WAG 5, with the greatest increase at SP006. Almost all of the tritium flux in Melton Branch is attributable to WAG 5, with most of the flux entering between Melton Branch Tributary and drainage D-2 (areas A and B).

Based on the 1992 stream transect sampling events corresponding to wet season baseflow and dry season baseflow, Melton Branch contributes 32 to 43% of the ^{90}Sr flux at White Oak Dam. The main ^{90}Sr source in Melton Branch is SP006, which accounts for 16 to 25% of the ^{90}Sr flux at White Oak Dam. The 1992 stream transect sampling events also indicated that 70 to 75% of the tritium flux at White Oak Dam is from Melton Branch (Clapp and Watts 1993).

Shallow groundwater sampling

Spalding and Munro (1984) dug single-use boreholes (0.45 m deep) at 3- to 5-m intervals along the southern boundary of WAG 5 (Fig. B2.4.5). Samples from each borehole were analyzed for ^{90}Sr





Source: 1992 and 1993 WAG 2 stream transect sampling events.

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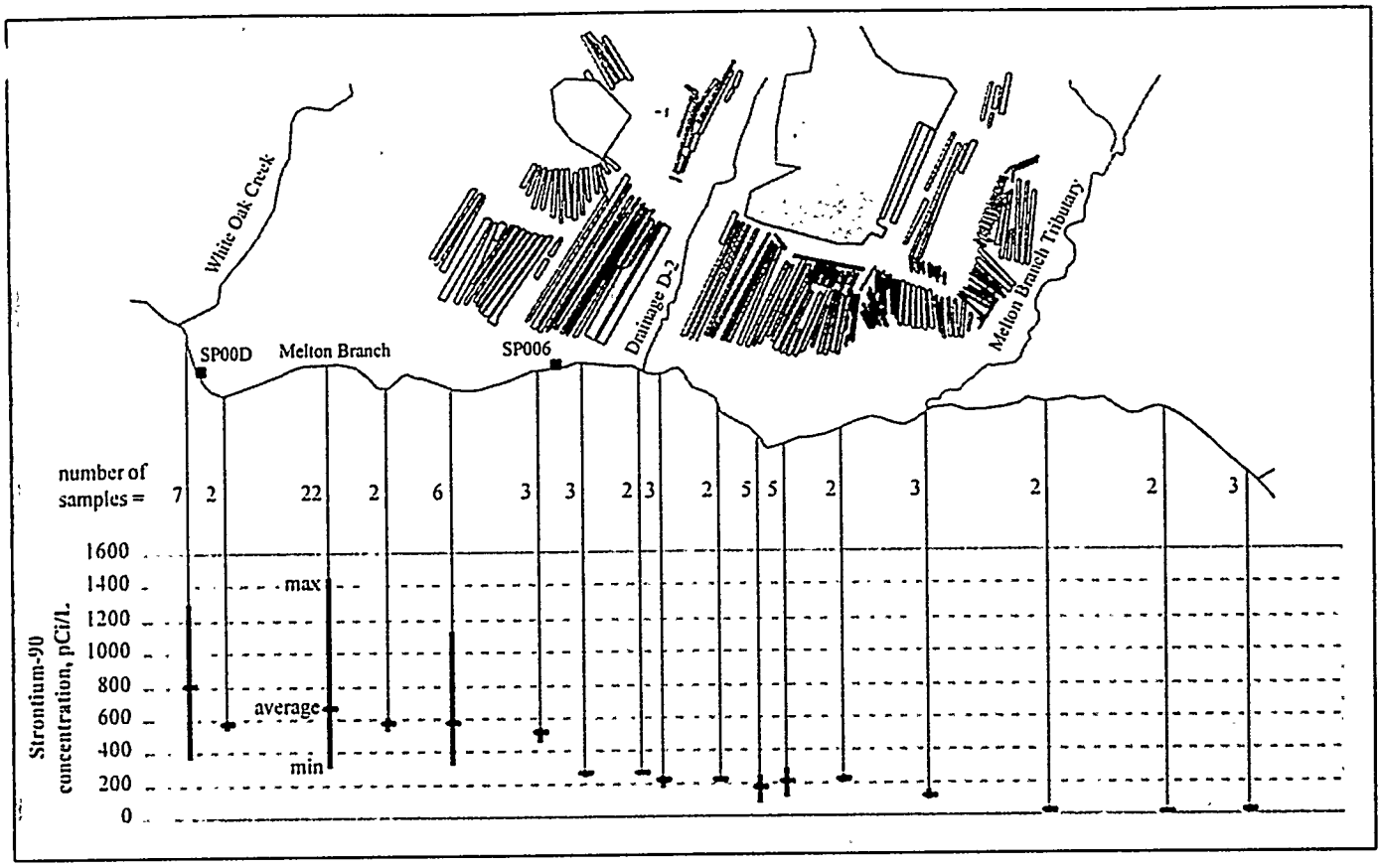
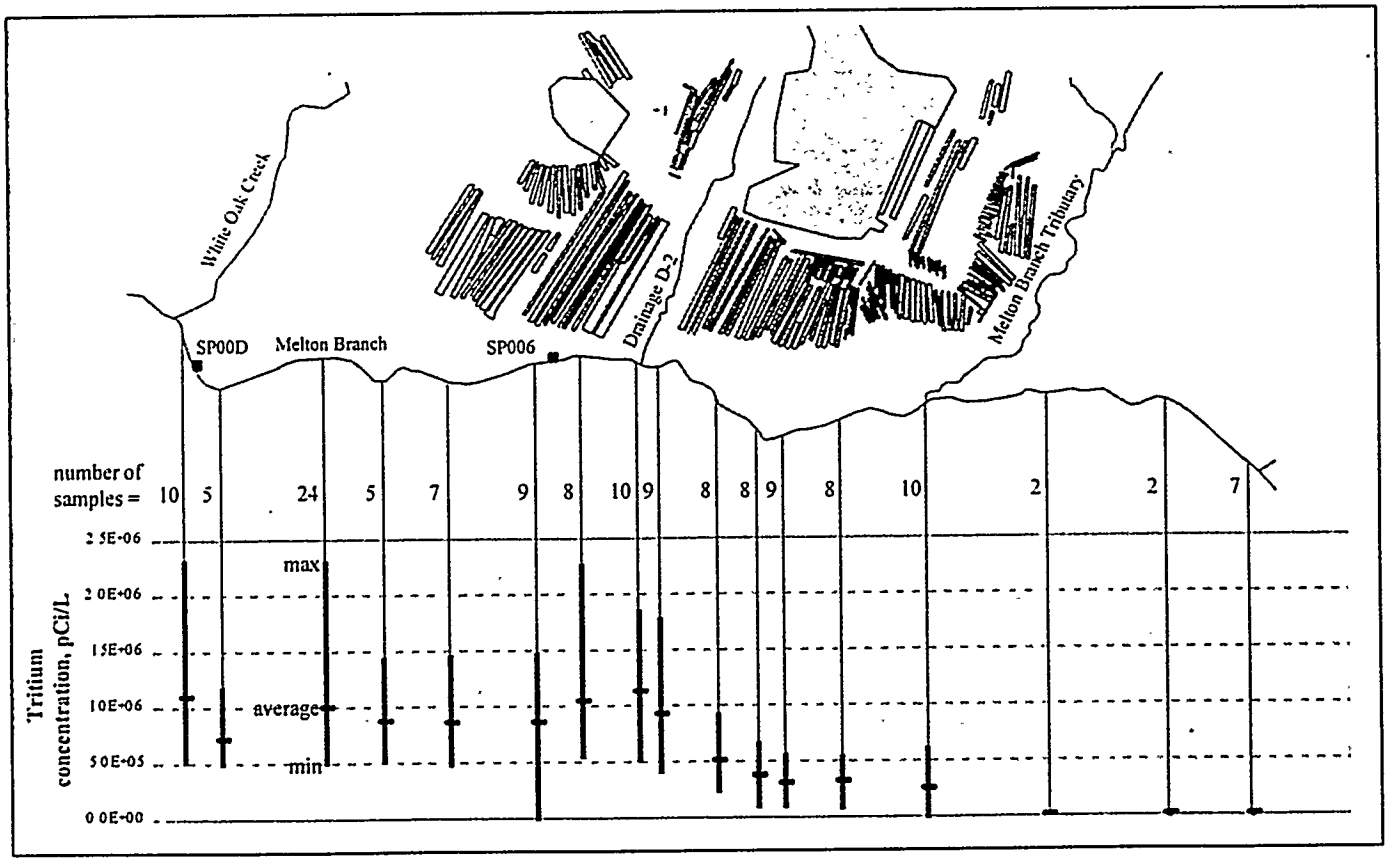
Fig. B2.4.1. Gross alpha and gross beta concentrations in Melton Branch.

^{90}Sr



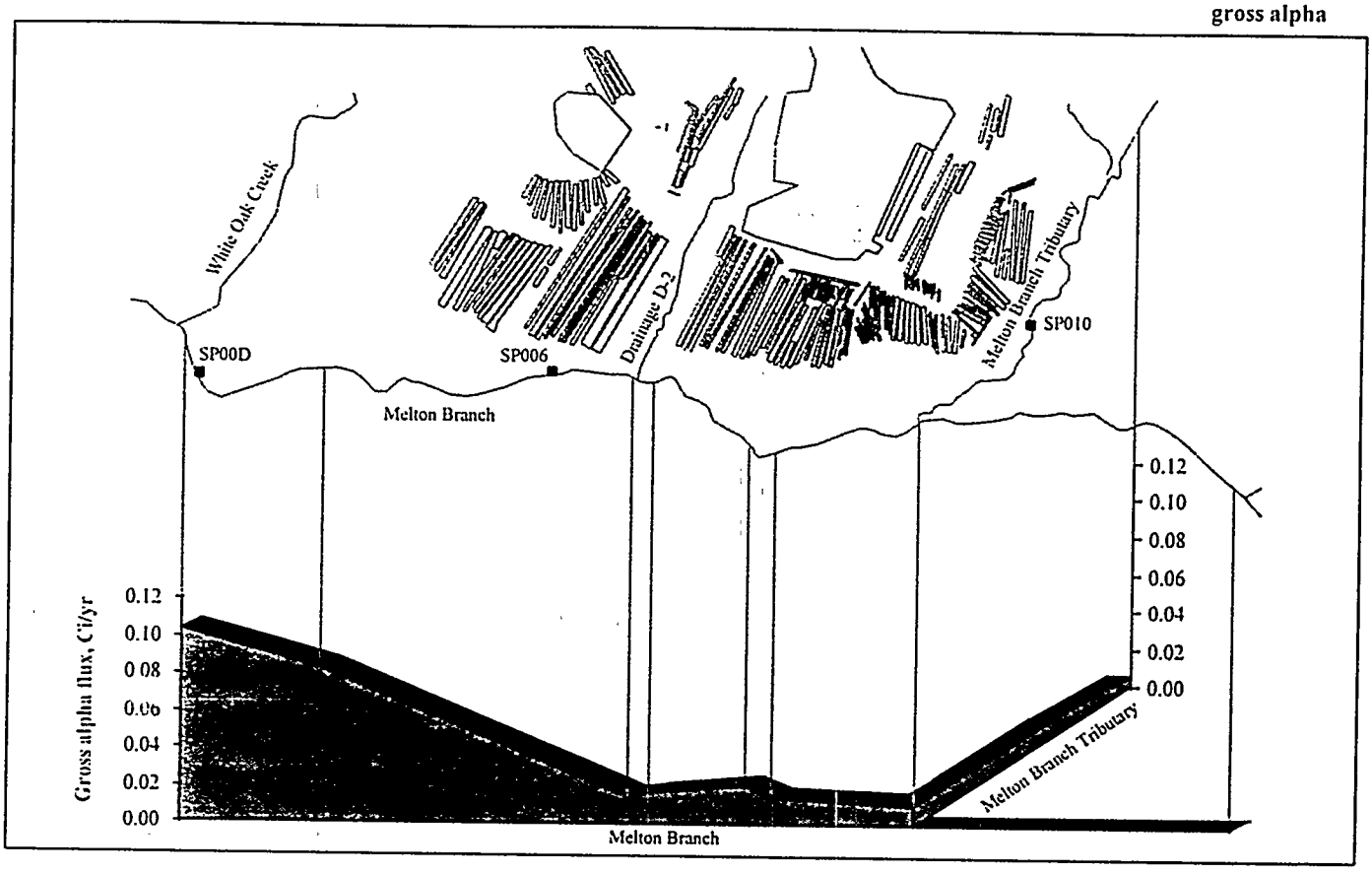
Tritium



Source: 1992 and 1993 WAG 2 stream transect sampling events.

Fig. B2.4.2. Strontium-90 and tritium concentrations in Melton Branch.

B2_F4_1 PPT



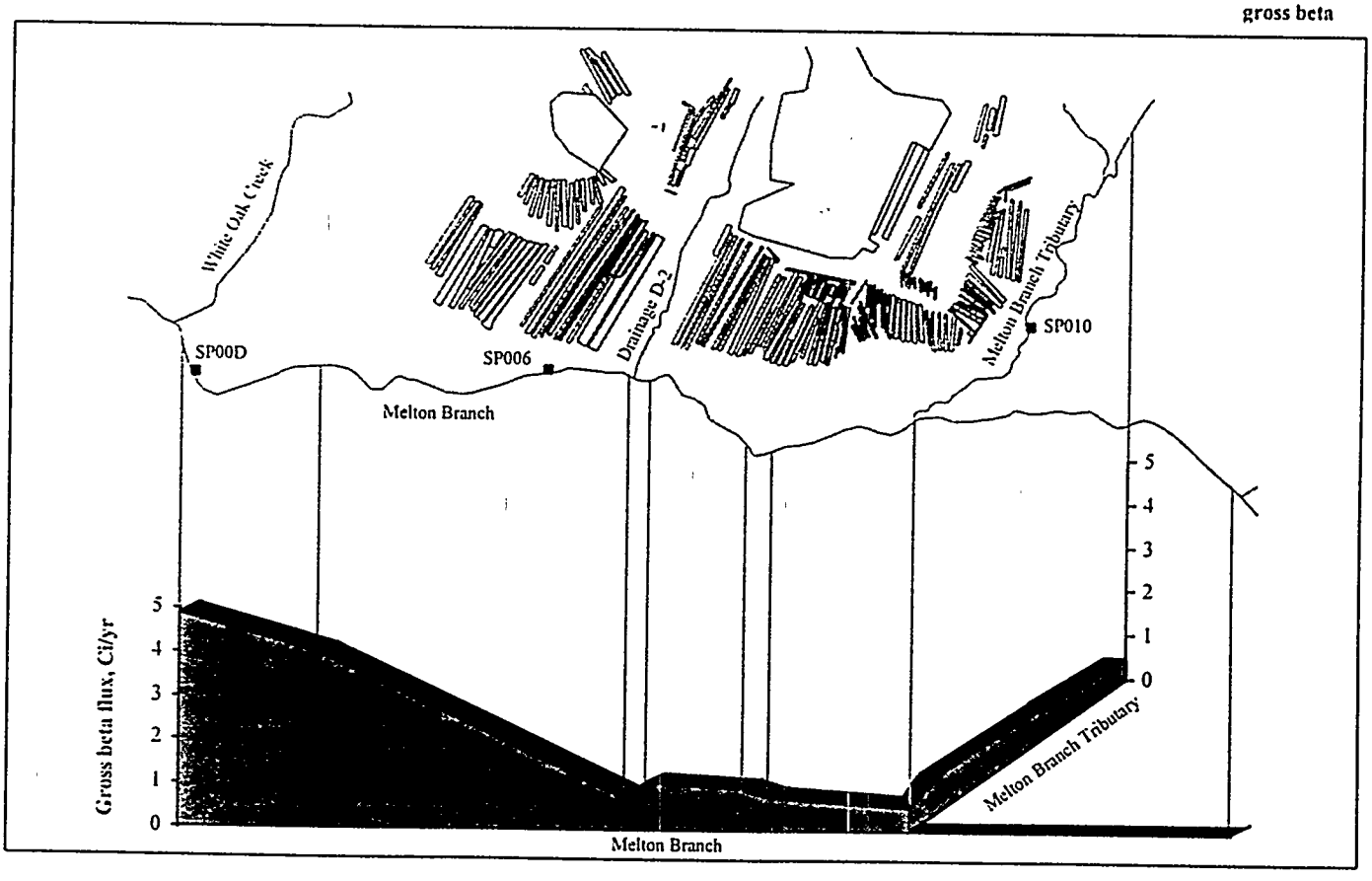
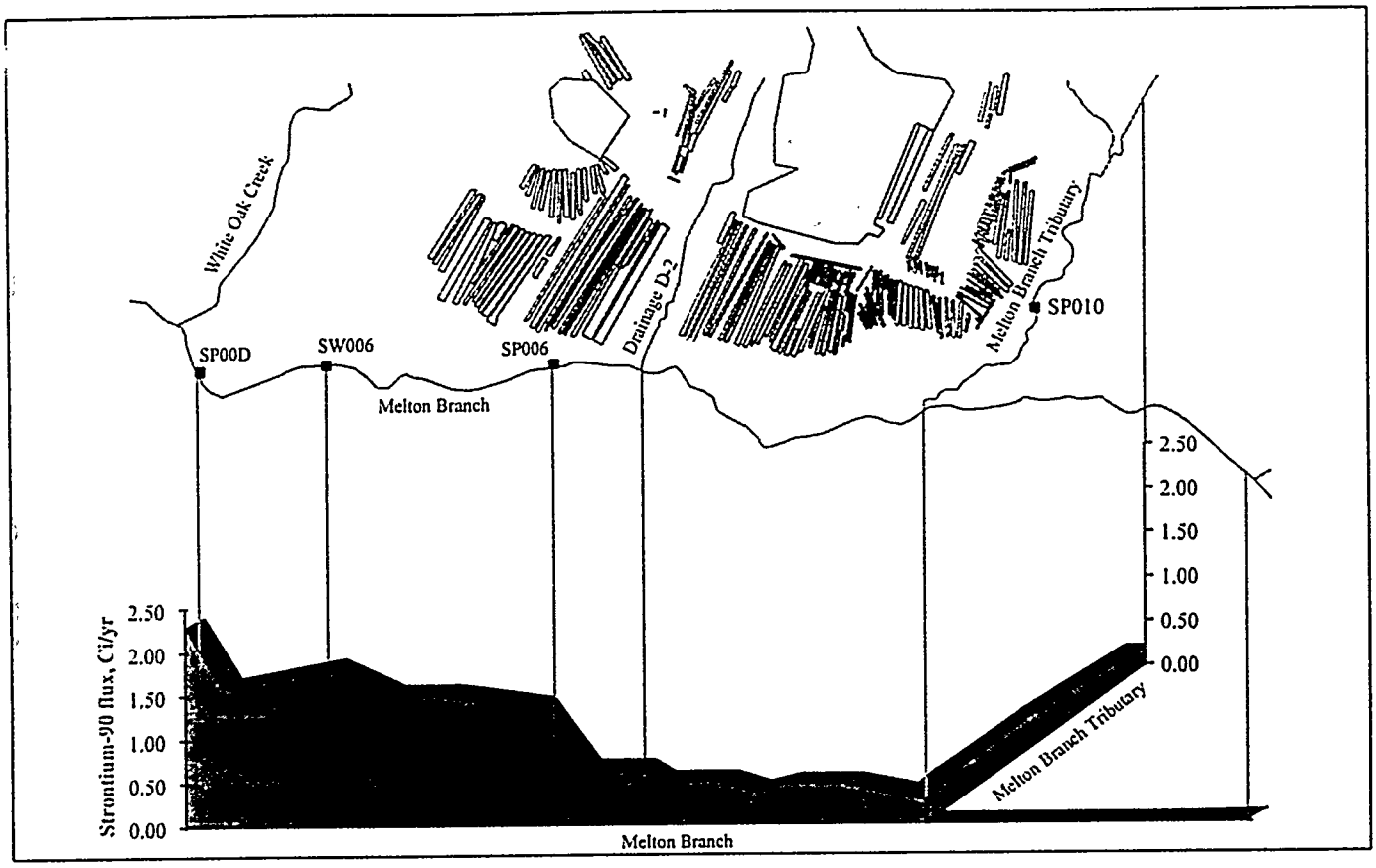


Fig. B2.4.3. Gross alpha and gross beta flux in Melton Branch.

B2_F4_3 PPT

^{90}Sr



Tritium

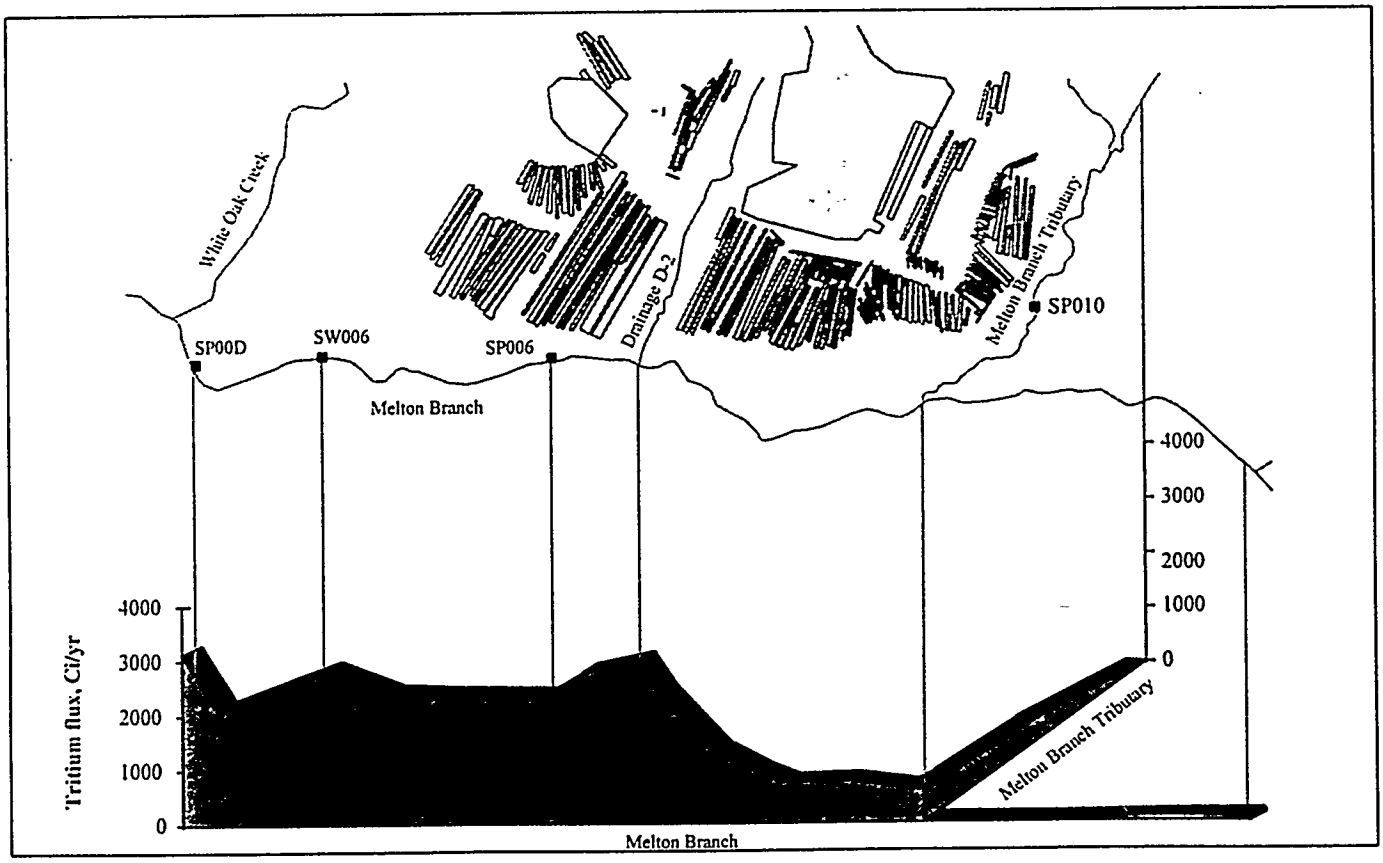


Fig. B2.4.4. Strontium-90 and tritium flux in Melton Branch.

B2_F4_3 PPT

and miscellaneous water quality parameters. Results for ^{90}Sr, also shown in Fig. B2.4.4, ranged from nondetect to 10.6 kBq/L (286,000 pCi/L), with the maximum occurring directly below the OHF area (see Sect. B2.4.6 for more discussion). The three other ^{90}Sr peaks shown in Fig. B2.4.5 include seep SP006, an area below trench 117 in area B, and another area at the eastern boundary of area B.

Streambed gravels data

A survey of streambed gravels was performed in 1978 to determine the areal concentration of ^{60}Co, ^{137}Cs, and ^{90}Sr in the White Oak Creek system (Cerling and Spalding 1981). The study collected sediment samples from the upper 10 cm of streambed sediment at approximately 35-m intervals along the stream channel. Only sand and gravel were analyzed these larger sediment particles historically had had higher activity levels and were more resistant to downstream movement.

Concentrations of ^{60}Co, ^{137}Cs, and ^{90}Sr in Melton Branch and Melton Branch tributary show that most of the ^{60}Co in Melton Branch comes from a source upstream of WAG 5 on Melton Branch. The highest concentrations of ^{60}Co occurred downstream of the confluence of Melton Branch and Melton Branch Tributary; concentrations in Melton Branch decreased below that point. Cesium-137 and ^{90}Sr had higher concentrations in the Melton Branch Tributary than in Melton Branch. Levels of ^{137}Cs and ^{90}Sr increase downstream of the Melton Branch Tributary confluence.

B2.4.2 Melton Branch Surface Water/Drainage Summary

Drainage D-2

Introduction. Drainage D-2 receives runoff from an area of 10.6 acres in the south-central portion of WAG 5 (Fig. B2.4.7), including 29% of area C and 27% of area B. The drainage consists primarily of grassed-over SWSA 5 South trench areas and wooded areas along the stream channel.

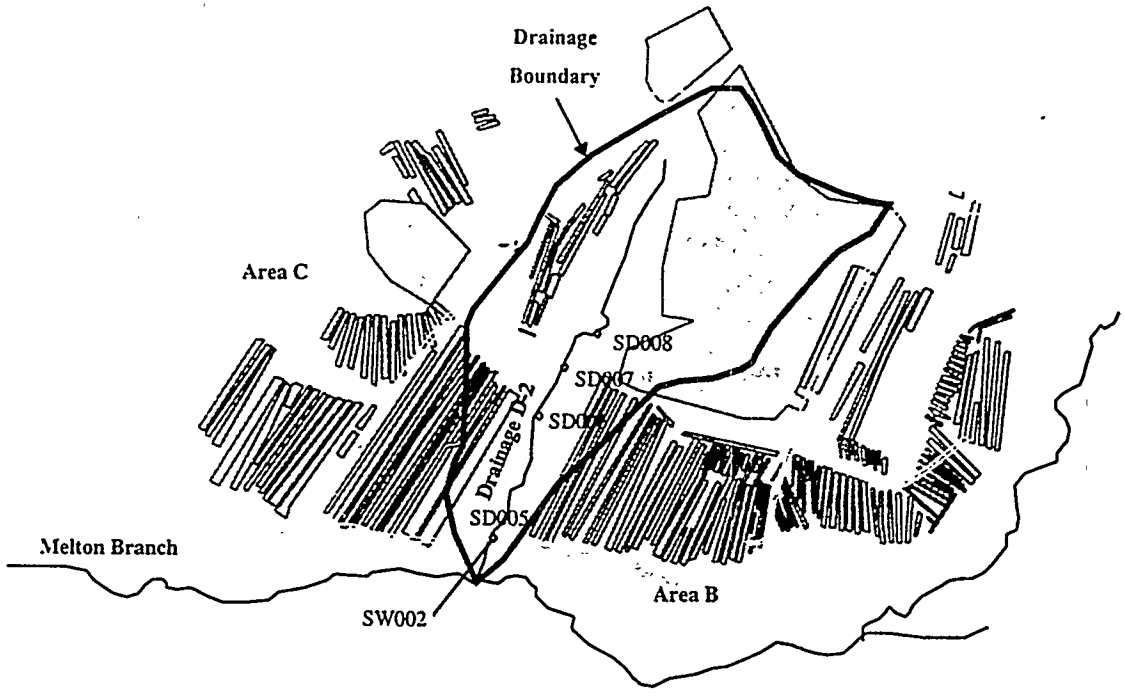
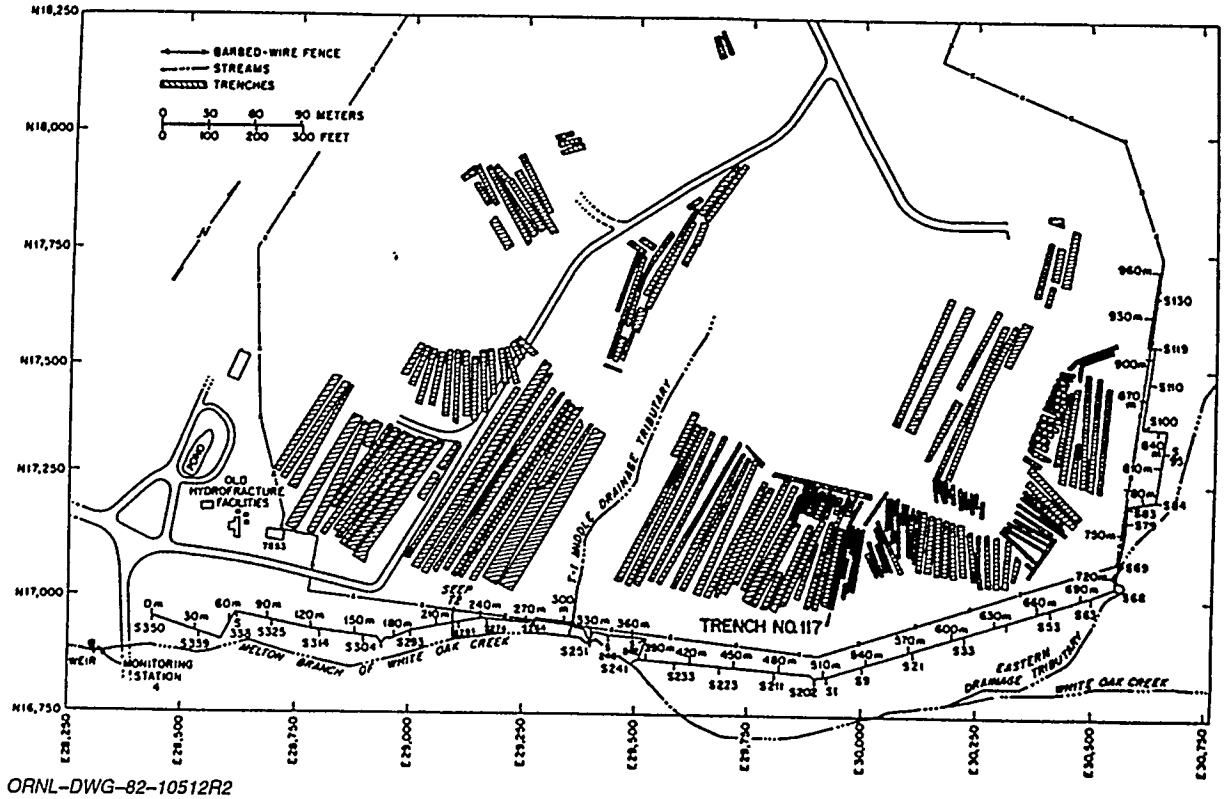


Fig. B2.4.7. Boundary and sampling locations for drainage D-2.



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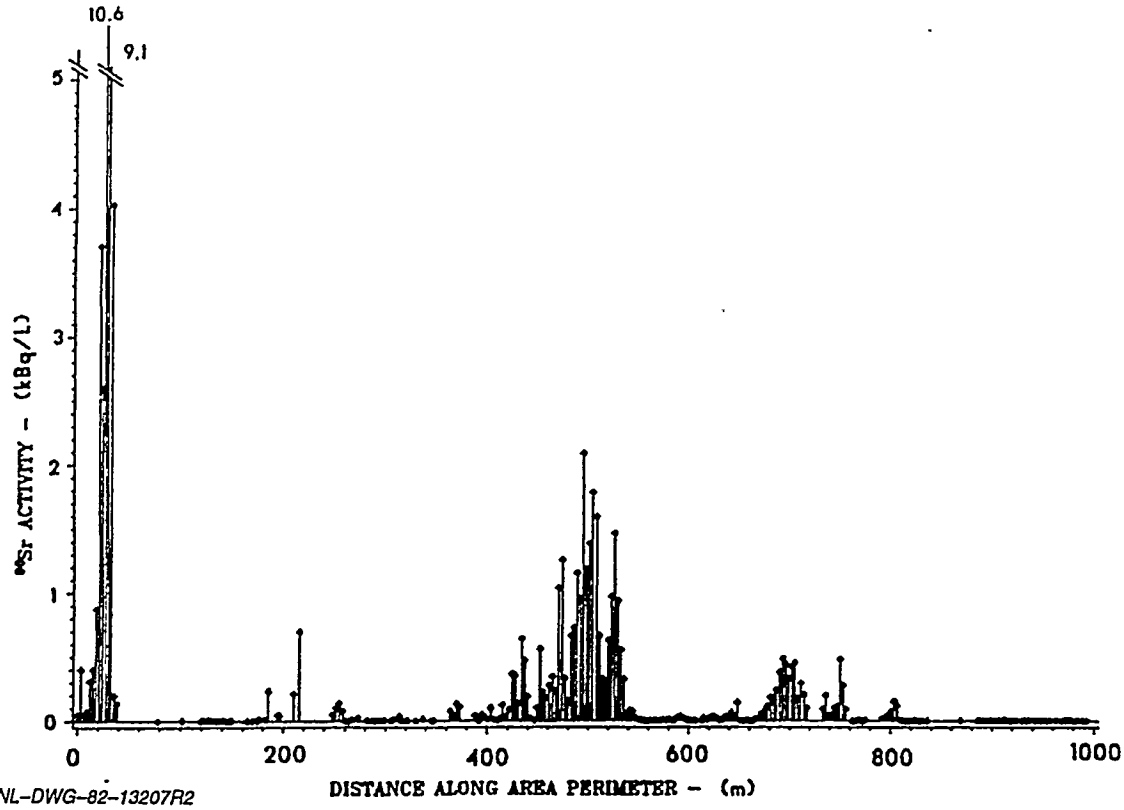

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Fig. B2.4.5. Concentrations of ^{90}Sr in shallow groundwater along the southern perimeter of WAG 5. *Source*: Spalding and Munro (1984).

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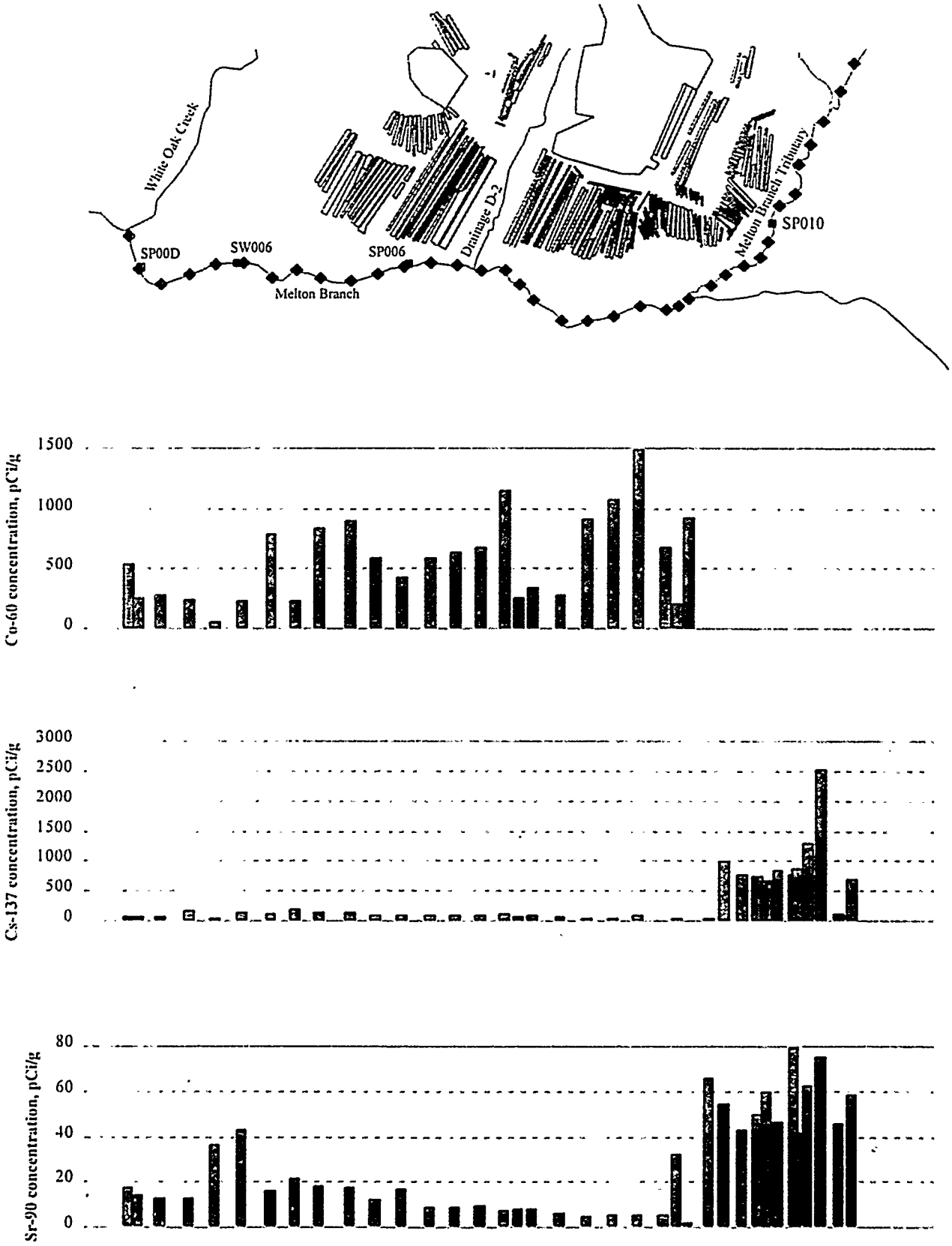


Fig. B2.4.6. Colbalt-60, ^{137}Cs, and ^{90}Sr concentrations in streambed gravels in Melton Branch.

B2_F4_6.PPT

RI sample summary. Surface water samples were collected from station SW002 during wet and dry seasonal conditions (June and October 1993) and during five storms between May 1993 and March 1994. Figure B2.4.8 shows each sampling event at SW002 in relation to the flow hydrographs. Samples taken during the storms were analyzed at the CSL, and baseflow samples were analyzed at the analytical support laboratory (ASL) (see Appendix A2 for a complete sample summary). Sediment samples were collected in June/July 1993 from four stations in drainage D-2.

Nature and extent of contamination. Sampling of the surface water and sediments in drainage D-2 identified a number of contaminants of concern: ^{241}Am, ^{135}Ca, $^{243/244}$Cm, ^{137}Cs, ^{238}Pu, ^{90}Sr, ^{99}Tc, ^{230}Th, tritium, ^{232}U, and $^{233/234}$U. Table B2.4.1 presents sample-specific results.

Tritium, ^{241}Am, ^{238}Pu, ^{99}Tc, ^{90}Sr, and $^{233/234}$U were detected in all samples in which the constituents were analyzed. Tritium was generally detected between 3,000,000 and 12,000,000 pCi/L. Strontium-90 was found at levels between 1300 and 2500 pCi/L, with little difference between storm and baseflow concentrations. Sediment samples also had elevated ^{90}Sr concentrations (~ 1000 pCi/L) at each location. Cesium-137 was not detected during baseflow sampling but was detected during storm events—however, only at values at or slightly above background (40 pCi/L). Values of ^{137}Cs were greatest at SD005 and decreased further upgradient. Gross alpha was detected at a range of 8 to 330 pCi/L. Isotopic analyses were only performed for off-site samples, and ^{241}Am and ^{238}Pu were detected each time, at levels as high as 9.7 and 17 pCi/L. Alpha also appears to be at elevated levels in the sediment, with the highest levels at SD006 and then decreasing to near background levels at SD008.

Flux calculations. Figures B2.4.9 and B2.4.10 present gross beta transport at SW002 during two storms. The June 14–15, 1993, storm was a typical summer storm with short-duration, high-intensity rainfall; total rainfall over ~3 h was 0.79 in. The March 9–10, 1994 storm, typical of low-intensity, longer duration winter storms, had 0.75 in of total rainfall during the 9-h storm.

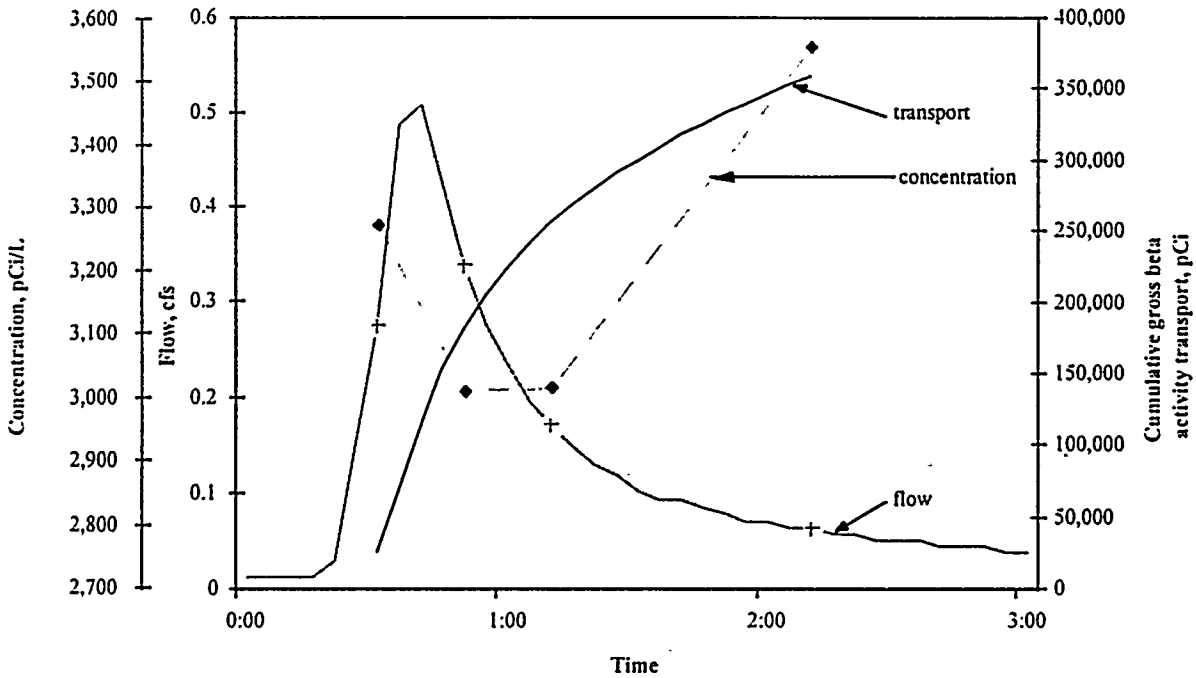


Fig. B2.4.9. Gross beta transport at SW002 during the June 1993 storm.

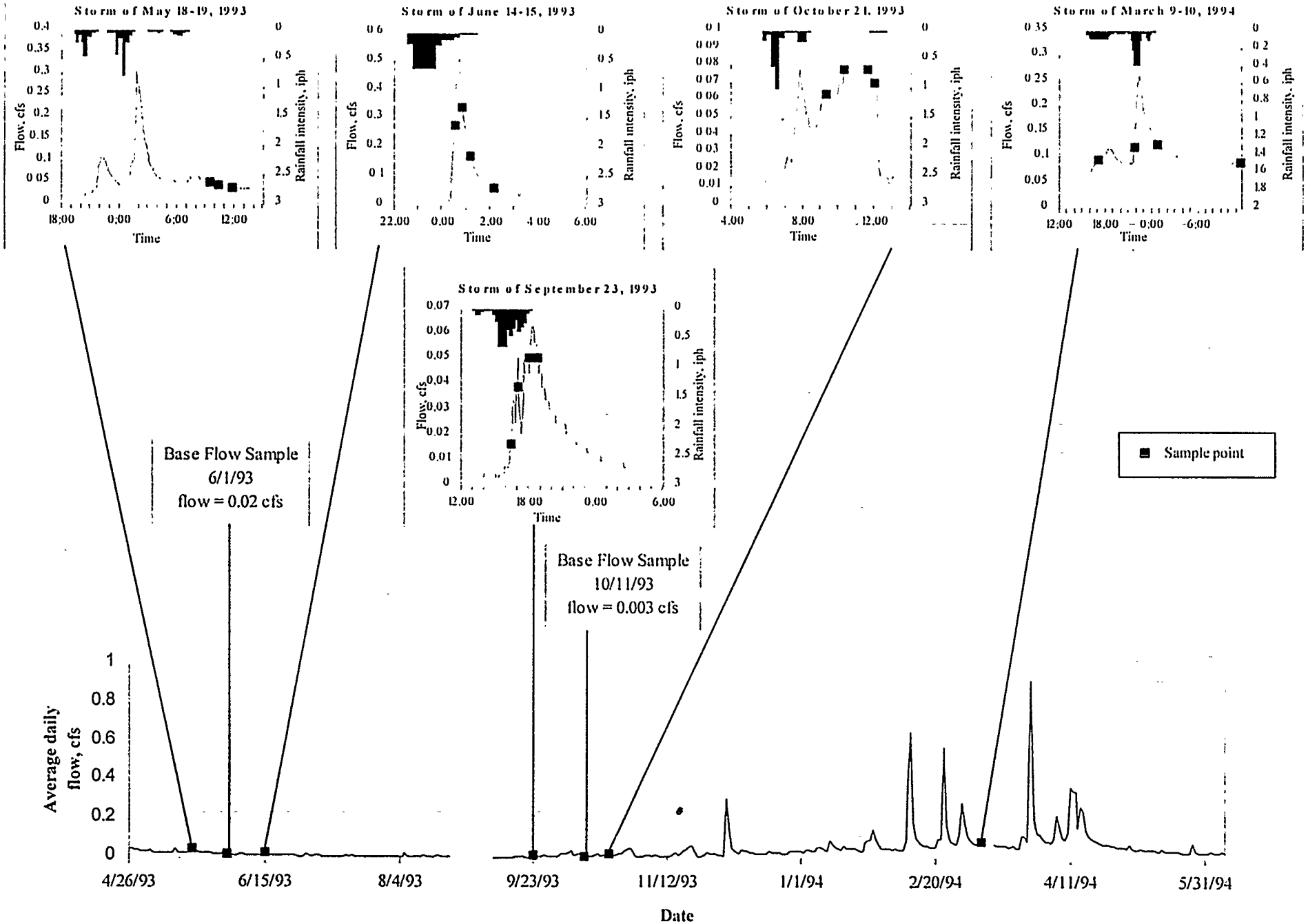


Fig. B2.4.8. Surface water sampling events at SW002.

Table B2.4.1. Analytical data summary for selected radionuclides in drainage D-2

Sample				(β)		(β)		(β)		(β−γ)		(α)		(α)		(α)		(α)	
Type	ID	Date	Time	Gross Beta		Tritium		Sr-90		Cs-137		Gross Alpha		U-233/234		Pu-238		Am-241	
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				8		1620				40		9		2					
SW002		5/19/93	09:26	3275.4	2888.2	7.62E+6	7.01E+6		2190			27	25.9						
SW002		5/19/93	10:26	3416.2	3383.4	7.91E+6	7.36E+6		2157.3			26.2	17.4						
SW002		5/19/93	11:46	3735.8	3337.9	8.01E+6	7.41E+6		2009.1			25	19.5						
SW002		6/1/93	14:42	4400	4500	7.60E+6	7.40E+6	2500	2600	-	-	16	11	3.7	5				
SW002		6/3/93	13:39	2149.3	2614	9.01E+6	8.93E+6					-	21.9						
SW002		6/15/93	00:28	3273.1	2097.8	6.06E+6	5.70E+6		2.4	22.7		58.6	19.4						
SW002		6/15/93	00:48	3009.6	1880.1	3.09E+6	3.09E+6				205	27.8	10.1						
SW002		6/15/93	01:08	3013.9	2386.7	4.13E+6	4.03E+6			16.6	41.8	17.5	12.7						
SW002		6/15/93	02:08	3555.9	3592.7	6.71E+6	6.50E+6				93	16.1	8.7						
SW002		9/23/93	16:27	5197	3851.5	8.83E+6	8.45E+6	1815.3		18.9	27.4	293.3	315.2						
SW002		9/23/93	17:07	5046.5	3665.9	9.76E+6	1.01E+7	1947.5		23.1	26.7	54.5	78						
SW002		9/23/93	18:07	4886		7.63E+6		1963				331.5							
SW002		9/23/93	18:47	4467.4	3700.7	7.07E+6	8.00E+6	1968 1		75.3	26.2	83.5	261.6						
SW002		10/11/93	10:01	4025.5	6237.5	9.60E+5	9.49E+6	1780	1810	-	-	10.9	104.4	3.2	3.32	17.72	17.24	9.3	9.74
SW002		10/21/93	09:20	4431.6		1.18E+7						39.2							
SW002		10/21/93	10:20	3699.4		1.19E+7						27							
SW002		10/21/93	11:40	5960.6		1.20E+7						42.9							
SW002		10/21/93	12:00	4680	4350	1.08E+7	8.68E+6	2090	2120	-	-	63.8	170	6.2	5.39	19.1	11.8	0.902	0.356
SW002		3/9/94	16:59	3431.1	2769.4	5.79E+6	5.50E+6			72.3		51	15.8						
SW002		3/9/94	21:45	3328.3	2686.5	6.22E+6	5.99E+6			202		23.7	11.2						
SW002		3/10/94	00:45	2911.9	2950.4	5.81E+6	5.64E+6			245		17.8	13.9						
SW002		3/10/94	12:09	2820	3030	4.15E+6	4.23E+6	1410	1370	-	-	13.2	13.2	1.73	2.17	14	10.4	0.144	0 0829
WAG 2 data																			
mid.drain		4/9/92		4575		8.70E+6		2115		-		144							
mid.drain		10/1/92		5250		1.02E+7						140							
mid.drain		3/9/93		3841.08				1897.9				53.6							
mid.drain		3/24/93		3533.35								83.97							
mid.drain		7/21/93		3696.72								74.12							

SEDIMENT (pCi/g)								
Background Reference		54	100	1.34	0.82	44	2.6		
SD005	6/28/93	1900	1668	830	9.7	120	1.9	31.3	-
SD006	6/28/93	2700	684.4	1400	7.1	170	1	18	0.322
SD007	7/6/93	2000	1409	890	7	64	16	3.5	
SD008	7/7/93	2400	1479	1100	6	47			0.62

Notes: 1. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfilter/Filtered - = not detected (α, β, γ) = Alpha, beta, gamma emitter

Storm concentrations at SW002 are much more variable than at SW001. Both the June 1993 and March 1994 storms caused dilution as surface runoff and interflow increased; however, after the flow decreased, the concentration increased after the June 1993 storm and decreased after the March 1994 storm. Contaminant concentrations at SW002 during all of the storms sampled were highly variable and did not correspond to the flow.

The average contaminant concentration in the quickflow (composed of both surface runoff and interflow) and baseflow were estimated at SW002 based on the sample results. To calculate average contaminant concentrations, the storm hydrographs were separated into baseflow and stormflow. An average concentration was assumed for both baseflow and stormflow, and a contaminant flux was calculated based on the assumed average concentrations. The total contaminant flux was then compared with the actual flux calculated from the measured concentrations and the flow at the time the sample was taken. A trial-and-error-method was used to find the best fit of the flux calculated with the assumed stormflow and baseflow concentrations and the measured flux.

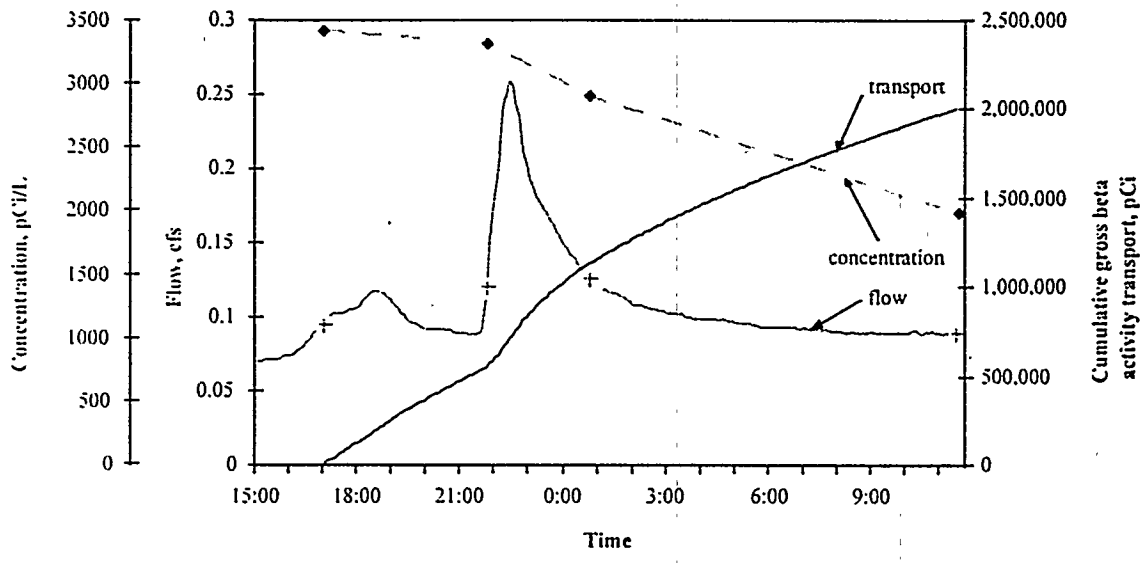


Fig. B2.4.10. Gross beta transport at SW002 during the March 1994 storm.

The average annual flux in the stormflow and baseflow was calculated using the average annual discharge from the HSPF model; surface runoff and interflow components were combined into stormflow. Table B2.4.2 shows average concentrations and annual contaminant fluxes from D-2.

Table B2.4.2. Average concentration and flux at SW002

	CONCENTRATION (pCi/L)		FLUX (MCi/YR)		TOTAL FLUX
CONTAMINANT	STORMFLOW	BASEFLOW	STORMFLOW	BASEFLOW	(MCi/YR)
Gross alpha	75	13	0.83 (76 %)	0.27 (24 %)	1.1
Gross beta	2,108	2,557	23 (31 %)	53 (69 %)	76
Tritium	3,950,161	5,243,374	43,900 (29 %)	108,000 (71 %)	151,900
^{90}Sr	1,660	2,173	18 (29 %)	45 (71 %)	63
^{99}Tc	25	39	0.28 (26 %)	0.80 (74 %)	1.08
$^{233/234}U$	7	2	0.08 (65 %)	0.04 (35 %)	0.12
^{238}Pu	18	15	0.20 (39 %)	0.31 (61 %)	0.51

Except for $^{233/234}U$ and gross alpha, approximately 70% of the contamination in D-2 is received from groundwater discharge. Alpha emitters generally adsorb tightly to sediment particles, so a higher concentration of gross alpha is expected when increased flow tends to mobilize the sediment in the stream channel.

Drainage D-3

Introduction. Drainage D-3 receives runoff from an area of 9.3 acres along the eastern portion of WAG 5 (Fig. B2.4.11). The drainage is primarily forested and lies almost completely outside the WAG 5 administrative boundary. Section B1.5 (Volume 3) presents a more complete description of the hydrology and physical characteristics.

RI sample summary. Surface water samples were collected from station SW003 during wet and dry seasonal conditions (June and October 1993) and during four storms between May 1993 and March 1994. Figure B2.4.12 shows the dates and times for each sampling event at SW001 in relation to the flow hydrographs. Storm samples were analyzed at the CSL, and baseflow samples were analyzed at the ASL. A sediment sample was collected from location SD009 in July 1993.

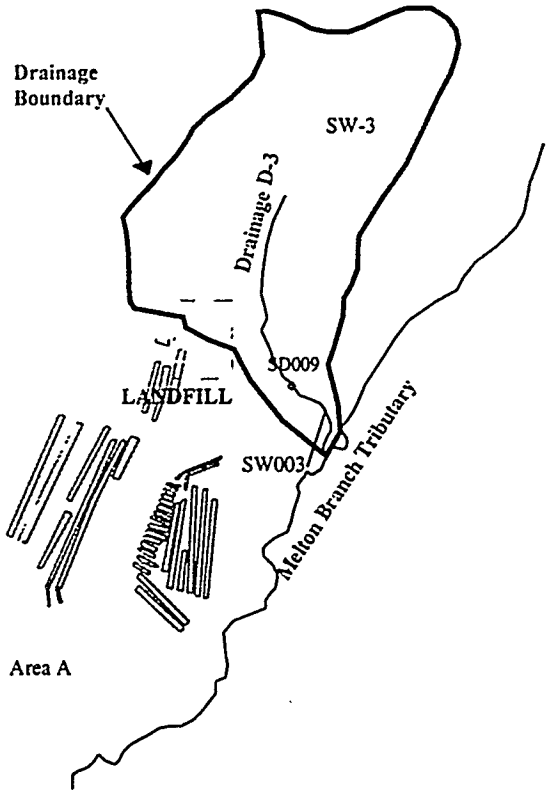


Fig B2.4.11. Boundary and sampling locations for drainage D-3.

Nature and extent of contamination. Sampling of the surface water and sediments in drainage D-3 identified a number of contaminants of concern: ^{241}Am, $^{243/244}Cm$, ^{60}Co, ^{137}Cs, ^{238}Pu, $^{239/240}Pu$, ^{90}Sr, and tritium (Table B2.4.3). Tritium was consistently detected at relatively low levels between

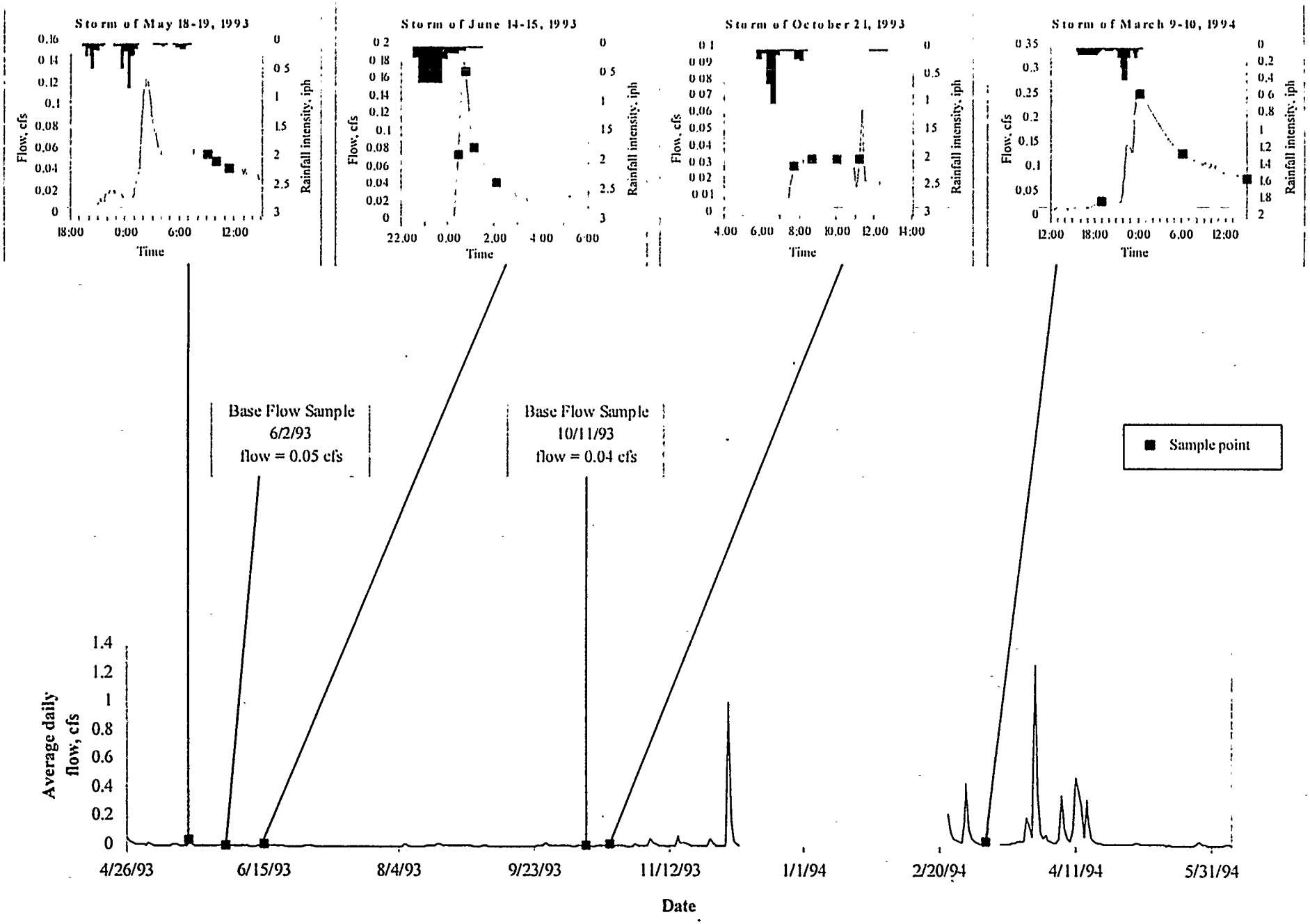


Fig. B2.4.12. Surface water sampling events at SW003.

Table B2.4.3. Analytical data summary for selected radionuclides in drainage D-3

Sample ID	Date	Time	(β) Gross Beta U	(β) Gross Beta F	(β) Tritium U	(β) Tritium F	(β−γ) Co-60 U	(β−γ) Co-60 F	(β) Sr-90 U	(β) Sr-90 F	(β−γ) Cs-137 U	(β−γ) Cs-137 F	(α) Gross Alpha U	(α) Gross Alpha F	(α) Pu-238 U	(α) Pu-238 F	(α) Pu-239/240 U	(α) Pu-239/240 F	(α) Cm-243/244 U	(α) Cm-243/244 F
SURFACE WATER (pCi/L)																				
Background Reference			8		1620						40		9							
SW003	5/19/93	09:05	57.8	21.7	2821.6	3013.5				4.9			-	6.7						
SW003	5/19/93	10:05	-	108	2512.6	3056.8			700.7	47.6			-	7.6						
SW003	5/19/93	11:25	-	23.4	2283.8	2608.1				4			5.7	8.3						
SW003	6/2/93	10:30	-	-	2400	1400	-	-	-	-	-	-	0.52	-						
SW003	6/3/93	14:53	59.5	-	5760.4	6166.7							-	-						
SW003	6/15/93	00:24	58.8	16	2514.4	3153.2	51.7						21.8	6.7						
SW003	6/15/93	00:44	82.3	26.1	1862.2	6673.9							10.9	6.7						
SW003	6/15/93	01:04	44.5	-	2015.3	2338.7							8.5	16.1						
SW003	6/15/93	02:08	-	-	2024.3	2046.8		41					8	-						
SW003	10/11/93	13:45	6.7	5.2	2680.9	1767.8			-	1.24	-	-	-	-	-	-	-	-		
SW003	10/21/93	07:40	69.5	39.8	2541.4	2766.7			-				32.2	20.1						
SW003	10/21/93	08:40	830.6	32.4	2351.4	2061.3			-			922	25.6	-						
SW003	10/21/93	10:00	101	24.4	3194.6	2687.4			-		38.7	313	8.8	12.9						
SW003	10/21/93	11:10	4.39	6.34	1160	2210			-	-	-	-	-	-	-	-	-	0.191	-	-
SW003	3/9/94	18:53	36.7	56.8	1880.2	134962				18.5		98.8	-	-						
SW003	3/10/94	00:08	16.7	83.5	1233.3	4321.6				36.7		95	-	-						
SW003	3/10/94	06:08	46.9	37.7	1369.4	1640.5					186	279	6.7	-						
SW003	3/10/94	15:40	3.08	11.2	385	436			57	0.884	-	-	-	1.42	-	1.22	-	0.805	-	3.2
SEDIMENT (pCi/g)																				
Background Reference			54		100				1.34		0.82		44							
SD009	7/7/93		22		11.35				1		0.39		27							

Notes: 1. Blanks indicate analyte not analyzed for; **Bold** results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfilter/Filtered - = not detected (α,β,γ) = alpha, beta, gamma emitter

1100 and 6600 pCi/L. Strontium-90 and ^{137}Cs were generally detected during storms and not during baseflow. Gross alpha values were low, with the highest value at 32 pCi/L (<3 times background). After the March 1994 storm, TRU constituents $^{238/239/240}Pu$ and $^{243/244}Cm$ were detected in filtered grab samples only. All detects from SD009 were below background.

Flux calculations. Contaminant concentrations at SW003 during storms are much more variable than at SW001 and do not correspond to flow (Figs. B2.4.13 and B2.4.14). Table B2.4.4 shows the average concentrations and the resulting average annual contaminant fluxes from D-3.

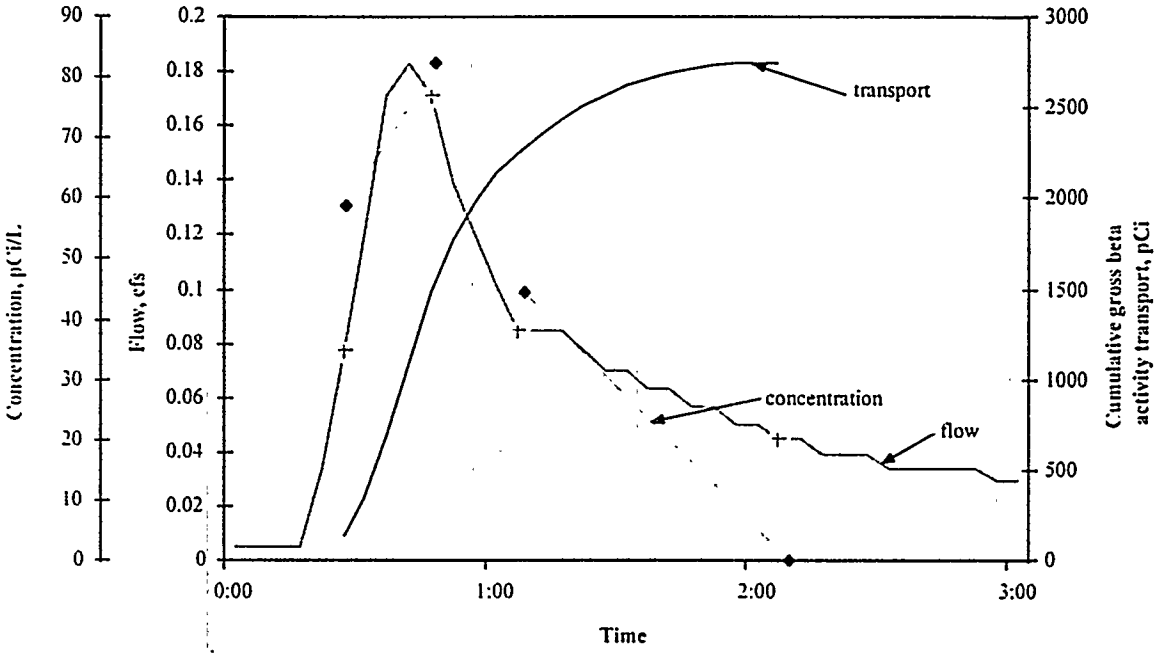


Fig. B2.4.13. Gross beta transport at SW003 during the June 1993 storm.

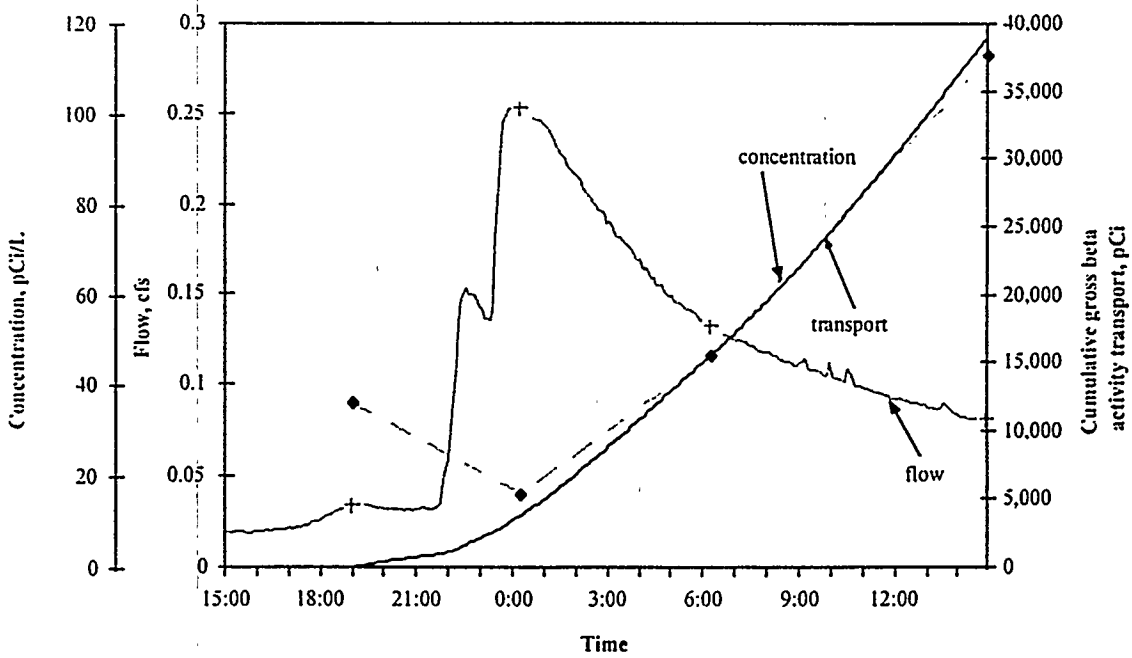


Fig. B2.4.14. Gross beta transport at SW003 during the March 1994 storm.

Table B2.4.4. Average concentration and flux at SW003

CONTAMINANT	CONCENTRATION, pCi/L STORMFLOW	CONCENTRATION, pCi/L BASEFLOW	FLUX, mCi/yr STORMFLOW	FLUX, mCi/yr BASEFLOW	TOTAL FLUX, mCi/yr
Gross alpha[a]	11.1				0.28
Gross beta	49	83	0.66 (40 %)	1.0 (60 %)	1.7
^{3}H	970	1387	13 (44 %)	17 (56 %)	30
^{90}Sr	39	2	0.52 (96 %)	0.02 (4 %)	0.54

[a]Gross alpha at SW003 was not separated into the stormflow and baseflow components because of variability in the sample data; however, the average gross alpha concentration for all the samples is shown.

Melton Branch

Melton Branch receives runoff from an area of 1.51 mi^2, including WAGs 8 and 9 and the southern portion of WAG 5. Surface water samples were collected at two locations upstream of WAG 5 to separate the contaminant contribution of WAGs 8 and 9 from the contribution of WAG 5. SW004 is on Melton Branch Tributary upstream of WAG 5, and SW005 is upstream of WAG 5 on Melton Branch (Fig. B2.4.15). SW006 is at the southwestern corner of SWSA 5 at the Melton Branch weir.

Runoff samples were collected during five storms at SW005 (Fig. B2.4.16) four at SW006 (Fig. B2.4.17), and three at SW004. Flow data are not available for SW004. Baseflow samples were collected in June and October 1993 from each sample location. Table B2.4.5 lists analytes of concern.

Table B2.4.5. Contaminants of concern detected at SW004, SW005, and SW006

CONTAMINANT	SW004	SW005	SW006
^{241}Am	X	X	X
^{45}Ca	X		X
$^{243/244}Cm$	X		X
^{60}Co		X	X
^{137}Cs	X	X	X
^{238}Pu			X
^{99}Tc	X	X	X
^{230}Th	X	X	X
^{90}Sr	X	X	X
Tritium	X	X	X

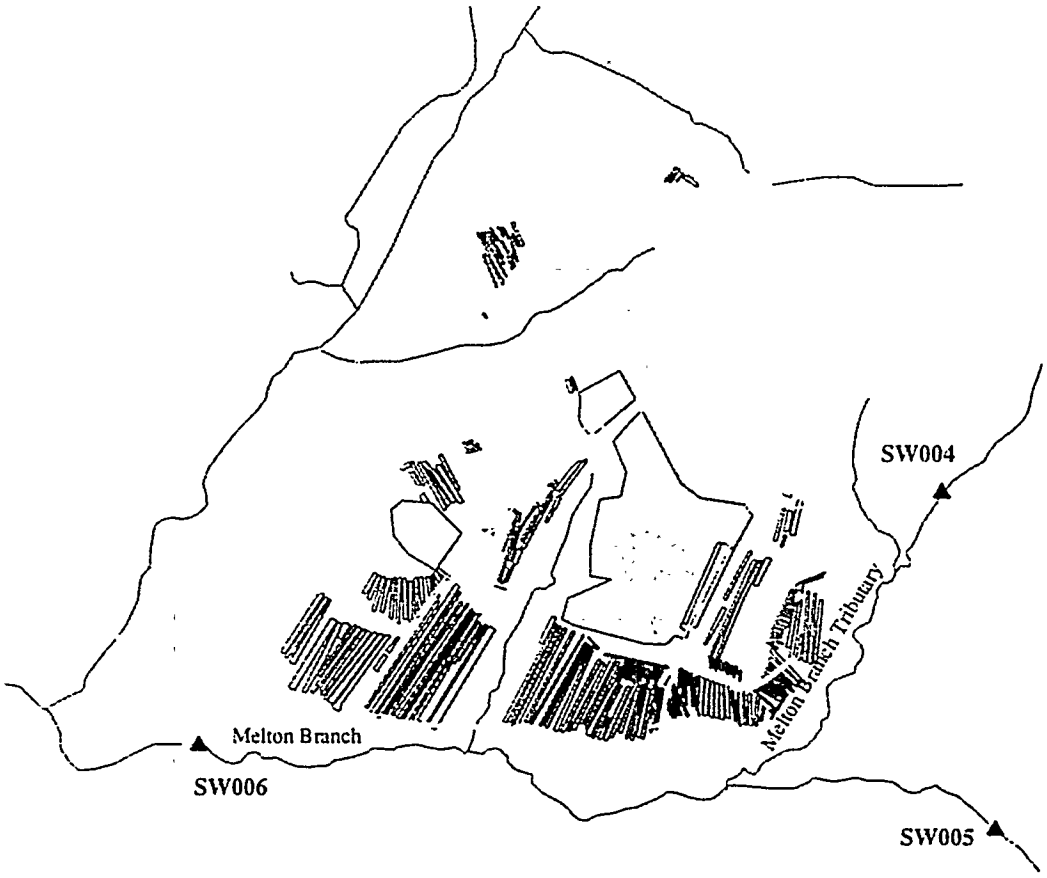


Fig. B2.4.15. Location of surface water stations SW004, SW005, and SW006.

Tables B2.4.6–B2.4.8 present the quantitative results for the analytes of concern at stations SW004, SW005, and SW006. SW006 has high levels of ^{90}Sr, tritium, and ^{137}Cs. Due to the high concentrations of ^{90}Sr and tritium, Melton Branch is a significant contributor to the overall flux of both constituents at White Oak Dam (see Sect B2.4.4 for discussion). Plutonium-238 and ^{238}Pu were also detected at SW006 in all samples in which they were analyzed. Plutonium-238 was not detected at either of the upstream locations. The concentration of ^{241}Am was significantly higher at SW006 than at SW005; however, SW006 and SW004 had similar concentrations. The flow at SW006 is much higher than at SW004, causing the overall flux of ^{241}Am at SW006 to be much greater. Curium-243/244 was detected at SW006 only during the storm of March 9-10, 1994; ^{230}Th was detected at higher levels (over twice background reference) during this storm.

Figures B2.4.18 and B2.4.19 present the gross beta transport at SW005 for the June 14–15, 1993, storm and at SW006 for the September 23, 1993 storm (no sample was collected from SW006 during the June 14—15, 1993, storm). The June and the September 1993 storms had similar intensities and durations.

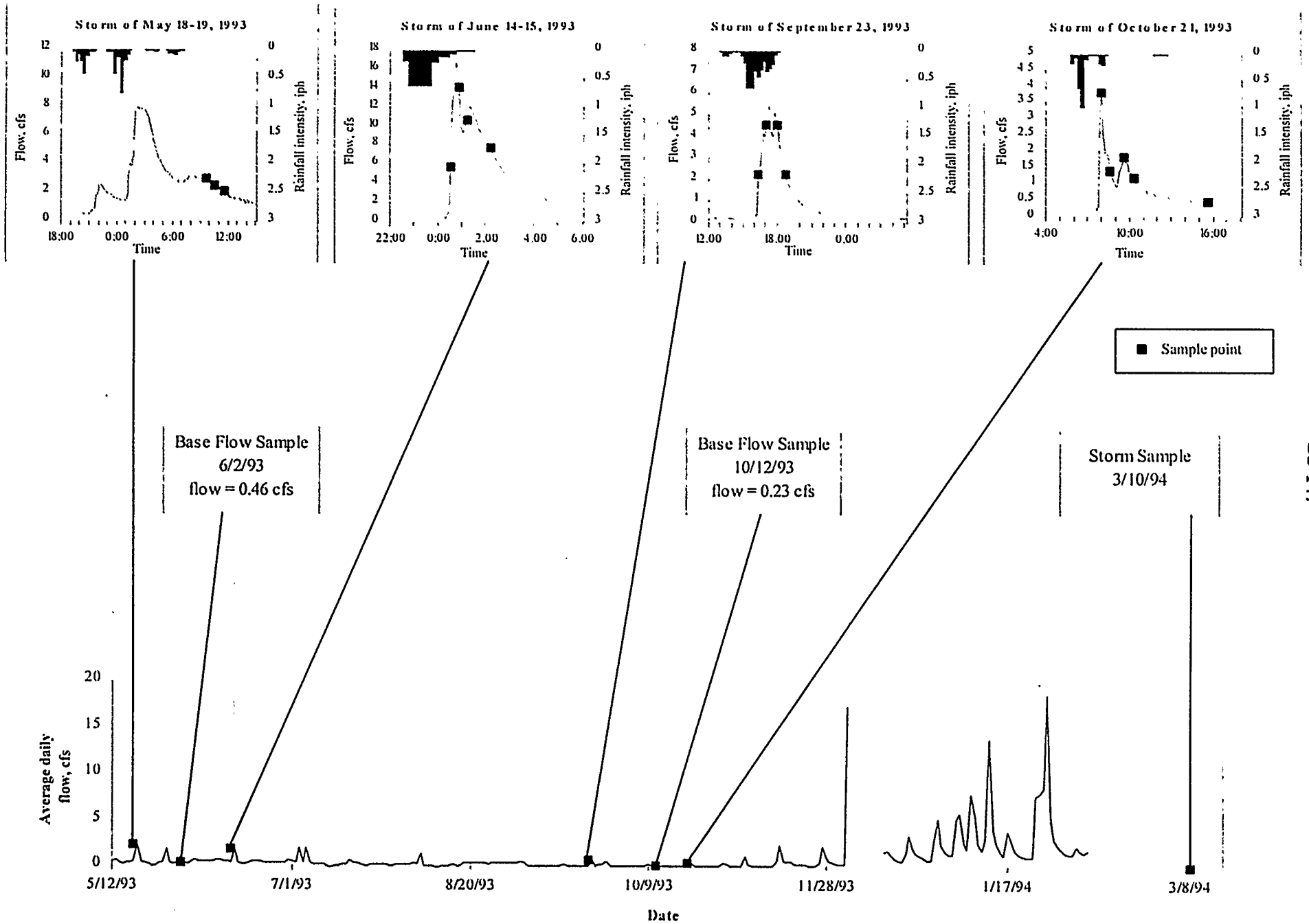
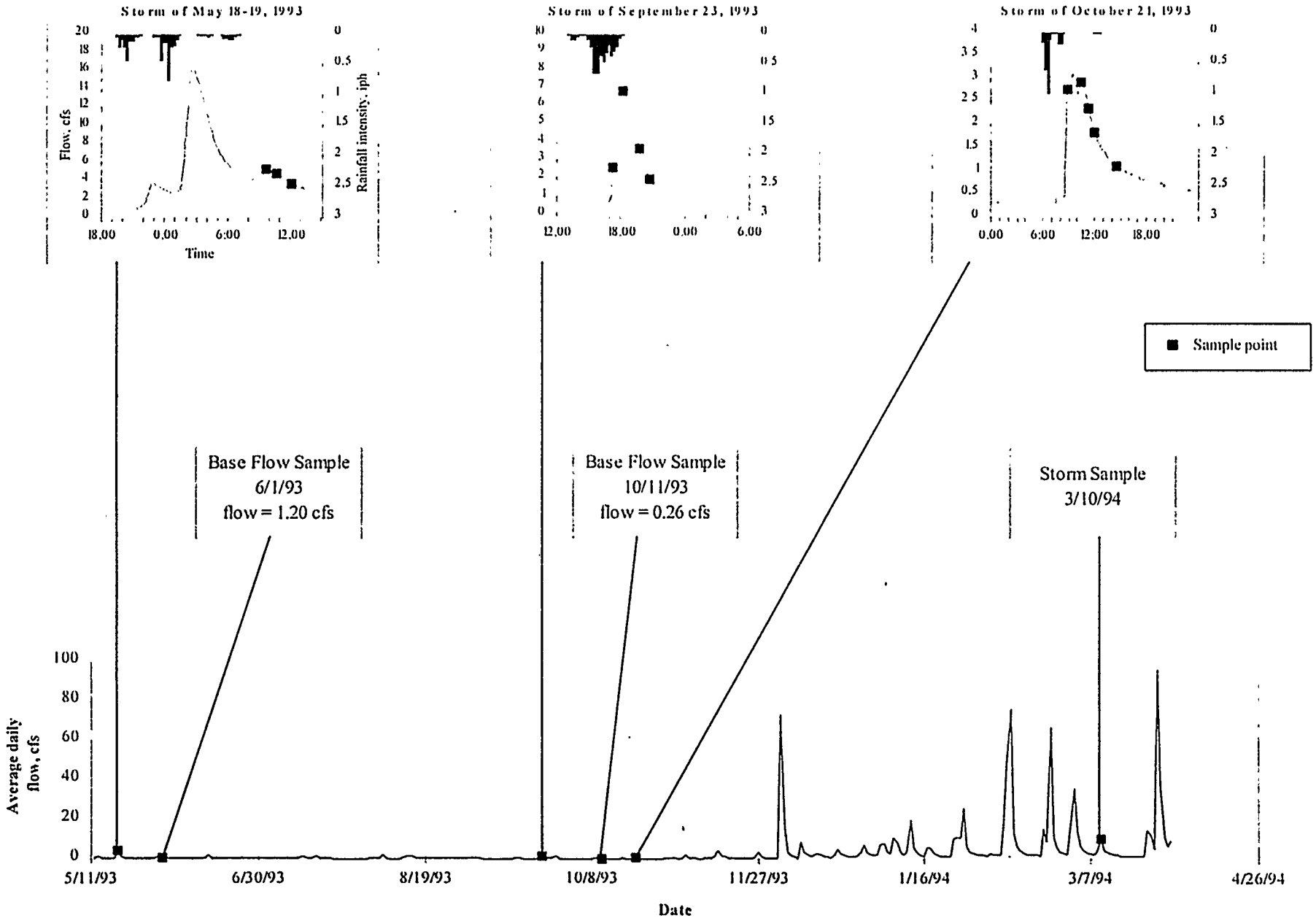


Fig. B2.4.16. Surface water sampling events at SW005.

B2_F4_16.PPT



B2_F4_17.PPT

Fig. B2.4.17. Surface water sampling events at SW006.

Table B2.4.6. Analytical data summary for selected radionuclides at surface water station SW004

Sample			(a)		(b)		(b)		(b)		(a)		(a)		(a)	
ID	Date	Time	Gross Alpha		Gross Beta		Sr-90		Cs-137		Pu-239/240		Am-241		Cm-243/244	
SURFACE WATER (pCi/L):			U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference			9		8				40							
SW004	6/2/93	14:36	1.5	0.52	3200	3100	1400	1300	-	-						
SW004	6/4/93	10:58	-	-	1445.4	1291.6		63.9								
SW004	10/12/93	14:41	1.9	2.2	2189.6	1544.8	613	728	-	-	-	-	5.15	5.06		
SW004	10/21/93	08:15	217.3		2202.8		679.1		185	8120						
SW004	10/21/93	09:00	19.1	139.1	1619	1471.1		697.5	319	112						
SW004	10/21/93	09:30	12.1	54.6	1832.3	1446.5	843.8		132	387						
SW004	10/21/93	10:00	14.6	8.3	2215.5	1825.2				268						
SW004	10/21/93	16:15	3.6	27.2	2180	2040	976	982	-	-	-	-	-	0.09	-	-
SW004	3/10/94	19:06	2.9	3.2	2080	2050	208	986	-	-	0.07	-	0.05	-	0.62	-
WAG 2 Data																
HRT-3	4/9/92						1100		-							
HRT-3	10/1/92						1069		-							
HRT-3	3/9/93		38.1		2360.19		1072.5									
HRT-3	3/24/93		26.0		1799.41		691									
HRT-3	5/24/93		41.1		3519.67		1211.4									
HRT-3	7/21/93		30.8		1463.14		1492.6									
HRT-3	9/30/93															
HRT-3	12/1/93															

Notes: 1. Blanks indicate analyte not analyzed for; **Bold** results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfilter/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emitter

Table B2.4.7. Analytical data summary for selected radionuclides at surface water station SW005

Sample			(α)		(β)		(β)		(β)		(β)		(β)		(α)		(α)	
ID	Date	Time	gross alpha		gross beta		Tritium		Co-60		Sr-90		Cs-137		Th-230		Am-241	
SURFACE WATER (pCi/L)			U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference			9		8		1620						40		4.2			
SW005	5/19/93	09:36	5.8	-	-	-	8653	8633				6.1						
SW005	5/19/93	10:36	-	9.2	-	45.8	9083	9314			703.3	262.7						
SW005	5/19/93	11:36	8.5	-	47.8	20.1	10019	10538				3.5						
SW005	6/1/93	14:18	-	1.3	41	16	18000	17000	-	-	3.4	6	-	-	-	-		
SW005	6/4/93	10:23	-	-	104.7	-	29978	28544										
SW005	6/15/93	00:29	10.6	6.7	19.4	42.5	8669	6732	68.7	74.4				23				
SW005	6/15/93	00:49	13.3	8	85.6	29.8	17294	18184										
SW005	6/15/93	01:09	16.1	9.3	51.5	-	6885	9378	31.8									
SW005	6/15/93	02:09	15	10	50.2	36.1	4141	4078						340				
SW005	9/23/93	16:20	49.7	63.3	137.1	122	5475	5038			12			19.8				
SW005	9/23/93	17:00	262.1	28.1	99.6	44.5	6314	6415			1.8							
SW005	9/23/93	18:00	29.9	291.9	40.8	71.6	4792	5942			3.7		38.4					
SW005	9/23/93	18:40	20.7	60.8	62.2	49.2	5622	4293			2.9							
SW005	10/12/93	11:04	2.6	-	8.8	8.2	22300	23200					-	-	-			
SW005	10/21/93	08:00	84.2	70.8	154.8	95.9	2308	1379			3.3		65.2	1880				
SW005	10/21/93	08:36	8.9	7.2	90.6	34.6	10643	10296			2.9			445				
SW005	10/21/93	09:36	12.3	-	948.9	87.9	12112	11375			3			1400				
SW005	10/21/93	10:16	7.6	-	129.1	66.6	17686	16637			-			277				
SW005	10/21/93	16:37	-	-	5.75	5.42	10500	10600			-	1.45	-	-	1.9	1.9	-	-
SW005	3/10/94	17:41	-	-	17.8	4.02	3880	3480			34.5	1.21	-	-	9.6	9.4	0.092	0.055
WAG 2 Data																		
MB-15	4/9/92						7364		-		18		-					
MB-15	10/1/92						31304		-		26		-					
MB-15	3/9/93				9.9		13120				12.14							
MB-15	3/24/93				6.6		4150											
MB-15	7/21/93				6.0		28390											
MB-15	9/30/93						35560											
MB-15	12/1/93						27260											

Notes: 1. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfilter/Filtered - = not detected (α,β,γ) = alpha, beta, gamma emitter

Table B2.4.8. Analytical data summary for selected radionuclides at surface water station SW006

Sample ID	Date	Time	(α) gross alpha		(β) gross beta		(β) Tritium		(β) Sr-90		(β) Cs-137		(α) Pu-238		(α) Am-241	
SURFACE WATER (pCi/L)			U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference			9		8		1620				40					
SW006	5/19/93	09:42	14.5	10.9	1186	965.3	1.42E+6	1.30E+6		377.4						
SW006	5/19/93	10:42	20.2	15.5	1182.3	959.6	1.26E+6	1.17E+6		520.6						
SW006	5/19/93	12:02	15.1	11.7	1069.6	1043.9	1.28E+6	1.18E+6	2.8	16		16.1				
SW006	6/1/93	11:10	3.1	2	1400	1200	1.40E+6	1.40E+6	570	730	-	-				
SW006	6/4/93	09:29	-	22	1169.6	1055.9	1.74E+6	1.75E+6	990.8	950.3						
SW006	9/23/93	17:09	36.5	36.9	1240.1	743.6	7.05E+5	7.15E+5	452.2		916	23.3				
SW006	9/23/93	18:09	23.8	239.3	651.3	476.1	1.75E+5	1.81E+5	200		109	19.2				
SW006	9/23/93	19:39	12.3	63.1	807.8	639.6	2.66E+5	2.67E+5	244.9		19	23.3				
SW006	9/23/93	20:39	33.6	25.1	1097.7	297.6	3.32E+5	3.40E+5	399.4		18.7					
SW006	10/11/93	15:08	5.7	3	1586.9	1573.5	8.78E+5	8.83E+5	633	666	-	-	4.18	2.5	5.7	6.97
SW006	10/21/93	08:50	14.7	11.9	2431.8	1145	1.14E+6	1.08E+6			79.9	236				
SW006	10/21/93	10:20	16.1	-	962	472.8	4.55E+5	4.75E+5				867				
SW006	10/21/93	11:20	11.7	11.7	1221.1	2541.5	4.23E+5	4.23E+5	348.1		22.8	377				
SW006	10/21/93	12:20	8.1	-	1063.6	1206.3	4.76E+5	4.69E+5	514.4		185	220				
SW006	10/21/93	14:30	9.4	13.2	1090	1060	5.20E+5	5.08E+5	484	572	-	-	2.61	2.11	0.08	0.09
SW006	3/10/94	14:25	-	-	889	923	5.74E+5	6.03E+5	431	185	-	-	0.33	0.25	0.16	0.12
WAG 2 Data																
MBWEIR	3/25/92						1.10E+6		518		-					
MBWEIR	4/9/92						1.47E+6		607		-					
MBWEIR	9/16/92						5.09E+5		551		0.1					
MBWEIR	10/1/92						6.49E+5		480		-					
MBWEIR	3/9/93		11.2		909		1.11E+6		441				0.2		0.66	
MBWEIR	3/11/93		15.0		914		1.48E+6		448							
MBWEIR	3/24/93		12.1		793		5.90E+5		358							
MBWEIR	4/14/93		14.8		1188		1.25E+6		498							
MBWEIR	5/24/93		18.9		2154		2.33E+6		1019							
MBWEIR	7/13/93		71.0		2879		1.05E+6		1434							
MBWEIR	7/19/93		56.5		1836		7.41E+5		843							
MBWEIR	7/21/93		75.5		2317		5.54E+5		1044							
MBWEIR	9/30/93						1.36E+6									
MBWEIR	12/1/93						9.04E+5									

Notes: 1. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfilter/Filtered - = not detected (α,β,γ) = alpha, beta, gamma emitter

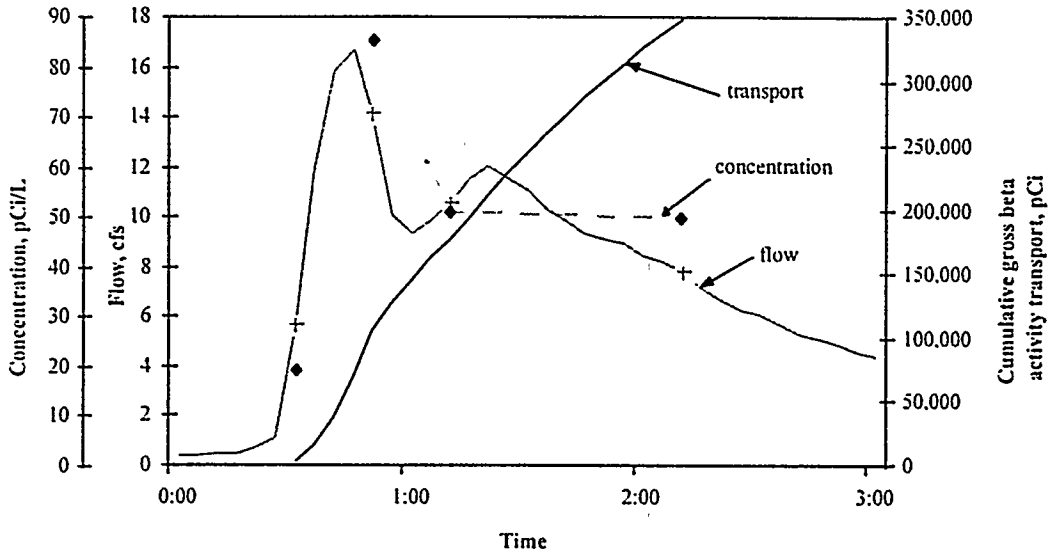


Fig B2.4.18. Gross beta transport at SW005 during the June 1993 storm.

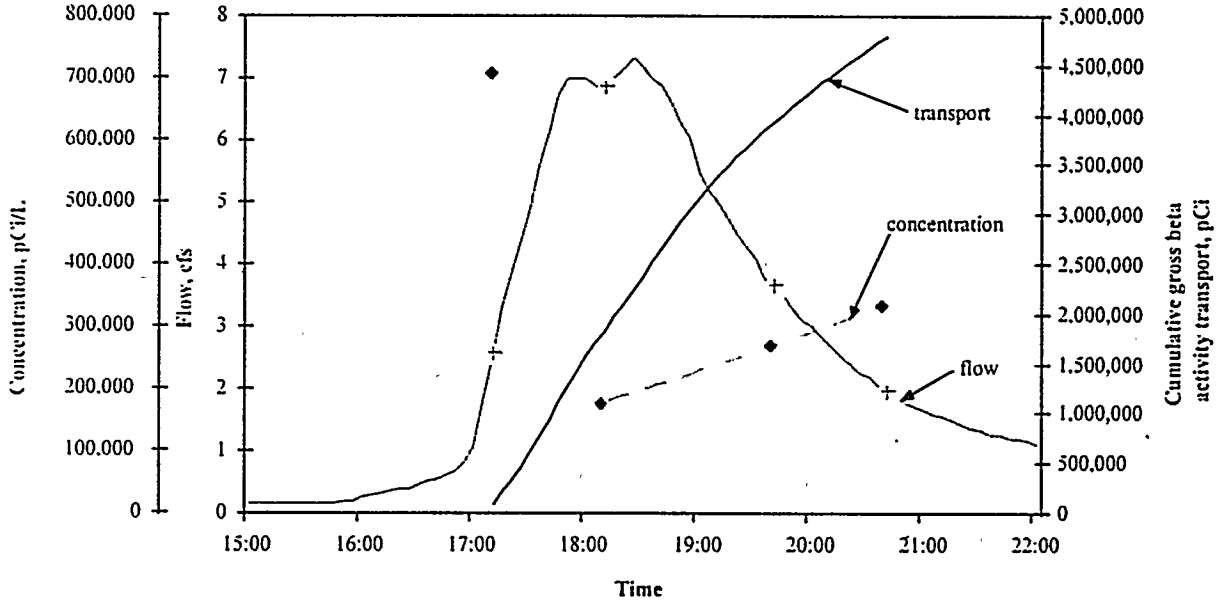


Fig B2.4.19. Gross beta transport at SW006 during the September 1993 storm.

Contaminant concentrations at SW006 are generally inversely proportional to flow. As the flow increases, the concentration decreases due to dilution from surface runoff and interflow during and following a storm. Most of the contaminant flux at SW006 is groundwater discharge.

In contrast to SW006, the contaminant concentration at SW005 is proportional to flow in Melton Branch, and most contaminant movement at SW005 occurs during storms when increased flow mobilizes contamination on the land surface and in the stream channel.

Table B2.4.9 shows calculated average contaminant concentrations in stormflow and baseflow at SW005 and SW006.

Table B2.4.9. Average concentrations in stormflow and baseflow at SW005 and SW006

	SW005 AVG. CONCENTRATION (pCi/L)		SW006 AVG. CONCENTRATION (pCi/L)	
CONTAMINANT	STORMFLOW	BASEFLOW	STORMFLOW	BASEFLOW
Gross alpha	21	0	27	7
Gross beta	49	0	624	1,050
Tritium	5,617	9,841	92,234	1,441,131
^{90}Sr	2	7	183	889

Almost all of the contamination (except for tritium) above SW005 is in the stormflow.. Except for gross alpha, which travels more with the stormflow, SW006 has the highest concentrations in the baseflow. The average contaminant flux at SW004, SW005, and SW006 was calculated by multiplying the average concentration in the samples collected at each station by the average flow. The average flow at SW006 is the average flow at Melton Branch weir from October 1989 through December 1993. The average flow at SW004 and SW005 was calculated by multiplying the average flow at SW006 by the fraction of the Melton Branch drainage area above each sample location. Table B2.4.10 shows average concentrations and annual fluxes.

Except for gross alpha, which is higher at SW005 than at SW006, most of the contaminant flux in Melton Branch enters below SW004 and SW005. Approximately 10% of the ^{90}Sr in Melton Branch comes from sources upstream of WAG 5, and less than 1% of the tritium in Melton Branch is from upstream sources.

Table B2.4.10. Average concentrations and fluxesat SW004, SW005, and SW006

	SW004		SW005		SW006	
CONTAMINANT	CONCENTRATION (PCI/L)	FLUX (MCI/YR)	CONCENTRATION (PCI/L)	FLUX (MCI/YR)	CONCENTRATION (PCI/L)	FLUX (MCI/YR)
Gross alpha	34	5.6	36	70	16	44
Gross beta	1,693	276	65.7	127	838	2,320
^{60}Co	--	--	50	97	440	1,217
^{137}Cs	212	35	52	101	193	534
^{90}Sr	787	129	7.5	15	439	1,215
Tritium	--	--	7,651	14,826	588,900	1,630,250

B2.4.3 SW-3 Study Area

The SW-3 study area lies along the eastern perimeter of WAG 5; its configuration is based on the drainage catchment associated with drainage D-3. Although much of the catchment lies outside the WAG 5 boundary, it receives surface runoff and groundwater discharge from the eastern portion of SWSA 5. Contaminant source areas upgradient of SW-3 include the northeast landfill—identified as an area of concern in the WAG 5 field sampling plan (FSP)—and a group of waste disposal trenches on the uphill side of the landfill. A portion of the landfill extends into the SW-3 area, and therefore it is discussed in detail in this section. The trenches lie within SWSA 5 South Area A and are addressed in Sect. B2.4.5. Figure B2.4.20 is a photograph of the landfill area showing general conditions as of November 1994.

Fig. B2.4.20. Photograph of SW-3/northeast landfill.

Description and history

The 9.3-acre SW-3 study area is forested except for those portions associated with the WAG 5 decontamination facility and gravel roads. The northeast landfill covers an area of 0.5 acres on the western (and east-facing) slope of the D-3 drainage catchment. Observations and measurements with field instrumentation identified an extensive accumulation of both contaminated and uncontaminated solid wastes dumped on the slope (Fig. B2.4.20). The USRADS survey showed high gamma exposure rates associated with several discrete accumulations of landfill debris. Surface waste materials include metal ammunition boxes, scrap metal, corrugated pipe, concrete debris, a B-25 box, miscellaneous equipment parts and hoses, and a 55-gal plastic drum. The upper portion (western edge) of the landfill includes some buried wastes, evident from the topography and observations make during the collection of the 0- to 2-ft soil samples from boring SB044. In other areas, some of the wastes were partially covered with soil, but there was no apparent attempt to bury much of the material now exposed (i.e., these wastes have not been exposed through erosion of cover

material). A complete inventory of wastes dumped on the hillside and dates of disposal were not available. Table B2.4.11 is a source characterization matrix for the landfill.

Table B2.4.11. Northeast landfill source characterization matrix.

SOURCE	AREA	WASTE TYPES & CONTAMINANTS OF CONCERN	DISPOSAL METHODS & PACKAGING	WASTE VOLUME	INVENTORY	DATES
Landfill/ hillside dump area Status: *active*	0.5 acre	Clean & contaminated solid wastes; debris incl. drums, boxes, piping, hoses, scrap metal; contam. include ^{137}Cs, ^{90}Sr, ^{60}Co; minor TRU contamination also	Some wastes containerized; some buried, most dumped over hillside where it remains exposed	500 yd^3 *(est.)*	Unknown	pre-1973; exact dates unknown

The other potential samples in the SW-3 study area are the WAG 5 decontamination facility, the waste consolidation area for investigation-derived waste (IDW), and the waste burial trenches on top of the hill west of the landfill. The decontamination facility collects all potentially contaminated fluids in a lined holding basin that is periodically pumped into a truck and transferred to the Process Waste Treatment Plant. This area is not considered a potential source or contributor of contamination to SW-3 (or any other WAG 5 areas). The waste consolidation area is not a significant source of contamination for several reasons.

- The levels of contamination in the IDW are low (based on soil analytical data).
- The IDW is lying on top of a liner and is covered by a well-secured plastic tarp to prevent contact with precipitation.
- The area is bermed to divert run-on from adjacent areas.

The trenches lie within the Melton Branch tributary drainage basin and area A of SWSA 5 South. Some of the groundwater that passes beneath these trenches may discharge to SW-3, but most follows more southeasterly flowpaths. These trenches are addressed in Sect. B2.4.5.

Previous investigations

No studies have been completed that specifically focused on the SW-3 area or the northeast landfill. The SW-3 study area contains two perimeter monitoring wells (0967 and 0968) and two earlier (USGS) monitoring wells (1874 and 1875). The perimeter wells were sampled three times prior to the RI—1990, 1991, and 1992. Analyses included volatile organics, metals, and selected radiological parameters, and results showed most constituents either below detection limits or in concentrations similar to background levels. The 1991 samples from both perimeter wells had ^{60}Co at higher levels than either the 1990 or 1992 results (which were both below the background threshold). These samples also had higher turbidity than samples from other years, and the suspended sediment may have biased the results. Tritium concentrations in well 0968, located at the base of the landfill, increased by two orders of magnitude in the 1992 sample when compared with previous years. Tritium concentrations in 0967 declined over this same period.

RI sampling summary

Portions of the SW-3 area were included with the RI USRADS survey. USRADS data were used to select a surface soil sampling location (SB044) in an area of high exposure, and field instrumentation was used to select a second location as part of the ecological risk assessment (earthworm study). A flume was installed in drainage D-3 to allow for flow monitoring and sample collection during the RI. Both stormflow and baseflow (dry season and wet season) samples were collected from the flume and analyzed for radiological and chemical parameters. A sediment sample was also collected in D-3 upstream of the flume (and downgradient of the landfill) and analyzed for radiological and chemical parameters. Wet season and dry season groundwater samples were collected from wells 0967 and 0968 in 1993; a screening sample for CSL analysis was collected from well 1875 in 1992. Seep SP016, located on the bank of drainage D-3 downhill from the landfill, was also sampled in 1992 and 1993. Figure B2.4.21 shows sampling locations and the cross section used to depict the hydrologic model.

Hydrologic model

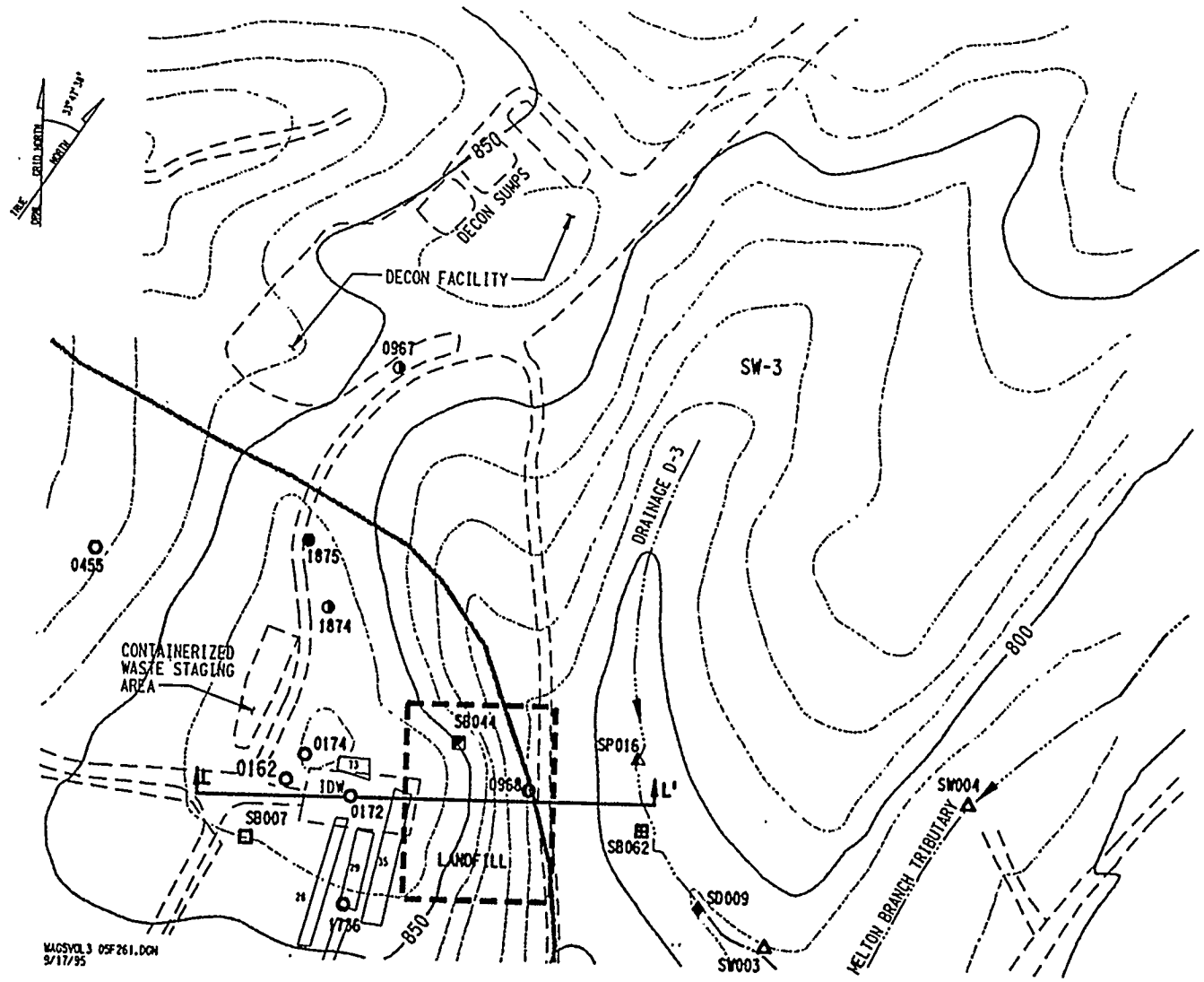
Figure B2.4.22 depicts the hydrologic model for the northeast landfill area. Surface water, interflow, and groundwater move generally to the east toward drainage D-3. The SW-3 study area drains entirely into Melton Branch Tributary, which discharges into Melton Branch approximately 900 ft south of the mouth of D-3. Average flow in D-3, measured through a continuous flow monitoring system at station SW003 during 1993–1994, is only 0.03 cfs. The drainage is dry several months of the year, typically from the late spring until mid-fall. When flowing, the headwaters are marked by seep SP016, except during storms, at which time flow occurs in the upstream channel segments.

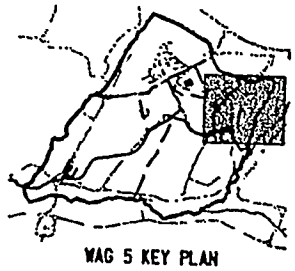
Table B2.4.12 presents the annual water balance for the SW-3 study area based on an evaluation of the SW003 flow data and HSPF modeling. Nearly 80% of the flow in D-3 was attributed to interflow (stormflow) and groundwater discharge. The predominance of these subsurface flow pathways was expected, given that the study area is largely undisturbed and forested. The minor contribution from runoff is probably at least partly responsible for the general absence of contamination in this study area despite the large amount of contaminated materials on the ground surface.

Table B2.4.12. Annual water balance summary for SW-3 study area.

	PERCENT OF FLOW	ANNUAL DISCHARGE (M^3/YEAR)
Surface Runoff	19	655
Interflow	34	1,216
Groundwater flow	47	1,670
Total	100	3,541

The cross section (Fig. B2.4.22) shows that the trenches and landfill wastes on the adjacent hilltop and slope were well above the seasonally high water table measured in 1993, and thus groundwater is not in direct contact with any of the wastes in the SW-3 source areas. Infiltration of





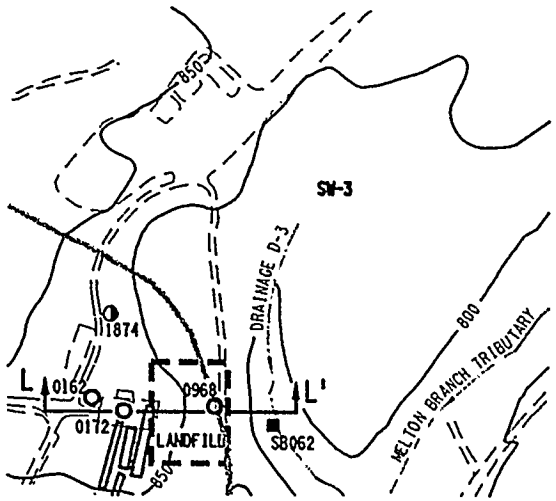
LEGEND

- APPROXIMATE LANDFILL BOUNDARY
- WAG 5 BOUNDARY
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- 0968 — GROUNDWATER SAMPLING LOCATION W/NO. (REGOLITH <50')
- 0967 — GROUNDWATER SAMPLING LOCATION W/NO. (BEDROCK <100')
- SD009 — SEDIMENT SAMPLING LOCATION W/NO.
- SP016 — SEEP LOCATION W/NO.
- SW004 — SURFACE WATER LOCATION W/NO.
- SB007 — VERTICAL SOIL SAMPLING LOCATION W/NO.
- SB044 — SOIL SAMPLING LOCATION W/NO. (HIGH EXPOSURE)
- SB062 — AREAL SOIL BORING LOCATION W/NO.
- 13 — TRENCHES W/NO.

Drainage Group: SW-3
Study Area: Landfill Area
Sources: Soil covered contaminated equipment

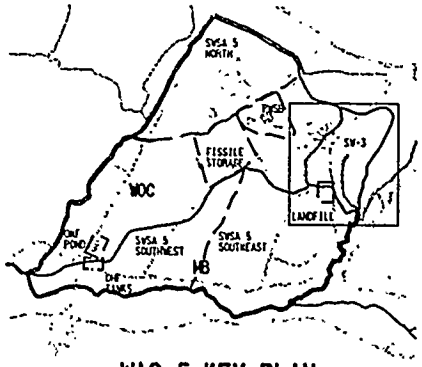
SCALE
0 50 100 FEET
0 10 20 30 METERS

Fig. B2.4.21. Surface water drainage D-3 plan view.

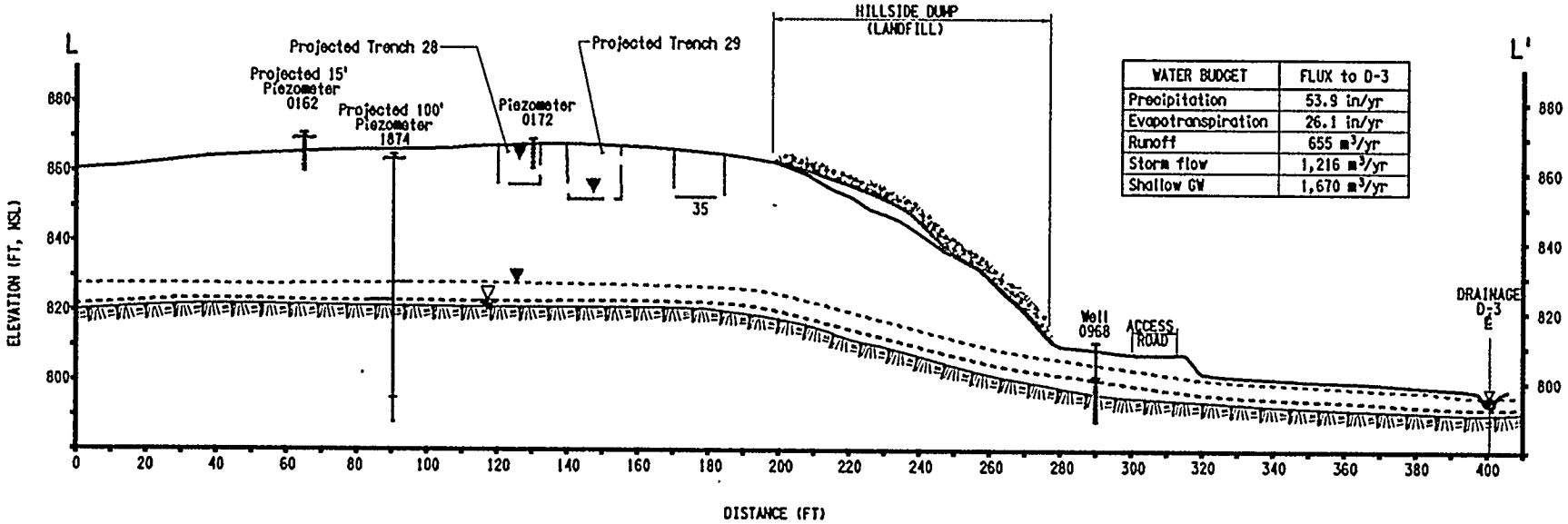


LEGEND

- HIGH BASE WATER LEVEL (3/93)
- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0968 — WELL, WELL NO., SCREEN SECTION
- 35 — APPROXIMATE TRENCH BOUNDARY W/TRENCH NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX to D-3
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	655 m^3/yr
Storm flow	1,216 m^3/yr
Shallow GW	1,670 m^3/yr

Fig. B2.4.22. Hydrologic model for SW-3 northern landfill site (Section L-L').

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precipitation and either lateral flow in the stormflow zone or downward percolation to the water table are the most likely release mechanisms for the site. This is particularly true in cases where the precipitation has been in contact with contaminated surface debris, where the stormflow zone passes through areas of contaminated soil, or where percolation through trench wastes occurs. Both stormflow and groundwater follow the topographic slope eastward toward discharge into D-3. Some of the groundwater may also flow southeastward toward Melton Branch Tributary.

Nature and extent of contamination

The USRADS survey identified one relatively significant area of surface gamma contamination corresponding to the center of the hillside dumping/landfill area. Field surveys identified the main source as a plastic 55-gal drum (sealed with unknown contents) approximately halfway down the hillside. Field instruments recorded a dose rate of 20 mR/h at 6 in. from the drum and 140,000 cpm above background. Other contaminated equipment (mostly partially buried hoses and metallic scrap) was identified during sampling activities; however, radiation exposures from these other materials were considerably lower than that of the 55-gal drum. The field instruments were also used to investigate the extent of contaminated soil around the drum and other materials; no measurable beta-gamma contamination was identified.

Table B2.4.13 lists analytes of concern in the SW-3 study area. In most cases, concentrations were far below those observed elsewhere in the WAG 5 Melton Branch drainage basin. No chemical (organic or inorganic) contaminants of concern were identified above either detection limits or background reference levels. Table B2.4.14 summarizes sample-specific analytical results.

Table B2.4.13. Contaminants of concern detected in the SW-3 northeast landfill study area.

CONTAMINANT	SOIL	SED[A]	GW	SW[B]
^{241}Am		X	X	X
$^{243/244}Cm$			X	X
^{60}Co	X			X
^{137}Cs	X			X
Tritium	X		X	X
^{238}Pu	X		X	X
$^{239/240}Pu$	X		X	X
^{228}Ra	X		X	X
^{90}Sr	X			X
^{228}Th			X	
^{230}Th			X	X
^{232}Th				X
$^{233/234}U$		X	X	
^{235}U			X	
^{238}U			X	

[A] *D-1 sediment*
[B] *D-1 surface water and seep SP016*

Table B2.4.14. Analytical data summary for selected radionuclides in SW-3

Sample Type	ID	Date	Intv (ft)	(α) Gross Alpha	(β) Gross Beta	(β) Tritium	(β-γ) Co-60	(β) Sr-90	(β-γ) Cs-137
SOIL (pCi/g)									
Background Reference				9.9	42	0.084	0.0097	1.94	1.44
	SB044	12/10/93	0-2.0	**10.4**	36.1	**0.56**		**3.74**	**6.91**
	SB062	5/18/94	0-0.5	5.08	21.1		0.016	0.328	0.591
SEDIMENT (pCi/g)									
Background Reference				44	54	100		1.34	0.82
	SD009	7/7/93	0-0.3	27	22	11.35		1	0.39

				U	F	U	F	U	F	U	F	U	F	U	F
GROUNDWATER (pCi/L)															
Background Reference				5.2	3.2	16	7.4	2400	1040	44	9.6	10.4	3.6	12.4	5.4
	0967	4/5/93	29.7-59.7	-	-	-	-	1108	1351	-	-	-	1.24	-	-
	0967	11/1/93	29.7-59.7	37.5	30.9	-	4.26	929	1120			-	-	-	-
	0968	4/30/93	10.2-20.2	-	-	-	-	324000	324000	-	-	1.65	-	-	-
	0968	11/8/93	10.2-20.2	-	59.7	8.95	-	2200	1940			-	7.83	-	-
*	1875	6/30/92	185-194.6	-	170.5	188.3	241.8	-	242				2.1		
Historical Samples															
(a)	0967	7/31/90	29.7-59.7		1.05		-	1323			-		1.08		-
(a)	0967	6/28/91	29.7-59.7	2.16	1.46	2.7	2.97	1269	1431	27	21.6	-	1.62	24.3	-
(a)	0967	9/23/92	29.7-59.7	0.59	0.32	1.35	0.54	810	567	0.54	3.24	-	14	0.54	2.97
(a)	0968	8/2/90	10.2-20.2		1.43		-	2187			0.81		0.27		-
(a)	0968	7/10/91	10.2-20.2	2.24	1.89	4.59	4.86	1108	1755	-	45.9	-	-	-	-
(a)	0968	10/2/92	10.2-20.2	0.32	0.05	6.75	16.2	145800	432000	0.27	3.51	0.16	1.22	2.97	1.08
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				9		8		1620						40	
*	SP016	9/28/92		53.6	-	180.3	20	658.6	718.9						
	SP016	5/17/93		15.3	3.9	49.8	11.2	1299	1162			2.9	-	-	-
	SW003	6/2/93		0.52	-	-	-	2400	1400	-	-	-	-	-	-
	SW003	10/11/93		-	-	6.7	5.2	2680.9	1767.8			-	1.24	-	-
storm *	SW003	5/19/93	3 samples	5.7	8.3	57.8	108	2821.6	3056.8			700.7	47.6		
storm *	SW003	6/15/93	4 samples	21.8	16.1	82.3	26.1	2514.4	6673.9	51.7	41				
storm *	SW003	10/21/93	3 samples	32.2	20.1	830.6	39.8	3194.6	2766.7				-	38.7	922
storm	SW003	10/21/93	grab	-	-	4.39	6.34	1160	2210			-	-	-	-
storm *	SW003	3/9-10/94	3 samples	6.7	-	46.9	83.5	1880.2	4321.6				36.7		279
storm	SW003	3/10/94	grab	-	1.42	3.08	11.2	385	436			57	0.884	-	-

Notes:
1. Historical samples:
   (a) Data from Environmental Surveillance Program and Active Sites Environmental Monitoring Program
2. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
3. * CSL analysis performed
4. Abbreviations: U/F = Unfilter/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emitter

SB044, completed at an USRADS hot spot location, had ^{137}Cs and ^{90}Sr in concentrations only slightly higher than background. The sample also had low concentrations of several transuranic radionuclides, including ^{238}Pu, $^{239/240}Pu$, ^{241}Am, indicating that at least some of the wastes dumped on the hillside were contaminated with TRU constituents. Results for $^{233/234}U$ were also elevated (5.65 pCi/g); however, the laboratory was not able to determine which isotope (^{233}U or ^{234}U) was present. If ^{233}U is present, it would be further evidence of TRU contamination in the landfill wastes. The sample from SB044 also contained low concentrations of naturally occurring U/Th series radionuclides; none of these were present in concentrations indicating site-related contamination. Where detected, the radiological parameters in a soil sample collected from SB062 during earthworms sampling activities did not exceed background reference levels.

Results from perimeter wells 0967 and 0968 indicate that periodically the wells show contamination from ^{60}Co and/or ^{3}H, but that generally the water table interval is uncontaminated in this area. As stated above, one round of historical samples from these wells showed higher ^{60}Co and tritium. Sampling of these wells in 1993 did not show any ^{60}Co but did show a ^{3}H concentration that varied by 2 orders of magnitude. Periodic fluctuations in contaminant concentrations may be related to any one or combination of several factors, including

- release and migration of discrete "slugs" of contamination, for example when a container is breached through rust or subsidence or consolidation of backfill materials;
- seasonal position of the water table, such that at certain times the water table rises upward into more highly contaminated vadose zone soils, and leaching and transport of contamination results;
- annual variations in the amount of contaminated percolation waters that recharge the water table (a function of precipitation patterns in a given year); and
- sampling methods, specifically the amount and rate of purging, time between purging and sampling, rate of sample container filling, and depth from which the samples are withdrawn (e.g., samples collected near the bottom of the well screen would be more likely to contain suspended particles).

The perimeter wells also contained low levels of several transuranic and U/Th decay series radionuclides. The TRU constituents were typically present at trace levels between 0.1 and 0.2 pCi/L, which is close to the detection limits. Consideration of the error associated with these measurements indicates that the TRU radionuclide results for 0967 are probably not significantly greater than zero. Higher confidence is associated with the results for 0968, which is at the base of the landfill and downgradient of the TRU-contaminated soils detected in SB044. The data provide important evidence that some minor amount of TRU radionuclide transport is occurring in this area. Further evidence to support this conclusion was obtained from surface water storm sampling in D-3 (discussed below).

Seep samples collected from SP016 did not show any contamination above background levels. The absence of contamination in the seep, particularly ^{3}H, indicates that the flowpath between well 0968, the landfill area, and the inferred discharge areas along D-3 is further evidence of the anisotropic character of the water table aquifer; groundwater flow and contaminant transport follow discrete pathways that are difficult to either monitor or predict.

Results for the numerous surface water samples collected from D-3 at the SW003 flume (Sect. B2.3.2) indicated little to no contamination. The drainage is an insignificant contributor to the levels of contamination and overall contaminant flux to Melton Branch from WAG 5. Runoff, stormflow, and groundwater from the landfill and SWSA 5 South area discharging to D-3 contain variable but generally low levels of ^{90}Sr, ^{3}H, and ^{137}Cs; however, this contamination is apparently diluted by the flux of noncontaminated water contributed by the eastern and northern portions of the drainage catchment.

One noteworthy finding from the D-3 sampling was the detection of small concentrations of several TRU radionuclides (^{241}Am, $^{243/244}Cm$, ^{238}Pu, and $^{239/240}Pu$). All were detected in the filtered samples collected at the end of a storm event, when stormflow and baseflow contributions dominate the flow hydrograph. TRU radionuclides were also detected at low levels in soil from SB044 and groundwater from 0968. These constituents evidently are migrating through the subsurface to D-3. The concentrations and overall flux are negligible, and thus there is not likely to be any adverse risk or environmental impact, but the results do have important implications for TRU fate and transport considerations elsewhere in WAG 5 (see Appendix B3).

Results for the D-3 sediment sample did not indicate any radiological contamination for the analytes of concern. No isotopic uranium or TRU analyses were performed because the gross alpha activity was fully accounted for by the radium and thorium content of the sediment. The results for these radionuclides were all below background reference levels for sediment.

Summary and conceptual model for SW-3

The SW-3 area has neither major sources nor areas of contamination. Discrete areas of contamination are associated with some of the debris dumped on the hillside in the northeast landfill; however, sampling locations downgradient (topographically and hydraulically) of the landfill showed no significant contamination. Storms increase the amount of contamination being released from the study area, but the net contribution from SW-3 to the total flux of contamination in the Melton Branch drainage basin is: gross alpha, 0.3%; gross beta, 0.07%; tritium, 0.001%; ^{60}Co, 0.08%; ^{90}Sr, 0.004%; and ^{137}Cs, 2% (i.e., the flux contribution from SW-3 is negligible).

Figure B2.4.23 illustrates the conceptual model for the SW-3 area. The source area is the northeast landfill; principal contaminant release mechanisms are precipitation falling onto contaminated surface debris and/or infiltrating through contaminated soil. The stormflow zone and shallow groundwater are the principal pathways for contaminant migration, and most discharge occurs immediately to the east in drainage D-3. Exposure points in the study area include the landfill area, where high surface exposures from gamma radiation are present, and, to a much lesser extent, in the surface water and sediment of drainage D-3.

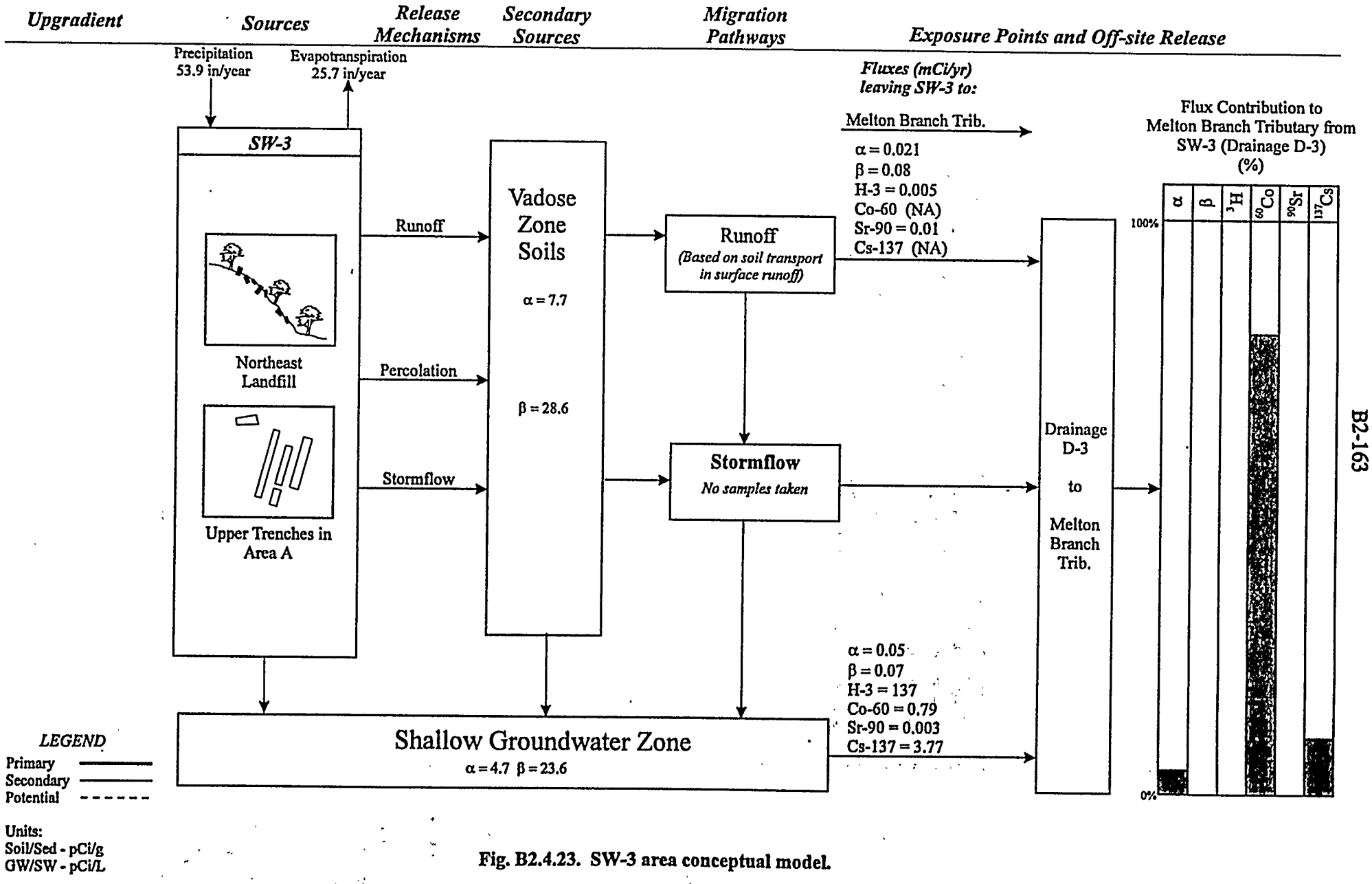

Fig. B2.4.23. SW-3 area conceptual model.

B2.4.4 Area A

Area A consists of 9.5 acres in the easternmost portion of SWSA 5 South in the southeast corner of WAG 5 (Fig. B2.1.1). The configuration of the study area is based on both surface water drainage patterns and the inferred groundwater flowpaths in the area. Figure B2.4.24 shows conditions as of November 1994.

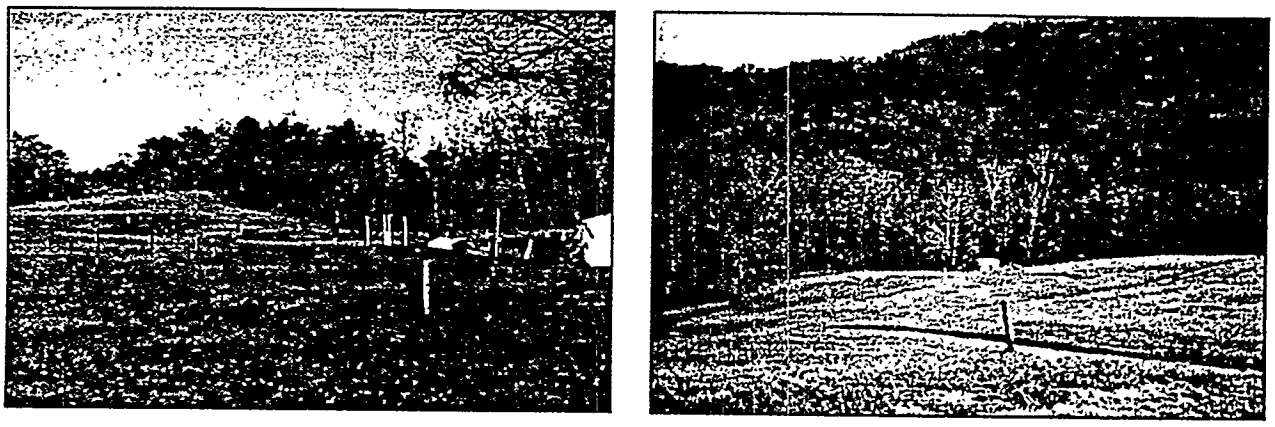

Fig. B2.4.24. Photographs of area A looking north toward landfill and SW-3 (left) and southeast toward seepage area adjacent to Melton Branch Tributary (right).

Description and history

Seep discharges in area A have long been recognized as significant contributors to the flux of ^3H in Melton Branch and White Oak Creek. The earliest indication was provided by Duguid (1975), who reported ^3H concentrations of 432 µCi/L (equivalent to 4.3E+08 pCi/L) from seep S-15 in what is now area A. The significance of ^3H discharges from this area has been confirmed through numerous other studies, most recently the WAG 2 Phase I RI report (ORNL/ESD 1993). Field sampling conducted for the WAG 5 RI identified five seeps in the area that discharge groundwater containing ^3H concentrations exceeding 1.0E+6 pCi/L. Information presented in Newsom et al. (1993) indicates that discharges from area A account for 10 to 20% of the total tritium flux in the White Oak Creek watershed.

Primary contaminant sources in area A are the 121 auger holes and 79 trenches. Auger holes on WAG 5 have generally been used for disposal of higher-activity and fissile wastes, but disposal records collected by ORNL/ER-DMG indicate that most auger holes in area A contain biological wastes (see Table B2.4.15). Trench wastes in area A include both high-activity hot cell waste and low-activity/general radwaste. An estimated 26 of the trenches contain only biological wastes, including carcasses, bedding, and animal wastes contaminated with radionuclides. All of the biological wastes were from off-site sources, including Oak Ridge Associated Universities, Oak Ridge Institute for Science and Education, University of Tennessee/AEC, and Building 9207 at Y-12. Disposal records also show that concrete casks with TRU wastes were placed in trenches 126, 130, 159 (southeast corner of the area) and in trench 166 (centrally located).

Table B2.4.15. Disposal records of burial wastes in Area A

	Total Number	High Activity β–γ	TRU	Sludge	Low-Activity β–γ	Biological Waste	No Data
Auger Holes	121	*No data to confirm types of wastes*				15 (may be as high as-110)	106
Upland Trenches	23	5	--	1	--	9	8
Inundated Trenches	56	11	4	--	14	26	1

According to Cowser et al. (1961), a special area was set aside as a "Y-12 special burial" area; this area now contains trenches 28, 29, 30, 35, and 73. Cowser et al. (1961) described a new trench design apparently used in this area to improve monitoring. The design consisted of sloping the bottom of the trench to an asphalt-lined sump at one end in which a 6-in. corrugated metal well was installed, and then covering the bottom with 6 in. of gravel (Fig. B2.4.25). When the trench was filled with waste, void areas were filled with shale. Then the trench was capped with shale, tamped, covered with gravel, and finally sprayed with about 1 in. of asphalt. Trenches 29 and 30 were constructed in this manner and filled in 1959 with metal drums containing alpha-contaminated material from Y-12.

To evaluate the role of container integrity in the release of contaminants from the waste, the drums in trench 29 were placed in an upright position, and those in trench 30 were dumped at random. Monitoring was conducted over the next year and a half, and no apparent difference in activity (as measured in the trench sumps) was noted (Cowser et al. 1961). Monitoring also showed that water was present in the trench sumps after heavy rains or prolonged wet periods even though the trenches were sealed with asphalt and well above the water table. The water was attributed to seepage through the sides of the trench; it may also have been due to an active stormflow zone in the area.

Notes on a 1962 ORNL drawing (E-52834) indicate that trench 35, immediately east of trenches 29 and 30, contains sludge disposed of sometime between January 1962 and August 1963; according to ORNL/ER-DHG, the sludges came from both on-site and off-site sources. Trench 30 is immediately adjacent to and possibly even underneath the western portion of the hillside dump identified as a source area for study area SW-3. In May 1965, trench 73 was dug 40 ft north of trenches 29 and 30 specifically for disposal of wastes from Y-12 (according to logbooks, the wastes were sodium and potassium solutions).

Previous investigations

The earliest documented investigation in area A was the seep sampling study as reported in Duguid (1975). In 1988, stream transect sampling confirmed the input of ^{3}H into Melton Branch. In 1989, ^{3}H concentrations in evapotranspired water in the southeastern portion of the area were investigated. Between trenches 177 and 123, 116 locations were sampled. Elevated ^{3}H concentrations (0.02 to 0.1 μCi/L) were detected across the area; the highest concentrations were near the downgradient end of trenches 124 and 123.

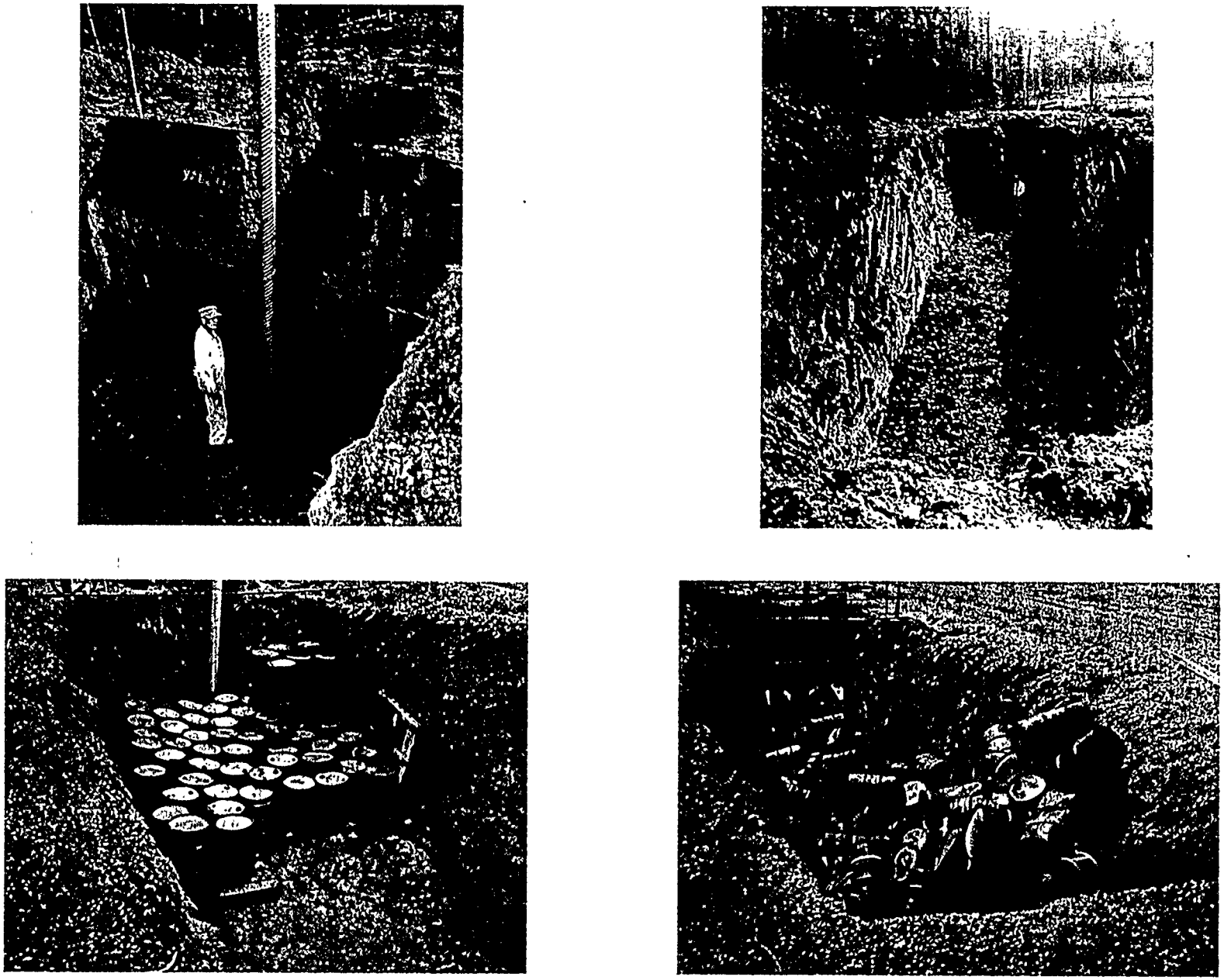

Fig. B2.4.25. Photographs of trench construction in northern portion of area A.

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Graphical stream hydrograph separation techniques were used by Solomon et al. (1991) to estimate that approximately 16% of the total ^3H release (based on 1988 data) to Melton Branch resulted from quickflow (equivalent to stormflow and surface runoff; see Sect. B3.2.2); the balance was attributed to baseflow (discharging groundwater). During storm events, as much as 60% of the ^3H flux was due to quickflow. These results were among the first to identify the significance of the stormflow zone in contaminant transport; however, groundwater was identified as the principal transport medium.

To determine the vertical profile and extent of ^3H, soil core and groundwater samples were collected from various depths at three locations in the area between trenches 124 and 122 and the seeps (Wickliff et al. 1991). Analytical results showed that ^3H concentrations in the soil core and groundwater samples increased with depth and ^{90}Sr concentrations tended to decrease with depth. The vertical distribution of ^3H suggested that diffusion was an important ^3H transport mechanism in the area. Like Solomon et al. (1991), Wickliff concluded that groundwater was the principal migration pathway for ^3H; however, ^{90}Sr migration was primarily in the stormflow zone.

In 1993, WAG 2 personnel began characterizing contaminant transport in area A. The first activity was drilling a 25-ft-deep corehole for downhole cameras to examine subsurface zones. Point-dilution tests were then conducted at varying depth intervals to identify zones of greatest flow. Ongoing work involves installing multizone packers in two downgradient coreholes and approximately 20 drive points in the area around these two holes. Finally, injection of a bromine tracer into an upgradient source boring is planned.

RI sampling summary

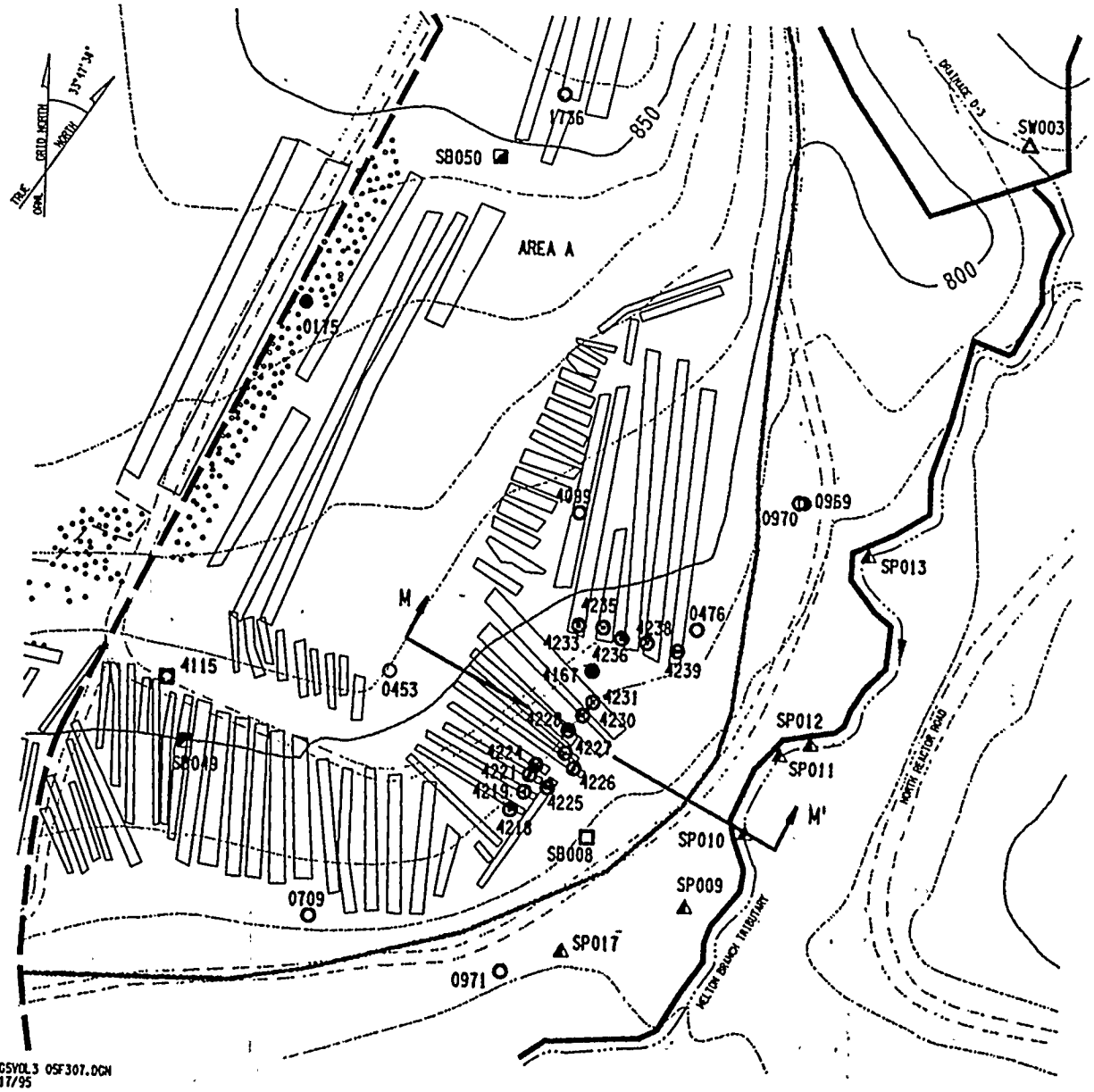
Figure B2.4.26 shows the sampling locations associated with the study area and cross section location used in the hydrologic model. One groundwater sample was collected from each of the 15 trench drive point wells and analyzed at the CSL for volatile organics, radiological constituents, major ions, and water quality parameters. Approximately half of the drive points were dry during the initial sampling attempt made on September, 1993; these were successfully sampled in March 1994 during wetter conditions. Five of the six seeps identified during the RI were also sampled.

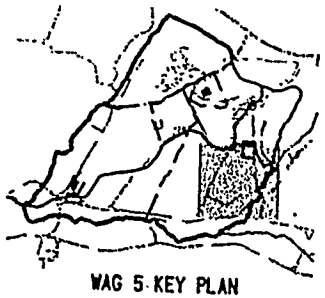
Hydrologic model

Figure B2.4.27 depicts the hydrologic model for Area A. Essentially all of the study area drains to the Melton Branch tributary. Table B2.4.16 summarizes the annual water balance for surface flow, interflow (stormflow), and groundwater, determined based on HSPF modeling. Shallow groundwater accounts for the largest water flux and represents the primary contaminant migration pathway.

Table B2.4.16. Annual water balance summary for area A

	Percent of Flow	Annual Discharge to Melton Branch Tributary (M^3/Year)
Surface Runoff	7	1,855
Interflow	28	8,105
Groundwater Flow	65	18,456
Total	100	28,416





WAG 5 KEY PLAN

LEGEND

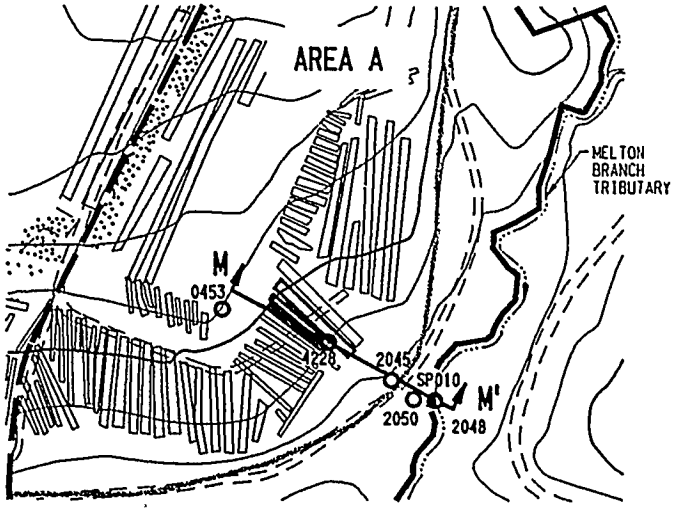
- APPROXIMATE STUDY AREA BOUNDARY
- WAG 5 BOUNDARY
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- 0453 — GROUNDWATER SAMPLING LOCATION W/NO. (REGOLITH <30')
- 0969 — GROUNDWATER SAMPLING LOCATION W/NO. (BEDROCK <100')
- SP013 — SEEP LOCATION W/NO.
- SW003 — SURFACE WATER LOCATION W/NO.
- SB008 — VERTICAL SOIL SAMPLING LOCATION W/NO.
- SB049 — SOIL SAMPLING LOCATION W/NO. (HIGH EXPOSURE RATE)
- SB050 — SOIL SAMPLING LOCATION W/NO. (MED TO LOW EXPOSURE)
- TRENCHES
- AUGER HOLE

Drainage Group: Melton Branch
Study Area: Area A
Sources: Trenches and Auger holes

SCALE

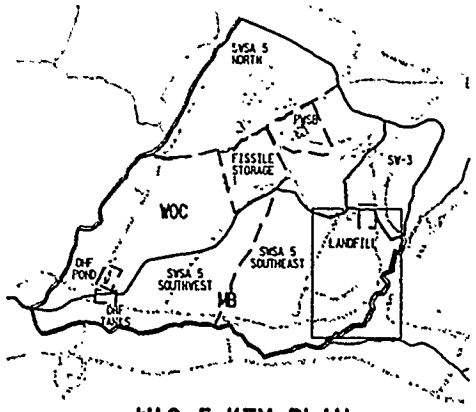
0 50 100 FEET
0 10 20 30 METERS

Fig. B2.4.26. Area A plan view.

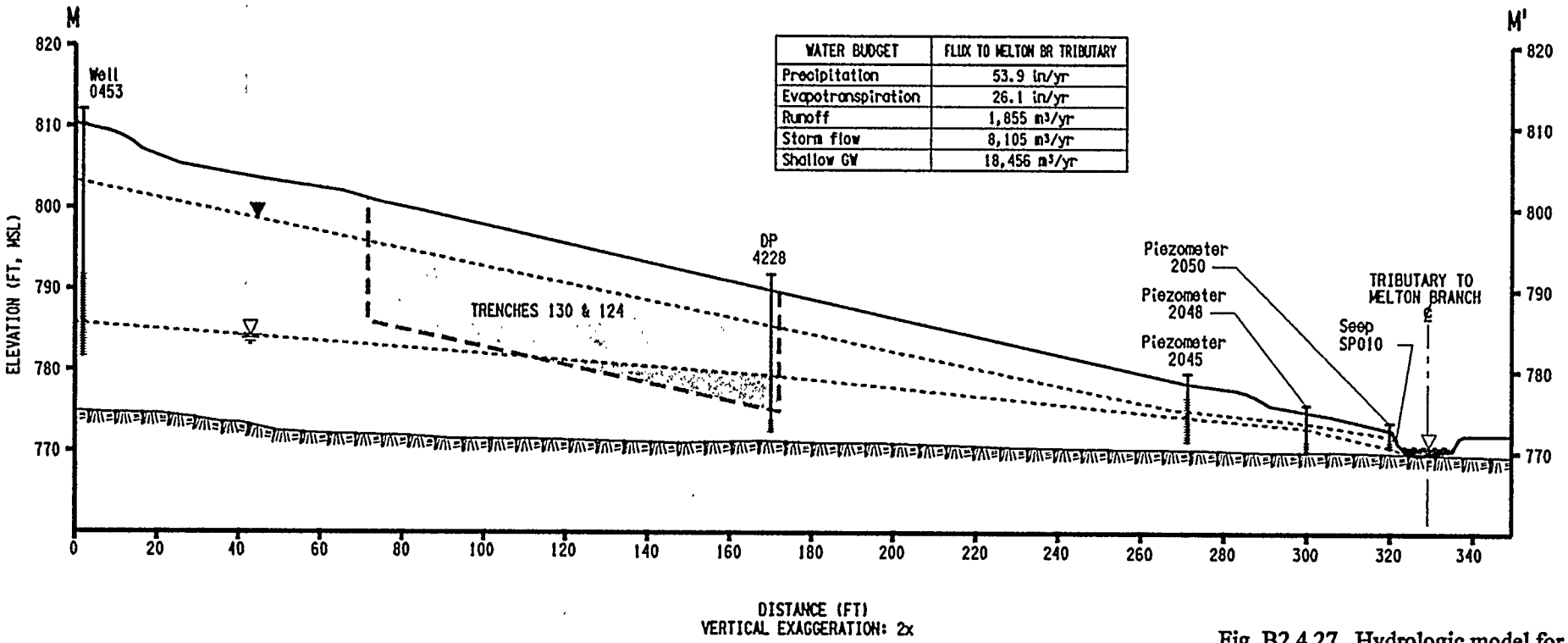


LEGEND

- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0453 — WELL, WELL NO., SCREEN SECTION
- APPROXIMATE TRENCH LIMIT W/NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX TO MELTON BR TRIBUTARY
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	1,855 m^3/yr
Storm flow	8,105 m^3/yr
Shallow GW	18,456 m^3/yr

Fig. B2.4.27. Hydrologic model for area A (Section M-M').

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An important feature of the model is the perennial inundation of trenches with groundwater. As shown in Figs. B1.6.7 and B1.6.8, most trenches south and west of trench 122 were at least partially inundated during the dry season of 1993. During the wet season, the area of inundation expanded to the centrally located trenches and even to the upland area on the northeast perimeter. There was no evidence of "bathtubbing" in the area A trenches. Groundwater inundation represents the most likely release mechanism and migration pathway for contaminants in the lower trenches. The area has an active stormflow zone, but the zone is probably disrupted in the trench area; during episodic inundation of upland trenches, trench water may recharge the stormflow zone. A thin vadose zone beneath the upland trenches indicates that vertical percolation of infiltration liquids through the wastes is also an important release mechanism.

Nature and extent of contamination

Table B2.4.17 summarizes analytes of concern detected in area A by medium, and Table B2.4.18 presents quantitative results for each major contaminant.

Table B2.4.17. Contaminants of concern detected in study Area A

CONTAMINANTS	SOIL	GW	SEEPS
^{241}Am	X	X	X
^{14}C		X	
^{45}Ca			X
$^{243/244}Cm$	X	X	
^{60}Co		X	
^{137}Cs	X	X	X
^{238}Pu	X	X	
$^{239/240}Pu$		X	
^{226}Ra		X	
^{228}Ra		X	X
^{99}Tc		X	X
^{228}Th		X	
^{230}Th	X	X	
^{231}Th		X	
^{232}Th	X		
^{90}Sr	X	X	X
Tritium	X	X	X
$^{233/234}U$		X	X
^{235}U		X	
^{238}U	X	X	
Manganese		X	
Nickel		X	
Aroclor 1260	X		
Tetrachloroethene		X	
Vinyl Chloride		X	

Table B2.4.18. Analytical data summary for selected radionuclides in area A

Sample				(α)	(β)	(β)	(β)	(β)	(β–γ)
Type	ID	Date	Intv (ft)	Gross Alpha	Gross Beta	Tritium	C-14	Sr-90	Cs-137
SOIL (pCi/L)									
	Background Reference			9.92	42	0.084		1.94	1.44
	SB007	3/24/93	0-2	30	38	-	-	0.43	1.4
	SB007	3/24/93	2-8	-	63	4.6	-		
	SB007	3/24/93	8-14	23	45	-	5.2	-	-
	SB007	3/24/93	14-20	-	47	-	-		
	SB008	8/24/93	0-2	16.4	255	1480.6	-	107	0.34
	SB008	8/24/93	4-10	11.3	51	966.1	-	7.3	-
	SB008	8/25/93	10-13.7	-	39	1198.3	-		
comp.	SB049	3/17/93	0-2	-	81.3	4.9	-		1.47
discrete	SB049	3/17/93	0-2	350	9400	0.91	-	28	6700
	SB049	4/18/94	0-1	12.1	844	2.8	-	18.3	1160
	SB050	3/8/93	0-2	-	46	11.7	-		
	4115	2/24/93	0-6	-	47	12	-		
	4115	2/24/93	6-12	37	45	24	-	6.8	-
	4115	2/24/93	12-15.8	-	73	52.8	-		

GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference			5.2	3.2	16	7.4	2400	1080			10.4	3.2	12.4	5.4
	0175	6/24/92	36-145.4	-	-	133.2	90.7	9.65E+5	9.39E+5	-	-		13.1		
	0476	4/29/93	25-29	150	82	24000	22000		7.60E+6	1500	250	11000	11000	-	-
	0476	10/25/93	25-29	51.4	171	28100		5.16E+6	6.31E+6	295	182	14600	14400	-	-
	0709	6/9/92	11.5-18	18.8	-	143.3	41.4		3.98E+6	-	-		18.2		
	0968	4/30/93	8.4-20.2	-	-	nd	-	3.24E+5	3.24E+5	-	-	1.65	-	-	-
	0968	11/8/93	8.4-20.2	-	60	8.95	-	2200	1940	-	-	-	7.8	-	-
	0969	4/29/93	4-15.3	-	5.4	432	459	1.50E+7	2.10E+7	-	-	146	176	-	-
	0969	11/2/93	4-15.3	7.15	13.9	320	366	4.70E+6	5.91E+6	91.5	100.2	135	168	-	-
	0970	4/29/93	58-74.7	-	-	7.6	-	1.00E+6	1.00E+6	-	-	-	1.8	-	-
	0970	11/11/93	58-74.7	-	-	3.9	-	9.33E+5	1.05E+6	-	-	0.8	5.1	-	-
	0971	4/27/93	8.6-14.7	-	-	10.8	17.6	1.10E+6	1.10E+6	-	-	7.6	4.8	-	-
	0971	11/5/93	8.6-14.7	-	6.4	97.1	129	1.22E+6	1.27E+6	-	136	40.5	46.7	-	-
	1736	6/16/92	0-11.6	702507	613424	330503	279181	254	254	65624	66686		1289		
	4099	12/6/93	0.5-1	6.9		219.7		7301		-					
	4115	4/20/93	7.54-17.26	16	-	49	29	1.20E+6	1.10E+6	140	-	18	-	-	-
	4115	10/20/93	7.54-17.26	-	-	44.4	15.3	2.25E+6	1.53E+6	228.1	191.1	5.1	5.4	-	-
tr-dp (126)	4218	3/11/94	8-8.8	269	14.2	24072	16049	9.03E+5	8.41E+5	22359	22158		9096	783	67.2
tr-dp (145)	4219	10/1/93	10.3-11.1	426	232	1498	101	1.87E+6	1.85E+6	-	-		13.8		
tr-dp (143)	4221	9/30/93	13-13.8	396	11.4	532.3	133.1	2.23E+5	1.99E+5	-	-		9.4		
tr-dp (141)	4224	9/30/93	12.8-13.6	557	30.8	1565	192.3	6.83E+4	6.48E+4	-	-		103		
tr-dp (138)	4225	3/11/94	9.9-10.7	-	-	158.7	115.6	9.65E+5	1.01E+6	16111	-			136	118
tr-dp (136)	4226	9/30/93	10-10.8	763	75	193201	56583	1.16E+7	1.11E+7	10948	-	131673	40294		239

Table B2.4.18. Analytical data summary for selected radionuclides in area A (cont.)

Sample				(α) Gross Alpha		(β) Gross Beta		(β) Tritium		(β) C-14		(β) Sr-90		(β-γ) Cs-137	
Type	ID	Date	Intv (ft)												
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				5.2	3.2	16	7.4	2400	1080			10.4	3.2	12.4	5.4
tr-dp (132)	4227	9/30/93	15.5-16.3	7357	82	43514	9397	1.22E+7	1.20E+7	-	-	131996	511.7		
tr-dp (130)	4228	10/4/93	12.4-13.2	4004	39	49365	5068	3.14E+8	2.97E+8	864960	1E+06	13449	2142	221	
tr-dp (124)	4230	3/11/94	8.4-9.2	693	9.5	37868	18626	3.20E+8	3.52E+8	6E+06	6E+06		13242	34	37.4
tr-dp (122)	4231	9/29/93	15.3-16.1	75893	199	1E+06	10217	2.08E+7	2.02E+7	7540	4338	277619	87623	52600	555
tr-dp (146)	4233	3/11/94	9.4-10.2	29.3	-	14271	8247	1.04E+6	1.00E+6	24419	24053		5231	111	203
tr-dp (144)	4235	3/11/94	10.8-11.6	104	64	17285	18085	4.27E+5	4.54E+5	10783	14968		11202	48.7	162
tr-dp (139)	4236	3/11/94	9-9.8	1647	1819	52162	55993	1.66E+6	1.65E+6	58821	58168		24599	7920	8100
tr-dp (133)	4238	3/11/94	9.5-10.3	10851	2382	158473	134411	5.19E+5	6.03E+5	66304	66749		82744	123	71.3
tr-dp (125)	4239	3/11/94	15.1-15.9	2354	219	96068	88519	6.02E+7	6.13E+7	1E+06	1E+06		48653	941	78.9
	SB008	8/26/93	0-13.7		17.6		1840		1.02E+7		-		1354		75.9
Historical Samples															
(a)	0969	8/90	4-15.3		2.7		97.2	2.32E+7					540		0.27
(a)	0969	7/91	4-15.3	2.97	4.32	378	213.3	1.24E+7	1.70E+7			172.8	86.4	-	-
(a)	0969	10/92	4-15.3	8.37	8.37	1377	1647	1.65E+7	1.70E+7			594	891	0.54	0.27
(a)	0970	8/90	58-74.7		0.97		2.43	9.18E+5					2.7		0.81
(a)	0970	7/91	58-74.7	2.16	0.27	6.48	4.32	7.56E+5	1.30E+6			-	0.1	-	-
(a)	0970	10/92	58-74.7	0.3	-	45.9	4.59	1.22E+6	1.19E+6			7.02	1.6	0.27	-
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				5.2	3.2	16	7.4	2400	1080			10.4	3.2	12.4	5.4
(a)	0971	8/90	8.6-14.7		0.27		67.5	1.16E+6					24		5.94
(a)	0971	7/91	8.6-14.7	4.05	2.97	8.9	97.2	1.03E+6	1.03E+6			35.1	48.6	5.4	43.2
(a)	0971	10/92	8.6-14.7	1.46	1.35	132.3	94.5	1.11E+6	1.11E+6			67.5	45.9	0.27	2.7
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				9		8		1620							
	SP009	8/24/92		811.3	675.3	63379	53497	1.34E+7	1.39E+7	-	-		47449		
	SP009	5/12/93		-	4.1	69002	101459	7.62E+6	2.44E+7	560	490	31545		-	-
	SP010	9/28/92		89.3	87.7	6342.4	6015.5	1.51E+8	1.52E+8	-	-		5692.2		
	SP011	8/24/92		12	9.1	517.3	512.7	1.90E+7	1.91E+7	555610	549970		300.4		
	SP011	4/27/93		-	-	550	610	2.40E+7	2.30E+7	150	-	270	280	-	-
	SP012	8/25/92		21.2	94.3	921.5	1005.5	2.93E+7	2.84E+7	-	-		932.2	20.7	29.9
	SP012	5/12/93		-	-	928	1683.9	4.08E+7	4.02E+7	280	320	437.4	454.6	27.9	-
	SP017	5/13/93		-	7.7	26337	19771	5.59E+6	3.48E+6	140	220	3136.8	3157.9	12.4	-

Notes:
1. Historical Samples:
   (a) Data taken from Environmental Surveillance Program and Active Sites Monitoring Program
2. Blanks indicate analyte not analyzed for; **Bold** results indicate values greater than background reference (2x mean background)
3. Abbreviations: U/F = Unfiltered/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emmiter
   tr-dp = trench drive point (trench no.) *comp.* = composite sample

Radiological contaminants. In general, areas of surface beta/gamma contamination in area A are few, small, and widely distributed. Soil samples did not contain significant alpha activity except for a single elevated reading of 350 pCi/g measured in surface soils sampled in SB049, located directly above trench 203. The same sample also contained elevated ^{137}Cs (6700 pCi/g) and ^{90}Sr (28 pCi/g) concentrations. Surface soil collected at SB008 (just upgradient of the seeps) was the only other sample containing significant contamination (^{90}Sr and ^{3}H in the surface interval but primarily ^{3}H in the deeper intervals). Results from surface soils collected at SB008 agree well with the Wickliff et al. (1991) and Solomon et al. (1991) studies and support their suggestions that ^{3}H migration in the area (and possibly the WAG in general) occurs primarily via groundwater and ^{90}Sr migration occurs primarily via stormflow.

With two exceptions, all groundwater and seep samples from area A contained elevated ^{3}H concentrations. The exceptions were samples from wells upgradient of possible influence from inundated trenches—the low-base sample from well 0968 in the landfill area; and the sample collected from well 1736 in trench 29. Unfiltered ^{3}H concentrations ranged from 68,000 to 320,000,000 pCi/L in the drive point samples and from over 5,000,000 to 150,000,000 pCi/L in seep samples. Drive point sample concentrations were highest in trenches 124 and 130, which are approximately 150 ft upgradient of seeps SP010 and SP009. Examination of site contour maps made prior to burial excavation and grading activities indicates the presence of a small swale linking these two areas. Though this feature may be funneling stormflow and shallow groundwater through trenches 124 and 130 to the seeps, it must be noted that based on RI and previous investigators' results, ^{3}H has migrated at high concentrations laterally and at depth throughout the southern portion of area A. Mitigation of the ^{3}H flux associated with trenches 124 and 130 may reduce concentrations discharging from the seep SP010 area but may have a limited impact on the flux of ^{3}H from the area as a whole due to the extensive groundwater and secondary source soil contamination.

Other beta emitters detected at high concentrations in trenches were ^{14}C, ^{90}Sr, and ^{137}Cs. Though ^{137}Cs was detected well above background concentrations in each of the analyzed trench groundwater samples (filtered concentration range: 37 to 8100 pCi/L), little was detected in the seep samples (not detected to 29.9 pCi/L), reflecting its somewhat typical lack of mobility through the WAG 5 soils. Like ^{137}Cs , ^{90}Sr was detected relatively uniformly in the trench samples, being detected in 12 of the 14 samples analyzed at concentrations at least 10 times background. The concentration range in filtered trench samples was from 9.4 to 88,000 pCi/L. The highest ^{90}Sr concentrations were detected in trench 122, which is one of those near the center of the preexcavation swale, and in adjacent trenches 125 and 133 approximately 75 ft northeast of trench 122. Unlike the ^{137}Cs results, ^{90}Sr was detected at elevated concentrations in samples from all five seeps, indicating migration from trenches in the southeast corner of the study area. The ^{90}Sr concentrations ranged from 280 to 47,449 in filtered seep samples. Examination of WAG 2 ^{90}Sr flux results for 1992 and 1993 (Fig. B2.4.4) shows that area A contributes approximately 7% of the ^{90}Sr flux migrating into Melton Branch.

Results of gross alpha analyses show that discharges from seep SP009 (811 pCi/L) were the highest from area A. Unfiltered samples from all but one drive point (in trench 126) contained above-background concentrations. Maximum gross alpha in trench water was detected in samples from trenches 122 (75,893 pCi/L) and 133 (10,851 pCi/L). Water from these two trenches also contained the highest ^{90}Sr concentrations.

The highest gross alpha concentration measured in area A (702.507 pCi/L) was detected in the groundwater sample from the well placed in the trench 29 sump, in the Y-12 special burial area. Due to the affinity of alpha-emitting radionuclides for soils, and the distance between the trench bottom and the water table in the vicinity, it is unlikely that much of the alpha contamination has reached the water table. This area was set aside for the disposal of Y-12 wastes (Cowser et al. 1961), and it can be assumed that a sizable inventory of alpha-emitting wastes are contained in trenches 28, 29, 30, 35, and 73. These trenches may be a significant source of other contaminants as well, based on the detection of high concentrations of U/Th series radionuclides and ^{99}Tc in a water sample from trench 29; specific results include ^{99}Tc (67.6 pCi/L), ^{228}Th (97,600 pCi/L), ^{230}Th (19,000 pCi/L), ^{231}Th (14,900 pCi/L), ^{226}Ra (5,520 pCi/L), and ^{235}U (17,000 pCi/L).

Chemical contaminants. Analytical results indicate that chemical contamination also exists in the area. Detections were mostly limited to low concentrations of chlorinated aliphatic compounds, either tetrachloroethene or compounds formed by the reductive dechlorination of tetrachloroethene (Table B2.4.19). The presence of low concentrations of PCBs in two of the soil samples was not considered indicative of a widespread PCB contamination problem nor indicative of a significant PCB source in area A.

Table B2.4.19. Organic contamination in Area A

	TETRACHLOROETHENE (µG/L)	1,2 DICHLOROETHENE (µG/L)	VINYL CHLORIDE (µG/L)	AROCLOR 1260 (µG/L)
SB008	ND	ND	ND	11
SB049	ND	ND	ND	140
0175	3	ND	ND	ND
0476	6	32	7	ND
0969	2	84	5	ND
4115	34	20	ND	ND
SP009	ND	33	8	ND
SP012	ND	13	2	ND
SP017	ND	3	ND	ND

Conceptual model

The conceptual model for study area A is illustrated in Fig. B2.4.28 and summarized in Table B2.4.20. The model can be summarized as follows.

Source materials containing radioactive contaminants are buried in area trenches and auger holes. Most of the trenches in the southern portion of the area are perennially or seasonally inundated with groundwater. The auger holes and trenches in the central and northern portions of the area do not appear to make direct contact with groundwater on a regular basis. Radionuclides have been released and detected in downgradient surface waters (seeps and Melton Branch Tributary). The primary contaminant release mechanism in the southern portions of area A is direct contact of groundwater with wastes in the trenches and subsequent flow to downgradient discharge areas. In the upland areas, percolation of precipitation through trench and auger hole wastes and into the underlying water table accounts for most of the contamination released from this portion of the study area. In both areas, groundwater is the major contaminant migration pathway.

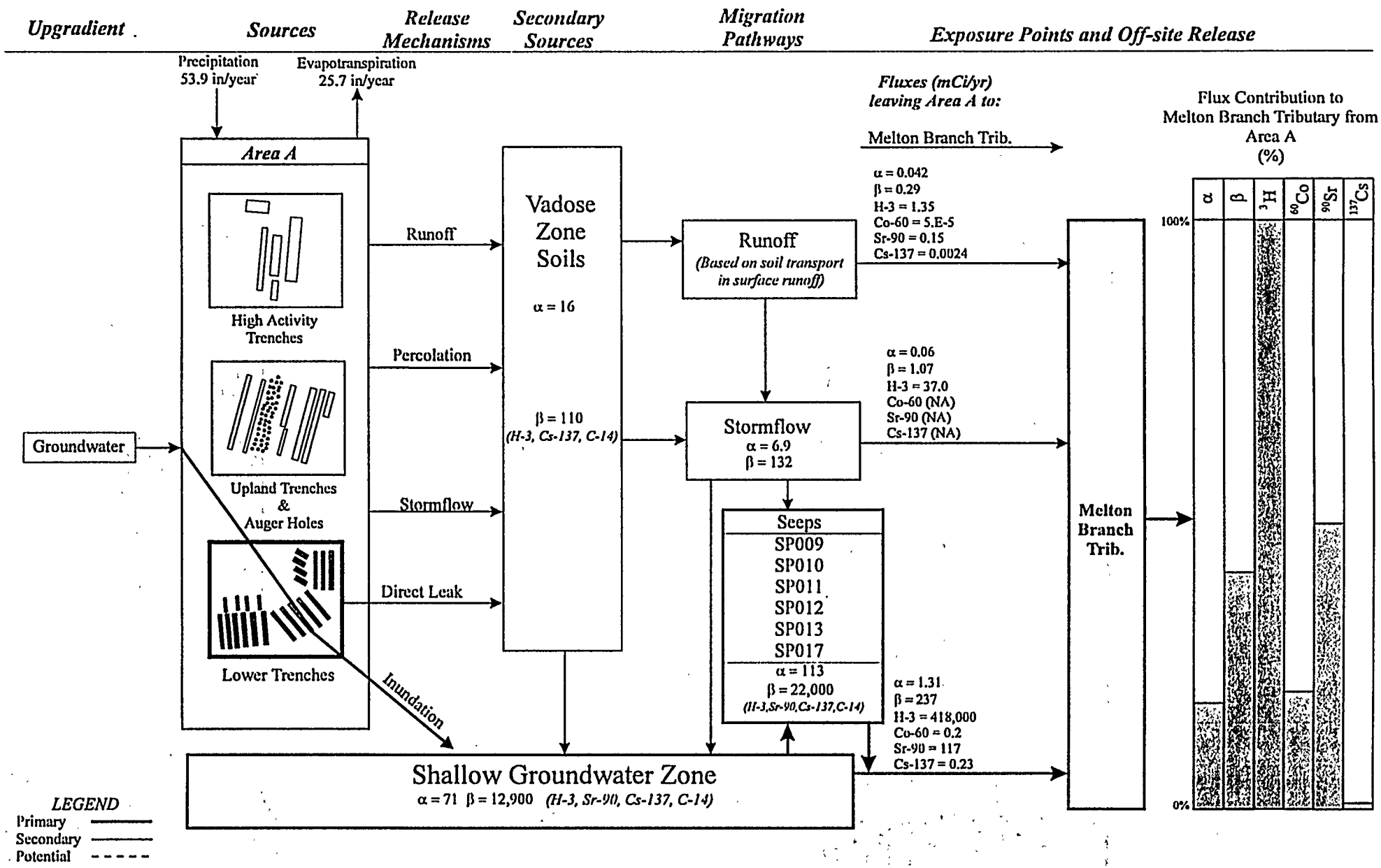


Fig. B2.4.28. Area A conceptual model.

The stormflow zone may also be important in both upland and downslope areas: in the upland areas, the zone may introduce potentially significant quantities of water into trenches or auger holes. In low-lying areas, as the trenches become inundated (or fill with water under bathtubbing conditions in other locations), contaminated water may flow out of the trenches via the stormflow zone.

Table B2.4.20. Conceptual model summary for area A

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
ACTIVE: 121 Auger Holes and Noninundated Trenches	• Infiltration of precip. w/ percolation through wastes • Recharging waters from stormflow zone	• Shallow groundwater discharging to Melton Branch Tributary	• Seep discharge areas • Downstream surface water and sediment
ACTIVE: Inundated Trenches	• Direct contact between wastes and groundwater	• Same as above • Storm flow zone	• Same as above
ACTIVE: 5 High-Activity Trenches	Infiltration/percolation	• Same as above	• Same as above

B2.4.5 Area B

Area B study area encompasses 15.8 acres immediately west of Area A along the southern perimeter of WAG 5 (Fig. B2.1.1). The configuration of the study area was based largely on surface drainage patterns—the west side is bounded by drainage D-2—and the orientation of source trenches. Figure B2.4.29 shows conditions as of November 1994.

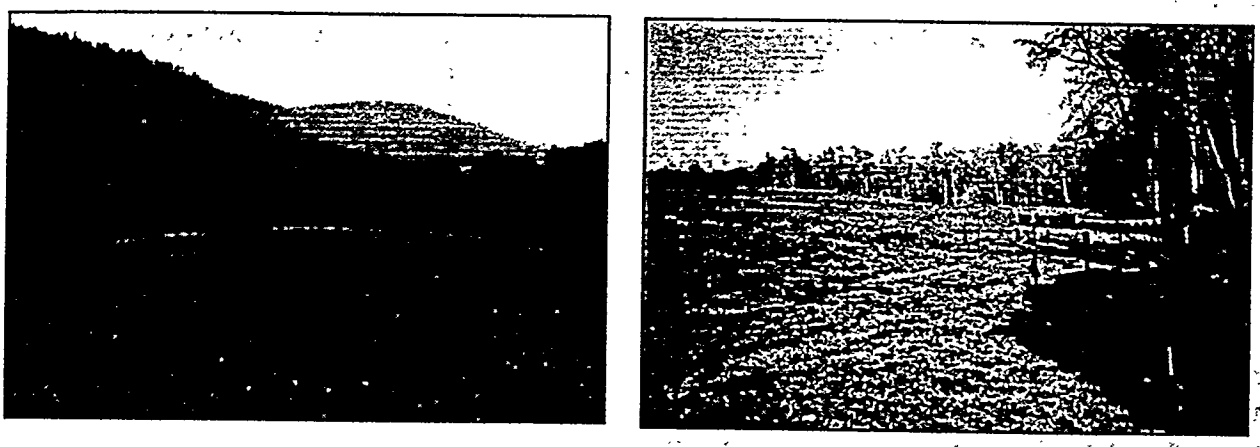


Fig. B2.4.29. Photographs of area B looking downslope over undefined trench area (left) and looking east toward area A along perimeter road.

Description and history

Area B has been characterized as a significant source of tritium to Melton Branch, contributing approximately 15 to 30% of the total flux of tritium in the White Oak Creek watershed. Primary sources include 47 trenches in the lower portion of area A, 27 trenches in the northern section in an area historically identified as the "undefined trench area," and 177 auger holes located between the two sets of trenches. Table B2.4.21 summarizes the area B waste characterization; more detail is given in Sect. B2.4.3.

Table B2.4.21. Waste disposal records for area B

	NUMBER	HIGH ACTIVITY β–γ	LOW ACTIVITY β–γ	BIOLOGICAL	NO RECORDS
Auger Holes	177				177
Inundated Trenches	45	5	17	13	12
Upland Trenches					
• undefined trench area	27				27
• other areas	2				2

The earliest burials in area B (and SWSA 5 as a whole) occurred along the road in the northern part of the undefined trench area on the northern hillslope of area B (Fig. B2.4.29). The area was used from 1959 to 1962, based on information provided by ORNL Drawing E-52834. A total of 27 trenches were apparently used, since the lowest numbered trench in Drawing E-52834 was 28. Limited historical records were collected as part of the ORNL/ER-DMG efforts. Earlier characterizations of SWSA 5 wastes (e.g., Grizzard 1986, Shoun 1987) stated that the undefined

trench area was used for disposal of segregated alpha-contaminated waste that was buried in trenches and then covered with a slab of concrete, but the area also received a variety of beta-gamma wastes from both on-site and off-site sources.

Data for the earliest burials identified plutonium waste from the cleanup of Building 3109 between November 3, 1960, and January 9, 1961. Examination of logbooks obtained from the document control office in Building 3001 also indicated that large quantities of biological waste were disposed of in the undefined trench area; most of this waste, consisting of carcasses, bedding, and animal wastes, was from off-site sources. Other potential off-site waste types included transuranics, contaminated sludges, and chemical wastes (including some that were apparently radiologically contaminated). Much of the biological waste appears to have been tritium-contaminated and buried in a variety of containers, including fiber drums and cardboard boxes.

There are 45 trenches in the southern portion of area B, downslope of the undefined trench area. These trenches contain solid low-level waste, debris (glassware, scrap material, etc.), and biological wastes (animal carcasses, bedding, wastes) contaminated with mixed fission products, activation products, actinides (U/Th and transuranic radionuclides), and organic solvents. Section B2.2 gives a more complete description of wastes buried in SWSA 5 South trenches based on the available data collected by ER-DMG and/or reported in previous studies.

The auger holes south of the undefined trench area were used primarily for disposal of biological wastes. Auger holes 475 and 476 are reported to contain ^{233}U from Building 9204-3. After the last auger hole (507) was filled, trench 79, directly below the auger holes, was opened for biological waste.

Previous investigations

Duguid (1975) sampled three floodplain seeps and one overflowing trench seep in area B and reported tritium concentrations between 100,000,000 and 800,000,000 pCi/L and ^{90}Sr concentrations between 2000 and 60,000 pCi/L. The greatest ^{90}Sr concentrations were detected in the seep directly above the overflowing trench.

Between October 1978 and February 1979, Cerling and Spalding (1981) sampled streambed gravel to determine the areal distribution of ^{60}Co, ^{90}Sr, and ^{137}Cs in the White Oak Creek watershed (Fig. B2.4.6). Results indicated that the largest concentrations of ^{60}Co were along the reach of Melton Branch below area B. Between January and March 1980, Spalding and Munro (1984) took groundwater samples from shallow boreholes approximately 3 m apart along the southern perimeter of WAG 5. Elevated ^{90}Sr concentrations were found along the eastern half of area B, approximately 120 ft downslope of the trenches; concentrations ranged from 3000 to 60,000 pCi/L, and the maximum occurred 150 ft south of trench 106.

Spalding (1984) performed a field experiment that involved injecting caustic soda, soda ash, and lime/soda ash solutions into trench 117 on four occasions between October 1979 and October 1981 in an attempt to immobilize ^{90}Sr. Post-injection soil sampling results indicated that as much as 98% of the total ^{90}Sr was present as a coprecipitate with calcium carbonate. Migration of ^{90}Sr from the trench to the SP008 sump, immediately below trench 117, was reduced by approximately 90%. Several wells were installed around SP008 to monitor the trench discharge contamination plume; Spalding (1984) concluded that although the soluble cations in groundwater would eventually replace all of the

exchangeable sodium (from the ash), the time required for this process would allow for radioactive decay of the ^{90}Sr. The major transport mechanism of ^{90}Sr from the trench was observed to be a mixture of surface flow during "bathtub" overflow and "chronic" subsurface seepage (possibly analogous to delayed drainage from the bathtubbing trench). During the fourth chemical treatment, Spalding (1984) excavated a 1-m-wide (north-south) and 2.5-m long (east-west) ditch for the lime and soda ash. Waste encountered at approximately 1.5 m, despite having been buried 12 years earlier, appeared "just like freshly disposed waste." Spalding (1984) also performed hydrologic tests on trench 117 and calculated a waste void space of 0.41; however, during excavation of the ditch, large void spaces were encountered that "seemed to penetrate to the bottom of the trench" and "were large enough that spelunking of the void spaces would have been possible" (Spalding 1984).

Phase I field activities were performed as part of the WAG 2 RI between March and October 1992 (ORNL 1993). Based on the WAG 2 transect sampling along Melton Branch (summarized in Sect. B2.4.1), the discharge of ^{3}H into the reach of Melton Branch along area B was calculated to contribute 15 to 30% of the total ^{3}H flux in the White Oak Creek watershed.

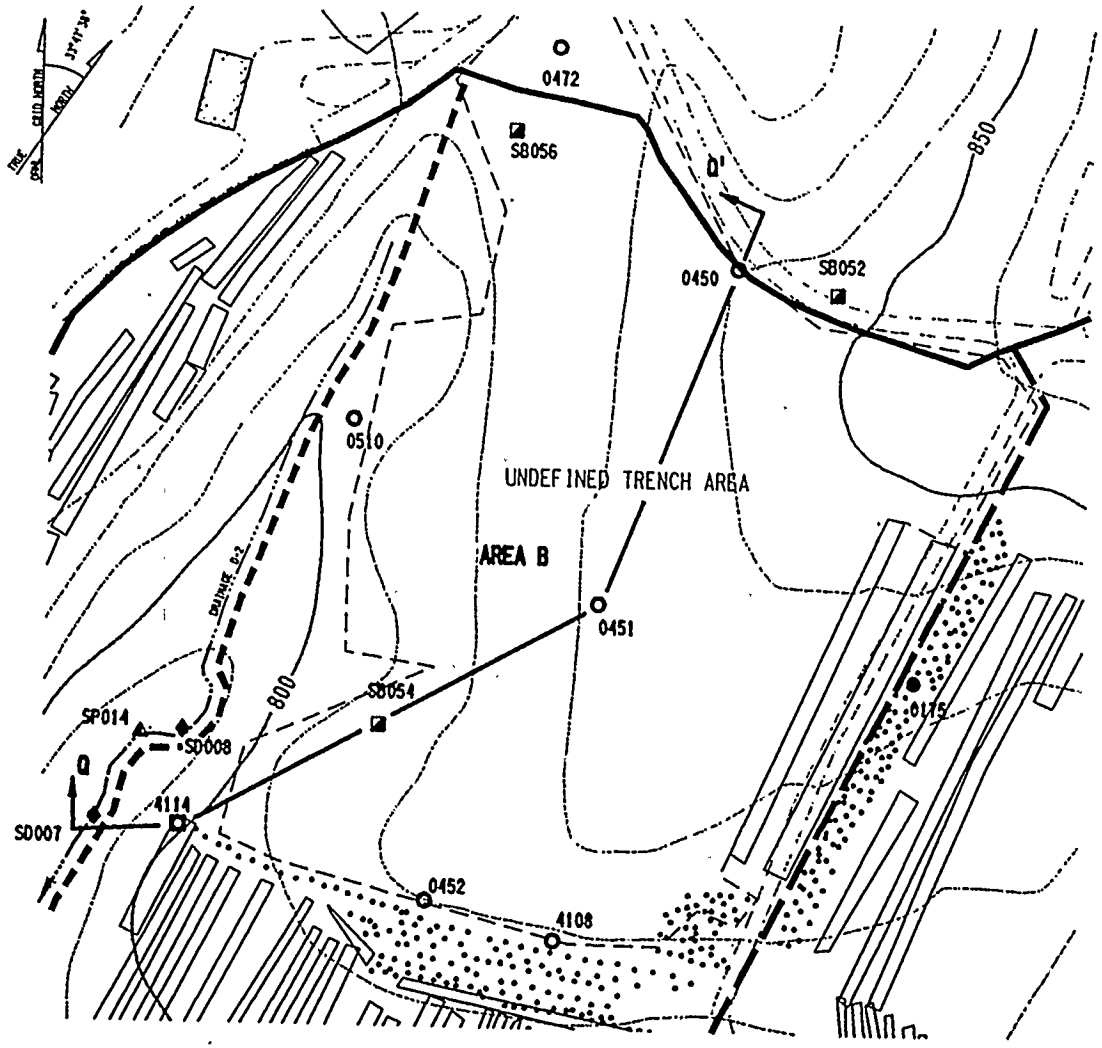
RI sampling summary

Figure B2.4.30 shows the sampling locations within and surrounding the undefined trench area and the cross section limits used for the hydrologic model. Soil sampling involved one vertical soil boring completed into bedrock (later completed as monitoring well 4114) and two areal (0- to 2-ft) composite samples identified by USRADS as low- to medium- exposure rate locations. Groundwater from six wells and piezometers was sampled. Shallow storm flow piezometer 4108 was sampled at the downgradient edge of the undefined trench area. Surface water seep SP014 was initially screened at the CSL for radiological constituents and then later sampled for total analysis during wet weather conditions. Surface water was also collected at the drainage D-2 flume during base conditions and several storms. Four sediment samples were collected in drainage D-2.

Figure B2.4.31 is a plan view of the area directly below the undefined trench area. Twenty-seven drive points were installed in trenches along the southern boundary of area B, and 14 were installed in the area B Melton Branch floodplain. One groundwater sample was collected from each drive point and analyzed at the CSL. Drive point well 4179 was resampled for off-site isotopic analyses after the CSL results showed a high concentration of alpha-emitting isotopes. Most of the trench drive points were sampled in September 1993, and floodplain drive points and trench drive points that were dry during September 1993 were sampled in March 1994. Seeps SP007, SP008, SP014, and SP019 were identified within or near area B. When samples from seeps SP007 and SP014 were initially screened at the CSL in the fall of 1992, SP008 and SP019 were dry. During wet seasonal conditions in spring 1993, all four seeps were sampled and analyzed off site.

Hydrologic model

Area B includes a surface drainage divide between drainage D-2 and Melton Branch, and the study area is about equally divided (7.2 acres and 8.6 acres) between the D-2 and Melton Branch sub-basins. Figures B2.4.32 through B2.4.34) depict the hydrologic relationships between shallow groundwater and trench water; show the spatial relationship between the water table, top of bedrock, and ground surface;



WAG 5 KEY PLAN

LEGEND

- APPROXIMATE STUDY AREA BOUNDARY
- GRAVEL ROAD
- 800 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- TRENCHES
- AUGER HOLES
- SP014 SEEP SAMPLING LOCATION W/NO.
- SD008 SEDIMENT SAMPLING LOCATION W/NO.
- SB054 SOIL SAMPLING LOCATION W/NO. (MEDIUM TO LOW EXPOSURE)

GROUNDWATER WELL/PIEZOMETER LOCATION W/NO.

- 0451 REGOLITH <50'
- 0175 BEDROCK >100'

Drainage Group: Melton Branch
Study Area: Area B Undefined Trench Area
Sources: Trenches and auger holes

SCALE

0 50 100 FEET
0 10 20 30 METERS

Fig. B2.4.30. Area B undefined trench area plan view.

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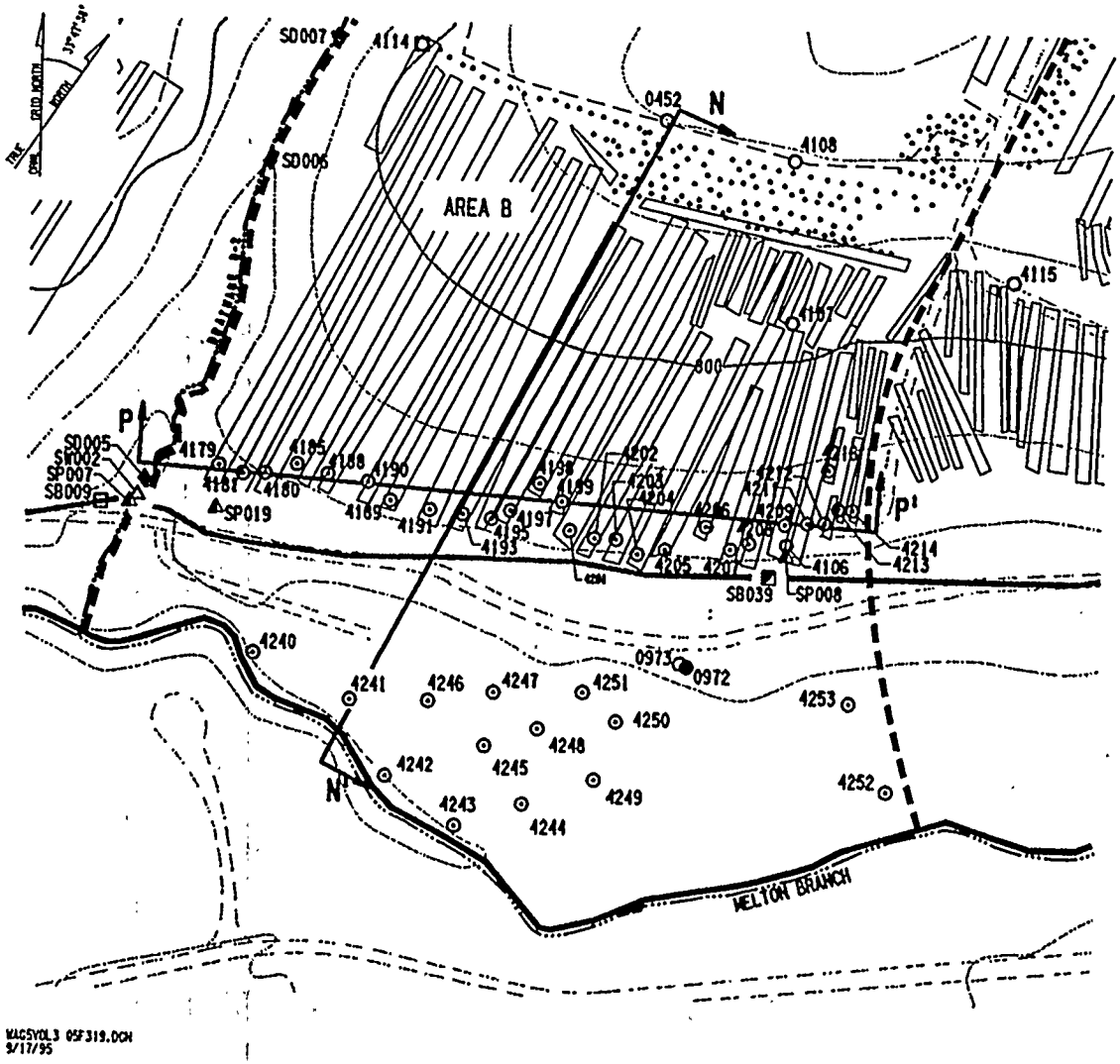
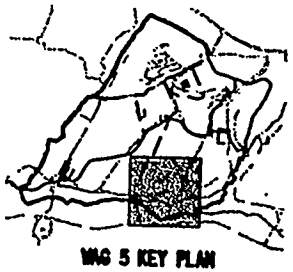




WAG 5 KEY PLAN

LEGEND

- WAG 5 BOUNDARY
- APPROXIMATE STUDY AREA BOUNDARY
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- TRENCHES
- AUGER HOLES
- SURFACE WATER LOCATION W/NO.
- SEEP SAMPLING LOCATION W/NO.
- SEDIMENT SAMPLING LOCATION W/NO.
- DRIVE POINTS
- SOIL BORING LOCATION W/NO.
- SOIL BORING LOCATION W/NO. (HIGH EXPOSURE RATE)

GROUNDWATER WELL/PIEZOMETER LOCATION W/NO.

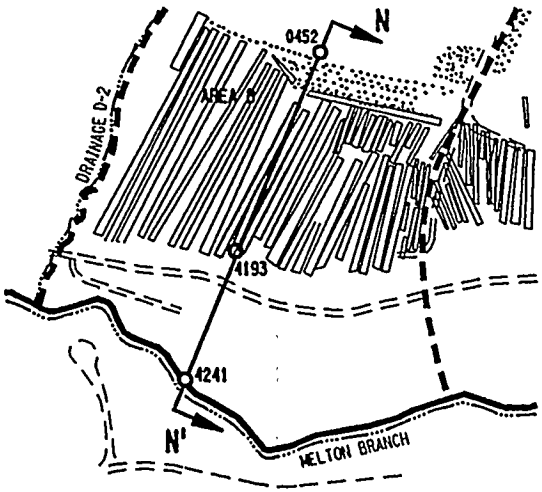
- 0973 REGOLITH <30'
- 0972 BEDROCK <100'

Drainage Group: Melton Branch
Study Area: Area B
Sources: Trenches and Auger holes

SCALE

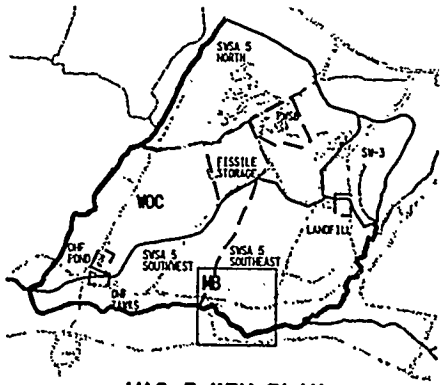
0 50 100 FEET
0 10 20 30 METERS

Fig. B2.4.31. Area B plan view.

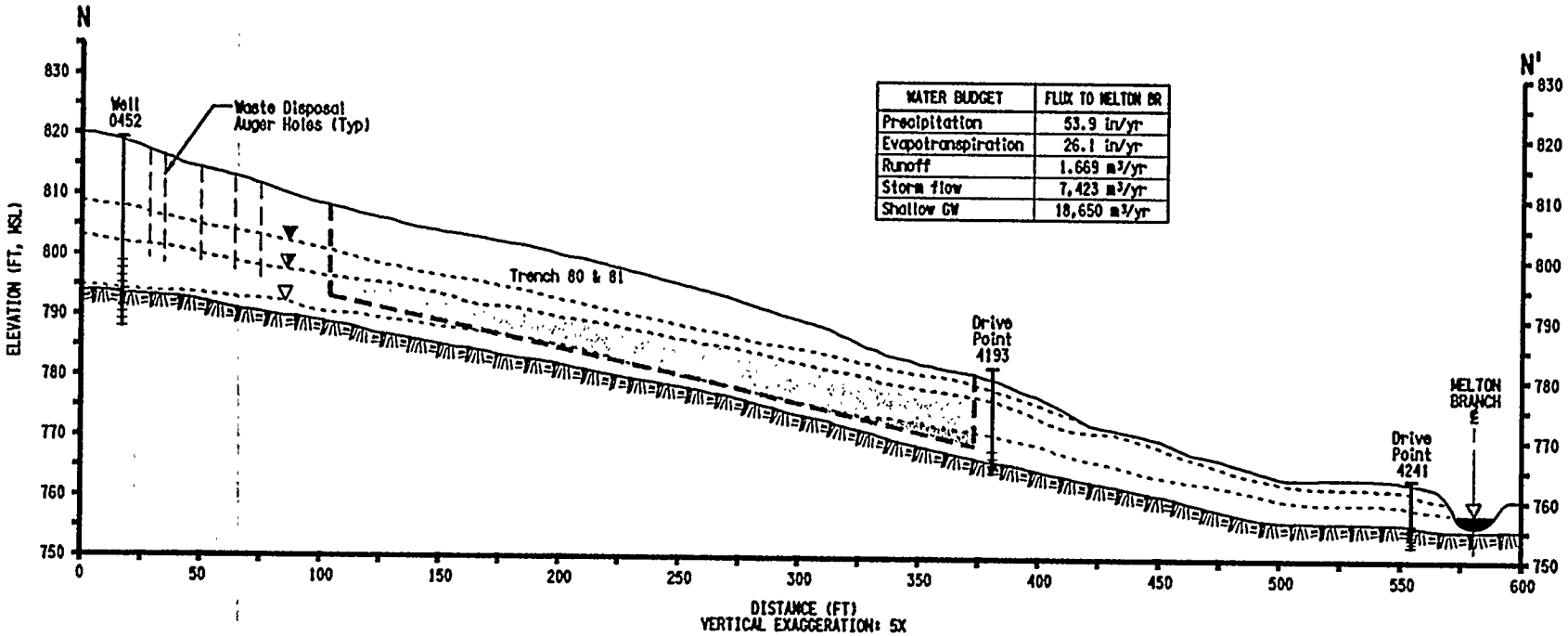


LEGEND

- HIGH BASE WATER TABLE STORM (4/94)
- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0452 — WELL, WELL NO., SCREEN SECTION
- 80 — HYPOTHESIZED TRENCH LIMIT W/ NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX TO MELTON BR
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	1,669 m³/yr
Storm flow	7,423 m³/yr
Shallow GW	18,650 m³/yr

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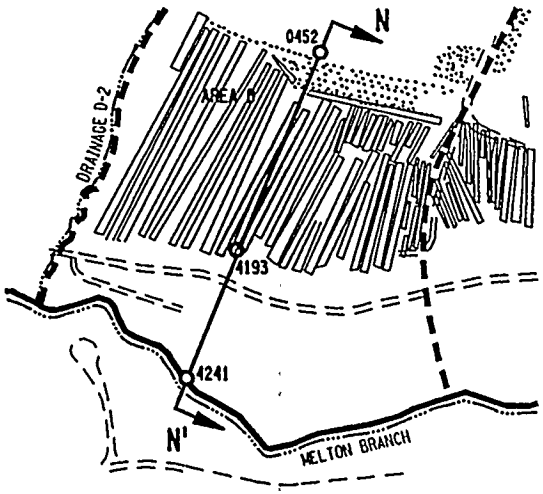
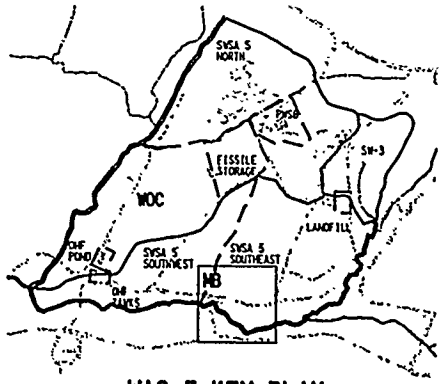
Fig. B2.4.32. Hydrologic model for area B (Section N-N').

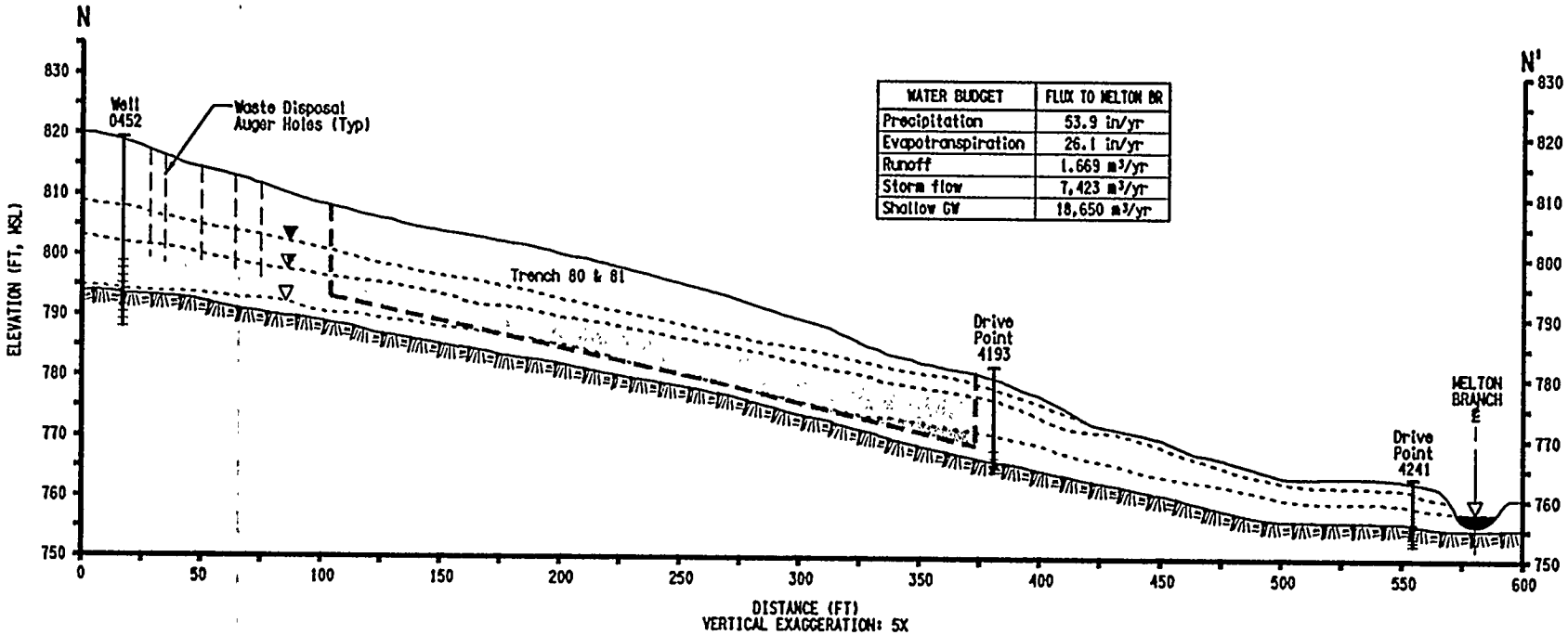


LEGEND

- HIGH BASE WATER TABLE STORM (4/94)
- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0452 — WELL, WELL NO., SCREEN SECTION
- 80 — HYPOTHESIZED TRENCH LIMIT W/ NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX TO MELTON BR
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	1.669 m^3/yr
Storm flow	7,423 m^3/yr
Shallow GW	18,650 m^3/yr

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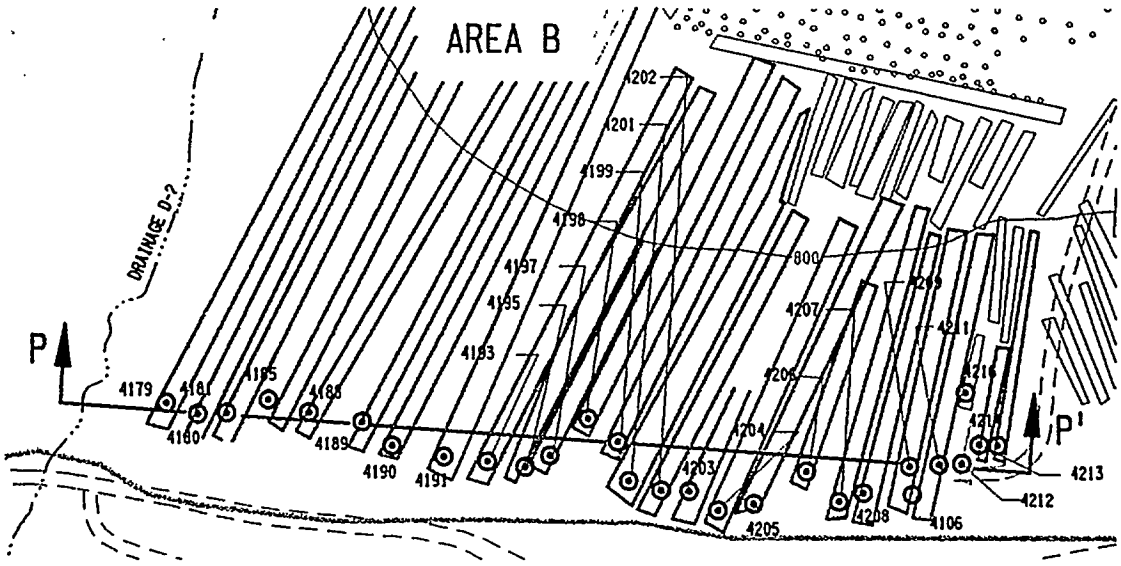
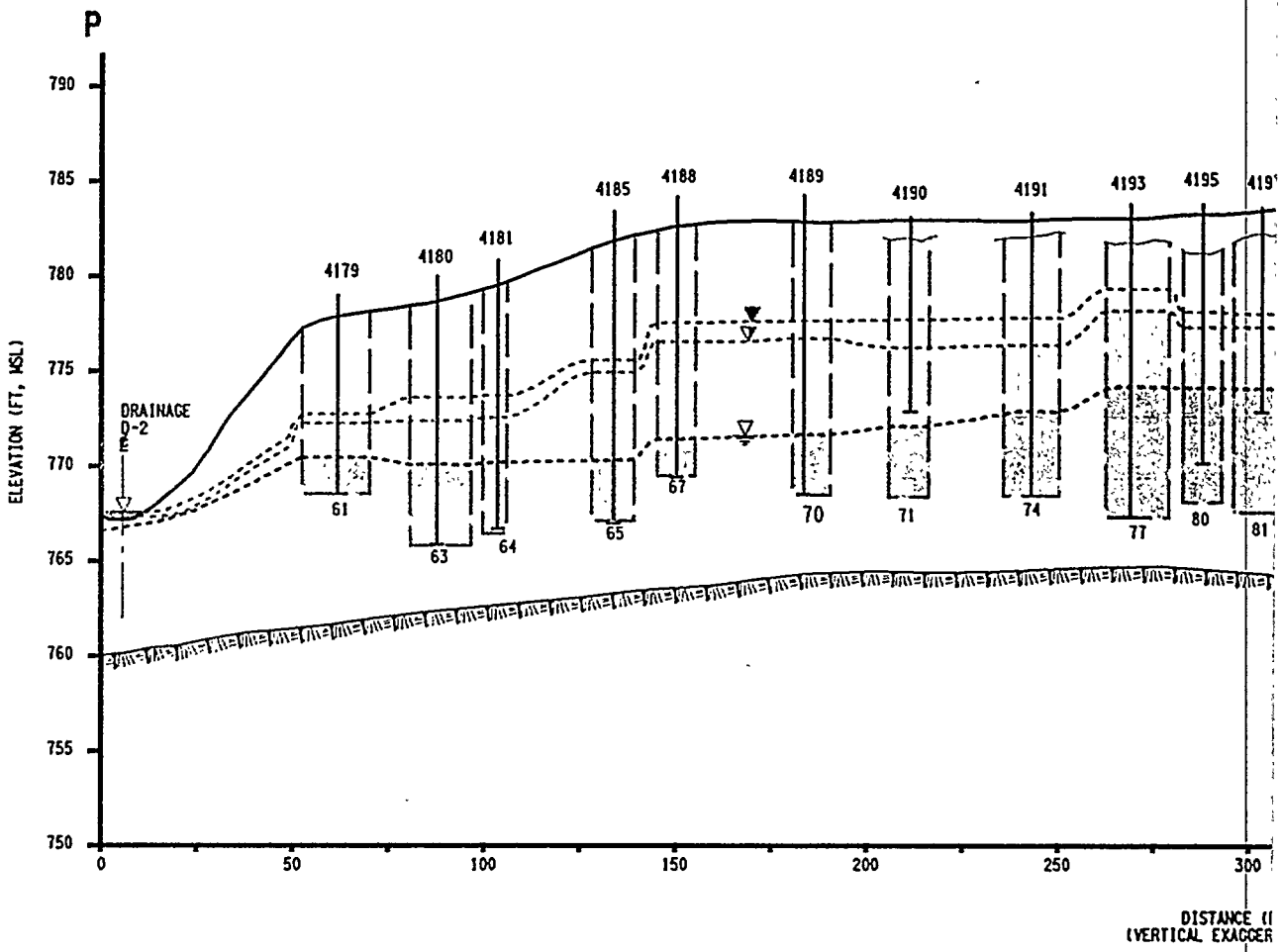
Fig. B2.4.32. Hydrologic model for area B (Section N-N').





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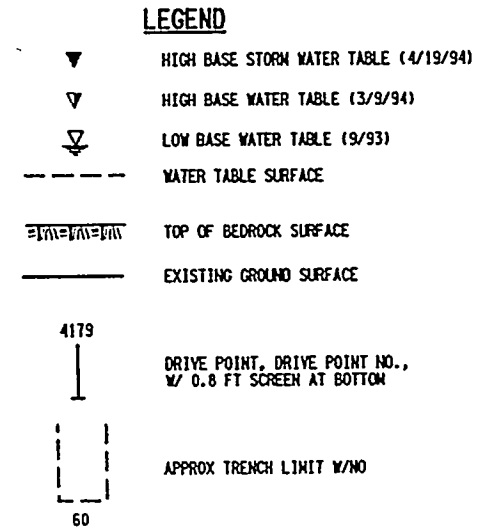
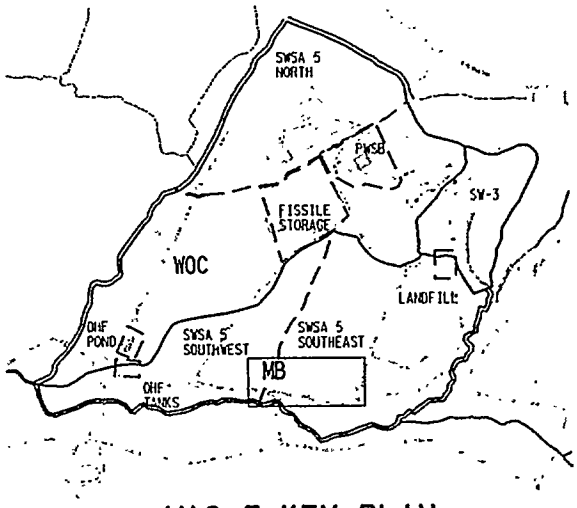




WAG 5 KEY PLAN

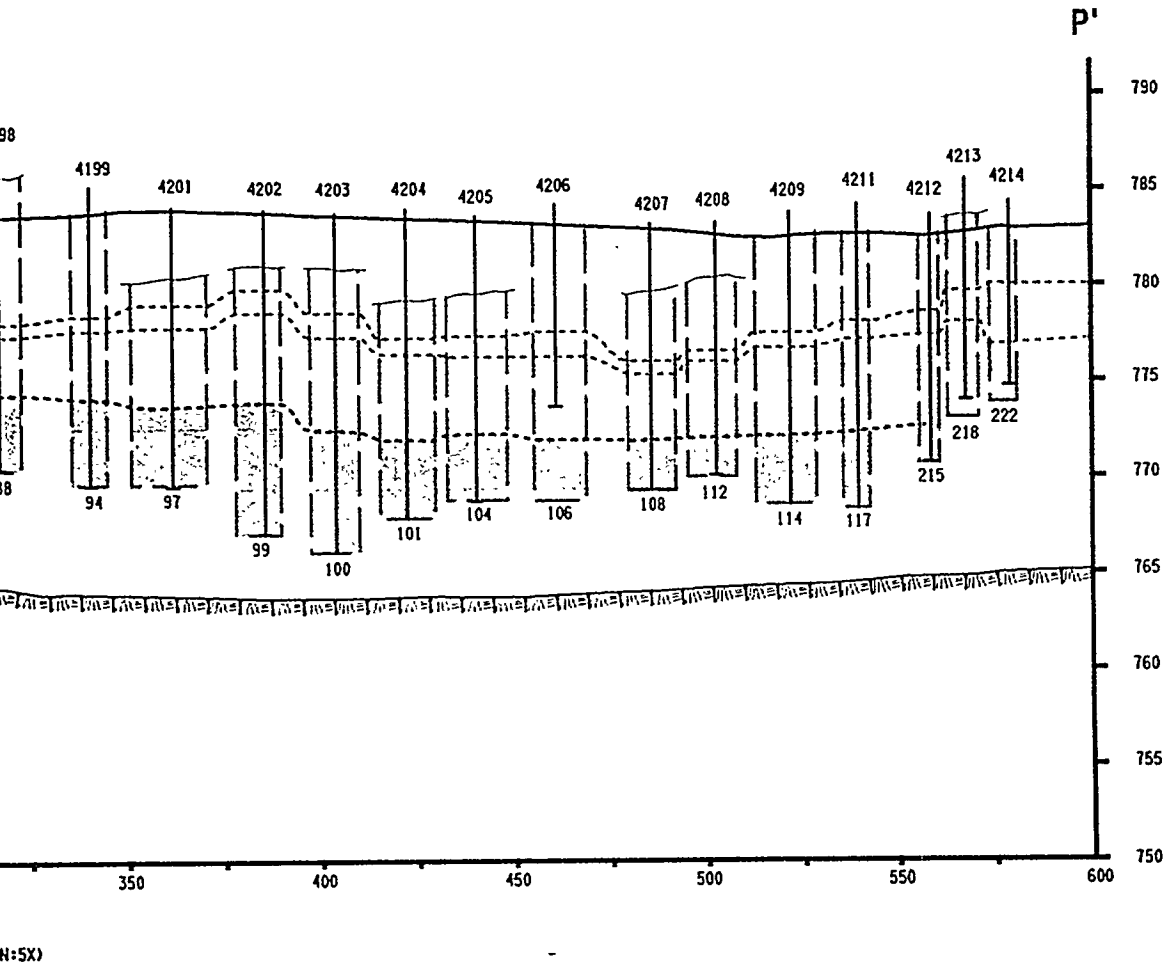
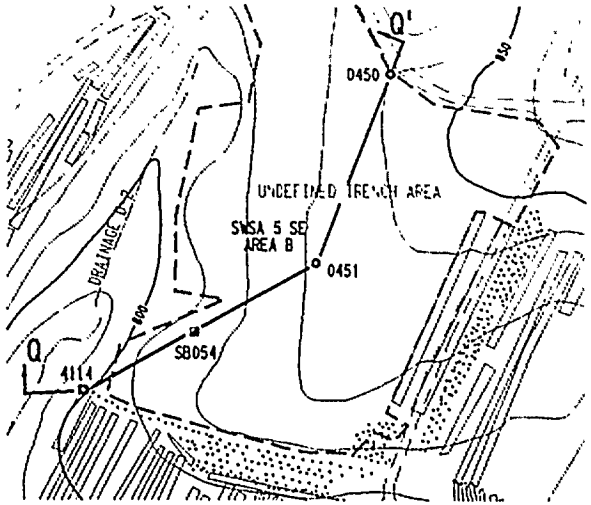
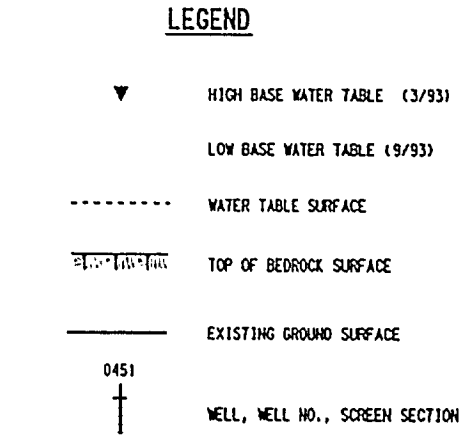
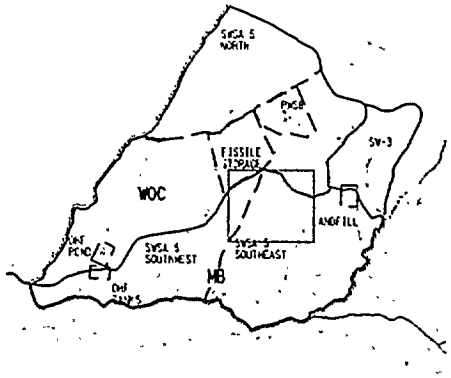


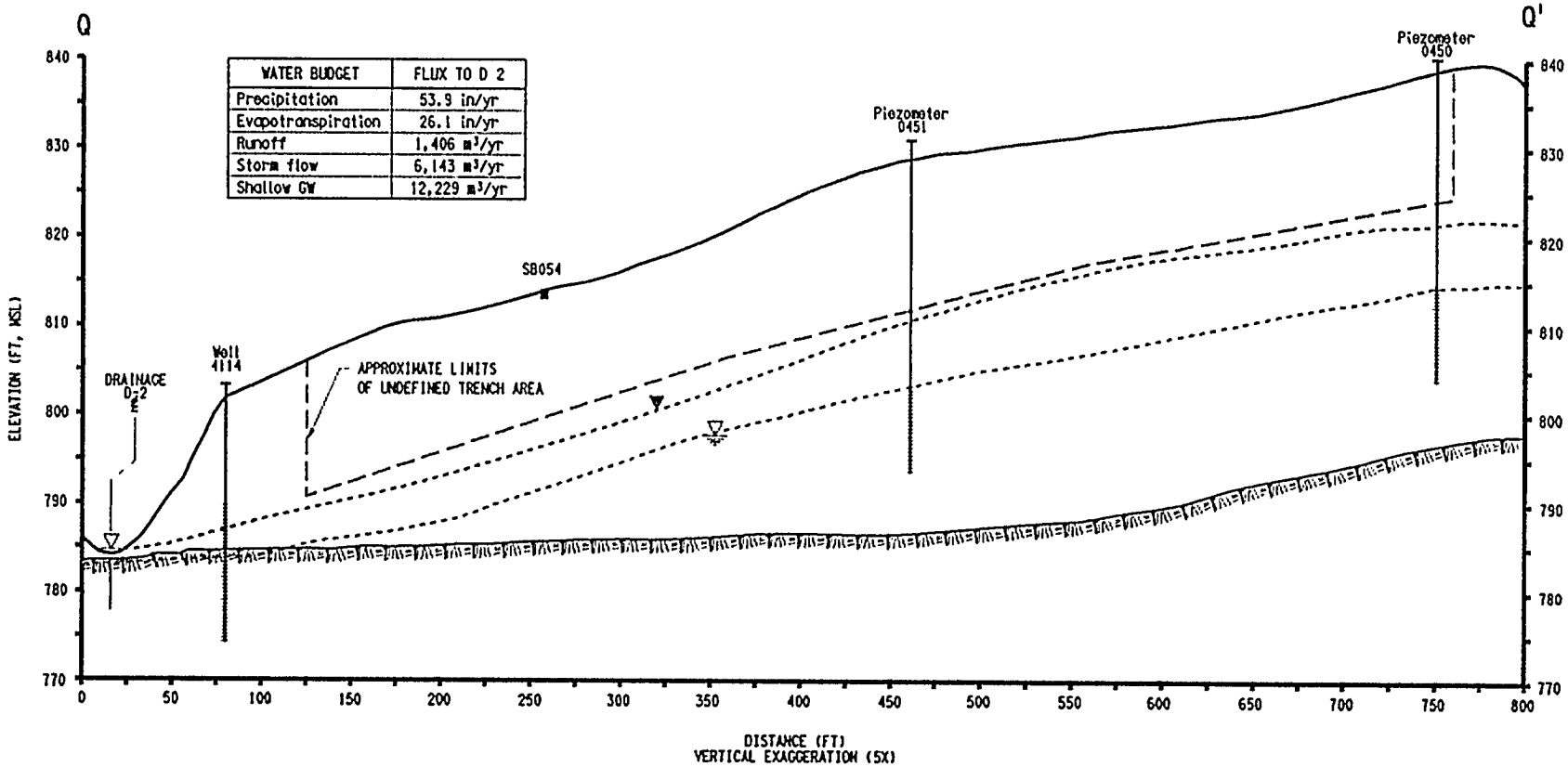
Fig. B2.4.33. Area B drive points (Section P-P').







WAG 5 KEY PLAN



WATER BUDGET	FLUX TO D 2
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	1,406 m^3/yr
Storm flow	6,143 m^3/yr
Shallow GW	12,229 m^3/yr

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Fig. B2.4.34. Hydrologic model for undefined trench area (Section Q-Q').

and show the influence of topography and seasonal conditions on the location and number of seeps. Sections N-N' and Q-Q' are oriented parallel to groundwater flow. Section P-P' shows a cutaway view of the trenches perpendicular to flow path. Groundwater flow direction in area B is generally southward toward Melton Branch; flow in the undefined trench area has a more southwesterly component, indicating probable discharge into D-2.

Based on the HSPF modeling, Table B2.4.22 shows the annual water balance for area B and the undefined trench area. Separate fluxes are provided for each of the drainage sub-basins in area B (note: the actual percentage of groundwater discharge to Melton Branch is greater than that to drainage D-2 due to the effects of trench hydrology on groundwater movement).

Table B2.4.22. Annual water balance summary for area B

	PERCENT OF FLOW (%)	DISCHARGE TO DRAINAGE D-2 (m^3/year)	DISCHARGE TO MELTON BRANCH (m^3/year)	TOTAL ANNUAL DISCHARGE (m^3/year)
Surface runoff	6.5	1,406	1,699	3,105
Interflow	28.5	6,143	7,423	13,566
Groundwater flow	65	12,239	18,650	30,889
Total	100	19,788	27,772	47,560

Inundation of trenches is the most significant contaminant release mechanism in this area. Water levels monitored by drive points indicate that most trenches in the southern portion of area B are at least partially inundated throughout the year. No trench water level data for the undefined trench area are available. The undefined trenches are in an upland area, and direct infiltration of precipitation, possibly resulting in the formation of perched water tables (bathtubbing), may also be important, but there is no direct evidence of this condition. The stormflow zone is also active in area B and is probably important from a contaminant migration perspective when the trenches are filled with water (i.e., the trenches act to recharge the stormflow zone).

Nature and extent of contamination

Table B2.4.23 summarizes analytes of concern detected in SWSA 5 Southeast area B. Tables B2.4.24 and B2.4.25 present quantitative results for the major contaminants in the undefined trench area and the trenches and auger holes directly downgradient of the undefined trench area.

Undefined trench area. Well 4114, installed for the RI, is between the southwest corner of the undefined trench area and drainage D-2. Wet and dry season sampling identified significant alpha contamination (^{238}Pu and ^{233}U) in the groundwater. Filtered results of 2600 pCi/L and 4200 pCi/L for ^{238}Pu and ^{233}U, respectively, were reported for the wet season sample collected in April 1993. During the dry season sampling event in October 1993, concentrations declined to 48.8 pCi/L (^{238}Pu) and 29.1 pCi/L (^{233}U).

Table B2.4.23. Contaminants of concern in SWSA 5 Southeast area B

CONTAMINANT	SOIL	SED[a]	GW	SW[b]
^{241}Am	X	X	X	X
^{14}C			X	
$^{243/244}Cm$	X	X	X	
^{60}Co		X	X	
^{137}Cs	X	X	X	X
Tritium	X	X	X	X
^{238}Pu	X	X	X	
$^{239/240}Pu$			X	
^{226}Ra			X	
^{228}Ra			X	X
^{90}Sr	X	X	X	X
^{99}Tc			X	X
^{228}Th			X	
^{230}Th	X		X	
^{231}Th			X	
$^{233/234}U$		X	X	X
^{235}U			X	
^{238}U		X		
Manganese			X	
Nickel			X	
Aroclor 1260	X			
Tetrachloroethene			X	
Vinyl Chloride		X		

[a] *Sediment samples obtained from drainage D-2*
[b] *Surface water samples obtained from Area B seeps*

The increase in alpha levels during the wet season indicates a possible release mechanism associated with a higher water table and possible trench inundation. The source of this alpha contamination is probably the wastes in the undefined trench area immediately upgradient of well 4114. Historical data indicate that this area was used for the disposal of alpha-contaminated wastes, including plutonium-bearing wastes from the cleanup of Building 3019. The high concentrations of ^{238}Pu in this well are particularly relevant to ongoing efforts by ORNL to characterize the migration of actinides in groundwater. Plutonium is not a relatively mobile radionuclide, yet it has migrated a potentially significant distance (the location of the specific source trench is not known) in unusually high concentrations.

Table B2.4.24. Analytical data summary for selected radionuclides in the undefind trench area

Sample				(α)		(β)		(β)		(β)		(β−γ)		(α)		(α)		(α)	
Type	ID	Date	Intv (ft)	Gross Alpha		Gross Beta		Tritium		Sr-90		Cs-137		U-233/234		U-238		Pu-238	
SOIL (pCi/g)																			
Background Reference				9.92		42		0.084		1.94		1.44		1.6		2.4		0.166	
SB054		3/1/93	0-2	-		41.7		9.71				0.702							
SB056		2/18/93	0-2	-		39		-				0.57							
4114		3/8/93	0-6	-		45.8		-		2.43		0.51							
SEDIMENT (pCi/g)																			
Background Reference				44		54		100		1.34		0.82		2.6		2			
SD007		7/6/93	0-0.3	64		2000		1409		890		7		16		2.2		3.5	
SD008		7/7/93	0-0.3	47		2400		1479		1100		6							
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				5.2	3.2	16	7.4	2400	1040	10.4	3.6	12	5.4						
0450		7/9/92	24-34	50.9	8.8	289	48.4	1.3E+5	1.2E+5		5.3								
0451		6/4/92	24-34	-	-	6664	6474	2.2E+5	2.2E+5		4776	863							
0452		6/17/92	20-30	83.6	715	745	292	6.1E+6	6.8E+6		14.1								
0472		6/18/92	15-20	175.6	338	1104	1168	2.5E+6	2.5E+6		852								
0472		4/26/93	15-20	40	8.3	1100	850	1.5E+6	1.0E+6	440	360	-	-	8.4	4.4	-	-	-	-
0472		10/21/93	15-20	39.4	23	889	943	1.1E+6	1.5E+6	322	417	-	-	6.38	2.43	5.4	2	-	-
0510		6/22/92	0-13	45	22.3	983	754	4.7E+6	4.7E+6		770		85						
4108		12/6/93	0.5-1																
4114		4/21/93	12-26.7	35000	7700	1000	360	1.4E+6	1.7E+5	43	44	-	-	3800	4200	73	71	23000	2600
4114		10/25/93	12-26.7	4920	44.4	3210	1990	1.5E+6	1.4E+6	1280	867	-	-	58.6	29.1	1.8	1.1	6460	48.8
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				9		8		1620				40		2		2			
SP014		8/26/92		18.1	86	1932	143	4.1E+6	4.1E+6		958								
SP014		5/18/93		-	5.8	1359	2361	2.3E+6	2.3E+6	610	656	-	-	1.1	0.71	0.6	0.6		

Notes: 1. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfiltered/Filtered - = not detected (a, b, g) = alpha, beta, gamma emitter

Table B2.4.25. Analytical data summary for selected radionuclides in area B trenches and auger holes

Sample				(α)		(β)		(β)		(β)		(β−γ)		(α)	
Type	ID	Date	Intv (ft)	Gross Alpha		Gross Beta		Tritium		Sr-90		Cs-137		Am-241	
SOIL (pCi/g)															
	Background Reference			9.92				0.084		1.94		1.44		0.08	
	SB009	8/19/93	0-6			48.3		13.4		9.1		-			
	SB009	8/19/93	6-8.4	-		68		1365							
	SB039	12/9/93	0-2	286		15900		1860		10300		8.68		6.78	
SEDIMENT (pCi/g)															
	Background Reference			44		54		100		1.34		0.82			
	SD005	6/28/93	0-0.3	120		1900		1668		830		9.7		-	
	SD006	6/28/93	0-0.3	170		2700		684.4		1400		7.1		0.32	
	SD007	7/6/93	0-0.3	64		2000		1409		890		7			
	SD008	7/7/93	0-0.3	47		2400		1479		1100		6		0.62	
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
	Background Reference			5.2	3.2	16	7.4	2400	1040	10.4	3.6	12.4	5.4		
	0452	6/17/92	20-20.9	83.6	715	745	292	6.05E+6	6.76E+6		14.1				
	0972	4/27/93	59-74.7	-	-	-	-	2.68E+4	2.86E+4	1.43	-	-	-	-	-
	0972	11/10/93	59-74.7	27.8	-	62.3	-	4.31E+3	3.60E+4		-	-	-	0.08	0.11
	0973	4/26/93	9.1-15.3	25	27	378	324	2.70E+8	2.70E+8	114	100	-	-	1.65	0.51
	0973	11/4/93	9.1-15.3	28.7	14.4	636	573	2.99E+8	3.40E+8	176	273	-	-	-	-
	0974	4/23/93	10.1-22.1	-	-	37.8	35.1	8.10E+7	8.10E+7	17.6	17	-	-	-	0.1
	0974	11/8/93	10.1-22.1	-	3.77	63.2	60	7.09E+7	7.47E+7	21.3	29.4	-	-	-	0.24
	1735	6/15/92	0-8.5	109440	4797	1931581	1006791	1.40E+8	1.38E+8		796247	1250			
	1767	6/10/92	5-14.9	930	167	4480.4	2736.4	9.12E+7	9.27E+7		1675	26			
	4107	12/6/93	0.5-1	14		82.9		1.47E+4							
tr-dp(61)	4179	9/23/93	7.5-8.3	7505436	9721498	653060	2216683	2.33E+7	2.30E+7	3000	134181	8.74	101	1.1E+6	765
tr-dp(63)	4180	9/23/93	10.7-11.5	628773	5357.5	84513	2461	5.79E+7	5.80E+7	80075	955	55.2			
tr-dp(64)	4181	9/23/93	11.2-12	12522	108	6507	1404	1.00E+8	9.48E+7	5508	507		230		
tr-dp(65)	4185	9/23/93	13.2-14	10919	245	6353	479.5	1.06E+8	1.06E+8	5680	288				
tr-dp(67)	4188	9/23/93	11.7-12.5	148438	10759	23198	6541	9.51E+7	9.27E+7	12470	2309	178	104		
tr-dp(70)	4189	9/23/93	12.7-13.5	8196	324	12484	2941		2.68E+8	2330	1592	587		765	
tr-dp(71)	4190	3/11/94	7.3-8.1	1249	230	7462	4333	5.76E+7	5.61E+7		2719	996	37.6		

Table B2.4.25. Analytical data summary for selected radionuclides in area B trenches and auger holes (cont.)

Sample				(α)		(β)		(β)		(β)		(β−γ)		(α)
Type	ID	Date	Intv (ft)	Gross Alpha		Gross Beta		Tritium		Sr-90		Cs-137		Am-241
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U	F
Background Reference				5.2	3.2	16	7.4	2400	1040	10.4	3.6	12.4	5.4		
tr-dp(74)	4191	9/24/93	11.8-12.6	12939	85.3	27137	4560	2.99E+8	2.77E+8	11803	1988	44			
tr-dp(77)	4193	9/24/93	12.7-13.5	18640	158	21118	9180	4.71E+8	5.12E+8	12834	4560	104	5810		
tr-dp(80)	4195	9/24/93	9.6-10.4	13976	153	201312	68934	3.31E+8	3.37E+8	450589	38586	2960			
tr-dp(88)	4198	9/24/93	13.1-13.9	49641	279	226713	73547	1.82E+8	1.83E+8	78834	40426	53200	567		
tr-dp(94)	4199	9/24/93	12.3-13.1	23379	2196	222470	115354	5.50E+7	5.26E+7	139574	111428	2640	128		
tr-dp(97)	4201	9/24/93	8.9-9.7	11798	672.7	326116	180469	6.90E+7	6.88E+7	133894	113510	911			
tr-dp(99)	4202	9/27/93	12.3-13.1	24105	668	320371	74603	4.04E+7	4.05E+7	308854	40113	2780	205		
tr-dp(100)	4203	9/27/93	13.1-13.9	2154375	426	533211	43965	5.68E+7	5.59E+7	46622	24709	97000	92.2	2980	
tr-dp(101)	4204	9/27/93	9.2-10	4229976	704	968937	38314	1.70E+8	1.70E+8	176136	20713	139000		3600	
tr-dp(104)	4205	9/27/93	9.8-10.6	329.5	601	49314	38743	6.14E+7	6.12E+7	26031	20589	4710	1380		
tr-dp(106)	4206	3/11/94	7.1-7.9	18672	450	97562	81806	8.50E+8	7.94E+8		168468	444	395	134	
tr-dp(108)	4207	9/28/93	8.6-9.4	6895	1541	4640666	102455	2.15E+8	2.12E+8	939951	120713	4E+06	10500		
tr-dp(112)	4208	9/28/93	8.6-9.4	11832	430	367383	207968	3.40E+8	3.40E+8	331452	263976	75.7			
tr-dp(114)	4209	9/29/93	11.9-12.7	15963	171	260357	157122	6.08E+7	3.05E+7		136549	34800	139	24800	
tr-dp(111)	4211	9/29/93	12.8-13.6	3260682	4309	1.6E+07	1428781	5.91E+8	5.76E+8	1.4E+07	1255647	536000	222		
tr-dp(215)	4212	9/29/93	10.1-10.9	2426	237	2715	203.3	1.94E+8	1.91E+8		57	47.3			
tr-dp(218)	4213	3/3/94	9-9.8	140	-	461.1	121.1	1.16E+4	1.12E+4			81.9	151		
tr-dp(222)	4214	3/2/94	7.5-8.3	-	16	358.4	65.7	2.18E+4	2.37E+4			77.7	136		
tr-dp(212)	4216	3/3/94	13.8-14.6	874	52	4551814	150018	2.49E+3	2.20E+3		115709	93.2	110		
fp-dp	4240	3/1/94	2.7-3.5	796	21.5	12358	2406	1.08E+8	9.91E+7		1748	67.9	85.6	236	
fp-dp	4241	3/1/94	3.1-3.9	305	22.2	2172	114.6	1.39E+8	1.11E+8		74.9	29.7	130		
fp-dp	4242	3/29/94	3.4-4.2	814	-	4105	168	1.28E+8	1.27E+8			59.2	62.2		
fp-dp	4243	3/29/94	4.6-5.4	529	-	5140	56.8	1.01E+8	9.80E+7			29.4	61.4		
fp-dp	4244	3/22/94	5.5-6.3	-	10.6	3502	19.8	7.70E+7	7.16E+7			47.8			
fp-dp	4245	3/22/94	4.7-5.5	477	19.7	2200	203.3	1.37E+8	1.33E+8		10.2	56.2	62.7		
fp-dp	4246	3/22/94	4.8-5.6	-	-	7616	153.8	1.20E+8	1.19E+8		97.3	38.8	81.3		
fp-dp	4247	3/21/94	6.1-6.9	267	-	22198	3218	8.35E+7	7.65E+7		1868	44.5	80.3	42.3	
fp-dp	4248	3/17/94	7.5-8.3	372	-	3884	59.5	1.11E+8	1.05E+8			1220	70.5		
fp-dp	4249	3/17/94	5.9-6.7	502	-	3600	26.6	1.39E+8	1.39E+8			33.4			

Table B2.4.25. Analytical data summary for selected radionuclides in area B trenches and auger holes (cont.)

Sample				(α)		(β)		(β)		(β)		(β−γ)		(α)
Type	ID	Date	Intv (ft)	Gross Alpha		Gross Beta		Tritium		Sr-90		Cs-137		Am-241
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U F
Background Reference				5.2	3.2	16	7.4	2400	1040	10.4	3.6	12.4	5.4	
fp-dp	4250	3/17/94	6.3-7.1	425.5	13.8	5091	475	2.43E+8	2.47E+8		33515	47.2	83.1	
fp-dp	4251	3/17/94	6.1-6.9	-	-	7283	699	2.12E+8	2.09E+8		509.6	53.5	97.7	
fp-dp	4252	3/16/94	2.9-3.7	817	-	4155	21.6	1.18E+7	1.16E+7			58.2		
fp-dp	4253	3/16/94	8-8.8	491	-	5633	101	3.43E+7	3.22E+7		7.5	78.4	75.8	
fp-dp	SB009	8/23/93	0-9.5		22.8		113		4.31E+7					
Historical Sampling														
	0972	8/6/90	59-74.7		1.62		-	4.32E+5			-		-	
	0972	7/16/91	59-74.7	7.29	1.16	270	3.78	1.76E+5	1.76E+5	137.7	6.75	-	-	
	0972	10/8/92	59-74.7	0.49	0.32	2.2	5.4	7.83E+3	6.48E+3	-	4.32	-	-	
	0973	8/7/90	9.1-15.3		18.1		210.6	7.29E+4			102.6		-	
	0973	7/16/90	9.1-15.3	-	26.7	-	297	2.57E+8	2.59E+8	14.3	132.3	10.8	21.6	
	0973	10/7/92	9.1-15.3	10.8	12.4	324	324	2.43E+8	2.40E+8	140.4	137.7	-	-	
	0974	8/7/90	10.1-22.1		1.35		26.7	1.54E+4			20.3		-	
	0974	7/15/91	10.1-22.1	-	1.6	119	67.5	7.56E+7	8.37E+7	64.8	35.1	5.4	-	
	0974	10/9/92	10.1-22.1	0.86	0.57	26.7	29.7	8.10E+7	8.10E+7	21.9	22.7	-	-	
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F	U F
Background Reference				9		8		1620				40		
	SP007	8/20/92		67.5	88.3	3546	5330	1.22E+7	9.07E+6		2876			
	SP007	5/11/93		39	7.1	1231	1582	6.75E+6	6.84E+6	564	404	-	-	
	SP008	5/11/93		408.8	475.5	1872468	2936732	7.73E+7	7.75E+7	1064739	965238	-	-	
	SP014	8/26/92		18.1	86	1932	142.5	4.13E+6	4.13E+6		958			
	SP014	5/18/93		-	5.8	1359	2361	2.27E+6	2.31E+6	610	656	-	-	
	SP019	3/11/94		229.5	82.5	671	495	2.01E+7	2.47E+7		198.5	75.7	37.2	

Notes: 1. Historical Samples:
(a) Data taken from ORNL Environmental Surveillance Program
2. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
3. Abbreviations: U/F = Unfiltered/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emitter
tr-dp = trench drive points (trench no.) tr-fp = floodplain drive points

Sampling of sediment and surface water in drainage D-2 identified the probable migration pathway for the ^{238}Pu and ^{233}U (Fig. B2.4.35). The nearest seep to 4114 is SP014, which is the headwaters of D-2 (except during storms and unusually wet weather) and also receives groundwater flow from west of the drainage (i.e., SWSA 5 South area C); thus discharge from this seep probably includes groundwater flowing beneath the high-activity trenches and auger hole "hot garden" to the west. The SP014 sample did not have any transuranics and only low concentrations of other alpha-emitting isotopes. Plutonium and uranium were detected in both sediment and surface water samples from station SW002 in drainage D-2, indicating that the contaminated groundwater detected in 4114 is discharging into D-2; however, the precise location of this discharge is not known.

The discharge apparently occurs south of seep SP014, as evidenced by the absence of contamination in both the seep and upgradient sediment location SD008. Sediment in D-2 is apparently a sink for some of the plutonium, as evidenced by sediment concentrations as high as 31 pCi/g. Sampling from SW002 indicates that an appreciable fraction of the ^{238}Pu and ^{233}U contamination is flowing down through D-2 and out into Melton Branch. Dry season sampling (10/93) and storm sampling (10/93 and 3/94) in SW002 yielded samples with filtered ^{238}Pu concentrations in the range of 10 to 17 pCi/L, the highest of any surface water samples collected in SWSA 5 South. The same samples also had elevated levels of ^{233}U. The overall patterns observed—contaminated groundwater discharging into D-2 and eventually flowing into Melton Branch—are consistent with the framework of the hydrologic model for the study area.

Well 0452, immediately downgradient of the undefined trench area (and east of 4114), had elevated gross alpha and gross beta, providing further evidence that contamination is being released from the undefined trench area and (in this case) migrating southward toward the lower trenches in area B and Melton Branch. The undefined trench area contains a fairly diverse suite of contaminants in addition to transuranics (^{238}Pu and ^{233}U). Well 0472 in the northwest corner of the undefined trench area (reportedly installed in a trench) yielded a sample with elevated concentrations of ^{45}Ca, ^{234}Th, ^{228}Ra, ^{90}Sr, and uranium isotopes; well 0451, in the center of the undefined trench area, had relatively high concentrations of ^{90}Sr (4776 pCi/L in a filtered sample) but did not contain any alpha activity. The area may also have a ^{3}H source because all six wells in the undefined trench area had ^{3}H concentrations greater than 1.0E+06 pCi/L.

The USRADS radiological walkover survey did not indicate areas of significant surface soil contamination in the undefined trench area. Results from near-surface soil sampling at two locations selected on the basis of USRADS data were at or slightly above background threshold values, indicating minimal contamination.

The undefined trench area is also a source of chlorinated VOCs, determined based on the presence of tetrachloroethene, trichloroethene, 1,2-dichloroethene (and other dichloroethene isomers), and vinyl chloride in samples from well 4114 (Fig. B2.4.36). VOCs detected in seep SP014 indicate that the area to the west of D-2 is also an organics source area. High concentrations of VOCs in the sediment in drainage D-2 provide evidence of direct discharge of contaminated groundwater into the stream channel; the half-life/residence time for VOCs in surface water is relatively short due to volatilization, especially in flowing surface water, which has greater mixing and agitation. Most of the VOCs are lost in the downgradient reach of D-2, as shown by the absence of these compounds in the downstream sediment and surface water samples from SW002.

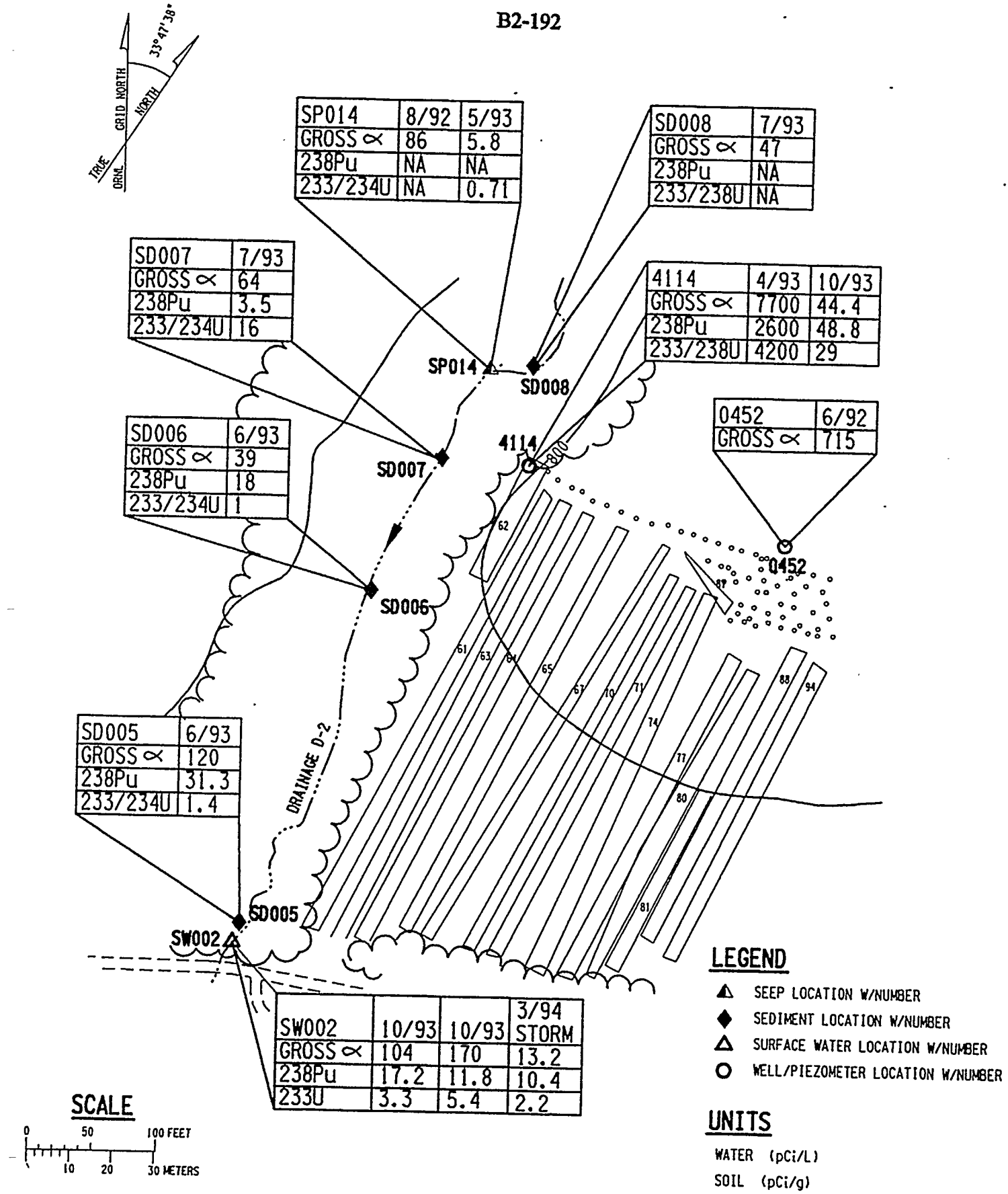

Fig. B2.4.35. Selected sampling location showing migration pathway of transuranic contaminants from undefined trench area.

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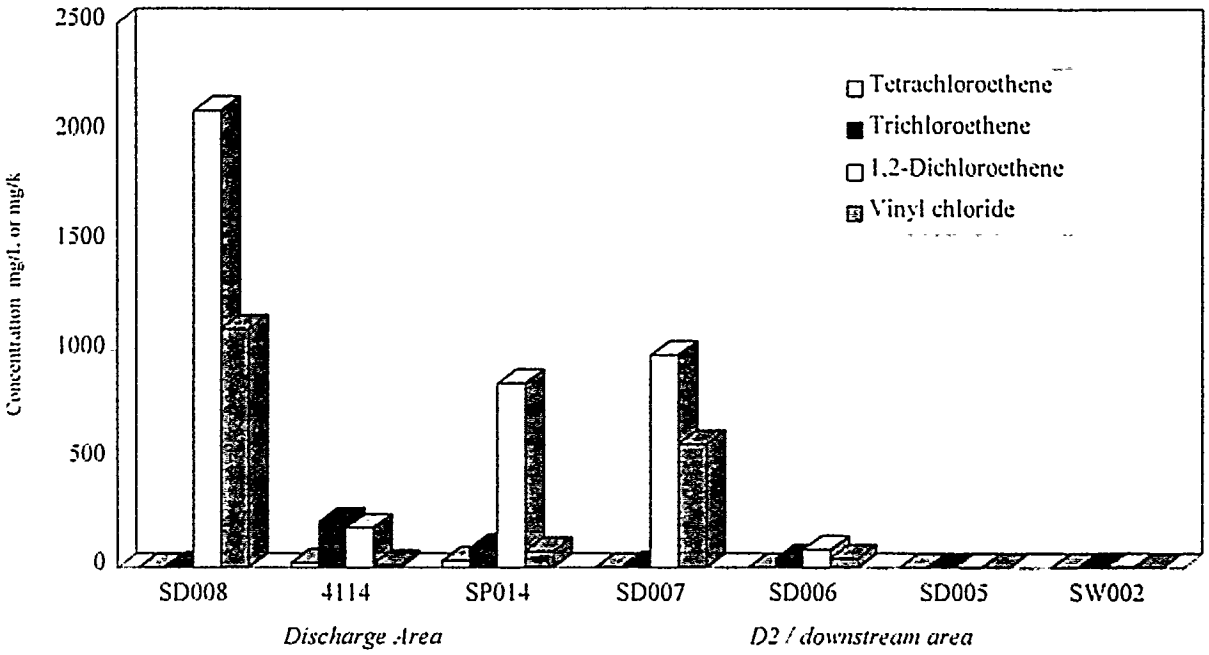

Fig. B2.4.36. VOCs detected in drainage D-2.

Trenches and auger holes below undefined trench area. Tritium was detected in all trench and floodplain drive point samples. Unfiltered tritium results ranged from 2500 to 850,000,000 pCi/L. Thirteen trenches had tritium activities greater than 100,000,000 pCi/L, and all are likely major contributors to the tritium-contaminated groundwater discharging into Melton Branch in area B. Tritium concentrations in excess of 100,000,000 pCi/L in floodplain drive points indicate that contaminants migrate in shallow groundwater from the trenches to Melton Branch across a relatively broad front. Upgradient sources (i.e., undefined trench area and auger holes) provide only minor contributions to the tritium flux because the concentrations are relatively lower (< 7,000,000 pCi/L).

Strontium-90 was detected in all drive point samples analyzed for ^{90}Sr in concentrations ranging from 2300 to 14,000,000 pCi/L unfiltered and 7.5 to 1,300,000 pCi/L filtered. Drive point 4211 in trench 117 had a filtered ^{90}Sr concentration of 1,300,000 pCi/L, which is comparable to the maximum value reported by Spalding (1984) of 3,000,000 pCi/L. The USRADS walkover survey also identified seep/sump SP008, located at the downgradient end of trench 117, as a high exposure rate area. An areal composite surface soil sample collected at this location identified ^{90}Sr as the major contaminant (10,300 pCi/g). Strontium-90 concentrations in surface water from this seep during wet seasonal conditions showed activity of approximately 1,000,000 pCi/L, which is similar to the maximum activity of 1,800,000 detected by Spalding (1984).

Quantifiable gross alpha activity was detected in all of the trenches: results ranged from 30 to 57,000,000 pCi/L unfiltered and 11 to 9,700,000 pCi/L filtered. Unfiltered gross alpha activities exceeding 1,000,000 pCi/L were detected in samples from trenches 61, 100, 101, and 117. Gross alpha activities were much lower in the floodplain drive points and in nearby seeps (in both cases typically <500 pCi/L). Figure B2.4.37 is a graph of filtered alpha concentrations at the contaminant source

(trenches) and filtered alpha concentrations in the downgradient floodplain. Floodplain alpha activity slightly exceeds background. Activity within the trenches is several orders of magnitude greater, which appears to indicate that alpha-emitting isotopes in the trench water are not migrating in appreciable quantities.

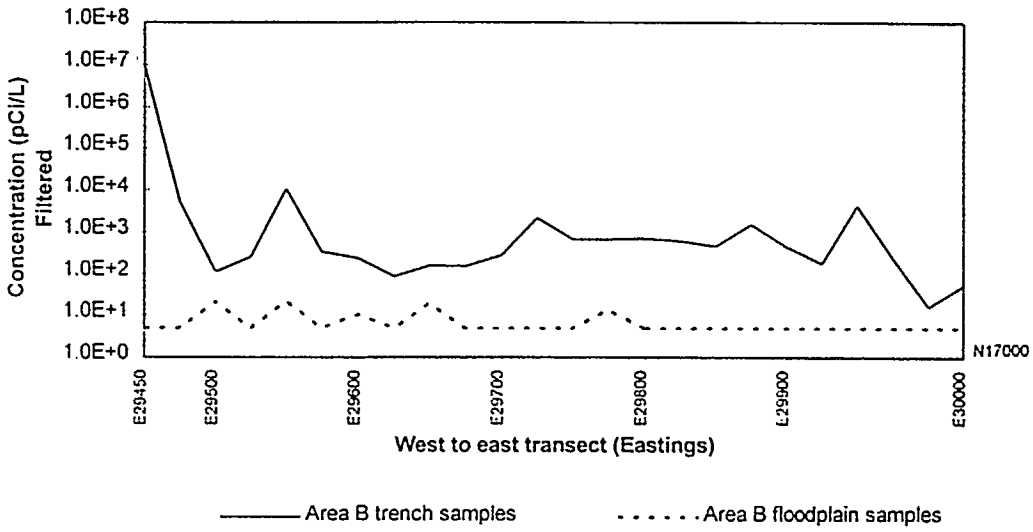

Fig. B2.4.37. Gross alpha concentrations in shallow groundwater from trench and floodplain drive point wells.

Given the evidence of ^{238}Pu and ^{233}U migration from the undefined trench area, the immobility of alpha constituents in the trench waters is difficult to explain. It is possible that well 4114 intercepted a fracture transmitting highly contaminated groundwater from the undefined trench area to discharge points in D-2. Similar features may not exist in the southern portion of the study area, but it is rather more likely that none of the drive points intercepted any of these discrete pathways. Americium, plutonium, and uranium were detected in a number of the samples from SW006, downstream of area B in Melton Branch. Some of this contamination may be due to discharge from area B through pathways that have not been identified by the drive points.

During the unusually wet conditions in spring 1994, surface seep SP019 developed approximately 20 ft downgradient of trench 61 (drive point 4179). A filtered sample indicated elevated alpha and beta activities (82 and 495 pCi/L, respectively). The source of contamination is probably either trench 61 or 63, since both have elevated alpha and beta activities.

Because the CSL gross alpha results for drive point 4179 were unusually high (57,000,000 pCi/L), an additional sample was collected and analyzed for alpha isotopes by the ASL. The extremely high activity required the sample to be diluted to a 10,000:1 ratio, but significant cross-contamination occurred among the isotopic analyses even after dilution. The analyses did identify high ^{241}Am (>1,000,000 pCi/L). Further evidence of the high ^{241}Am content was observed when ^{241}Am spectra were found in the gamma spectroscopy analyses. Significant concentrations of ^{238}Pu (776,800 pCi/L), $^{239/240}$Pu (13,620 pCi/L), and ^{226}Ra (7,040 pCi/L) were also identified in the sample, but the results were suspect due to the cross-contamination.

Strontium-90 as detected in all of the drive point samples, and relatively high levels were detected in samples from the trench drive points. Results for ^{90}Sr include an unfiltered range of 1.4 to 1,400,000 pCi/L and a filtered range of not detected to 1,300,000 pCi/L. Maximum filtered ^{90}Sr was detected in trench 117, and trenches 94, 97, 106, 108, 112, 114, and 212 had filtered results greater than 100,000 pCi/L. Strontium-90 levels in the floodplain drive point samples were much lower than those observed in the trench samples; however, no drive points were installed in the eastern portion of area B, directly downgradient of the trenches with the greatest ^{90}Sr activity (e.g., 117, 114, 112). Based on the sampling of Spalding (1984), which showed a maximum ^{90}Sr concentration of 60,000 pCi/L, a bimodal contamination front (plume) is apparently moving south-southwest directly below this group of trenches in the eastern part of area B. WAG 2 data from Melton Branch do not show a significant input of ^{90}Sr opposite these trenches (Fig B2.4.4); thus, the flux of strontium being released from the trenches is apparently not great.

Significant concentrations of ^{137}Cs were detected in trench drive points with results ranging from 37 to 10,500 pCi/L (filtered). Unfiltered concentrations (55 to 4,380,000 pCi/L) were often several orders of magnitude greater than filtered, indicating the ^{137}Cs is attached to the sediment particles (e.g., through adsorption). Downgradient floodplain drive points showed little variation between filtered and unfiltered concentrations and were typically within an order of magnitude of concentrations detected in filtered trench groundwater.

Conceptual model summary

A summary of the site conceptual model for area B is summarized in Table B2.4.26 and illustrated in Fig. B2.4.38. The major sources in area B are the upland trenches in the undefined trench area and inundated trenches in the southern part of the study area. The group of approximately 160 auger holes along the southern boundary of the undefined trench area is also a potential source, but no specific contributions have been delineated. Most of these holes reportedly contain biological wastes.

Principal release mechanisms for area B include inundation of trenches in the south and infiltration/percolation, possibly combined with episodic bathtubbing, in the upland trenches. In the southern area, bathtubbing also occurs, and overflowing of trench liquids onto the ground surface may also be a significant release mechanism.

Contamination is being transported primarily through shallow groundwater that discharges either into D-2 or Melton Branch. Most of the groundwater discharging into D-2 is derived from the undefined trench area, and after discharging, it mixes with water discharged from the high-activity trench and auger hole "hot garden" to the west (area C). Some of the discharge occurs via seeps, which then flow overland to D-2 or Melton Branch. Groundwater discharging directly into D-2 or Melton Branch flows downstream into White Oak Creek.

From a contaminant perspective, ^{3}H was the most widespread groundwater contaminant with levels greater than 100,000,000 pCi/L detected in samples from 13 trenches. The migration of ^{3}H from these trenches occurs across a broad front and, based on the flux calculations from the HSPF modeling, may be responsible for more than 50% of the tritium flux in the White Oak Creek watershed. This estimate is considerably higher than the 15 to 30% that historically has been assigned to area B (e.g., as reported in Newsom et al. 1993 and the WAG 2 Phase I RI).

Table B2.4.26. Conceptual model summary for area B

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
Active: 177 Auger holes	• Infiltration of precip. w/percolation through wastes • Stormflow/lateral movement of water through wastes	• Shallow groundwater discharging to drainage D-2 and Melton Branch • Stormflow discharge to drainage D-2	• Seep discharge areas • Downstream surface water and sediment
Active: 47 Trenches	• Infiltration/percolation • Stormflow recharging trenches • Partial, episodic inundation by water table • Overflow of trenches	• Same as above	• Contaminated soil over trenches • Seep discharge areas • Downstream surface water and sediment
Active: 27 Trenches (Undefined Trench Area)	• Infiltration of precip. w/percolation through wastes • Stormflow/lateral movement of water through wastes	• Same as above	• Seep discharge areas • Downstream surface water and sediment

High concentrations of ^{90}Sr and gross beta (>1,000,000 pCi/L) were detected in several trenches. Trench 117 and downgradient seep SP008 had the greatest ^{90}Sr concentrations, which corresponds to the ^{90}Sr peaks detected by Spalding and Munro (1984). Spalding (1984) also detected a bimodal plume of ^{90}Sr from this area, indicating discrete pathways away from the source trenches. Based on WAG 2 sampling and HSPF modeling, Melton Branch receives only a small contribution (6%) of ^{90}Sr from area B.

The undefined trench area is a source of TRU contamination (^{238}Pu and ^{233}U), which is migrating from the study area to Melton Branch via drainage D-2. High concentrations of gross alpha (exceeding 1,000,000 pCi/L in unfiltered samples) were detected in four trenches and, although not detected in any of the drive points, are probably migrating into Melton Branch as well. The overall flux of alpha from area B is 8.5 mCi/year (29% of the total flux leaving WAG 5).

High concentrations of VOCs were also detected in drainage D-2 and in a groundwater well associated with the undefined trench area. These VOCs are not making it as far as Melton Branch but are important from an exposure point perspective in the study area, particularly given the presence of high concentrations of vinyl chloride.

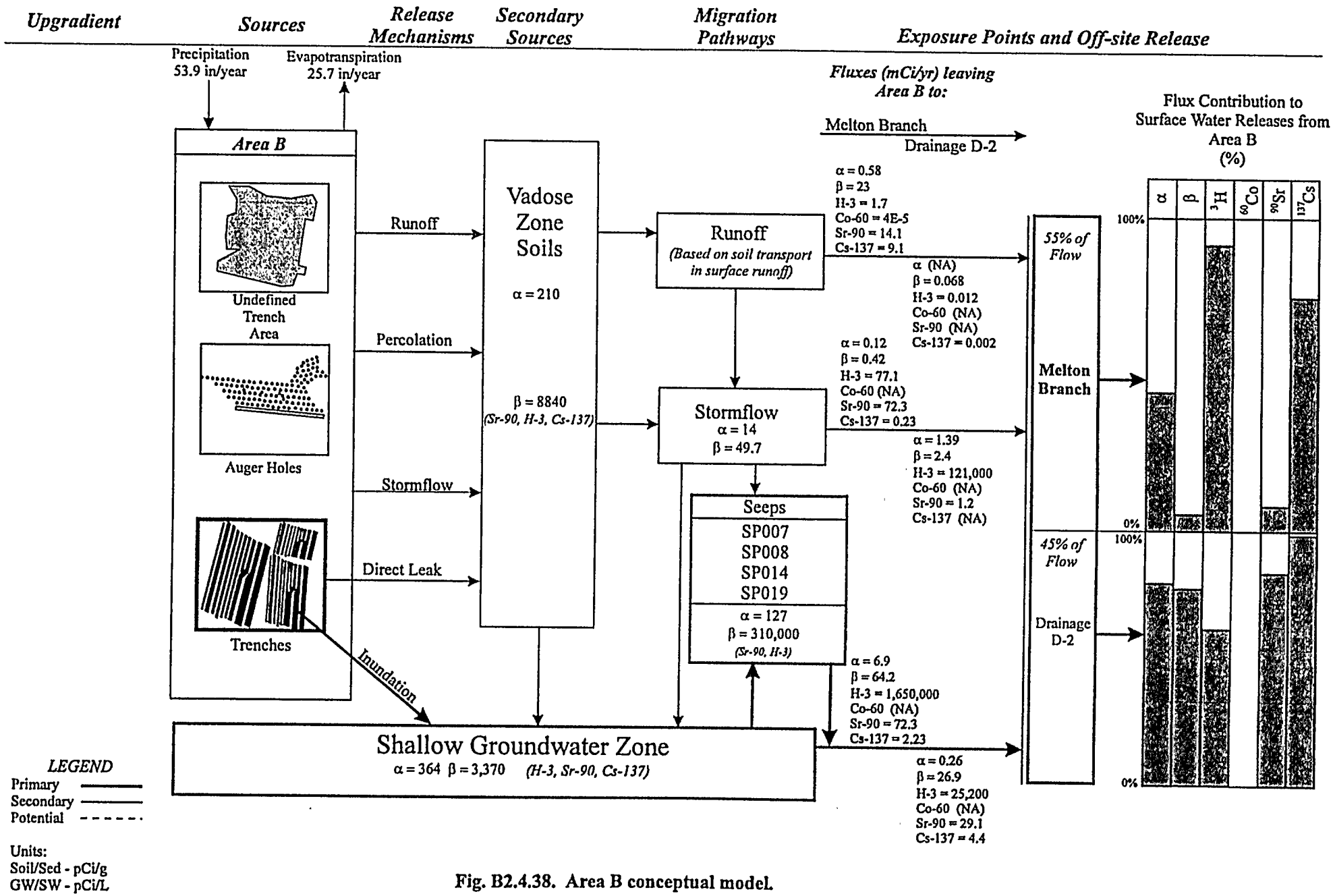

Fig. B2.4.38. Area B conceptual model.

B2.4.6 Area C

The SWSA 5 area C study area encompasses 14.3 acres, of which 4.7 acres drain into D-2, and the remainder into Melton Branch. The study area boundary was based primarily on surface water drainage features: the White Oak Creek-Melton Branch drainage divide to the north, drainage D-2 to the east, and Melton Branch to the south. Figure B2.4.39 shows conditions as of November 1994.

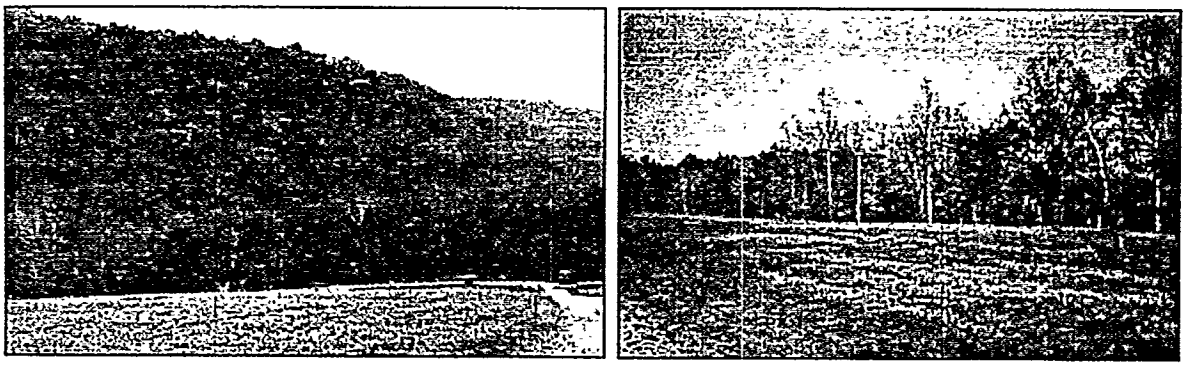

Fig. B2.4.39. Photographs of area C looking south toward Melton Branch (left) and northeast toward drainage D-2.

Description and history

Area C has been characterized as a significant source of ^{90}Sr discharge to Melton Branch, contributing approximately 25% of the total ^{90}Sr flux in the White Oak Creek watershed. The majority of the contamination was attributed to discharge of ^{90}Sr-contaminated water from seep SP006 (identified in WAG 2 as seep SW5-4). DOE has initiated a non-time-critical removal action for seep SP006 involving a collect-and-treat system for removal of ^{90}Sr. Construction of the system was completed in October 1994 and operation began in November 1994. No data were available as of December 1, 1994, to determine the impact of the system on ^{90}Sr concentrations in Melton Branch or White Oak Creek.

Primary sources in area C include 57 trenches and 344 auger holes Based on historical trench disposal records collected by ER-DMG, this area accepted its first wastes in February 1962 (trench 72) and continued accepting wastes through April 1972 (trench 219). Disposal records were available primarily for trenches numbered greater than 60. Materials stored in these trenches include solid low-level wastes and debris (e.g., glassware, scrap material), mixed fission products, and organic solvents in metal/plastic containers and drums mixed with radioactive wastes; Sect. B2.2 presents a more complete description of wastes buried in SWSA 5 South trenches.

The northern (upland) trenches west of drainage D-2 were in an area apparently set aside for disposal of high-activity wastes. Historical records show that seven of the trenches in this area (102, 110, 128, 168, 188, 206, 214) have TRU wastes (^{238}Pu, ^{244}Cm, ^{241}Am) buried in concrete casks. Trench 128 reportedly contains two layers of casks, the lower of which was immobilized with concrete to provide flooring for the second level, which was also covered with concrete. The other area trenches containing TRU wastes also have other, mostly beta-gamma, wastes mixed in with the TRU: it is unlikely that these trenches were also sealed with concrete.

The high-activity trench area also contains a large group of unlined auger holes in what was designated the "hot garden" in burial ground logbooks. These holes were evidently used for disposal of wastes with high beta-gamma activity levels. Partial disposal records for most of the holes identified waste types as assorted cell wastes (samples, by-products), cell trash, cell debris (scrap metal), organic solvents mixed with radioactive contaminants, uranium/thorium wastes, depleted uranium, and miscellaneous salvage materials. Waste containers included metal/wood boxes, plastic containers, and drums. It is also possible that organic wastes contained a liquid fraction but this has not been confirmed.

North of the hot garden are five concrete-lined silos used for disposal of control rods from the Yankee Atomic Energy Commission in 1963. The control rods had extremely high gamma activity levels, and ER-DMG reports that as much as 11,000 Ci of radioactive cobalt (probably ^{60}Co) may be contained in the rods. Also in the area are two groups of concrete vaults, wells 96–103, reportedly built specifically to contain wastes from Building 3019. The vaults were filled in 1964 and 1965 with wastes that included liquid waste salts from the Vitrification Pilot Plant contaminated with mixed fission products; other wastes reportedly include isotope carriers holding unspecified materials. The vaults are similar to those used in SWSA 5 North for storage of high beta-gamma TRU waste but probably do not contain the stainless steel liners installed in the SWSA 5 North vaults.

Information for the auger holes at the western edge of area C indicates that most were apparently used for disposal of high-activity beta-gamma wastes, and there is some evidence that TRU wastes may also have been disposed of there. Some information concerning the types of contaminants placed in this area identified ^{3}H, U/Th, beryllium, and plutonium. Waste types included filters, cell waste, metal scrap and other materials in drums and boxes. Table B2.4.27 shows a breakdown by waste type.

Table B2.4.27. Area C waste disposal records

	Number	High Activity β-γ	TRU	Low Activity β-γ	Biological	No Records
Auger holes	344					344
Inundated trenches	13	4	1	4		4
Upland trenches	44	10	7	3	1	23

Previous and concurrent investigations

Duguid (1975) was the first to identify the release of ^{90}Sr from area C via seep SP006, approximately 60 ft south of the gravel road that runs along the base of SWSA 5. Duguid (1975) sampled the seep in March 1974 and found elevated concentrations of ^{90}Sr (160,000 pCi/L), ^{3}H, and gross alpha. The alpha activities were attributed to ^{244}Cm and ^{238}Pu. Duguid (1975) attributed the contaminant release to the "bathtub effect" in which downgradient ends of trenches filled with water and overflowed onto the ground surface (in this case giving rise to the seep). Based on the ^{90}Sr activities measured in SP006, corrective measures were applied to trenches 83 and 105. In May 1975, two dams, one of bentonite-shale and the other of concrete, were installed across these

trenches (shown in Fig. B2.4.40). A 10-mil PVC liner was placed over trenches 69, 72, 83, and 105 and then covered with 2 ft of overburden. The dam successfully reduced the concentrations of ^{90}Sr in seep S-5, but it was later determined that the contaminant migration pathway had merely been rerouted, not remediated.

Between October 1978 and February 1979, Cerling and Spalding (1981) sampled streambed gravels to obtain an areal distribution of ^{60}Co, ^{137}Cs, and ^{90}Sr in the White Oak Creek watershed. Their studies indicated that a diffuse source of ^{90}Sr was present, most likely due to groundwater seepage. The activity of streambed gravel directly below SP006 was 14 pCi/g. Between January and March 1980, Spalding and Munro (1984) took groundwater samples from shallow boreholes spaced 3 m apart along Melton Branch opposite the southern perimeter of SWSA 5. Results of groundwater samples taken below SP006 indicated ^{90}Sr concentrations of 19,000 pCi/L. Spalding and Munro (1984) also took sporadic seep grab samples and groundwater samples from boreholes along the flowpath to and from SP006 between March and December 1980. These results indicated the seep had an average ^{90}Sr concentration of 208,000 pCi/L; similar concentrations were detected in the boreholes. On Dec. 8, 1980, they treated SP006 with soda ash to reduce the concentration of ^{90}Sr leaving WAG 5. After the placement of soda ash at and above the seep, the ^{90}Sr concentrations decreased, but over the following year the concentrations returned to pretreatment levels.

Another area of historical interest in area C is the floodplain directly below OHF. During the streambed sampling of Cerling and Spalding (1981), the highest activity detected in Melton Branch (30 pCi/g) was along the reach directly downslope of the OHF area. During the Spalding and Munro (1984) borehole sampling along the southern perimeter of WAG 5, the greatest concentrations of ^{90}Sr (286,000 pCi/L) were detected directly downslope of OHF (near the highest ^{90}Sr sampling locations from Cerling and Spalding). A review of historical information indicates the major source of ^{90}Sr in this area may be from the drilling of well S-220 (ORNL No. 1965) when a grout sheet was penetrated at a depth of 864 ft and an estimated 2 Ci of ^{90}Sr leaked out of the fracture to the surface (letter from Stow to Myrick 1969). For further information see discussion of SWMU 5.1a in Sect. B2.3.7 (OHF area).

Between March and October 1992, Phase I field activities were performed as part of the WAG 2 RI (ORNL 1993). Based on the WAG 2 transect sampling along Melton Branch (summarized in Sect. B2.4.1), seep SP006 (WAG 2 seep SW5-4) was calculated to contribute between 16 and 25% of the total ^{90}Sr flux to White Oak Creek watershed. DOE initiated a non-time-critical removal action to reduce the ^{90}Sr contributions from seep SP006 in 1993. The response action involves construction of a gravel-filled trench perpendicular to flow and slightly uphill from the seep. Groundwater intercepted by the drain flows under gravity through a zeolite-based treatment system and is then discharged to Melton Branch.

RI sampling summary

Figures B2.4.40 (a and b) and B2.4.41 show the study are sampling locations and cross-section locations used in the hydrologic model. Soil sampling involved 10 surface soil (0- to 2-ft) samples, 2 vertical soil borings, and 2 soil samples taken near bedrock from RI-installed piezometers (4303 and 4304). The 10 surface soil samples included 2 USRADS (1 high and 1 medium/low exposure)

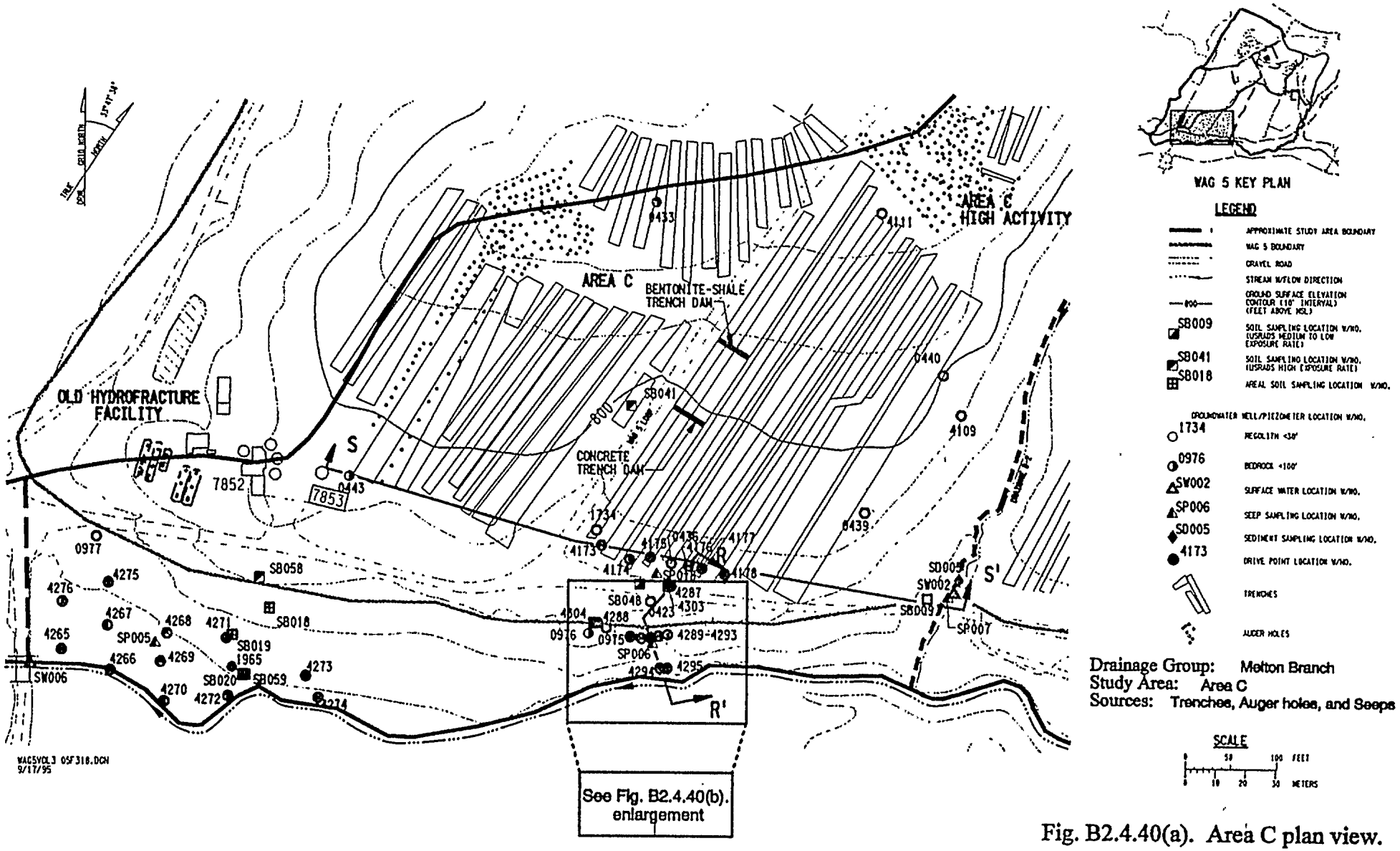

Fig. B2.4.40(a). Area C plan view.

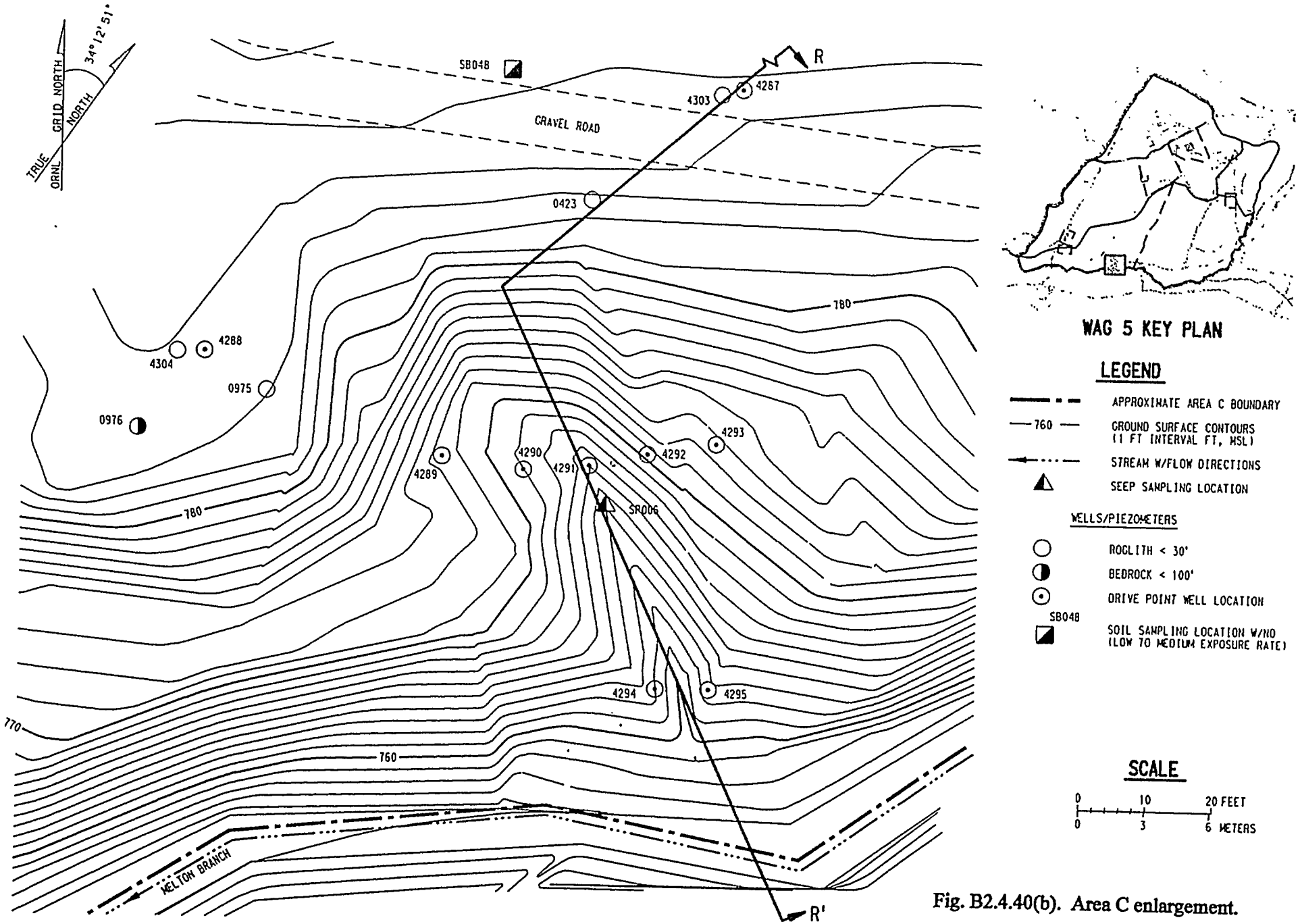

Fig. B2.4.40(b). Area C enlargement.

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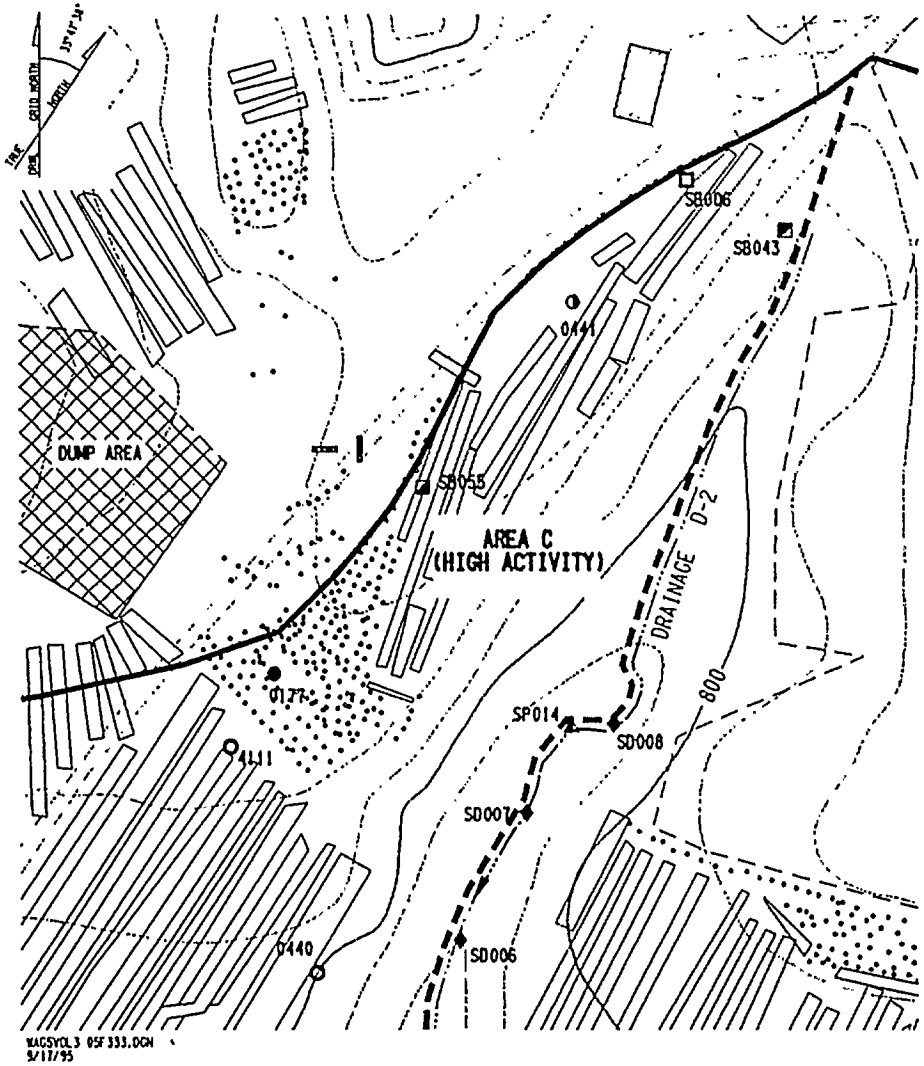


WAG 5 KEY PLAN

LEGEND

- APPROXIMATE STUDY AREA BOUNDARY
- BUILDING
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- 850 — GROUND SURFACE ELEVATION CONTOUR (10' INTERVAL) (FEET ABOVE MSL)
- SB055 — SOIL SAMPLING LOCATION W/NO. (USRADS MEDIUM TO LOW EXPOSURE RATE)
- SB043 — SOIL SAMPLING LOCATION W/NO. (USRADS HIGH EXPOSURE RATE)
- SB006 — SOIL SAMPLING LOCATION W/NO.
- GROUNDWATER WELL/PIEZOMETER LOCATION W/NO.
- 4111 — REGOLITH <30'
- 0441 — BEDROCK <100'
- 0177 — BEDROCK >100'
- SP014 — SEEP SAMPLING LOCATION W/NO.
- SD006 — SEDIMENT SAMPLING LOCATION W/NO.
- TRENCHES
- AUGER HOLES

Drainage Group: Melton Branch
Study Area: Area C High Activity
Sources: Trenches, Vaults, and Auger holes

SCALE
0 50 100 FEET
0 10 20 30 METERS

Fig. B2.4.41. Area C high activity plan view.

and 3 areal composites taken below the OHF facility. Two vertical composite samples were taken from SB009 at 0 to 6 ft and 6 to 8.4 ft and a groundwater grab sample was also collected prior to backfilling the borehole. Additional sampling was performed during an episode of trench overflow (bathtubbing) in April 1994; surface water samples from the vicinity of drive points 4173 and 4175 were collected, as was a soil sample from an area of high activity (based on field instrumentation). SP018, southeast, was also sampled [SP018 roughly corresponds to the S-4 sample taken by Duguid (1975)].

Hydrologic model

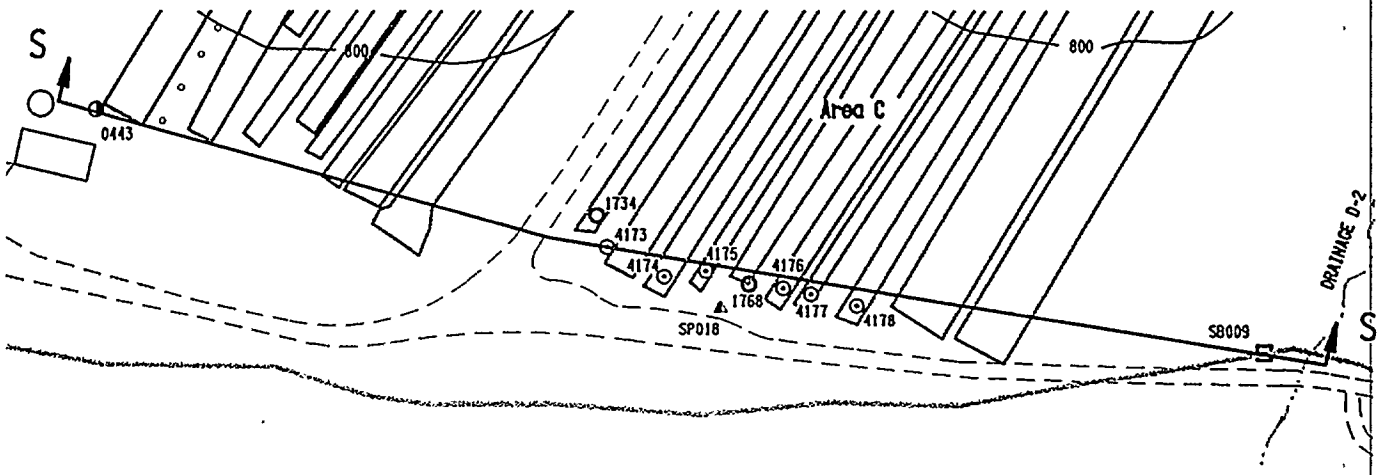
Figures B2.4.42 and B2.4.43 depict the hydrologic model for the SWSA 5 South area C. The study area drains to both Melton Branch (88%) and drainage D-2 (12%). Surface water, interflow (stormflow), and groundwater flow either eastward to drainage D-2 or south to Melton Branch. Table B2.4.28 summarizes the annual water balance for the three pathways determined based on the HSPF modeling described in Appendix B1. (Note: the actual percentage of groundwater discharge to Melton Branch is greater than that to drainage D-2 due to the effects of trench hydrology on the groundwater movement.) The total flux of water through the subsurface is the greatest (over 93%), due to the large amount of disturbed earth and resulting increases in vertical permeability, infiltration and percolation rates.

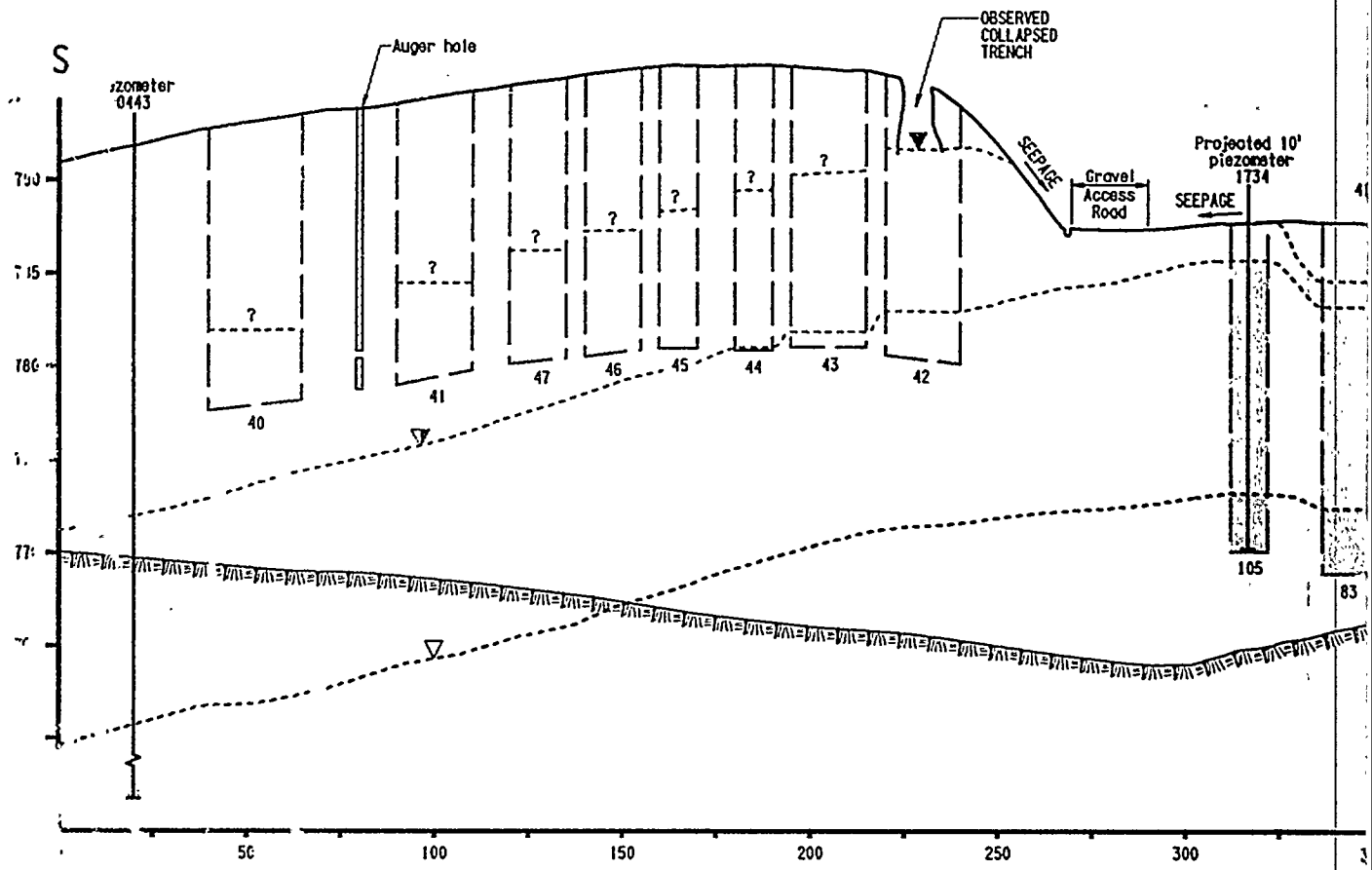
Table B2.4.28. Annual water balance summary for area C

	PERCENT OF FLOW	DISCHARGE TO MELTON BRANCH (m^3/year)	DISCHARGE TO DRAINAGE D-2 (m^3/year)	TOTAL ANNUAL DISCHARGE (m^3/year)
Surface runoff	6.5	1,680	1,133	2,813
Interflow	28.5	7,337	4,948	12,285
Groundwater flow	65	18,845	8,937	27,782
Total	100	27,862	15,018	42,880

The most notable feature of the hydrologic model is the perennial inundation of wastes in the lower ends of the southeastern group of area C trenches. This inundation is mostly due to a rising water table, but in wetter years the lateral (downslope) movement of trench water from upland areas brings an even greater amount of water into the toe of the trenches. During these conditions, which were observed in April 1994, several of the trenches in area C overflow at the surface (i.e., bathtubbing occurs). Duguid (1975) also observed bathtubbing in trenches 69, 72, 83, and 105 (as discussed above).

Sampling of the liquids seeping out of the bathtubbing trenches showed that this mechanism may be responsible for a significant release of contamination from the buried wastes; however, the frequency of such events could not be established, and the absence of any residual surface soil contamination (based on USRADS survey, Fig. B2.4.44) indicates that it probably does not happen regularly.





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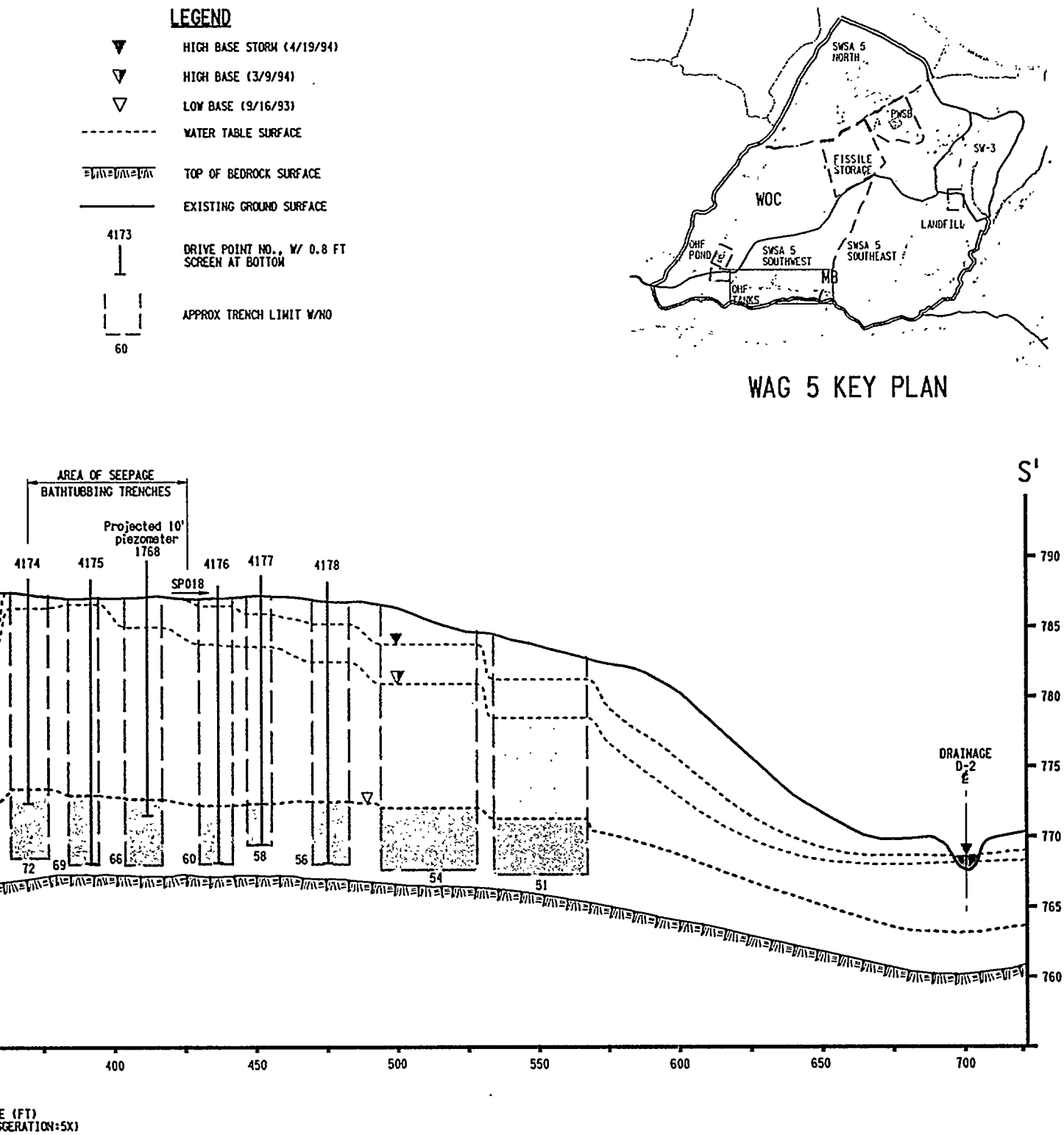
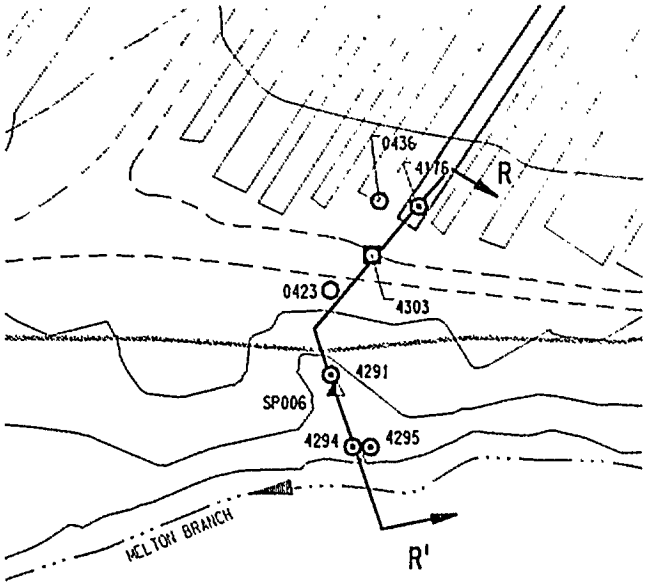
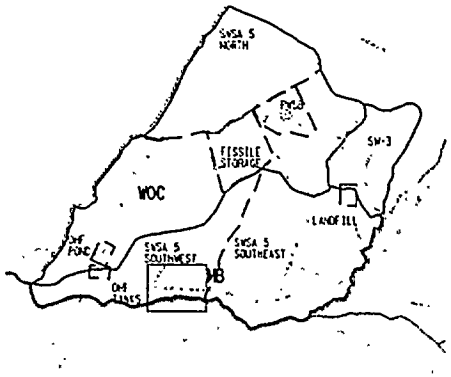


Fig. B2.4.42. Area C trench drive points. (Section S-S').

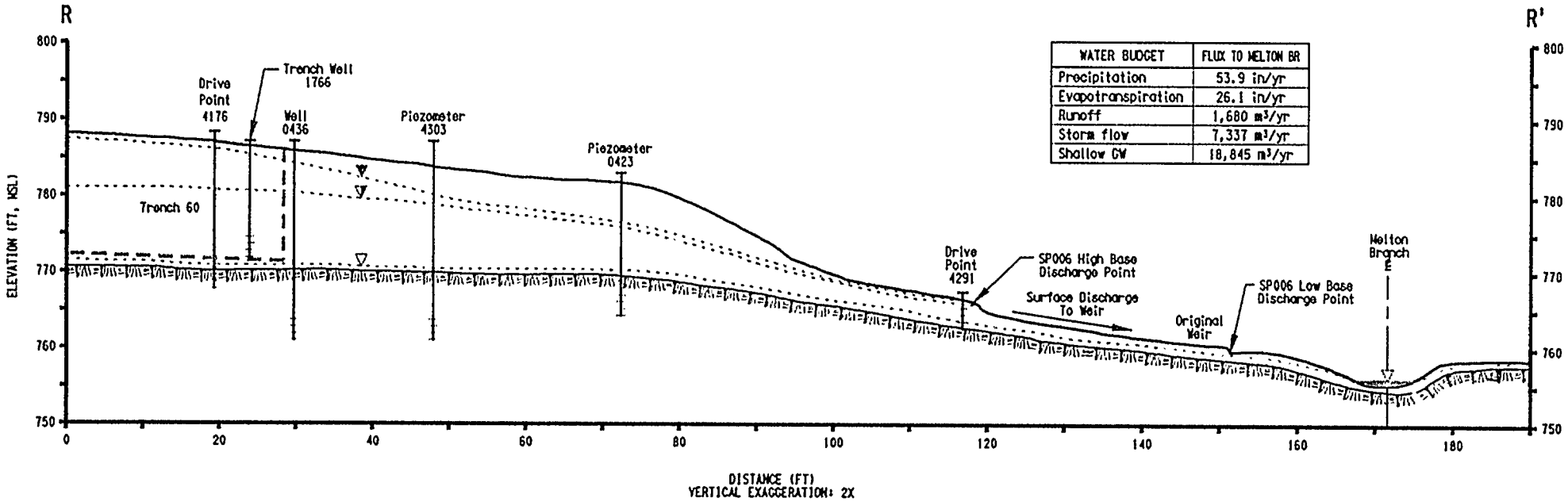


LEGEND

- HIGH BASE STORM WATER TABLE (4/94)
- HIGH BASE WATER TABLE (3/93)
- LOW BASE WATER TABLE (8/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 0423 — WELL, WELL NO., SCREEN SECTION
- 60 — APPROXIMATE TRENCH LIMIT W/NO.



WAG 5 KEY PLAN



WATER BUDGET	FLUX TO WELTON BR
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	1,680 m³/yr
Storm flow	7,337 m³/yr
Shallow GW	18,845 m³/yr

Fig. B2.4.43. Hydrologic model for area C (Section R-R').

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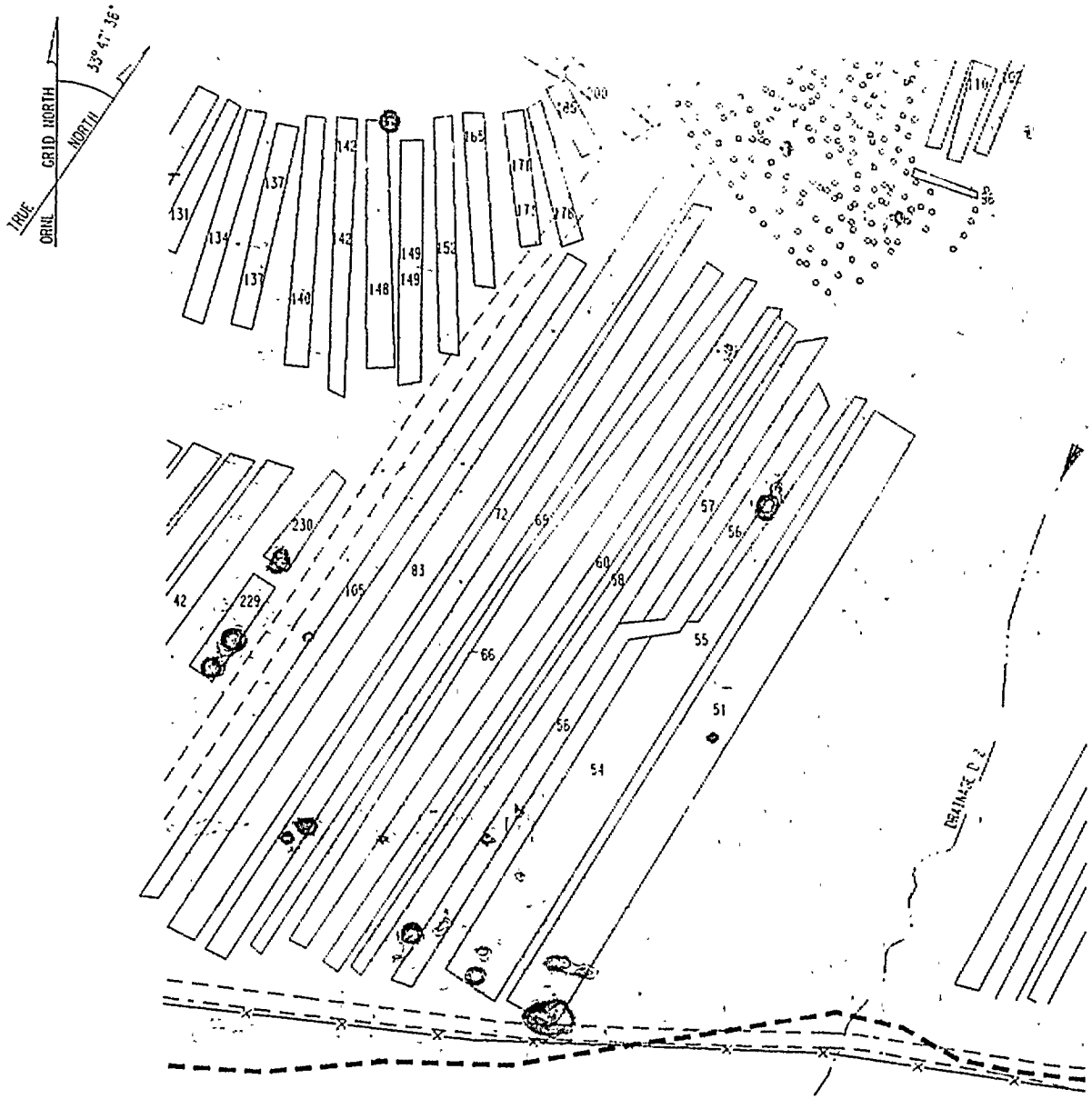

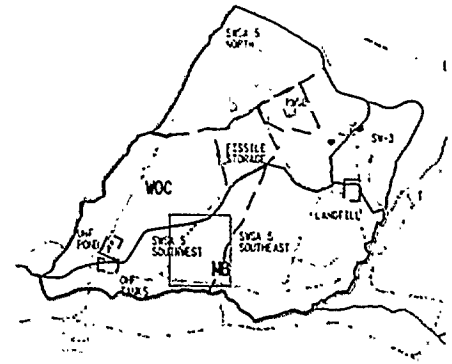

WAG 5 KEY PLAN

LEGEND

- WAG 5 BOUNDARY
- GRAVEL ROAD
- STREAM W/FLOW DIRECTION
- TRENCHES WITH NUMBER
- AUGER HOLES
- 0 - 19,999 cpm
- 20,000 - 39,999 cpm
- 40,000 - 59,999 cpm
- 60,000 - 79,999 cpm
- 80,000 - 99,999 cpm
- > 100,000 cpm

SCALE

0 50 100 FEET

0 10 20 30 METERS

Fig. B2.4.44. USRADS results for area C cpm contours.

Nature and extent of contamination

Table B2.4.29 summarizes contaminants of concern detected in SWSA 5 South area C. Table B2.4.30 summarizes data for the areas surrounding the trenches and auger holes, and Table B2.4.31 presents results for the floodplain drive points and other wells in the area immediately downgradient of the OHF facility.

Table B2.4.29. Contaminants of concern in SWSA 5 South area C

CONTAMINANT	SOIL	GW	SEEPS
^{14}C		X	
^{45}Ca			X
^{60}Co		X	
^{137}Cs	X	X	X
^{212}Pb		X	
^{228}Ra		X	
^{90}Sr	X	X	X
^{99}Tc		X	X
^{228}Th		X	
^{230}Th		X	
^{231}Th		X	
^{232}Th		X	
Tritium	X	X	X
$^{233,234}U$	X	X	
^{238}U	X	X	
Manganese			X
1,2-Dichloroethene (Total)		X	X
Vinyl Chloride		X	

Trenches and seep SP006. Based on historical sampling of seep SP006 and WAG 2 transects along Melton Branch, the primary contaminants in area C are ^{90}Sr and tritium. Drive point and well samples from trenches 60, 69, 72, 83, and 105 all had levels of ^{90}Sr above 500,000 pCi/L. The maximum ^{90}Sr activity detected in area C was 19,600,000 pCi/L in a sample from drive point 4175 installed in trench 69. All of the trenches with high ^{90}Sr concentrations were designated "high activity" trenches and all reportedly contain high activity wastes; trench 83 also has TRU wastes.

Upgradient wells near the upland trenches and auger hole "hot garden" (e.g., 0177, 0433, 0440, 0441) had much lower concentrations of ^{90}Sr (less than 700 pCi/L), but most had elevated concentrations of ^{3}H (>1.0E+05 pCi/L). The generally low levels of contamination in samples from the upland trench and auger hole area indicates either that this area is not an active source of contamination or that contamination is confined to discrete pathways that have not been intercepted by existing wells. The large quantity of wastes in the upland portions of area C include many with high beta-gamma activity and other contaminants, including TRU radionuclides; if a release were

Table B2.4.30. Analytical data summary for selected radionuclides in area C trenches and auger holes

Sample			(α)	(β)	(β)	(β)	(β)
ID	Date	Intv (ft)	Gross Alpha	Gross Beta	Tritium	Sr-90	Cs-137
SOIL (pCi/g)							
Background Reference			9.9	42	0.08	1.9	1.4
SB006	3/25/93	0-2	19	340	0.34	6	47
SB006	3/25/93	2-6.5	24	293.5	6.4	30	9.6
SB009	8/19/93	0-6	15.5	48.3	13.4	9.1	-
SB009	8/19/93	6-8.4	-	68.4	1365		
discrete SB041	3/17/93	0-2	380	10000	0.29	5200	120
composite SB041	3/17/93	0-2	-	251.2	18.48		3.2
SB043	3/18/93	0-2	13	430	0.41	200	42
SB048	3/8/93	0-2	7.05	57.18	6.28		
SB055	2/17/93	0-2	-	113	3.9		85.8
4173	4/14/94	surface	-	103884.7	1667		
4175	4/14/94	surface	9.7	74.8	388.1		
4303	2/5/94	17.2-18.0	24.6	650.4	240.8		
4304	1/26/94	13.5-15.0	202.4	22278.3	1518.3		
SEDIMENT (pCi/g)							
Background Reference			44	54	100	1.34	0.82
SD008	7/7/93	0-0.3	47	2400	1479	1100	6
SD007	7/6/93	0-0.3	64	2000	1409	890	7
SD006	6/28/93	0-0.3	170	2700	684.4	1400	7.1
SD005	6/28/93	0-0.3	120	1900	1668	830	9.7

GROUNDWATER (pCi/L)			U	F	U	F	U	F	U	F	U	F
Background Reference			5.2	3.2	16	7.4	2400	1080	10.4	3.6	12.4	5.4
0177	7/7/92	44-147.6	11.3	-	66.6		1.10E+06	1.12E+06		23.6		
0423	9/13/93	0-17.8	187.8	178.3	96001.6	59633.9	7.67E+06	7.77E+06	29957.5	39393		
0433	5/27/92	34-45.4	-	-	44.1	-	1.41E+04	1.39E+04			27.9	
0436	9/8/93	21-32.4	21.4	13.5	7027.3	4536.3	1.24E+06	1.19E+06	3243.3	6415.7	75.7	31.8
0439	5/28/92	24-34.1	-	-	32.1	48.9	1.22E+07	1.34E+07		4.4		
0440	4/30/93	26-36	24.3	4.8	307	74.7	4.94E+03	3.00E+06	-	-	-	-
0440	10/26/93	26-36	-	-	661	12.5	2.72E+07	2.97E+06	574	2.34	-	-

Table B2.4.30. Analytical data summary for selected radionuclides in area C trenches and auger holes (cont.)

Sample			(α)		(β)		(β)		(β)		(β)	
ID	Date	Intv (ft)	Gross Alpha		Gross Beta		Tritium		Sr-90		Cs-137	
GROUNDWATER (pCi/L)			U	F	U	F	U	F	U	F	U	F
Background Reference			5.2	3.2	16	7.4	2400	1080	10.4	3.6	12.4	5.4
0441	5/20/92	32-47.8	-	-	870.9	844	1.05E+05	1.16E+05		678		
0441	4/14/93	32-47.8	10	4.3	720	770	1.00E+05	1.20E+05	290	310	-	-
0441	10/19/93	32-47.8	52.5	19.9	1025.7	869	3.08E+04	6.48E+04	176	328	7.1	21.5
0975	4/22/93	16.5-28	-	-	-	324	7.00E+06	7.00E+06	540	514	-	-
0975	11/4/93	16.5-28	15.2	-	1060	1120	7.34E+06	8.00E+06	547	555	-	-
0976	4/22/93	63.2-83.9	-	2.7	-	5.4	6.20E+06	6.20E+06	3.24	2.37	-	-
0976	11/9/93	63.2-83.9	-	-	-	4.07	5.37E+06	5.47E+06		3.16	-	-
1734	6/11/92	1-15	27146.5	6307.2	18293748	18061383	1.05E+08	1.05E+08		1567790	756	513
4109	12/6/93	0.5-2.9	8.3		143.3		2.38E+04					
4111	12/2/93	0.5-1	89.9		259.5		4.46E+03					
tr-dp (83) 4173	9/7/93	17.3-18.1	1443.6	1425.5	9570807	2225035	5.39E+06	5.12E+06	5378920	852648		
tr-dp (72) 4174	9/7/93	13.5-14.3	7987.5	2331.1	3184927	1359644	8.15E+06	7.03E+06	1995413	984764		139
tr-dp (69) 4175	9/8/93	17.5-18.3	19189.5	210.3	29236821	6389254	9.49E+06	8.52E+06	2E+07	5312442	608	
tr-dp (60) 4176	9/9/93	17.2-18	1697	139.8	788435.4	226035.7	5.29E+06	5.33E+06	83938	538630		
tr-dp (58) 4177	9/9/93	16.3-17.1	403.8	66.7	5122.4	807.8	2.65E+07	2.65E+07	385.2	19818.1	2080	29.1
tr-dp (56) 4178	9/9/93	17.2-18	70777.3	481.3	574631.9	148036.1	8.99E+06	9.04E+06	284160	72938.7	65500	902
fp-dp 4287	3/10/94	7.6-8.4	278.2		1629.6		1.23E+05				241	
fp-dp 4289	2/24/94	3-3.8	185.5	-	833.3	242.4	7.02E+05	6.59E+05				
fp-dp 4290	2/4/94	3.6-4.4	501.3	14.5	474177.6	249089.2	6.24E+06	5.68E+06	143729	154336	81.2	
fp-dp 4291	2/4/94	2-2.8	718.1	29.6	1362453	518676.8	5.91E+06	5.67E+06	648106	147639	2820	
fp-dp 4294	2/4/94	1.7-2.5	736.7	27.5	1948100	351904.5	4.03E+06	3.89E+06	676147	213088		
fp-dp 4295	2/4/94	1.8-2.6	900	33.9	1676130	398956.4	3.92E+06	3.84E+06	95077.4	222309		
4303	2/10/94	7.8-22.7	370.6	-	13994.5	7574.4	6.11E+06	6.05E+06		6465		
4304	1/31/94	3.7-13.3	6776.2	3568.8	742548.5	514343.5	1.81E+07	1.85E+07	520094	433430		
SB009	8/23/93	0-8.4		22.8		113		4.31E+07				

Table B2.4.30. Analytical data summary for selected radionuclides in area C trenches and auger holes (cont.)

Sample				(α) Gross Alpha		(β) Gross Beta		(β) Tritium		(β) Sr-90		(β) Cs-137	
	ID	Date	Intv (ft)										
GROUNDWATER (pCi/L)				U	F	U	F	U	F	U	F	U	F
Background Reference				5.2	3.2	16	7.4	2400	1080	10.4	3.6	12.4	5.4
Historical Samples													
(a)	0975	8/9/90	16.5-28		3.78		621		837		**240.3**		2.16
(a)	0975	7/17/91	16.5-28	2.16	1.62	1026	1215	7.02E+06	7.02E+06	513	540	-	10.8
(a)	0975	10/9/92	16.5-28	1.03	3.42	1188	972	7.83E+06	7.83E+06	540	459	1.89	-
(a)	0976	8/9/90	63.2-83.9		2.16		12.42		7.02E+06		3.24		-
(a)	0976	7/17/91	63.2-83.9	0.54	-	3.51	4.32	5.13E+06	5.13E+06	3.51	11.61	-	27
(a)	0976	10/13/92	63.2-83.9	1.62	3.24	6.21	3.51	4.86E+06	5.13E+06	1.65	0.27	1.62	-
SURFACE WATER (pCi/L)				U	F	U	F	U	F	U	F	U	F
Background Reference				9.9		42		1620				40	
	SP006	8/20/92			-	1185553	1174738	9.16E+06	1.22E+07		689550		
	SP006	5/10/93		15.2	26.8	790210.6	1250896	5.66E+06	6.51E+06	359224	352172	-	-
	SP006	11/15/93		-	13.2	720475.2	768401.2	5.95E+06		438533	357530		89.6
	SP006	12/6/93		12.6		649545.3		2.80E+06		292753	66198.9	134	
	SP007	8/20/92		67.5	88.3	3546.3	5330.2	1.22E+07	9.07E+06		2876.1		
	SP007	5/11/93		39	7.1	1231	1581.8	6.75E+06	6.84E+06	563.7	404.1	-	-
	SP014	8/26/92		18	86	1932	142	4.13E+06	4.13E+06		957		
	SP014	5/18/93		-	5.8	1359	2361	2.27E+06	2.31E+06	610	656	-	-
	SP018	3/10/94		-	26.1	265.2	94.9	2.18E+05	2.17E+05		25.2	113	97.8
	4173	4/14/94		843.2		3846592		4.93E+06		4578238			
	4175	4/14/94		224.7		18583.4		2.07E+06		107.4		65.5	

Notes: 1) Historical Samples:
(a) Data taken from ORNL Environmental Surviellance Program and Active Sites Environmental Monitoring Program
2) Blanks indicate analyte not analyzed for; Bold indicates detected over background reference (2x mean background)
3) Abreviations: U/F = Unfiltered/Filtered - = not detected (α, β, γ) = Alpha, beta, gamma emitter
tr-dp = trench drive point (trench no.) fp-dp = floodplain drive point
4) Trench drive points 4173 and 4175 were artesian during Spring 1994. Surface water and soil were sampled from these locations at this time

Table B2.4.31. Analytical data summary for selected radionuclides in area C floodplain

Sample ID	Date	Intv (ft)	(α) Gross Alpha		(β) Gross Beta		(β) Tritium		(β) Sr-90		(β-γ) Cs-137	
SOIL (pCi/g)												
Background Reference			9 9		42		0.08		1.9		1.4	
SB018	2/10/93	0-2	-		58		24.4				2.3	
SB019	2/9/93	0-2	-		24 3		17.6					
SB020	2/9/93	0-2	-		238 2		6.7				1.9	
SB058	12/9/93	0-2	15		103		1.32		18.6		61.6	
SB059	2/9/93	0-2	-		410		8.95				2.3	
GROUNDWATER (pCi/L)			U	F	U	F	U	F	U	F	U	F
Background Reference			5.2	3.2	16	7 4	2400	1080	10.4	3.6	12.4	5.4
0443	5/27/92	37-47	82.8	22.5	853000	747000	2.27E+07	2.22E+07		3.63E+5		
0977	4/20/93	3-19 5	2 56	-	26.2	22.4	4.60E+06	4.60E+06	11.1	9.73	-	-
0977	11/6/93	3-19 5	46.4	-	23.9	20.1	5.38E+06	6.03E+05	7.7	8.33	-	-
4265	2/15/94	5 9-6 7	845	-	33900	7880	1.46E+07	1.35E+07		6940		
4266	2/15/94	4 7-5 5	557.4	-	3107	109	2.75E+07	2.34E+07			36.6	
4267	2/14/94	6 1-6 9	813.6	-	4030	-	1.98E+07	1.95E+07				
4268	2/17/94	5 4-6 2	672	-	4586	16.1	3.14E+07	3.00E+07			72.8	
4269	2/17/94	4 3-5 1	-	10.2	2180	65.4	8.10E+06	6.78E+06		32.7	33.7	
4270	2/15/94	3 0-3 8	369.2	7.4	31500	6960	8.10E+06	8.33E+06		4580	140	
4271	2/24/94	6 4-7 2	306.4	-	1630	32.7	5.30E+06	3.55E+06				
4272	2/24/94	3 2-4.0	-	-	4460	2720	1.24E+07	1.32E+07		24000	104	
4273	2/28/94	5 7-6.5	315	7.2	2530	186	4.15E+07	3.33E+07		155		
4274	2/28/94	4 0-4 8	261.7	18.5	1990	27.8	4.30E+07	4.40E+07				
4275	2/14/94	6 0-6 8	928	-	2180	138	9.51E+06	9.36E+06		65.5		
4276	2/15/94	5 5-6 3	1086.9	-	3070	206	1.46E+07	1.38E+07		21.9		
Historical Samples												
(a) 0977	8/10/90	3-19 5		1 35		32 4		7 56E+03		8 1		-
(a) 0977	7/22/91	3-19 5	153 9	-	40 5	3 24	7 02E+06	7 02E+06	5 94	2 16	5 4	40 5
(a) 0977	9/29/92	3-19 5	1 54	3 24	21 1	15 9	7 29E+06	7 02E+06	3 24	6 21	-	-
SURFACE WATER (pCi/L)			U	F	U	F	U	F	U	F	U	F
Background Reference					16	7.4	2400	1080	10 4	3.6	12.4	5.4
SP005	5/10/93		-	-	6450	4740	9.80E+06	5.25E+06	1930	1900	-	-

Notes: 1) Historical Samples.
(a) Data taken from ORNL Environmental Surveillance Program and Active Sites Environmental Monitoring Program
2) Blanks indicate analyte not analyzed for, Bold indicates detected over background reference (2x mean background)
3) Abreviations: U/F = Unfiltered/Filtered - = not detected (α,β,γ) = Alpha,beta,gamma emitter

occurring from these sources, it is unlikely (though not impossible) that none of the wells in the area would have encountered any contamination. The absence of contamination supports conclusions reached elsewhere that trench inundation is probably the most important release mechanism for the site. The formation of transient, perched saturation in bathtubbing trenches above the water table is also important, but the correlation between contamination and inundation indicates that such processes are secondary.

Seep SP006 has historically been the greatest WAG 5 contributor of ^{90}Sr to Melton Branch, with typical concentrations around 100,000 pCi/L (Fig. B2.4.45); the source of this contamination is the trenches immediately upgradient. Contamination appears to be following a discrete flow path as evidenced by relatively low levels of contamination in the wells and drive points in the vicinity. Well 4303, installed 70 ft to the west of SP006 and 20 ft upgradient, had ^{90}Sr concentrations of 430,000 pCi/L, possibly indicating another discrete pathway to the west of SP006 (samples from this well also had high gross alpha concentrations). Perimeter wells 0975 and 0976, each less than 10 ft from well 4303, had ^{90}Sr activities at much lower levels, typically 500 and 5 pCi/L, respectively, supporting the discrete pathway hypothesis. However, based on the increase of ^{90}Sr in Melton Branch shown by WAG 2 data and the flux calculations from SP006, most ^{90}Sr entering Melton Branch is attributed to SP006.

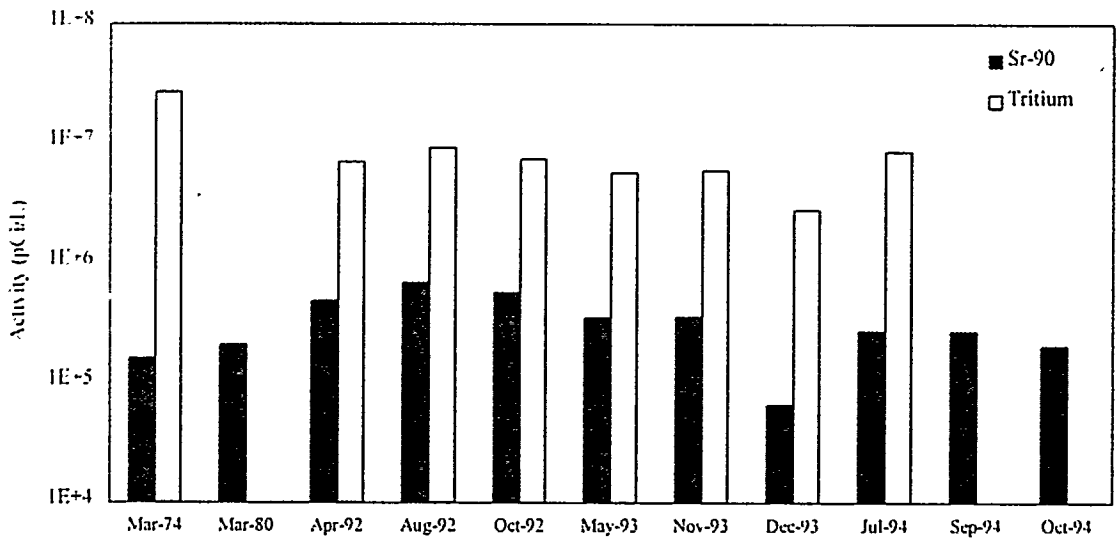

Fig. B2.4.45. Strontium-90 and tritium measured at seep SP006.

Tritium concentrations exceeded background at all sampling locations in the trench and auger hole area, indicating widespread contamination. Trench wells and drive points in the southern portion of the study area had the highest concentrations, with activities between 5,300,000 and 105,000,000 pCi/L. The maximum tritium concentration in area C was detected in a sample from trench 105. Downgradient wells/drive points had detections between 120,000 and 18,000,000 pCi/L, with well 4304 having the greatest activity. Even RCRA perimeter well 0976 (total depth of 84 ft) had activities over 5,000,000 pCi/L, indicating downward movement of potentially significant levels of contamination. Well 0439, on the eastern slope near trench 51, also had elevated tritium concentrations at 13,400,000 pCi/L.

Tritium concentrations in seep SP006 were at a maximum of 27,000,000 pCi/L in a sample collected by Duguid in 1974; since then, concentrations have decreased slightly to approximately 8,600,000 pCi/L (sampled 7/22/94). The decrease may be due entirely to decay (half-life of ^{3}H is 12.3 years), but depletion of the source is also expected to be occurring. Upgradient wells 0177, 0433, and 0441 (and deeper wells) had lower activities of tritium, generally around 150,000 pCi/L. Seeps SP007 and SP014 in drainage D-2 had activities over 2,000,000 pCi/L, confirming both the relatively short flow paths in shallow groundwater and the fact that tritium is being released from area C via surface water discharges.

Gross alpha activities also were highest in the trenches, with a maximum of 71,000 pCi/L in a drive point sample from trench 56. Downgradient wells and drive points had unfiltered activities that were typically an order of magnitude less. The greatest concentrations were found in well 4304 (6,800 pCi/L unfiltered), located near perimeter wells 0975/0976. Gross alpha activities in wells 0975 and 0976 were either below detection limits or background levels. Alpha concentrations at SP006 are comparable to those in shallow groundwater south of the trenches. Seep SP007 had slightly higher alpha activities, but the water at that location may be influenced by the unusually high concentrations of ^{241}Am and other alpha-emitting contaminants in trench 61 in area B (see Sect. B2.4.5).

Melton Branch transect sampling for the WAG 2 RI identified a significant input of alpha contamination between SP006 and the Melton Branch weir (station SW006 for the RI). Little information is available for the group of trenches to the west of the road (trenches 40–50, 52–53, 229, and 230). These trenches may have a significant inventory of alpha waste, some of which is being released and migrating to Melton Branch (see below for further discussion).

Cobalt-60 and ^{137}Cs were also detected at high concentrations in trench wells. Drive point 4178 (trench 56) had the highest concentrations of ^{60}Co and ^{137}Cs at 354 and 65,500 pCi/L, respectively. Drive points between the trenches and seep SP006 also detected ^{137}Cs in the range of 81 to 2820 pCi/L. Cesium-137 was detected in seep SP006 samples at around 100 pCi/L in the fall of 1993 but not in earlier samples; ^{137}Cs also was detected in the surface water associated with the bathtubbing trenches but not in either SP007 or SP014. Evidently, ^{137}Cs and ^{60}Co are not highly mobile in the southern part of area C, and the resulting contribution of these contaminants to Melton Branch from this study area is negligible.

Volatile organics detected in area C include 1,2-dichloroethene (total), trichloroethene, tetrachloroethene, and vinyl chloride (Table B2.4.32). These VOCs were detected at four locations: perimeter well 0975 (west of seep SP006); well 0439, along the eastern edge of the area C trenches; seep SP014, in the headwaters of drainage D-2; and seep SP007, in the lower reaches of drainage D-2. The source of the VOCs in SP014, discussed in Sect. B2.4.5, was attributed to the auger holes and trenches in the high-activity area. VOC contamination in 0439 and SP007 may be due to the downgradient (southern) migration of VOC-contaminated groundwater from the high-activity trench and auger hole area. A different source of VOCs is probably responsible for the contamination in well 0975, but that source has not been located.

Table B2.4.32. Organic compounds detected in area C sampling locations

VOC	CONCENTRATION (mg/L)			
	0975	0439	SP007	SP014
1,2-Dichloroethene (Total)	52	--	31	850
Tetrachloroethene	--	4	--	29
Trichloroethene	8	14	3	89
Vinyl Chloride	36	--	16	73

Melton Branch floodplain below OHF. Based on the RI sampling, ^{3}H is the only widespread contaminant of concern in the area C floodplain below OHF. Concentrations of ^{3}H in this area were typical of those detected elsewhere in SWSA 5 South (between 4,000,000 and 40,000,000 pCi/L). Strontium-90 was detected at lower concentrations than found in the vicinity of seep SP006. Concentrations below OHF ranged from 9 to 24,000 pCi/L; the highest concentration was at drive point 4272, approximately 20 ft southwest of the S-220 well where the spill of 2 Ci of ^{90}Sr occurred in 1968 (Letter from Stow to Myrick 1969). The ^{90}Sr activity in groundwater at this location may be a residual of contaminated soil from the spill. Concentrations greater than 1000 pCi/L were also detected in floodplain wells adjacent to Melton Branch (Fig. B2.4.46), indicating that the 1968 spill may have spread farther than originally documented. Conversely, the contamination may be from another source.

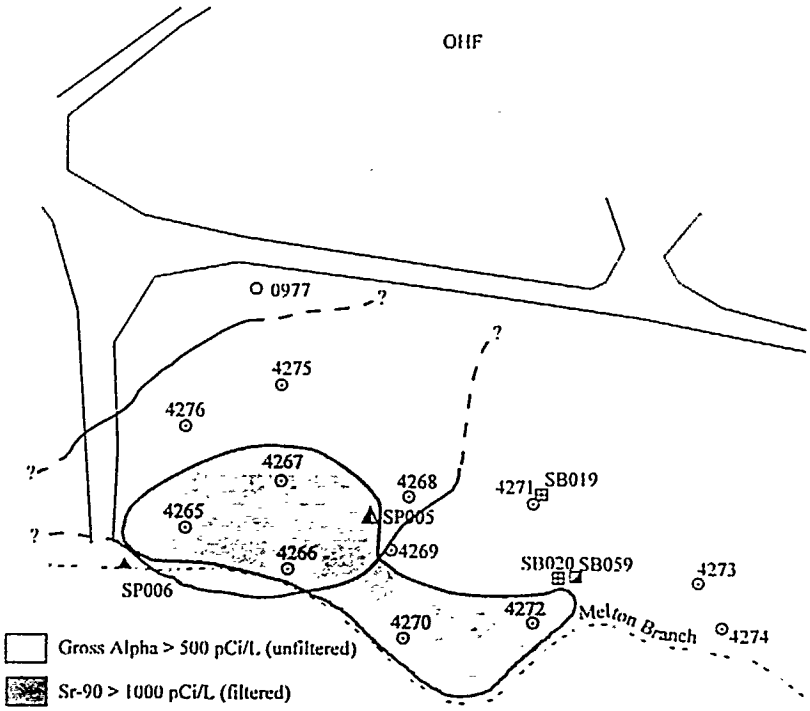

Fig. B2.4.46. Strontium-90 and alpha contamination in area C floodplain.

A plume of alpha contamination is also present in the floodplain, centered around drive point 4276 (1090 pCi/L) and extending westward to drive point 4268 (672 pCi/L) and to Melton Branch, shown in Fig. B2.4.46. WAG 2 sampling also identified an increase in the input of alpha contamination along this reach of Melton Branch; the source could not be identified but may be

related to the group of trenches in the western part of area C. At this time, there are insufficient monitoring data along the probable flowpaths leading to this part of the floodplain or to Melton Branch in general to evaluate this relationship in detail.

The alpha results appear to be biased by particulate matter in the samples since the filtered results are either nondetects or near background levels; however, they do indicate that contamination has moved through the regolith within the water table interval in this area. Alpha activities appear to be associated with higher alkalinity levels, as shown in Fig. B2.4.47. The alkalinity and corresponding total suspended solids values are highest in samples taken adjacent to Melton Branch and decrease with distance upgradient of the creek (i.e., toward OHF). The source of the alpha and higher alkalinity may be groundwater from upgradient sources (i.e., trenches and auger holes) with longer travel times or deeper groundwaters displaced by earlier hydrofracture activities.

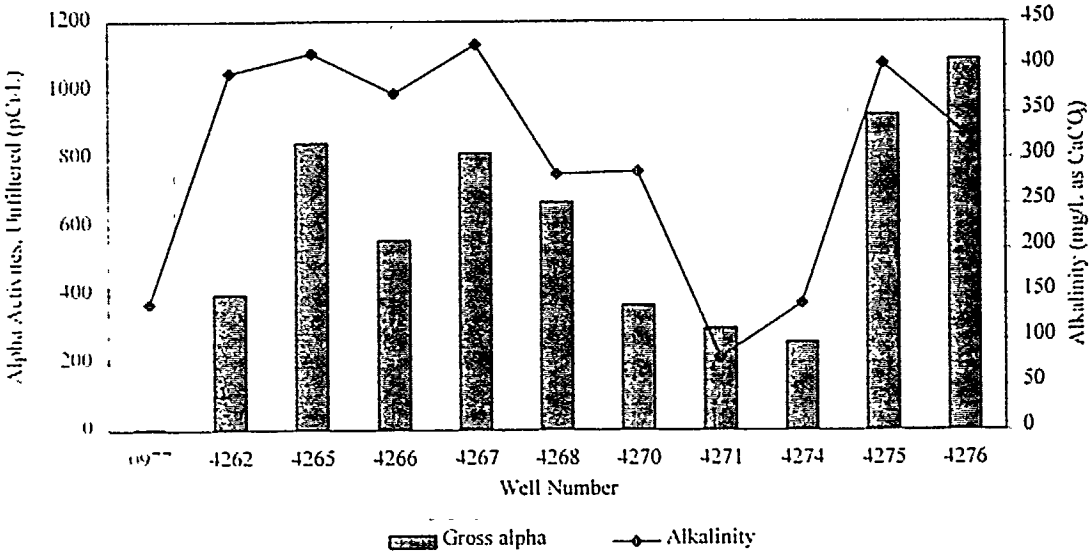

Fig. B2.4.47. Alpha activities and alkalinity in area C floodplain wells.

Conceptual model summary

A summary of the site conceptual model for area C is summarized in Table B2.4.33 and illustrated in Fig. B2.4.48. The major sources in area C are the upland trenches and auger holes, both in the high-activity disposal area and the western portion of the study area, and inundated trenches in the southern part of the study area. Of these, the inundated trenches are apparently the most active sources, based on contamination levels in trench drive points, nearby water table wells, and downgradient seeps and drive points. Data from drive points installed at the downslope toe of the inundated trenches identified significant inventories of ^{90}Sr, ^{3}H, gross alpha, and, to a lesser extent, ^{137}Cs in the trench liquids.

Principal release mechanisms for area C include inundation of trenches in the south and infiltration/percolation, possibly combined with episodic bathtubbing, in the upland trenches and auger holes. In the southern area, bathtubbing also occurs, and overflowing of trench liquids onto

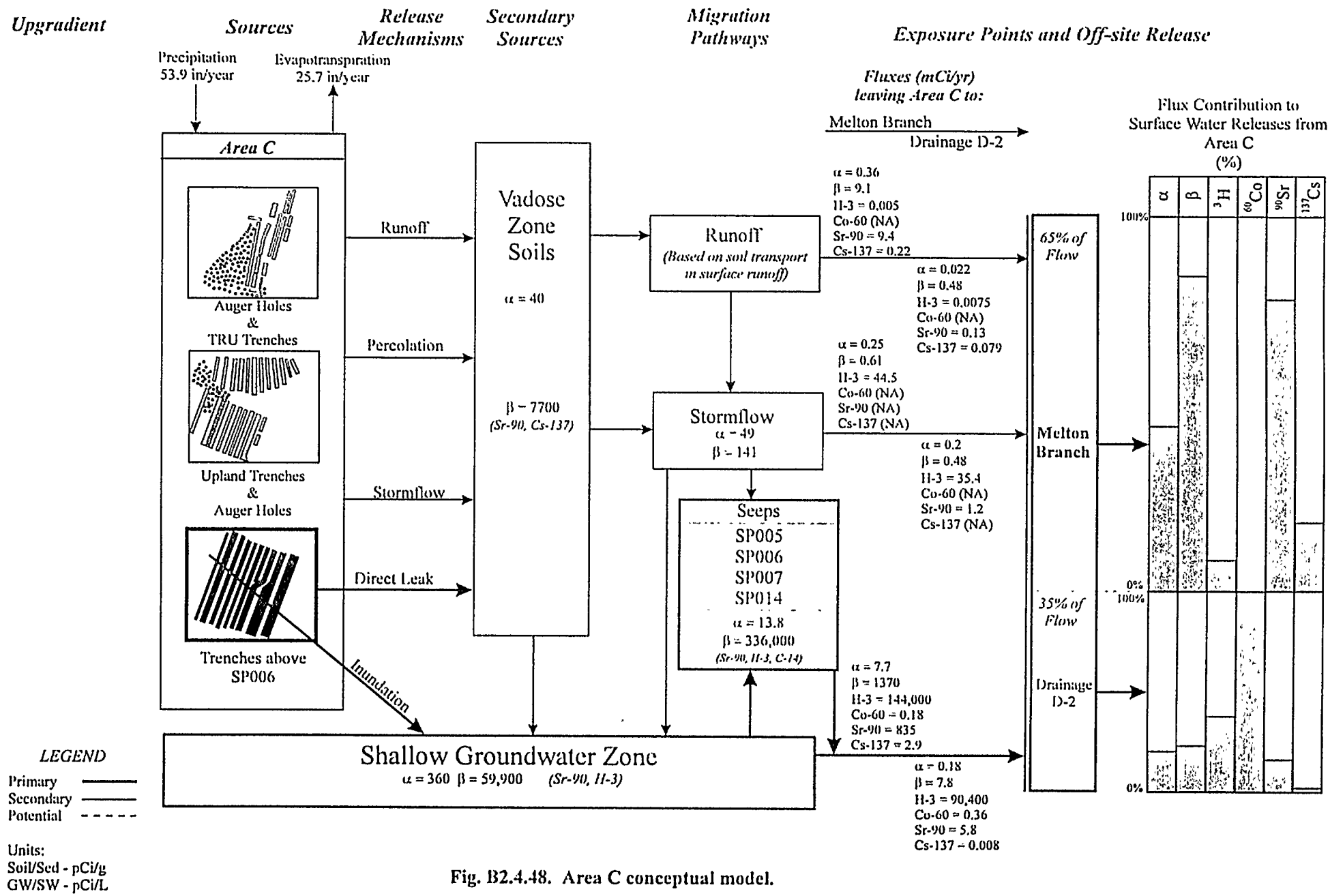

Fig. B2.4.48. Area C conceptual model.

Table B2.4.33. Conceptual model summary for area C

SOURCES	RELEASE MECHANISMS	MIGRATION PATHWAYS	EXPOSURE POINTS
Active: 344 auger holes	• Infiltration of precip. w/ percolation through wastes • Stormflow/lateral movement of water through wastes	• Shallow groundwater & stormflow downslope to inundated trenches or discharging to Melton Branch & D-2	• Seep discharge areas • Downstream surface water & sediment
Active: 13 inundated trenches	• Inundation by rising water table • Infiltration/percolation of precipitation • Stormflow from upland areas	• Shallow groundwater & stormflow as above • Overflowing trenches	• Seep discharge areas • Contaminated soil along drainage paths from overflowing trenches • Downstream surface water & sediment
Active: 44 upland trenches	• Infiltration/percolation • Stormflow • Episodic bathtubbing (perched saturation)	• Same as above	• Seep Discharge areas • Downstream surface water and sediment

the ground surface may be a significant release mechanism, depending on frequency of occurrence. Monitoring data from downgradient seeps and wells confirm that significant contamination has been released from area C; the significantly higher levels of contamination observed in trench liquids, as compared to nearby groundwater, indicate that the release is limited by various processes. These processes were not studied in detail for the RI but probably include geochemical reactions between contaminants and other wastes or aquifer matrix materials (e.g., adsorption to organic matter or cation exchange by clay minerals in the soil and saprolite) as well as the heterogeneities and anisotropic properties of the water table aquifer that physically limit the transport of certain contaminants such as particle reactive alpha-emitting radionuclides.

The major pathway for contaminant migration in area C is via shallow groundwater toward discharge at surface seeps or directly into the channel of Melton Branch or drainage D-2. Most of the contaminated groundwater discharges into Melton Branch; a smaller fraction discharges to drainage D-2, in some cases mixing with contaminated groundwater from area B at or near the point of discharge. All of the groundwater discharging from area C eventually flows into Melton Branch and is carried downstream to White Oak Creek. From a contaminant flux perspective, SP006 is the most important seep in area C. Discharge from this seep is currently being collected and treated to remove ^{90}Sr. Based on sampling of 4303, there appears to be a discrete pathway of ^{90}Sr to the west of SP006, but it does not appear to be a factor in the overall release of ^{90}Sr to Melton Branch.

WAG 2 sampling in Melton Branch and samples from drive points in the floodplain south of OHF indicate that alpha contamination is being released from area C. The study area contains a potentially significant inventory of alpha contamination; sources include several of the inundated trenches sampled with drive points, eight trenches with TRU waste, and numerous auger holes in the western part of area C that reportedly contain TRU wastes. The westernmost group of trenches, for

which there is little disposal information, may also contain a significant quantity of alpha waste. The primary alpha constituents are likely ^{244}Cm and ^{238}Pu, based on results from Duguid (1975).

Elevated concentrations of ^{90}Sr detected in floodplain shallow groundwater below the OHF area indicate that the release of 2 Ci of ^{90}Sr from hydrofracture well S-220 in 1968 may have created a secondary source that is still active. Alternatively, the contamination in this area may be due to the discharge of deeper groundwaters contaminated by releases from SWSA 5. The contaminant release from well S-220 (secondary source) does not contribute a significant amount of contamination to Melton Branch, but it may be significant from an on-site exposure (risk) perspective.

The primary exposure points for area C are the contaminated seep areas, Melton Branch and, to a lesser extent, drainage D-2. Potential exposures also occur in areas contaminated by bathtubbing trenches, in the area of the overflow as well as along surface drainage pathways. The USRADS survey did not identify any significant areas of gamma exposure that were not related to discharge of contaminated groundwater (i.e., the surface soils in area C are relatively free of contamination).

B2.4.7 Area D

Description and history

Area D occupies 1.9 acres in the floodplain between Melton Branch and White Oak Creek, southwest of OHF (Fig. B2.1.1). The study area boundary is based on Melton Branch and the surface drainage divide between White Oak Creek and Melton Branch. Although the area lies entirely outside the WAG 5 administrative boundary, it was included in the scope of the RI because it is a discharge area and exposure point for contamination from WAG 5.

The area consists of a relatively flat and poorly drained floodplain. There are no known contaminant sources in area D—the area was not used for disposal of wastes and was not part of SWSA 5 South burial ground. Melton Branch is incised approximately 4 ft below the general floodplain elevation on the northeast bank and about 4 to 15 ft below the west/south bank. Area D has been characterized as a significant source of the ^{90}Sr flux in Melton Branch. Newsom et al. (1993) estimated that discharges from the area contribute approximately 10 to 15% of the total ^{90}Sr flux in the White Oak Creek watershed. Most of the ^{90}Sr has been found to be discharging at a discrete seep identified as seep SP00D, located in the bank and bed of Melton Branch approximately 150 ft upstream of its confluence with White Oak Creek. A non-time-critical removal action for seep SP00D involving a collect-and-treat system for removal of ^{90}Sr was begun in November 1994.

Previous and concurrent investigations

Pre-existing data characterizing this area were limited to the 1992 WAG 2 seep sampling effort, which identified the seep as a significant contributor of ^{90}Sr to Melton Branch. The average ORNL WAG 2 result for ^{90}Sr concentrations from the seep was approximately 150,000 pCi/L.

During the course of removal action construction activities, a hole approximately 6 ft^2 was excavated 2 to 3 ft into the bedrock (weathered shale) under the streambed and into the bank area containing seep D. Two bedrock seeps discharging upwards through fractures and into the stream bed were identified. This observation confirmed interpretations based on drive point sampling results that the discharge was from vertically upward movement of intermediate or deep groundwater rather than lateral migration of shallow groundwater from the floodplain (area D) area. The combined flow rate for these seeps was approximately 0.8 gal/min, and filtered water samples collected from these seeps contained an average gross beta activity of approximately 160,000 pCi/L.

RI sampling summary

Figures B2.4.49(a) and (b) show the study area sampling locations and cross-section location used in the hydrologic model. Details of RI sampling activities can be found in the WAG 5 source areas investigation technical bulletin (DOE 1993).

- Forty-one drive point wells were installed in the Melton Branch floodplain to investigate contaminant migration pathways from the southwest corner of WAG 5 to the seep discharge along Melton Branch. Three drive point wells were installed in the streambed and one was installed near the base of the opposite (west) bank.

- Three sampling tubes were installed by ORNL WAG 2 personnel in the stream bank along the base of the seep D discharge point.

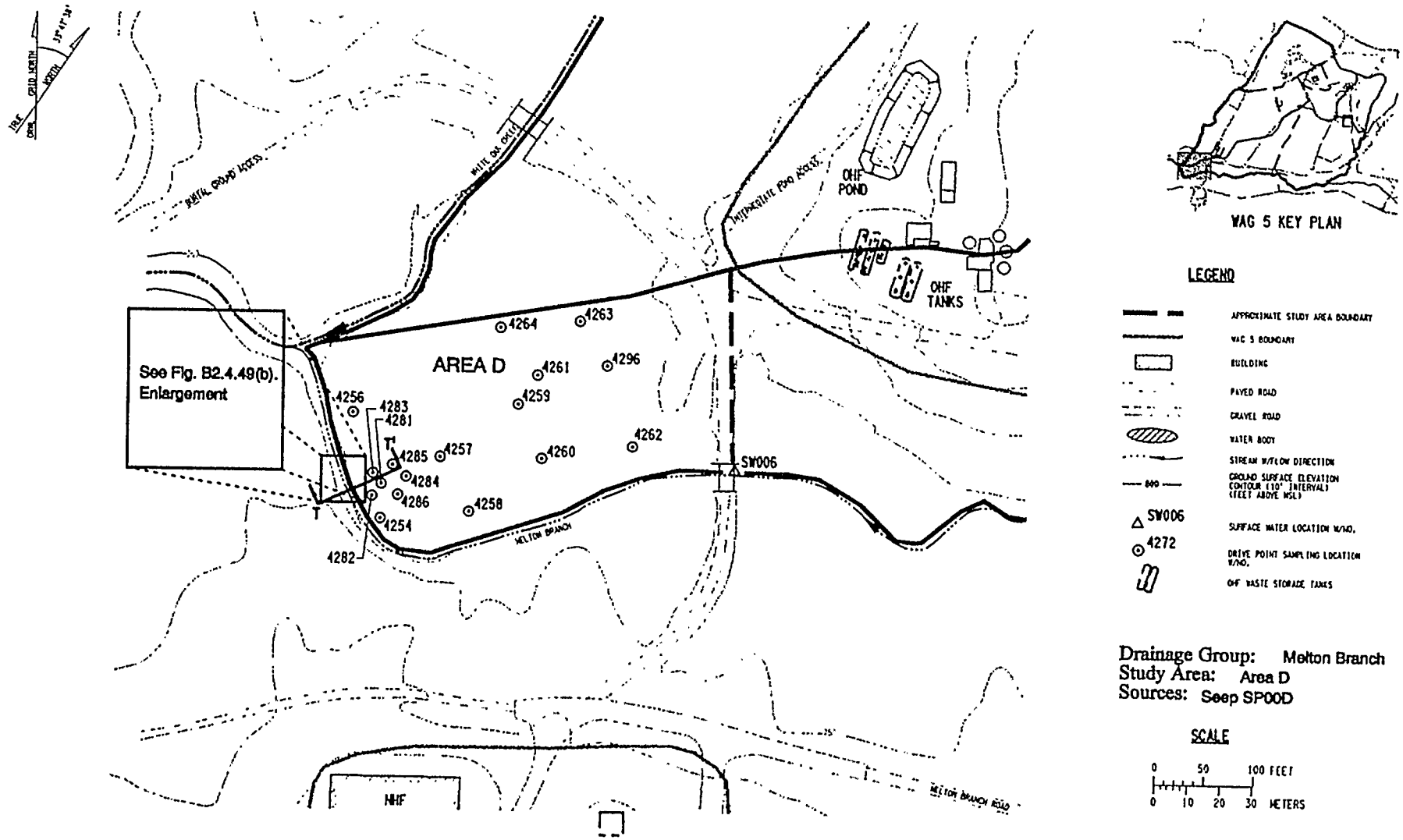

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Fig. B2.4.49(a). Area D plan view.

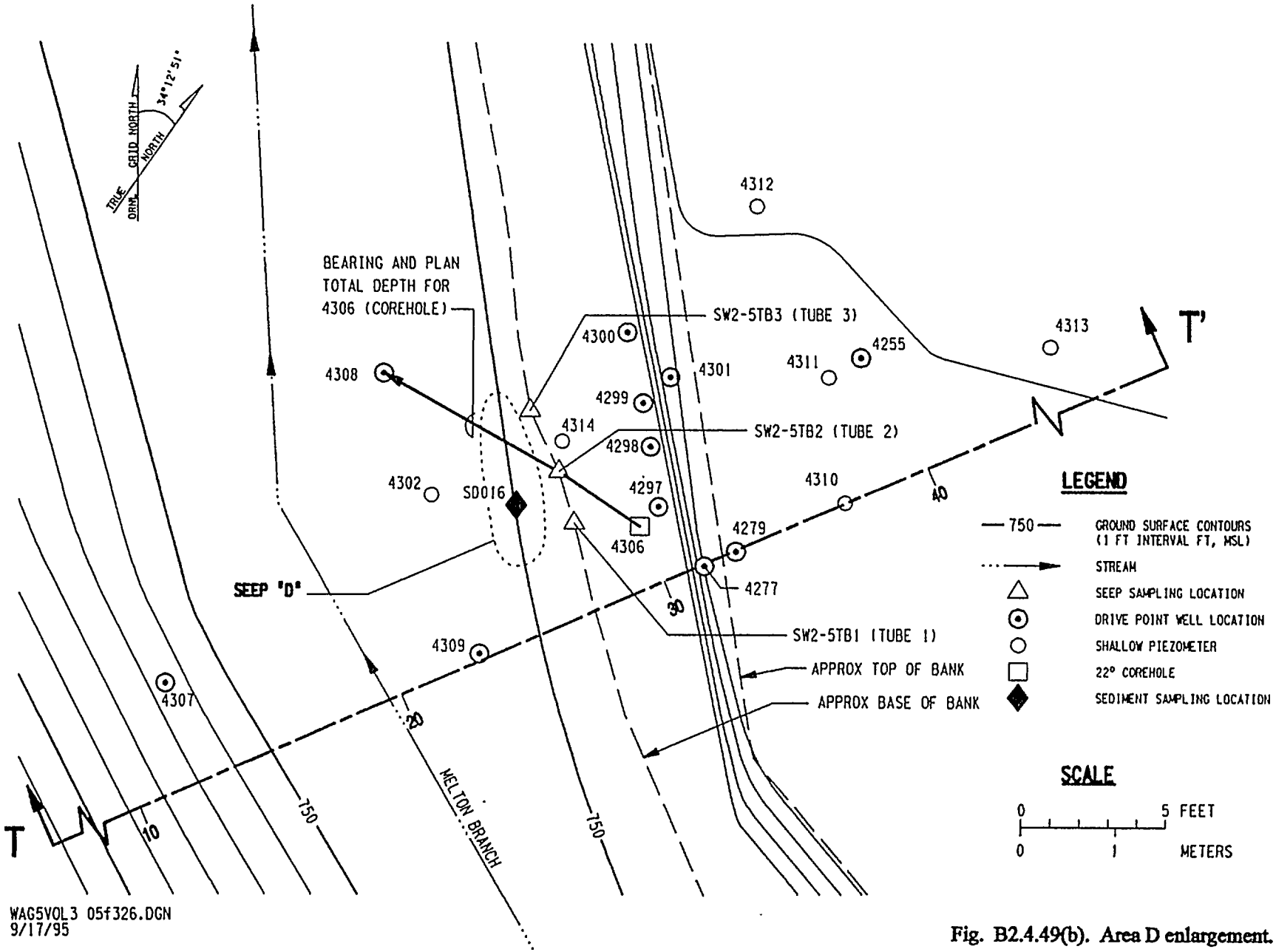


Fig. B2.4.49(b). Area D enlargement.

- Five shallow piezometers were installed on the floodplain near the east bank and upgradient of the seep discharge. Four of the piezometers were power-augered to refusal, soil-sampled at 1-ft intervals, and completed with a PVC riser and screen. The other was completed by the WAG 2 team to support installation of continuous monitoring equipment (no sampling was performed).

- An angled, 27-ft-deep corehole was drilled on the east bank of Melton Branch to investigate potential pathways from deeper bedrock zones to seep D; sampling and hydraulic testing were conducted before the corehole was plugged and abandoned.

All samples collected from area D were analyzed at the CSL for screening-type analyses.

Hydrologic model

Figure B2.4.50 depicts the hydrologic model for area D. The depth to water in the floodplain ranges from approximately 0.2 to 1.5 ft below the ground surface; in the seep D vicinity, the range is 3.0 to 3.8 ft. Shallow groundwater flows generally from east-northeast to west-southwest at a gradient of approximately 0.01 ft/ft. Packer tests indicate an upward hydraulic gradient from bedrock into shallow groundwater under the streambed, denoting area D as an area for discharge of shallow, intermediate, and (possibly) deep groundwater. Table B2.4.34 summarizes the annual water balance based on HSPF modeling.

Table B2.4.34. Annual water balance summary for area D

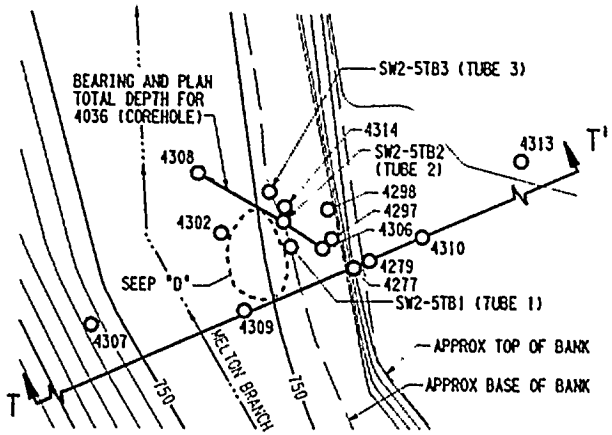
	PERCENT OF FLOW	ANNUAL DISCHARGE TO MELTON BRANCH (m^3/Year)
Surface Runoff	7	371
Interflow	28	1,621
Groundwater Flow	65	3,691
Total	100	5,683

No known burials occurred in the area and there is no evidence of surface soil contamination, which negate the importance of percolation, surface runoff, interflow, and shallow groundwater as release mechanisms and/or migration pathways. Shallow groundwater accounts for two-thirds of the water budget leaving the area but contaminant flux is probably limited to deeper groundwater.

Nature and extent of contamination

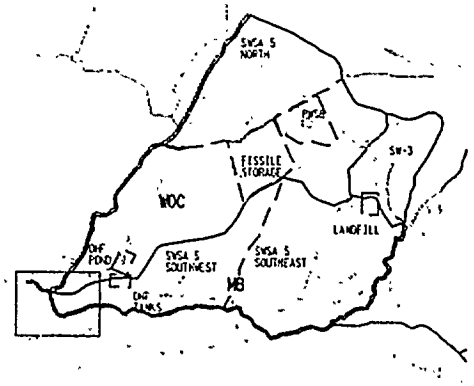
Table B2.4.35 presents quantitative results for each major contaminant detected. Tritium was found at high concentrations throughout the area, generally in the range of 1,000,000 to 10,000,000 pCi/L, with maximum concentrations exceeding 40,000,000 pCi/L. These results are consistent with ^3H concentrations elsewhere in SWSA 5 South. Tritium concentrations in seep D were comparable to the levels detected in groundwater samples collected throughout area D and indicate discharging waters of approximately 10,000,000 pCi/L.

The highest concentrations of other radiological contaminants (gross alpha and beta results from CSL screening analyses) were generally found in water samples from three sampling tubes pushed into the base of the stream bank and from drive points in the immediate vicinity of seep D, either in the streambed or on the opposite bank (locations 4302, 4307, 4308, 4309). The results for the tube

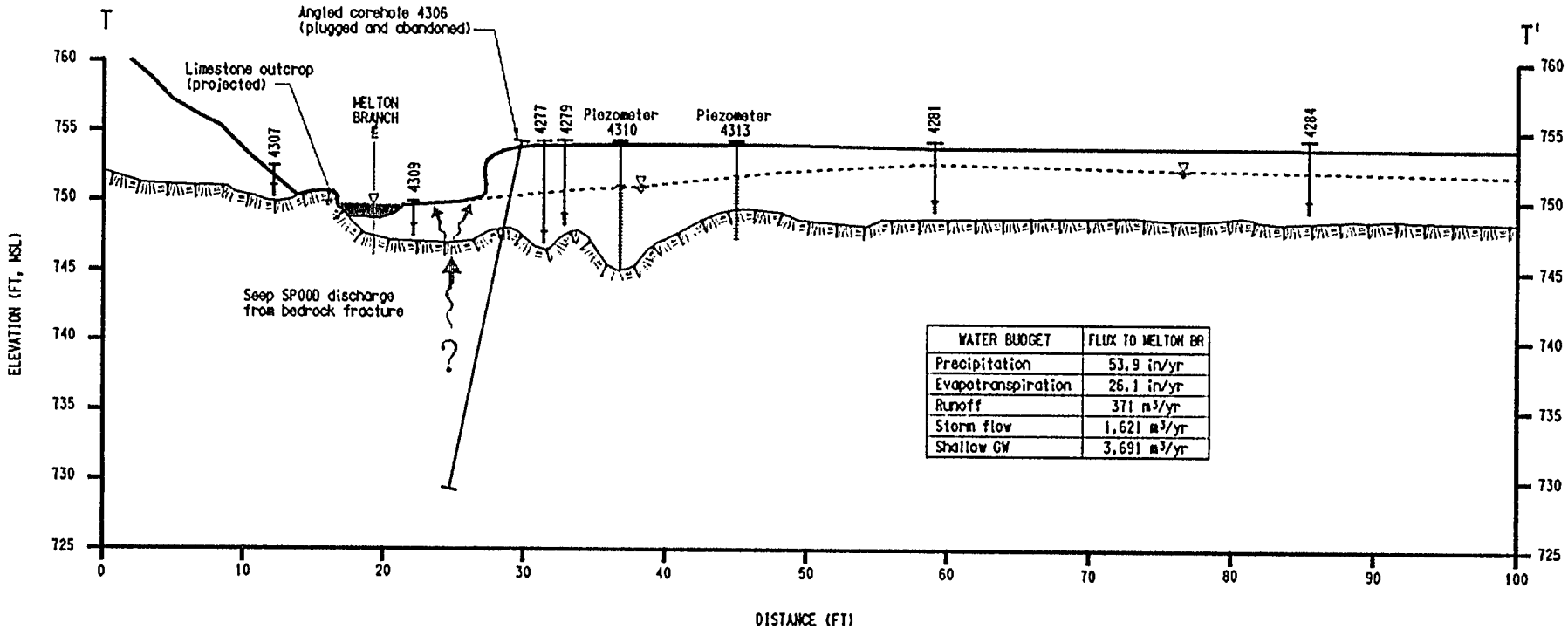


LEGEND

- LOW BASE WATER LEVEL (9/93)
- WATER TABLE SURFACE
- TOP OF BEDROCK SURFACE
- EXISTING GROUND SURFACE
- 4281 — WELL, WELL NO., SCREEN SECTION



WAG 5 KEY PLAN



WATER BUDGET	FLUX TO MELTON BR
Precipitation	53.9 in/yr
Evapotranspiration	26.1 in/yr
Runoff	371 m³/yr
Storm flow	1,621 m³/yr
Shallow GW	3,691 m³/yr

Fig. B2.4.50. Hydrologic model for area D (Section T-T').

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Table B2.4.35. Analytical data summary for selected radionuclides in area D

Sample				(α)	(β)	(β)	(β)	(β–γ)			
Type	ID	Date	Intv (ft)	Gross Alpha	Gross Beta	Tritium	Sr-90	Cs-137			
SOIL (pCi/g)											
Background Reference				9.92	42	0.084	1.94	1.44			
	4310	3/30/94	3-4	-	461	-		14.5			
	4310	3/30/94	7-8	-	191.6	-		4.61			
	4310	3/30/94	8-9	-	99.8	-		2.32			
	4311	3/30/94	5-6	-	96	-		14.6			
	4312	3/30/94	6-6.8	15.3	204.3	-		6.82			
SEDIMENT (pCi/g)											
Background Reference				44	54	100	1.34	0.82			
	SD016	3/30/94	0-0.3	-	510.2	-		1.98			
GROUNDWATER (pCi/L)				U	U	U	U	U	U	U	U
Background Reference				5.2	9.2	116	7.4	2400	1040	10.4	3.6	12.4	5.4
	4254	1/3/94	5.3-6.1	-	-	933.3	-	7.05E+6	6.89E+6				
	4255	1/3/94	4-5.4	367.7	-	1794	60.1	1.09E+7	9.42E+6		38.2	200	1830
	4256	12/30/93	4.3-5.1	627.5	-	1863.6	20.4	3.30E+5	2.99E+5		3.7		125
	4257	1/4/94	3.8-4.6	79.2	-	133.8	-	2.05E+6	2.07E+6			126	
	4258	1/4/94	3.9-4.7	529.2	-	1457.2	15.2	1.17E+5	1.19E+5				
	4259	1/4/94	4.6-5.4	-	-	1247.8	-	3.96E+6	3.86E+6			22.8	
	4260	1/4/94	6-6.8	395	-	1617.3	-	3.13E+6	3.18E+6				
	4261	1/6/94	4.1-4.9	120	-	366.7	22.6	6.69E+6	7.19E+6			110	
	4262	1/5/94	5.7-6.5	400	-	2662.4	68.5	7.06E+6	6.82E+6		731.2		
	4263	1/6/94	3.5-4.3	-	-	830.6	57.1	5.87E+6	5.63E+6		162.6	429	
	4264	1/6/94	5.6-6.4	167.7	22.5	1298.7	241.2	5.59E+6	5.50E+6			152	
	4277	12/17/93	5.1-5.9	135.2	12.6	1865.6	821.4	1.09E+7	1.08E+7		719.9	130	
	4279	12/17/93	4.4-5.2	86.1	11.1	2422.4	1110.8	5.63E+6	5.70E+6		252.4		
	4281	12/17/93	3.6-4.4	394.4	95.3	56826.2	29959.9	1.16E+7	1.15E+7		18625.7	28	
	4282	12/17/93	4-4.8	70.7	-	476.2	119	2.20E+6	2.19E+6		280.3	22.6	
	4283	12/17/93	3.2-4	181.6	-	974.9	64.1	5.15E+6	5.03E+6		66.2	359	
	4284	1/5/94	3.6-4.4	144.2	14.3	888.1	139.3	5.61E+6	6.30E+6		132.1	193	
	4285	1/5/94	4.3-5.1	199.9	-	411.8	23.8	1.29E+6	1.18E+6			230	

Table B2.4.35. Analytical data summary for selected radionuclides in area D (cont.)

Sample				(α) Gross Alpha		(β) Gross Beta		(β) Tritium		(β) Sr-90		(β–γ) Cs-137	
Type	ID	Date	Intv (ft)	U	F	U	F	U	F	U	F	U	F
GROUNDWATER (pCi/L)													
Background Reference				5.2	3.2	16	7.4	2400	1040	10.4	3.6	12.4	5.4
	4286	1/5/94	4.5-5.3	239.9	23.7	1732.5	14.6	7.11E+5	1.14E+6			160	
	4296	1/6/94	3.9-4.7	111.4	8	362.5	28.4	4.87E+6	4.78E+6			168	
	4297	1/26/94	6.3-7.1	-	-	604.8	-	1.11E+7	1.07E+7		17.9		
	4298	1/26/94	4.7-5.5	-	83.6	20844.9	6179.5	1.09E+7	9.44E+6	8970.5	5168	146	
	4299	1/26/94	4.4-5.2	4528.7	781.3	397513.6	109261.4	1.21E+7	1.04E+7	184087.7	86690.4	394	
	4300	1/26/94	4.6-5.4	915.5	57.6	23185.2	2890.7	1.14E+7	9.05E+6	3560.6	127345.8		
	4302	1/27/94	1.5-2.3	6817.1	1446.3	688021.5	153881.5	1.26E+7	1.07E+7	273209.9	131101.5	139	
ac	4306	2/23/94	0-6.9	-	17	22730	4532	4.06E+5	1.04E+6		2434	1590	
ac	4306	3/9/94	6.9-10.3	90	17	58514	25116	9.95E+6	1.00E+7		22856	91.1	59.1
ac	4306	2/26/94	9.6-12.3	70	-	3590	1944	4.50E+6	5.74E+6		1092		65.1
ac	4306	2/28/94	12.3-15.3	24	-	1151	804	1.59E+6	2.23E+6		636	47.4	
ac	4306	3/1/94	15.3-18.3	22	-	508	221	9.68E+5	1.03E+6		187	56.2	73.5
ac	4306	3/2/94	17.8-20.9	35	9	713	250	2.39E+5	2.17E+5		198	80	56.3
ac	4306	3/3/94	20.9-24.1	-	-	740	182	2.54E+5	2.63E+5		104	66.5	84.7
ac	4306	9/7/94	24.2-27.2	25	-	128	52	3.28E+5	3.24E+5		37.6	51.5	107
	4307	3/11/94	1.3-2.1	755.3	35.1	403783	137070.9	9.29E+6	8.94E+6		85584.1	1010	44.4
	4308	3/11/94	0.9-1.7	884.3	34.5	727831.6	170824.8	7.62E+6	9.00E+6		101972.7	90.1	52.4
	4309	3/11/94	0.8-1.6	775.9	-	74549	8749.5	3.30E+6	2.69E+6		4567.4	2440	51
	4310	3/29/94	2.8-9		-		24490.9		1.02E+7				
	4311	3/29/94	3-8.7		-		1877.6		5.19E+6				
	4312	3/29/94	2.9-6.7		-		462.6		2.54E+6				
	4313	3/30/94	2.5-6.7		18.2		724.4		7.92E+6				
SURFACE WATER (pCi/L)													
Background Reference				19		8		1620				40	
	SP00D	11/19/93		480.8	499.4	203177.6	157350	1.10E+7	1.10E+7	96955	32145		

Notes: 1. Blanks indicate analyte not analyzed for; Bold results indicate values greater than background reference (2x mean background)
2. Abbreviations: U/F = Unfiltered/Filtered - = not detected (α, β, γ) = alpha, beta, gamma emitter ac = angle corehole

samples identified filtered gross beta concentrations (180,000 to 370,000 pCi/L) higher than in any other samples, including those collected directly from the bedrock seep uncovered during the removal action. Filtered gross alpha concentrations were below detection limits in these samples. Gross beta results from the drive points in the streambed and opposite bank averaged approximately 120,000 pCi/L in filtered samples, similar to the 160,000 pCi/L filtered gross beta concentrations detected in the bedrock seep samples. Slightly lower gross beta concentrations were measured in water samples from a sub-streambed interval in corehole 4306, three drive points in the stream bank just above seep D (4300, 3299, 4298) and in the sample from drive point 4281, 45 ft east of the seep.

Investigation results support the conclusion that shallow groundwater and saturated soil near the seep have become contaminated from the upward movement of contaminated groundwater. Dilution via mixing with Melton Branch surface water and the relatively cleaner shallow groundwater also discharging at seep D can account for the decrease in concentrations observed with increasing distance from the sources (i.e., the seeps discharging from the fractured shale under the streambed). Elevated gross alpha concentrations (maximum of 6817 pCi/L) were detected in samples containing high gross beta, indicating migration of TRU radionuclides in addition to beta emitters. Though it was not possible to identify additional bedrock seeps in the area, their existence cannot be totally dismissed based on available data. The source of the contamination migrating into deep groundwater is also not known. Direct pathways from shallow to deep groundwater zones are known to exist in five OHF observation wells (0174–0179) completed as open holes to approximately 150 ft below the surface. It is also possible that the contamination is related to hydrofracture injections; this relationship will be evaluated for the WAG investigation.

Results of analyses for VOCs indicate that little organic contamination exists in the area. The only detection was 1,2-dichloroethene at 2 µg/L in a groundwater sample from upgradient drive point 4296. Results of TCLP analyses on samples from the seep were below regulatory limits.

Conceptual model.

The conceptual model for study area D is illustrated in Fig. B2.4.51 and summarized in Table B2.4.36. The area does not have any primary sources. Secondary sources, created by movement of contaminated groundwater through the soil, may be present but are not likely to have a significant impact on either the extent of contamination or contaminant flux from area D.

Table B2.4.36. Conceptual model for area D

SECONDARY SOURCE	MIGRATION PATHWAYS	EXPOSURE POINTS
Saturated Soil		
Shallow Groundwater	Shallow groundwater discharging to Melton Branch	• Seep discharge areas • Downstream surface water and sediment
Deep Groundwater		

Contaminated deep groundwater is moving upward through fractures in the bedrock, thus contaminating Melton Branch and shallow groundwater in the immediate vicinity of seep D. Radionuclides have been detected in downgradient surface waters (seeps and Melton Branch Tributary). The primary contaminant release mechanism and migration pathway is direct discharge of groundwater from seeps into Melton Branch. This pathway is being addressed through the collect-and-treat removal action recently begun in area D.

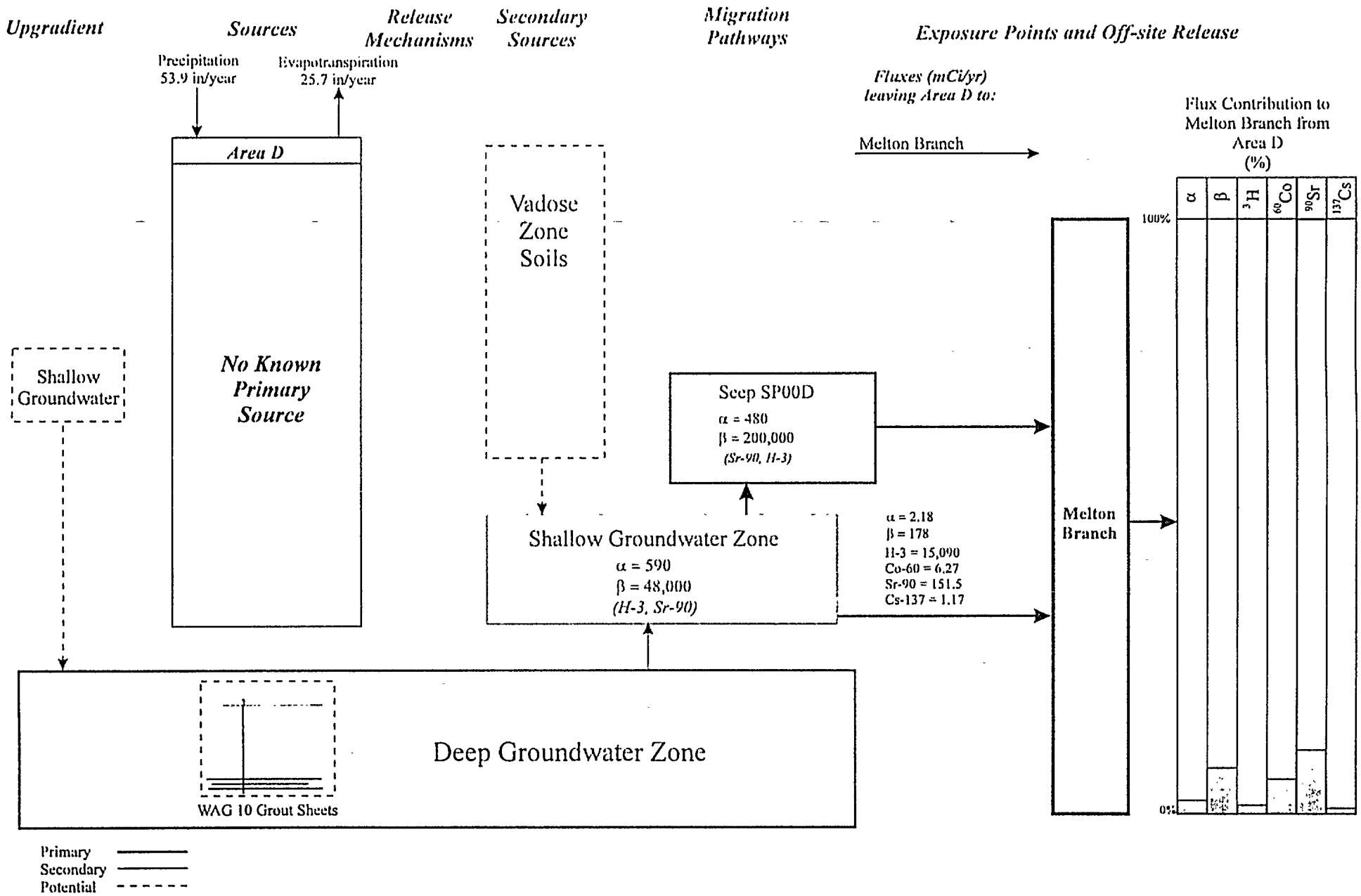


Fig. B2.4.51. Area D conceptual model.

B2.4.8 Melton Branch Drainage Basin Summary

The Melton Branch drainage area of WAG 5 contains five study areas: SWSA 5 South Areas A, B, C, and D and SW-3 (Fig. B2.1.1). The total drainage area associated with WAG 5 (including the area beyond the administrative SWSA 5 boundary) is 52.9 acres. Drainages D-2 and D-3 are the main WAG 5 surface water contributors to Melton Branch with 20 and 18% of the drainage area, respectively. Table B2.4.37 presents the annual water balance based on HSPF modeling.

Table B2.4.37. Annual water balance summary for Melton Branch drainage basin

	PERCENT OF FLOW	ANNUAL DISCHARGE (m^3/year)
Surface Runoff	7	8,800
Interflow	28	36,600
Groundwater Flow	65	82,500
Total	100	127,900

Conceptual models were developed for each study area, based on surface water modeling and detailed interpretation of sampling results. These models describe contaminant sources within the study area, release mechanisms, secondary sources, migration pathways, and exposure points; Table B2.4.38 summarizes the major findings. The primary contaminant source areas are the trenches and auger holes in areas A, B, and C and the landfill in SW-3. Primary contaminant types include mixed fission/activation products, TRU and fissile constituents, and VOCs. The principal release mechanism is inundation of wastes in trenches by shallow or perched groundwater. Contaminants are then transported through shallow groundwater and discharged to seeps and surface waters (Melton Branch and drainages D-2 and D-3).

Flux calculations

To determine the magnitude and extent of WAG 5 releases to Melton Branch, contaminant fluxes (gross alpha, gross beta, tritium, ^{60}Co, ^{90}Sr, and ^{137}Cs) from each study area were determined. These fluxes are pathway-dependent and are calculated based on average annual flow rate (Table B2.4.37) and the average concentration found in that pathway during the RI sampling events. (Note: the surface runoff pathway flux is based on erosion potential, sediment/soil transport in surface runoff, and average contaminant concentration in soil.) Figure B2.4.52 presents the percent flux contribution of contaminants, broken down by study area and pathway. These results show the dominance of the groundwater pathway in transport of contaminants to Melton Branch. The stormflow and surface runoff pathways are generally insignificant except in SW-3, where most waste is at or near the surface.

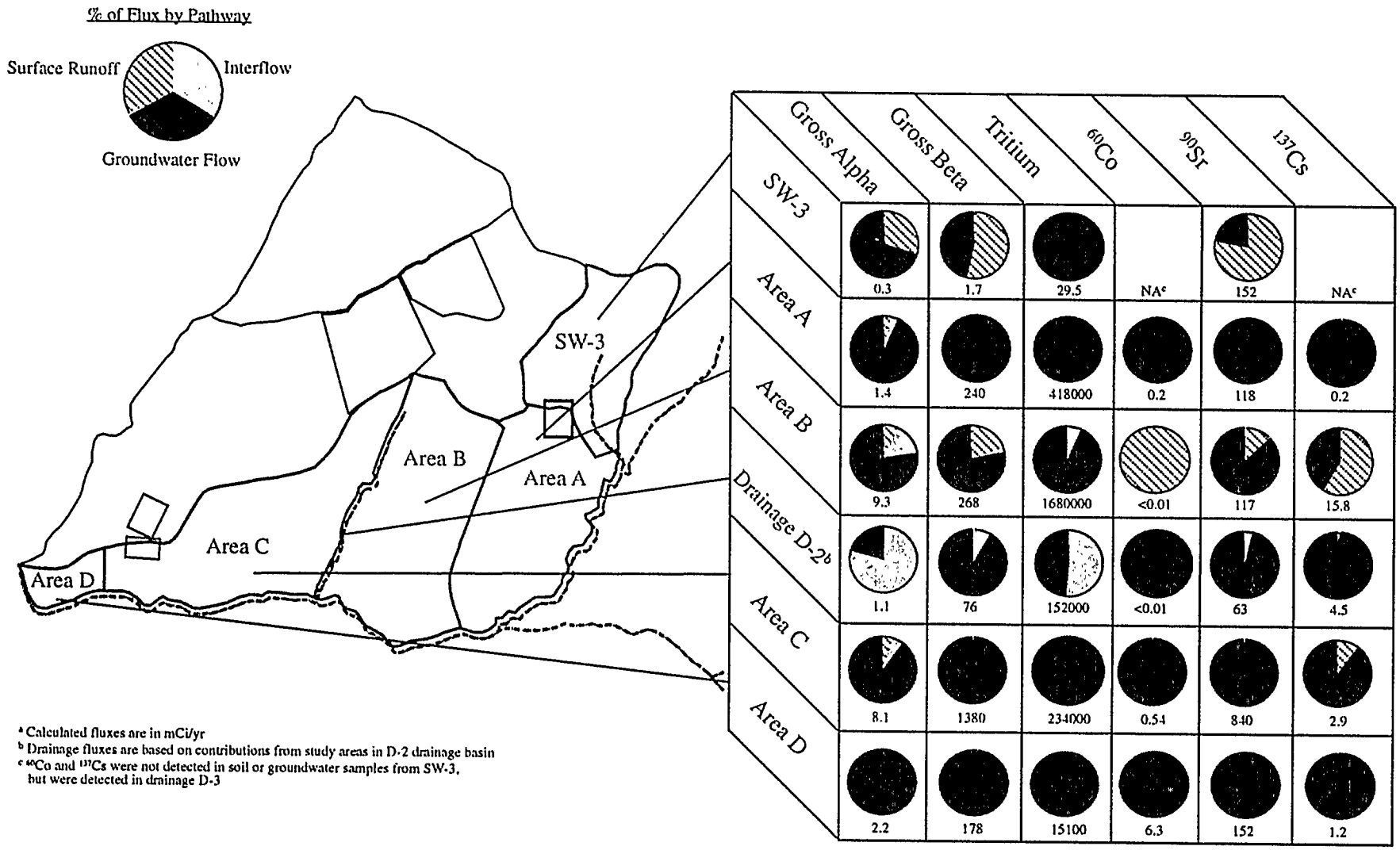
Table B2.4.39 summarizes the fluxes (and relative percentages) from each source, beginning with SW-3 study area and culminating with the total flux measured at the mouth of Melton Branch and presents fluxes calculated from upgradient input (SW004 and SW005). Results indicate good correlation between calculated and observed fluxes, typically in the same order of magnitude. Differences between the two can be attributed to (but not limited to) assumptions in the surface water mathematical model; use of average concentrations of analytes in each pathway and homogeneous soil properties and flow paths; and neglecting the effects of contaminant retardation in the soil matrix or sediment deposition in the streambed.

Table B2.4.38. Melton Branch conceptual model summary

Study Area	Sources	Contaminant Types	Release Mechanisms	Secondary Source	Migrations Pathways	Exposure Points
SW-3	Active: Northern landfill/ hillside dump	Fission/Activation Products: ^{90}Sr, ^{137}Cs, ^{60}Co TRU: ^{241}Am, $^{243/244}Cm$	Surface runoff or percolation dominant since wastes are at/near surface	Surface and subsurface soils	Surface runoff, stormflow, and lesser amounts of shallow groundwater	Soils and contaminated wastes at surface drainage D-3 Seep discharge area
Area A	Active: 121 auger holes 23 upland trenches 56 inundated trenches	^{3}H, ^{90}Sr VOCs	Trench inundation and perched conditions in trenches and auger holes; infiltration and percolation through wastes	Surface and subsurface soils adjacent to trenches and auger holes	Shallow groundwater and release to seeps; stormflow	Seep discharge areas Melton Branch Trib.
Area B	Active: 177 auger holes 27 upland trenches 47 inundated trenches	^{90}Sr, ^{3}H VOCs TRU: ^{241}Am $^{243/244}Cm$	Trench inundation and perched conditions in trenches and auger holes; infiltration and percolation through wastes	Surface and subsurface soils adjacent to trenches and auger holes	Shallow groundwater and release to seeps; stormflow	Seep discharge areas Drainage D-2 Melton Branch
Area C	Active: 344 auger holes 44 upland trenches 13 inundated trenches	Fission Products: ^{90}Sr VOCs Gross Alpha	Trench inundation and perched conditions in trenches and auger holes; infiltration and percolation through wastes	Surface and subsurface soils adjacent to trenches and auger holes	Shallow groundwater with releases to surface seeps; stormflow	Seep discharge areas Drainage D-2 Melton Branch
Area D	No known sources Potential sources: Upgradient trenches and auger holes WAG 10 grout sheets	^{90}Sr, ^{3}H	Unknown		Shallow/deep groundwater directly to seep discharge at surface	Seep SP006 Melton Branch

Figure B2.4.53 presents the relative percent fluxes from each study area and non-WAG 5 contributors in a funnel representation. Fluxes calculated from individual areas are combined into four hydrologically distinct groups: WAG 5 study areas draining into D-2; WAG 5 study areas draining directly into Melton Branch; WAG 5 and non-WAG 5 contributors to Melton Branch Tributary; and contributors upgradient of WAG 5 along Melton Branch. The groups are then combined to give relative percent contributions to the fluxes calculated for the mouth of Melton Branch. Total fluxes at the mouth of Melton Branch—measured flux at Melton Branch weir and calculated flux from Area D—are also summarized. The relative percent flux from the WAG 5 Melton Branch drainage basin and from the Melton Branch weir to the total flux at the White Oak Dam is also presented. (Note: The White Oak Creek drainage basin summary includes an example of the use of the funnel figure).

Based on the flux calculations, the WAG 5 Melton Branch drainage basin is contributing a large portion of the tritium and ^{90}Sr fluxes to White Oak Dam, lesser amounts of gross alpha and ^{60}Co, and very little ^{137}Cs. The total tritium and ^{90}Sr fluxes from WAG 5 are around 81 and 45%, respectively, slightly greater than those calculated from the WAG 2 RI fluxes (75 and 36%, respectively). Gross alpha, ^{60}Co, and ^{137}Cs fluxes were much less (10, 3.6 , and 0.5%, respectively).



[a] Calculated fluxes are in mCi/yr
[b] Drainage fluxes are based on contributions from study areas in D-2 drainage basin
[c] ^{60}Co and ^{137}Cs were not detected in soil or groundwater samples from SW-3, but were detected in drainage D-3

Fig B2.4.52. Flux summary by study area and pathway for WAG 5 Melton Branch drainage.

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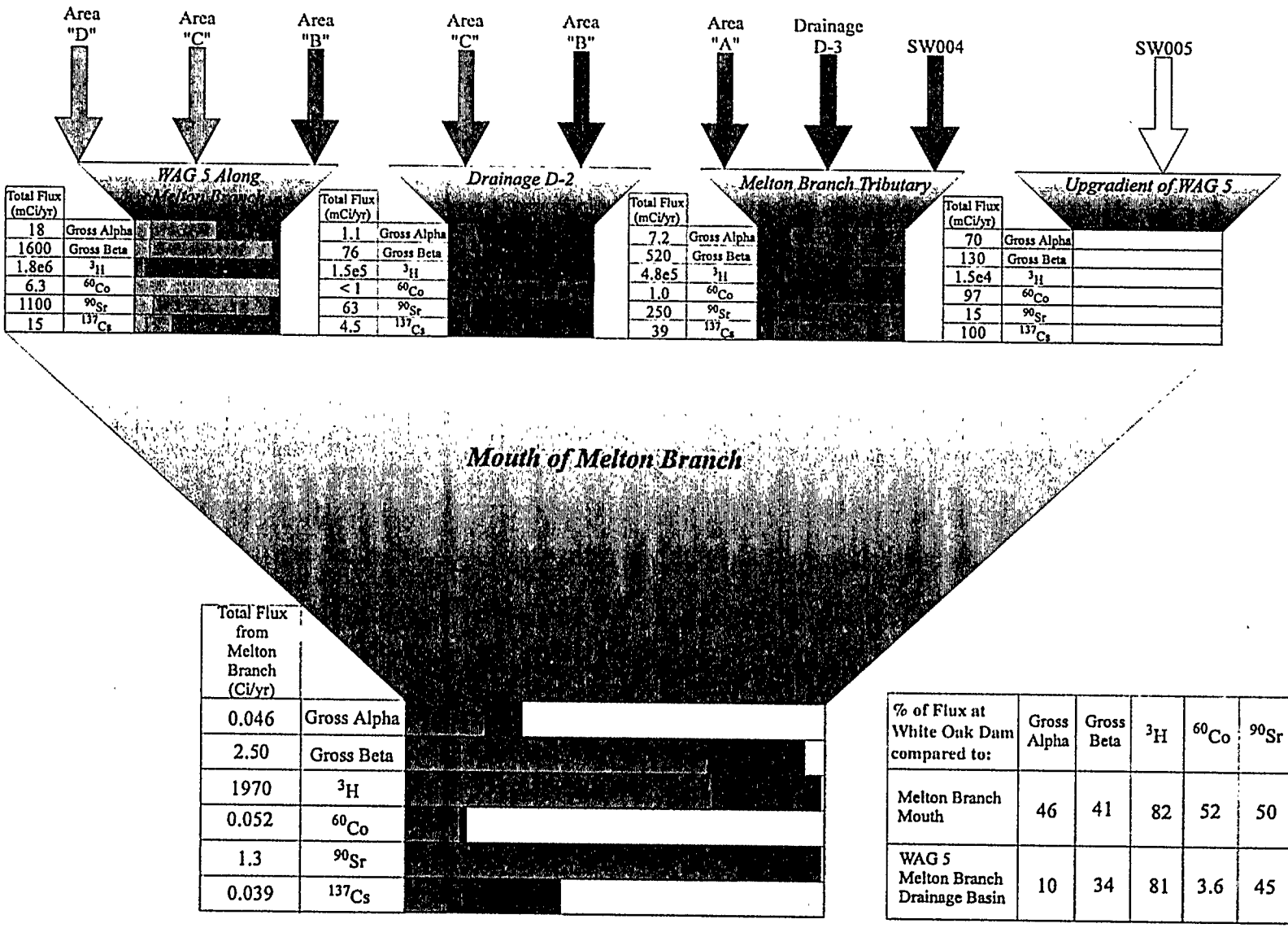
Table B2.4.39. Flux contributions to drainage D-2 and Melton Branch

	Alpha Flux		Beta Flux		H-3 Flux		Co-60 Flux		Sr-90 Flux		Cs-137 Flux	
	mCi/yr	(%)	mCi/yr	(%)	mCi/yr	(%)	mCi/yr	(%)	mCi/yr	(%)	mCi/yr	(%)
Drainage D-2												
Area B	1.7	(80%)	29.4	(77%)	146375	(62%)		(0%)	30.3	(84%)	4.40	(98%)
Area C	0.4	(20%)	8.7	(23%)	90400	(38%)	0.36	(100%)	5.9	(16%)	0.09	(2%)
Calculated total flux from drainage D-2	2.1		38.0		236775		0.36		36.2		4.49	
Measured total flux from drainage D-2	1.1		76.1		151875		not detected		63.2		4.50	
Melton Branch												
					Non WAG 5 Sources							
SW005	69.8	(73%)	127.3	(5%)	14826	(1%)	96.89	(93%)	14.5	(1%)	100.38	(63%)
SW004	5.6	(6%)	276.4	(12%)	0	(0%)	0.00	(0%)	128.5	(9%)	34.62	(22%)
WAG 5 sources												
Drainage D-3	0.3	(0%)	1.6	(0%)	30	(0%)	0.79	(1%)	0.5	(0%)	3.77	(2%)
Area A	1.4	(1%)	238.8	(10%)	481048	(20%)	0.20	(0%)	117.6	(8%)	0.23	(0%)
Area B -> Melton Branc	7.6	(8%)	87.6	(4%)	1649829	(67%)	0.00	(0%)	86.4	(6%)	11.33	(7%)
Drainage D-2	1.1	(1%)	76.1	(3%)	151877	(6%)	0.00	(0%)	63.2	(5%)	4.50	(3%)
Area C -> Melton Branc	7.7	(8%)	1370.5	(58%)	144063	(6%)	0.18	(0%)	834.6	(60%)	2.86	(2%)
Area D	2.2	(2%)	177.7	(8%)	15094	(1%)	6.27	(6%)	151.5	(11%)	1.17	(1%)
Calculated total flux at mouth of Melton Branch	95.6		2356.0		2456767		104.33		1396.9		158.86	
Measured flux at Melton Branch Weir + Area D	46.2		2497.7		1967713		51.85		1274.1		39.01	

Notes:
1. (%) are based on the percentage of calculated total flux, not measured flux.
2. All data is based on sampling and flow measurements taken during the RI.
3. Total flux is taken at mouth of Melton Branch since Area D is downstream of surface water station SW006.



% of Flux at White Oak Dam compared to:	Gross Alpha	Gross Beta	^{3}H	^{60}Co	^{90}Sr	^{137}Cs
Melton Branch Mouth	46	41	82	52	50	3.5
WAG 5 Melton Branch Drainage Basin	10	34	81	3.6	45	0.5

Fig. B2.4.53. Melton Branch contaminant flux summary.

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B2.5 WAG 5 SUMMARY

Sections B2.3 and B2.4 delineate the nature and extent of contamination for each study area by developing and evaluating area-specific hydrologic and conceptual models. The evaluation was based on an integrated assessment of historical data and sampling results from the RI field investigation. This section provides a WAG-wide overview of the nature and extent of contamination, including a summary matrix (Table B2.5.1) that identifies the primary sources in each area, assigns a status for each source (active or potential, inactive or unlikely), and provides a media-specific summary of contamination in and being released from each area.

In addition to the summary matrix, WAG-wide, contaminant-specific maps (Figs. B2.5.1 through B2.5.10) show the distribution and magnitude of radiological contamination (gross alpha, gross beta, ^{3}H, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{241}Am, $^{243/244}Cm$, and ^{238}Pu) in soil, sediment, surface water, and groundwater. For display purposes, contaminant levels are grouped into classes according to the following criteria.

(1) Results *not detected* above the background level of the alpha, beta, or gamma spectrum for the particular contaminant.

(2) Results greater than two times the mean background threshold for that contaminant.

(3) Results greater than the maximum contaminant level promulgated by the Tennessee Department of Environment and Conservation.

(4) Results greater than the risk-based concentration for a residential scenario corresponding to an excess cancer risk of 1.0E-04.

(5) Results greater than the 1.0E-04 risk-based concentrations but less than or equal to 100 times that concentration (i.e., an excess cancer risk of 1.0E-02).

(6) Results greater than (5) above.

This section highlights important trends based on an evaluation of the WAG-wide, media-specific contaminant maps. Table B2.5.1 presents area-specific contaminant summaries developed for the site conceptual model for each study area. These summaries were integrated into the WAG-wide conceptual model discussion in Sect. 3 of Volume 1 (Technical Summary).

Contaminant concentrations shown in the following maps are based on samples collected for the WAG 5 RI field investigation and the Phase I RI for WAG 2 (ORNL 1993). WAG 2 samples were limited to surface water samples from Melton Branch and White Oak Creek. The data for each contaminant are based on the following.

- Soil and sediment: maximum concentrations for a particular contaminant in the sample from that location, regardless of depth.

- Surface water: maximum unfiltered results from samples collected from surface water stations along Melton Branch and White Oak Creek, North Tributary, Melton Branch Tributary, interior WAG 5 drainages (D-1, D-2, and D-3), and WAG 5 seeps.

- Groundwater: maximum results from analyses of water samples from the perimeter wells surrounding WAG 5, the interior wells adjacent to and within each study/source area, and the drive points constructed for the source characterization. Except for tritium, all results are from filtered samples.

B2.5.1 Gross Alpha

Gross alpha activity (Fig. B2.5.1) slightly exceeds the background threshold concentration (10 pCi/g) in soil samples from SWSA 5 North, PWSB, OHF, and in the sediment from all three drainages within WAG 5. Higher concentrations indicative of site-related wastes were associated with samples collected in the vicinity of waste sources and seep discharge areas; the highest gross alpha activity (>12,000 pCi/g) was observed in sediment samples from the OHF pond and PWSB.

High (>170 pCi/L) gross alpha activity in surface water was seen in association with the seep discharge areas in SWSA 5 South and along Melton Branch. Seep SP015, downgradient of the fissile storage area, also yielded samples with high alpha levels, as did samples from downgradient sampling in D-1.

Gross alpha activity was detected in groundwater throughout WAG 5. SWSA 5 North activities exceed background levels, and activities in well 0516 near the TRU trenches exceed the acceptable risk-based concentration (equivalent to alpha activity for ^{238}U). High alpha activities are also associated with the trenches in SWSA 5 South and the OHF pond, both of which were confirmed to be sources of TRU and other alpha-emitting radionuclides.

B2.5.2 Gross Beta

The distribution of gross beta activity in soil, sediment, surface water, and groundwater (Fig. B2.5.2) is similar to that of ^{90}Sr, indicating that most of the beta activity at the site can be accounted for by ^{90}Sr rather than other beta emitters. Several locations in the vicinity of the SWSA 5 South trenches yielded soil samples with unusually high concentrations (>8900 pCi/g). For sediment, the highest beta activities are in the pond and basin sediments. Seeps in the vicinity of the trenches in SWSA 5 South account for the highest concentrations.

B2.5.3 Tritium

Soils and sediments (Fig. B2.5.3) show ^{3}H activity exceeding background (0.08 pCi/g) for most of the site; the highest concentrations are seen in the D-2 drainage and the soils adjacent to the seeps in SWSA 5 South. No results near the risk-based level (1,500,000 pCi/g) were observed.

Tritium activity in surface water in the upper reach of White Oak Creek, upstream of SWSA 5 North, is relatively minor in comparison to the rest of the site. Contributions from WAG 4 and drainage D-1 cause the lower reach of White Oak Creek to exceed the MCL for ^{3}H (20,000 pCi/L). As shown in the evaluation of SWSA 5 South, Melton Branch is significantly affected by ^{3}H

migration from the wastes in this area. Some of the highest ^{3}H concentrations observed result from discharge of seeps adjacent to the trenches and along Melton Branch. Seeps in the vicinity of the fissile storage area also have concentrations exceeding the acceptable risk-based level (88,000 pCi/L), indicating an active source of ^{3}H in the northern part of SWSA 5 South. Interior drainage D-3 and upstream reaches of Melton Branch Tributary show only minor concentrations.

Figure B2.5.4 shows ^{3}H concentrations in groundwater. Because of its high specific activity (>9000 Ci/g) and nonreactive transport properties (discussed in Appendix B3), even a small mass of ^{3}H would create a widespread plume with relatively high concentrations. The amount of ^{3}H disposed of on WAG is unknown, but it was detected almost everywhere on site. The area with ^{3}H concentrations greater than the effective dose equivalent (EDE) (20,000 pCi/L) of the MCL for gross beta (4 mrem/yr) is limited to the lower (southern) half of the site. Those areas with concentrations exceeding the acceptable residential risk level (88,000 pCi/L) are associated with SWSA 5 South, the D-1 drainage area (reflecting input from the northern part of SWSA 5 South, including the undefined trench area), and the OHF area (also due to migration from SWSA 5 South).

B2.5.4 Cobalt-60

Cobalt-60 concentrations in soil and sediment were less than background levels (0.02 pCi/g) over most of WAG 5 (Fig. B2.5.5) except for samples from the OHF pond and PWSB. Two seeps near the fissile storage area had elevated ^{60}Co concentrations, but this was not seen in the downgradient sediment samples of the D-1 drainage. The only occurrence of ^{60}Co in surface water above the 10E-04 risk threshold was in a sample from the Melton Branch weir. Cobalt-60 is not a significant groundwater contaminant at WAG 5. Although several wells showed concentrations of ^{60}Co above the background level (9.6 pCi/L), no WAG 5 groundwater samples had concentrations that exceeded risk-based concentration (310 pCi/L).

B2.5.5 Strontium-90

Strontium-90 activity in soil and sediment (Fig. B2.5.6) was limited to background concentrations (2 pCi/g) or below detection limits over most of WAG 5. Concentrations above background but below the risk-based level (2200 pCi/g) were prevalent in the D-2 drainage and surrounding OHF. The highest concentrations of ^{90}Sr were found in PWSB and OHF pond sediments and near a seep in SWSA 5 South.

Strontium activity in surface water is consistently high, and samples from White Oak Creek, Melton Branch, and all three interior drainages exceeded the risk-based concentrations from WAG 5. Maximum concentrations were observed in seeps adjacent to the trenches and along Melton Branch.

Radioactive strontium in groundwater was detected only occasionally in the northern portion of WAG 5, but a few isolated locations exceed the MCL (8 pCi/L). As with tritium, the areas having unacceptable levels of radioactive strontium (> 130 pCi/L) are associated with the SWSA 5 trenches.

B2.5.6 Cesium-137

Cesium-137 in soil was detected mainly in the southern portion of WAG 5 (Fig. B2.5.7). Similar to ^{90}Sr, ^{137}Cs in soil was primarily in the D-2 drainage and surrounding OHF. Cesium-137 concentrations (>220 pCi/g) were also high in PWSB and OHF pond sediments. Cesium-137 exceeded background (40 pCi/L) at isolated surface water locations throughout WAG 5. Concentrations exceeding the risk threshold were detected in samples from drainages D-1 and D-3 and in the reach of Melton Branch Tributary above the confluence with D-3, indicating the presence of an upstream source area. Cesium-137 is not a significant groundwater contaminant at WAG 5.

B2.5.7 Americium-241

Americium-241 in groundwater exceeded the 10^{-4} risk threshold in SWSA 5 North and in area A (Fig. B2.5.8). Highly elevated concentrations were detected in a groundwater sample from trench 61 in area B and in sediment samples from both PWSB and the OHF pond. Americium-241 was detected above 1 pCi/L but below risk levels in surface water samples from Melton Branch, Melton Branch Tributary above the D-3 confluence, and drainage D-2.

B2.5.8 Curium-243/244

The greatest levels of $^{243/244}Cm$ above the risk threshold were detected in the PWSB and OHF pond. SWSA 5 North also had levels above the risk threshold in the RCRA perimeter well downgradient of the trenches in that area. Other WAG 5 RCRA perimeter wells also detected levels of $^{243/244}Cm$, but were generally below the risk threshold. The perimeter wells which detected $^{243/244}Cm$ were shallow with their corresponding deeper wells not detect any. Low levels of $^{243/244}Cm$ were detected in sediment samples from drainage D-2 which is suspected to be released from trenches immediately east of the drainage. Curium-243/244 was also detected at below risk levels in the soil directly below SP008. The low levels of $^{243/244}Cm$ detected at surface water station SW003 in drainage D-3 are believed to be from the upper trenches in area A.

B2.5.9 Plutonium-238

Plutonium-238 was detected above risk levels in the sediment sample from the OHF pond and a groundwater sample taken downgradient of the undefined trench area (Fig. B2.5.10). Plutonium-238 was also detected in surface water samples taken from all three drainages and in samples taken over Melton Branch weir. Sediment samples in D-2 also had elevated activities of ^{238}Pu.

B2.5.10 Vinyl Chloride

Vinyl chloride was detected primarily in groundwater in the shallow RCRA wells along the southern perimeter of WAG 5. These wells had concentrations ranging from 5 to 4000 mg/L; the greatest concentration was found downgradient of the dump area in the White Oak Creek study area. Vinyl chloride was also detected in a number of seeps, typically at estimated values below 10 mg/L but above the 10^{-4} risk level of 2.5 µg/L. SP014, however, had concentrations at 73 mg/L. Sediment samples adjacent to SP014 in D-2 also high levels of vinyl chloride (> 500 mg/kg), but it was not detected in any soil samples.

Table B2.5.1. Area-specific contamination summary for WAG 5

	Source Status & Waste/Types	Contamination Summary
Process Waste Sludge Basin	*Inactive/Potential Source* • Surface water (220 m^3) w/ low activities of ^{90}Sr, ^{60}Co, ^{137}Cs, TRU • Sludge & sediment (960 m^3) w/ inventory of ^{90}Sr (8 Ci), ^{137}Cs (4 Ci), ^{60}Co (< 1 Ci), minor TRU	*All Media* • No evidence of any releases of contamination from the PWSB
SWSA 5 North	*Active Sources:* • 10 partially inundated & bathtubbing trenches with alpha-contaminated LLW and TRU wastes in boxes • Bldg 7831A Decon Pad drain field *Inactive/Potential Sources:* • 17 partially inundated & upland trenches with alpha-contaminated LLW and TRU in concrete casks *Inactive/Unlikely Sources:* 8 stainless-steel storage wells	*Groundwater* • Well 0516 w/ high concentrations of ^{241}Am, ^{244}Cm (63-250 pCi/L in filtered samples collected in 1993; historically as high as 5940 pCi/L) • Episodic releases of actinides create intermittent "plumes" with low levels of contamination (^{241}Am, ^{244}Cm, ^{238}Pu) migrating toward White Oak Creek, North Tributary and D-1 *Soil* • No TRU contamination in soil borings on perimeter of 7802N trenches • No significant levels of contamination • Slightly elevated U/Th decay series in surface soils--probably not site-related--has risk impact *Seeps* • Low concentrations of actinides in episodic (seasonal) releases along White Oak Creek *Downgradient Surface Water and Sediment* • Infrequent detections of low concentrations of actinides in White Oak Creek confirms release to downgradient surface water; overall flux is insignificant
Fissile Storage	*Active Sources:* • Trench 36 (landfill) w/ debris, possibly includes sludge *Potential Sources (may be active)* • 2 Fissile waste trenches w/ ^{235}U • 151 Fissile waste auger holes w/ ^{235}U, lesser amounts of ^{233}U • Ravine Landfill	*Groundwater* • Limited data show ^{137}Cs in shallow groundwater; ^{137}Cs & ^{90}Sr in stormflow zone • Upgradient groundwater is contaminated w/ ^{90}Sr & ^{3}H from undefined trench area (SWSA 5 South Area B) *Soil* • Surface soil in USRADS hot spot indicate elevated ^{137}Cs, ^{60}Co, ^{90}Sr, ^{234}U, and ^{238}U *Seeps* • Seep at base of trench 36 shows ^{235}U and other U/Th isotopes, ^{3}H minor ^{90}Sr • No significant contamination in seep at base of Ravine Landfill *Downgradient Surface Water and Sediment* • ^{235}U was detected in surface water and sediment of D-1; flux increases during storms • Discharge from this area contributes bulk of ^{90}Sr, ^{3}H, ^{60}Co, and gross alpha flux in D-1; overall contribution to contaminant flux in White Oak Creek is insignificant

Table B2.5.1. Area-specific contamination summary for WAG 5 (cont.)

	Source Status & Waste/Types	Contamination Summary
SWSA 5 South - White Oak Creek	*Active Sources* • 12 Trenches organics, TRU, high & low activity, misc. & acid wastes • 110 Auger Holes w/ organic & misc. radioactive wastes • Dump area w/ debris, misc. wastes & soil w/ ^{137}Cs, ^{90}Sr	*Groundwater* • Low levels of ^{137}Cs and ^{60}Co in shallow groundwater • High concentrations of VOCs in perimeter well 0978, including 1,2-DCE (1600-3300 µg/L),and vinyl chloride (2700-4000 µg/L); VOCs detected in lower concentrations in several other shallow wells , mostly in concentrations <100 µg/L *Soil* • High gamma exposures in surface soil over trenches based on USRADS • Surface soils in USRADS hot spot show relatively high ^{137}Cs, ^{90}Sr, ^{60}Co *Seep* • ^{60}Co, ^{90}Sr, TCE, DCE & vinyl chloride in seep downgradient of trenches, auger holes & dump area *Downgradient Surface Water and Seeps* • Discharges from this area comprise the largest component of radionuclide input to White Oak Creek from WAG 5; overall, radionuclide flux is negligible. • VOCs not detected in White Oak Creek; apparently due to loss from volatilization
OHF Waste Pit T-4	*Inactive/Potential Source* • 3 cell concrete pit containing 20 m^3 monolith of radioactive grout Contaminated water & sediment	*Groundwater* • Upgradient groundwater is contaminated w/ ^{90}Sr & ^{3}H from SWSA 5 South Area C *Soil* • Localized areas of surface soil contamination (^{90}Sr, ^{137}Cs) attributed to incidental, *de minimis* releases from OHF operations; no evidence of release from the Waste Pit • Deeper soil contamination at depth of water table unrelated to Waste Pit *Downgradient Surface Water & Sediment* • No specific contribution from Waste Pit T-4 was identified
OHF Waste Storage Tanks	*Inactive/Potential Source* • 5 carbon steel tanks w/ 20 m^3 of ILW sludge residues w/ >4500 Ci ^{90}Sr, ^{137}Cs, ^{244}Cm, ^{239}Pu, ^{239}Pu, ^{60}Co, ^{144}Ce	*Groundwater* • Upgradient groundwater is contaminated w/ ^{90}Sr & ^{3}H from SWSA 5 South Area C; no indication of release from tanks *Soil* • Localized areas w/ slightly contaminated surface soil (^{137}Cs, ^{238}Pu) • Deeper soil contamination (^{90}Sr) at depth of water table unrelated to Waste Storage Tanks *Downgradient Surface Water and Sediment* • No specific contribution from OHF Waste Storage Tanks was identified

Table B2.5.1. Area-specific contamination summary for WAG 5 (cont.)

	SOURCE STATUS & WASTE/TYPES	CONTAMINATION SUMMARY
OHF POND	*Active Sources*: • Sediment:(54 m^3) with 79 Ci ^{137}Cs (62 Ci), ^{90}Sr (12 Ci) ^{244}Cm (5 Ci) • Surface Water (380 m^3) w/ inventory <0.007 Ci, include. ^{90}Sr, ^{137}Cs, ^{60}Co, ^{99}Tc and ^{233}U,	*Groundwater* • Pond in direct communication with water table • High concentrations of ^{137}Cs, ^{90}Sr, ^{60}Co, 233U, ^{244}Cm ^{238}Pu detected in groundwater (also detected in Pond) *Soil* • USRADS hot spot borings in vicinity of pond show elevated concentrations of ^{137}Cs; contamination attributed to releases during operations, not due to overflow of Pond *Downgradient Surface Water and Sediment* • The bulk of the contaminant flux into White Oak Creek from OHF area is from discharge of contaminated groundwater from OHF Pond; • Overall input as a function of the total contaminant flux in White Oak Creek is minor
SW-3	*Potential Source* • Hillside dump (0.2 ha) w/ clean & contaminated solid waste, debris, misc. Equipment, trash, drum 137, ^{60}Co, ^{90}Sr, minor TRU	*Groundwater* • Perimeter wells show periodic, minor increases in ^{60}Co and ^{3}H concentrations; groundwater quality in area has not been impacted *Soil* • USRADS hot spot in vicinity of drum had minor levels of ^{137}Cs and ^{90}Sr *Seeps* • No contamination in seep opposite base of landfill. *Downgradient Surface Water and Sediment* • Surface water samples from D-3 indicate little to no contamination
SWSA 5 SOUTH AREA A	*Active Sources* • 56 inundated trenches • 23 upland trenches trench types include 16 high activity β–γ, 14 low activity β–γ, 4 TRU, 1 sludge, 35 biological waste, 9 unknowns • 121 Auger holes: most probably contain biological waste	*Groundwater* • Extremely high ^{3}H concentrations (up to 3.5E+08 pCi/L); highest concentrations in inundated trenches but widespread, high levels of ^{3}H contamination exist throughout the area • Southern area also has high concentrations of ^{137}Cs, ^{90}Sr, 14C, highest levels were in trench water but contaminants have migrated throughout this portion of Area A • High gross alpha detected in several trench water samples but no appreciable migration from trenches has occurred *Soil* • Samples from USRADS hot spot show high levels of ^{137}Cs and ^{90}Sr • No evidence of widespread soil contamination outside of seep areas (based on USRADS and soil sampling) *Seeps* • Seeps discharging high concentrations of ^{3}H similar to levels observed in groundwater • Individual seeps with high gross alpha and/or ^{90}Sr, ^{14}C *Downgradient Surface Water and Sediment* • Contributes 100% of tritium flux measured in Melton Branch Tributary, also significant quantities of ^{90}Sr • Discharge from Area A is a sizable contributor (20%) of ^{3}H flux in Melton Branch

Table B2.5.1. Area-specific contamination summary for WAG 5 (cont.)

	Source Status & Waste/Types	Contamination Summary
SWSA 5 South Area B	Active Sources • 45 inundated trenches • 29 upland trenches trench types incl. 5 high activity β–γ, 17 low activity β–γ, 13 biological waste, 31 unknown • 177 auger holes waste types unkown	*Groundwater* • Widespread, high levels of ^{3}H contamination w/ significantly higher levels in trenches • Several trenches with high ^{90}Sr, ^{3}H and gross alpha; isotopic analyses from trench 61 show ^{241}Am in concentration > 1.0E+06 pCi/L • Groundwater from undefined trench area has significant levels of ^{238}Pu and other TRU isotopes; chlorinated VOCs (TCE, DCE, vinyl chloride) also detected *Soil* • USRADS show no surface soil contamination outside of seep areas *Seeps* • Seeps discharging high concentrations of ^{3}H into Melton Branch • VOCs in seeps along D-2 (possible sources include undefined trench area, Area C) *Downgradient Surface Water and Sediment* • VOCs in D-2 sediment downgradient of seeps; • Significant contributor (67%) of ^{3}H flux in Melton Branch 5
SWSA 5 South Area C	*Active Sources*: • 13 inundated trenches • 44 upland trenches trench types include 14 high activity β–γ, 7 low activity β–γ, 8 TRU, 1 biological, 27 unknown • 331 auger holes *Inactive/unlikely Sources*] • 13 concrete lined vaults	*Groundwater* • Widespread, high concentrations of ^{3}H • Several trenches with high ^{90}Sr, ^{3}H and gross alpha; smaller number with high ^{137}Cs • High concentrations of ^{90}Sr along flowpaths from trenches to seep discharge area *Soil* • Localized areas with high gamma exposures in seep discharge areas • .Soil samples from USRADS hot spot locations show high ^{90}Sr, ^{137}Cs *Seep* • Seep SP006 (seep "C") major contributor of ^{90}Sr to Melton Branch • RI sampling results for SP006 had maximum filtered result of 689,550 pCi/L for ^{90}Sr *Downgradient Surface Water and Sediment* • Significant contributor (60%) of ^{90}Sr flux in Melton Branch and at White Oak Dam (25%) • ORNL ER initiated Removal Action for treatment of seep C discharges in Nov 1994
SWSA 5 South Area D	No sources of contamination identified	*Groundwater* • Widespread ^{3}H contamination (> 1.0E+06 pCi/L) • No other contamination except ^{90}Sr from samples in vicinity of seep *Soil* • No significant contamination; slightly elevated ^{137}Cs detected in floodplain soils near seep Seeps • Seep "D" major contributor of ^{90}Sr to Melton Branch • RI sampling showed maximum of 32,145 pCi/L of ^{90}Sr (filtered) *Downgradient Surface Water and Sediment* • Removal Action for interception and treatment of seep D discharges initiated November 1994

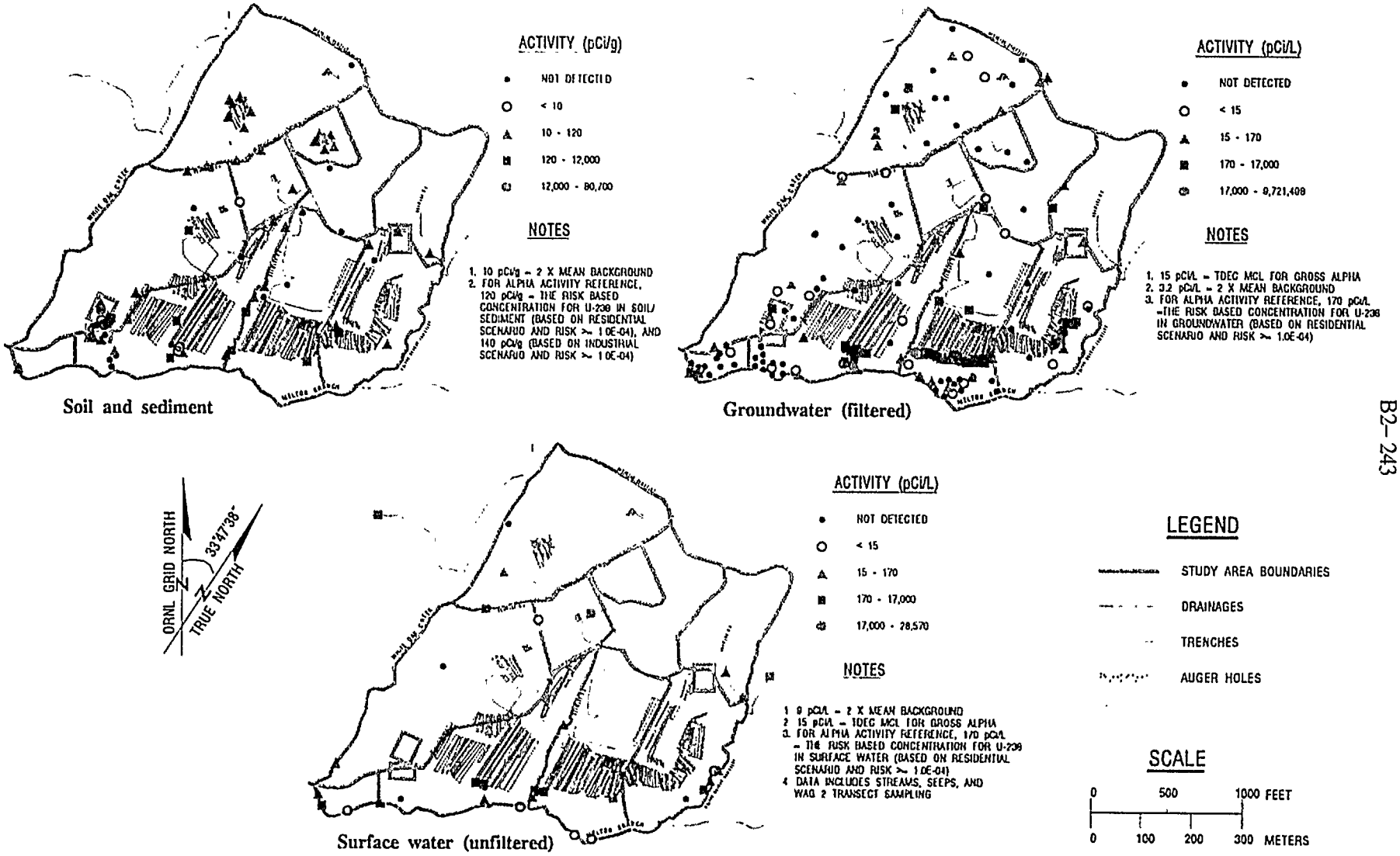


Fig. B2.5.1 Maximum gross alpha activity in all media.

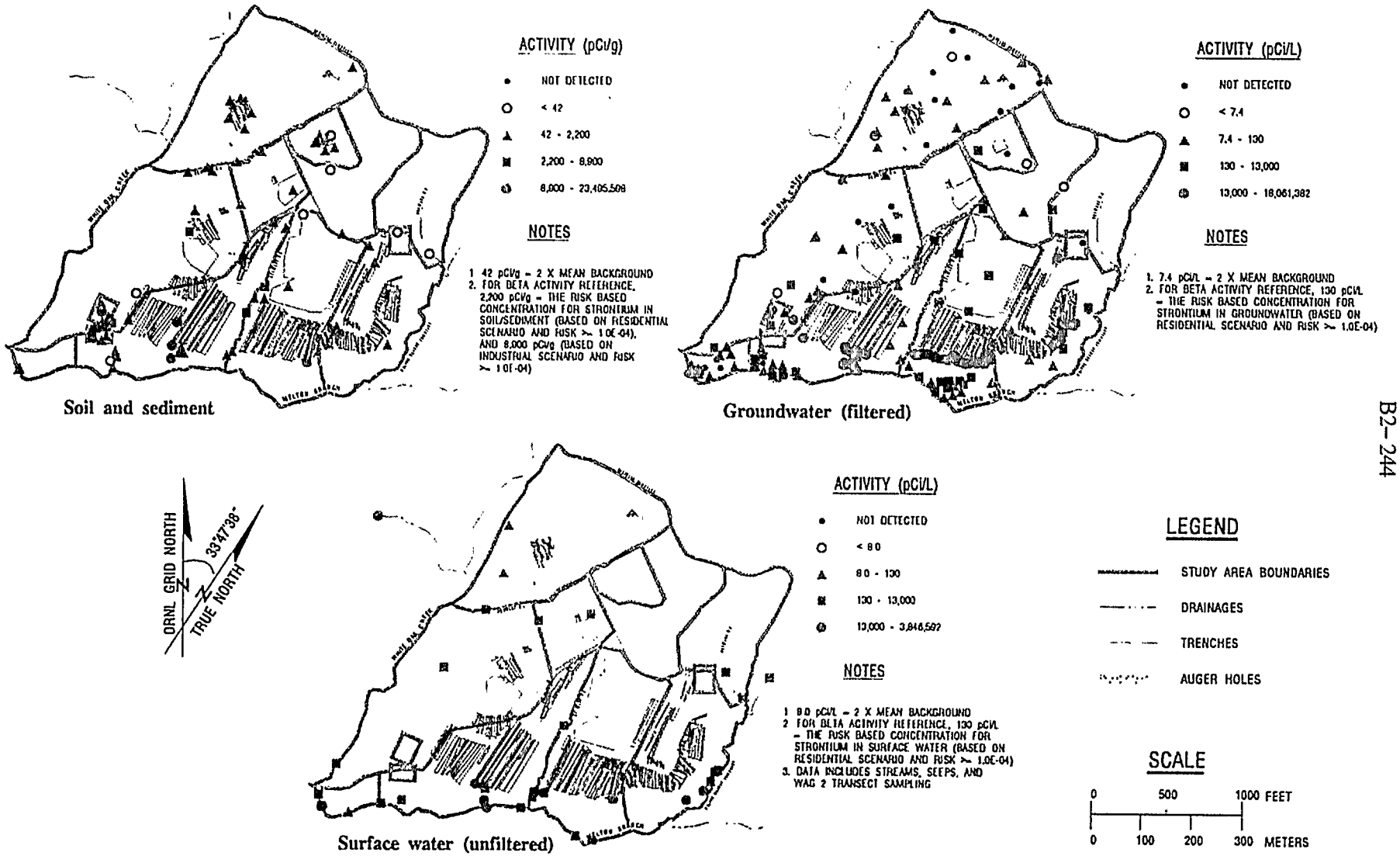


Fig. B2.5.2. Maximum gross beta activity in all media.

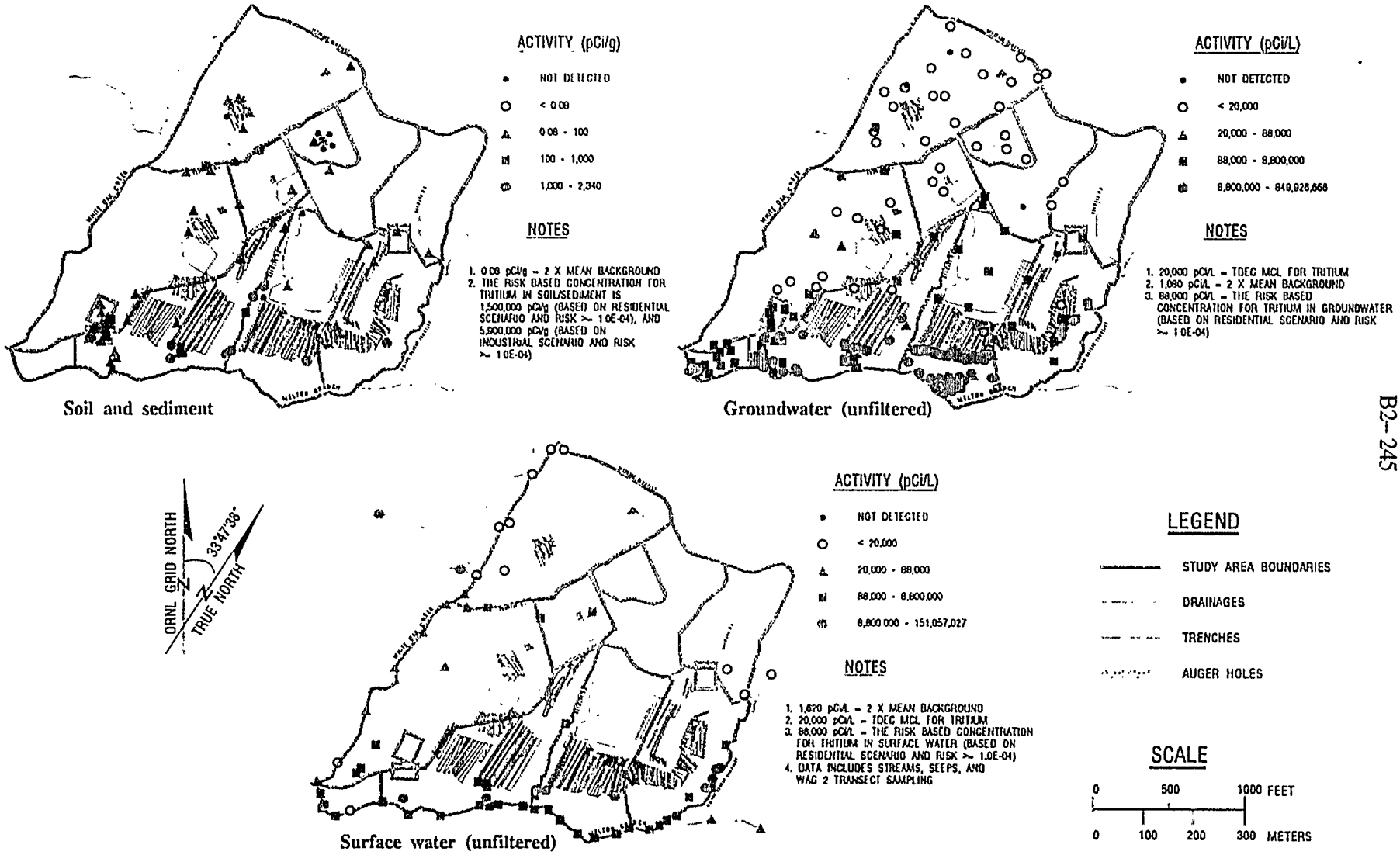


Fig. B2.5.3. Maximum tritium activity in all media.

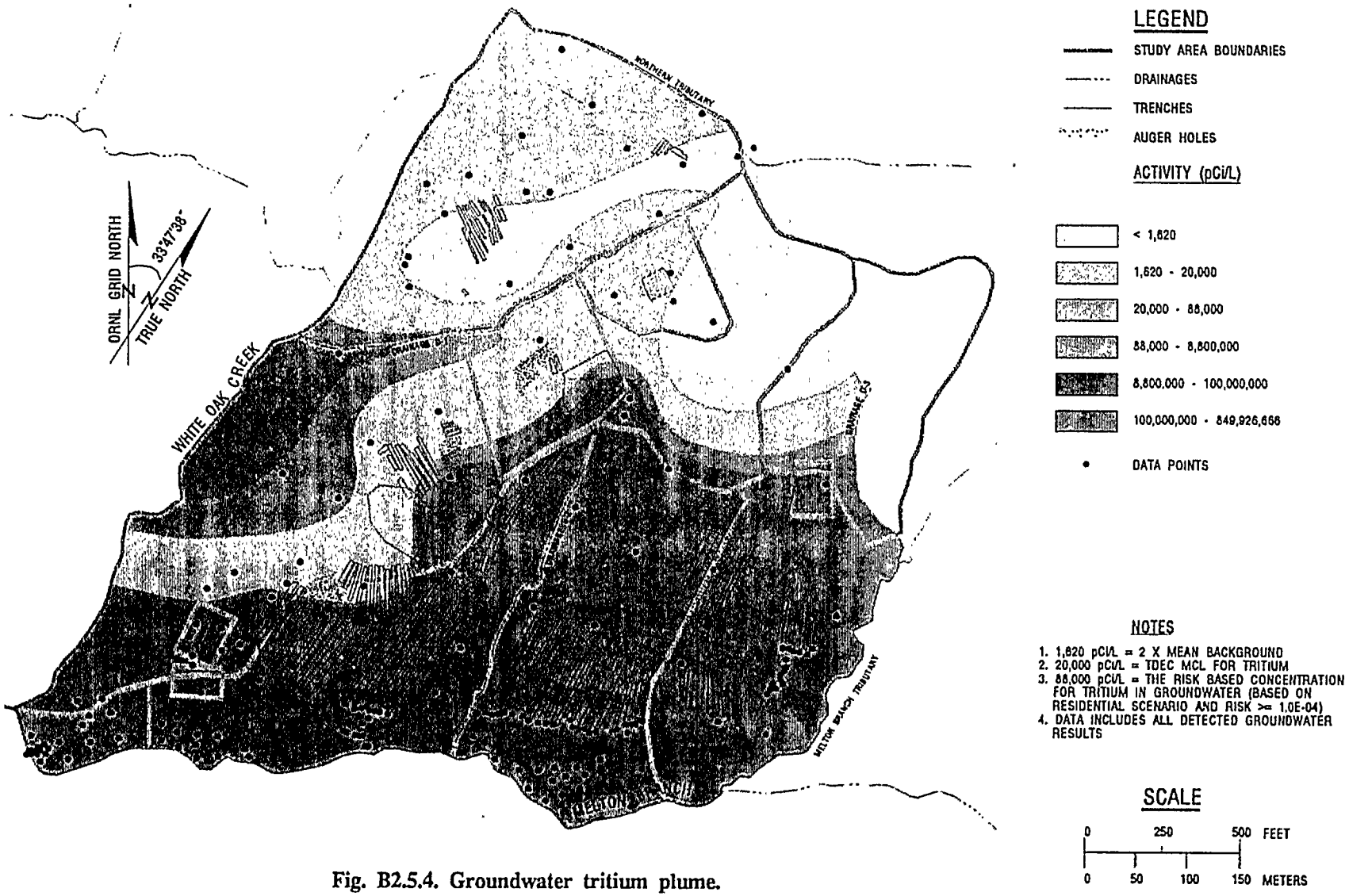


Fig. B2.5.4. Groundwater tritium plume.

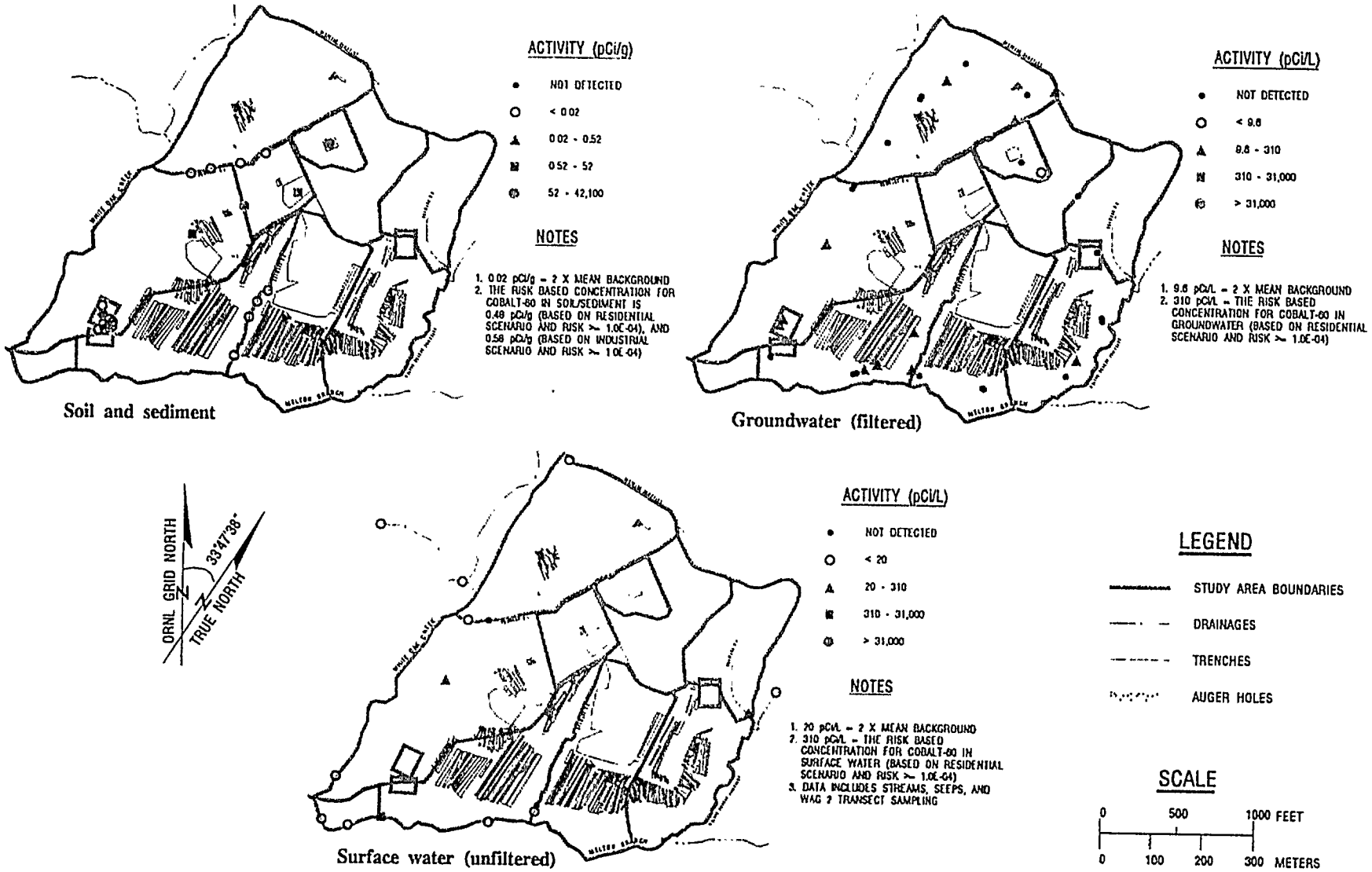


Fig. B2.5.5. Maximum cobalt-60 activity in all media.

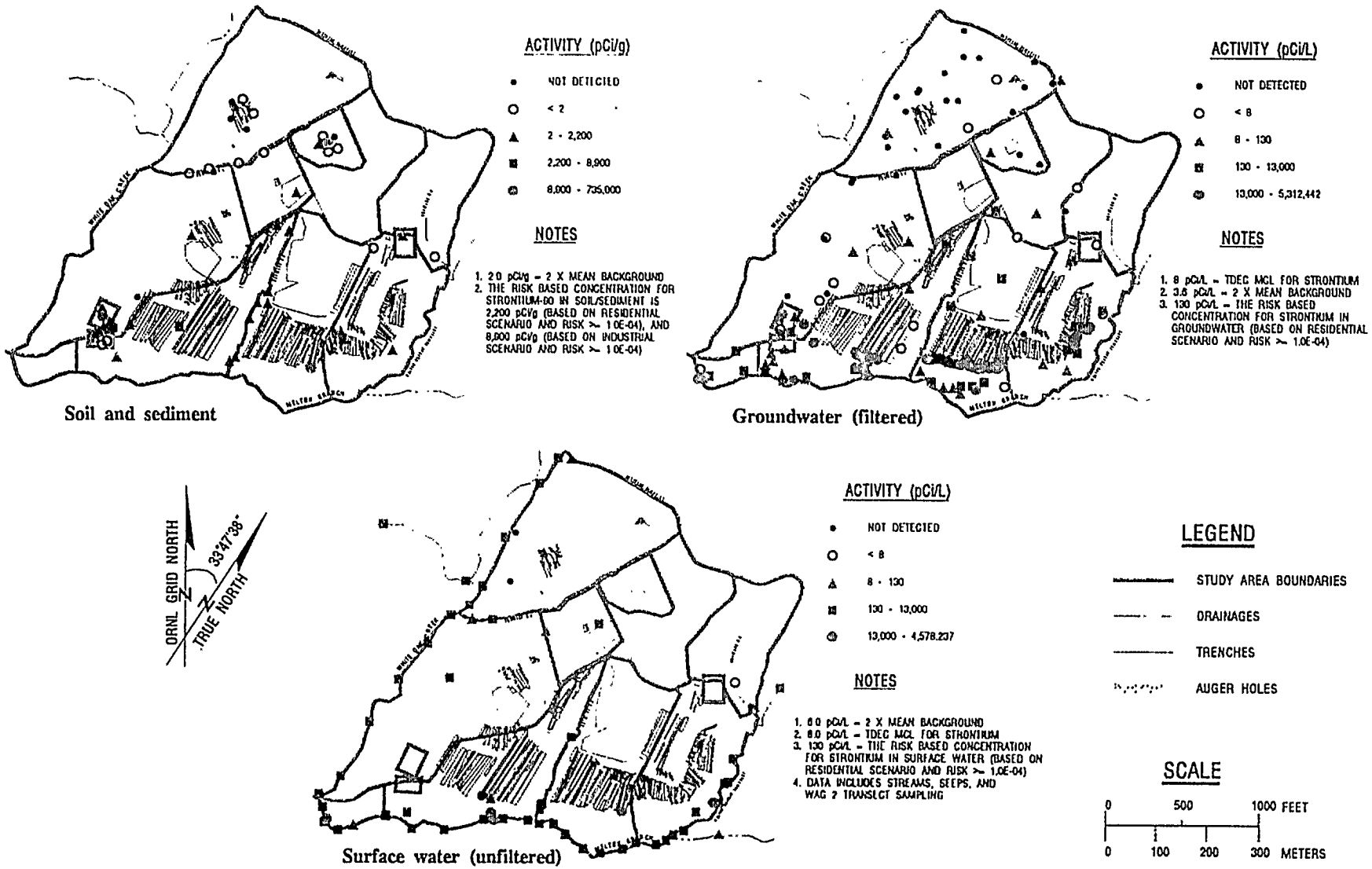


Fig. B2.5.6. Maximum strontium activity in all media.

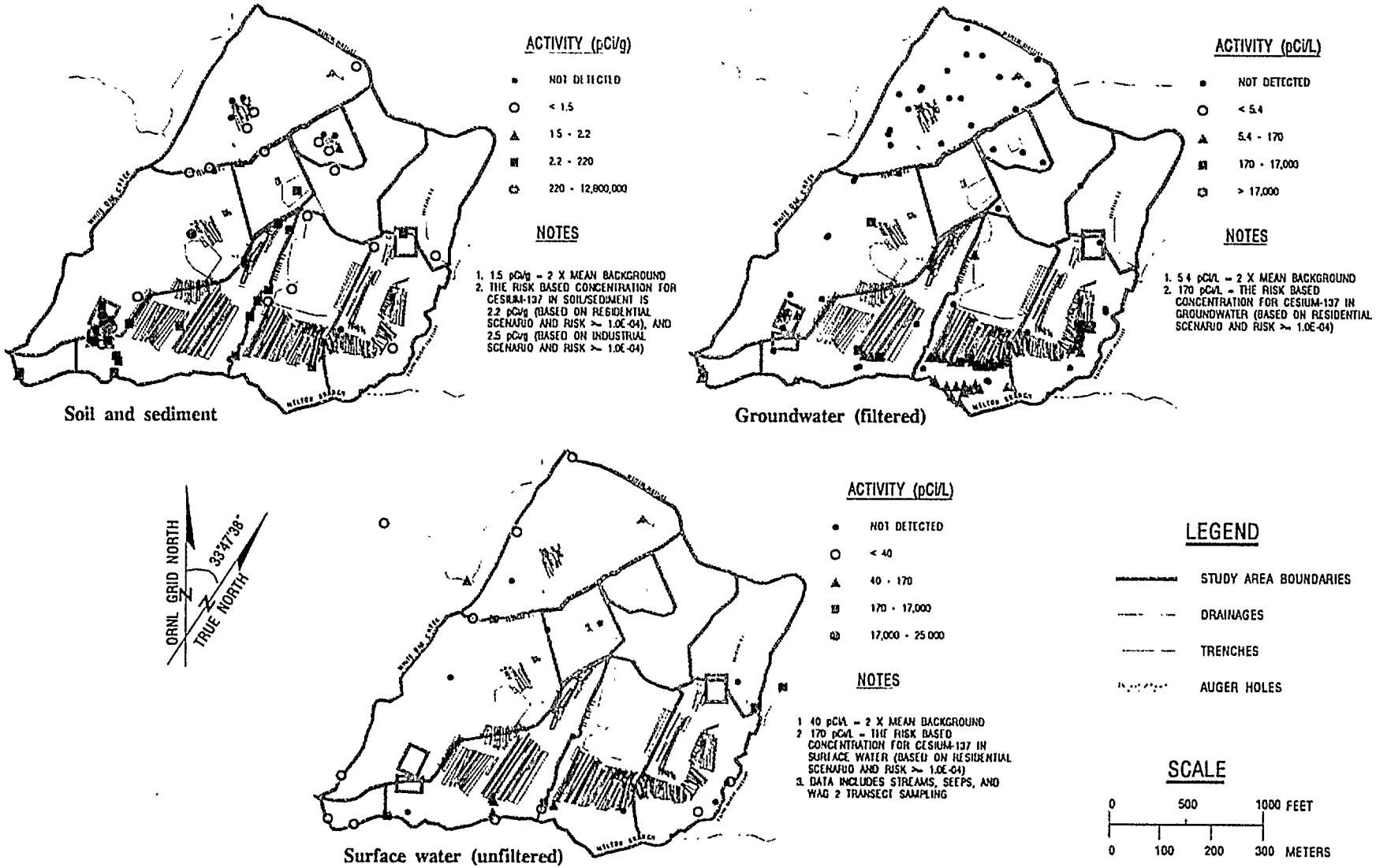


Fig. B2.5.7. Maximum cesium-137 activity in all media.

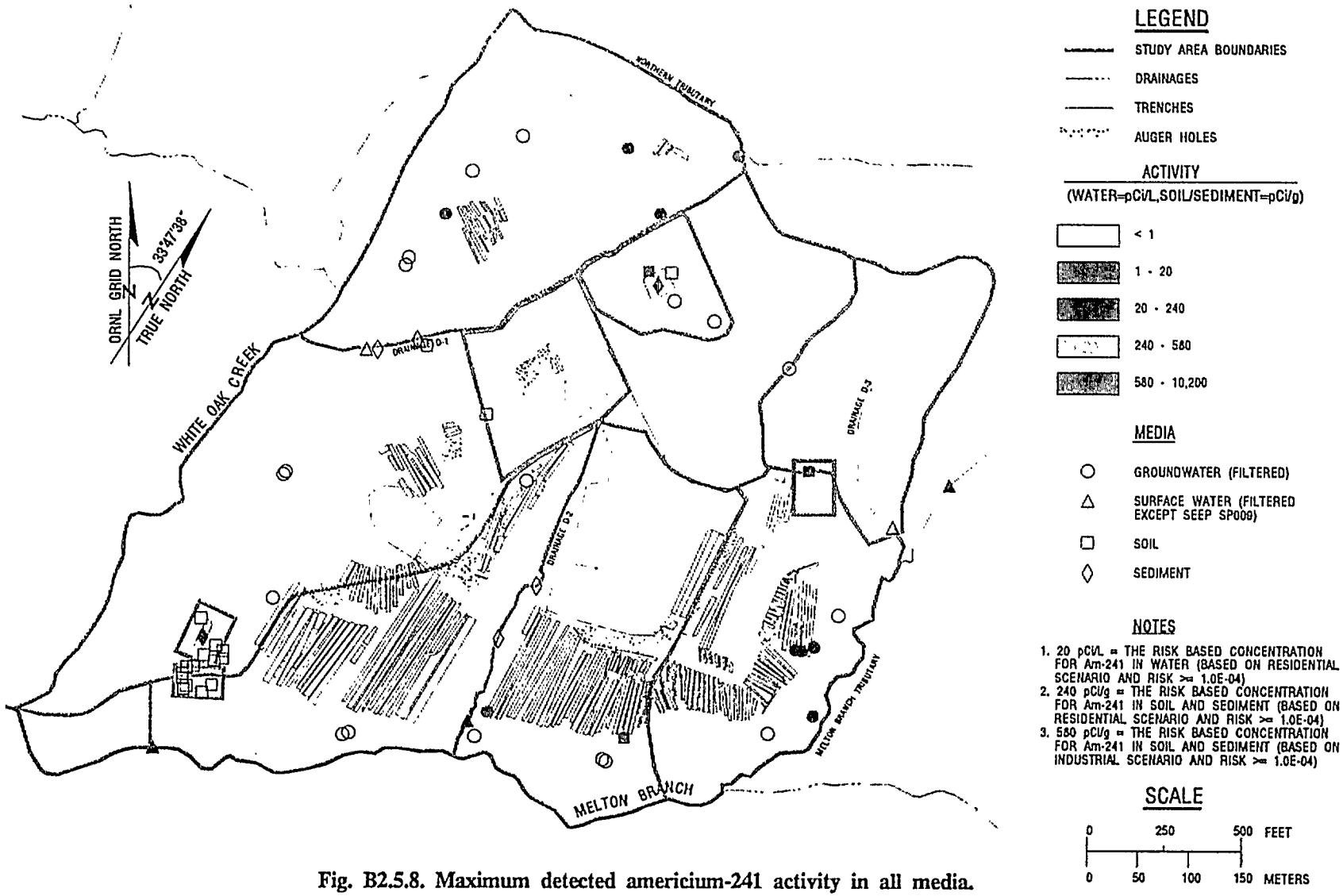
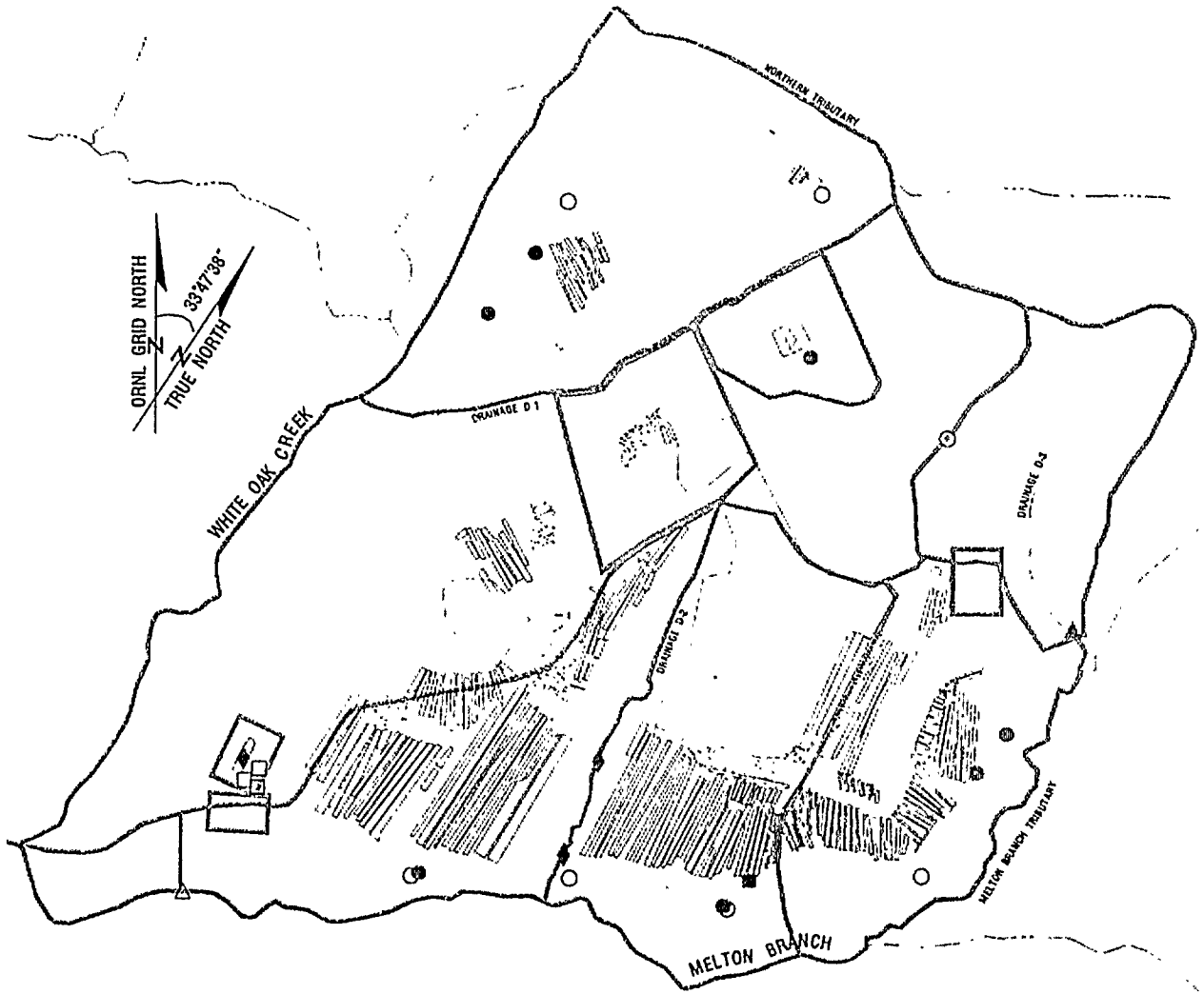


Fig. B2.5.8. Maximum detected americium-241 activity in all media.



LEGEND

- STUDY AREA BOUNDARIES
- DRAINAGES
- TRENCHES
- AUGER HOLES

ACTIVITY
(WATER=pCi/L,SOIL/SEDIMENT=pCi/g)

- < 1
- 1 - 31
- 31 - 510
- 510 - 2,000
- 2,000 - 24,400

MEDIA

- ○ GROUNDWATER (FILTERED)
- △ SURFACE WATER (FILTERED)
- □ SOIL
- ◇ SEDIMENT

NOTES

1. 31 pCi/L = THE RISK BASED CONCENTRATION FOR Cm-243/244 IN WATER (BASED ON RESIDENTIAL SCENARIO AND RISK >= 1.0E-04)
2. 510 pCi/g = THE RISK BASED CONCENTRATION FOR Cm-243/244 IN SOIL AND SEDIMENT (BASED ON RESIDENTIAL SCENARIO AND RISK >= 1.0E-04)
3. 2,000 pCi/g = THE RISK BASED CONCENTRATION FOR Cm-243/244 IN SOIL AND SEDIMENT (BASED ON INDUSTRIAL SCENARIO AND RISK >= 1.0E-04)

SCALE

0 250 500 FEET
0 50 100 150 METERS

Fig. B2.5.9. Maximum detected curium-243/244 activity in all media.

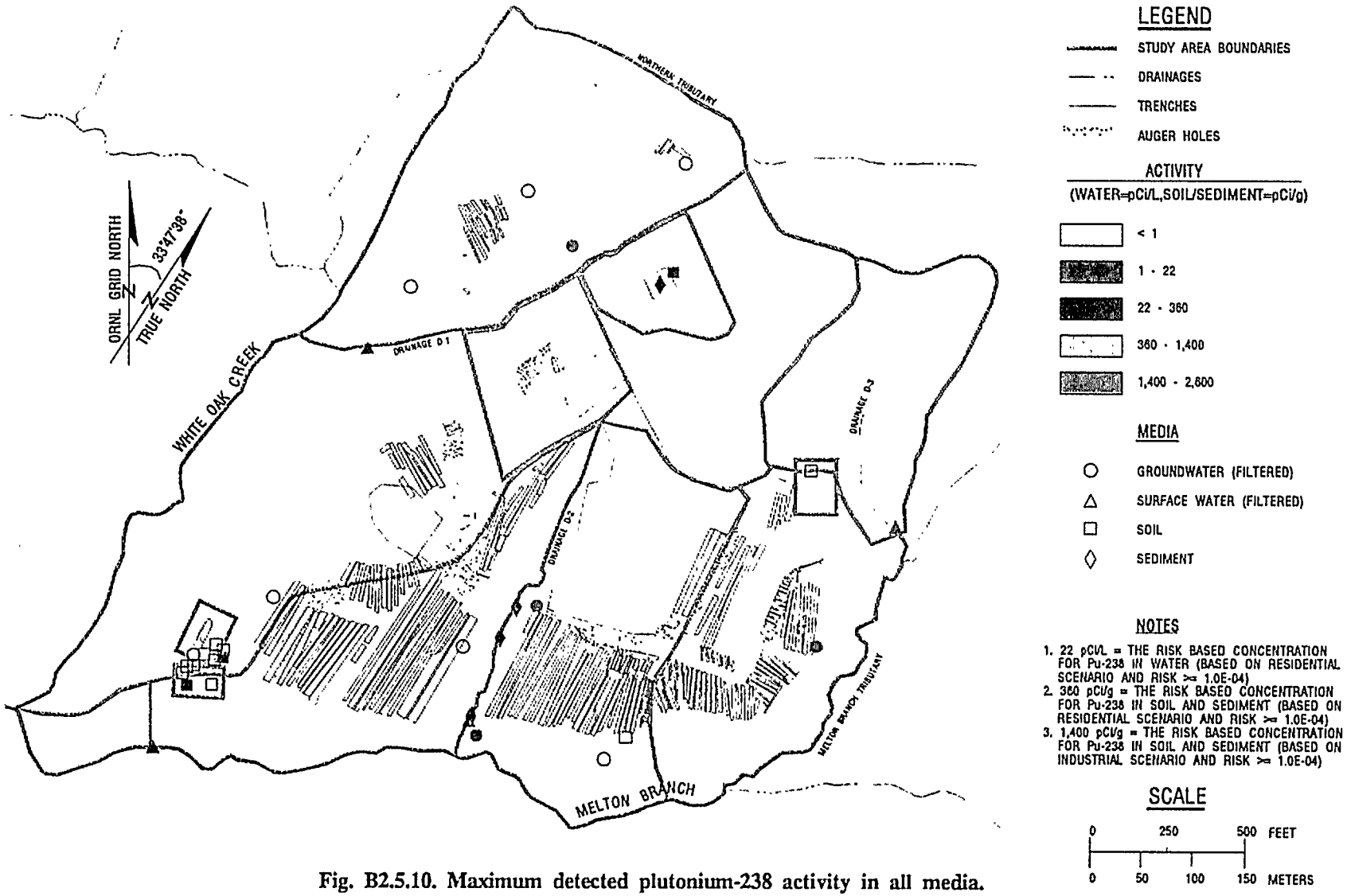


Fig. B2.5.10. Maximum detected plutonium-238 activity in all media.

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B3. CONTAMINANT FATE AND TRANSPORT

B3.1 INTRODUCTION

This assessment of contaminant fate and transport at WAG 5 is intended to support Appendix B2 (Nature and Extent of Contamination) in defining areas that are significant contributors to on-site and off-site receptors. Because knowledge of the actual contaminant sources is limited and the site history is complex, this assessment does not provide a quantitative model of future contaminant migration or an exposure point concentration for future human health risk assessment purposes. Identification of historical and current contaminant transport from source areas in WAG 5 supports prioritization of remedial actions, and information regarding the fate of WAG 5 contaminants, especially the shorter-lived radionuclides, has a potentially significant influence on the prioritization process.

The fate and transport of contaminants in the environment are governed by their physical, chemical, and radiological characteristics and their interactions with environmental media. The physical processes of advection and dispersion, which control transport, are largely dependent on characteristics of the media. Change in the contaminant mass can result from chemical or biological reactions or radiological decay.

This discussion of fate and transport is limited to the primary radionuclides observed at the WAG 5 boundaries. Some VOCs have also been detected within WAG 5, but their impact on site risks is greatly overshadowed by that from radiological contaminants. Tritium and radioactive strontium (reported as ^{90}Sr) are discussed as discrete isotopes, and gross alpha and gross beta activities are used as indicators of other radionuclides present.

The properties of radionuclides most relevant to their fate and transport are radioactive half-life and mobility in water. Half-life is a statistical measure of the time required for a radionuclide to decay to one-half its original activity level. It is an inherent property of and specific to each radionuclide (Table B3.1.1). Mobility is governed by the chemical form of the radionuclide, the geochemistry of the environment (primarily groundwater in the subsurface), the mineralogical composition of the soil and bedrock, and the physical structure of the transport medium. These influences are characterized by the distribution coefficient (K_d), a parameter describing the bulk mobility of a contaminant in water. Distribution coefficients are largely controlled by clay mineralogy and the total organic carbon content of the soils and are site-specific; they can vary greatly even among samples from the same area.

Tritium is transported by groundwater and has the same mobility as water (i.e., it has a K_d equal to 0). Accordingly, tritium distribution is a useful tool for measuring the maximum transport rate for any contaminant and absolute groundwater velocities. Its presence and quantity downgradient of a source is a direct indicator of migration pathways unaffected by the transport media. By contrast, strontium is particle reactive (adsorbed by charged clay particles) and taken up in subsurface chemical reactions. Strontium is chemically similar to calcium and often substitutes for calcium in those reactions. It is reported to have K_d values upward of 2400 and was measured in the range of 13.5 to 8.1 for the WAG 1 RI (Table 5.1.2, DOE 1992).

Table B3.1.1. Half-lives of primary radiological contaminants at WAG 5

RADIONUCLIDE	HALF-LIFE (yrs)
^{241}Am	432
Tritium	12.33
^{60}Co	5.27
^{90}Sr	28.8
^{244}Cm	18.1
^{137}Cs	30.17
^{226}Ra	1.6×10^3
^{228}Ra	5.76
^{234}U	2.45×10^5
^{235}U	7.038×10^8
^{238}U	4.468×10^9
^{238}Pu	87.74
^{239}Pu	2.41×10^4
^{240}P	6.57×10^3

Source: Gilbert, T. L. et al. 1989

B3.1.1 Approach

Appendix B2 discusses the nature and extent of contamination in each study area within WAG 5. This appendix evaluates the site as a whole to characterize contaminant transport by examining temporal and spatial boundary conditions for WAG 5 and for divisions within the WAG. These boundaries coincide with the surface water drainages of White Oak Creek and Melton Branch and the interior drainages of WAG 5 (D-1, D-2, and D-3). Surface water is considered the dominant migration pathway for offsite releases from WAG 5; it integrates contaminant contributions from various sources and is an important exposure pathway for on-site and off-site receptors. Almost all of the groundwater at WAG 5 discharges to the surface water and ultimately flows over White Oak Dam. Transport by groundwater is the principal migration pathway for on-site contaminants and the primary main link between contaminant sources and the surface water integrator. The stormflow zone is also active as both a release mechanism and migration pathway, but it is not a significant transport medium for contamination.

The approach taken here is to observe contaminant concentrations along their migration pathway and correlate source data, groundwater contaminant concentrations (drive point and monitoring well samples), and surface water fluxes. Groundwater data were supplemented by sediment and seep data to identify contributions from specific areas of the site. Published results and WAG 5 RI results were used to determine contributions for major source areas. Historical long-term monitoring data were used to support interpretations about trends and the fate of primary radiological contaminants.

B3.1.2 Data Sources

Data are available from historical records, past investigations, and the current RI. ORNL researchers are conducting several investigations on specific aspects of contaminant migration in WAG 5, and data from these sources were incorporated where available. The data gathered for this RI are discussed in Appendix A2.

RI data for soil, groundwater, seeps, and sediments include the full range of analyses of metals, organics, and radionuclides. Samples collected from drive points for the source area investigation were analyzed at the CSL; these data are limited to ^{3}H, ^{90}Sr, gross alpha, gross beta, and VOCs. Many of the historical data are restricted to a few radionuclides. Tritium and strontium were common to most data sets and are incorporated into the discussion. Where appropriate, other isotopic data are presented and gross alpha and beta are used. When both on-site CSL screening analyses and off-site ASL radiochemical analyses are available, the ASL data were used. Both filtered and nonfiltered aliquots were analyzed for many water samples. Because strontium adsorbs to suspended solids in water, filtered samples were normally used to assess the dissolved (and therefore mobile) fraction of the contaminant.

B3.2 SOURCE CHARACTERIZATION

Historical records provide general inventories of waste types, dates, gross volumes, and possible radionuclides; however, specific knowledge of waste forms, isotope abundance/activity, or concentrations has often not been retained. Many waste sources are listed as cell debris (metal, scrap, piping, lab equipment, etc.), cell wastes (samples, by-products, etc.), or equipment scrap, junk, benches, chairs, bottles, pumps, filters, and carcasses. Similarly, isotopes listed for the waste sources may include ^{90}Sr, ^{244}Cm, ^{239}Pu, ^{137}Cs, ^{241}Am, ^{23X}U, ^{60}Co, ^{252}Cf, ^{147}Pm, ^{170}Tm, ^{75}Se, ^{90}Y, ^{131}I, ^{3}H, and/or TRU. The initial source mass is an unknown, and thus a change in the mass (i.e., depletion) through leaching cannot be estimated. Because of the absence of long-term monitoring data for WAG 5, any change in subsurface contaminant flux rate is also unknown and back-calculation of source depletion is not possible. Moreover, whether the contaminant flux has reached a steady state cannot be determined and, consequently, future releases to the environment cannot be confidently modeled.

The source areas investigation conducted as part of the WAG 5 RI (ORNL 1993a) for the trenches in SWSA 5 South produced trench-specific source data by placing drive points in the downslope terminus ("toe") of 44 trenches in SWSA 5 South areas A, B, and C. Most of these trenches were inundated by groundwater during 1993.

B3.3 TRANSPORT

Subsurface transport was assessed using several data sources including groundwater, seeps/springs, drive points, and sediments. Because tritium and strontium contribute the largest risk component to the site and comparable data sets are necessary to conduct an evaluation, these analytes are used to illustrate the transport phenomenon. Gross alpha and gross beta activities are used as surrogates for other radionuclides.

B3.3.1 Site-Wide Spatial and Temporal Transport

Site-wide contaminant transport from WAG 5 was assessed by evaluating the perimeter wells, which intersect the subsurface migration pathway between the waste sources and the surface water discharge points. These wells identify widespread movement from waste sources to the surface water drainages and provide a temporal and spatial characterization of subsurface transport. The perimeter wells cannot detect all contamination leaving the site because of the preferred migration pathways in the site regolith and bedrock. Because such features may result in point discharges, both seep data and sediment analyses are used to supplement the groundwater results.

The data set of groundwater analyses from the perimeter wells consists of three years of annual sampling by ORNL and two rounds of sampling by the WAG 5 RI team during the fourth year. Sixteen locations (22 wells) were sampled for the full range of metals, organics, and radionuclides. Six of the locations contain nested well pairs with one well screened in a deeper bedrock horizon. The shallow wells are screened at a depth of less than 30 ft from ground surface and are representative of shallow groundwater flow. Table B3.3.1 provides the well construction details. The wells were sampled during August 1990, June 1991, October 1992, and April and November 1993. With the exception of April 1993, the sampling events are representative of dry seasonal (low base flow) conditions.

Tritium is an excellent indicator of groundwater flow and maximum contaminant flux in the subsurface because it is essentially controlled by the physical parameters (hydraulic conductivity, gradient, effective porosity) of the subsurface system and is not retarded in the environment. Figure B3.3.1 displays the unfiltered tritium activity for all the perimeter wells over four years. No contrast between the high base and low base conditions is discernible. In fact, for the two rounds of groundwater samples taken in 1993, the average low base flow activity (17.9×10^6 pCi/L) is slightly higher than the average high base flow activity (17.6×10^6 pCi/L). A possible explanation is that tritium is leaching from the source areas in proportion to the hydrologic flux; while the total tritium flux increases during high flow periods, the relative concentration in the groundwater remains constant.

No overall temporal trends for tritium are obvious during the four-year period covered by the sampling. Anomalous high values were observed in August 1990 in some wells along White Oak Creek, but anomalous low values were seen in the same sampling event in some wells along Melton Branch. Tritium values for most of the other wells are generally consistent over this period (with a few possibly spurious exceptions).

Migration of tritium can be deduced from the extreme spatial variations seen in the perimeter wells around WAG 5, ranging over five orders of magnitude from background concentrations (1200 pCi/L mean, 2400 pCi/L maximum) to the highest concentration in well 0973 (300×10^6 pCi/L). The wells along the northern and northeastern (relative to grid north) portions of WAG 5 contain background concentrations. The highest overall tritium concentrations are hydraulically downgradient of and very close to the SWSA 5 South trenches. Elevated tritium levels are also noted along White Oak Creek in wells 0978/0979 and 0981 (but not 0980).

Table B3.3.1. Well construction details

Well	Date	Elev.	Top Bedrock	Screened Interval		TD	Screen ID	Casing Type
				Top	Bottom			
0963	7/28/87	837.5	23.4	64.8	94.8	95.0	1.9	SS
0964	7/30/87	831.8	22.3	29.0	49.0	49.2	1.9	SS
0965	8/17/87	812.5	2.5	18.3	28.3	28.5	1.9	SS
0966	8/24/87	810.2	2.0	9.1	24.1	24.4	1.9	SS
0967	8/21/87	852.4	22.7	29.7	59.7	60.0	3.9	SS
0968	8/24/87	809.6	8.3	10.2	20.2	20.4	1.9	SS
0969	8/28/87	786.0	8.3	5.3	15.3	15.6	1.9	SS
0970	8/25/87	784.9	11.7	59.7	74.7	75.0	3.9	SS
0971	8/26/87	775.9	7.7	9.7	14.7	14.9	1.9	SS
0972	8/31/87	774.7	14.0	59.7	74.7	75.0	3.9	SS
0973	9/9/87	774.8	13.3	10.3	15.3	15.5	1.9	SS
0974	9/1/87	771.2	10.7	12.1	22.1	22.3	1.9	SS
0975	9/9/87	783.1	10.3	18.0	28.0	28.3	1.9	SS
0976	8/22/89	784.1	11.3	68.9	83.9	84.2	3.9	SS
0977	7/14/87	765.9	10.2	4.5	19.5	19.8	1.9	SS
0978	7/23/87	765.7	4.4	9.7	19.7	20.0	1.9	SS
0979	8/13/87	765.8	9.9	34.3	49.3	49.6	3.9	SS
0980	8/17/87	764.2	10.2	34.7	49.7	50.0	3.9	SS
0981	7/25/87	762.3	7.6	9.7	19.7	20.0	1.9	SS
0982	8/11/87	775.6	2.8	6.2	16.2	16.4	1.9	SS
0983	8/14/87	789.0	8.6	9.7	24.7	25.0	1.9	SS
0984	8/19/87	789.3	13.5	59.7	79.7	80.0	3.9	SS

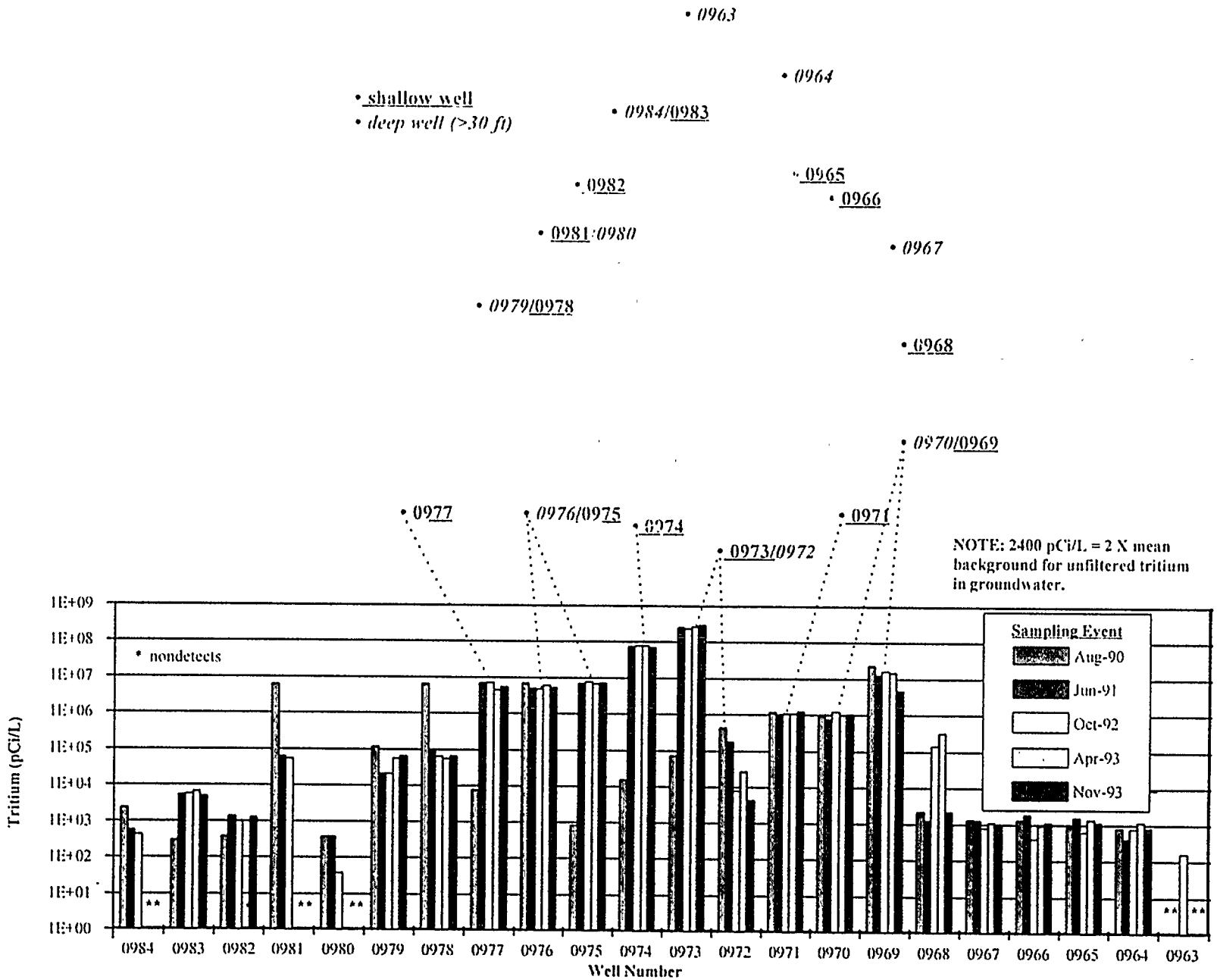


Fig. B3.3.1. Unfiltered tritium concentrations in perimeter wells.

Vertical migration of contaminants via deeper groundwater flow paths can be assessed by comparing tritium concentrations in the shallow and deep wells of nested pairs. Of the six pairs that surround WAG 5, four (0984/0983, 0981/0980, 0973/0972, 0970/0969) show lower tritium concentrations in deeper bedrock zones. The other two well pairs (0979/0978 and 0976/0975) have similar levels of tritium that greatly exceed background concentrations in both the deep and shallow wells, indicating a flow path in these areas from shallow groundwater into the deeper horizons.

Migration of strontium is more complex than that of tritium because it is reactive in the subsurface and may be affected by a number of factors. Figure B3.3.2 displays filtered sample results for total radioactive strontium for the same time period shown with tritium. Again, no obvious relationship is apparent between high and low base flow periods, and no temporal trends can be distinguished over the four-year period. Unlike tritium, strontium migration is generally localized at WAG 5; strontium was detected only in wells 0975, 0974, 0973, 0971, and 0969. Of this group, wells 0975 and 0969 had levels roughly two orders of magnitude higher than most WAG 5 wells. The remaining 17 wells are equivalent to or below background concentrations (5.2 pCi/L mean, 9.5 pCi/L maximum). Vertical migration of strontium into the deeper horizons has been very limited. Three of the four wells are the shallow well in a nested pair; none of the deep wells in the pair contain strontium concentrations exceeding background levels.

Gross alpha activity is displayed in Fig. B3.3.3; potential contributors to alpha activity include isotopes of the uranium/thorium decay series and transuranic elements. Levels for the WAG 5 perimeter wells are below those noted as the maximum background for gross alpha (11.4 pCi/L) in all but two instances, and most wells are near the average background concentrations (2.8 pCi/L). No difference was apparent during low and high base flow periods, and no overall temporal trend was obvious. The highest gross alpha levels were detected in wells 0973 and 0982. Well 0973 also had high strontium; it appears to have intersected a contaminant migration pathway downgradient of area B. Well 0982 is downgradient of SWSA 5 North, which contains TRU waste.

B3.3.2 Subsurface Contaminant Transport and Retardation

Data from the perimeter wells provide a site-wide view over time of contaminant migration from WAG 5 but do not estimate source loading to the system or attenuation in the subsurface. The WAG 5 source areas investigation (ORNL 1993a) measured contaminant loading in the SWSA 5 trenches and downgradient floodplain locations along Melton Branch with the intent of evaluating contaminant migration pathways to the creek. Drive points were installed at the lower ends of 48 trenches (Table B3.3.2); an additional 62 drive points were installed in the floodplain. Twelve seeps were monitored to support the drive point data.

One round of groundwater samples from each drive point was submitted to the CSL for gross alpha, gross beta, tritium, and total radioactive strontium analyses. Seep sampling events included one round of high base flow samples that were submitted to the ASL for complete radiochemical analyses. Some seeps for which there are CSL data were inaccessible during high base flow (SP010, SP013). The ASL analyses are used in this discussion except when specifically noted otherwise.

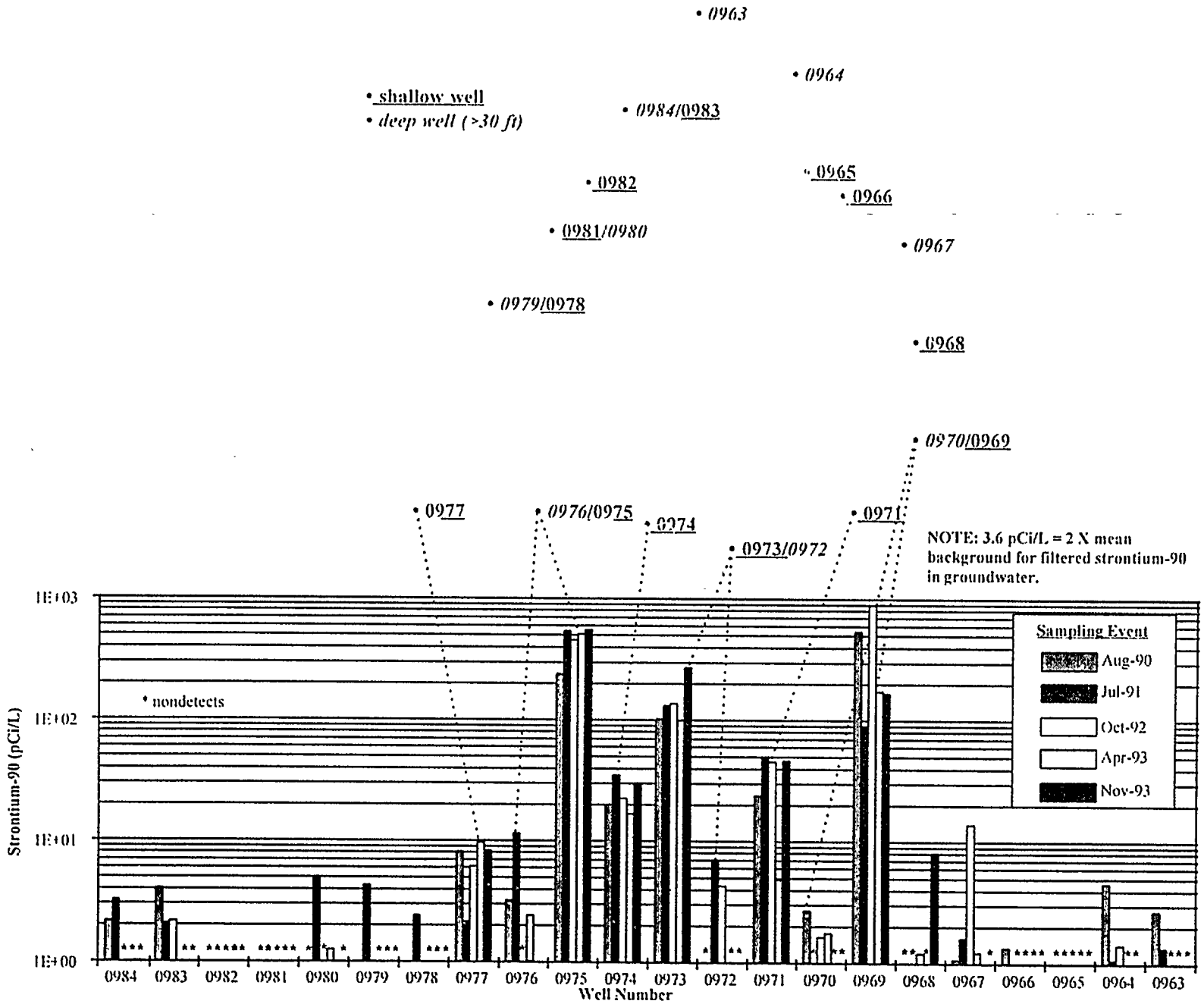


Fig. B3.3.2. Filtered strontium-90 concentrations in perimeter wells.

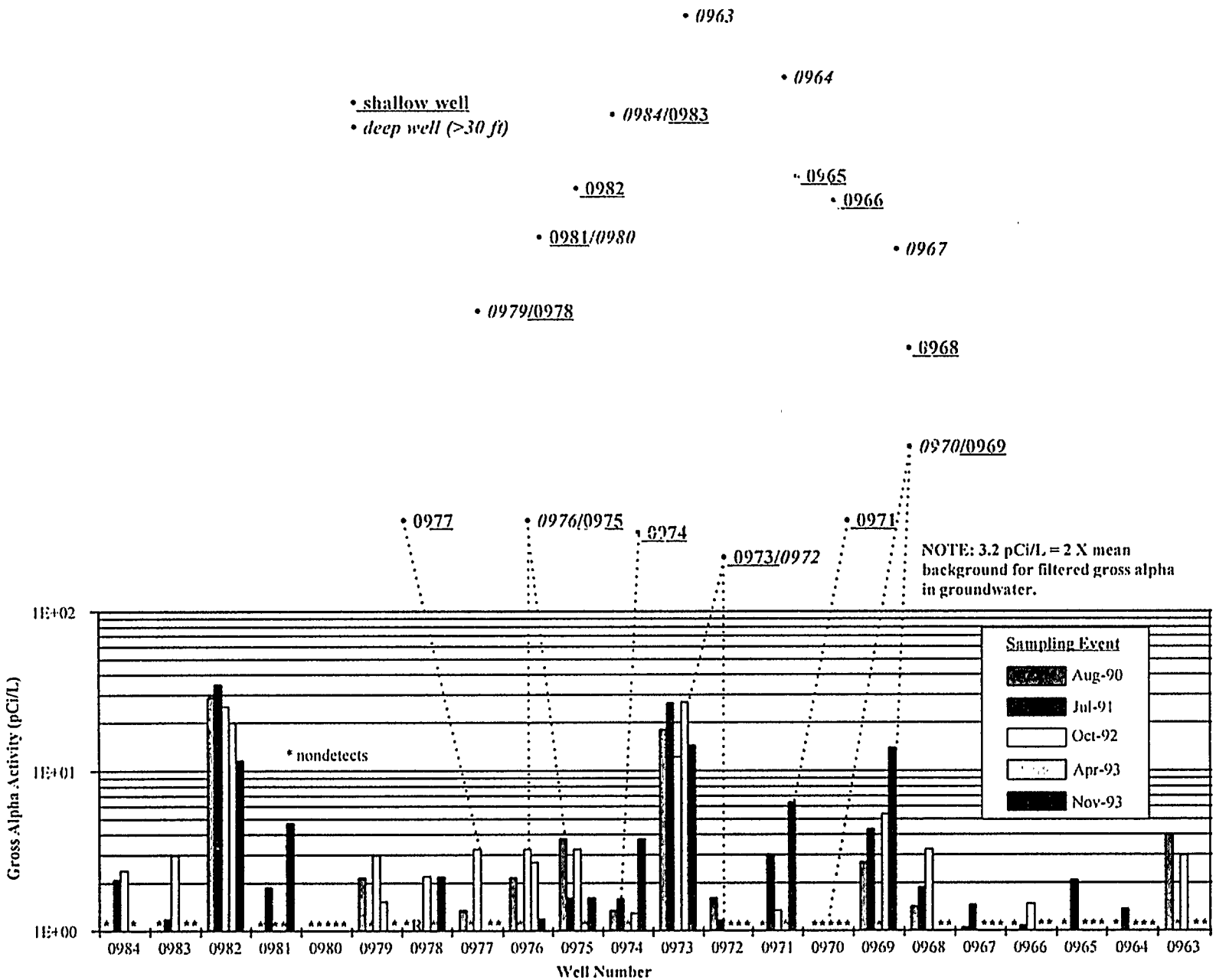


Fig. B3.3.3. Filtered gross alpha concentrations in perimeter wells.

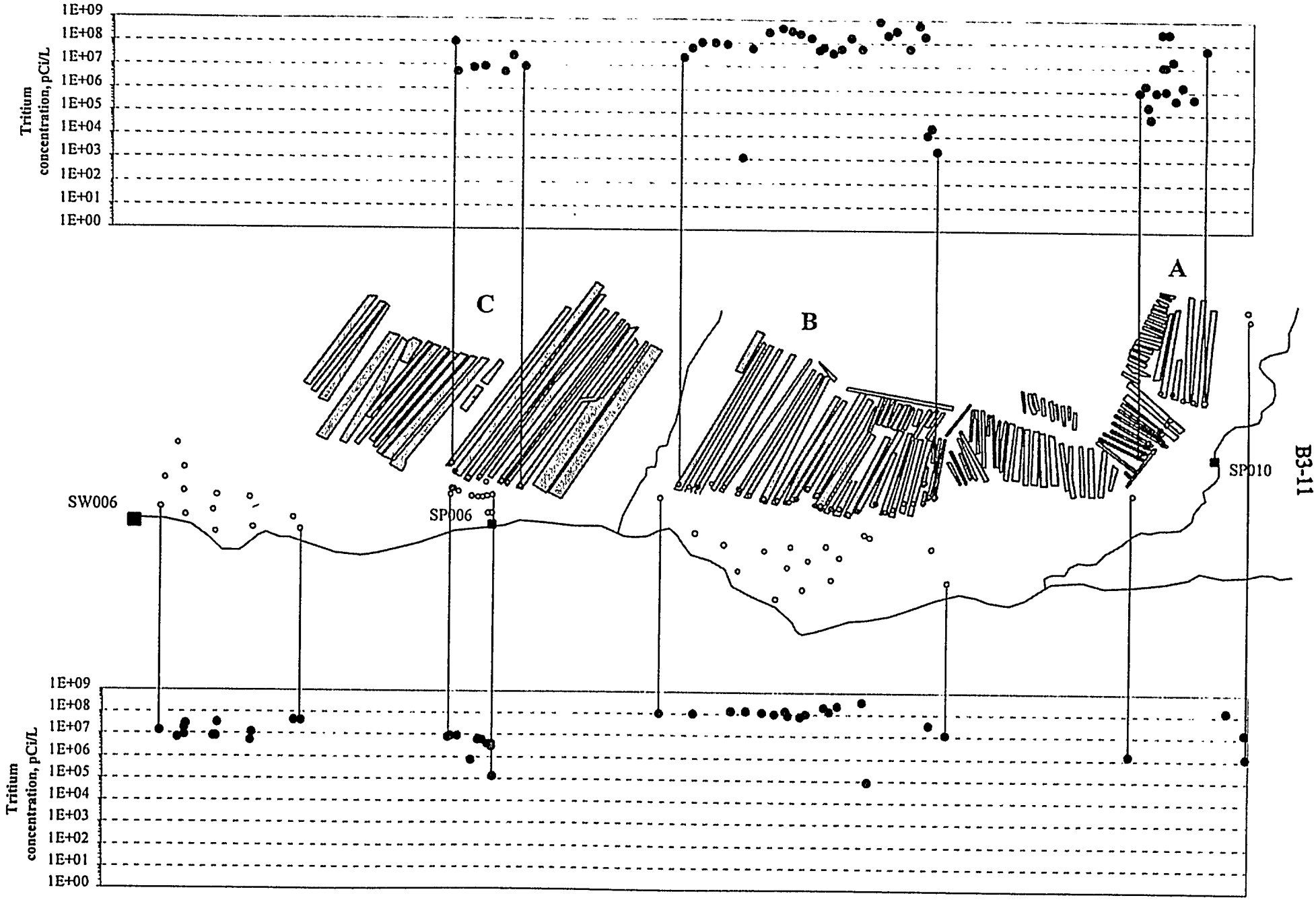
B3_F1 1PT

Table B3.3.2. Drive point well location summary

STUDY AREA	D	C	B	A	TOTAL
Trench drive point	0	6	27	15	48
Floodplain drive point	41	7	14	0	62
Seeps	2	2	3	5	12
TOTAL	43	15	44	20	122

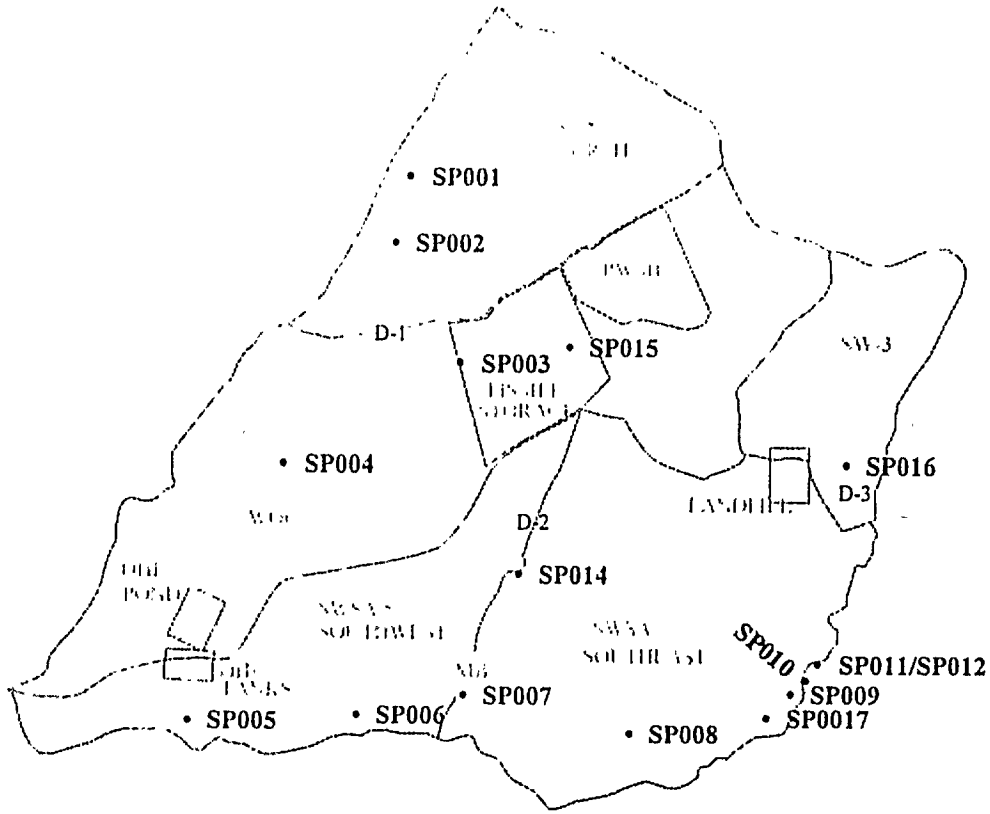
Figure B3.3.4 shows the locations of the drive points in the trenches and floodplain and the corresponding activity levels. Source characterization for tritium in SWSA 5 trenches shows concentrations exceeding 100 million pCi/L for study area B and 10 million pCi/L (10 mCi/L) for study areas A and C. Tritium concentrations observed in trench water are similar to those in seeps and in floodplain groundwater, indicating that only limited attenuation or dilution is occurring (Fig. B3.3.5). One seep (SP008) near the southern extent of the trenches has readings almost equivalent to the trenches, and another seep (SP010, situated between SP009 and SP011) farther from the trenches exhibits higher levels (150 million pCi/L; CSL analysis). Similar patterns of migration from upland seeps within the D-2 drainage were observed. Even with the expected dilution in surface water, migration from trench sources via diffuse flow and point discharge from seeps create high tritium levels (10^6 pCi/L) in Melton Branch. Figure B3.3.6 compares surface water tritium activity with that seen in the trenches.

Similar figures demonstrate the difference in transport of radioactive strontium in the subsurface. Figure B3.3.7 shows radioactive strontium activities in the study area trenches; strontium activities in the trenches are not only lower than tritium but also more variable from trench to trench. This variability may be caused by a difference in source types or volumes within each trench; however, such source variabilities should be present for tritium also. Differences in the leachability of strontium from the original waste materials and variable rates of migration and pooling at the lower end of the trenches may also account for the variations. Even larger variances are exhibited after transport in the subsurface. Radioactive strontium activities in the floodplain vary over four orders of magnitude and are, on the average, two to three orders lower than the trenches (10^2 to 10^3 pCi/L compared to 10^5 to 10^6 pCi/L). Significant retardation of strontium is taking place to attenuate the transport of radioactive strontium. One exception is the point discharge at seep SP006: the drive points in the trenches of study area C, seep SP006 (Fig. B3.3.8), and the drive points immediately downgradient of SP006 have equivalent strontium activities (10^5 to 10^6 pCi/L). Seep SP008 also appears to be a direct pathway from the trench sources. Seeps SP006 and SP008 probably represent flow along a preferred pathway, (e.g., a fracture connection from source areas with high strontium fluxes); any retardation capacity along a preferred pathway has been exhausted. The remaining seeps in SWSA 5 South including drainage D-2 have levels analogous to those in the floodplain. Surface water concentrations of strontium (Fig. B3.3.9) are significantly reduced and appear to be affected mostly by point discharges of individual seeps (such as SP010 at 5692 pCi/L—CSL analysis and SP006).



NOTE: 2400 pCi/L =2 X mean background for unfiltered tritium in groundwater

Fig. B3.3.4. Unfiltered tritium concentrations in trench and floodplain drive points.



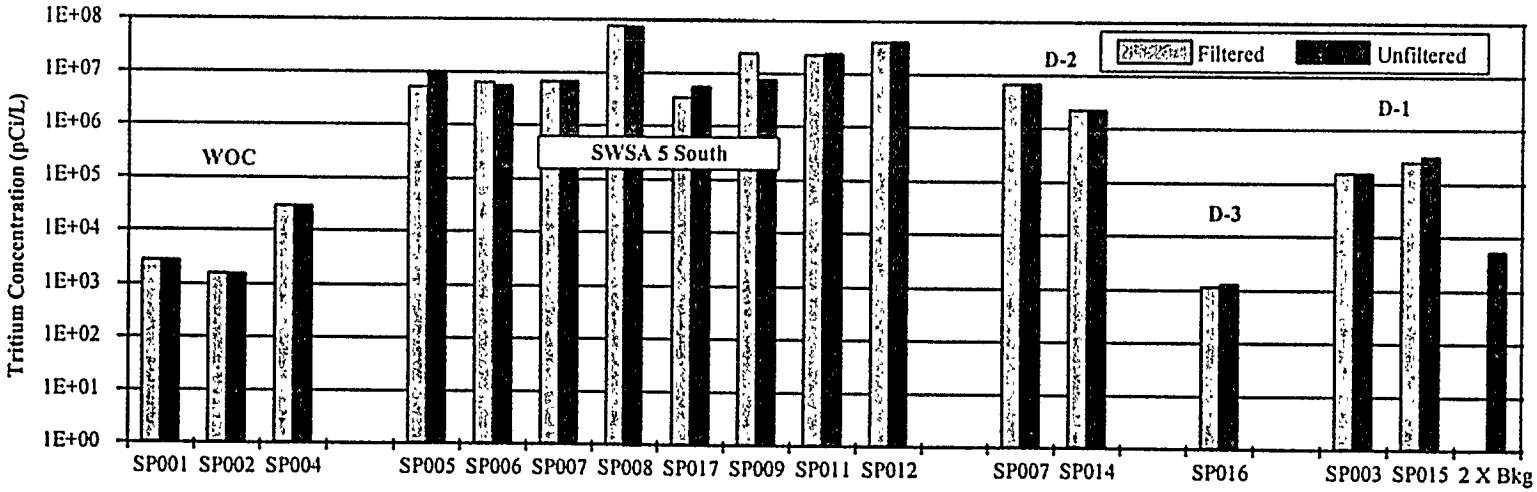


Fig. B3.3.5. Tritium concentrations in seeps.

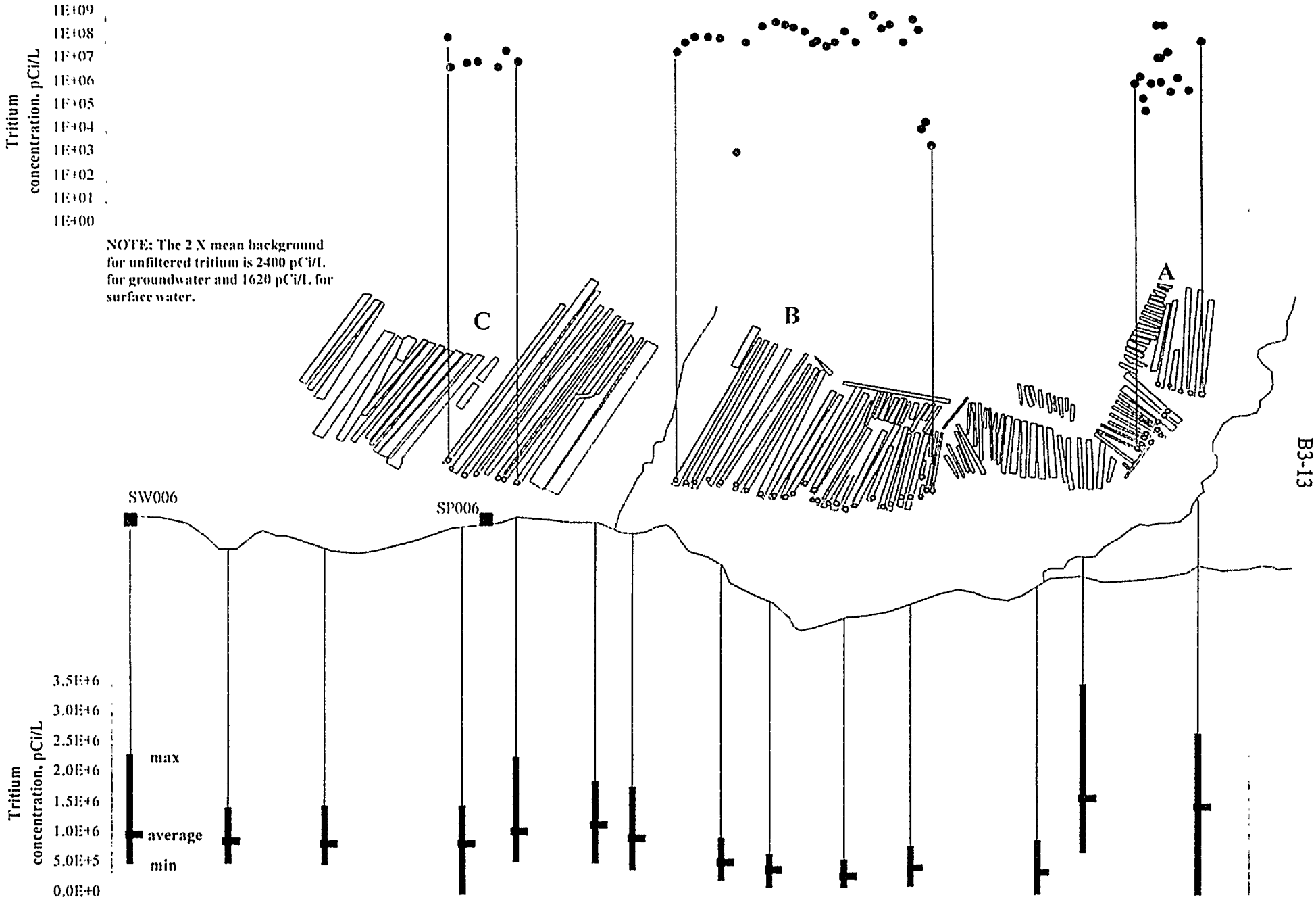


Fig. B3.3.6. Unfiltered tritium concentrations in trench drive points and surface water.

B3_F3_6.PPT

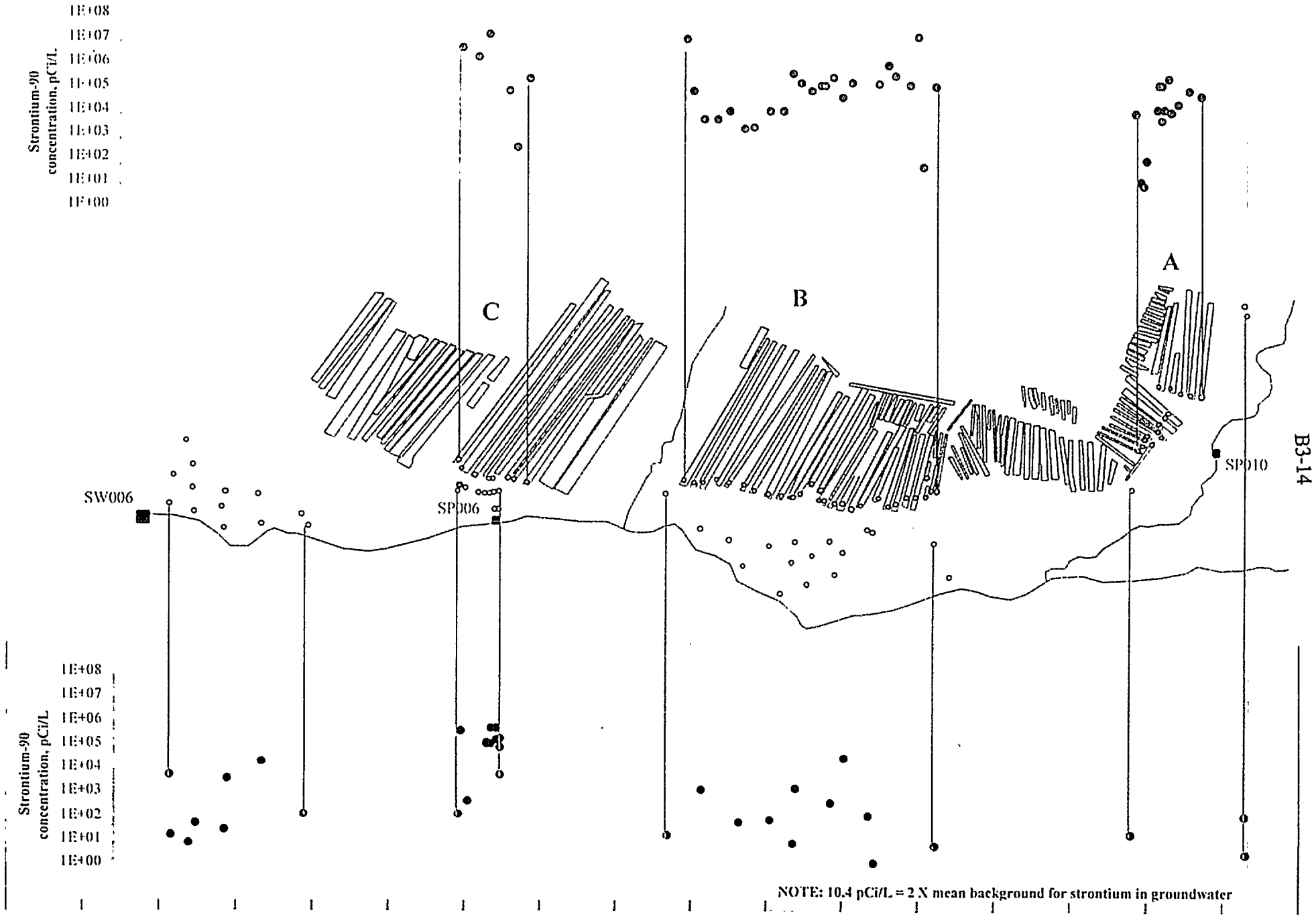


Fig. B3.3.7. Strontium-90 concentrations in trench and floodplain drive points.

B3_F3_7.PPT

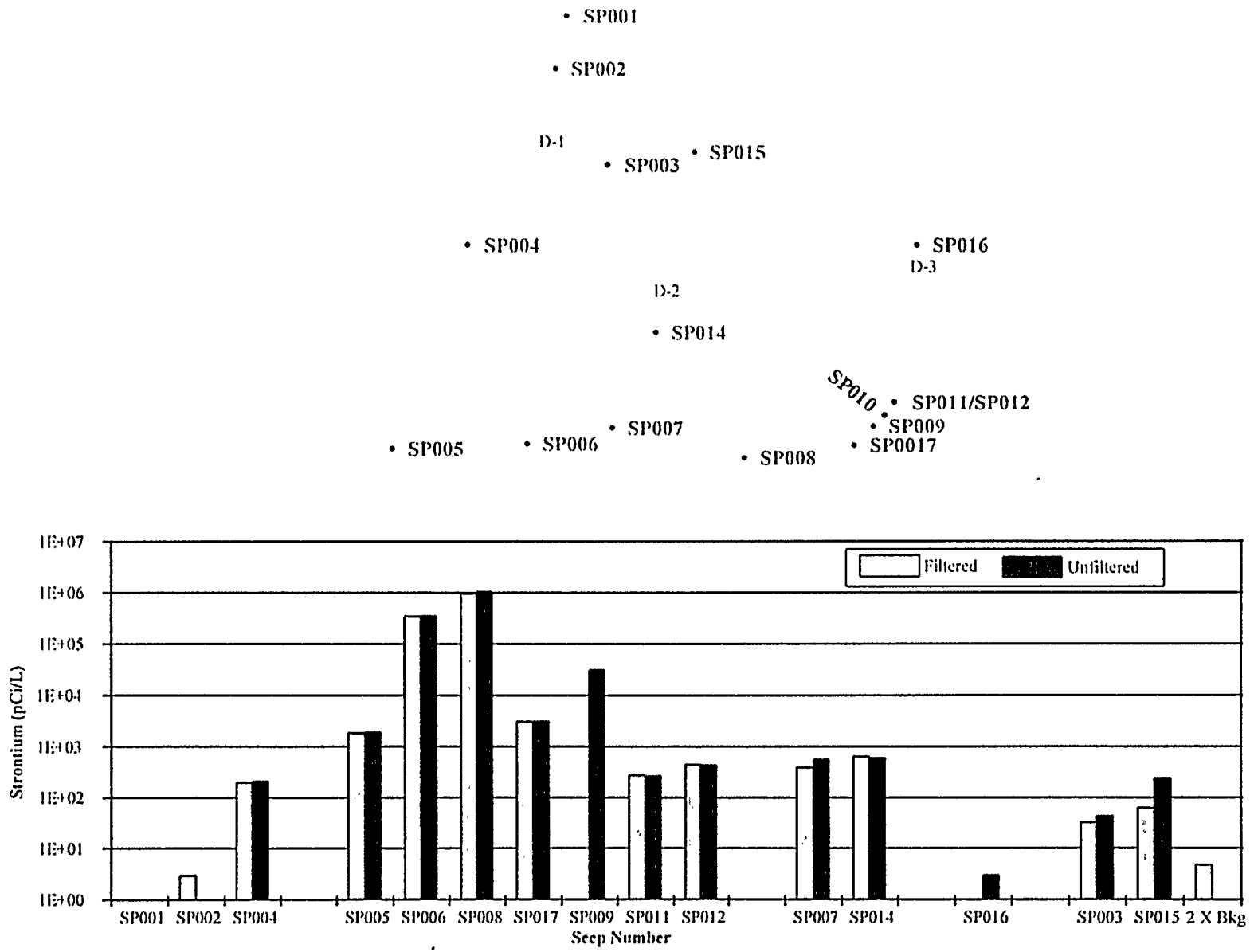


Fig. B3.3.8. Strontium-90 concentrations in seeps.

B3_F3_8.PPT

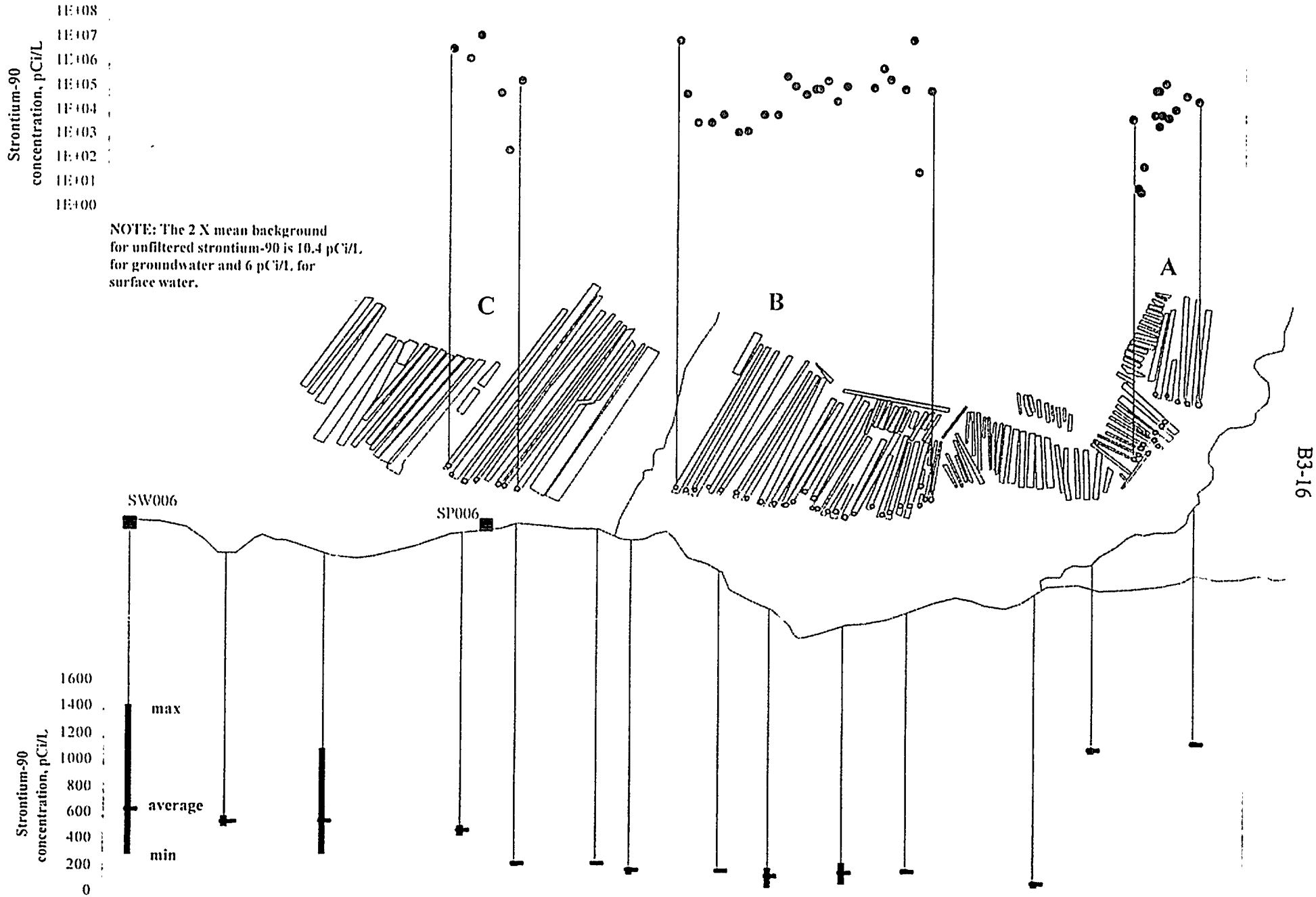


Fig. B3.3.9. Unfiltered strontium-90 concentrations in trench drive points and surface water.

Gross alpha activity (Figs. B3.3.10, B3.3.11, and B3.3.12) averages 10,000 pCi/L in the trench waters of study areas C and D and 1000 pCi/L in study area A in SWSA 5 South. A slight reduction in concentration levels is seen in the floodplain (ranging from 10^2 to 10^3 pCi/L). More significantly, a large reduction is seen in the point discharge of the area seeps (with the exception of SP008). A review of the isotopic data for SP008 could not identify any obvious alpha emitters other than small amounts of uranium (by contrast, SP015 in drainage D-1 contained 2000 pCi/L ^{238}U). Surface waters in Melton Branch generally reflect alpha activities close to those seen in the seeps. The reach of Melton Branch Tributary near study area A is obviously affected by SP010 (89 pCi/L; CSL analysis) and has the highest gross alpha in this reach of Melton Branch.

B3.3.3 Contaminant Flux Trends

D. Hicks (ORNL 1993b) evaluates site-wide contaminant migration and transport from WAG 5. Throughout the White Oak Creek watershed, flow and contaminant measurements were made for various reaches of White Oak Creek and Melton Branch and for tributaries to each. Tritium and strontium concentrations combined with flow measurements provide contaminant fluxes for both high base and low base flow periods at each sampling location. Hicks reports the flux at each location as a percent contribution to the flux at White Oak Dam. The total WAG 5 contribution and contributions from segments of WAG 5 can be estimated using these measurements (see Appendix B2 for estimates for individual sites and watersheds within WAG 5). By removing upstream contributions (Table B3.3.3), WAG 5 appears to contribute approximately three-fourths of the tritium flux to the White Oak Creek watershed and about one-third of the strontium. Within WAG 5, the western edge of the site along White Oak Creek is a minor contributor to tritium (3%) and strontium (5 to 10%). It should be noted that these numbers also include a contribution from WAG 4. Melton Branch is by far the largest contributor of tritium to the White Oak Creek watershed. Moreover, the reach of Melton Branch along the SWSA 5 trenches accounts for over one-half of the total tritium flux to the dam. This is in addition to that provided by the interior of WAG 5 from drainage D-2 (10%) and that provided along the trenches in study area A (13% upstream from HRT-2). Transect sampling along Melton Branch shows that the major transport of tritium occurs downgradient of the trenches in study area B. Melton Branch also contributes a significant portion of the strontium flux to the White Oak Creek watershed (32 to 43%). Of that, the largest contributor (16 to 25%) is seep SP006, downgradient of the trenches in study area C of SWSA 5 South.

B3.4 FATE

The question of contaminant fate is important at WAG 5 because estimates of future contaminant concentrations and the resulting exposure rates will influence remedial action decisions. Unfortunately, critical information needed to support the effective use of predictive models is not available. The absence of source characterization data and the limited period for which monitoring data exist further complicate any efforts to calibrate such models. However, data are available for contaminant measurements at White Oak Dam for an extended period, and a projection of trends is possible.

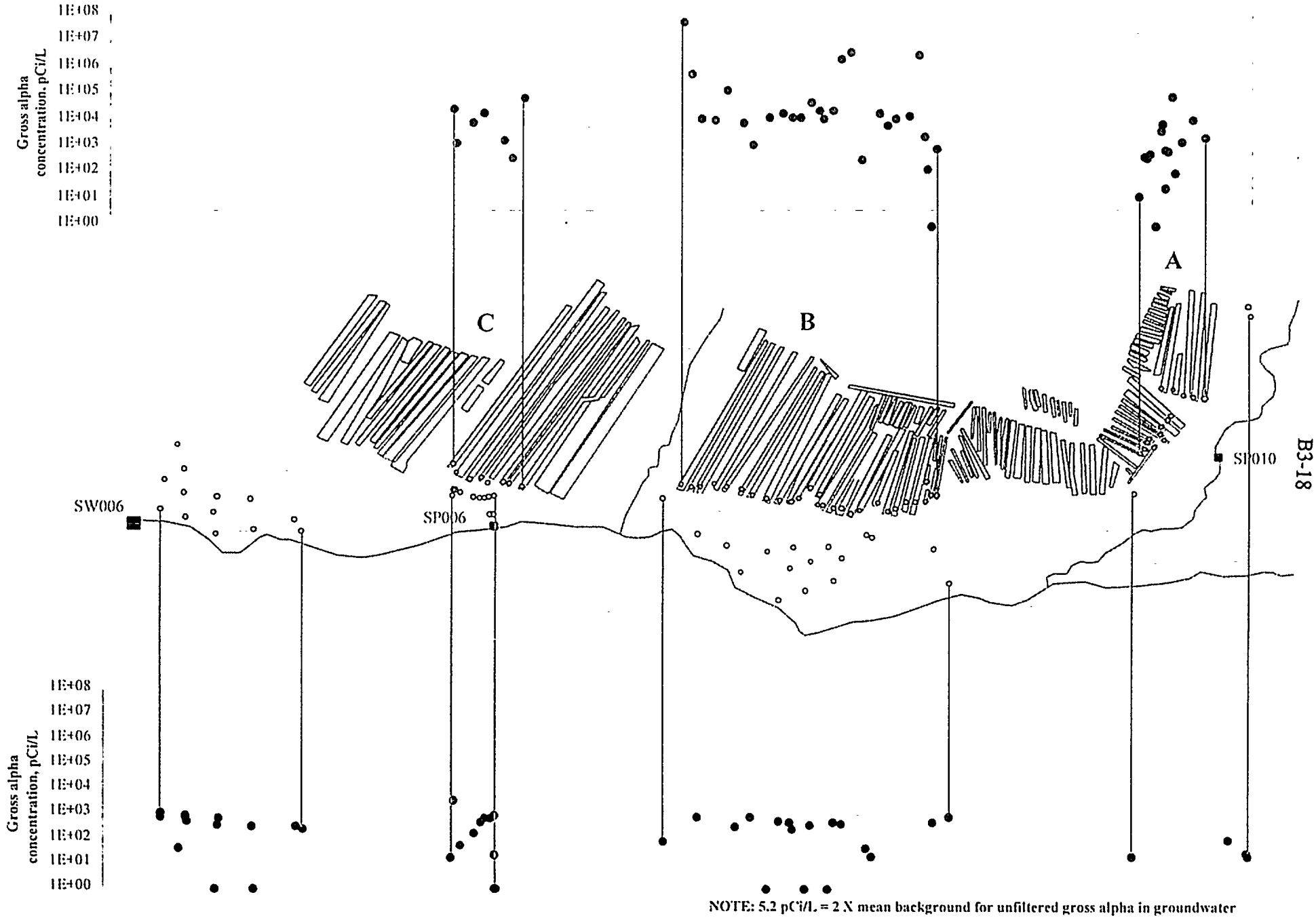


Fig. B3.3.10. Unfiltered gross alpha concentrations in trench and floodplain drive points.

B3_F3_10.PPT

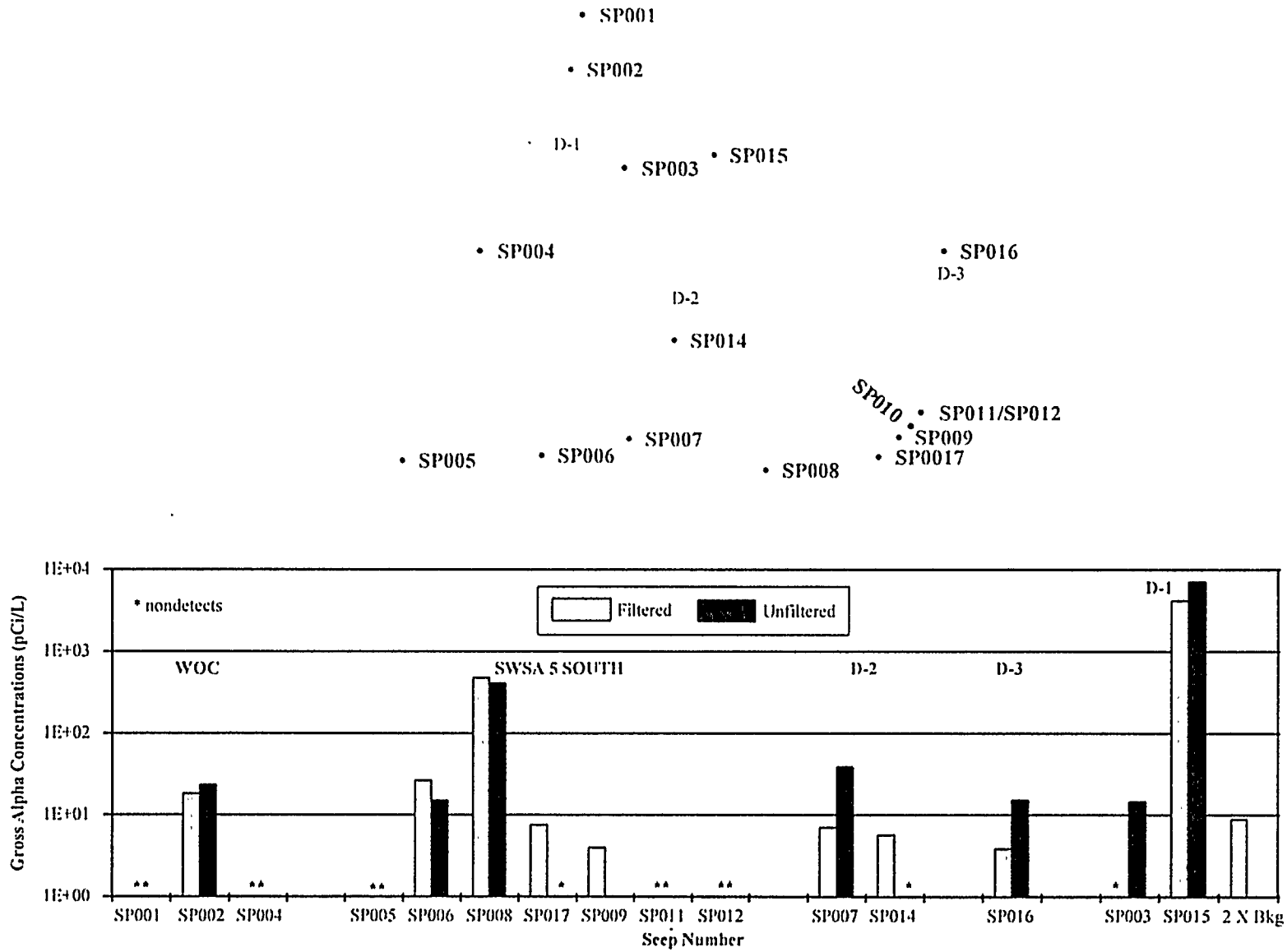


Fig. B3.3.11. Gross alpha concentrations in seeps.

B3_F3_11.PPT

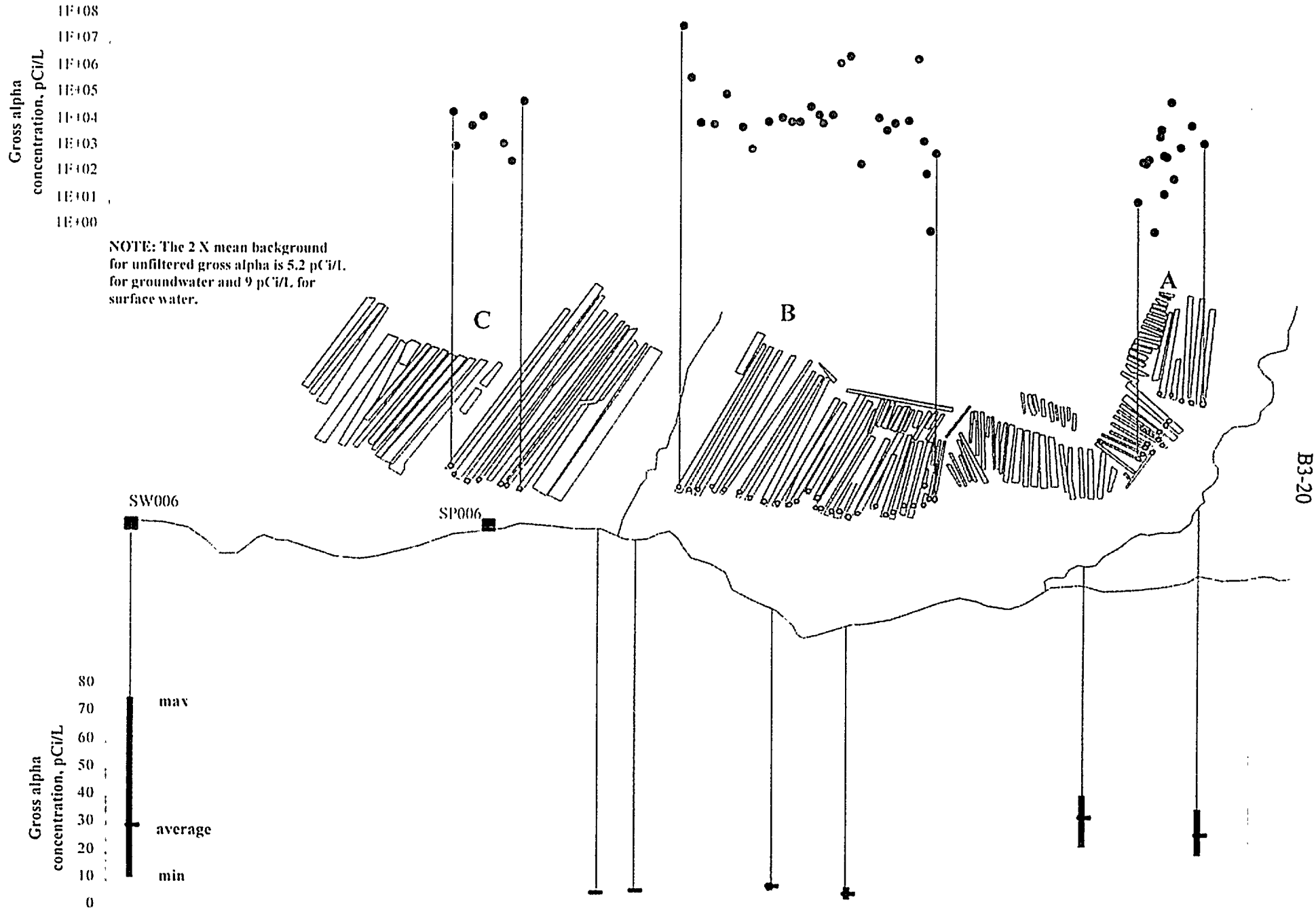


Fig. B3.3.12. Unfiltered gross alpha concentrations in trench drive points and surface water.

B3_F3_12.PPT

Table B3.3.3. Percent contribution to White Oak Dam contaminant flux

	HIGH BASE		LOW BASE	
	TRITIUM	STRONTIUM	TRITIUM	STRONTIUM
White Oak Creek*	22	48	6	48
WAG 4	-15	-10	-1	-1
7500 Bridge	-4	-32	-2	-37
Net	3	6	3	10
Melton Branch	75	43	70	32
HRT 3	-1	-8	-1	-9
Melton Branch 15	-1	-2	-1	-2
Net	73	33	68	21
WAG 5 Net	76	39	71	31

Source: ORNL 1993b.
* Contributions from WAG 4 also

B3.4.1 Tritium

Tritium flux measurements for White Oak Dam are shown in Fig. B3.4.1 along with the annual precipitation data. Since WAG 5 appears to be the major tritium contributor to the White Oak Creek watershed, trends observable at White Oak Dam should apply to the site (data for tritium at Melton Branch are not available). The most notable observation from this figure is timing of the increase in tritium flux (1967) with the construction of the waste trenches in SWSA 5 South area B—the area with the largest tritium migration. Waste disposal in these trenches began in 1965 and was most active during 1966 to 1968. From 1966 to 1967, the tritium flux at White Oak Dam increased by a factor of four (3090 to 13,300 Ci/year), which suggests that tritium migration began essentially immediately after the waste was placed in the trenches. Also, a definite relationship can be seen between precipitation and the tritium flux.

The most interesting feature of this figure, however, is the long-term but steady decline in tritium flux. To correct for isotopic decay, the tritium fluxes were normalized for precipitation to remove the annual variation due to possible flushing (Fig. B3.4.2). For a year with precipitation above the mean annual precipitation for 1964–1993, the tritium flux was decreased by the same percentage. The reverse was performed if precipitation was below the mean for a particular year. This procedure removed a significant amount of variation to produce a strong correlation coefficient for tritium versus years ($r^2 = 0.88$). An exponential best fit performed for the tritium fluxes provided an initial flux of 12,900 Ci for 1967 (compared to the observed value of 13,300 Ci). This value was then decayed according to the following equation:

$$A = A_o e^{-0.693t/T1/2}$$

where:

A	=	activity after a time interval t (1993)
A_o	=	activity of sample at some original time (1967)
t	=	elapsed time (1967 to 1993 +1 year assumed = 27 years)
$T1/2$	=	half-life (12.33 years)

The predicted flux for 1993, only taking into account the decay, is 2828 Ci; the normalized flux was estimated to be 2143 Ci, and the actual observed value for that year was 1827 Ci. Given the error limits in estimating activity decay from flux values (flow rates times contaminant activity) and similarity between the best fit curve of the normalized flux and the radioactive decay curve of tritium (Fig. B3.4.2), it would appear that most of the decrease in tritium activity can be accounted for by the half-life decay. The corollary to this conclusion is that the tritium source is not being depleted and sufficient tritium remains in the source areas to be a potential problem for the extended future. Based on the similarity of the normalized tritium fluxes and the radioactive decay curve, there apparently have been no new sources of tritium in the White Oak Creek basin since the mid-1960s.

B3.4.2 Strontium

Data for radioactive strontium are available from 1949 for White Oak Dam and from 1964 for the Melton Branch weir (National Research Council 1985) (1984–1986 annual Oak Ridge environmental monitoring report, 1987–1993 WAG 2/WAG 5 database). The historical trend at White Oak Dam shows a significant decrease between 1949 and 1961 (Fig. B3.4.3). Since 1962, however, the strontium flux over the dam has leveled off and appears to fluctuate mainly in response to annual precipitation levels. Because WAG 5 is only one of several major strontium contributors to the White Oak Creek watershed (32 to 43% as reported by Hicks), the data at the Melton Branch weir are more representative of the site. Figure B3.4.4 is a plot of the normalized flux at Melton Branch weir between 1964 and 1993; the flux from WAG 5 was relatively constant over this period. The consistent level of strontium flux in Melton Branch is probably due to the activation of additional sources in WAG 5. The relative contribution of Melton Branch to the total flux of strontium appears to be increasing, as shown in Fig. B3.4.5. Given the persistent levels of contamination observed at the Melton Branch weir, the relationship indicates that the other sources of strontium in the White Oak Creek Watershed are being depleted.

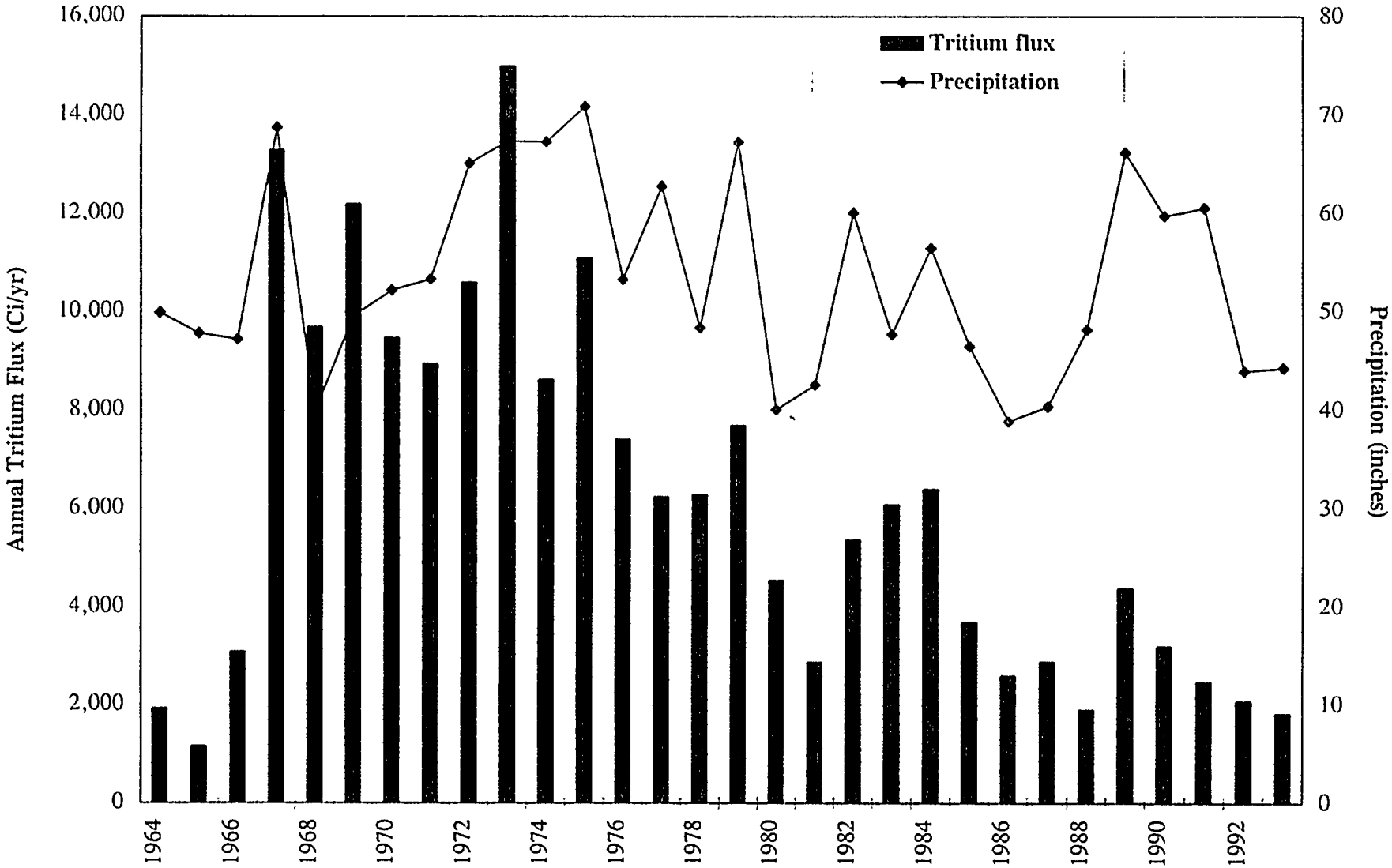
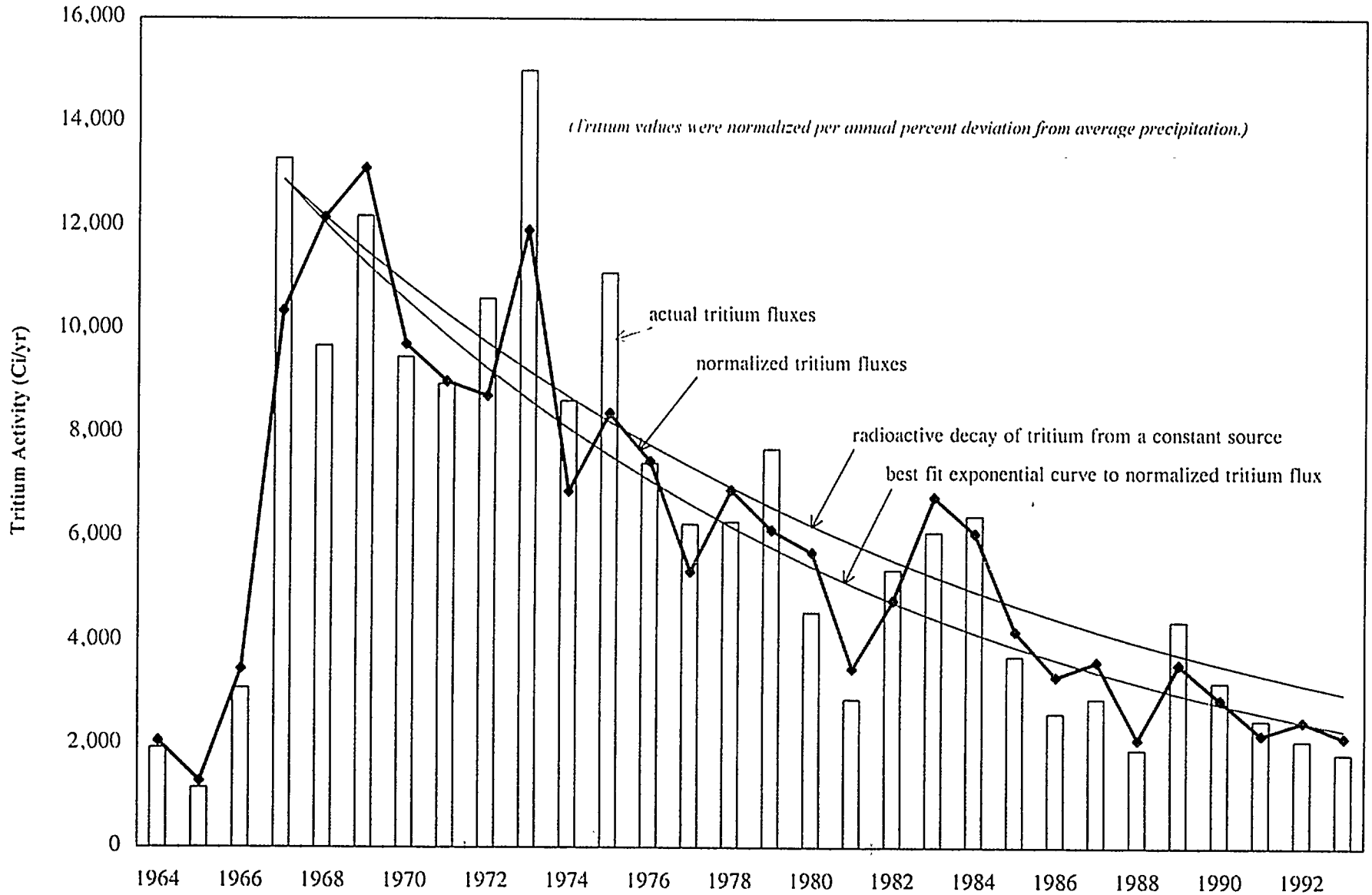


Fig. B3.4.1 Annual tritium flux over White Oak Dam.

B3_F4_1 XLS



B3.14.1XLS

Fig. B3.4.2. Normalized tritium flux over White Oak Dam, 1964-1993.

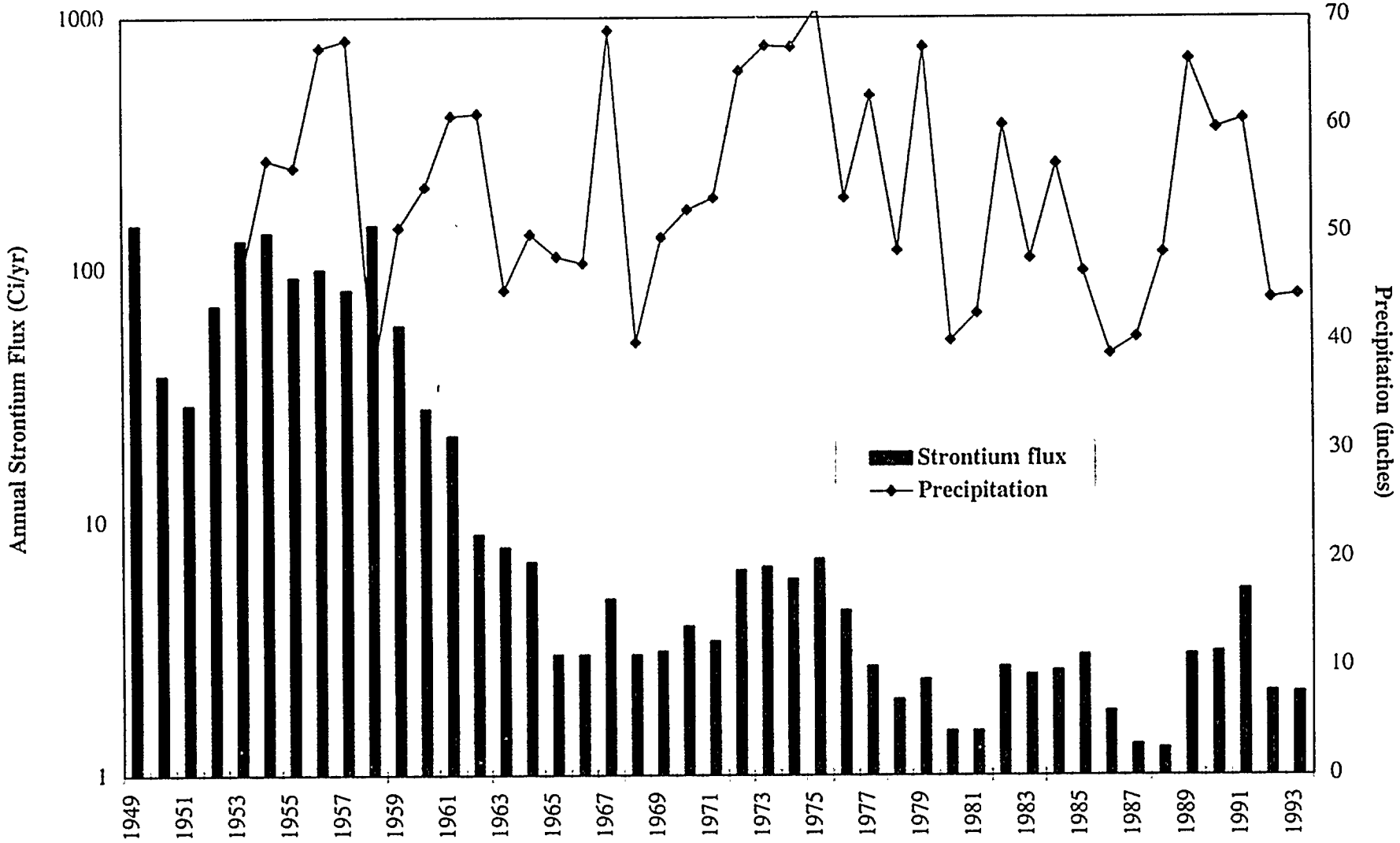


Fig. B3.4.3. Annual radioactive strontium flux over White Oak Dam.

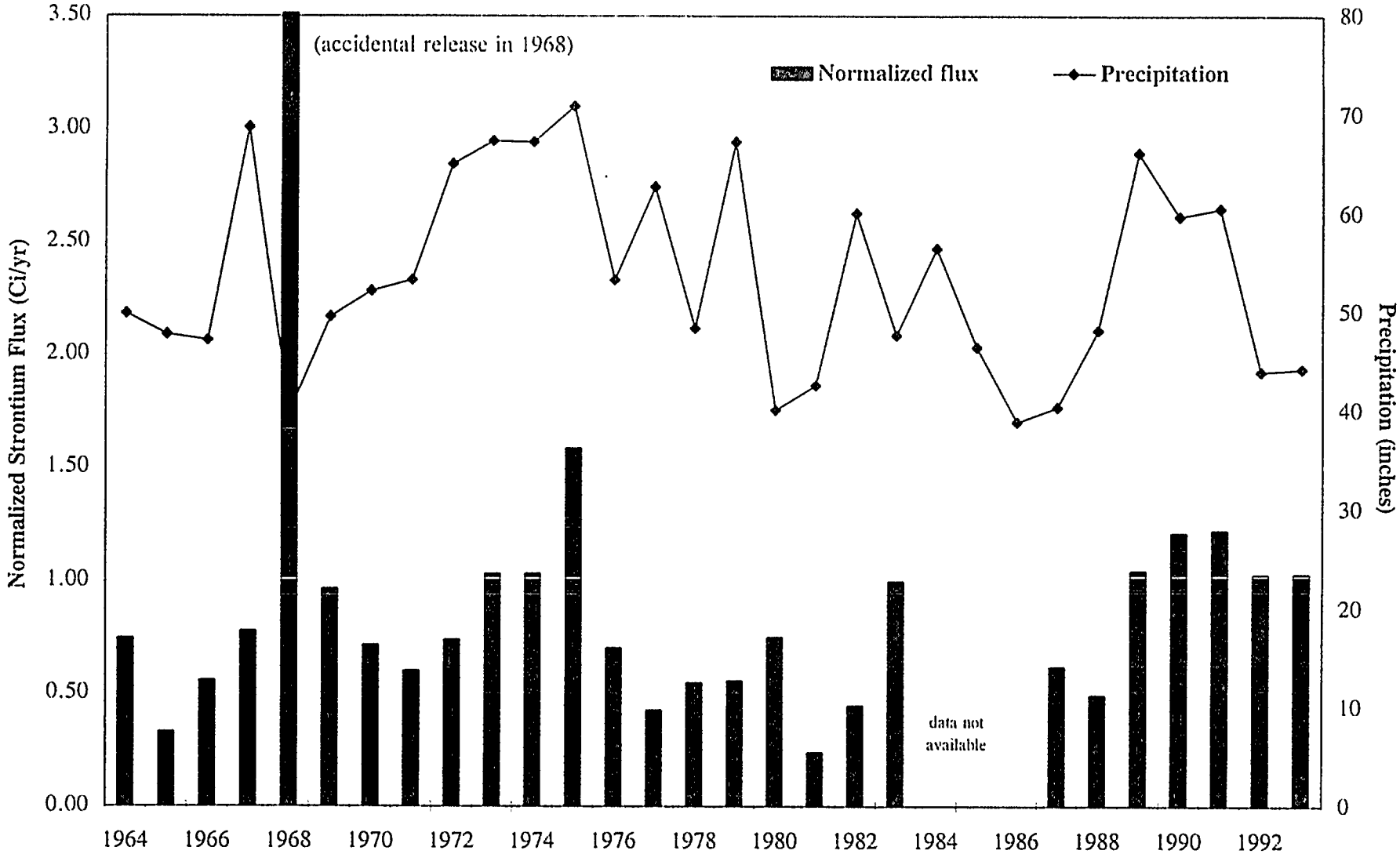


Fig. B3.4.4 Annual strontium flux at Melton Branch, normalized for precipitation.

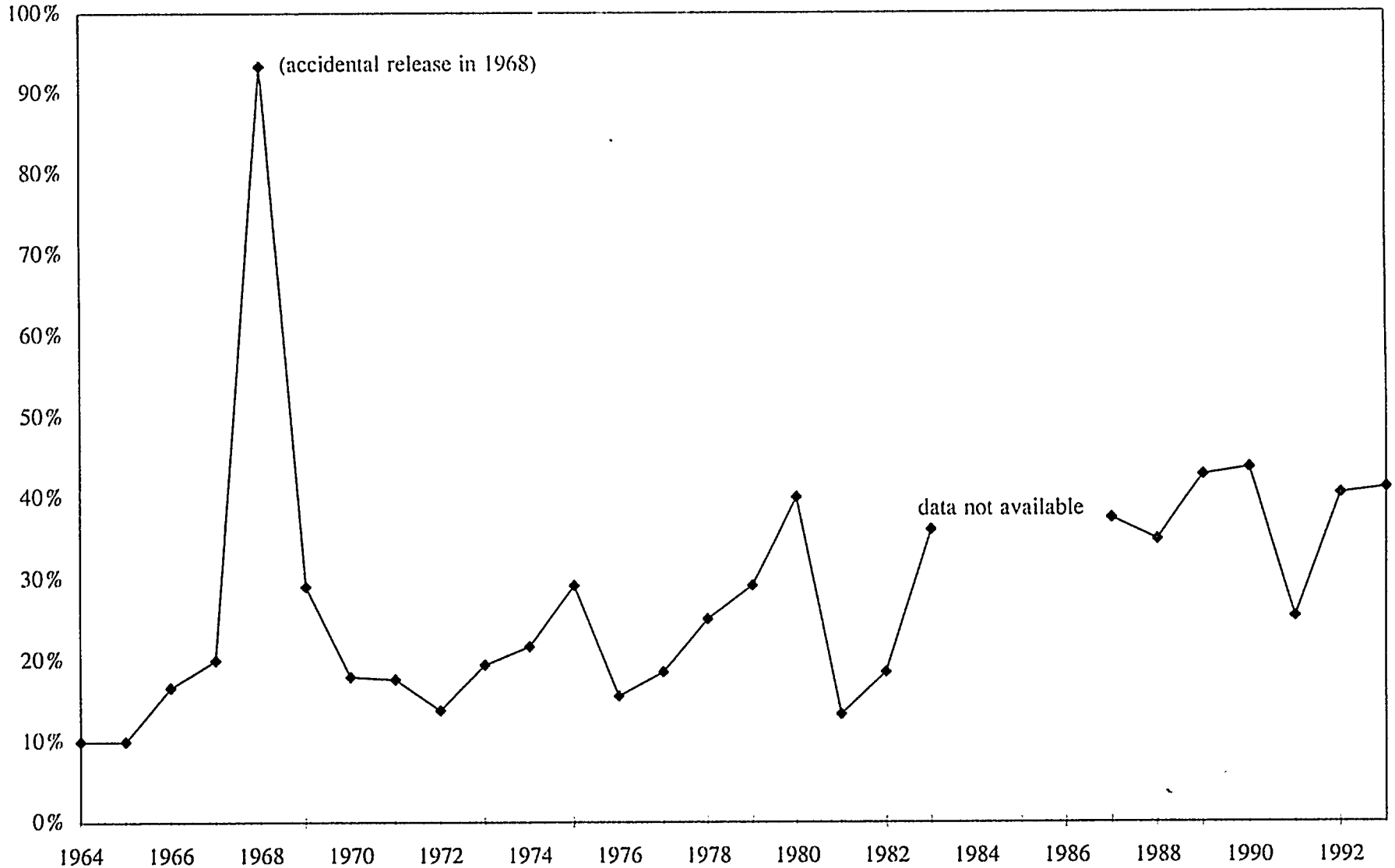


Fig. B3.4.5. Melton Branch strontium-90 flux as a percentage of strontium-90 flux over White Oak Dam.

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ORNL, 1993a. *WAG 5 Source Areas Investigation.* ORNL/ER-165. Oak Ridge, Tennessee.

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B4. WAG 5 HISTORICAL PHOTOGRAPHS

Shallow land burial of solid low-level radioactive wastes began in July 1959 at the undefined trench area in the northern portion of SWSA 5. Approximately 230 trenches (average of 13 trenches per year) and 1000 auger holes were excavated and filled during the life of the facility (SWSA 5 South), which was officially closed in 1973. An area for storage of TRU wastes was opened in the northern section of SWSA 5 in 1970.

Numerous photographs taken during construction and disposal activities depict both routine burial practices and special case waste burial events. This appendix presents historical photographs relevant to WAG 5 burial ground operations obtained from ORNL Laboratory Records to illustrate the disposal methods used and types of waste placed in WAG 5.

Fig. B4.1. Trench 29 or 30 excavated in the Y-12 special burial area, northeastern part of SWSA 5 South (Area A); trench was filled in 1959 with drummed, alpha-contaminated wastes from Y-12 Plant. (ORNL Photo No. 45990)

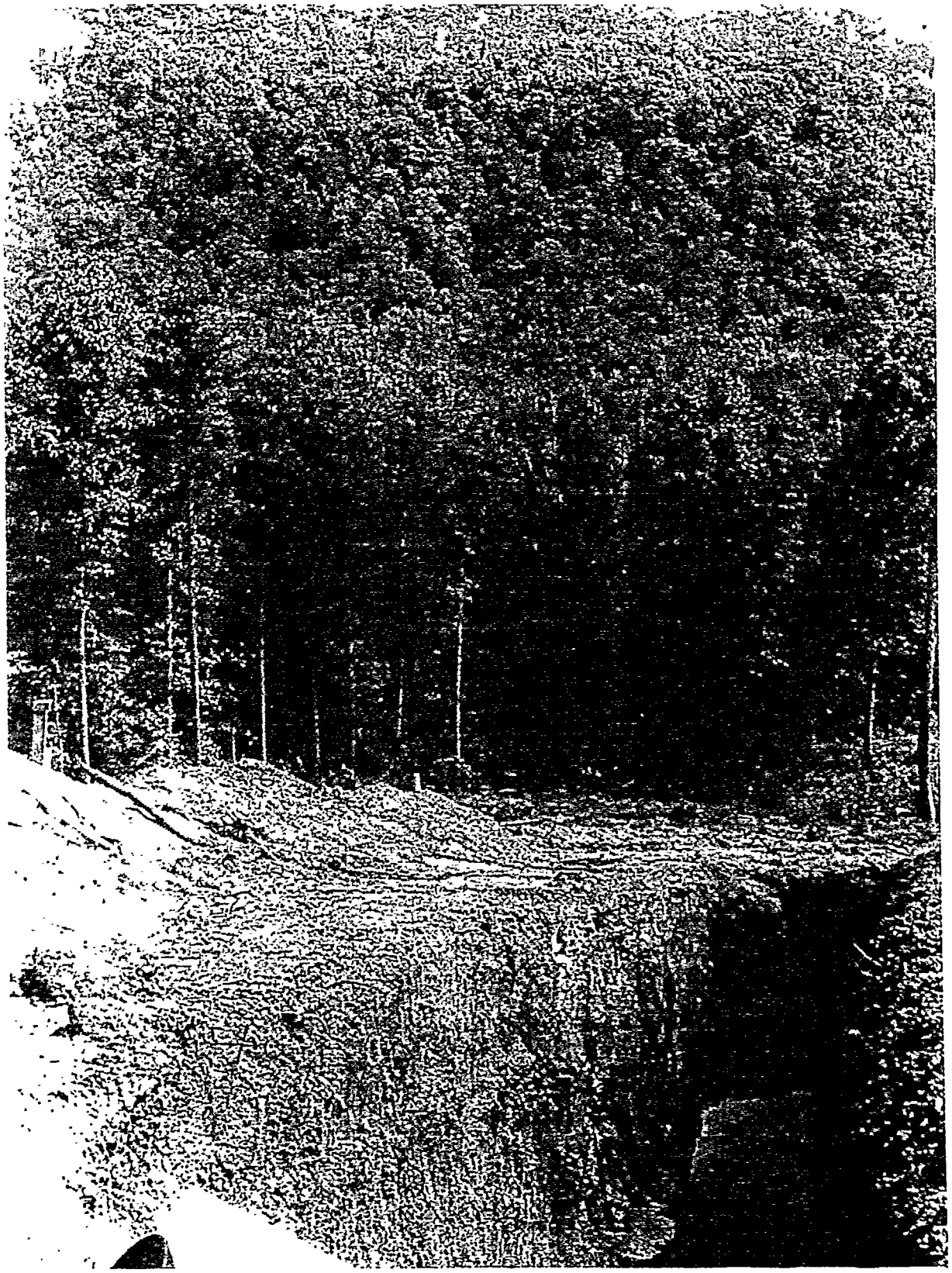


Fig. B4.2. Trench in Y-12 special burial area, northeastern part of SWSA 5 South (Area A); may be trench 28. (ORNL Photo No. 47476)

Fig. B4.3. Close-up of sump area in trench 29 or 30; tar coating on sides and bottom was done to enhance pooling of water for monitoring via corrugated standpipe; trench design was described in Cowser et al. 1961. (ORNL Photo No. 45988)

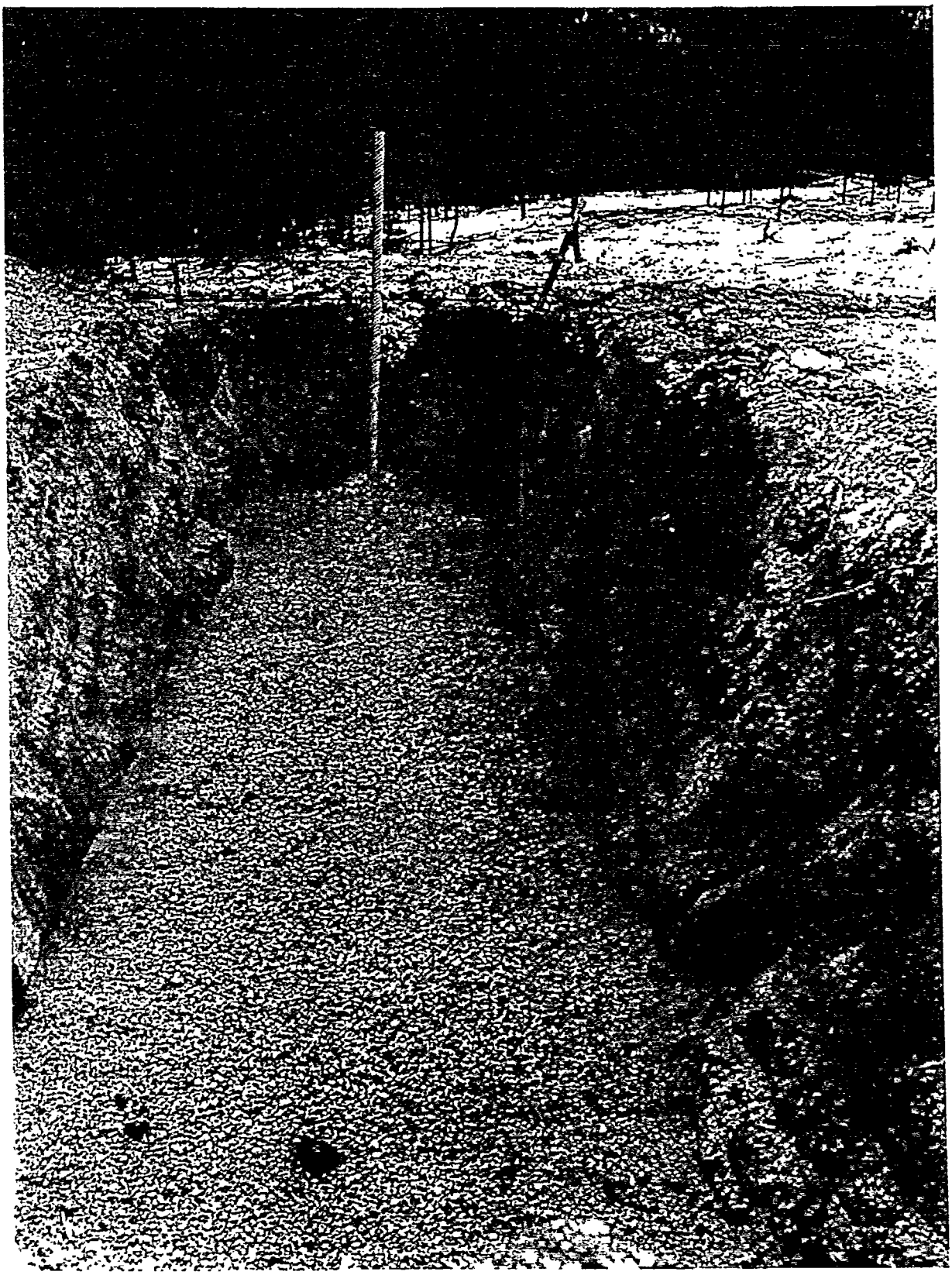


Fig. B4.4. Trench 29 or 30 in Y-12 special burial area; example of trench design described by Cowser et al. (1961); gravel-covered bottom slopes to asphalt-lined sump with standpipe. Trench was filled with drums of alpha-contaminated waste from Y-12. (ORNL Photo No. 45993)

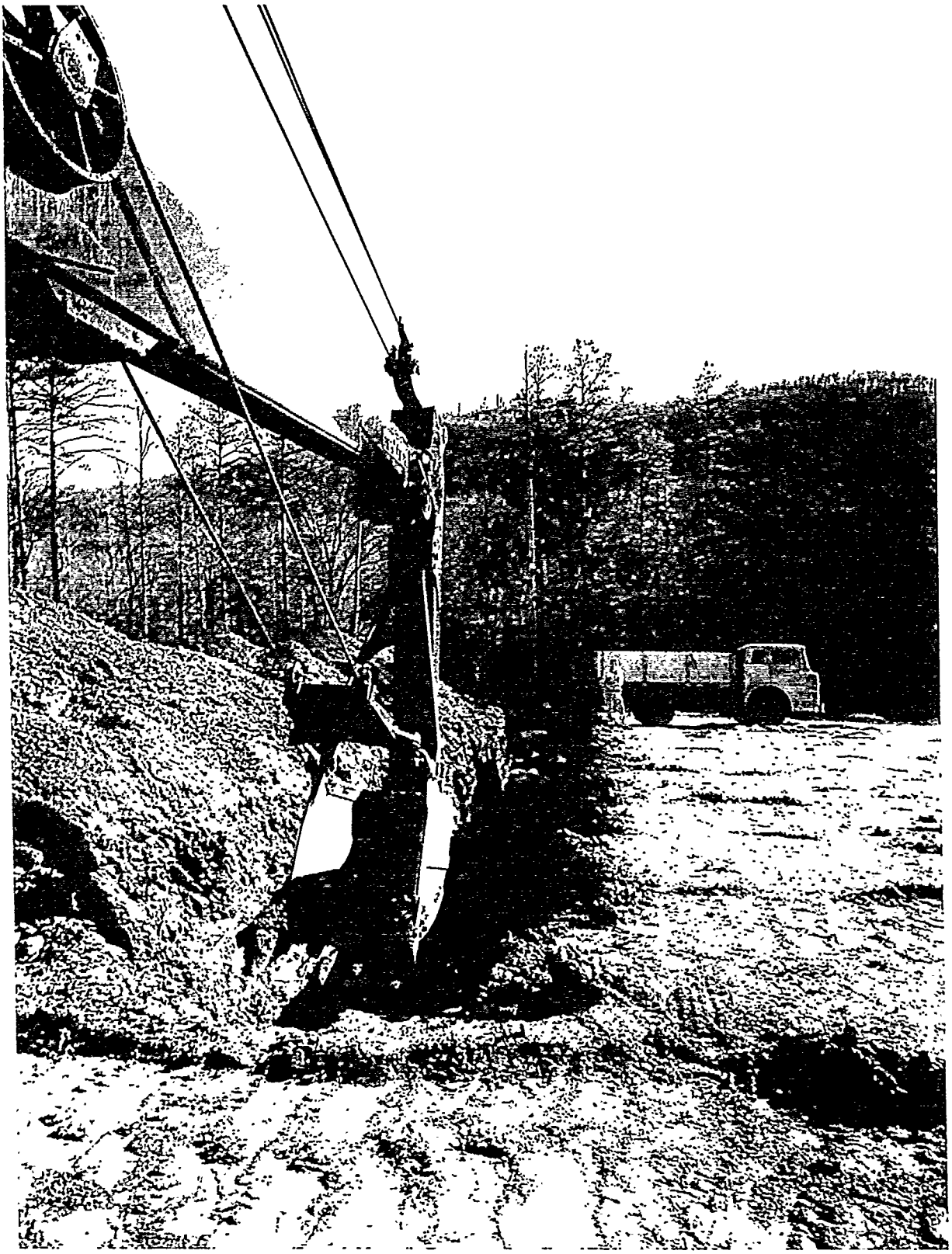


Fig. B4.5. Trench excavation in the southeast corner of SWSA 5 South. (ORNL Photo No. 97988)

Fig. B4.6. Trench in SWSA 5 South, east of OHF, partially filled with a diverse waste mixture; note water in base of trench. Another trench is being excavated to left of this one, backfilling this trench with the excavated soil from the new one. (ORNL Photo No. 60822)

Fig. B4.7. Same subject found in Fig. B4.6, only facing south instead of north; showing trench dimensions and backfilling concurrent with excavation of neighboring trench. (ORNL Photo No. 60818)

Fig. B4.8. Disposal of waste containers from off-site source; disposal method used (tossing cans into trench) may have been in response to health and safety concerns. (ORNL Photo No. 101775)

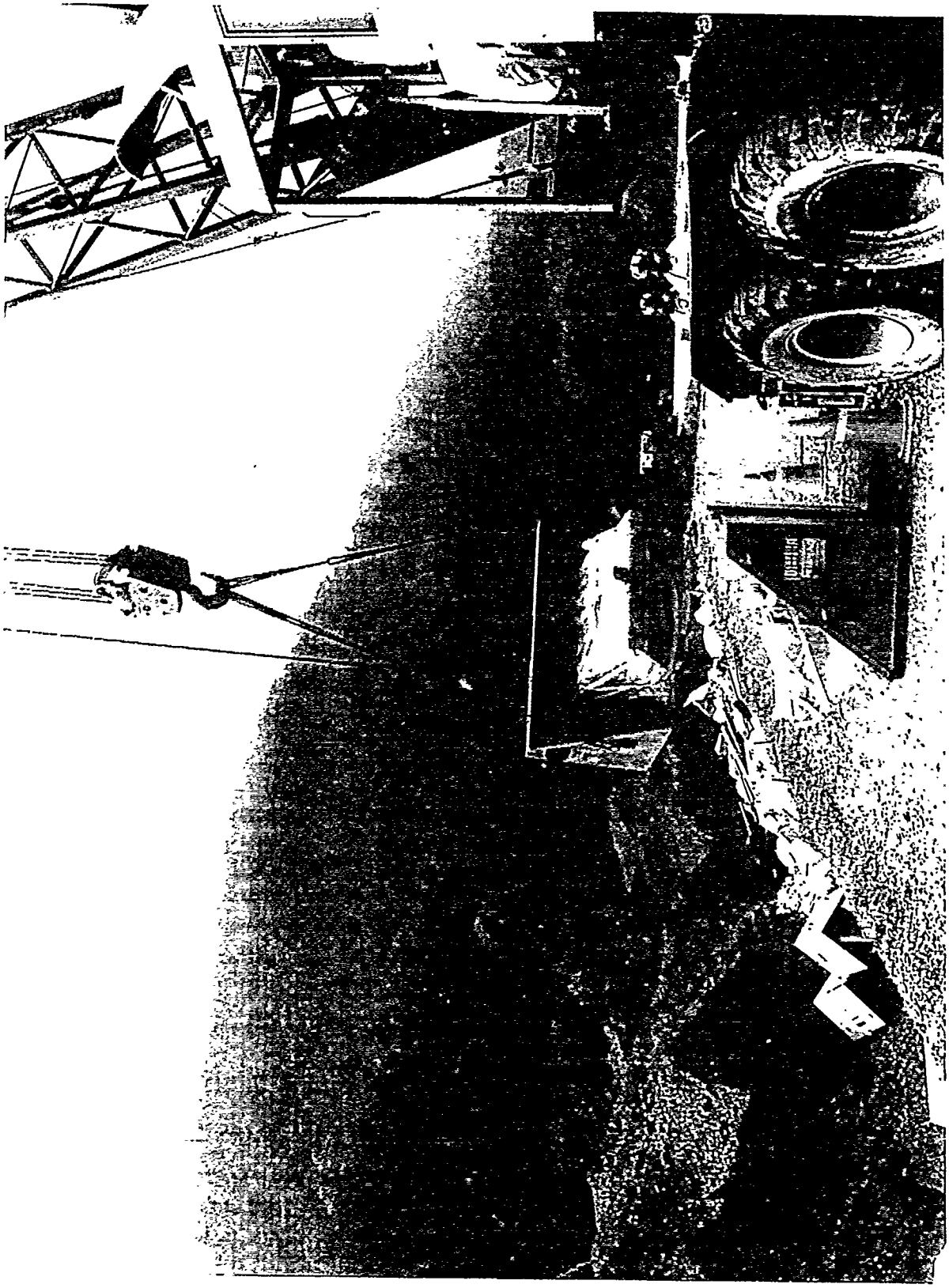


Fig. B4.9. Placement of radioactive solid wastes from lead-lined dumpster in SWSA 5 South. (ORNL Photo No. 66231)

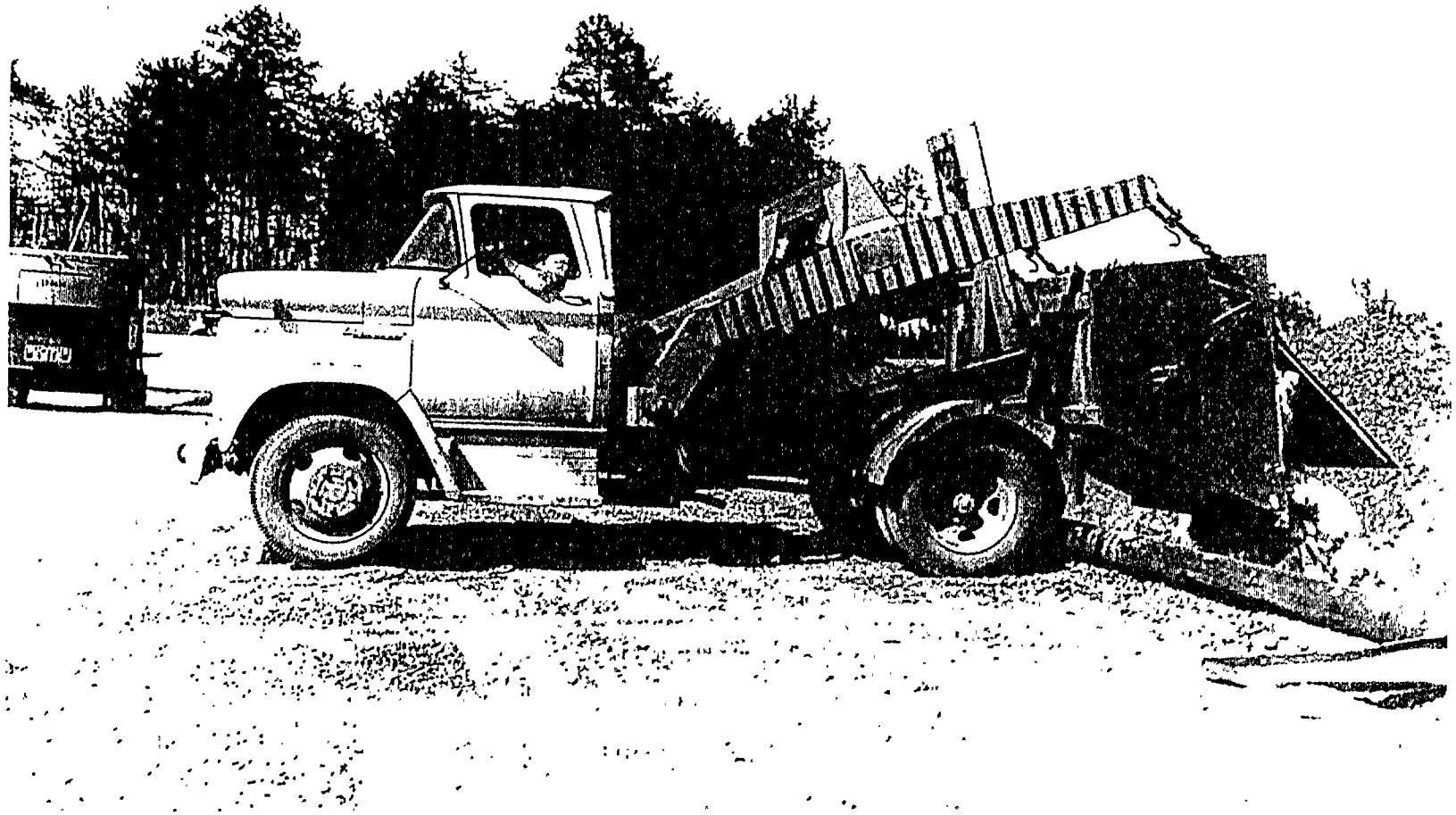


Fig. B4.10. Emptying of dumpster trash from ORNL sources; lead-lined dumpsters were used to collect low-level solid waste for disposal in the burial ground. (ORNL Photo No. 60823)

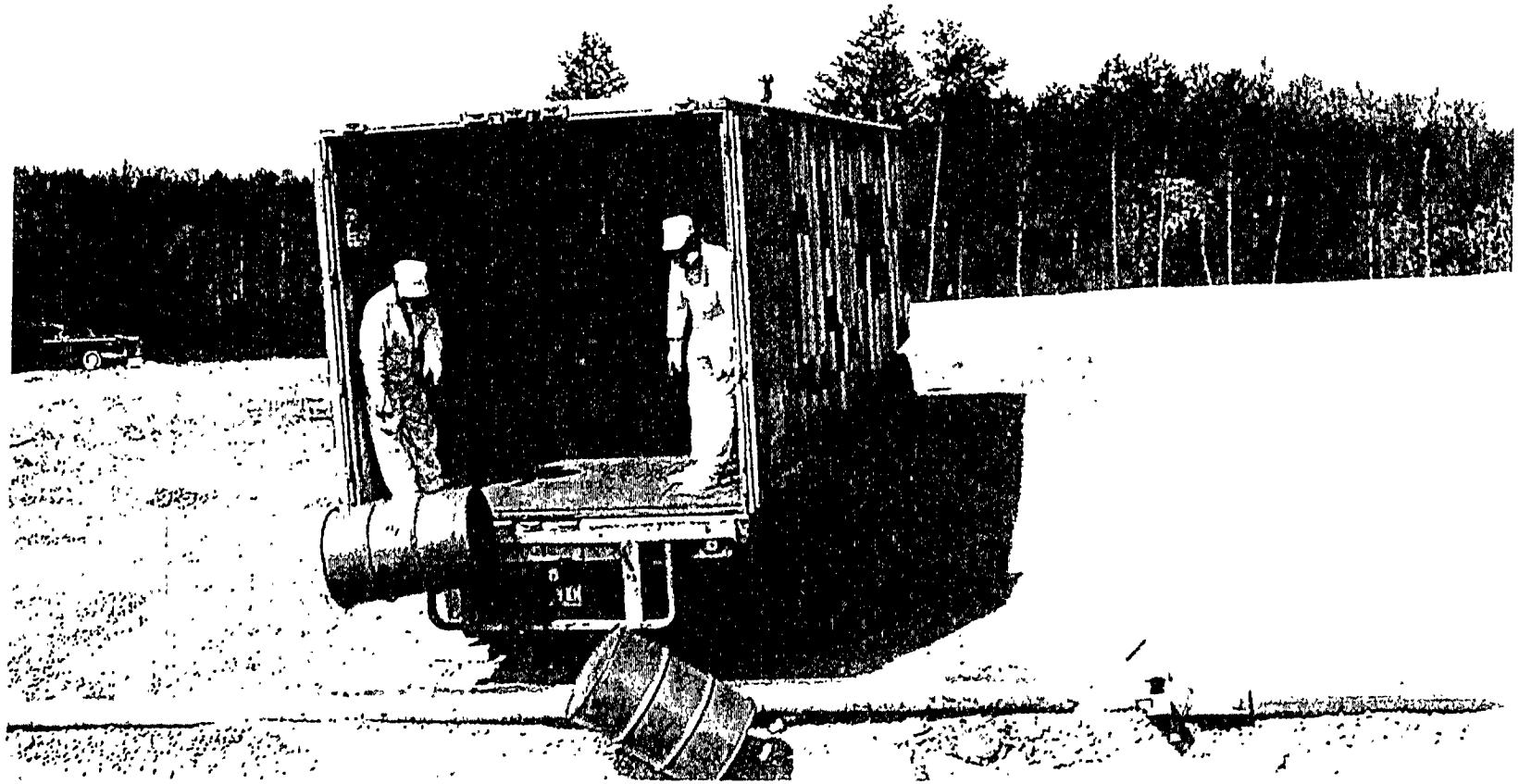


Fig. B4.11. Disposal of 55-gal drums containing radioactive waste from off-site generators (disposal probably occurred when ORNL was AEC Southern Regional Burial Ground). (ORNL Photo No. 60855)

Fig. B4.12. Disposal of drummed and boxed wastes in SWSA 5 South trench. (ORNL Photo No. 61791)

Fig. B4.13. Example of procedure used to empty dumpsters with more highly contaminated wastes; wastes in this case consisted of metal cans wrapped in plastic. (ORNL Photo No. 66229)

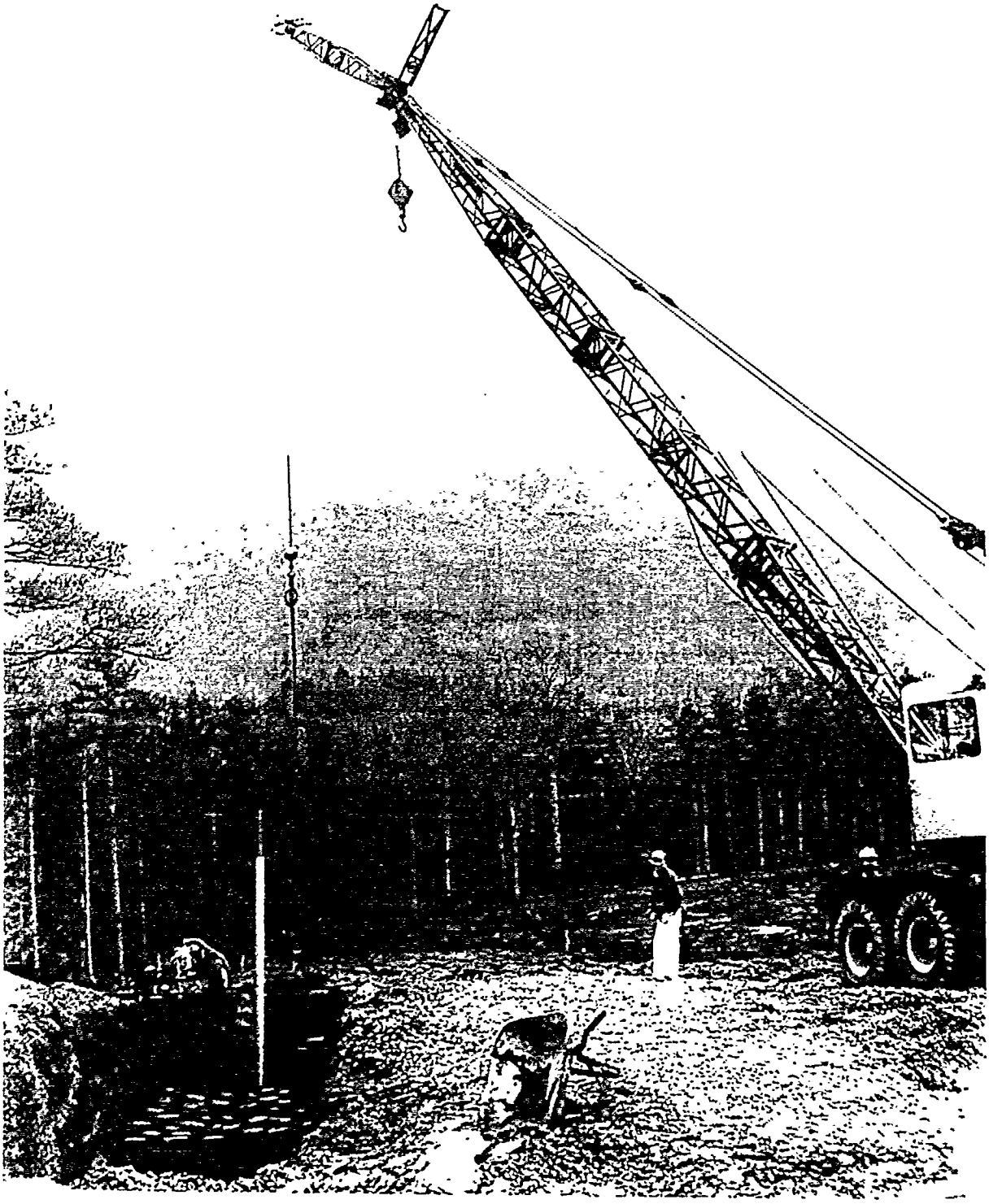


Fig. B4.14. Systematic stacking of waste drums in a SWSA 5 South trench. (ORNL Photo No. 45992)

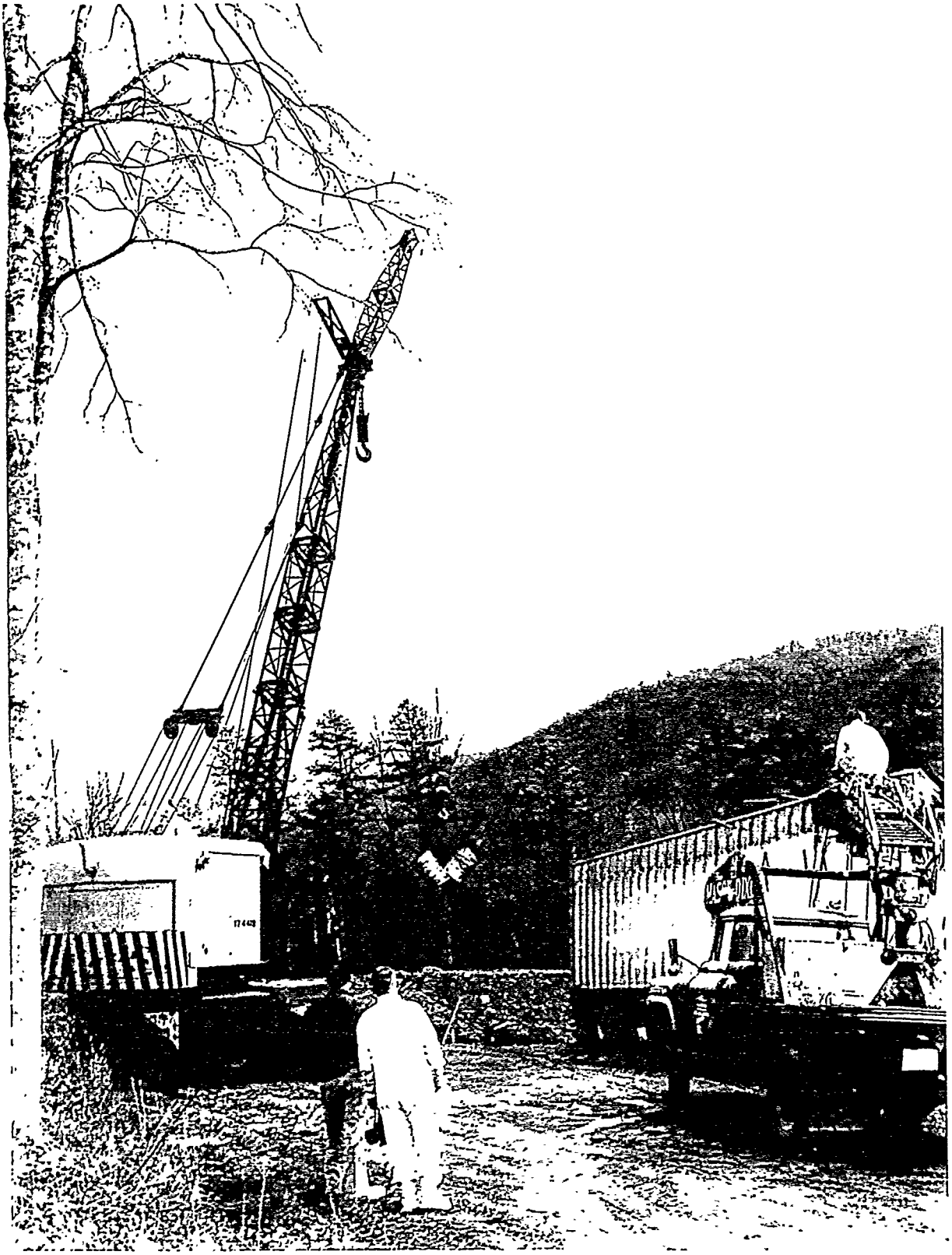


Fig. B4.15. Disposal of off-site wastes in SWSA 5 South; drums that could not be handled, possibly due to high exposure levels, were lifted by crane and lowered into the trenches. (ORNL Photo No. 101781)

Fig. B4.16. Stacked 55-gal steel drums in trench 29 or 30, Y-12 special burial area, buried in 1959; note 6-in.-ID perforated corrugated metal standpipe for monitoring trench fluid. (ORNL Photo No. 45989)

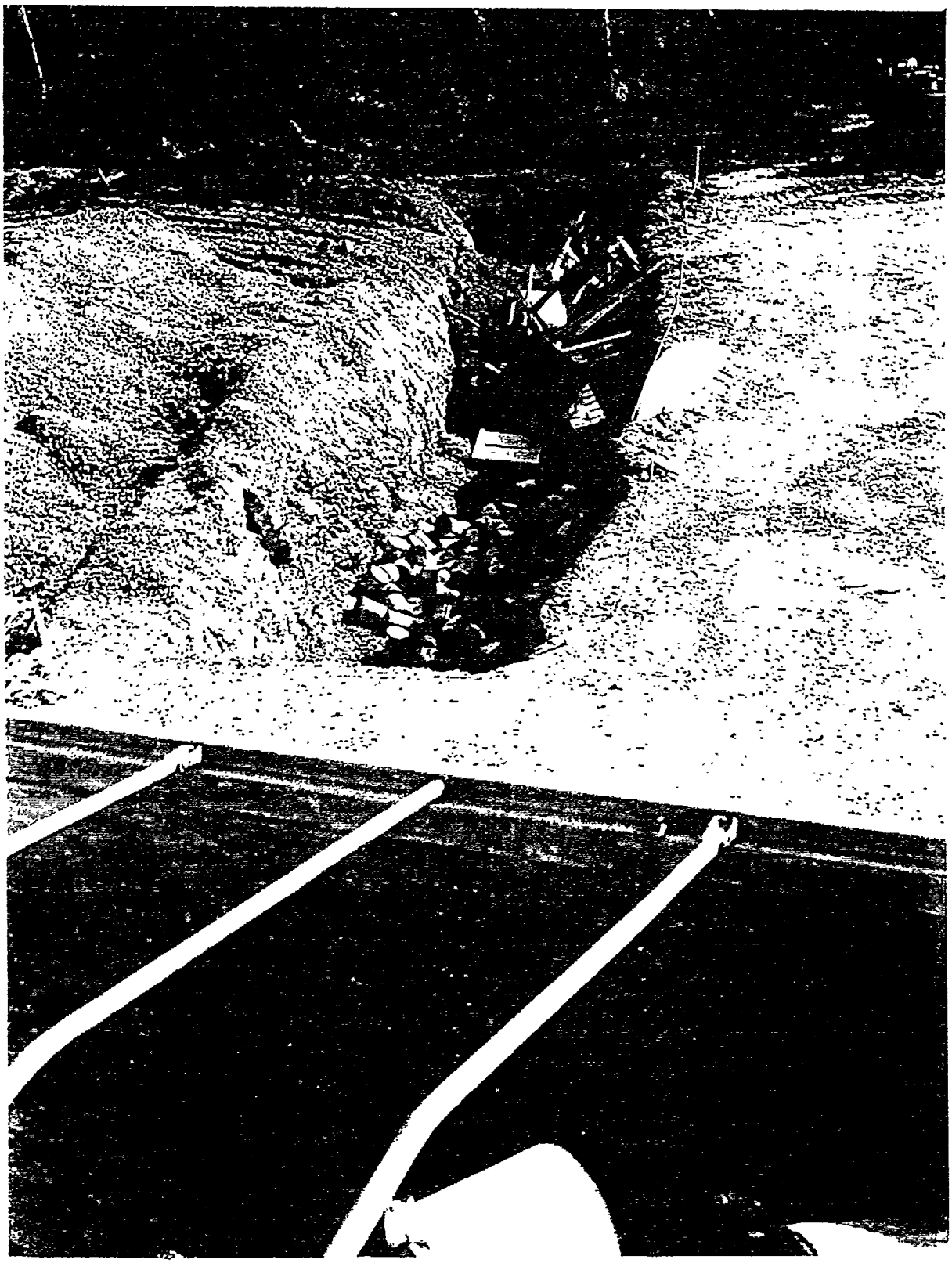


Fig. B4.17. Trench in SWSA 5 South showing mixture of wastes typical for burial ground; cans in foreground probably contained wastes; debris in background was probably not contaminated. (ORNL Photo No. 101778)

Fig. B4.18. Partially filled trench and typical solid wastes in SWSA 5 South. (ORNL Photo No. 101139)

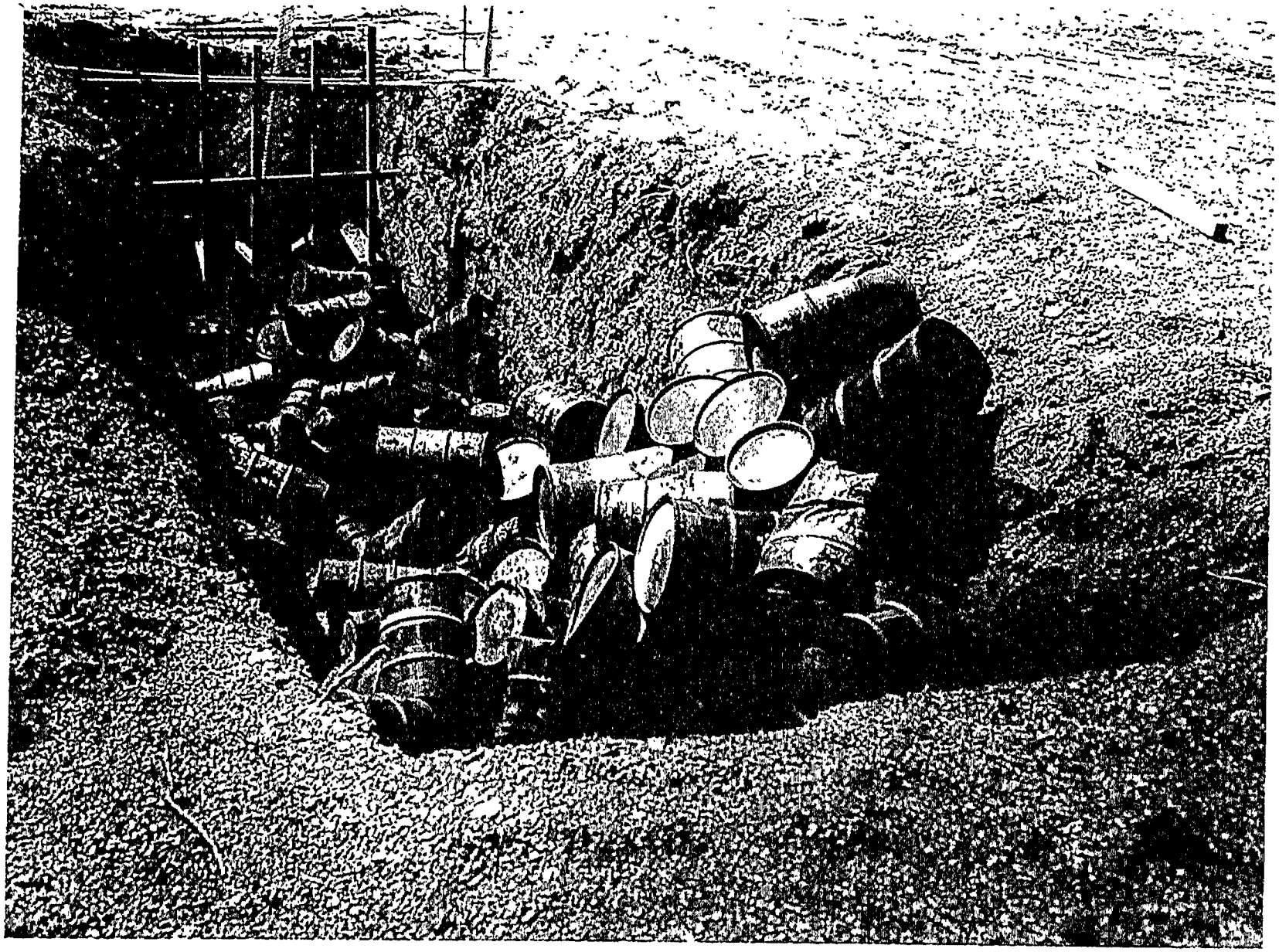


Fig. B4.19. Drums dumped into trench 29 or 30, Y-12 special burial area in Area A of SWSA 5 South; part of a study to see if container integrity affected quality of water monitored in trench standpipes (background). (ORNL Photo No. 46368)

Fig. B4.20. Sealed concrete casks containing TRU wastes were placed in the SWSA 5 North TRU trenches in the early 1970s. Perforated corrugated metal pipes were typically installed to monitor trench fluids. (ORNL Photo No. 1625-73)

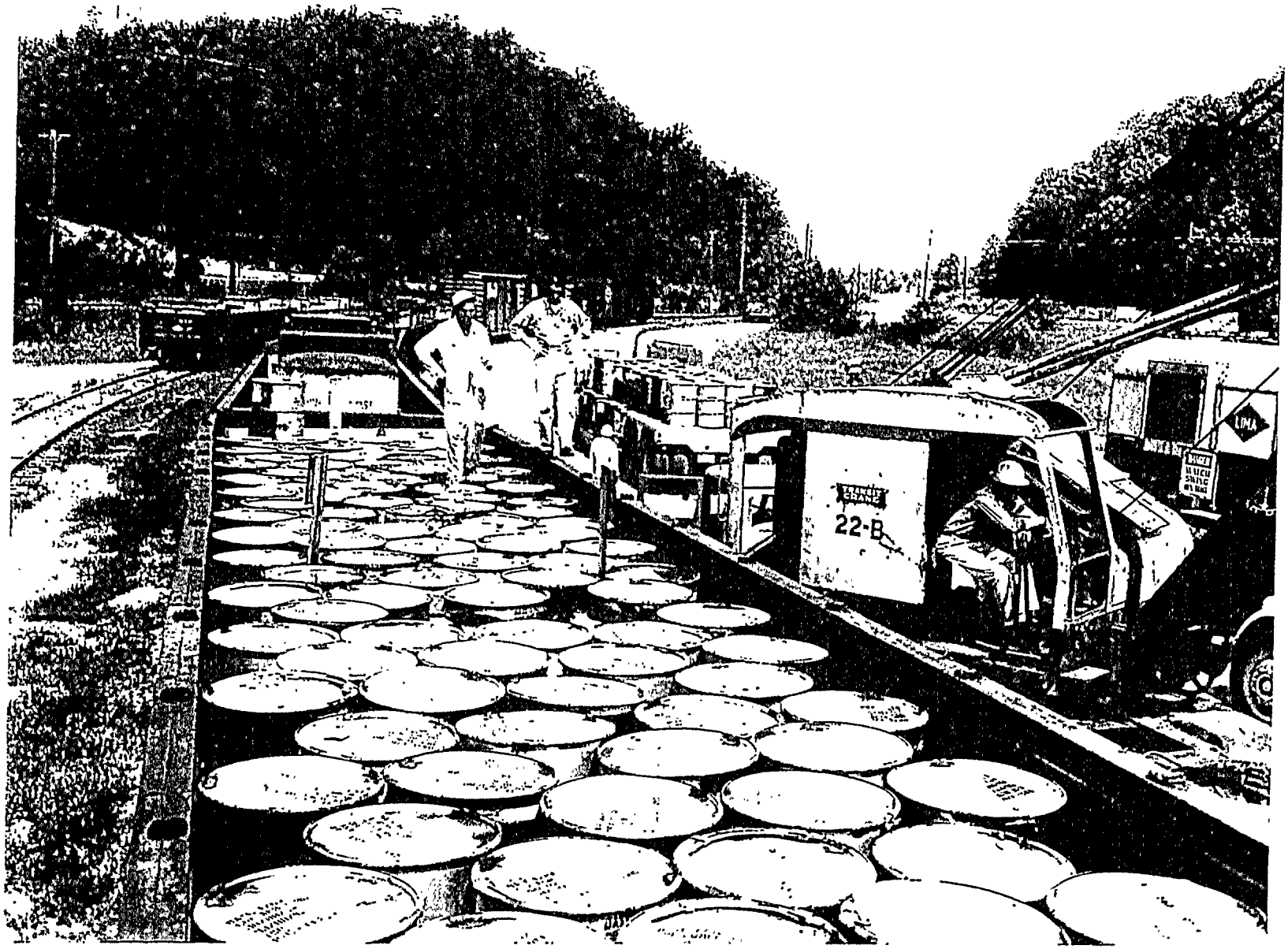


Fig. B4.21. Unloading of off-site shipments of radioactive waste in 1963 when ORNL was AEC Southern Regional Burial Ground; wastes were probably disposed of in SWSA 5. (ORNL Photo No. 61792)

Fig. B4.22. Truckload of off-site wastes shipped to ORNL for disposal in SWSA 5; may be same shipment shown in Fig. B4.23. (ORNL Photo No. 101783)

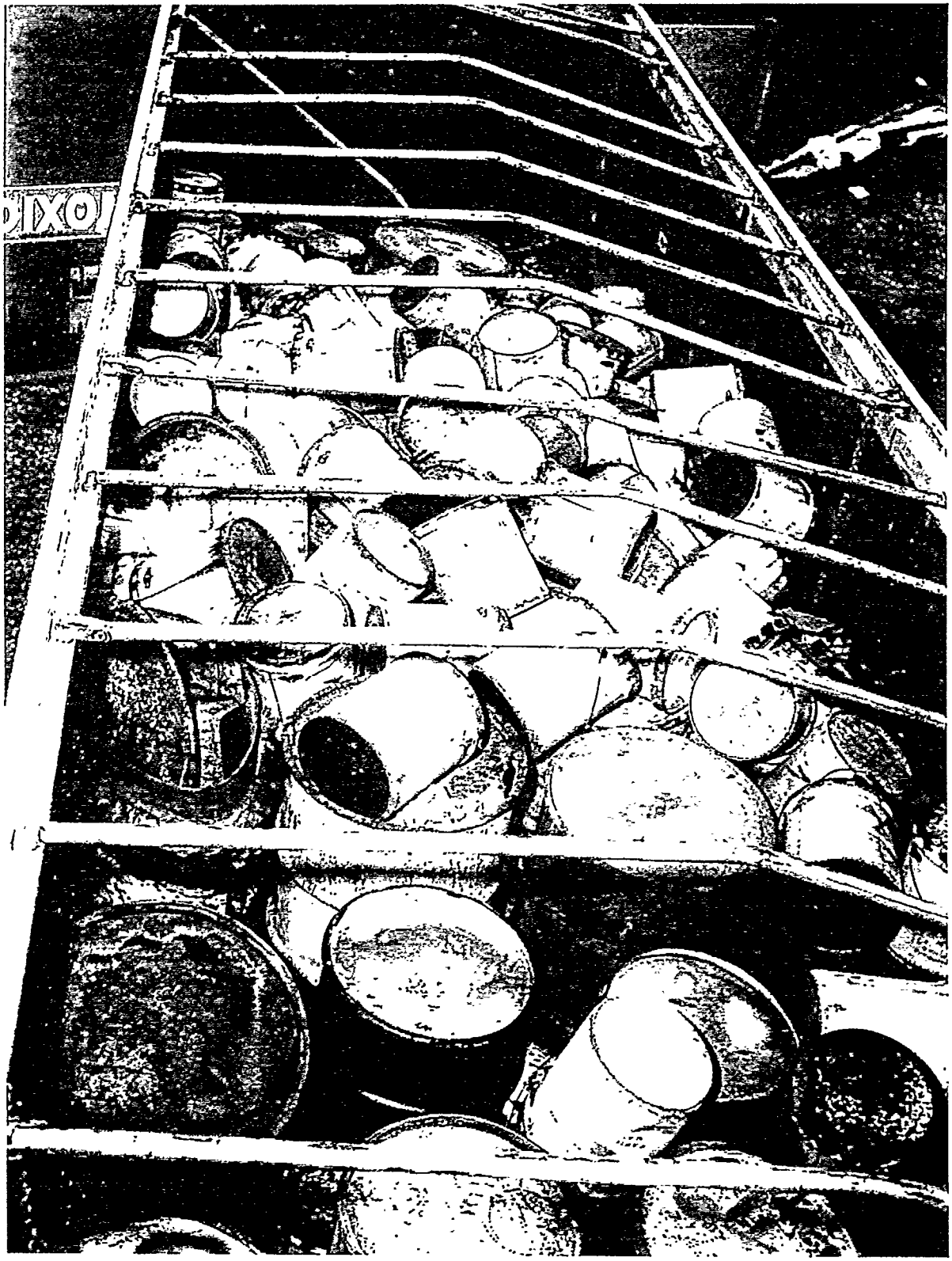


Fig. B4.23. Carrier truck loaded with containerized radioactive waste from off-site sources when ORNL was AEC Southern Regional Burial Ground; note poor integrity of many of the containers. (ORNL Photo No. 101776)

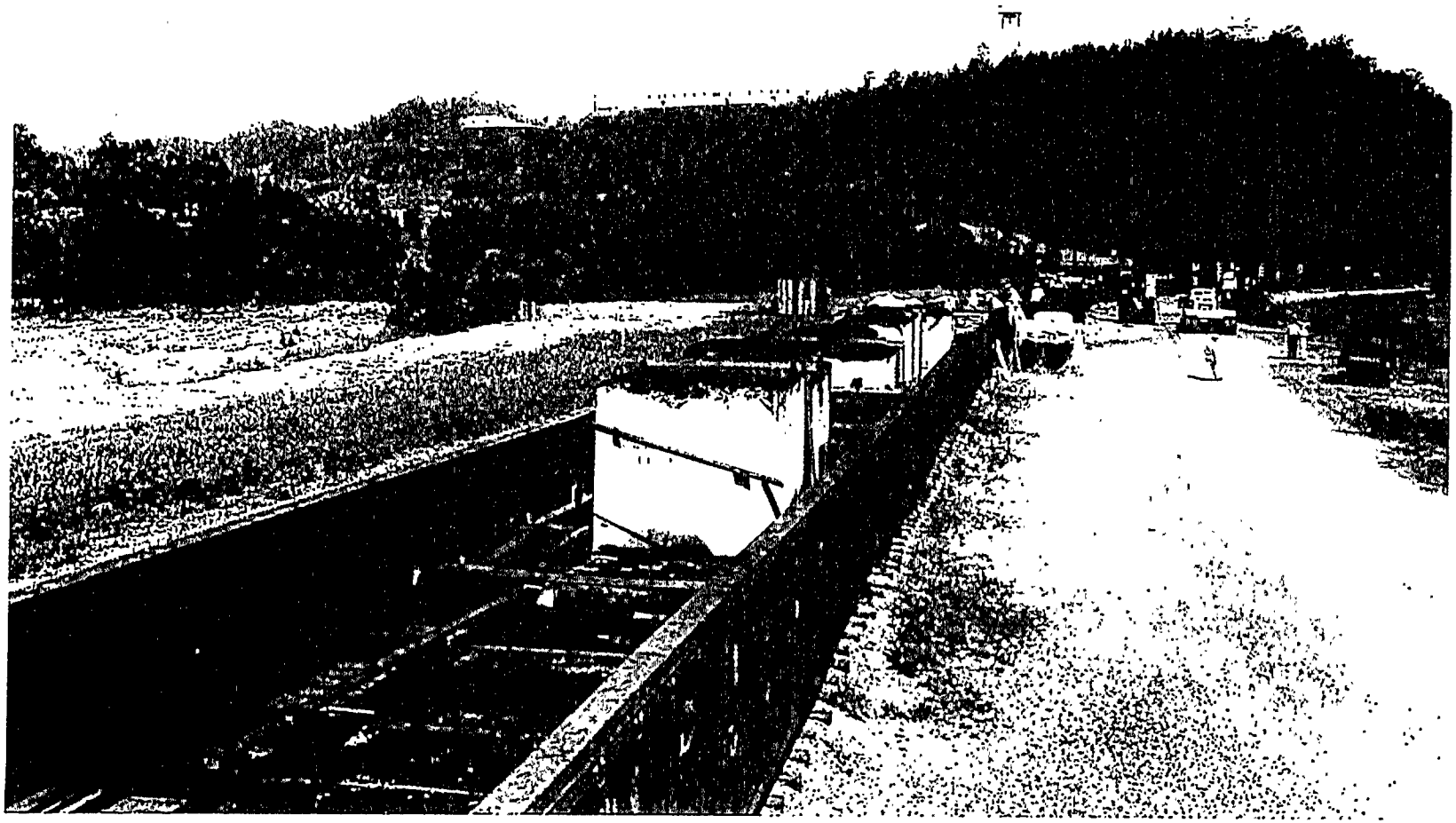


Fig. B4.24. Same period of time as Fig. B4.21; unloading of concrete casks from off-site sources for burial in SWSA 5. (ORNL Photo No. 61794)

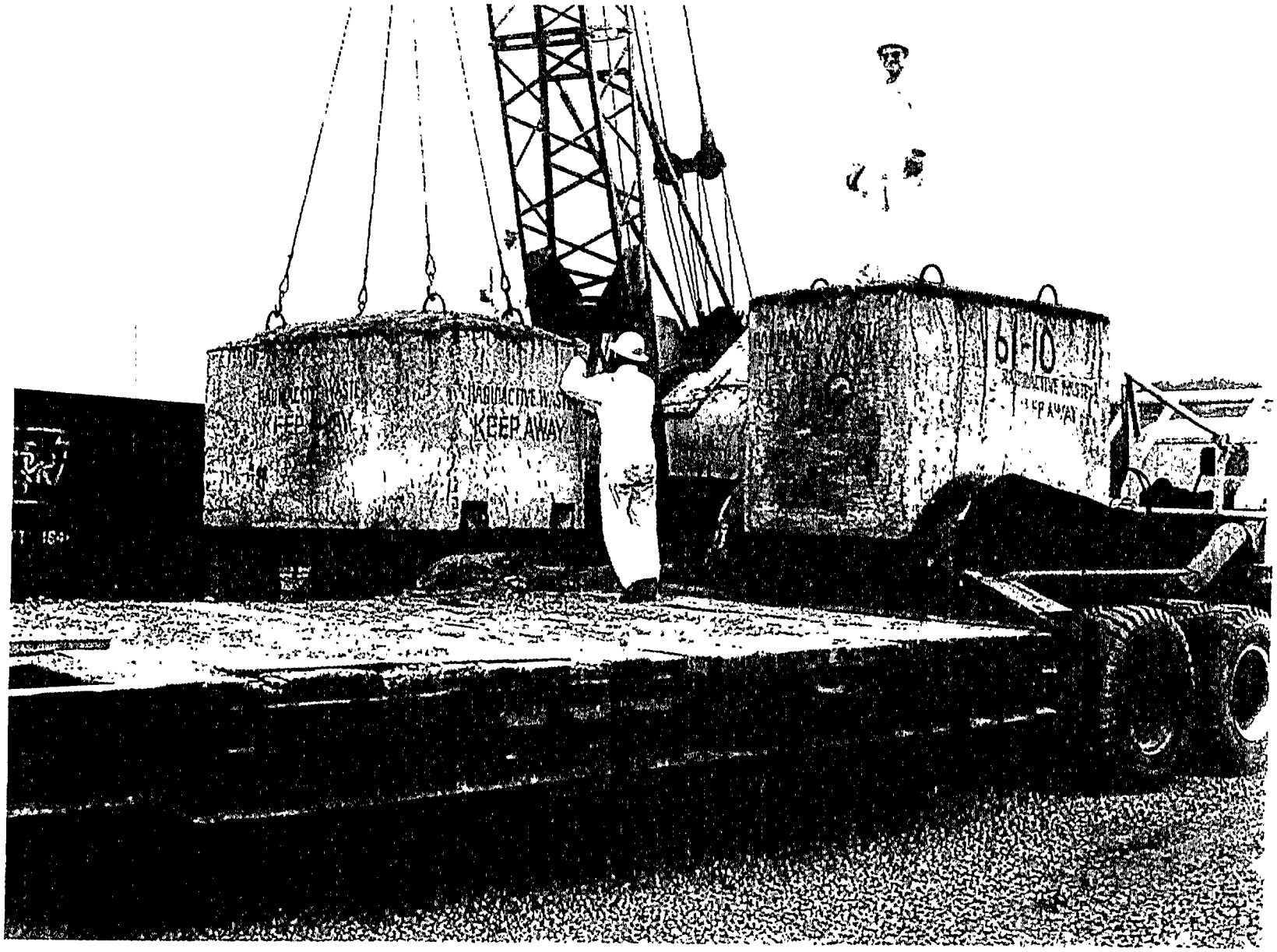


Fig. B4.25. Off-loading of radioactive waste casks at Y-12 railroad siding for disposal in SWSA 4 or 5 when ORNL was the AEC Southern Regional Burial Ground. (ORNL Photo No. 61841)

Fig. B4.26. Trench in SWSA 5 South showing variety of waste containers—wooden boxes, concrete boxes stacked on top of wooden boxes, and metal cans and drums; note void spaces between boxes. (ORNL Photo No. 61846)

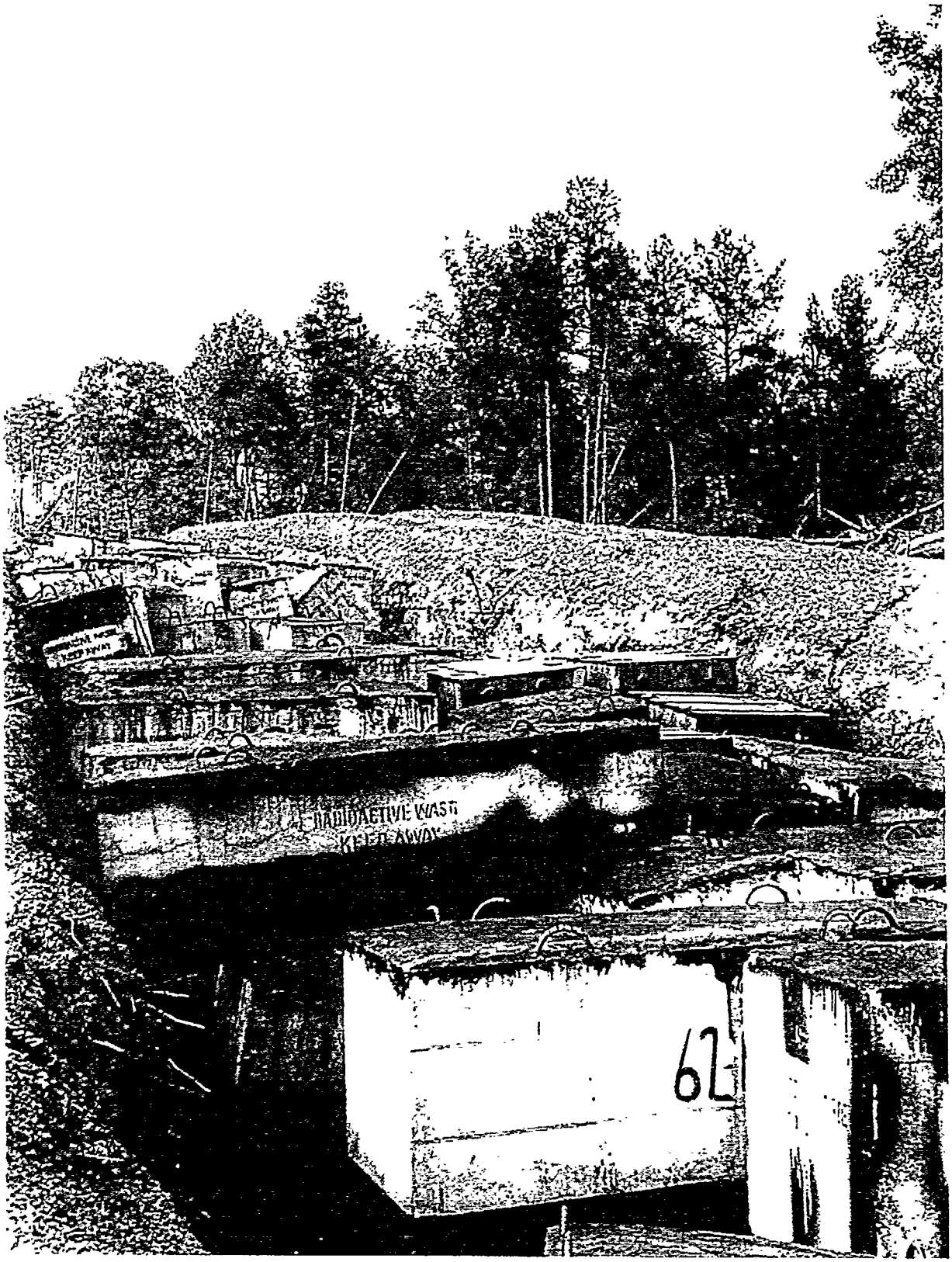


Fig. B4.27. Large concrete boxes in SWSA 5 South trench. (ORNL Photo No. 61842)

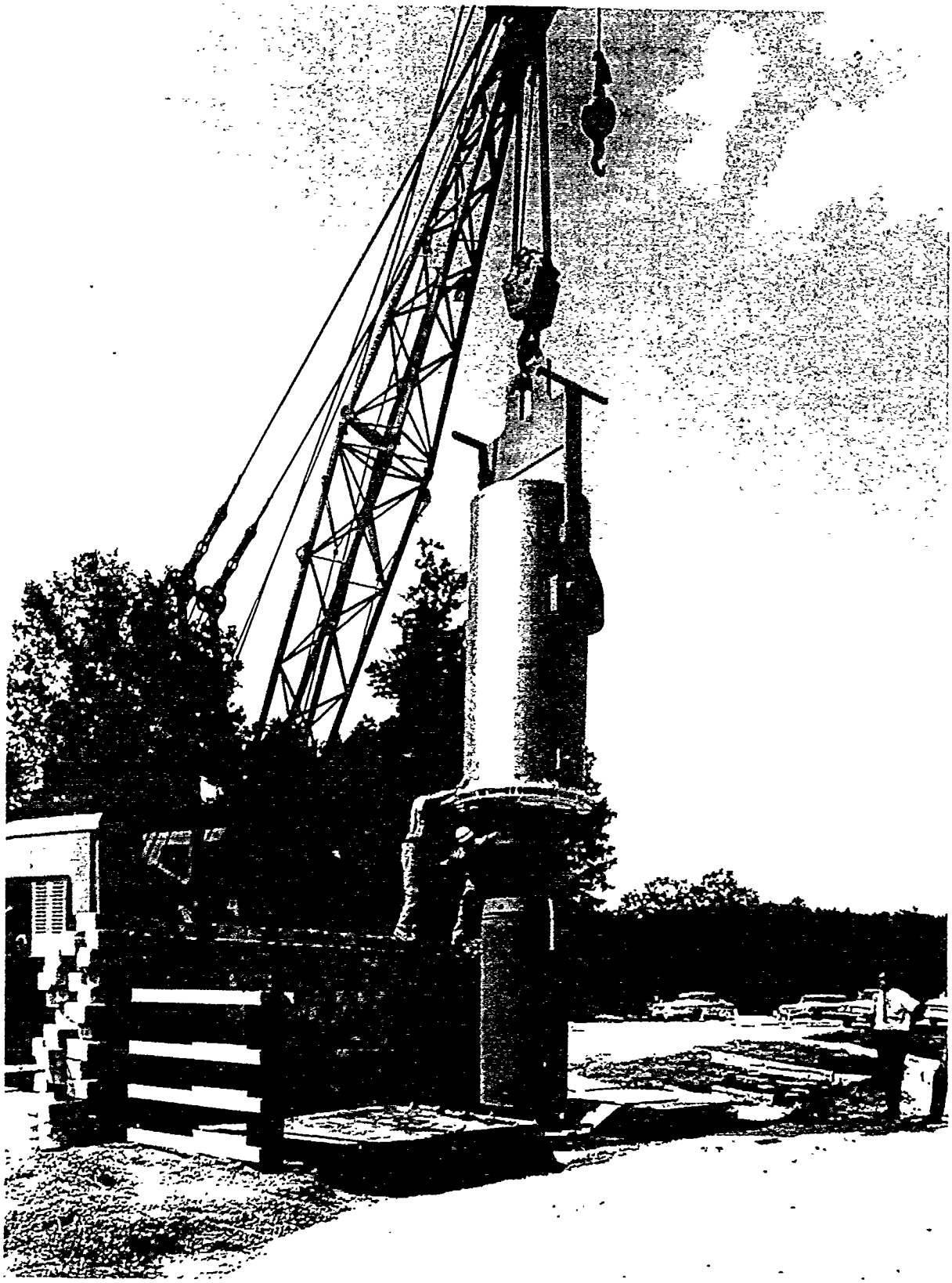


Fig. B4.28. Placement of control rods from Yankee Atomic Energy facility in specially constructed vaults in northern portion of SWSA 5 South in 1959; wastes had high gamma activity—note barrier of lead blocks. (ORNL Photo No. 96970)

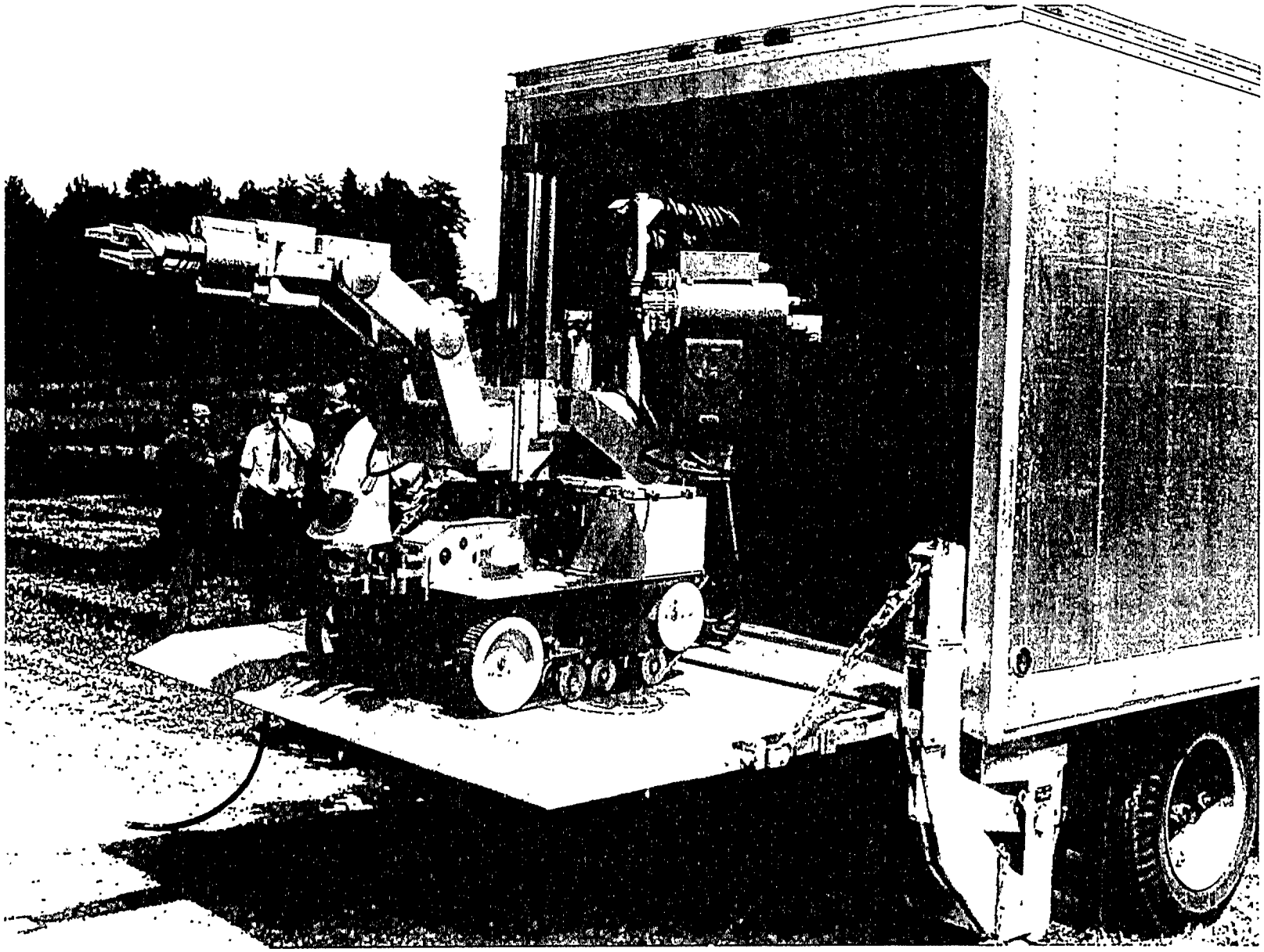


Fig. B4.29. Robotics device used during burial activities related to placement of Yankee Atomic Energy wastes (high gamma activity due to Co-60). (ORNL Photo No. 96974)

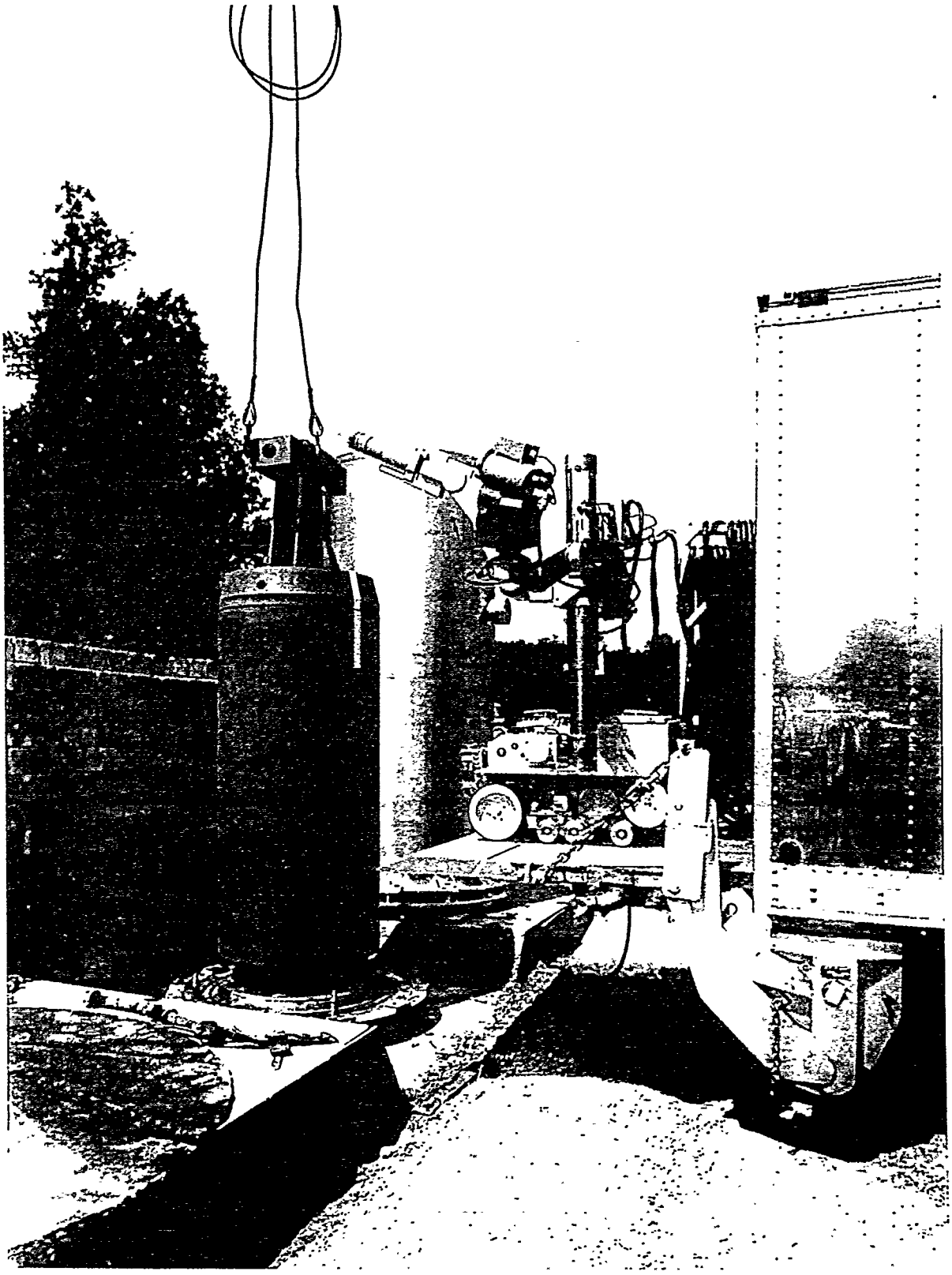


Fig. B4.30. Robotics used to aid in the burial of the waste from the Yankee Atomic Energy facility. (ORNL Photo No. 96964)

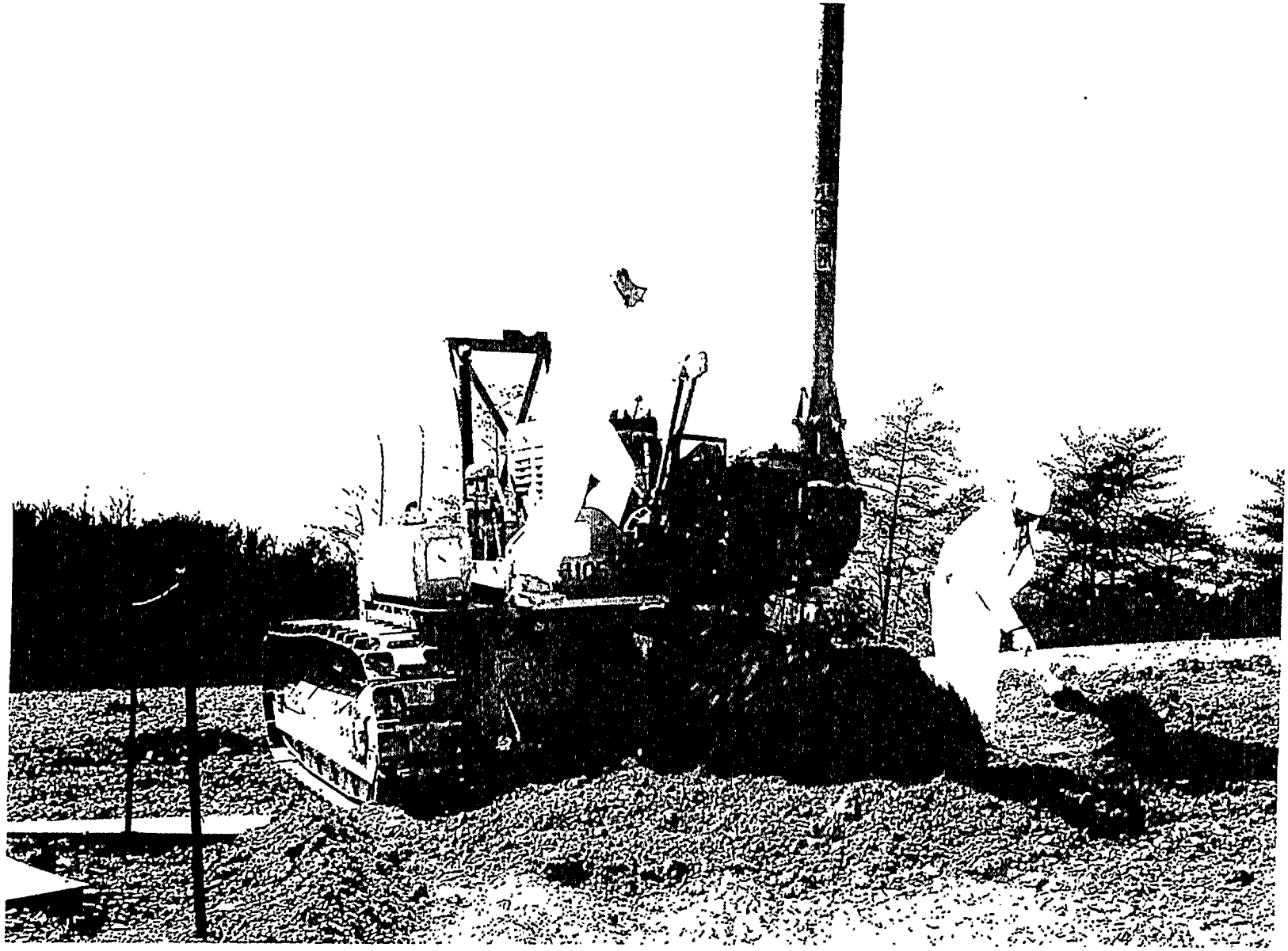


Fig. B4.31. Auger holes were excavated with a mobile unit typically using a 3-ft-diam auger bit to a depth not exceeding 20 ft. (ORNL Photo No. 60821)

Fig. B4.32. Emptying of wastes from shielded container into unlined auger hole in SWSA 5 South. (ORNL Photo No. 66347)

Fig. B4.33. Filling of auger holes in SWSA 5 with high-activity beta/gamma waste; location is west of drainage D-2 in so-called " hot garden" of high-activity auger holes; note concrete-capped filled auger holes in foreground. (ORNL Photo No. 60817)

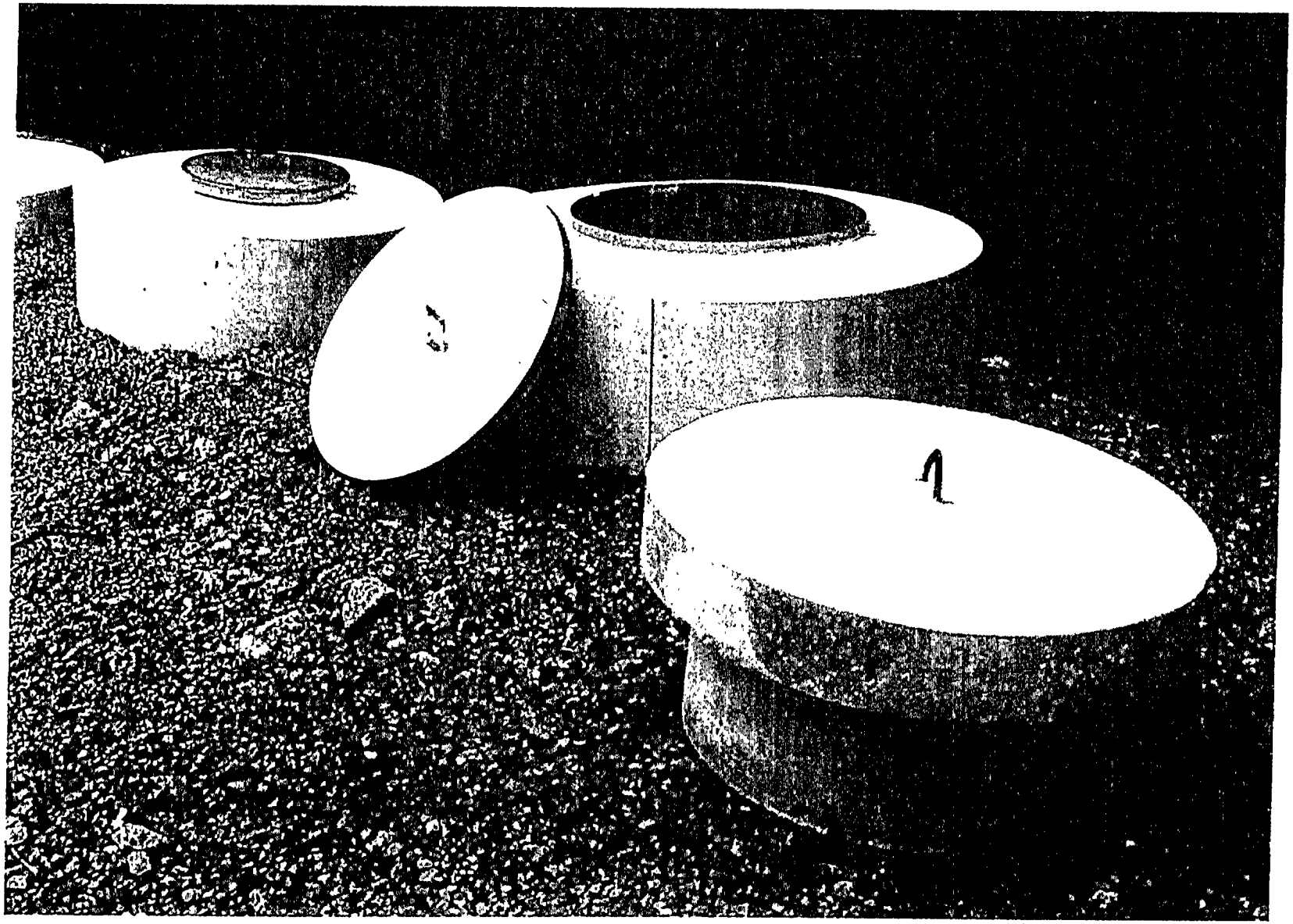


Fig. B4.34. Stainless steel and concrete-lined auger holes were constructed during the early 1970s in SWSA 5 North for storage of high-activity (beta/gamma) TRU waste. (ORNL Photo No. 1646-71)

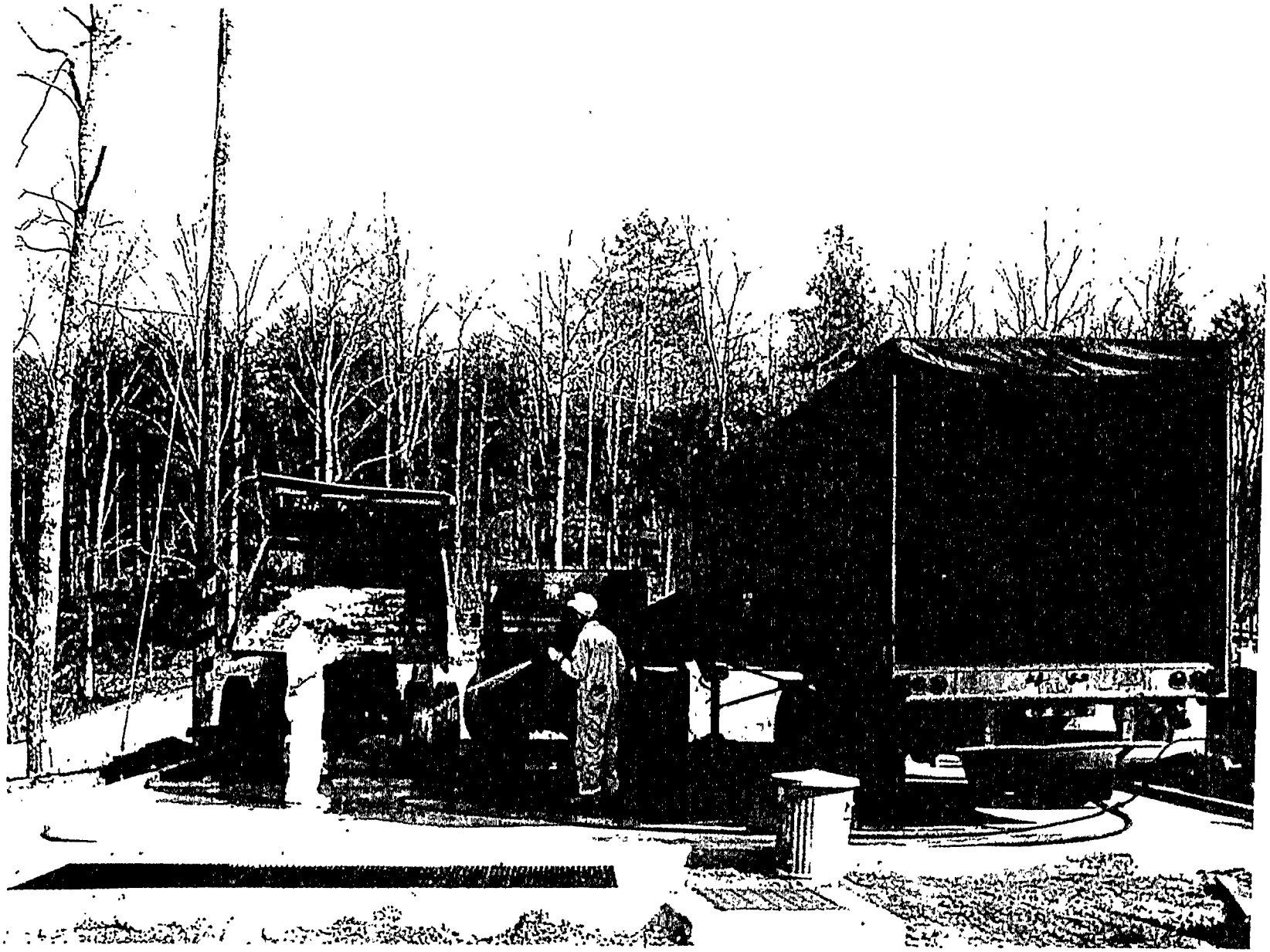


Fig. B4.35. Decontamination of waste carrier trucks at Bldg. 7831 decon pad outside main entrance to WAG 5; decon fluids from this operation were conveyed to drainfield in vicinity of North Tributary. (ORNL Photo No. 60824)

B5. HYDROLOGIC MODEL

An objective of the WAG 5 RI was to characterize the contaminant flux from the burial ground into adjacent surface waters. Contaminant fluxes were determined based on current knowledge of the nature and extent of contamination (Appendix B2) and the hydrologic processes involved with contaminant transport. Appendix B1 presents a qualitative description of the hydrologic processes at WAG 5, and the purpose of this appendix is to describe the methodology used to quantify these processes.

B5.1 MODELED WAG 5 DRAINAGE STREAMS

The WAG 5 hydrologic model included intermittent drainage streams D1, D-2, and D-3, shown in Fig. B5.1.1. Physical characteristics are provided in Table B5.1.1. Flow in D-1 is gauged via a 2.5-ft H-flume installed at monitoring station SW001. Flows in D-2 and D-3 are gauged by a 2-ft H-flumes at SW002 and SW003, respectively. Continuous flow measurements were recorded at each of these stations between April 1993 and April 1994.

Table B5.1.1. Physical characteristics of WAG 5 drainage streams

Drainage	Area (acres)	Discharge to	Average Slope
D-1	27.9	White Oak Creek	12
D-2	10.6	Melton Branch	10
D-3	9.3	Melton Branch Tributary	18

B5.2 HSPF CALCULATION

Previous studies have identified surface water discharge as the primary conduit at WAG 5 for off-site contaminant migration. Better delineation of the surface water hydrology allows for better understanding of flow contributions from the drainage basins and the relative significance of their flow pathways (i.e., groundwater, interflow/stormflow, and runoff) in the context of total discharge. An understanding of the surface water system is essential to accurate quantification of contaminant flux because hydrologic fluxes drive contaminant fluxes. HSPF was used to simulate the long-term discharge of surface runoff, interflow, and groundwater into drainage channels and ultimately into Melton Branch and White Oak Creek.

B5.2.1 Model Description

HSPF is a continuous hydrologic model that uses long-term water balance equations to account directly for effects of antecedent conditions. It is general enough that it can be applied to all types of watersheds from undisturbed to urban and simulate the actual physical processes of the hydrologic cycle.

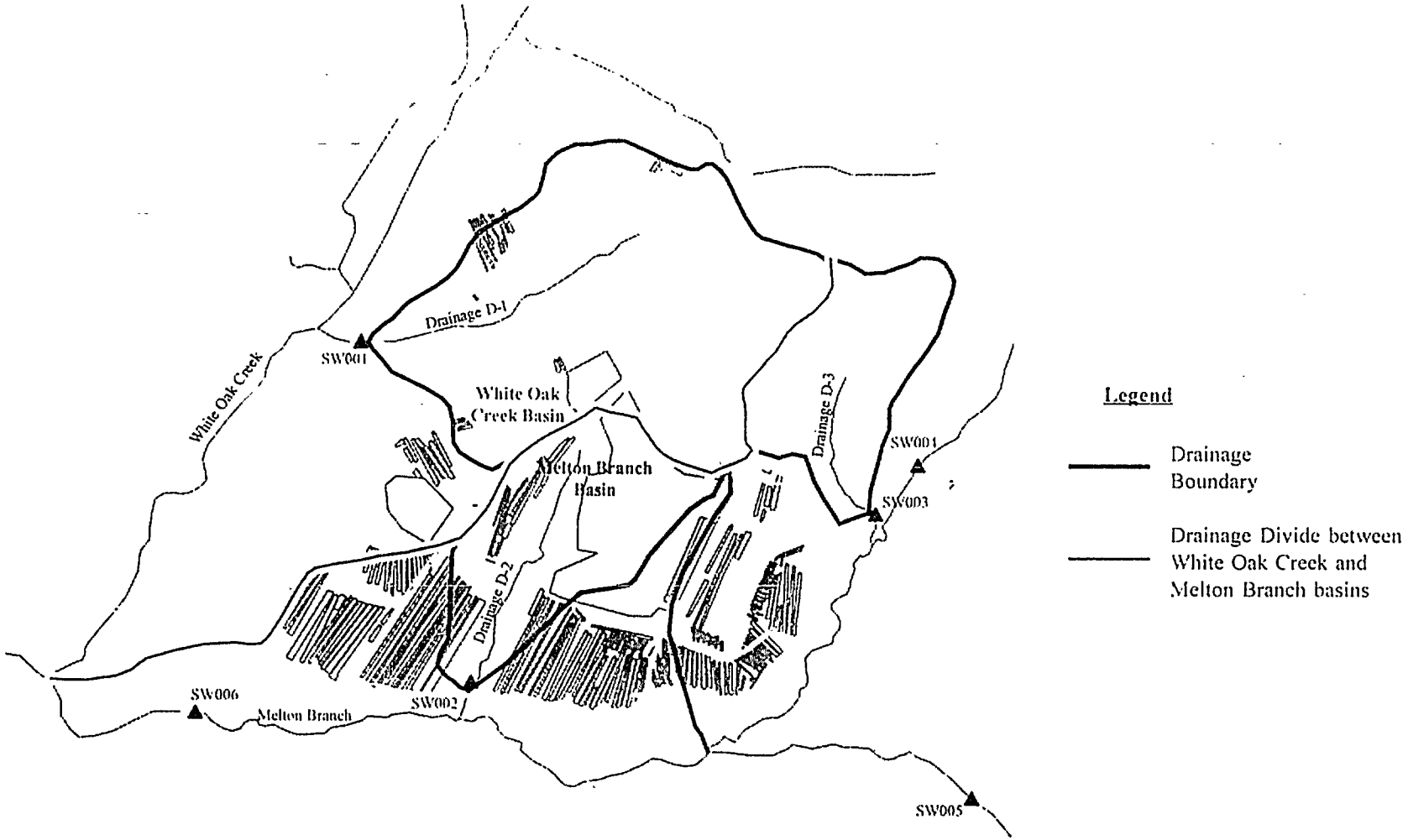


Fig. B5.1.1. WAG 5 Drainage Areas.

HSPF performs watershed stream flow simulations based on temporal precipitation and evaporation records for water input and parameters describing physical characteristics (e.g., topography, soils) for storage and transport input. HSPF simulates stream discharge by dividing flow into three separate components: surface runoff, interflow, and shallow groundwater discharge. Surface runoff travels over the ground surface and is merged into drainage channels. Interflow is the component of flow associated with the transient, perched water table occurring in the root zone of the upper soil layer. Interflow is transmitted laterally (downslope) until it reaches the stream channel. Groundwater discharge occurs when the water table intersects the stream channel and the hydraulic potential causes groundwater to discharge into the stream.

HSPF was calibrated for drainages D-1, D-2, and D-3 by adjusting the physical parameters describing the soil, vegetation, and topography. The model was calibrated to match 12 months of stream flow data measured at surface water stations SW001, SW002, and SW003 from April 1993 through April 1994.

B5.2.2 Time-Series Data

The main input to HSPF included breakpoint precipitation data measured at SWSA 4 that was converted into 15-min intervals for the period January 1992 through April 1994, and daily pan evaporation data measured at the University of Tennessee's Agriculture Research Station in Knoxville, Tennessee. The evaporation data were adjusted for the Oak Ridge area by multiplying the daily values by a pan coefficient of 0.77 (Farnsworth 1982) to approximate lake surface evaporation, which is assumed to be equal to the potential evapotranspiration.

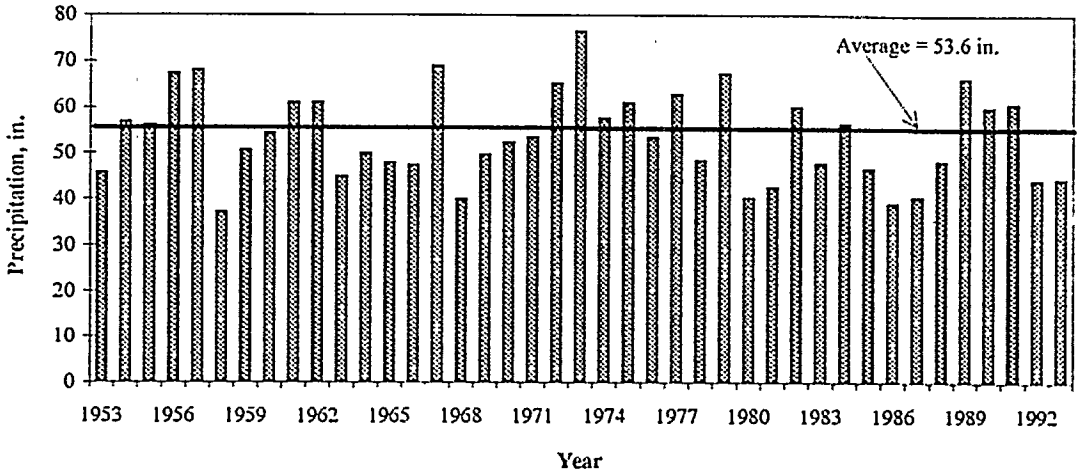
Simulations run with the precipitation and evaporation data from January 1992 through April 1994 were compared with the stream flow data from April 1993 through April 1994 for calibration. The simulations from 1992 through April 1993 were to minimize the effects of the initial conditions.

After HSPF was calibrated for stations SW001, SW002, and SW003, stream flow was simulated at each for a 41-year period using hourly precipitation data recorded at the Oak Ridge Atmospheric Turbulence and Diffusion Laboratory from 1953 through 1993. Figure B5.2.1 shows the annual precipitation. Potential evaporation data were generated for this period using the Hydrologic Evaluation of Landfill Performance (HELP) model. HELP estimates the potential evaporation with a modified form of the Penman equation, which is based on daily temperature and solar radiation. The simulated potential evapotranspiration was calibrated to eight years of pan evaporation data recorded by the University of Tennessee.

B5.2.3 Soil and Vegetation Data

The model was calibrated to match one year of stream flow data from stations SW001, SW002, and SW003. The HSPF module that characterizes pervious land segments was used for the three drainage basins. Drainage D-1 is only 7% impervious (roads and building in SWSA 5 North), and drainages D-2 and D-3 have no impervious areas.

The model parameters were calibrated by comparing the simulated flow hydrograph with the measured flow averaged over 6-h intervals. Figure B5.2.2 is an example of a plot used to calibrate the simulated and measured flow for SW001.



Source: Oak Ridge Atmospheric Turbulence and Diffusion Laboratory

Fig. B5.2.1. Annual precipitation at Oak Ridge from 1953 to 1993.

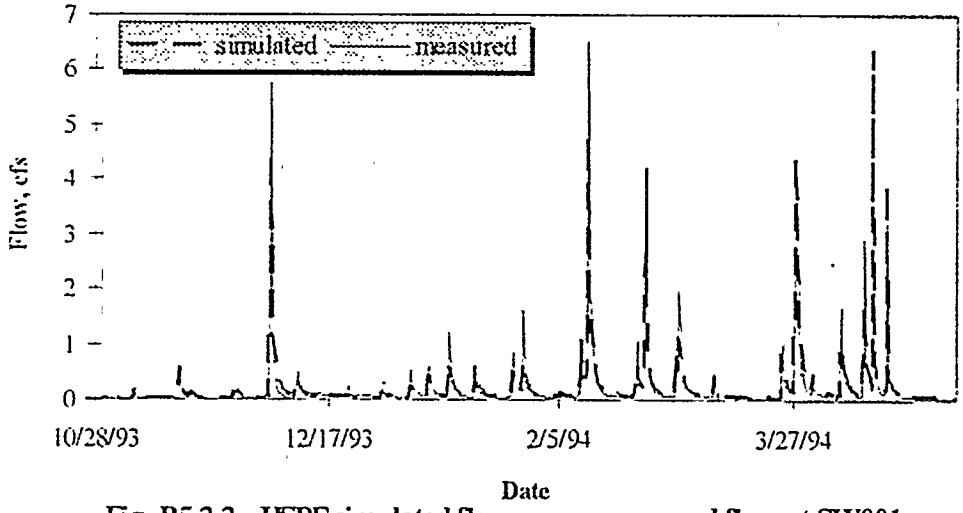


Fig. B5.2.2. HSPF simulated flow versus measured flow at SW001.

fgb5_2_2.xls

Several iterations were typically made to calibrate the model. Table B5.2.1 lists the calibrated model parameters; those in bold are were found to be the most sensitive.

Table B5.2.1. HSPF parameters for D-1, D-2, and D-3

Parameter	Drainage Basin D-1	D-2	D-3	Parameter description
FOREST	0	0	0	fraction of pervious land segment with coniferous trees
LZSN	4.0	4.0	4.0	lower zone soil nominal storage
INFILT	0.08	0.20	0.08	index to the infiltration capacity of the soils
LSUR	300	300	300	length of assumed overland flow plane
SLSUR	0.12	0.10	0.14	slope of assumed overland flow plane
AGWRC	0.93	0.93	0.93	groundwater recession rate
PETMAX	40	40	40	air temperature below which ET will be reduced
PETMIN	35	35	35	air temperature below which ET will be zero
INFEXP	2	2	2	exponent in the infiltration equation
INFILD	2	2	2	ratio between maximum and the mean infiltration capacities
DEEPFR	0	0	0	fraction of groundwater inflow that will enter deep groundwater
BASETP	0	0	0	fraction of PET that can be satisfied from baseflow
AGWETP	0	0	0	fraction of PET that can be satisfied from active groundwater
CEPSC	0.05	0.05	0.05	interception storage capacity
UZSN	0.35	0.15	0.35	nominal upper soil zone storage
NSUR	0.4	0.4	0.4	Manning's "n" for the assumed overland flow plane
INTFW	1.50	1.50	1.50	interflow parameter
IRC	0.30	0.30	0.30	interflow recession parameter
LZETP	0.4	0.4	0.4	lower zone evapotranspiration parameter

The parameters for pervious land segments are the same for each drainage basin except D-2, which has a higher infiltration capacity and lower soil water storage capacity, attributable to the large areas of soils disturbed during the waste disposal activities.

B5.2.4 Results

After the model was calibrated for each station, simulations were performed using the 41 years of precipitation data (1953 to 1993). Table B5.2.2 summarizes the average annual water balance components for the three drainages.

Table B5.2.2. WAG 5 average annual water balance components

Component	Volume (in.) D-1	D-2	D-3
Precipitation	53.9	53.9	53.9
Evapotranspiration	26.1	24.7	27.4
Total discharge	27.8	29.2	26.5
Surface runoff	7.6 (23.0%)	2.0 (6.9%)	4.9 (18.5%)
Interflow	8.5 (30.6%)	8.3 (28.4%)	9.1 (34.3%)
Groundwater	11.7 (42.1%)	18.9 (64.7%)	12.5 (47.2%)

Drainages D-1 and D-3 are similar in their water balance distributions because both are relatively undisturbed. Drainage D-1 has slightly more surface runoff because of the impervious areas (i.e., SWSA 5 North roads and buildings). Drainage D-2 has a much greater percentage of flow from

groundwater discharge, which is attributable to the large areas disturbed during waste burial operations. Fill placed on top of the trenches is generally more permeable than the undisturbed areas, which results in greater amounts of infiltration.

The portion of WAG 5 in the White Oak Creek drainage basin is assumed to have the same runoff characteristics as the D-1 basin. That portion draining into Melton Branch (exclusive of the D-3 basin) is assumed to have the same water balance as the D-2 basin.

B5.3 CONTAMINANT FLUX

Pathway-specific fluxes were calculated on the basis of the average annual flow rate and average concentration measured in that pathway from RI samples. WAG 5 was divided into subareas based on the study areas and site hydrology (shown in Fig. B5.3.1). Contaminant flux from each subarea was determined assuming three flow pathways: surface runoff, interflow, and groundwater discharge. In addition, contaminant fluxes in D-1, D-2, and D-3 were calculated on the basis of average contaminant concentrations in surface water samples. For verification, the calculated contaminant fluxes were compared with measured data collected as part of the WAG 2 investigation.

B5.3.1 Subarea Contaminant Flux

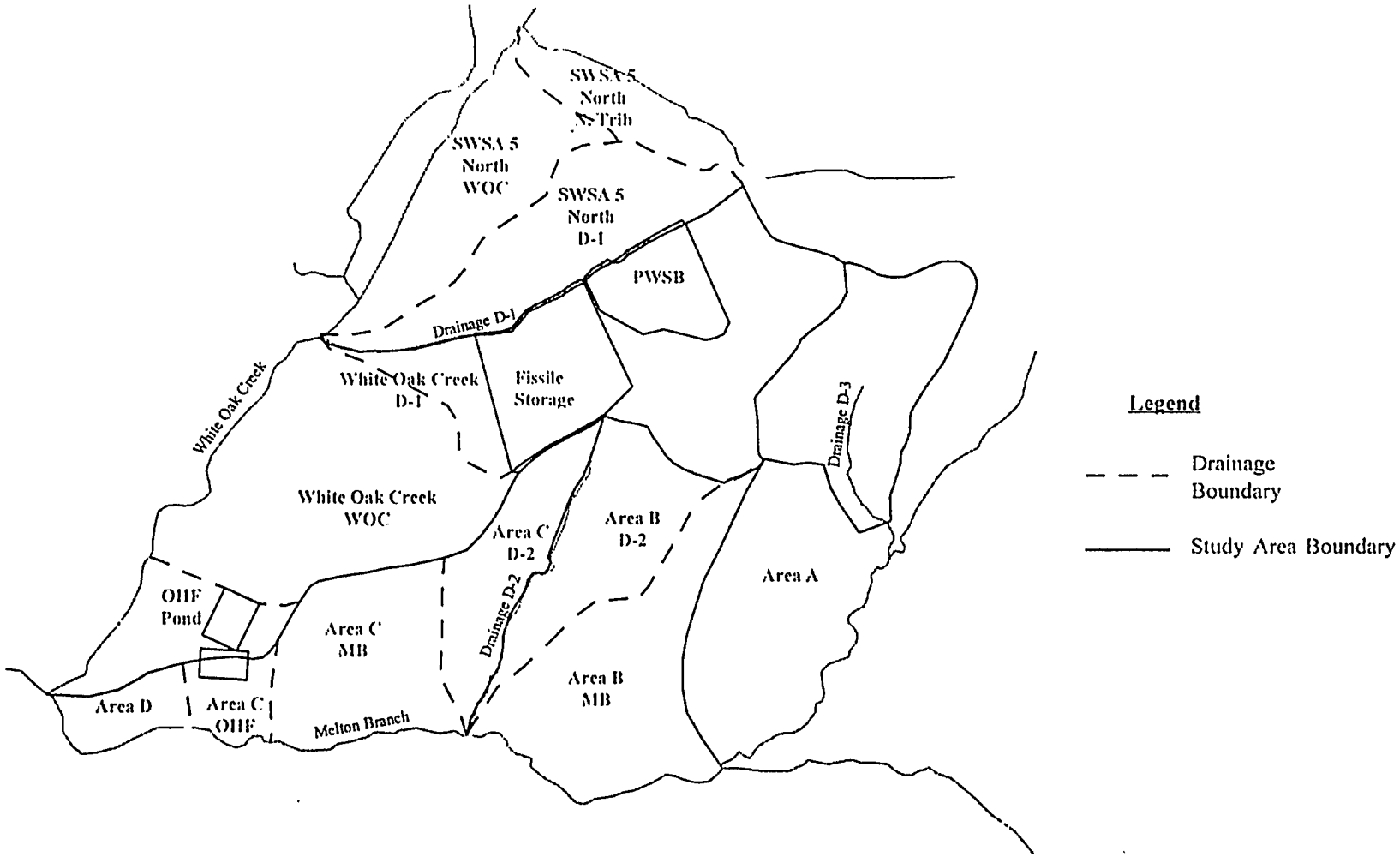
Average concentrations in groundwater, interflow, and surface soils were determined for each subarea. Groundwater monitoring well samples were assumed to be representative of the groundwater discharge from their subareas. Shallow flow piezometers, screened from a depth of 0.5 ft to 2 ft and sampled after storm events, were assumed to be representative of the contaminant concentrations in the interflow pathway. The average concentrations in groundwater and interflow were multiplied by flow in each pathway to determine flux.

Transport of contamination via the surface runoff pathway typically occurs through erosion and sediment transport. An average contaminant concentration in shallow soils was determined for each subarea. The Modified Universal Soil Loss Equation (MUSLE) was used to calculate the average annual sediment yield from each subarea. MUSLE calculates the sediment yield from a single storm, and the average annual sediment yield was determined by separating 41 years of output from the HSPF model into separate storm events on the basis of surface runoff. The peak flow and total runoff volume were determined for individual storms, and the sediment yield was calculated. The annual sediment yield from each subarea was multiplied by the average contaminant concentration in the surface soils.

Tables B5.3.1 and B5.3.2 present the calculated fluxes from each WAG 5 subarea in the White Oak Creek and Melton Branch basins.

B5.3.2 Contaminant Flux in Drainages D-1, D-2, and D-3

The average annual flux in drainages D-1, D-2, and D-3 was calculated based on the surface water samples collected from SW001, SW002, and SW003 over a 12-month period. Grab samples were collected during periods of baseflow representing high and low seasonal groundwater levels, and automatic samplers were used to collect time-series samples during five storm events.



B5_F3_1.PPT

Fig. B5.3.1. WAG 5 subareas for flux calculation.

Table B5.3.1. Subarea flux contributions in White Oak Creek basin

	Alpha flux (mCi/yr)	(%)	Beta flux (mCi/yr)	(%)	^{3}H flux (mCi/yr)	(%)	^{90}Sr flux (mCi/yr)	(%)	^{137}Cs flux (mCi/yr)	(%)	^{60}Co flux (mCi/yr)	(%)
White Oak Creek basin												
SWSA 5 N. Trib												
SRO	0	(0%)	0.29	(62%)	0.053	(1%)	NA		0.0035	(26%)	NA	
INT	NA		NA		NA		NA		NA		NA	
GW	0.04	(100%)	0.17	(38%)	8.15	(99%)	0.0009	(100%)	0.0102	(74%)	0.07	(100%)
total	0.04		0.46		8.20		0.0009		0.014		0.07	
SWSA 5 N WOC												
SRO	0.34	(45%)	0.59	(52%)	0.001	(0%)	0	(0%)	0	(0%)	NA	
INT	NA		NA		NA		NA		NA		NA	
GW	0.42	(55%)	0.53	(48%)	34.6	(100%)	0.0056	(100%)	0.04	(100%)	0.0582	(100%)
total	0.76		1.12		34.6		0.006		0.04		0.058	
SWSA 5 N. D-1												
SRO	0.28	(65%)	0.34	(57%)	0.002	(0%)	0.004	(67%)	0.0023	(19%)	NA	
INT	NA		NA		NA		NA		NA		NA	
GW	0.15	(35%)	0.26	(43%)	15.6	(100%)	0.002	(33%)	0.01	(81%)	0.17	(100%)
total	0.43		0.60		15.6		0.006		0.01		0.17	
PWSB												
SRO	0.14	(100%)	0.55	(50%)	0.003	(0%)	0.01	(8%)	0.017	(100%)	0	
INT	NA		NA		NA		NA		NA		NA	
GW	0	(0%)	0.54	(50%)	206	(100%)	0.12	(92%)	0	(0%)	0	
total	0.14		1.09		206		0.13		0.017		0	
Fissile Storage												
SRO	0.03	(0%)	0.46	(7%)	0.0007	(0%)	0.11	(11%)	0.064	(3%)	0.16	(100%)
INT	0.16	(2%)	0.29	(4%)	20	(2%)	0.27	(27%)	1.5	(80%)	NA	
GW	7.5	(98%)	5.9	(89%)	1202	(98%)	0.61	(62%)	0.3	(16%)	NA	
total	7.69		6.65		1222		0.99		1.86		0.16	
WOC D-1												
SRO	0.04	(21%)	0.2	(59%)	0.013	(0%)	0		0.06	(100%)	0.003	(100%)
INT	0.15	(79%)	0.14	(41%)	7.2	(92%)	NA		NA		NA	
GW	0.0003	(0%)	0.00015	(0%)	0.61	(8%)	0		0	(0%)	0	(0%)
total	0.19		0.34		7.82		0		0.06		0.003	
WOC WOC												
SRO	1.1	(50%)	15	(27%)	0.017	(0%)	1.2	(1%)	16.1	(77%)	0.2	(23%)
INT	1.05	(48%)	1.03	(2%)	51.7	(1%)	NA		NA		NA	
GW	0.04	(2%)	40.0	(71%)	6260	(99%)	93.6	(99%)	4.92	(23%)	0.66	(77%)
total	2.19		56.0		6312		94.8		21.0		0.86	
OHF Pond												
SRO	0.05	(12%)	0.66	(1%)	0.001	(0%)	0.33	(1%)	0.28	(6%)	0.0002	(0%)
INT	NA		NA		NA		NA		NA		NA	
GW	0.37	(88%)	70.8	(99%)	2761	(100%)	42.4	(99%)	4.49	(94%)	0.16	(100%)
total	0.42		71.5		2761		42.7		4.77		0.16	

Note: Numbers in parenthesis are the percentage of the pathway to the total flux from the subarea.
NA - no sample data available

Table B5.3.2. Subarea flux contributions in Melton Branch basin

	Alpha Flux (mCi/yr)	(%)	Beta Flux (mCi/yr)	(%)	^{3}H Flux (mCi/yr)	(%)	^{90}Sr Flux (mCi/yr)	(%)	^{137}Cs Flux (mCi/yr)	(%)	^{60}Co Flux (mCi/yr)	(%)
Melton Branch Basin												
SWSA 5 Area "A"												
SRO	0.042	(3%)	0.29	(0%)	1.35	(0%)	0.15	(0%)	0.0024	(1%)	5.00E-05	(0%)
INT	0.06	(4%)	1.07	(0%)	36.98	(0%)	NA		NA		NA	
GW	1.31	(93%)	237	(99%)	481,009	(100%)	117	(100%)	0.23	(99%)	0.20	(100%)
total	1.41		239		481,048		118		0.23		0.20	
SWSA 5 Area "B" MB												
SRO	0.58	(8%)	23	(26%)	1.7	(0%)	14.1	(16%)	9.1	(80%)	4.00E-05	(100%)
INT	0.12	(2%)	0.42	(0%)	77.05	(0%)	NA		NA		NA	
GW	6.93	(91%)	64	(73%)	1,649,751	(100%)	72	(84%)	2.23	(20%)	0.00	(0%)
total	7.63		88		1,649,829		86		11.33		0.00	
SWSA 5 Area "B" D-2												
SRO	0	(0%)	0.068	(0%)	0.012	(0%)	NA		0.002	(0%)	NA	
INT	1.39	(84%)	2.4	(8%)	121,140	(83%)	1.2	(4%)	NA		NA	
GW	0.26	(16%)	26.9	(92%)	25,235	(17%)	29.1	(96%)	4.4	(100%)	NA	
total	1.65		29.4		146,375		30.3		4.402		0	
SWSA 5 Area "C" D-2												
SRO	0.022	(5%)	0.4	(5%)	0.0075	(0%)	0.13	(2%)	0.079	(91%)	0	(0%)
INT	0.2	(50%)	0.48	(6%)	35.4	(0%)	NA		NA		NA	
GW	0.18	(45%)	7.8	(90%)	90,365	(100%)	5.8	(98%)	0.008	(9%)	0.36	(100%)
total	0.40		8.68		90,400		5.93		0.087		0.36	
SWSA 5 Area "C" MB												
SRO	0.35	(9%)	9.1	(1%)	0.0038	(0%)	9.4	(1%)	0.22	(9%)	NA	
INT	0.25	(6%)	0.61	(0%)	44.50	(0%)	NA		NA		NA	
GW	3.29	(85%)	1323	(99%)	44,663	(100%)	790	(99%)	2.17	(91%)	0.18	(100%)
total	3.89		1333		44,708		799		2.39		0.18	
SWSA 5 Area "C" OHF												
SRO	0.001	(0%)	0.018	(0%)	0.0011	(0%)	0.003	(0%)	0.0026	(1%)	NA	
INT	NA		NA		NA		NA		NA		NA	
GW	3.78	(100%)	37.8	(100%)	99,356	(100%)	35.17	(100%)	0.47	(99%)	0.00	
total	3.78		37.8		99,356		35.17		0.48		0.00	
SWSA 5 Area "D"												
SRO	NA		NA		NA		NA		NA		NA	
INT	NA		NA		NA		NA		NA		NA	
GW	2.18	(100%)	178	(100%)	15,094	(100%)	152	(100%)	1.17	(100%)	6.27	(100%)
total	2.18		178		15,094		152		1.17		6.27	

Note: Numbers in parenthesis are the percentage of the pathway to the total flux from the subarea.
NA - no sample data available
SRO - surface runoff
INT - interflow
GW - groundwater discharge

Approximately four discrete samples—each representing a different section of the storm hydrograph—from each station were analyzed.

To calculate the average contaminant flux in the drainages, the flow hydrographs at each sample point were separated into two components: quickflow and groundwater discharge. Quickflow is defined as a combination of the surface runoff and interflow pathways. In addition to the hydrograph separation, the measured fluxes for specific contaminants were determined by multiplying contaminant concentrations by the corresponding flow at individuals stations.

In the flux calculation, concentrations in quickflow and baseflow are assumed to be constant and are multiplied by the flow in each pathway determined by hydrograph separation to get an assumed flux. Assumed fluxes were compared to measured fluxes, and assumed concentrations were adjusted by trial and error until the best correlation between assumed and measured fluxes was achieved. The average annual fluxes in each drainage basin were then calculated by multiplying the average concentration by the annual flow in the pathway.

Table B5.3.3 lists the calculated average annual fluxes in D-1, and Table B5.3.4 lists those in D-2 and D-3. The fluxes from the subareas in the D-1 and D-2 drainage basins are included for comparison.

B5.3.3 Comparison with WAG 2 Data

To determine the overall contaminant flux in Melton Branch and White Oak Creek, the WAG 5 flux was combined with flux values upgradient of WAG 5. The flux values were verified by comparing calculated flux with measured flux at Melton Branch weir (SW006) and White Oak Creek weir. In Melton Branch, the upstream sample locations are SW004 (Melton Branch Tributary) and SW005 (Melton Branch). Both locations were sampled as part of the WAG 5 RI, and average concentrations at each station were calculated.

In White Oak Creek, the upgradient locations at the 7500 bridge and the mouth of the WAG 4 discharge were used to determine total contaminant fluxes. Sample data from the WAG 2 investigation were used for the average concentration of all constituents at WAG 4 and gross alpha and gross beta at the 7500 bridge. The 7500 bridge is continuously monitored for ^{3}H, ^{90}Sr, ^{60}Co, and ^{137}Cs, and an average of the annual fluxes from 1987–1993 were used instead of the WAG 2 data. Average annual flux values for ^{3}H, ^{90}Sr, ^{60}Co, and ^{137}Cs were also used for the Melton Branch and the White Oak Creek weirs, and WAG 2 data were used for average concentrations of gross alpha and gross beta.

Table 5.3.5 lists the contaminant fluxes at the White Oak Creek and Melton Branch weirs. The flux at the weirs is compared to a sum of the fluxes from individual subareas in each basin. The percentage of flux in each subarea to the drainage basin flux is given in parentheses.

Table B5.3.3. Drainage D-1 flux

	Alpha flux (mCi/yr)	(%)	Beta flux (mCi/yr)	(%)	H flux (mCi/yr)	(%)	Sr flux (mCi/yr)	(%)	^{137}Cs flux (mCi/yr)	(%)	^{60}Co flux (mCi/yr)	(%)
D-1 basin												
SWSA 5 N. D-1												
SRO	0.28	(65%)	0.34	(57%)	0.002	(0%)	0.004	(67%)	0.0023	(19%)	NA	
INT	NA		NA		NA		NA		NA		NA	
GW	0.15	(35%)	0.26	(43%)	15.6	(100%)	0.002	(33%)	0.01	(81%)	0.17	(100%)
total	0.43		0.60		15.6		0.006		0.01		0.17	
PWSB												
SRO	0.14	(100%)	0.55	(50%)	0.003	(0%)	0.01	(8%)	0.017	(100%)	0	
INT	NA		NA		NA		NA		NA		NA	
GW	0	(0%)	0.54	(50%)	206	(100%)	0.12	(92%)	0	(0%)	0	
total	0.14		1.09		206		0.13		0.017		0	
Fissile Storage												
SRO	0.03	(0%)	0.46	(7%)	0.0007	(0%)	0.11	(11%)	0.064	(3%)	0.16	(100%)
INT	0.16	(2%)	0.29	(4%)	20	(2%)	0.27	(27%)	1.5	(80%)	NA	
GW	7.5	(98%)	5.9	(89%)	1202	(98%)	0.61	(62%)	0.3	(16%)	NA	
total	7.69		6.65		1222		0.99		1.86		0.16	
WOC D-1												
SRO	0.04	(21%)	0.2	(59%)	0.013	(0%)	0		0.06	(100%)	0.003	(100%)
INT	0.15	(79%)	0.14	(41%)	7.2	(92%)	NA		NA		NA	
GW	0.0003	(0%)	0.00015	(0%)	0.61	(8%)	0		0	(0%)	0	(0%)
total	0.19		0.34		7.82		0		0.06		0.003	
Subarea Totals												
SRO+INT	0.80	(9%)	1.98	(23%)	27.2	(2%)	0.39	(35%)	1.64	(84%)	0.17	(50%)
GW	7.65	(91%)	6.70	(77%)	1424	(98%)	0.73	(65%)	0.31	(16%)	0.17	(50%)
total	8.45		8.68		1451		1.13		1.95		0.34	
Drainage D-1												
SW001												
SRO+INT	1.06	(17%)	1.48	(27%)	106	(6%)	0.88	(61%)	NA		NA	
GW	5.10	(83%)	3.99	(73%)	1712	(94%)	0.57	(39%)	NA		NA	
total	6.16		5.47		1818		1.45		NA		NA	

Note. Numbers in parenthesis are the percentage of the pathway to the total flux from the subarea.

NA - no sample data available

SRO - surface runoff

INT - interflow

GW - groundwater discharge

Table B5.3.4. Drainage D-2 and D-3 fluxes

	Alpha Flux (mCi/yr)	(%)	Beta Flux (mCi/yr)	(%)	H Flux (mCi/yr)	(%)	Sr Flux (mCi/yr)	(%)	Cs Flux (mCi/yr)	(%)	Co Flux (mCi/yr)	(%)
D-2 basin												
SWSA 5 Area "B" D-2												
SRO	0	(0%)	0.068	(0%)	0.012	(0%)	NA		0.002	(0%)	NA	
INT	1.39	(84%)	2.4	(8%)	121,140	(83%)	1.2	(4%)	NA		NA	
GW	0.26	(16%)	26.9	(92%)	25,235	(17%)	29.1	(96%)	4.4	(100%)	NA	
total	1.65		29.4		146,375		30.3		4.402		0	
SWSA 5 Area "C" D-2												
SRO	0.022	(5%)	0.4	(5%)	0.0075	(0%)	0.13	(2%)	0.079	(91%)	0	(0%)
INT	0.2	(50%)	0.48	(6%)	35.4	(0%)	NA		NA		NA	
GW	0.18	(45%)	7.8	(90%)	90,365	(100%)	5.8	(98%)	0.008	(9%)	0.36	(100%)
total	0.40		8.68		90,400		5.93		0.087		0.36	
Subarea Totals												
SRO+INT	1.61	(79%)	3.35	(9%)	121,175	(51%)	1.33	(4%)	0.08	(2%)	0.00	(0%)
GW	0.44	(21%)	34.70	(91%)	115,600	(49%)	34.90	(96%)	4.41	(98%)	0.36	(100%)
total	2.05		38.05		236,775		36.23		4.49		0.36	
Drainage D-2												
SW002												
SRO+INT	0.83	(76%)	23.4	(31%)	43,901	(29%)	18.4	(29%)	NA		NA	
GW	0.27	(24%)	52.7	(69%)	107,975	(71%)	44.7	(71%)	NA		NA	
total	1.10		76.1		151,875		63.2		NA		NA	
Drainage D-3												
SW003												
SRO+INT	NA		0.66	(40%)	12.98	(44%)	0.52	(96%)	NA		NA	
GW	NA		0.99	(60%)	16.57	(56%)	0.02	(4%)	NA		NA	
total	0.28		1.65		29.56		0.55		NA		NA	

Note Numbers in parenthesis are the percentage of the pathway to the total flux from the subarea

NA - no sample data available

SRO - surface runoff

INT - interflow

GW - groundwater discharge

Table B5.3.5. Drainage flux in White Oak Creek and Melton Branch basins

White Oak Creek basin flux

	Alpha flux (mCi/yr)	(%)	Beta flux (mCi/yr)	(%)	^{3}H flux (mCi/yr)	(%)	^{90}Sr flux (mCi/yr)	(%)	^{14}C flux (mCi/yr)	(%)	^{60}Co flux (mCi/yr)	(%)
Upgradient of WAG 5												
7500 Bridge	80	(64%)	2,871	(52%)	43,291	(3%)	761	(38%)	1,081	(96%)	90	(99%)
WAG 4	35	(28%)	2,519	(46%)	1,219,968	(96%)	1,081	(55%)	20	(2%)	0	(0%)
WAG 5 sources												
SWSA 5 North	0.81	(1%)	1.59	(0%)	42.80	(0%)	0.01	(0%)	0.06	(0%)	0.13	(0%)
Drainage D-1	6.16	(5%)	5.47	(0%)	1818	(0%)	1.45	(0%)	0.06	(0%)	0.13	(0%)
WOC	2.19	(2%)	56.0	(1%)	6312	(0%)	94.8	(5%)	21.0	(2%)	0.86	(1%)
OHF Pond	0.42	(0%)	71.5	(1%)	2761	(0%)	42.7	(2%)	4.77	(0%)	0.16	(0%)
TOTAL	124.7		5,524		1,274,192		1,981		1,127		90.8	
White Oak Creek basin												
WOC Weir	70.4		3,009		640,047		1,389		1,306		84.9	

Melton Branch basin flux

	Alpha flux (mCi/yr)	(%)	Beta flux (mCi/yr)	(%)	^{3}H flux (mCi/yr)	(%)	^{90}Sr flux (mCi/yr)	(%)	^{14}C flux (mCi/yr)	(%)	^{60}Co flux (mCi/yr)	(%)
Upgradient of WAG 5												
SW005	70	(75%)	127	(6%)	14,826	(1%)	15	(1%)	100	(65%)	97	(99%)
SW004	6	(6%)	276	(13%)	0	(0%)	129	(10%)	35	(22%)	0	(0%)
WAG 5 sources												
Drainage D-3	0.28	(0%)	1.65	(0%)	29.6	(0%)	0.55	(0%)	0	(0%)	0	(0%)
SWSA 5 Area "A"	1.41	(2%)	239	(11%)	481,048	(20%)	118	(9%)	0.23	(0%)	0.20	(0%)
SWSA 5 Area "B"	7.63	(8%)	87.6	(4%)	1,649,829	(68%)	86.4	(7%)	11.33	(7%)	0.00	(0%)
Drainage D-2	1.10	(1%)	76.1	(3%)	151,875	(6%)	63.20	(5%)	4.49	(3%)	0.36	(0%)
SWSA 5 Area "C"	7.67	(8%)	1,370	(63%)	144,063	(6%)	835	(67%)	2.86	(2%)	0.18	(0%)
TOTAL	93.4		2,178		2,441,671		1,245		153.9		97.6	
Melton Branch basin												
MB Weir	44.0		2,320		1,952,619		1,123		37.8		45.6	

Note: Numbers in parenthesis are the percentage of the subarea to the total basin flux.

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Appendix B: Technical Findings and Conclusions

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