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Characterization Plan for the Waste Holding Basin (3513 Impoundment)

R. G. Stansfield
C. W. Francis

ENVIRONMENTAL SCIENCES DIVISION
PUBLICATION NO. 2685

ENVIRONMENTAL SCIENCES DIVISION · OAK RIDGE NATIONAL LABORATORY

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04 Microfiche A01

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R. G. Stansfield
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Publication No. 2685

NUCLEAR AND CHEMICAL WASTE PROGRAMS
(Activity No. AR 05 10 10 0; ONL-WD18)

Date Published: September 1986

Prepared for the
Office of Defense Waste and Transportation Management

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC
for
U.S. DEPARTMENT OF ENERGY
Under Contract No. DE-AC05-84OR21400

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ABSTRACT

STANSFIELD, R. G., and C. W. FRANCIS. 1986. Characterization plan for the waste holding basin (3513 Impoundment). ORNL/TM-9969. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 56 pp.

U. S. Department of Energy (DOE) facilities are required to comply fully with all federal and state regulations. In response to this requirement, the Oak Ridge National Laboratory (ORNL) has established the remedial action program, to provide comprehensive management of areas where past research, development, and waste management activities have been conducted and have resulted in residual contamination of facilities or the environment. One of the objectives of this program is to define the extent of contamination at these sites. The intent is to document the known environmental characteristics of the sites and identify the additional actions, such as sampling, analytical measurements, and modeling, necessary to confirm contamination and the possible migration of contaminants from the sites. One of these sites is the waste holding basin (3513 impoundment).

The 3513 impoundment is an unlined waste settling basin constructed in 1944 for collection of ORNL wastewater before its discharge into White Oak Creek. Operation of the facility ceased in 1976 when a new process waste treatment plant came into operation. Considerable site-specific environmental information has been developed over the years relative to the type and quantities of radionuclides and hazardous substances contained in the pond water and sediment. The concentrations and patterns of distribution for many of the

radionuclides in the aquatic biota as well as for the terrestrial plants growing on the berm of the impoundment have been determined byDOE ecological studies. Recently, some data were collected that evaluate the extent of contaminant movement to the groundwater. Results from these studies are summarized in this report. Also included in this report is an outline of additional tasks needed to obtain the necessary information to model the transport and dose pathways of hazardous substances from the site.

1. INTRODUCTION

U. S. Department of Energy (DOE) facilities are required to comply fully with all federal and state regulations. In response to an application to the U. S. Environmental Protection Agency (USEPA) by the Oak Ridge National Laboratory (ORNL) for a permit to operate a hazardous waste storage facility, the USEPA has required ORNL to comply with the 3004 (u) provision of the 1984 Hazardous and Solid Waste Amendment of the reauthorization of the Resource Conservation and Recovery Act (RCRA). Under these regulations the Permittee is required to identify and characterize all solid waste management units currently or previously located within ORNL's boundary. The intent of this regulation is to determine whether a prior or continuing release of hazardous waste or hazardous constituents have occurred and/or to characterize the nature and extent of the releases.

One of the facilities that may pose an undue risk to health, safety, and environment as a result of the migration of hazardous substances to groundwater is the Old Hydrofacture Facility (OHF). This report documents the existing environmental information on the 3513 impoundment and defines additional actions, such as the installation of monitoring wells, collection of samples, and analytical measurements, required to confirm contamination and the possible migration of contaminants from the site. Also included are descriptions and estimated costs of activities required to collect additional geologic and hydrologic information necessary to model the site performance.

2. DESCRIPTION OF THE FACILITY

The 3513 impoundment at ORNL is located on the north side of westward-flowing White Oak Creek between Building 3544 on the west and two smaller impoundments, 3539 and 3540, on the east (see Fig. 1). On the north side lies Basin 3524 which, like the two smaller impoundments on the east side, is a part of the ORNL process waste system. Figure 2 is a photograph looking northward from south of White Oak Creek, with the 3513 impoundment in the center, the 3539 and 3540 basins on the right, and the 3524 basin in the upper left portion of the figure. Groundwater monitoring wells were installed in January 1985 for the 3513 impoundment and in the fall of 1985 for the other three facilities. Impoundment 3513 is positioned such that groundwater at this facility might well be influenced by the other three impoundments.

2.1. IMPOUNDMENT CONSTRUCTION

The unlined impoundment was constructed in 1944 to serve as a settling basin for laboratory wastewater before its discharge into adjacent White Oak Creek. The impoundment was constructed by excavating into the clay soil overlying the limestone bedrock at the site. No lining was added to the facility. Dimensions of the impoundment at normal water-level elevation [237 m (778 ft)] are approximately 67 x 67 m (220 x 220 ft), sloping to 61 x 61 m (200 x 200 ft) at the bottom. The bottom elevation of the north end of the impoundment [approximately 235 m (772 ft)] is approximately 0.3 m (1 ft) lower than the south end (Stansfield and Francis 1986). Inflow to the impoundment was by five waste lines emptying into the north

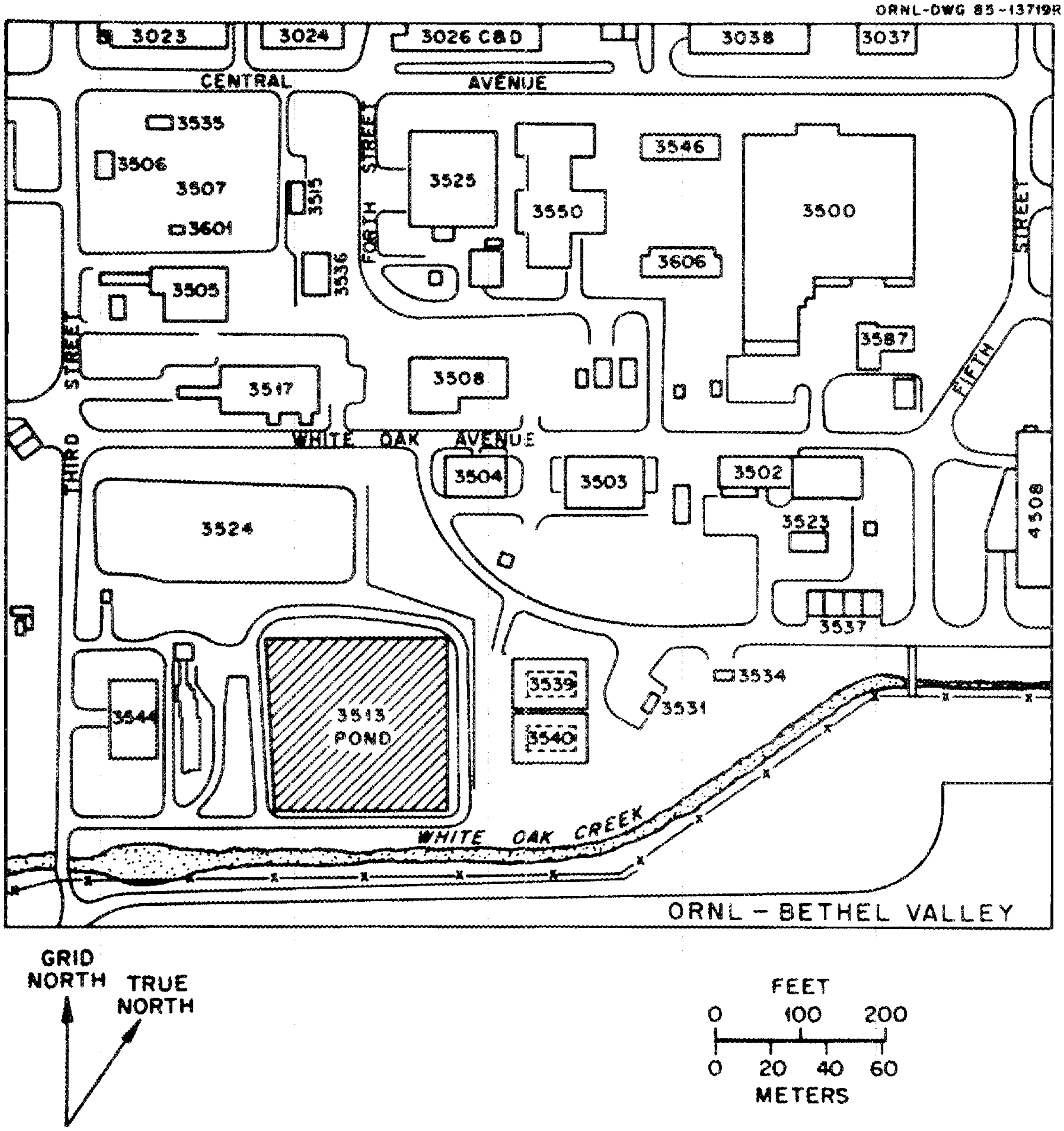

Fig. 1. Location of 3513 impoundment within ORNL.

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Fig. 2. Photograph taken looking northward with 3513 impoundment in the center and White Oak Creek visible in the lower left.

side, while outflow was through a like number of lines on the south side. Employing the above dimensions and water level, a normal storage capacity of approximately 7.1 x 10^3 m^3 (1,880,000 gal) of water and sediment has been calculated for the impoundment (Stansfield and Francis 1986).

2.2. IMPOUNDMENT OPERATION

Operation of the facility ceased in 1976 when a new process waste treatment plant came into operation. From 1944 until 1949, the impoundment received supernatant from the Gunite tanks in which most of the radioactive chemical waste at ORNL was collected. Fly ash and soda lime were added to the impoundment water to precipitate the major portion of radionuclides before releasing the water to White Oak Creek. Other waste streams routed to the impoundment during its service years consisted of wastes from laboratory floor and sink drains, chemical process cells, and shield and cooling water from the graphite reactor.

In 1977, the depth of waste sediment at the south end of the impoundment averaged 0.76 m (2.5 ft) and at the north end 1.2 m (3.8 ft) (J. R. Horton, ORNL, personal communication). It appears that the sludge may have consolidated somewhat since the cessation of activities because the average depths measured in 1985 (Stansfield and Francis 1986) were 0.49 m (1.6 ft) and 0.8 m (2.8 ft), respectively.

3. CURRENT STATUS OF INFORMATION ON SITE

Considerable site-specific environmental information on the facility exists in published reports (Stockdale 1951; Tamura et al. 1977; Stansfield and Francis 1986). Unpublished data of S. F. Huang (ORNL) on radiological and chemical studies of the impounded sediment were used extensively throughout this report and are referenced to Huang, personal communication.

3.1. CONTAMINANT INVENTORY

3.1.1. 3513 Impoundment Water

Stansfield and Francis (1986) sampled the 3513 impoundment water in May of 1985 and analyzed it for heavy metals, herbicides/pesticides, PCBs, and radionuclides. The pH of the pond water was slightly alkaline (pH of 8.0), with a specific conductance of 160 μS/cm. Counts for coliform bacteria (12 counts/100 mL) were in excess of the limit (1 count/100 mL) established by the National Interim Primary Drinking Water Standard (NIPDWS), probably due to the wildlife that inhabit the area (see the Section 3.4 on Ecology). The pond water was analyzed for metal content using inductively coupled plasma (ICP) spectroscopy and its limit of detection for some metals exceeded NIPDWS. For example, the detection limit for silver was in excess of the maximum allowable NIPDWS (see Table 1). Concentrations of chromium, lead, and selenium in unfiltered pond water were observed to be in excess of the limits. However, levels of As, Ba, Cd, F, Hg, and nitrate, as well as levels of pesticides and herbicides, were below the maximum allowable limits (Tables 1 and 2). The concentration of total

Table 1. Concentration and inventory of metals and anions in 3513 pond water[a]

Constituent	Concentration (mg/L) Pond	NIPDWS	Inventory (kg)
Metals			
Antimony	<0.3	ND	<1.4
Arsenic	<0.001	0.05	<0.1
Barium	0.0636	1.0	0.3
Beryllium	0.0029	ND	<0.1
Boron	<0.1	ND	<0.5
Cadmium	<0.001	0.01	<0.1
Calcium	75.3	ND	359
Chromium	0.07	0.05	0.3
Cobalt	<0.02	ND	<0.1
Copper	0.352	ND	1.7
Iron	1.38	ND	6.6
Lead	0.15	0.05	0.7
Lithium	<0.2	ND	<1.0
Magnesium	14.3	ND	68.2
Manganese	0.46	ND	2.2
Mercury	0.003	0.002	<0.1
Molybdenum	<0.02	ND	<0.1
Nickel	<0.006	ND	<0.1
Potassium	2.4	ND	11.4
Selenium	0.016	0.01	0.1
Silver	<0.07	0.05	<0.3
Sodium	<0.5	ND	<2.4
Strontium	0.099	ND	0.5
Titanium	<0.02	ND	<0.1
Vanadium	<0.002	ND	<0.1
Zinc	0.118	ND	0.6
Anions			
Chloride	9	ND	42.9
Fluoride	1	1.2–2.4	4.8
Nitrate-N	<1	10	<4.8
Phosphate	1.64	ND	7.8
Sulfate	27	ND	129

[a]Taken from Stansfield and Francis (1986). Inventory based on pond water volume of 4.77×10^3 m^3.
ND = level not defined by National Interim Primary Drinking Water Standard (NIPDWS).

Table 2. Concentration and inventory of organic chemicals in 3513 pond water[a]

Constituent	Concentration (mg/L)		Inventory
	Pond	NIPDWS	(kg)
Herbicides and pesticides			
Endrin	<0.0001	0.002	<0.0005
Lindane	<0.0001	0.004	<0.0005
Methoxychlor	<0.0002	0.1	<0.0010
Toxaphene	<0.0002	0.005	<0.0010
Organic compounds[b]			
PCB	0.0006	ND	0.003
Phenols	<0.001	ND	<0.005
TOC	14.7	ND	70
TOX	0.67	ND	3.2

[a]Taken from Stansfield and Francis (1986). Inventory based on pond water volume of 4.77 x 10^3 m^3.

[b]PCB = polychlorinated biphenyls; TOC = total organic carbon; TOX = total organic halides; ND = limit not defined by National Interim Primary Drinking Water Standard (NIPDWS).

organic halides was relatively high (0.67 mg/L) and a detectable concentration (0.0006 mg/L) of PCBs was observed. Total organic carbon content, however, was relatively low (15 mg/L).

The major contaminants are radionuclides (Table 3). The bulk of the activity is from ^{137}Cs and ^{90}Sr, measuring 290 and 420 Bq/L (7.9 and 11 pCi/mL), respectively. Gross beta activity appears to be predominately from ^{90}Sr and ^{90}Y decay [i.e., gross beta (910 Bq/L or 25 pCi/mL) is slightly more than twice the ^{90}Sr activity]. Huang (personal communication) measured 400 Bq/L (11 pCi/mL) of ^{137}Cs and 300 Bq/L (8 pCi/mL) of ^{90}Sr in the pond water in September of 1983, values quite similar to those measured in 1985 by Stansfield and Francis (1986).

Gross alpha activity in the pond water is less than 2% of the gross beta and ^{137}Cs activity combined, according to measurements made by Stansfield and Francis (1986). Huang (personal communication) did not measure concentrations of transuranics in 3513 pond water. of collecting contaminated particulate material. The inventories of both radioactive and nonradioactive contaminants in pond water of the 3513 impoundment are presented in Tables 1, 2, and 3.

3.1.2. Impoundment Sediment

Inventories of potential contaminants in the sediment contained in the 3513 impoundment were conducted in 1977 (Tamura et al. 1977), in 1984 (Huang, personal communication), and most recently in 1985 (Stansfield and Francis 1986). The initial study, taken immediately after the discontinued use of the impoundment as a waste-receiving

Table 3. Concentration and inventory of radionuclides in 3513 pond water

Radionuclide	Concentration (Bq/L)	Inventory[a] (MBq)
Gross alpha	16	76.3
Gross beta	910	4300
Americium-241	3.4	16.2
Cesium-137	290	1400
Cobalt-60	5.2	24.8
Curium-244	2.6	12.4
Plutonium-238	0.15	0.7
Plutonium-239	4.1	19.6
Radium-226	0.12	0.6
Strontium-90	420	2000
Uranium-234	1.6	7.6
Uranium-235	0.16	0.8
Uranium-238	0.61	2.9

[a]Taken from Stansfield and Francis (1986). Inventory based on pond water volume of 4.77×10^3 m^3.

pond, addressed the quantities of radionuclides measured in the sediment. The quantity of plutonium isotopes in the sediment was of principal concern because decisions had been made on how the impoundment could be decommissioned based on the inventory of transuranics (Tamura et al. 1977). Trabalka et al. (in press) made monthly measurements of ^{238}U, ^{239}Pu, ^{241}Am, and ^{244}Cm in the 3513 pond water from March 1977 to May 1982 (concentrations the first two years are reported in Auerbach et al. 1980). Water samples taken near the center of the pond "just under the surface" and "from a depth of 1 m" were filtered through a 0.22-µm membrane filter before analysis. Water samples taken by Stansfield and Francis (1986) were also taken near the center of the pond using a stainless steel, bottom-loading bailer at both the lower and the upper depths; however, these samples were not filtered as were those collected by Trabalka et al. (in press). Measurements of ^{238}U by Stansfield and Francis (1986) are very similar to those by Trabalka et al. (in press) (i.e., concentrations on the order of 0.5 to 1.0 Bq/L). On the other hand, measurements of ^{241}Am, ^{244}Cm, and ^{239}Pu by Stansfield and Francis (1986) tended to be 10 to 100 times higher than those reported by Trabalka et al. (in press). The higher values by Stansfield and Francis (1986) are likely due to the analyses of unfiltered samples taken at greater water depths, increasing the risk Using core samples taken from each of the fifteen 12- by 15-m grid sections established for sampling the pond, an inventory of approximately 7300, 1100, and 200 GBq (200, 30, and 5 Ci), respectively, of ^{137}Cs, ^{90}Sr, and $^{239,240}Pu$ was determined. The core samples were taken by driving a

3.5-cm-diam (1.4-in.) aluminum tube "into the sediment until the hard bottom of the original floor was reached." A similar technique was used to take five core samples from the sediment of the impoundment in September of 1983 (Huang, personal communication). Four of the cores were taken from the center of the four quadrants making up the pond, whereas the fifth core was taken from approximately the middle of the impoundment. They estimated the inventory of ^{137}Cs and ^{90}Sr to be on the order of 4800 and 730 GBq (130 and 20 Ci), respectively. The inventory of transuranics was estimated to be 140 GBq (3.7 Ci), of which approximately 80% was ^{239}Pu. Measurable quantities of ^{238}Pu, ^{241}Am, and ^{244}Cm as well as ^{154}Eu were also detected. Table 4 contains a summary of the radionuclide inventories in pond sediment of the 3513 impoundment as reported by the two studies.

Sediment samples taken by Stansfield and Francis (1986) were not analyzed for radionuclides. The major objective in this study was to ascertain the status of this sediment using the protocol promulgated under the Resource Conservation and Recovery Act (RCRA, federal regulation 40 CFR 261) to determine whether the impoundment sediment would be classified as a hazardous or nonhazardous waste. Regulation 40 CFR 261 specifies that a solid waste is a hazardous waste if it exhibits any of the defined characteristics of ignitability, corrosivity, reactivity, or extraction procedure (EP) toxicity.

The EP toxicity was of primary concern because the inherent physical and chemical characteristics of the sediment ruled out classification as a hazardous waste based on ignitability or reactivity, and the pH of the sediment slurry (7.2) eliminated corrosivity as defined by 40 CFR 261. The EP toxicity characteristic

Table 4. Estimated inventory of radionuclides in sediment of 3513 impoundment

Radionuclides	Tamura et al. (1977)		Huang (pers. commun.)	
	[GBq(Ci)]			
Cesium-137	7300	(200)	4800	(130)
Strontium-90	1100	(30)	730	(20)
Transuranics	200	(5)	140	(4)

is based on measured concentrations of eight elements of the NIPDWS and six herbicides and pesticides in the filtrate of a 24-h solid waste extraction test (USEPA 1980). If levels of these constituents exceed established maximum permissible concentrations, that waste is considered hazardous.

The sediment from the 3513 impoundment was found to be hazardous on the basis of mercury concentrations in the EP extracts. For example, four of the five sediment samples extracted by the EP contained mercury concentrations in excess of the 0.2 mg/L maximum allowable concentration (mean concentration from the five samples was 3.0 mg/L). No other RCRA-regulated constituent was observed to be in excess of the maximum allowable concentration. The single exception might be selenium as the level of analytical detection (approximately 2.4 mg/L) was greater than the maximum allowable concentration (1.0 mg/L). The concentrations of RCRA-regulated herbicides and pesticides in the EP extracts were well below their maximum allowable concentrations. Concentrations of organic compounds in the EP extract, as measured by the TTO (total toxic organic compounds, a screening summation for 113 of the 115 organic compounds listed by EPA as priority pollutants), were quite low (concentrations less than 0.01 mg/L). The EP extracts were not analyzed for concentrations of PCBs, although detectable concentrations were measured in the sediments.

The total concentrations of certain nonradioactive contaminants in the impoundment sediment varied considerably between Huang (personal communication) and the Stansfield and Francis (1986) study. For example, mean concentrations of copper, lead, and zinc measured in the sediment by Stansfield and Francis were on the order of 4 to 6 times higher than those measured by Huang (personal communication) (see Table 5). Concentrations for cadmium, chromium, and PCBs varied by factors of less than 3 between the two studies. However, unlike the heavy metal contaminants, the PCB measurements made by Huang (personal communication) were higher than those determined by Stansfield and Francis. Mean concentrations from both studies were based on analyses of five sample cores.

The inventories of contaminants in the sediment were based on slightly different volumes of sediment as well as different physical characteristics. Huang (personal communication) estimated the volume of sediment to be 2.0×10^3 m^3, with a wet bulk density of 1.1 kg/L and a moisture content of 80% (on a wet basis). Stansfield and Francis, on the other hand, estimated the sediment volume to be slightly larger (2.35×10^3 m^3), having a bulk density of 1.2 kg/L and a moisture content of 83% (on a wet basis). There was relatively good agreement between the two estimates for the inventory of cadmium and PCBs (3.2 and 6.1 kg for cadmium and 7.0 and 3.2 for PCBs). The major difference in inventory estimates between the two studies was the estimate for lead. Stansfield and Francis estimated the lead inventory to be slightly greater than 1 Mg (1 metric ton), whereas Huang (personal communication) estimated the lead inventory to be 185 kg. The inventory of mercury, the heavy metal that resulted in classification of the sediment as a toxic hazardous waste according to the RCRA extraction protocol (EP), was estimated by Huang (personal communication) to be 25 kg.

Table 5. Concentrations and estimated inventories of nonradioactive contaminants in sediment of 3513 impoundment[a]

Contaminant	Stansfield and Francis (1986) Concentration (mg/kg)	Stansfield and Francis (1986) Inventory[b] (kg)	Huang (pers. commun.) Concentration (mg/kg)	Huang (pers. commun.) Inventory[c] (kg)
Ag	48	22	n.r.[d]	n.r.
As	<79	<37	2	0.9
Ba	378	177	n.r.	n.r.
Cd	13.1	6.1	7.2	3.2
Cr	1100	520	440	194
Cu	826	388	150	66
Hg	n.r.	n.r.	56	25
Pb	2800	1310	420	185
Se	156	73.2	2.8	1.2
Zn	632	297	130	57
PCB	6.9	3.2	16	7.0

[a]Mean concentration from five core analyses on dry weight basis.

[b]Sediment volume estimated to be 2.35×10^3 m^3, with a bulk density of 1.2 kg/L and a moisture content of 83% (wet basis).

[c]Sediment volume estimated to be 2.0×10^3 m^3, bulk density of 1.1 kg/L and a moisture content of 80% (wet basis).

[d]n.r. = not reported.

3.1.3. Groundwater

The recent investigation by Stansfield and Francis (1986) was the first dedicated effort to determine the status of the groundwater quality around the 3513 impoundment and to address the past and possible future impacts of the impoundment on groundwater quality. Five monitoring wells ranging in depth from 3.6 to 7.6 m (12 to 25 ft) were installed around the 3513 impoundment at the locations illustrated in Fig. 3. The methods used to drill the borings, the installation, and a detailed description of the 5.1-cm (2-in.) diam stainless steel well screen and casing, as well as the boring logs, for each of the wells are presented in Stansfield and Francis (1986). Two of the monitoring wells (MW-1 and MW-1A) were located at positions thought to be upgradient of the impoundment in an attempt to provide groundwater samples that were not affected by potential contamination from the 3513 impoundment. The locations of the other three monitoring wells were selected to determine if contaminants from the impoundment were migrating into the groundwater. A description of monitoring well locations, pertinent construction data, and water levels during the first, second, and third quarters of 1985 are presented in Table 6.

The primary goal in analyzing groundwater samples taken from the monitoring wells was to determine if the groundwater had been contaminated. To do this, the samples were analyzed for the 30 constituents promulgated under RCRA regulations (USEPA 1980). In addition, groundwater samples were analyzed by inductively coupled plasma (ICP) spectroscopy. This technique provides general information on concentrations of nearly 30 additional elements in one analysis.

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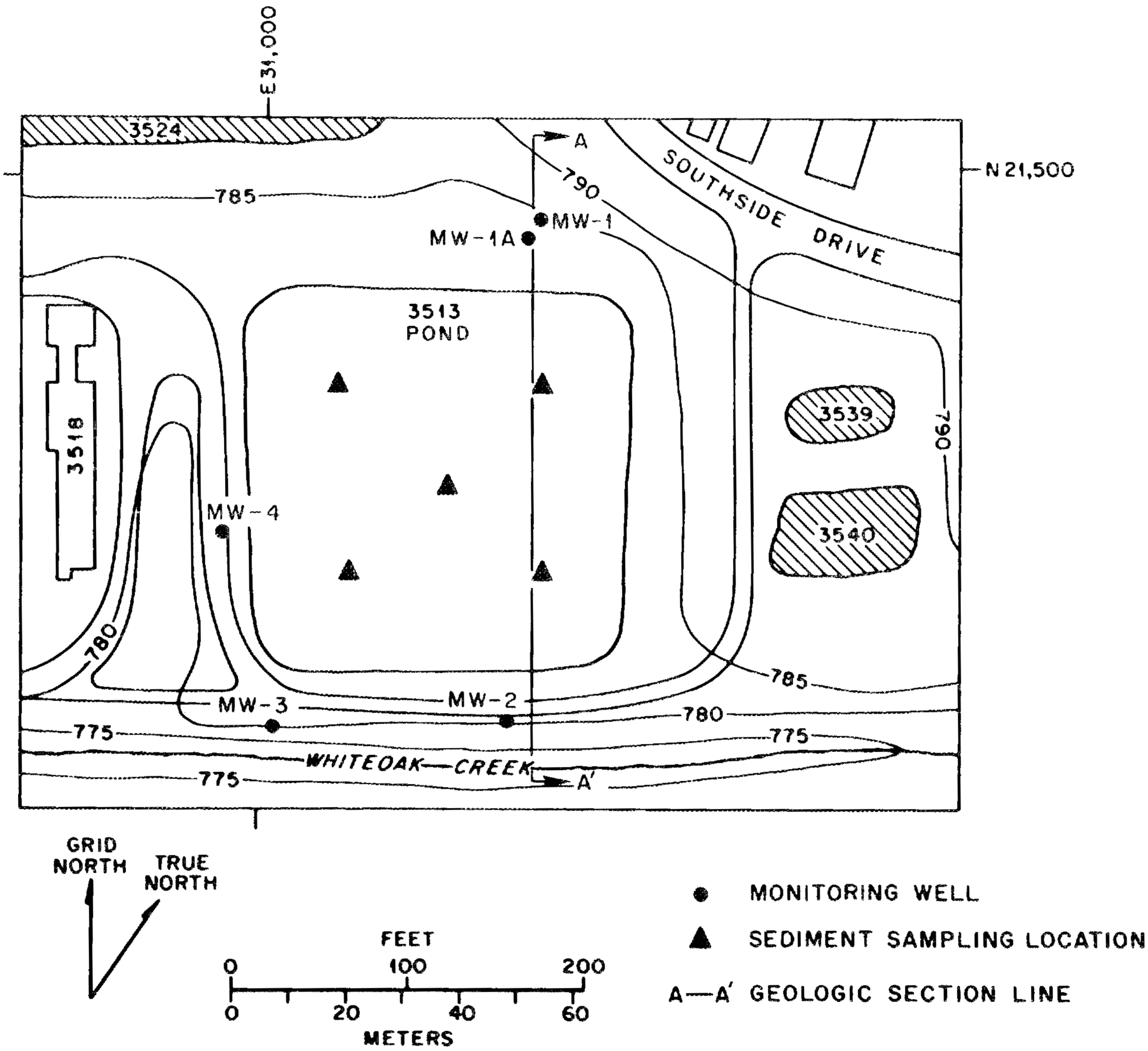

Fig. 3. Location of sediment sampling sites and groundwater monitoring wells.

Table 6. Summary of monitoring well location, construction data, and water levels at 3513 impoundment[a] (1st, 2d, 3d quarter 1985)

Well Number	MW-1	MW-1A	MW-2	MW-3	MW-4
		(ft)[b]			
North grid coordinate	21463.30	21462.19	21180.43	21180.33	21281.89
East grid coordinate	31157.39	31155.27	31141.45	31009.21	30970.03
Top of well casing elevation	786.61	786.37	785.96	785.24	783.25
Height of casing above ground	3.0	2.9	3.0	3.0	2.5
Ground surface elevation	783.6	783.5	783.0	782.2	780.8
Top of well screen elevation	777.8	769.2	776.2	766.1	774.2
Bottom of well screen elevation	775.8	762.2	769.2	769.1	767.2
Top of sand pack elevation	778.6	769.6	778.0	777.2	775.8
Bottom of well hole elevation	775.6	758.5	769.2	769.0	767.1
Water level elevation, 2-6-85	779.56	780.05	776.68	773.81	776.79
Water level elevation, 4-8-85	779.10	779.22	776.45	773.30	776.39
Water level elevation, 4-16-85	778.21	779.22	776.25	773.13	776.56
Water level elevation, 6-16-85	778.87	779.12	776.77	773.43	775.93
Water level elevation, 7-1-85	778.97	779.15	776.45	773.20	776.18

[a]All wells are 5-cm-diam (2.0-in.-diam) stainless steel pipes and screens. Width of screen opening is 0.025-cm (0.01 in).

[b]1 ft = 0.3048 m.

Many of these are not RCRA regulatory elements, but their concentrations in groundwater are useful in evaluating general groundwater quality. For instance, concentrations of copper, nickel, and zinc in groundwater samples were determined using this technique.

Stansfield and Francis (1986) reported concentrations in groundwater samples taken from the five monitoring wells during February and April of 1985. A summary of the concentrations of selected groundwater parameters from the downgradient monitoring wells samples collected during the first two quarters of 1985 is presented in Table 7. The major contaminants in the groundwater appeared to be radionuclides; for example, gross alpha and gross beta concentrations exceeded NIPDWS concentrations in upgradient as well as in downgradient wells. In the downgradient wells, the concentrations of chromium and lead occasionally exceeded NIPDWS. Because there was no general trend in the concentrations of either of these elements in the downgradient wells, the investigators felt that further sampling would be required to establish if these measurements reflected "real" contamination. The EP extracts from the 3513 sediment contained concentrations of mercury in excess of the RCRA permissible limits, classifying the sediment as a hazardous waste. On the other hand, levels of mercury in the groundwater samples were not in excess of NIPDWS. At some sampling dates, counts of coliform bacteria in groundwater taken from wells upgradient as well as downgradient of the pond were in excess of the NIPDWS. These counts may have resulted from the wildlife habitat such as waterfowl and terrestrial animals known to be in the area. At the same time, the counts may have been propagated by leakage from ruptured

Table 7. Summary of selected groundwater concentrations from downgradient wells at 3513 impoundment[a]

	Maximum level[b]	Measured[b,c]
National Interim Primary Drinking Water Standards (NIPDWS)		
Arsenic	0.05	<0.0018
Barium	1	0.2472
Cadmium	0.01	<0.0018
Chromium	0.05	0.3388
Fluoride	1.4-2.4	<1
Lead	0.05	0.244
Mercury	0.002	0.0002
Nitrate-N	10	3.5
Selenium	0.01	<0.005
Silver	0.05	<0.07
Endrin	0.0002	<0.001
Lindane	0.004	<0.0002
Methoxychlor	0.1	<0.0002
Toxaphene	0.005	<0.002
2,4-D	0.1	<0.0057
2,4,5-TP Silvex	0.01	<0.0058
Radium-226 (Bq/L)	0.19	<0.0463
Gross alpha (Bq/L)	0.556	1.47
Gross beta (mR/year)	4	19.92[d]
Coliform bacteria (counts/100 mL)	1	0.5
Parameters establishing groundwater quality		
Chloride	ND[e]	17.7
Iron	ND	19.8
Manganese	ND	3.73
Phenols	ND	<0.0025
Sodium	ND	30.2
Sulfate	ND	<12.8
Parameters used as indicators of groundwater contamination		
pH	ND	6.5
Specific conductance (μS/cm)	ND	592
Total organic carbon	ND	5.98
Total organic halogen	ND	0.0485
Nonregulated parameters		
PCBs	ND	0.0001
Tritium (Bq/L)	ND	2700
Cesium-137 (Bq/L)	ND	0.39
Strontium-90 (Bq/L)	ND	10.6

[a]Taken from Stansfield and Francis (1986).

[b]Concentrations are in mg/L unless otherwise stated.

[c]Measured concentrations are mean values of six determinations.

[d]Measured concentration of gross beta is expressed in Bq/L rather than mR/year (1 Bq = 27 pCi).

[e]ND = not defined.

underground sewage lines that service buildings upgradient of the impoundment. A similar pattern, elevated concentrations in upgradient as well as downgradient wells, was evident for total organic carbon (TOC), total organic halides (TOX), PCBs, and radionuclides, indicating that the upgradient wells were affected by the transport of contaminants from other sources, perhaps seepage from the 3524 waste impoundment or leakage from underground waste lines. Differences in groundwater concentrations between downgradient and upgradient samplings will be tested statistically after the third and fourth quarter samples are taken.

3.2. GEOLOGY AND SOILS

3.2.1. Regional Geology

Oak Ridge National Laboratory lies in the Ridge and Valley Physiographic Province. In Tennessee, the province consists of northeast-southwest striking rock strata of limestone, sandstone, and shale extending from the Georgia-Alabama border on the south to the Virginia border on the north. The strata are tilted from the horizontal to angles of 30 degrees and greater throughout its length, resulting in the erosion-resistant beds forming parallel ridges and those less resistant beds becoming intervening valley floors.

3.2.2. Site Geology

3.2.2.1. Bedrock

Impoundment 3513 lies in Bethel Valley approximately 213 m (700 ft) northwest of the Copper Creek fault. As shown on the geologic map (Fig. 4), the site is underlain by unit "G" of the

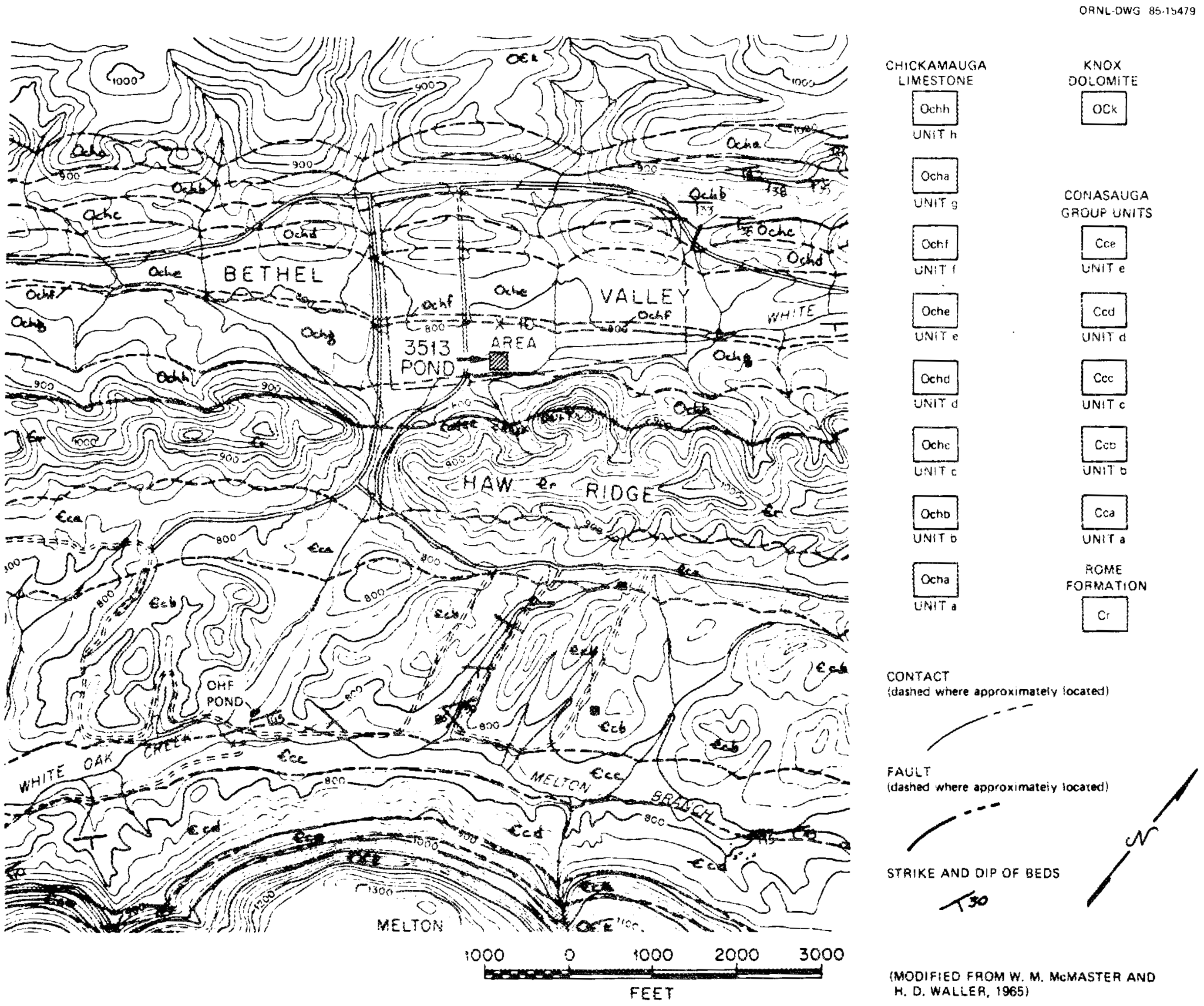

Fig. 4. Geologic map of the ORNL area including the 3513 impoundment.

Chickamauga Group, a hard, mostly thin-bedded limestone with shaly partings (Stockdale 1951). Locations of several core holes drilled for the Stockdale (1951) study in the vicinity of the 3513 impoundment are shown in Fig. 5. Thin-bedded limestone crops out in the bottom of White Oak Creek immediately adjacent to the south side of the impoundment. The limestone stratum beneath the impoundment dips to the southeast at an angle of approximately 35 degrees from the horizontal, and the beds strike approximately 58 degrees to the northeast. The bedding plane strike direction is approximately parallel with the section of White Oak Creek adjacent to the impoundment. With regard to bedrock units "G" and "H", Stockdale (1951) reports "small secondary openings in the rock brought about by solution through ground waters exist in minor amounts as revealed by core drilling." However, the log of core hole No. 1 of that study (drilled from the south side and directed beneath the impoundment at a 55 degree angle from the horizontal) shows only two solution openings of approximately 1.3 cm (0.5 in.) each, and they were at the inclined depth of between 65.6 to 65.8 m (215-216 ft). A geologic section through the impoundment (Stansfield and Francis 1986) is shown in Fig. 6.

3.2.2.2. Soil

The soil depth around the impoundment is approximately 3.7 m (12 ft) and consists mostly of material that would classify as clays under the Unified Soil Classification System. For the most part, these soils are likely to consist of colluvium overlying residuum derived from the underlying bedrock, but the area adjacent to White Oak Creek appears to be of alluvial and fill origin. During the construction of one of the

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MODIFIED FROM WATER TABLE MAP OF ORNL
BY GEORGE D. DeBUCHANANNE FROM STOCKDALE, 1951

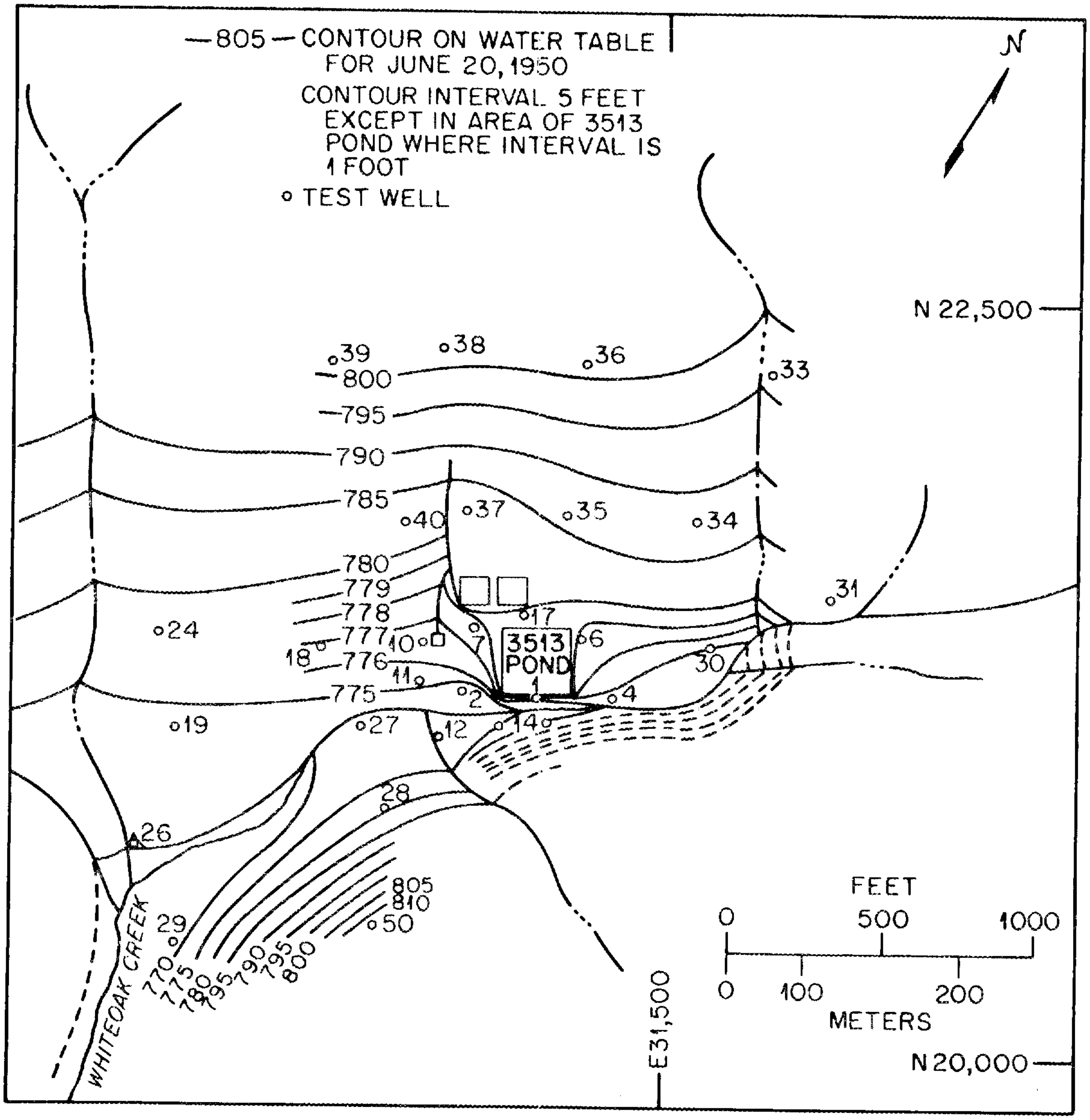

Fig. 5. General water table map of a portion of ORNL.

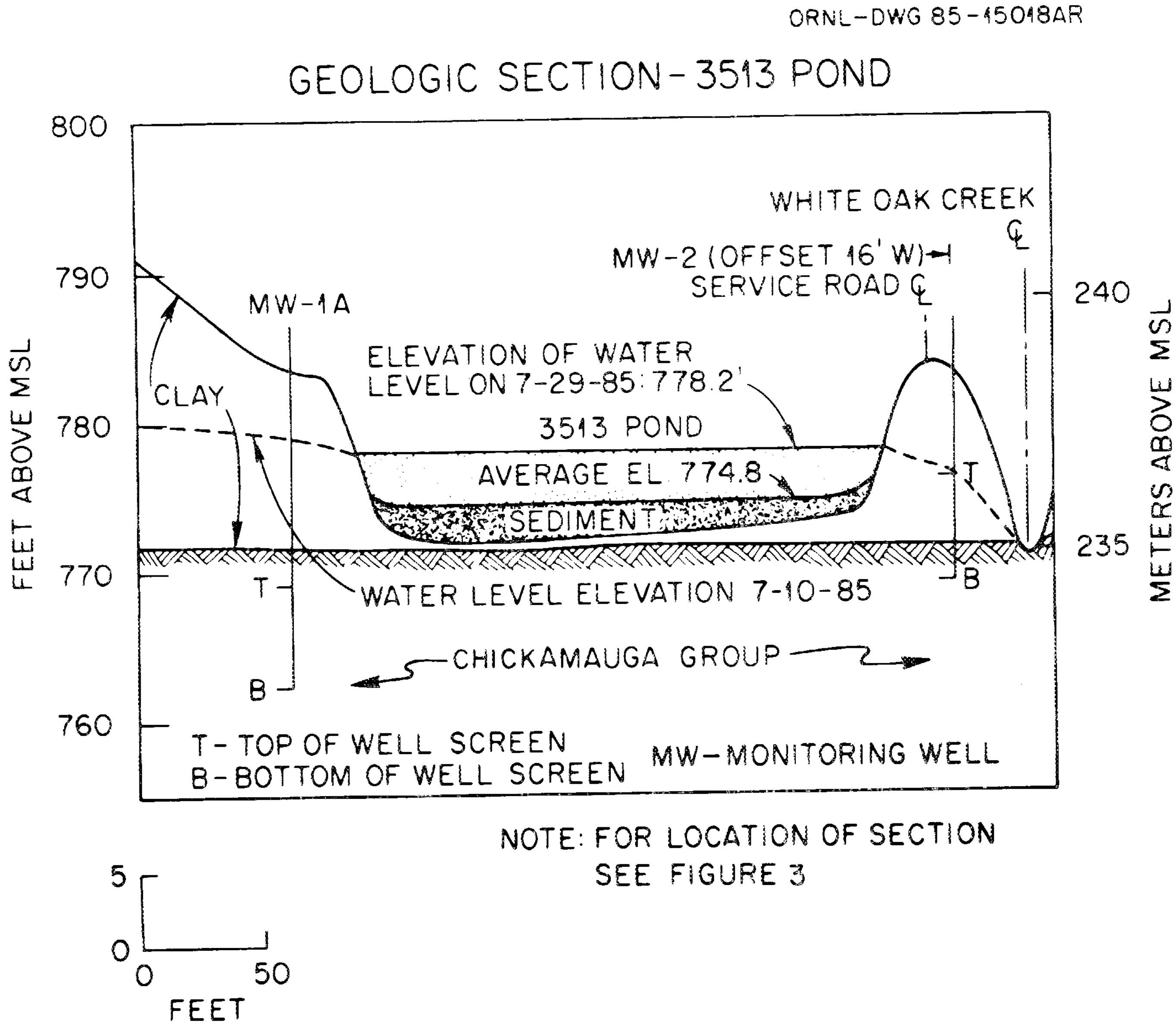

Fig. 6. Geologic section through 3513 impoundment.

monitoring wells at this impoundment in 1985, a clayey sand with some gravel was encountered, but is likely backfill material placed for an abandoned 21-cm-diam (8-in.) discharge line that exits into White Oak Creek near the location of the well. Logs of borings for existing monitoring wells and details of well construction are included in Stansfield and Francis (1986).

3.3. HYDROLOGY

From 1948 through 1983, the mean annual precipitation at Oak Ridge was 139 cm (55 in.). In this region, the heaviest precipitation normally occurs during winter and early spring, with the monthly maximum normally occurring during the period January to March. However, during some years, the monthly maximum has occurred in July because of thunderstorms. September and October are usually the driest months. According to the "Climatic Atlas of the United States" (U.S. Department of Commerce 1979), mean annual lake evaporation in the Oak Ridge area is 89 cm (33 in.). Thus, it can be estimated that yearly an average of approximately 56 cm (22 in.) of precipitation that falls directly into the impoundment is not lost to evaporation. Multiplying this amount by the surface area of the impoundment yields an average yearly retained precipitation contribution of approximately 93 m^3 (24,500 gal). The level of the pond is generally held at an elevation of 237.2 m (778 ft) which is the elevation of the effluent drain lines on the south side of the impoundment. Outflow from these lines goes to a sump from which it is pumped to the 3524 impoundment and processed. In the fall and winter of 1984, the water level in the impoundment was allowed to rise to a maximum elevation of approximately 237.9 m (780.5 ft). No measurement is made of the quantity of water pumped from the 3513 impoundment.

3.3.1. Groundwater Movement

Two water-table maps are shown in Figs. 5 and 7. Figure 5 is from a report by Stockdale (1951) and depicts the water table for a large portion of ORNL, based on well data available when the two impoundments now located just east of 3513 impoundment did not exist. Figure 7 is based on water-level observations from the five monitoring wells constructed in 1985 and is limited to the immediate site of the 3513 impoundment. Water-level observations, on which Fig. 7 is based, and monitoring well data are provided in Table 6. Both Figs. 5 and 7 show the hydraulic gradient to be generally toward White Oak Creek, with a lesser component to the west which is the downstream direction of White Oak Creek. As previously described in the section on bedrock, White Oak Creek flows in the direction of geologic strike on top of the limestone along the south boundary of the impoundment. In a homogeneous material, groundwater movement is in a direction normal to the water-table contours. However, studies on the ORNL reservation (Webster 1976; Davis et al. 1984) support the fact that the direction of groundwater movement in the bedrock is greatly affected by the directional permeability of the strata. Therefore, the overall groundwater flow through the bedrock is commonly in a direction at some acute angle to the groundwater contours. Such movement would not normally be expected to be in a straight line of flow but rather would

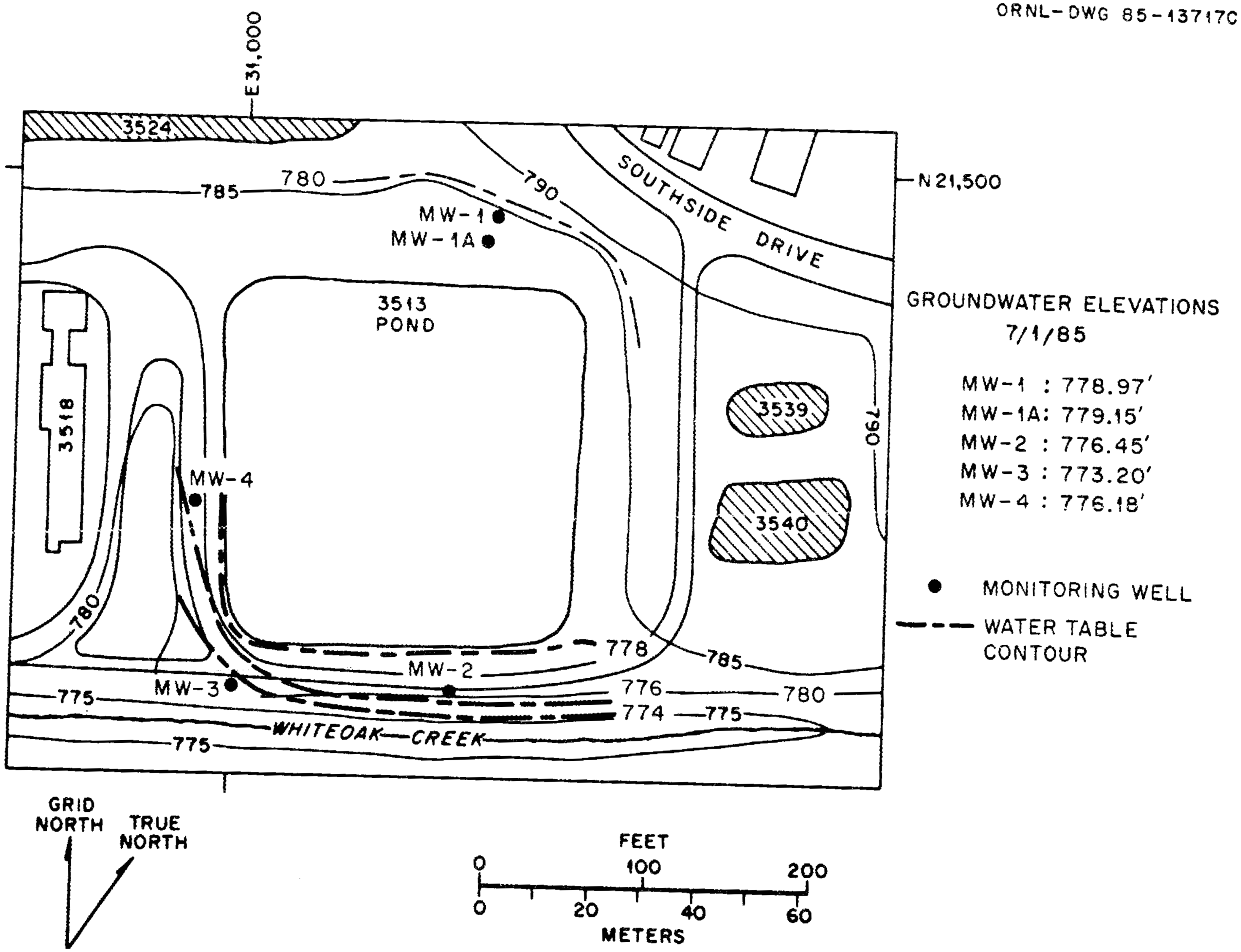

Fig. 7. Water table map 3513 impoundment.

follow irregular pathways along joints and bedding planes because the bedrock strata has insignificant primary permeability. At the site, a particular groundwater pathway could extend a distance westward in the form of a bedding plane joint (direction of geologic strike) before intersecting another fracture sloping in a steeper downgradient direction toward the creek. In addition to the lateral movement of groundwater at the 3513 site, the monitoring wells constructed in 1985 indicate the existence of a slight upward vertical gradient from the underlying bedrock to the overlying soil.

3.3.2. Uppermost Aquifer

The soil overlying the limestone bedrock aquifer (Chickamauga Group) consists of material that has been visually classified as clay (according to the Unified Soils Classification System) which categorically has a low hydraulic conductivity. One of the monitoring wells at the 3513 impoundment is constructed entirely in clay soil and to date produces water in a quantity adequate for sampling purposes. However, for most water uses, the clay would provide an insufficient quantity and would not be considered an aquifer. The two units are hydraulically connected as the clay immediately overlies the limestone bedrock.

3.4. ECOLOGY

The diverse assemblage of aquatic invertebrates in the 3513 pond water and sediment indicates that any residual toxic effects from nonradiological constituents of former waste effluent are small. For example, over 30 taxa of insects, including two caddis fly and one mayfly species, have been identified (see Table 8 for a general classification and trophic status of aquatic invertebrates). The pond may be characterized as eutrophic with a mixed phytoplankton (Hutchinson 1967). Benthic filamentous algae and submerged macrophytes are seasonally abundant, and before cutting in 1982, an approximately 1-m-wide strip of dense emergent vegetation (Typha, Juncus, and Eleocharis) fringed the pond.

The vertebrate fauna are generally limited to frogs (Rana catesbeiana and Rana palustris), some snapping turtles, and an occasional transient duck. In the spring of 1977, juvenile fish (goldfish, Carassius auratus; channel catfish, Ictalurus punctatus; bluegill, Lepomis macrochirus) were introduced into the pond (Table 9). In recent years, Canada geese have been sighted frequently on the pond. For example, in 1985 a pair of geese nested in the area.

Over the years, the pond has been useful as a radioecological research site to study the behavior of actinides and fission products in freshwater ecosystems. Concentrations and distribution patterns of actinides among aquatic biota and between shoreline plants and the soil were reported by Garten (1981) and (Garten et al. 1982). Similar studies relative to the ^{137}Cs and ^{60}Co in particular levels of the aquatic environment were conducted by B. G. Blaylock (personal communication). Woodchucks (Marmota monax), muskrats (Ondatra zibethicus), and cotton rats (Sigmodon hispidus) have also been collected from the area and counted for radioactivity (Kaye and Dunaway 1962; Garten 1979).

Table 8. Classification and trophic status of aquatic invertebrates sampled from 3513 impoundment

Genus	Common name	Trophic status
Burrowers/sprawlers		
Erythemis	Dragonfly naiad	Carnivore
Plathemis	Dragonfly naiad	Carnivore
Glyptotendipes[a]	Midge larva	Herbivore-detritivore
Pentaneura[a]	Midge larva	Herbivore-detritivore
Tabanus	Horsefly larva	Carnivore
Tipula	Cranefly larva	Herbivore-detritivore
Sprawlers/climbers		
Physa	Snail	Herbivore-detritivore
Callibaetis[a]	Mayfly nymph	Bivore-detritivore
Tramea	Dragonfly naiad	Carnivore
Enochrus[a]	Hydrophilid beetle larva	Herbivore-detritivore
Climbers/swimmers		
Anax	Dragonfly naiad	Carnivore
Enallagma	Damselfly naiad	Carnivore
Belostoma	Giant water bug	Carnivore
Ranatra	Water scorpion	Carnivore
Peltodytes[a]	Haliplid beetle larva	Herbivore
Swimmers/plankters		
Dineutus	Gyrinid beetle adult	Carnivore-scavenger at surface film
Notonecta	Backswimmer	Carnivore
Daphnia[a]	Cladoceran	Herbivore-detritivore
Simocephalus[a]	Cladoceran	Herbivore-detritivore

[a]Uncleared gastrointestinal tract samples only.

Table 9. Classification and trophic status of aquatic plants and vertebrates sampled from 3513 impoundment

Genus	Common name	Trophic status
Spirogyra	Filamentous alga	Primary producer
Hydrodictyon	Filamentous alga	Primary producer
Potamogeto	Rooted macrophyte	Primary producer
Rana catesbeiana	Bullfrog tadpole	Herbivore-detritivore
Carassius auratus	Goldfish	Herbivore-detritivore
Ictalurus punctatus	Channel catfish	Omnivore
Lepomis macrochirus	Bluegill	Carnivore-invertebrates

4. ADDITIONAL INFORMATION NEEDED

In future phases of the ORNL remedial action program, the intent is to evaluate the transport and dose pathways for hazardous substances from each of the facilities considered to pose an undue risk to health, safety and environment using standard as well as "state-of-the-art" mathematical models to provide adequate assessment of the site conditions. This pertains especially to the assessment of potential impacts on groundwater quality that are difficult to determine using conventional analytical procedures. One purpose of this report is to identify the necessary data requirements to be used as input to drive such models. This pathway analysis assessment will then be used to determine the proper course of action required for future remedial actions.

4.1. INVENTORY

The studies conducted by Tamura et al. (1977), Huang (personal communication), and Stansfield and Francis (1986) provided an adequate data base to determine the inventory of both radionuclides and nonradioactive contaminants for the pond water and sediment. However, additional samples of subsurface soils need to be taken from the berm as well as from under the impoundment to determine the extent of contamination, in terms of both concentration and soil depth. Also, if the modeling predictions associated with remedial action are truly dependent on being able to model the extent of contamination under existing conditions, then leaching studies on the sediment from the 3513 impoundment need to be conducted. The leaching should be conducted with pond water from the impoundment, and any subsequent attenuation of the transport of leached contaminants by the soil underlying the impoundment and subsurface surrounding soils should also be determined.

4.2. GEOLOGY AND SOILS

4.2.1. Site Geology

The extent of vertical contamination will be determined by taking core borings from below the impoundment. This will be done by angle corings upgradient and downgradient of the impoundment to depths approximately 33 m (100 ft) directly under the impoundment. Sections of coring will be taken from these corings and analyzed for radioactivity and RCRA contaminants (using the RCRA EP leaching test). If contamination is confirmed, the same borings will be used to observe bedding plane characteristics and frequency in the limestone aquifer for use in modeling the movement of contaminants into this limestone bedrock.

To aid in model verification, a dye-tracer study will be conducted if contamination in the bedrock is confirmed. The objective of these studies is to determine if there are solution cavities in the limestone bedrock that have the potential of providing migration pathways for contaminants from the 3513 impoundment to surface drainage ways such as White Oak Creek and First Creek. Because past exploration (Stockdale 1951; Stansfield and Francis 19[illegible]) indicates that the bedrock surface underlying the soil overburden is only very slightly weathered, these analyses and tests will be made on essentially nonweathered rock. Also, a short-lived radionuclide tracer (^{82}Br) will be placed in the pond water in an attempt to detect leakage through either the bedrock or soil and backfill around the pond.

4.2.2. Soils

In addition to the sampling of soils from the berm of the 3513 impoundment to determine the extent of contamination, sediment samples need to be taken to ensure that any engineering approaches to the remedial actions, such as stabilizing the sediment, can be completed. Soil samples also need to be taken so that the sorption/desorption of known contaminants in the pond water and sediment on the subsoils below and around the impoundment can be determined. To validate modeling of existing conditions, detailed spatial concentrations in soils near-field of the pond will be needed.

4.3. HYDROLOGY

The results of analyses and groundwater-level measurements from the monitoring wells constructed in the fall of 1985 at the adjacent impoundments (3524, 3539, and 3540) need to be evaluated in concert with those from the monitoring wells at the 3513 impoundment. Furthermore, several piezometer wells are scheduled for completion in the area around these four impoundments in 1986 as part of the comprehensive sitewide groundwater characterization activities. A potentiometric map for the area of the four impoundments will be prepared by using data from all wells.

4.3.1. Surface Water

To model the impoundment, inflow (from active pipelines) and outflow (to the adjacent 3524 pond) will be measured. Streamflow measurements will be made in White Oak Creek upstream and downstream of the 3513 impoundment to provide information on the effluent or influent characteristics of the stream for one year. Also, chemical analyses of the stream water from these same locations will be made.

4.3.2. Groundwater

Groundwater samples were taken and analyzed four times from February to September 1985. These results will be evaluated to determine whether contaminants other than radionuclides from the 3513 have significantly affected the groundwater. Pollution from chemical hazardous waste is assumed if an analysis by a statistical procedure, such as Cochran's Approximation to the Behrens-Fisher Student's t-test, indicates a significant increase (decrease in the case of pH) in the water quality parameters listed in Table 7 between the upgradient and downgradient wells.

If contamination is verified deep into the limestone bedrock by the deep cores taken below the impoundment (see Section 4.2.1), additional data on the aquifer properties (hydraulic conductivity, effective porosity, and degree of anisotropism) will be needed for constructing models of the groundwater flow system and contaminant transport. Hydraulic conductivity tests, using slug-test procedures, will be conducted and analyzed for the existing monitoring wells at the impoundment. A pump test with several observation wells will be necessary to study the anisotropic nature of the hydraulic conductivity and transmissivity. The well to be pumped in the test will need to be at least 10 cm in diameter so that a submersible pump can be installed. Because of this relatively large diameter, normal well drilling methods will be used rather than coring techniques. The strata in the well will be examined and logged using a down-the-hole camera.

Additional shallow groundwater-monitoring wells will be needed on the west side of the 3513 impoundment to define the limits of contamination. Wells will have to be sufficient in number and depth to determine the lateral extent of the contamination. Also, if contamination is verified by the deep cores taken below the impoundment, the extent of contamination and vertical flow will be determined by installing a deep groundwater-monitoring well and a deep piezometer to compare the water-level measurements with those in existing shallow wells.

4.4. ECOLOGY

The impoundment has served as a valuable radioecology study area for over 20 years [Kaye and Dunaway 1962, Garten et al. (1982), and Trabalka et al. (in press)]. Over that time, considerable information relative to the movement and distribution of radionuclides in the biota of the impoundment has been characterized. The removal of the pond water and stabilization of the sediment will decimate most of the present biota. No future studies appear to be necessary to characterize the existing or future ecological impacts.

5. MONITORING AND TESTING PLAN

5.1. RECOMMENDED TASKS

(1) Analyze groundwater monitoring data. Using an adequate statistical analysis procedure, evaluate four quarters of groundwater sampling data for parameters established by the Environmental Protection Agency (EPA) as indicators of significant groundwater contamination by chemical hazardous waste.

(2) Conduct sediment leaching and soil attenuation studies. Leach contaminated sediment with pond water to determine existing leach rates in conjunction with sorption/desorption studies of the leached contaminants on berm soils. To determine the extent of near-field migration of impoundment contaminants through the adjacent soils, additional sampling, chemical and radiological analyses, and data interpretation will be required.

(3) Determine leakage to groundwater. Install inflow and outflow measuring devices at the 3513 impoundment so that leakage into the groundwater can be calculated (after taking into consideration input from precipitation and losses via evaporation).

(4) Characterize input to White Oak Creek. Conduct tracer studies, by adding short-lived radioisotopes and/or dyes to the impoundment, to determine input to White Oak Creek. Also at three locations on White Oak Creek, quarterly flow measurements and samples for analyses will be taken. The locations will be immediately upstream of the 3513 impoundment, immediately downstream of the impoundment, and in the range of 60 m downstream of the impoundment. Samples will be

analyzed for gross alpha, gross beta, ^{90}Sr, and ^{3}H. In addition, if the statistical analyses of groundwater indicator parameters show significant contamination, the samples from White Oak Creek will also be analyzed for the four indicators of groundwater pollution (pH, specific conductance, total organic carbon, and total organic halogen).

(5) Construct monitoring wells to determine lateral contamination. Construct four additional shallow-monitoring wells to the top of bedrock to determine the lateral limits of contamination. The wells will be 5 cm (2 in.) in diameter and their construction shall be the same as that for the existing monitoring wells at the facility (Stansfield and Francis 1986). The wells will be constructed on the west side of the impoundment.

(6) Drill corings to determine vertical contamination. Two corings at depths to 33 m will be used to determine if the bedrock under the impoundment has been contaminated. Tentatively, the corings are planned at the northeast and southwest corners of the impoundment and will be angled to sample bedrock directly under the impoundment. Sections of these cores will be analyzed for contamination by radionuclides and RCRA constituents (using the EP leach test). If the bedrock is found to be contaminated, these cores will be used to determine bedding plane characteristics.

(7) Construct wells to monitor deep groundwater. A deep (33 m or more) monitoring well (tentatively located at the southwestern corner of the impoundment) will be constructed to monitor deep groundwater. Also to be constructed is a multistage deep piezometer to measure vertical flow.

(8) Collect and analyze data from new monitoring wells. Sample and analyze the new wells for gross alpha, gross beta, ^{90}Sr, and ^{3}H. Also, if the statistical analyses described earlier indicate significant pollution by chemical waste, groundwater from the wells will be analyzed for all RCRA-regulated constituents.

(9) Conduct single-well hydraulic conductivity tests. Conduct single-well hydraulic conductivity tests (slug tests) in all monitoring wells and calculate the hydraulic conductivities of the bedrock and soil.

(10) Preparation of pathways analysis. Using the data currently available and those proposed in this plan, a pathways analysis of the migration of contaminants from the impoundment will be completed.

(11) Manage project and prepare report. Coordination of the above actions, and the documentation of the information obtained in a report will be required.

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