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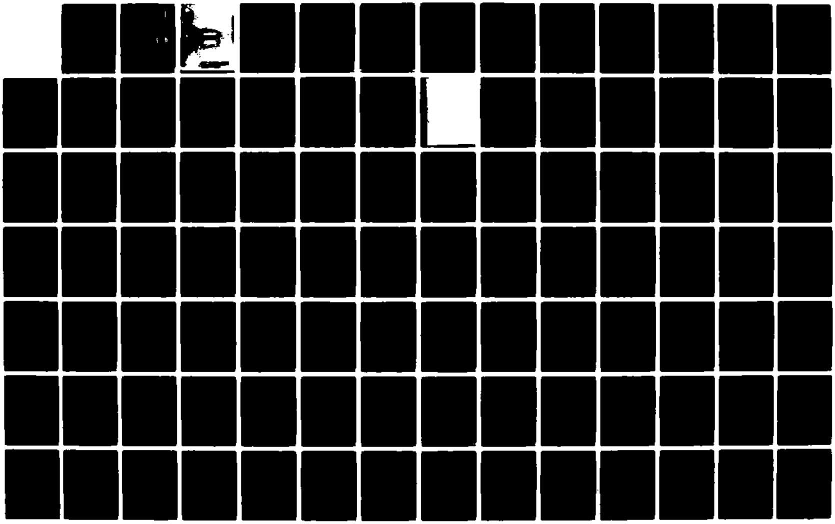

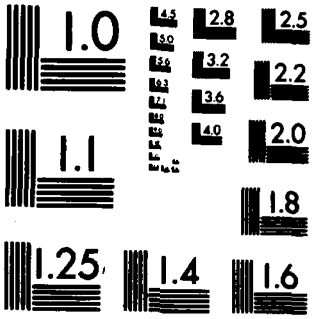
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Huntsville Spring Branch Pesticide Residues Chemical Analysis
Indian Creek

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

DDT contamination in northeast Alabama near Triana, in the Tennessee River system including Wilson, Wheeler, and Guntersville Reservoirs has occurred because wastes containing DDT residues (DDTR) have migrated to receiving streams. In the area DDTR levels in fish exceed the 5 ppm limit set by the FDA for edible portions of fish. Evidence of human DDT contamination has been found in persons routinely consuming the fish.

In the spring of 1979 an engineering and environmental study began to determine whether or not corrective action is required, and if so, the technical

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approach to such corrective action. The nature and extent of contamination have been defined, and engineering, economic, and environmental feasibility of alternative solutions have been evaluated. Study included extensive field and laboratory work. Data were gathered on fish, sediment, water, macroinvertebrates, plankton, aquatic plants, mammals, birds, and reptiles in the area. Additionally, efforts were made to secure all prior existing data.

Analysis of data provided quantification of pollutant transport by biological (food chain) and physical (mostly hydrologic) processes. Data collected during the current study have been compared to historical data to determine extent of sediment contamination and rate of movement downstream. Groundwater transport has been evaluated.

Principal study findings include:

1. An extensive amount of DDTR exists in reservoir sediments.

2. DDTR is being moved slowly downstream.

3. Fish, particularly channel catfish, are contaminated with DDTR throughout Wheeler Reservoir.

4. Contamination of aquatic organisms, results from low levels of DDTR that now exist in water and/or sediment.

5. Contamination of aquatic organisms also appears to be caused by migration of contaminated fish to relatively uncontaminated areas.

Remedial alternatives for mitigation were compared to the Natural Restoration Alternative, which is to allow clean-up by natural processes. Alternatives are based on various means of isolating DDTR from the environment and include: (1) dredging or removing the contaminated sediments and placing them in a secure landfill, (2) covering the contaminated sediments in place, and/or (3) bypassing flow around the contaminated area. For the six final alternatives, details regarding engineering and economic feasibilities and environmental and regulatory impacts are presented. Time required for remedial results is also discussed.

FINAL CONTRACT REPORT

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION OF HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA

NOVEMBER 1980

VOLUME 2 OF 3
APPENDICES I-III

PREPARED FOR:
UNITED STATES ARMY CORPS OF ENGINEERS
MOBILE DISTRICT
CONTRACT NO. DACW01-79-C-0224

SUBMITTED BY:
WATER AND AIR RESEARCH, INC.
GAINESVILLE, FLORIDA 32602

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I. APPENDIX I: GENERAL INFORMATION ON DDT AND DDTR

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I. APPENDIX I: GENERAL INFORMATION ON DDT AND DDTR

1.0 INTRODUCTION

This Appendix will address the subjects of:

1) the chemical and physical properties of DDT particularly in soil, sediment, and aqueous systems;
2) DDT degradation in the environment;
3) the non-human toxicology of DDT;
4) EPA's ambient water quality criteria; and
5) FDA's regulations regarding DDT in fish.

2.0 PHYSICAL AND CHEMICAL PROPERTIES OF DDT

DDT is the common name for the chemical 1,1'-(2,2,2-Trichloroethylidene) bis[4-chlorobenzene]. This compound is also referred to as p,p' DDT. The six compounds p,p' DDT; o,p' DDT; p,p' DDD; o,p' DDD; p,p' DDE; and o,p' DDE are collectively referred to in this report as DDTR. The chemical structure of these compounds is shown in Figure I-1. The physical and chemical properties of DDT are presented in Table I-1.

3.0 BEHAVIOR OF DDT IN SOILS AND WATER

3.1 ADSORPTION TO SOILS

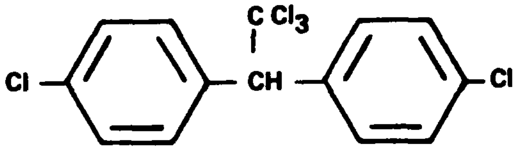
Shin et al. (1970) reported DDT adsorption to three soils, soil fractions and biological materials. They demonstrated linear adsorption isotherms for DDT and unextracted or hydrogen-peroxide digested soils when DDT was present in the aqueous matrix at less than 1 μg/l. Considerable DDT precipitation from aqueous solutions occurred at concentrations above 2 μg/l. Extraction of ether and alcohol soluble materials from soil increased DDT adsorption to mineral soils to a much greater extent than to muck soil or to fungal or plant tissues. Their results revealed probable sources of anomoly when trying to relate adsorption of non-ionic pesticides to soil organic matter content. A recent publication by Chiou et al. (1979) confirmed, however, that DDT partitions from the aqueous soil solution and moves into the soil organic matter.

Champion and Olsen (1971) evaluated the adsorption of DDT from water by ion exchange resins, aluminum oxides, ion exchange celluloses and soils. DDT adsorption was strongly enhanced by positively charged adsorbents in water. In addition, soils and sediments of low pH and/or high anion exchange capacity adsorbed more DDT than soils of higher pH or low anion exchange capacity. The presence of aluminum oxide in soil, as well as suspended and soluble soil matter could result in increased adsorption to soil particles.

Additional discussion of DDTR adsorption to soils and dredged material is found in Appendix III, Section 2.2.

3.2 VERTICAL MOVEMENT IN SOILS

A number of investigators have evaluated the vertical movement potential of DDT in soils (Hubbell et al., 1973; Ekstedt, 1975/1976; Kuhr et al.,



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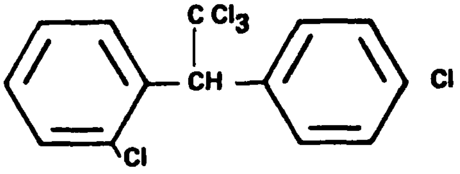

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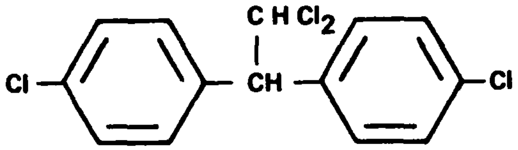

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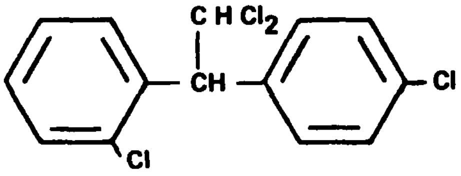

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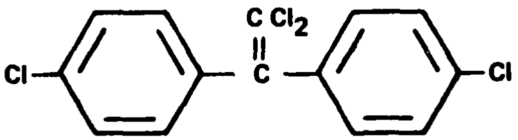

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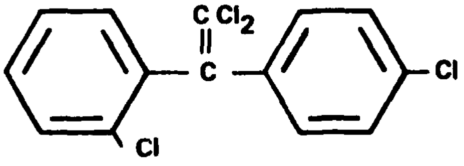

o,p' DDE

FIGURE I-1. Structure of DDT, DDE, and DDD

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
MOBILE DISTRICT

Engineering and Environmental Study
Of DDT Contamination of Huntsville Spring Branch,
Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

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Table I-1. Physical and Chemical Properties of DDT

Nomenclature	DDT. 1,1'-(2,2,2-Trichloroethylidene) bis[4-chlorobenzene]; 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane; α,α-bis (p-chlorophenyl)-β,β,β-trichlorethane; dichlorodiphenyltrichloroethane; chlorophenothane; dicophane; pentachlorin; p,p'-DDT; Gesarol; Neocid.
Chemical Abstracts Registry No.	50-29-3
Formula	$C_{14}H_9Cl_5$
Percentage Composition	C, 47.43%; H, 2.56%; Cl, 50.01%
Molecular Weight	354.50
Crystal Structure	Biaxial elongated tablets; Needles from 95% ethanol
Melting Point	108.5-109°C
Vapor Pressure	1.5×10^{-7} mm Hg at 20°C
Solubility	1.2 μg/l in water 58 gm/100 ml in acetone 78 gm/100 ml in benzene 45 gm/100 ml in carbon tetrachloride 74 gm/100 ml in chlorobenzene 116 gm/100 ml in cyclohexanone 2 gm/100 ml in 95% ethanol

Source: Bowman, et al., 1960; Harris, 1970; Windholz et al., 1976.

1972; Kiigemagi and Terriere, 1972; McCall et al., Unpublished; McCall et al., Unpublished a; Swann et al., Unpublished). Little evidence exists for significant vertical movement of DDT although some has been documented (Wheeler et al., 1980; Ekstedt, 1975/1976).

Wheeler et al. (1980) have been measuring DDT levels in soils at 0-6", 6-12", and 12-18" depths following surface DDT applications over a period of several years. A 10 percent granular formulation of DDT was applied to a Norfolk loamy fine sand at a rate of two pounds per acre weekly for 12 weeks starting in late March, 1970. These treatments have been applied each year during the same time intervals and are still continuing. The results of the analyses of one experimental treatment four and six years after the initiation of the study are presented below.

	Time, 4 Years		Time, 6 Years	
Depth	Conc., ppm	% Distribution	Conc., ppm	% Distribution
0-6"	4.14	93	6.83	92
6-12"	0.21	5	0.57	7
12-18"	0.09	2	0.04	1
	4.44		7.44	

The samples were taken four weeks after the final DDT application. The concentrations shown are mean values for three plots. The data show that the downward movement of DDT is slow if in fact it is occurring at all. The experimental plots have been harrowed for weed control on a number of occassions, which may explain the presence of DDT in the 6-12 inch samples. If DDT were moving vertically, one would expect to find increased levels at the 12-18 inch depths with time. The data indicate that this is not happening.

Ekstedt (1975/1976) reported DDT and DDE levels detected in two Swedish soils. Eighty-eight percent of the DDT remained in the top 10 cm and 94 percent was found in the top 15 cm (6 inches). No DDT was detected below 22 cm. DDE moved farther downward than did DDT with very low levels (1 ppb) being detected at 35-40 cm. Eighty-two percent of the DDE detected was in the top 15 cm.

Three unpublished papers by Dow Chemical Company personnel (McCall et al., unpublished; McCall et al., Unpublished a; Swann et al., Unpublished) describe the mobility of DDT in soils. One paper (McCall et al., Unpublished) states that when the soil adsorption coefficient is known along with organic carbon content of the soil, predictions can be made about vertical movement via leaching. The objective of these studies was to demonstrate that laboratory measurements of chemical sorption in a number of soils can lead to an estimate of the chemical's leaching potential in the field and can be compared with other pesticides in the same model system. These investigators used nine pesticides in their system. No compound tested had a higher sorption coefficient than DDT.

3.3 VOLATILIZATION FROM SOIL, WATER AND OTHER SURFACES

The major means of pesticide entry into the atmosphere are:

- o spray drift during application;
- o volatilization from treated surfaces; and
- o movement of wind blown dust particles (Spencer, 1975).

Potential volatility of the various DDT isomers and degradation products is related to their vapor pressures but actual volatilization rates will depend on environmental conditions and all factors that modify the effective vapor pressure (Spencer, 1975). Vapor pressure or potential volatility is greatly affected by the interactions with soil. Adsorption of DDT depends upon its concentration in soil, soil water content and soil properties (Spencer, 1970). Guenzi and Beard (1970) reported that the initial DDT volatilization rate was inversely related to soil organic matter content.

The o,p' and p,p' isomers of DDT, DDD, and DDE are generally only slightly soluble in water (Bowman et al., 1960). As a result they tend to accumulate at either air-water or soil-water interfaces. This tendency results in an accelerated volatilization of DDTR from such systems. This tendency, however, is offset by adsorption of DDTR to soil and colloidal materials. Bailey and White (1964 and 1970) and White and Mortland (1970) observed that soil or colloid type, temperature, nature of the cation on the exchange sites and the nature of the DDT formulation all directly influence adsorption.

In water-DDT systems, water and DDT vaporized independently of each other by diffusion (Hartley, 1969; Hanaker, 1972; Spencer et al., 1973). DDT exhibits a high affinity for concentrating at the water-air interface (Bowman, et al., 1959, 1964 and Acree et al., 1963). This enhanced volatilization was termed co-distillation (Acree et al., 1963).

Losses by volatilization from soil will depend on pesticide concentration and vapor density relationships at the soil surface. [Guenzi and Beard (1970) reported that the initial DDT volatilization rate was inversely related to soil organic matter content.] Volatilization rate decreases rapidly, however, as the concentration at the soil surface drops and, thereafter, becomes dependent upon the rate of movement of the pesticide to the soil surface (Spencer, 1920; Spencer and Cliath, 1973; Farmer et al., 1972 and 1973). Vapor pressure of pesticides at the soil surface is a major factor influencing volatilization rate. The vapor pressure of DDT in soil increases greatly with increased DDT concentration and temperature but decreases substantially when the soil water content decreases below one molecular layer of water (Spencer and Cliath, 1972). Further, the soil water content markedly influences the vapor pressure. Spencer and Cliath (1972) reported the relative vapor pressure of DDT in Gila silt loam was 21 times greater at 7.5 percent than at 2.2 percent soil water content.

Spencer and Cliath (1972) reported the relative vapor pressure and volatibility of DDTR (see Table I-2).

Table I-2. Saturation Vapor Densities and Apparent Vapor Pressures of DDT and Related Compounds at 30°C

Chemical	Vapor Density (ng/L)	Vapor Pressure[1] (mm Hg x 10^{-7})
p,p'-DDT	13.6	7.26
o,p'-DDT	104	55.3
p,p'-DDE	109	64.9
p,p'-DDD	17.2	10.2
o,p'-DDE	(104)[2]	(61.6)[2]
o,p'-DDD	(31.9)[3]	(18.9)[3]

[1] Calculated from vapor density, w/v, with the equation: $P = w/v \cdot RT/M$.

[2] Atmosphere probably not saturated with o,p'-DDE. DDE in sand column was mainly p,p'-DDE.

[3] Atmosphere probably not saturated with o,p'=DDD. The sand column was prepared with p,p'-DDD, which contained sufficient o,p'-DDD as an impurity to produce this vapor density.

Source: Spencer and Cliath, 1972.

The composition of vapor at 30°C in equilibrium with technical DDT applied to silica sand, a non-adsorbing surface, at a rate of 1-2 percent is listed in Table I-3 (Spencer and Cliath, 1972).

Table I-4 presents the vapor densities of DDTR and the percentage of the total vapor made up of each constituent as related to application rate of technical DDT to Gila silt loam.

Little information is available regarding volatilization from plant surfaces. One would assume vapor percentages would be similar to those presented in Table I-4 until only p,p'-DDT remained.

Actual estimates of volatilization from soils have rarely been made utilizing field conditions. Spencer (1975) did estimate a rate of 5 to 10 kg/ha/year for surface residues of DDT in the temperature range of 25-30°C based on available published laboratory data. Soil incorporated residues would volatilize at a much lower rate.

A study by Ware _et al_. (1977) measured DDTR loss from soil by volatilization over a one year period from a desert plot and over 76 days from a cultivated cotton field. The desert area lost 80 percent over 12 months while the irrigated, cultivated cotton plot only lost 20 percent during the 76 day period. These estimates are indicative of the range of loss rates under a variety of field conditions.

3.4 PERSISTENCE IN SOIL

A number of investigators have estimated the persistence of DDT in soils (see Table I-5 for a compilation). These estimates range from less than a year to some 30 years. It is difficult to predict degradation rates since many factors influence persistence. These factors include soil type, organic matter content (Liebtenstein and Schulz, 1959; Liebtenstein _et al_., 1960; Bowman _et al_., 1965) moisture level, pH, temperature, cultivation, mode of application and soil organisms (Lichtenstein, 1965).

3.5 WATER SOLUBILITY

The solubility of DDT in water is reported to 1.2 parts per billion (ppb)(Bowman _et al_., 1960; Harris, 1970). Gunther _et al_. (1968) noted, however, that natural waters contain salts, colloidal materials and suspended particulate matter which may increase the apparent solubility of DDT.

4.0 DDT DEGRADATION IN THE ENVIRONMENT

In order to describe the degradation of DDT in the environment, the subject will be broken down into several subsections for review. An overall metabolic pathway is shown in Figure I-2 in an effort to describe the picture concisely.

Table I-3. Vapor Composition in Association with Technical DDT at 30°C

Chemical	Vapor Density ng/L	Vapor Density % of Total	Conc. in Tech DDT (%)
p,p'-DDT	13.6	8.0	74.6
o,p'-DDT	104	61.7	21.1
p,p'-DDE	24.1	14.3	0.81
o,p'-DDE	26.9	16.0	0.07
TOTAL	168.6	----	----

Source: Spencer and Cliath, 1972.

Table I-4. Vapor Density of p,p'-DDT, o,p'-DDT, p,p'-DDE, and o,p'-DDE as Related to Concentration of Technical DDT in Gila Silt Loam at 7.5 Percent Water Content and 30°C

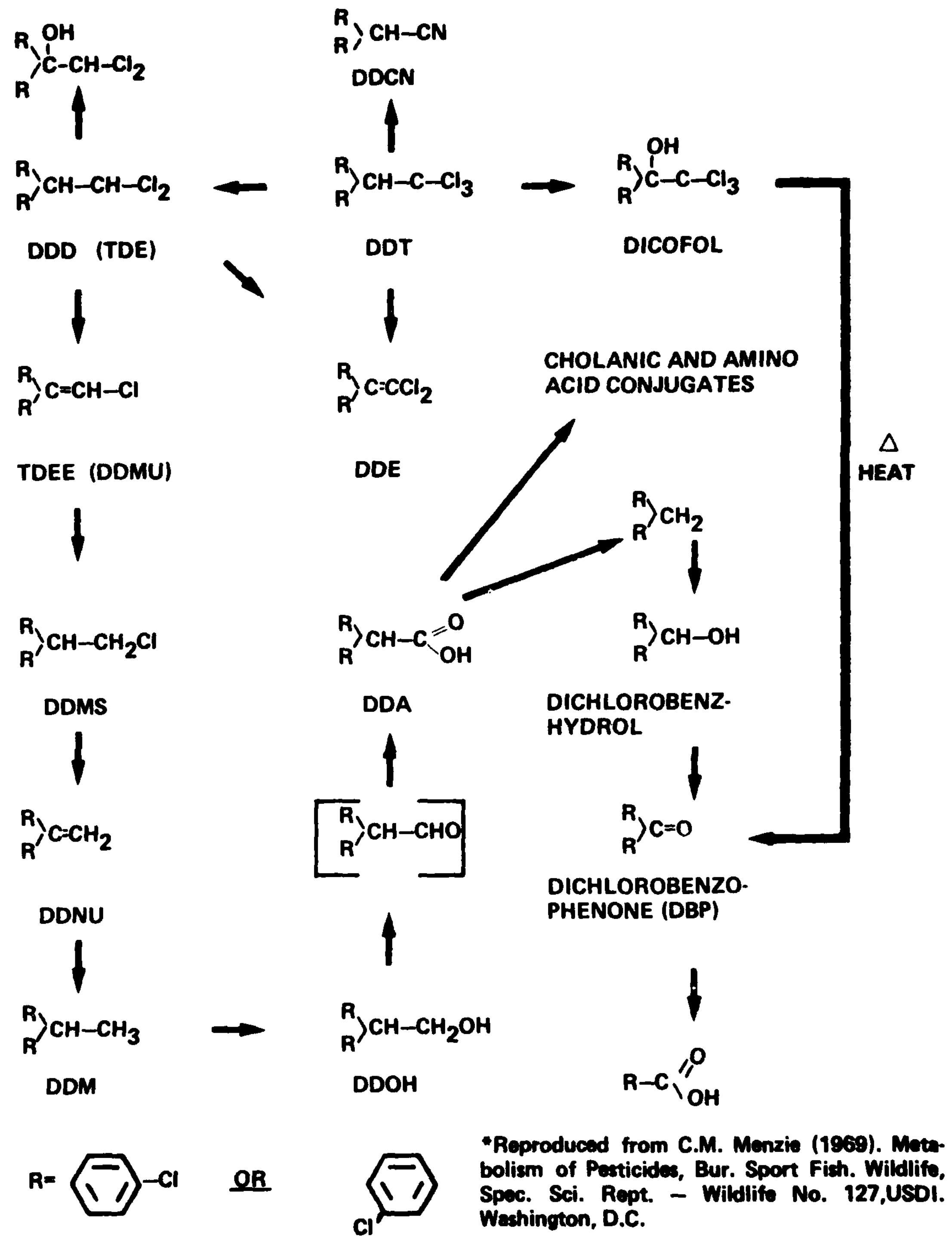
Tech. DDT[1] Conc. (μg/g)	Vapor Density (ng/L)					Vapor Density (% of Total)			
	p,p'-DDT	o,p'-DDT	p,p' DDE	o,p' DDE	Total	p,p'-DDT	o,p'-DDT	p,p'-DDE	o,p'-DDE
2.5	1.11	1.16	0.43	---	2.70	41.1	43.0	15.9	---
5	2.65	2.22	0.60	---	5.47	48.4	40.6	11.0	---
10	6.07	5.26	1.08	---	12.41	48.9	42.4	8.7	---
20	13.95	11.92	2.94	0.45	29.26	47.8	40.7	10	1.5
40	12.11	21.40	3.03	0.70	37.24	32.5	57.5	8.1	1.9
60	13.37	32.74	3.42	0.97	50.50	26.5	64.8	6.8	1.9
120	13.62	67.0	5.41	1.64	87.67	15.5	76.4	6.2	1.9

[1] Technical DDT containing 74.6 percent p,p'-DDT, 21.1 percent o,p'-DDT, 0.81 percent p,p'-DDE and 0.07 percent o,p'-DDE.

Source: Spencer and Cliath, 1972.

Table I-5. Estimates of Half Lives and/or Disappearance Rates from Soil

Estimate	Reference
16 years	Kiigemagi and Terriere (1972)
10% remained after 15 years	Lichtenstein *et al*. (1971)
0.9 years pH=4 laboratory conditions	
11.3 years pH=6.5 DDT + DDE	Ekstedt (1975/76)
3-10 years	Menzie (1972)
10 years	Yule (1973)
2-15 years	Martin (1966)
2-4 years	Metcalf and Pitts (1969)
39% remained after 17 years	Nash and Woolson (1967)
4-30 years (mean of 10 years) to eliminate 95% of applied	Edwards (1966)
30 year persistence	Dimond *et al*. (1970)
<1 year for surface deposits	
10+ years if incorporated 6-8" into soil	Freed (1970)
15 years	Chisholm and MacPhee (1972)
7 hours (anaerobic sewage sludge)	Jensen *et al*.



*Reproduced from C.M. Menzie (1969). Metabolism of Pesticides, Bur. Sport Fish. Wildlife, Spec. Sci. Rept. – Wildlife No. 127,USDI. Washington, D.C.

FIGURE I-2. Metabolic Pathway for DDT*

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Wheeler Reservoir, Alabama

4.1 DEGRADATION IN SOILS UNDER AEROBIC CONDITIONS

Commercial DDT consists of a mixture of about 84 percent p,p'-DDT and 15 percent o,p'-DDT (Lichtenstein et al., 1971). The major part of the following discussion will be in regard to the p,p'-DDT.

Many investigators have reported the degradation of DDT in a variety of soils and/or pseudo soils. p,p'-DDT is readily dehydrochlorinated to give the major decomposition product, p,p'-DDE (Baker and Applegate, 1970; Castro and Yoshida, 1971; Lichtenstein et al., 1971; Kuhr et al., 1972; Smith and Parr, 1972; Cliath and Spencer, 1972; Kiigemagi and Terriere, 1972; Frank et al., 1974a; Guenzi and Beard, 1976; Ekstedt, 1975/76; Johnsen, 1976) under aerobic conditions. The o,p'-DDT degrades to the corresponding o,p'-DDE isomer.

Other degradation products have also been reported. DDD (Kiigemagi and Terriere, 1972; Frank et al., 1974a), DBP (Kiigemagi and Terriere, 1972) and dicofol (Lichtenstein et al., 1971; Kiigemagi and Terriere, 1972) have been detected in a few instances. These derivatives were not detected in the bulk of the literature. If they were reported, usually trace quantities (Lichtenstein et al., 1971) were measured. The work of Kiigemagi and Terriere (1972), however, revealed relatively high levels of DDD and dicofol. Although dicofol per se had been applied, these authors suggested its presence might have been partially as a result of DDT degradation in orchard soils.

Other reports (Smith and Parr, 1972; Guenzi and Beard, 1976) have discussed the effects of temperature, soil water and pH on DDT stability. Guenzi and Beard (1976) reported that DDT degraded to DDE at increased rates at higher temperatures. When DDT was mixed with Raber silty clay loam at a rate of 10 ppm and incubated at various temperatures for 140 days, the following percentage conversions were detected:

Temp., °C	% DDT	% DDE
30	82.1	6.7
40	74.5	12.5
50	53.2	21.6
60	38.3	34.8

No other DDT related chemicals were detected. By comparing these data to data generated using sterilized soil, it was reported that this conversion to DDE was predominantly a chemical process (84 percent at 30° and 91 percent at 60°) rather than a biological process. Rates of DDE formation in sterile soil containing 1/3 bar moisture were much higher than in air dry soil.

Smith and Parr (1972) reported that DDT was stable in soil treated with anhydrous ammonia (pH >10). They further indicated that the threshold pH for dehydrochlorination of DDT to DDE in a model system using microbeads was 12.5 with extensive conversion at 13.0.

Ekstedt (1975/76) reported a higher retention of DDT and DDE in soils of pH 6.0-6.6 than in soils of lower pH (3.6-5.3). The higher pH soils averaged 94 percent of the original DDT applied 17 weeks after addition, compared to 79 percent DDT in the more acidic soils. The more acidic soil possessed less DDE as well. Soil type did not appear to influence these results.

Johnson (1976) has reviewed the subject in depth and the reader is referred to this article for further details.

4.2 DEGRADATION IN SOILS UNDER ANAEROBIC CONDITIONS

The degradation of DDT under anaerobic conditions is well-documented. Prior to work in soil systems a number of reports appearing in the late 1960's (cited by Parr *et al.*, 1970) indicated a more rapid degradation of DDT in anaerobic *microbial* systems than in aerobic systems.

Parr et al. (1970) incubated DDT in glucose-fortified, moist (1/3 bar) Crowley silt loam and Arch loamy fine sand either aerobically in CO_2-free air or anaerobically in Ar, N_2, and N_2+CO_2 (80:20). DDT degradation followed the order Ar > N_2 > N_2+CO_2 (80:20) > CO_2-free air. The major product of degradation was DDD and to a lesser extent DDE. While flooding of the Crowley soil provided an anaerobic environment it only led to 41 percent DDT degradation while moist soil incubated in N_2 or Ar resulted in 98 percent degradation. These authors also cautioned against using laboratory data as a predictor of field degradation.

Burge (1971) demonstrated that glucose or ground alfalfa added to soil accelerated the anaerobic disappearance of DDT. This investigation reported further that addition of a steam distillate from alfalfa will also increase anaerobic DDT disappearance. When volatile components of the steam distillate were compared with glucose, the following order of effectiveness was found: acetaldehyde = isobutyraldehyde > ethanol > glucose >> methanol. The anaerobic disappearance of DDT was inhibited by autoclaving the soil but could be re-established by innoculating the autoclaved soil with viable soil. DDT was converted to DDD although considerable DDT disappeared from the system and could not be accounted for. Burge (1971) indicated that neither DDD nor DDE were lost from his experimental system and thus DDT must be disappearing by some other mechanism.

Castro and Yoshida (1971) reported the degradation of DDT in Philippine soils. They compared aerobic and anaerobic conditions in several soil types. Both DDT and DDD were degraded much more rapidly under flooded (anaerobic) conditions than under aerobic conditions and in soils with high organic matter content. DDD accumulated in flooded soils and no other DDT related components were detected. The authors stated that DDD was more stable than DDT under these conditions but that after 6 months, even the DDD residue had declined substantially. Castro and Yoshida (1971) pointed out, after comparing sterilized and non-sterilized soils that losses through volatilization are small when compared to losses through microbial degradation.

Smith and Parr (1972) described the chemical stability of DDD under selected alkaline conditions. DDD remained stable for extended periods of time at pH=10 but it was rapidly converted to DDM at pH=13 and then disappeared with time.

Parr and Smith (1974) reported the relatively slow degradation of DDT under moist anaerobic and flooded anaerobic conditions in an Everglades muck soil amended with alfalfa meal. DDT degradation was increased in the flooded anaerobic environment subjected to continuous stirring. The authors suggested that the lack of substantial degradation might be the result of: (1) the adsorption of DDT so that it was unavailable for microbial or chemical degradation; and/or (2) the lack of organisms capable of degrading DDT.

Castro and Yoshida (1974) reported that both organic matter and the nature of its constituents influence the anaerobic biodegradation of DDT to DDD. They demonstrated that the process was microbial rather than chemical and that degradation was stimulated by the addition of several organic matter amendments. The kind of organic matter was only important to degradation in certain soil types and not in all.

Guenzi and Beard (1976a) incubated Raber silt loam contaminated with 10 ppm DDT under anaerobic conditions at various temperatures. Results after 7 days of incubation are summarized below:

Temp.	% DDT	% DDD	% DDE
30	80.0	12.34	0.8
40	63.6	19.5	2.1
50	44.2	38.8	3.4
60	9.8	43.6	4.1

The anaerobic degradation pathway was DDT → DDD → DDMU. Only minor amounts of DDE were formed and they remained stable throughout the study.

4.3 DEGRADATION BY SEWAGE SLUDGE

In late 1972 a previously unreported metabolite of DDT was reported by two research groups (Albone et al., 1972a; Jensen et al., 1972). Both groups incubated DDT in biologically active anaerobic sewage sludge. In addition to detecting DDD, DBP, DDMU, the formation of DDCN was confirmed. Neither group could speculate on whether the mechanism of formation was chemical or biological.

4.4 DEGRADATION IN SEDIMENTS

Albone et al. (1972) evaluated the fate of DDT in Severn River Estuary sediments. In situ sediments having a temperature range of 5-25°C caused less DDT degradation than did incubating the same sediment under water in the laboratory at 25°C. The same degradation products, mainly DDD, were detected in both systems. These authors reported evidence that another metabolite, DDA, was present but were unable to confirm its presence.

4.5 DEGRADATION BY SPECIFIC MICROBIAL POPULATIONS

The metabolism of DDT by microorganisms has been investigated by a number of researchers. Patil et al., (1970) reported that 20 microbial cultures which had been shown to degrade dieldrin were also able to degrade DDT. These organisms were incubated in stationary test tubes at 30°C for 30 days. Ten of the bacterial isolates degraded DDT to a dicofol-like compound; 14 of the isolates degraded DDT to DDA and possibly other acidic materials. None of the cultures produced DDE. Perhaps even more surprising was the formation of DDD by 17 of the isolates all under aerobic conditions.

Pfaender and Alexander (1972) examined the ability of extracts of Hydrogenomonas sp. cells to degrade DDT. Cell-free extracts (5 mg protein/ml) were incubated in 30 ml of 0.1 M phosphate buffer at pH 7.0 for 4 days at 30°C under a nitrogen atmosphere. DDT was converted to DDD, DDMS, DBP, and DDE under these anaerobic conditions. p-Chlorophenylacetic acid was isolated after adding whole cells and oxygen; this result indicated phenyl ring cleavage. These authors also demonstrated that a strain of Arthrobacter could grow on p-chlorophenylacetic acid converting it to p-chlorophenylglycoaldehyde. These studies reveal the possible extensive degradation of DDT under the proper conditions.

4.6 DEGRADATION BY FUNGI

The degradation of DDT by fungi has been reported (Anderson et al., 1970; Focht, 1972). Anderson et al. (1970) isolated several fungi from an agricultural loam soil and found that Mucor alternans partially degraded DDT in a period of two to four days. Shake cultures of M. alternans degraded DDT into three hexane-soluble and two water-soluble metabolites, none of which were identified at the time. These compounds were not DDD, DDE, DDA, DBP, of dicofol, or DDMS. Attempts to demonstrate this DDT degrading capacity in field soils, however, were fruitless.

Focht (1972) described the isolation of a fungus capable of degrading DDT metabolites to CO_2, water and chloride. The isolate was a hyaline Moniliceae fungus. Incubation of this organism with DDM resulted in growth of the fungus and the breakdown of DDM to CO_2, H_2O, and HCl. It was pointed out that the complete degradation of DDT occurred only under nearly optimal conditions.

4.7 DEGRADATION BY ALGAE

DDT degradation by algae has been studied in both marine (Keil and Priester, 1969; Patil et al., 1972; Bowes, 1972; Rice and Sikka, 1973) and fresh water forms (Moore and Dorward, 1968; Miyazaki and Thorsteinson, 1972).

Patil et al. (1972) used several unidentified marine cultures and detected DDD as a major organic soluble metabolite after incubation with ^{14}C-DDT. Smaller quantities of DDE, DDMS and DDOH were also detected. In certain instances, much of the radioactivity remained in the aqueous phase after chloroform extraction. These components were not identified.

Bowes (1972) and Rice and Sikka (1973) found considerable variation in the ability of seven marine algae to degrade DDT. DDE was the only organic soluble product detected.

Information regarding fresh water forms is sparse. Miyazaki and Thosteinson (1972) detected DDE as the only metabolic product of fresh water diatoms, Nitzschia sp.

4.8 DEGRADATION BY A SOIL AMOEBA

A soil borne amoeba has also been shown to degrade DDT. Pollero and dePollero (1978) reported that pure cultures of Acanthamoeba castellanii, incubated with 5 ppm DDT at 24°C for three weeks resulted in the formation of DDE, DDD and DBP. No water soluble materials were reported.

4.9 DEGRADATION AS CATALYZED BY METALS

The relationship between DDT degradation and iron redox systems in soils has been described (Glass, 1972; Parr and Smith, 1974; Ekstadt, 1975/76). Glass (1972) incubated 200 ppm DDT in four water-logged, urease amended soils varying in organic matter and free iron contents at 35°C for 3 to 28 days. The rates of DDT degradation were related to the rates of formation of ferrous iron in urease amended soils and DDT degradation was more rapid in soils with lower redox potentials. Twenty percent of DDT was converted to DDD in a 7-day period using an in vitro iron redox system. A mechanism was proposed whereby electrons from reduced organic substrates are transferred to DDT via Fe^{+2} ions thus initiating a free radical reaction in the absence of oxygen.

Parr and Smith (1974) arrived at the same conclusion using a flooded Everglades muck amended with alfalfa meal and ferrous iron.

Ekstedt (1975/76) utilized pure iron oxyhydroxide and manganese dioxide in aqueous solutions to determine if either of these materials would degrade DDT. Manganese dioxide had no effect even after 10 weeks but iron oxyhydroxide rapidly converted DDT to DDE. Fifty percent of the DDT was gone in less than one week.

Lopez-Gonzales et al. (1975) have shown that certain metals in pure systems can catalyse the decomposition of DDT.

Lopez-Gonzales and Valenzuela-Calahorra (1970) reported that DDT adsorbed onto homoionic clays could be catalytically converted to DDE. This reaction was affected by the clay mineral type and the nature of exchangeable cations.

5.0 DDT TOXICITY

The persistent nature of many organochlorine pesticides present difficult problems to natural ecosystems. The more complex an ecosystem, the greater resistance it has to change. If change were to occur, it would most likely be manifested as a decrease of the biological diversity. Conversely, a simple ecosystem is quite susceptible to change and small changes at times can bring about catastrophic effects.

Pollutants have a general tendency to simplify a community. Stickel (1975) has noted that several general effects are noted from such environmental pollution:

1) Broadly adapted species flourish, while narrowly adapted species are often eliminated.

2) Due to their place in the food chain, carnivores are often the first to suffer.

3) Within a genus, species differences in susceptibility often cause major shifts in population makeup within the ecosystem.

4) Many common pollutants may be mutagenic.

5) In those animals carrying lipophilic pollutants, the concentration of pollutants may vary according to the rise and fall of body lipids.

6) Behavioral changes can be caused by relatively small concentrations of pollutants.

Stickel (1968) also reported the effect in higher animals of organochlorines upon the stimulation of hormonal breakdown, involvement in embryonic and early post-embryonic toxicity, interference with antibody formation and interaction with various stress conditions such as nutritional deficiencies and food deprivation of various animals.

5.1 BIOCONCENTRATION

DDT and similar organochlorines are chemically stable, lipid soluble materials and are known to bioaccumulate. If they are present in aqueous solutions at levels of one part per trillion (ppt) to one part per billion (ppb) they will be present in the higher trophic organisms in the part per million (ppm) range. This represents a biological magnification of 10^3 to 10^6.

It should be noted that levels of biomagnification determined experimentally in the laboratory may not exactly reflect values found in actual field conditions. The reported values do, however, reflect accurate orders of magnitude and ranges. For example, Lake Michigan was reported to contain 1-5 ppt DDT in the water which resulted in predaceous coho salmon accumulating DDT levels of 5 to 10 ppm (Reinert, 1970). Factors affecting rates and extent of biomagnification are numerous and include: water composition, temperature, how the organism is exposed, as well as the age and size of the organism. Most of the factors affecting bioaccumulation also affect toxicity to aquatic organisms and are discussed in more detail in the next section.

Some examples of biomagnification in various aquatic organisms have been reported by Sodergren and Svensson (1973), Johnson et al., (1971), Yadav et al., (1978), Bedford and Zabik (1973) and Macek and Korn (1970). An extensive listing of bioconcentration factors taken from EPA's "Ambient Water Quality Criteria" for DDT may be found in Table I-6.

Sodergren and Svensson (1973) evaluated the kinetics of uptake of DDT and degradation in nymphs of the mayfly Ephemera danica. Using a continuous flow system for DDT exposure, a maximum and constant DDT level in the nymphs was reached after 4 to 5 days exposure. This indicates that an equilibrium between uptake and excretion had been established. The magnification factor (ratio of DDT concentration in organisms to DDT concentration in water) from 4 to 9 days exposure was on the order of $3x10^3$ for DDT + DDE + DDD, and the kinetics of uptake appeared to fit a first order rate equation. DDE was the major DDT metabolite found in most of the organisms.

Biomagnification and degradation of DDT in freshwater invertebrates was studied by Johnson et al. (1971), also using a continuous flow apparatus. Table I-7 shows the organisms studied and the biomagnification factor after 1, 2, and 3 days exposure to approximately 100 ppt DDT in the water. Rate of uptake was very rapid with the Cladoceran, Daphnia magna, and the mosquito larvae, Culex pipiens, exhibiting the greatest degree of biomagnification and having residue levels over 100,000 times that present in the water. No maximum accumulation level was reported in any species. Again the major DDT metabolite was DDE (see Table I-8) and in the mayfly nymph, Hexagenia bilineata, 85 percent of the residue was DDE.

Yadav et al. (1978) reported the uptake, degradation and excretion of DDT in the freshwater snail, Vivipara heliciformis. Aquaria maintained under static conditions were used to expose snails to three DDT concentrations, 0.005, 0.01 and 0.05 ppm resulting in biomagnification factors of 300, 325 and 76, respectively. DDE and DDD were the major metabolites, with slightly higher levels of DDE than DDD in the 0.005 ppm treated snails, while DDD was the major metabolite in the 0.01 and 0.05 ppm treated snails. Snails from the 0.05 ppm aquaria excreted 94 percent of the accumulated DDT in 9 days when transferred to "clean" water. It should be noted here that DDT concentrations exceeded the water solubility. Under these conditions some of the DDT may have precipitated out of solution or would possibly be present in suspension. Although the organisms would still be exposed to DDT the conditions are not the same as they would be if DDT were in solution.

Table I-6. Bioconcentration Factors for DDT and Metabolites

Organism	Bioconcentration Factor	Time (days)	Reference
Coontail, Ceratophyllum demersum	1,950	30	Eberhardt, et al. 1971
Cladophora, Cladophora, sp.	21,580	30	Eberhardt, et al. 1971
Duckweed, Lemna minor	1,210	30	Eberhardt, et al. 1971
Water milfoil, Myriophyllum sp.	1,870	30	Eberhardt, et al. 1971
Curly leaf pondweed, Potamogeton cripus	14,280	30	Eberhardt, et al. 1971
Narrow-leaf pondweed, Potamogeton foliosus	781	30	Eberhardt, et al. 1971
Sago pondweed, Potamogeton pectinatus	6,360	30	Eberhardt, et al. 1971
Soft stem bulrush, Scirpus validus	495	30	Eberhardt, et al. 1971
Bur reed, Sparganium eurycarpum	623	30	Eberhardt, et al. 1971
Bladderwort, Utricularia vulgaris	2,200	30	Eberhardt, et al. 1971
Mussel, Anodonta grandis	2,400	21	Bedford and Zabik, 1973
Clams (five species composite), Lampsilis siliquoidea Lampsilis ventricosa Lamsmigona costata Fusconaia flava Ligumia recta	12,500	56	Jarvinen, et al. 1977
Cladoceran, Daphnia magna	9,923*	14	Priester, 1965
Zooplankton (mixed), Daphnia sp. Keratella sp.	63,500	21	Hamelink and Waybrant,

Table I-6. Bioconcentration Factors for DDT and Metabolites (Continued, page 2)

Organism	Bioconcentration Factor	Time (days)	Reference
Freshwater prawn, *Palaemonetes paludosus*	7,000	field	Kolipinski *et al*. 1971
Crayfish, *Orconectes punctata*	5,060	30	Eberhardt, *et al*. 1971
Crayfish, *Procambarus alleni*	1,947	field	Kolipinski, *et al*. 1971
Mayfly (nymph), *Ephemera danica*	4,075	5	Sodergren and Svensson, 1973
Dragonfly (nymph), *Tetragoneuria* sp.	2,700	20	Wilkes and Weiss, 1971
Bloodworm, *Tendipes* sp.	4,750	30	Eberhardt, *et al*. 1971
Red Leech, *Erpobdella punctata*	7,520	30	Eberhardt, *et al*. 1971
Alewife, *Alosa pseudoharengus*	1,296,666	field	Reinert, 1970
Lake herring, *Coregonus artedi*	2,236,666	field	Reinert, 1970
Lake whitefish *Coregonus clupeaformis*	260,000	field	Reinert, 1970
Bloater, *Coregonus hoyi*	2,870,000	field	Reinert, 1970
Kiyi *Coregonus kiyi*	4,426,666	field	Reinert, 1970
Cisco, *Coregonus* sp.	368,777	field	Miles and Harris, 1973
Coho salmon, *Oncorhynchus kisutch*	1,563,571	field	Lake Michigan Interstate Pestic. Comm. 1972
Rainbow trout, *Salmo gairdneri* 1976	181,000	108	Hamelink and Waybrant, 1976
Rainbow trout, *Salmo gairdneri*	11,607	field	Miles and Harris, 1973

Table I-6. Bioconcentration Factors for DDT and Metabolites (Continued, page 3)

Organism	Bioconcentration Factor	Time (days)	Reference
Rainbow trout, Salmo gairdneri	38,642	84	Reinert, et al. 1974
Brown trout, Salmo trutta	45,357	field	Miles and Harris, 1973
Lake Trout, Salvelinus namaycush	458,259	field	Miles and Harris, 1973
Lake trout, Salvelinus namaycush	1,168,333	field	Reinert, 1970
Lake trout, Salvelinus namaycush	47,428	152	Reinert and Stone, 1974
American smelt, Osmerus mordax	70,000	field	Reinert, 1970
Carp, Cyprinus carpio	640,000	field	Reinert, 1970
Common shiner (composite) Notropis cornutus Northern redbelly dace, Chrosomus eos	363,000	40	Hamelink, et al. 1971
Fathead minnow, Pimephales promelas	99,000	226	Jarvinen, et al. 1977
White sucker, Catostomus commersoni	110,000	field	Miles and Harris, 1973
White sucker, Catostomus commersoni	96,666	field	Reinert, 1970
Trout-perch, Percopsis omiscomaycus	313,333	field	Reinert, 1970
Flagfish, Jordanella floridiae	14,526	field	Kolipinski, et al. 1971
Mosquitofish Gambusia affinis	21,411	field	Kolipinski, et al. 1971
Rock bass, Ambloplites rupestris	17,500	field	Miles and Harris, 1973
Green sunfish, Lepomis cyanellus	17,500	15	Sanborn, et al. 1975

Table I-6. Bioconcentration Factors for DDT and Metabolites (Continued, page 4)

Organism	Bioconcentration Factor	Time (days)	Reference
Green sunfish (composite), *Lepomis cyanellus* Pumpkinseed, *Lepomis gibbosus*	59,210	80	Hamelink, *et al*. 1971
Bluegill, *Lepomis macrochirus*	110,000	60	Hamelink and Waybrant, 1976
Bluegill, *Lepomis macrochirus*	16,071	field	Miles and Harris, 1973
Largemouth bass (young of year), *Micropterus salmoides*	317,000	40	Hamelink, *et al*. 1971
Yellow perch, *Perca flavescens*	1,073,333	field	Reinert, 1970
Slimy sculpin, *Cottus cognatus*	763,333	field	Reinert, 1970

* Value converted from dry weight to wet weight basis

Average fish bioconcentration factor = 640,000

Lowest permissible tissue concentration = 0.15 mg/kg

$\frac{0.15}{640,000}$ = .00000023 mg/kg or .00023 µg/l

Table I-7. Biological Magnification of ^{14}C-labeled p,p-DDT by Freshwater Invertebrates

				Pesticide Residue (mean value ± SE)				Biological Magnification Factor		
					Total Body (ng/mg)					
Pesticide	Organism	Stage of Development	No./Sample	Water (ng/liter)	1 day	2 days	3 days	1 day	2 days	3 days
DDT	Cladocera									
	Daphnia magna	Mature Adult	60	80.3±13.7	2.04±0.04	5.55±0.31	9.17±0.17	25,400	69,100	114,100
	Amphipoda									
	Gammarus fasciatus	Mature Adult	1	81.3±13.0	0.38±0.04	0.99±0.15	1.68±0.15	4,600	12,100	20,600
	Decapoda									
	Orconectes nais	Mature Adult	1	80.3±13.7	0.071	0.171	0.233	880	2,100	2,900
	Palaemonetes kadiakensis	Mature Adult	1	100.0±0.07	0.152±0.01	0.375±0.02	0.503±0.06	1,500	3,700	5,000
	Ephemeroptera									
	Hexagenia bilineata	Nymph	1	52.1±10.0	0.49±0.04	0.87±0.02	1.68±0.06	9,400	16,700	32,600
	Siphlomurus sp.	Nymph	10	47.0±5.1	0.48	0.94	1.08	10,200	20,000	22,900
	Odonata									
	Ischnura verticalis	Naiad	1	101.3±5.8		0.375±0.02			3,500	
	Libellula sp.	Naiad	1	79.3±4.3		0.072±0.005			910	
	Diptera									
	Chironomus sp.	Larvae	10	46.3±3.5	0.36±0.07	1.13±0.20	2.2±0.21	7,800	24,500	47,800
	Culex pipiens	Larvae	10	104.6±8.8		13.9±0.78			133,600	

Source: Johnson *et al*., 1971.

Table I-8. Degradation of ^{14}C-Labeled p,p'-DDT by Freshwater Invertebrates during 3-Day Exposure in a Continuous-Flow Apparatus

Organism	Stage of Development	No./ Sample	DDT and Degradation Expressed as Percent of Total Body Residue*	
Cladocera	Mature adult	60	DDE	19.7
Daphnia magna			DDT	73.4
			DDD	6.6
Amphipoda	Mature adult	1	DDE	20.9
Gammarus fasciatus			DDT	79.1
Decapoda	Mature adult	1	DDE	13.2
Palaemonetes kadiakensis			DDT	50.9
			DDD	7.2
			DTMC	13.1
			DBP	15.5
Ephemeroptera	Nymph	1	DDE	85.0
Hexagenia bilineata			DDT	14.9
Odonata	Naiad	1	DDE	60.2
Ischnura verticalis			DDT	39.2
Libellula sp.	Naiad	1	DDE	28.4
			DDT	56.3
			DTMC	15.0
Diptera	Larvae	10	DDE	19.1
Chironomus sp.			DDT	80.8

*Note: Data represent the mean value of triplicate samples.

Source: Table from Johnson, *et al*., 1971.

Bedford and Zabik (1973) studied the uptake and loss of DDT in freshwater mussels in lake water and distilled water. The biomagnification factor was 2400 in lake water and 1000 in distilled water after three weeks exposure. The authors concluded that previous conditioning and insecticide body burden can influence the concentration of DDT attained; other factors include the type of water and amount of food available.

Macek and Korn (1970) investigated the significance of bioaccumulation by lower trophic level aquatic organisms in relation to accumulation of DDT by brook trout. Trout were exposed to either feed pellets spiked with 3 ppm DDT, and "clean" water, or unspiked feed and 3 ppt DDT in the water. The 3 ppm DDT in feed resulted in accumulation of 1.92 ppm in the trout after 120 days; exposure to 3 ppt DDT treated water resulted in levels of 25.6 ppb in the trout after 120 days.

In an effort to develop laboratory data which would describe pesticide degradation and ecological magnification, Metcalf et al. (1971) developed a model ecosystem. This ecosystem is composed of a land-water interface and a seven component food chain. It simulates the application of pesticides to croplands and the eventual contamination of the aquatic environment. After application of ^{14}C-DDT at a rate of 1 pound per acre, the radioactive DDT was accumulated in mosquito larvae, snails and fish as DDE, DDD, and DDT and concentrated from 10,000- to 100,000-fold. ^{14}C-DDE introduced into the system was concentrated by a factor of 30,000-50,000 and stored with little metabolism.

Numerous papers have described the contamination of a variety of organisms with DDT when residues of the insecticide were present in water, sediments and soils. A few such papers (Miles and Harris, 1978; Frank et al. 1974) describe biomagnification in aqueous systems; another several papers discuss uptake of DDT from soil by earthworms (Davis, 1971; Edwards and Jeffs, 1974; Bailey et al. 1974; Davis and French, 1969; Gish, 1970) and various other soil inhabitants (Bailey et al. 1974; Davis and French, 1969; Gish, 1970). Numbers of other papers which will be discussed in a later section describe the presence of DDT in higher vertebrates, particularly the fishing birds. Birds such as the eagle, various falcons and the pelican are at top of the food chain and receive the highest doses of DDT as a direct result of the bioaccumulation. It is well known that these fishing birds have experienced reproductive failures and their numbers significantly dropped during a period some years ago.

Many similarities exist among the factors which affect bioaccumulation and toxicity of DDT toward aquatic invertebrate and vertebrate populations. Both bioaccumulation and relative (acute) toxicity are well documented in the literature and have been intensively reviewed. Emphasis here will be placed on factors affecting these parameters and presentation of a representative sample of specific papers concerning toxicity in a variety of aquatic organisms. Extensive listings of toxicity data for invertebrate organisms and fish, taken from EPA's "Ambient Water Quality Criteria" for DDT may be found in Tables I-9 and I-10.

Table I-9. Freshwater Invertebrate Acute Toxicity Values for DDT and Metabolites

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Cladoceran, <u>Daphnia magna</u>	S	U	DDT	26	5.5	4.66	Crosby, <u>et al</u>., 1966
Cladoceran, <u>Daphnia magna</u>	S	U	DDT	48	4	3.39	Macek and Sanders, 1970
Cladoceran, <u>Daphnia magna</u>	S	U	DDT	48	1.48	1.25	Priester, 1965
Cladoceran, <u>Daphnia pulex</u>	S	U	DDT	48	0.36	0.30	Sanders and Cope, 1966
Cladoceran, <u>Daphnia pulex</u>	S	U	TDE	48	3.2	2.71	Sanders and Cope, 1966
Cladoceran, <u>Simocephalus serrulatus</u>	S	U	DDT	48	2.5	2.12	Sanders and Cope, 1966
Cladoceran, <u>Simocephalus serrulatus</u>	S	U	DDT	48	2.8	2.37	Sanders and Cope, 1966
Cladoceran, <u>Simocephalus serrulatus</u>	S	U	TDE	48	4.5	3.81	Sanders and Cope, 1966
Cladoceran, <u>Simocephalus serrulatus</u>	S	U	TDE	48	5.2	4.40	Sanders and Cope, 1966

Table I-9. Freshwater Invertebrate Acute Toxicity Values for DDT and Metabolites (Continued, Page 2)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Sowbug, *Asellus brevicaudus*	S	U	DDT	48	4.7	1.71	Macek and Sanders, 1970
Sowbug, *Asellus brevicaudus*	S	U	DDT	96	4	3.39	Sanders, 1972
Sowbug, *Asellus brevicaudus*	S	U	TDE	96	10	8.47	Sanders, 1972
Scud, *Gammarus fasciatus*	S	U	DDT	48	3.6	1.31	Macek and Sanders, 1970
Scud, *Gammarus fasciatus*	S	U	DDT	96	3.2	2.71	Sanders, 1972
Scud, *Gammarus fasciatus*	FT	U	DDT	96	0.8	0.62	Sanders, 1972
Scud, *Gammarus fasciatus*	S	U	DDT	96	1.8	1.52	Sanders, 1972
Scud, *Gammarus fasciatus*	S	U	TDE	96	0.6	0.51	Sanders, 1972
Scud, *Gammarus fasciatus*	S	U	TDE	96	0.86	0.73	Sanders, 1972

Table I-9. Freshwater Invertebrate Acute Toxicity Values for DDT and Metabolites (Continued, Page 3)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Scud, *Gammarus lacustris*	S	U	DDT	96	9	7.62	Gaufin, *et al.*, 1965
Scud, *Gammarus lacustris*	S	U	DDT	96	1	0.85	Sanders, 1969
Scud, *Gammarus lacustris*	S	U	TDE	96	0.64	0.54	Sanders, 1969
Seed shrimp, *Cypridopsis vidua*	S	U	DDT	48	54	19.67	Macek and Sanders, 1970
Glass shrimp, *Palaemonetes kadiakensis*	S	U	DDT	48	4.2	1.53	Macek and Sanders, 1970
Glass shrimp, *Palaemonetes kadiakensis*	S	U	DDT	96	2.3	1.95	Sanders, 1972
Glass shrimp, *Palaemonetes kadiakensis*	FT	U	DDT	96	3.5	2.70	Sanders, 1972
Glass shrimp, *Palaemonetes kadiakensis*	S	U	TDE	96	0.68	0.58	Sanders, 1972
Crayfish, *Orconectes nais*	S	U	DDT	96	100	84.70	Sanders, 1972

Table I-9. Freshwater Invertebrate Acute Toxicity Values for DDT and Metabolites (Continued, Page 4)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Crayfish (1-day-old), *Orconectes nais*	S	U	DDT	96	0.30	0.25	Sanders, 1972
Crayfish (1-wk-old), *Orconectes nais*	S	U	DDT	96	0.18	0.15	Sanders, 1972
Crayfish, (2-wk-old), *Orconectes nais*	S	U	DDT	96	0.20	0.17	Sanders, 1972
Crayfish (3-wk-old), *Orconectes nais*	S	U	DDT	96	0.24	0.20	Sanders, 1972
Crayfish (5-wk-old), *Orconectes nais*	S	U	DDT	96	0.90	0.76	Sanders, 1972
Crayfish (8-wk-old), *Orconectes nais*	S	U	DDT	96	28	23.72	Sanders, 1972
Crayfish (10-wk-old), *Orconectes nais*	S	U	DDT	96	30	25.41	Sanders, 1972
Crayfish, *Procambarus acutus*	S	U	DDT	48	3	1.09	Albaugh, 1972
Mayfly, *Ephemerella grandis*	S	U	DDT	96	25	21.18	Gaufin, *et al.*, 1965

Table I-9. Freshwater Invertebrate Acute Toxicity Values for DDT and Metabolites (Continued, Page 5)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Stonefly, *Acroneuria pacifica*	S	U	DDT	96	410	347.27	Gaufin, *et al*., 1965
Stonefly, *Acroneuria pacifica*	S	U	DDT	96	320	271.04	Gaufin, *et al*., 1965
Stonefly *Claassenia sabulosa*	S	U	DDT	96	3.5	2.96	Sanders and Cope, 1966
Stonefly, *Pteronarcella badia*	S	U	DDT	96	1.9	1.61	Sanders and Cope, 1966
Stonefly, *Pteronarcys californica*	S	U	DDT	96	1,800	1,524.60	Gaufin, *et al*., 1965
Stonefly, *Pteronarcys californica*	S	U	DDT	96	7	5.93	Sanders and Cope, 1966
Stonefly, *Pteronarcys californica*	S	U	TDE	96	380	321.86	Sanders and Cope, 1966
Stonefly, *Pteronarcys californica*	S	U	DDT	96	560	474.32	Gaufin, *et al*., 1965
Damselfly, *Ischnura verticalis*	S	U	DDT	48	22.5	8.19	Macek and Sanders, 1970

Table I-9. Freshwater Invertebrate Acute Toxicity Values for DDT and Metabolites
(*Continued, Page 6*)

Caddisfly, *Arctopsyche grandis*	S	U	DDT	96	175	148.23	Gaufin, *et al*., 1965
Caddisfly, *Hydropsyche californica*	S	U	DDT	96	48	40.66	Gaufin, *et al*., 1965
Planarian, *Polycelis felina*	S	U	DDT	96	1,230	1,041.81	Kouyoumjian and Uglow, 1974
Planarian, *Polycelis felina*	S	U	DDE	96	1,050	889.35	Kouyoumjian and Uglow, 1974
Planarian, *Polycelis felina*	S	U	TDE	96	740	626.78	Kouyoumjian and Uglow, 1974

Notes: * S = static, FT = flow-through

**U = unmeasured

Geometric mean of adjusted values = 8.57 µg/l $\frac{0.57}{21}$ = 0.41 µg/l

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Coho salmon, *Oncorhynchus kisutch*	S	U	DDT	96	44	24.05	Katz, 1961
Coho salmon, *Oncorhynchus kisutch*	S	U	DDT	96	4	2.19	Macek and McAllister, 1970
Coho salmon, *Oncorhynchus kisutch*	S	U	DDT	96	11.3	6.18	Post and Schroeder, 1971
Coho salmon, *Oncorhynchus kisutch*	S	U	DDT	96	18.5	10.11	Post and Schroeder, 1971
Coho salmon, *Oncorhynchus kisutch*	S	U	DDT	96	13	7.11	Schaumburg, *et al*., 1967
Chinook salmon, *Oncorhynchus tshawytscha*	S	U	DDT	96	11.5	6.29	Katz, 1961
Cutthroat trout, *Salmo clarki*	S	U	DDT	96	0.85	0.46	Post and Schroeder, 1971
Cutthroat trout, *Salmo clarki*	S	U	DDT	96	1.37	0.75	Post and Schroeder, 1971
Rainbow trout, *Salmo gairdneri*	S	U	DDT	96	42	22.96	Katz, 1961

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 2)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	7	3.83	Macek α McAllister, 1970
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	7.2	3.94	Macek α Sanders, 1970
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	14	7.65	Marking, 1966
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	4.6	2.51	Marking, 1966
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	7.2	3.94	Marking, 1966
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	15	8.20	Marking, 1966
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	17	9.29	Marking, 1966
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	13	7.11	Marking, 1966
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>	S	U	DDT	96	12	6.56	Marking, 1966

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 3)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Rainbow trout, Salmo gairdneri	S	U	DDT	96	2.4	1.31	Marking, 1966
Rainbow trout, Salmo gairdneri	S	U	DDT	96	1.7	0.93	Post and Schroeder, 1971
Rainbow trout (fry), Salmo gairdneri	FT	U	DDT	96	2.4	1.85	Tooby, et al., 1975
Brown trout (alevin), Salmo trutta	FT	U	DDT	48	2.5	1.56	Alabaster, 1969
Brown trout (fingerling), Salmo trutta	S	U	DDT	96	17.5	9.57	King, 1962
Brown trout, Salmo trutta	S	U	DDT	96	2	1.09	Macek and McAllister, 1970
Brown trout, Salmo trutta	S	U	DDT	96	10.9	5.96	Marking, 1966
Brook trout, Salvelinus fontinalis	S	U	DDT	96	7.2	3.94	Marking, 1966
Brook trout, Salvelinus fontinalis	S	U	DDT	96	17	9.29	Marking, 1966

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 4)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Brook trout, *Salvelinus fontinalis*	S	U	DDT	96	17	9.29	Marking, 1966
Brook trout, *Salvelinus fontinalis*	S	U	DDT	96	20	10.93	Marking, 1966
Brook trout, *Salvelinus fontinalis*	S	U	DDT	96	1.8	0.98	Marking, 1966
Brook trout, *Salvelinus fontinalis*	S	U	DDT	24	54	19.48	Miller and Ogilvie, 1975
Brook trout, *Salvelinus fontinalis*	S	U	DDT	96	7.4	4.05	Post and Schroeder, 1971
Brook trout, *Salvelinus fontinalis*	S	U	DDT	96	11.9	6.51	Post and Schroeder, 1971
Lake trout, *Salvelinus namaycush*	S	U	DDT	96	9.1	4.97	Marking, 1966
Lake trout, *Salvelinus namaycush*	S	U	DDT	96	9.5	5.19	Marking, 1966
Northern pike, *Esox lucius*	S	U	DDT	96	1.7	0.93	Marking, 1966

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 5)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	21	11.48	Macek and McAllister, 1970
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	76	41.55	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	27	14.76	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	32	17.49	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	180	98.41	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	40	21.87	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	35	19.13	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	21	11.48	Marking, 1966
Goldfish, <u>Carassius</u> <u>auratus</u>	S	U	DDT	96	36	19.68	Henderson, <u>et</u> <u>al</u>., 1959

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 6)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Northern redbelly dace, *Chrosomus eos*	S	U	DDT	96	68	37.18	Marking, 1966
Carp, *Cyprinus carpio*	S	U	DDT	96	10	5.47	Macek and McAllister, 1970
Carp, *Cyprinus carpio*	S	U	DDT	96	9.2	5.03	Marking, 1966
Carp, *Cyprinus carpio*	S	U	DDT	96	4.0	2.19	Marking, 1966
Carp, *Cyprinus carpio*	S	U	DDT	96	11.3	6.18	Marking, 1966
Carp, *Cyprinus carpio*	S	U	DDT	96	12	6.56	Marking, 1966
Carp, *Cyprinus carpio*	S	U	DDT	96	6.9	3.77	Marking, 1966
Carp, *Cyprinus carpio*	S	U	DDT	96	6	3.28	Marking, 1966
Fathead minnow, *Pimephales promelas*	FT	M	DDT	96	48	48	Jarvinen, *et al.*, 1959

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 7)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Fathead minnow, *Pimephales promelas*	S	U	DDT	48	7.4	3.28	Lincer, *et al.*, 1970
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	19	10.39	Macek and McAllister, 1970
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	19.9	10.88	Macek and Sanders, 1970
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	58	31.71	Priester, 1965
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	42	22.96	Henderson, *et al.*, 1959
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	45	24.60	Henderson, *et al.*, 1959
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	26	14.21	Henderson, *et al.*, 1959
Fathead minnow, *Pimephales promelas*	S	U	DDT	96	26	14.21	Henderson, *et al.*, 1959
Black bullhead, *Ictalurus melas*	S	U	DDT	96	5	2.73	Macek and McAllister, 1970

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 8)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Black bullhead, *Ictalurus melas*	S	U	DDT	96	42	22.96	Marking, 1966
Black bullhead, *Ictalurus melas*	S	U	DDT	96	23.5	12.85	Marking, 1966
Black bullhead, *Ictalurus melas*	S	U	DDT	96	17	9.29	Marking, 1966
Black bullhead, *Ictalurus melas*	S	U	DDT	96	20	10.93	Marking, 1966
Channel catfish, *Ictalurus punctatus*	S	U	DDT	96	16	8.75	Macek and McAllister, 1970
Channel catfish, *Ictalurus punctatus*	S	U	DDT	96	17.4	9.51	Macek and Sanders, 1970
Channel catfish, *Ictalurus punctatus*	S	U	DDT	96	17.5	9.57	Marking, 1966
Channel catfish, *Ictalurus punctatus*	S	U	DDT	96	17.5	9.57	Marking, 1966
Mosquitofish, *Gambusia affinis*	S	U	DDT	48	43	19.04	Dziuk and Plapp, 1973

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 9)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Guppy, *Lebistes reticulatus*	S	U	DDT	96	19.5	10.66	King, 1962
Guppy, *Lebistes reticulatus*	S	U	DDT	96	56	30.62	Henderson, *et al.*, 1959
Brook stickleback, *Eucalia inconstans*	S	U	DDT	96	67	36.63	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	2.8	1.53	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	3	1.64	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	3.9	2.13	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	6.7	3.66	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	6.4	3.50	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	4.4	2.41	Marking, 1966

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 10)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	3.6	1.97	Marking, 1966
Green sunfish, *Lepomis cyanellus*	S	U	DDT	96	5	2.73	Marking, 1966
Pumpkinseed, *Lepomis gibbosus*	S	U	DDT	96	7.5	4.10	Marking, 1966
Pumpkinseed, *Lepomis gibbosus*	S	U	DDT	96	6.7	3.66	Marking, 1966
Pumpkinseed, *Lepomis gibbosus*	S	U	DDT	96	2.8	1.53	Marking, 1966
Pumpkinseed, *Lepomis gibbosus*	S	U	DDT	96	3.6	1.97	Marking, 1966
Pumpkinseed, *Lepomis gibbosus*	S	U	DDT	96	1.8	0.98	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	8	4.37	Macek and McAllister, 1970
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	9.5	5.19	Macek and Sanders, 1970

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 11)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	4.3	2.35	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	3.6	1.97	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	1.7	0.93	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	1.2	0.66	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	3	1.64	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	4.6	2.51	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	7	3.83	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	9.4	5.14	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	7	3.83	Marking, 1966

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 12)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	2.8	1.53	Marking, 1966
Bluegill, *Lepomis macrochirus*	S	U	DDT	96	21	11.48	Henderson, *et al.*, 1959
Longear sunfish, *Lepomis megalotis*	S	U	DDT	96	4.9	2.68	Marking, 1966
Longear sunfish, *Lepomis megalotis*	S	U	DDT	96	12.5	6.83	Marking, 1966
Redear sunfish, *Lepomis microlophus*	S	U	DDT	96	5	2.73	Macek and McAllister, 1970
Largemouth bass, *Micropterus salmoides*	S	U	DDT	96	2	1.09	Macek and McAllister, 1970
Largemouth bass, *Micropterus salmoides*	S	U	DDT	96	1.8	0.98	Macek and Sanders, 1970
Largemouth bass, *Micropterus salmoides*	S	U	DDT	96	0.8	0.44	Marking, 1966
Yellow perch, *Perca flavescens*	S	U	DDT	96	9	4.92	Macek and McAllister, 1970

Table I-10. Freshwater Fish Acute Values for DDT and Metabolites (Continued, Page 13)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Yellow perch, Perca flavescens	S	U	DDT	96	0.8	0.44	Marking, 1966
Yellow perch, Perca flavescens	S	U	DDT	96	0.6	0.33	Marking, 1966
Yellow perch, Perca flavescens	S	U	DDT	96	1.5	0.82	Marking, 1966
Freshwater drum, Aplodinotus grunniens	S	U	DDT	96	10	5.47	Marking, 1966

Notes: * S = static, FT = flow-through

** U - unmeasured, M = measured

Geometric mean of adjusted values = 5.05 µg/l $\frac{5.05}{3.9} = 1.3$ µg/l

Lowest value from a flow-through test with measured concentrations = 48 µ/l

Acute bioassays allow broad comparisons of the effects of toxic insecticides on a variety of aquatic species. Coupled with appropriate application factors, acute bioassay tests are typically used to evaluate actual impact and to formulate water quality standards. These tests, however, embody certain weaknesses when applied to this type of assessment, since there is a variability associated with species specific responses to different forms of stress as well as the effect of the method of dose application (adsorption, ingestion, etc.). In addition, differences in experimental conditions and physical parameters affect bioassay tests (Livingston, 1977). For example, two general mechanisms of DDT exposure have been used in acute bioassay testing, static vs. continuous flow systems. In static systems, aquaria of varying sizes have been used and generally the water composition has been defined. Insecticide (DDT) is then added to attain the desired concentration. The system is then left undisturbed, other than to remove samples for bioassay, typically over the range of 24 to 96 hours. Problems with this type of system occur because the original insecticide concentration may be different than the concentration at the end of the experiment. Factors such as hydrophobicity of the insecticide, sorption to detritus and aquaria surfaces, as well as removal of the insecticide from the water by gills or mucoidal surfaces of the organisms, also effect toxicity. In addition, particularly with fish, the environment is inevitably changed through normal biological functions such as decreasing oxygen and increasing carbon dioxide due to respiration, and increasing ammonia due to excretion. These factors can place unnatural stresses on the organism and may enhance apparent insecticide toxicity (Lincer, 1970). Continuous flow systems have been developed which overcome some of the deficiencies of static systems. Continuous flow systems supply fresh test solution at a rate fast enough to compensate for reduction in insecticide and oxygen concentrations and at the same time remove fish-produced metabolites and wastes. Thus, static bioassay tests often yield lower LC50's (concentration lethal to 50 percent of the population) for a given organism than dynamic tests. It should be noted, however, that data published by EPA (1978) indicates that there is considerable variation when static and flow through LC50 values are compared. In some cases, static LC50 values were lower than flow-through LC50 values and in other cases they were higher.

Physical parameters such as temperature, salinity, pH and dissolved oxygen can affect relative toxicities. Furthermore, the chemical formulation of the insecticide can also affect the acute toxicity. Other factors involved in toxicity are ontological history of the test organism (i.e., has it been previously exposed to insecticide), modes of respiration, feeding and method of exposure.

5.2 AQUATIC INVERTEBRATES

Kouyoumjian and Uglow (1974) determined the toxicity of DDT, DDE, and DDD to the freshwater planarian, Polycelis felina. The 96-hour LC50's for DDT, DDE, and DDD were 1.05 ppm, 1.23 ppm and 0.74 ppm, respectively.

Hummon (1974) studied the effects of DDT toxicity on reproductive rate in the freshwater micrometazoan, *Lepidodermella squammata* using static conditions. They found the reproductive lethality (RLC) at 96 hours for DDT to be 3 ppm. This indicates that 50 percent of the organisms ceased to reproduce when exposed to 3 ppm DDT for 96 hours. Ninety-five percent RLC occurred at 9 ppm (96 hours). LC50 at 96 hours was 5 ppm DDT and the LC95 at 96 hours was 12 ppm DDT.

Rawash *et al*. (1975) and Makin and Johnson (1975) both reported on the toxicity of DDT to the microcrustacean, *Daphnia magna* Straus. Maki and Johnson (1975) determined the LC50 for DDT after 14 days to be 0.67 ppb, while 50 percent inhibition of reproduction occurred at 0.5 ppb. In contrast, Rawash *et al*. (1975) reported LC50 values of 6.5 ppb after 24 hours of exposure. The difference can be explained by the length of the toxicity assay and/or experimental conditions.

Sanders and Cope (1968) determined the toxicities of DDT and several other insecticides to three species of stonefly nymphs, *Pteronarcys californica*, *Pteronarcella badia* and *Claassenia sabulosa*. DDT was the least toxic of the chlorinated hydrocarbons tested. The LC50's for the three species of stonefly nymphs were 7 ppb, 1.9 ppb and 3.5 ppb, respectively. They also observed that DDT was 5 to 10 times more toxic to smaller nymphs than larger ones.

Fredeen (1972) studied the toxicity of technical and formulated DDT and DDD (TDE) in river dwelling larvae of three rheophilic species of Trichoptera, *Hydropsyche morosa* Hagen, *H. recurvata* Banks, *Brachycentrus lateralos* (Say). Tables I-11, I-12, and I-13 list specific LC50 values associated with specific temperatures, metabolites and formulations. Generally, technical DDT was more toxic than formulated DDT. The LC50's increased as the size of the larvae increased; DDT was also more toxic at 10°C than 20°C.

Rawash *et al*. (1975) determined the LC50 for the fourth instar mosquito larvae, *Culex pipiens* L. The LC50 was obtained from a standard toxicity curve covering the range of concentration from 0.05 ppm to 2.5 ppm. The point at which 50 percent mortality occurred was approximately 0.36 ppm.

Albaugh (1972) determined the effect of insecticide pre-exposure on DDT toxicity to the crayfish *Procambarus acutus* (Girard). Crayfish were obtained from two areas in south Texas. One area had little insecticide use while the other area contained cotton fields that had been treated with DDT, toxaphene, and methyl parathion. The pre-exposed crayfish were more resistant to DDT than the non-exposed crayfish with LC50's at 48 hours of 7.2 ppb and 3 ppb, respectively.

5.3 AQUATIC VERTEBRATES

Post and Schroeder (1971) studied the toxicity of DDT in four species of salmonids: brook trout (*Salvelinus fontinalis*), rainbow trout (*Salmo gairdnerii*), cutthroat trout (*Salmo clarki*) and coho salmon (*Oncorhynchus kisutch*). Toxicity limits (TLM) from 24 to 96 hours exposure were

Table I-11. Approximate Lethal Concentrations (ppm) of DDT for Trichoptera Larvae (*Hydropsyche morosa* Hagen and *H. recurvata* Banks) in Water Circulated by Compressed Air at 11°C and 21°C. Montreal, 5 to 31 August, 1965

Species	Temp. (°C)	Exposure (hr)	DDT	
			LC50	LC90
H. morosa	11	3[1]	----	----
		6[1]	----	----
		6[2]	----	----
	21	3[1]	0.09	0.40
		6[1]	0.05	0.20
		6[2]	0.05	0.10
H. recurvata	11	3[1]	0.09	0.30
		6[1]	0.03	0.09
		6[2]	0.02	0.03
	21	3[1]	0.40	0.40
		6[1]	0.06	0.20
		6[2]	0.04	0.06

[1] These data were calculated from counts of larvae made immediately after 3- and 6-hour exposures to test solutions.

[2] These data were calculated from counts of larvae made after 6-hour exposure to the test solution plus 18 hours in fresh water.

Source: Fredeen, 1972.

Table I-12. Approximate Lethal Concentrations (ppm) of DDT and DDD for Trichoptera Larvae (Hydropsyche morosa Hagen) at 10°C in Water Not Circulated by Compressed Air. Montreal, 13 May to 8 June, 1966

	DDT			DDD		
Exposure (hr)	No. of replicates	LC50	LC90	No. of replicates	LC50	LC90
3[1]	10	0.07	0.30	20	0.07	0.30
6[1]	10	0.05	0.20	20	0.04	0.15
6[2]	10	0.05	0.15	20	0.04	0.15

[1] These data were calculated from counts of larvae made immediately after 3- and 6-hour exposures to test solutions.

[2] These data were calculated from counts of larvae made after 6-hour exposure to the test solution plus 18 hours in fresh water.

Source: Fredeen, 1972.

Table I-13. Approximate Lethal Concentrations (ppm) of Four Different Formulations of DDT for Trichoptera Larvae at 21°C in River Water Circulated by Compressed Air. Montreal, 1965

Formulation	Dates Tested (Aug.)	Exposure (hr)	*Hydropsyche morosa* No. of replicates	*Hydropsyche morosa* LC50	*Hydropsyche morosa* LC90	*Hydropsyche recurvata* No. of replicates	*Hydropsyche recurvata* LC50	*Hydropsyche recurvata* LC90
Ethanolic solution	5-14	3[1]	5	0.09	0.40	5	0.10	0.40
		6[1]	5	0.05	0.20	5	0.06	0.20
		6[2]	5	0.05	0.10	5	0.04	0.06
25% Emulsifiable conc.	31	3[1]	2	0.40	2.50	1	1.00	>2.5
		6[1]	2	0.15	1.50	1	0.15	1.50
		6[2]	2	0.25	1.50	1	0.40	2.00
3% Dust	1-12	3[1]	4	0.50	2.00	12	1.00	2.50
		6[1]	4	0.25	1.00	12	0.50	1.80
		6[2]	4	0.10	0.40	12	0.30	1.10
5% Granular	14	3[1]	0	----	----	2	>2.5	>2.5
		6[1]	0	----	----	2	2.5	>2.5
		6[2]	0	----	----	2	0.3	1.0
5% Granular (Milled)	17-25	3[1]	8	0.20	1.50	8	0.5	2.00
		6[1]	8	0.08	0.50	8	0.3	1.50
		6[2]	8	0.05	0.25	8	0.2	0.50

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[1] These data were calculated from counts of larvae made immediately after 3- and 6-hour exposures to test solutions.

[2] These data were calculated from counts of larvae made after 6-hour exposure to the test solution plus 18 hours in fresh water.

Source: Fredeen, 1972.

determined under static conditions and are presented for the four species in Table I-14. TLM's are in ppb and were determined for two different fish body weights for 3 of the 4 species. The results indicate that there was a difference in toxicity and susceptibility based on the size of the fish. The small fish were more susceptible than the larger fish. Macek and McAllister (1970a) reported 96-hour TLM50's for rainbow trout and coho salmon exposed to DDT under static conditions of 7 ppb and 4 ppb, respectively. Gardner (1973) determined a 24-hour LC50 for brook trout fingerlings (1.5g to 2.5g) under static conditions to be 30 ppb for DDT and 45 ppb for DDD. Although these values are higher than those reported by Macek and McAllister (1970), it is reasonable to expect that an LC50 based on a shorter time period will be higher within a particular species.

Dziuk and Plapp (1973) studied the effect of insecticide resistance on mosquito fish (Gambusia affinis) collected from three sites in areas of varying insecticide usage. One site was a high insecticide use area, the second was a moderate use area and the third site had not been subjected to extensive insecticide contamination. Mosquitofish from these three sites were exposed to DDT under static conditions for 48 hours. LC50 values for fish collected from the high, moderate and low insecticide usage areas were 528 ppb, 313 ppb, and 43 ppb, respectively; LC90's were 1282 ppb, 555 ppb and 77 ppb. Thus the data indicated that more resistant populations of mosquitofish were present and prior insecticide exposure could have induced this resistance. Kynard (1974) also reported DDT toxicity for two mosquitofish populations termed resistant and susceptible. The 24-hour LC50 for the resistant population was 100 ppb while for the susceptible population it was 20 ppb.

Yang and Sun (1977) exposed loaches (Misgurnus anguillicaudatus, Cantor) to DDT in a continuous flow apparatus and by injection of the toxicant. The 24-hour LC50 was 350 ppb for the aqueous exposure and the 24-hour LC50 by injection was 25 ppm. Rates of adsorption of the DDT by the aqueous-exposed loaches was determined by comparing the amounts of DDT recovered from water with and without fish. The results indicated that approximately 93 percent of the DDT had been absorbed by the loaches at the end of the 24-hour period and 50 to 60 percent was absorbed within the first two hours of exposure.

Korn and Earnest (1974) used an intermittent flow system to expose striped bass (Morone saxatilis) to DDT and DDD. They reported 96-hour TL50's for DDT and DDD of 0.53 ppb and 2.5 ppb respectively.

Lincer et al. (1970) compared the toxicity of DDT to fathead minnows (Pimephales promelas) under static versus dynamic bioassay conditions. The reported 48-hour LC50 values for the static and dynamic systems were 7.4 ppb and >40 ppb, respectively. The LC50 value obtained from the dynamic system was more than 5.4 times higher than that of the static system. Additional effects of DDT on invertebrates and vertebrates are presented in Table I-15 (EPA's Ambient Water Qualtiy Criteria for DDT).

Table I-14. TLM Values in ppb of the Toxicant and TLM Value Confidence Limits for DDT

Species	Fish Body Weight (g)	Time (hr)	TLM (ppb)	Confidence Limits
Brook Trout	1.15	48	7.35	6.08 - 8.89
	1.15	72	7.4	6.08 - 9.03
	1.15	96	7.4	6.07 - 9.03
	2.13	24	23.1	18.48 - 28.88
	2.13	48	12.75	10.49 - 15.49
	2.13	72	11.9	10.59 - 13.38
	2.13	96	11.9	10.59 - 13.38
Rainbow Trout	0.41	24	6.9	4.059 - 11.73
	0.41	48	3.05	2.678 - 3.474
	0.41	72	2.25	1.837 - 2.756
	0.41	96	1.72	1.416 - 2.090
Cutthroat Trout	0.33	48	1.63	1.333 - 2.006
	0.33	96	0.85	0.368 - 1.530
	1.25	96	1.37	1.28 - 1.454
Coho Salmon	0.5	24	25.0	18.4 - 34.0
	0.5	48	12.5	9.9 - 15.7
	0.5	72	11.7	9.4 - 14.5
	0.5	96	11.3	9.7 - 13.2
	1.65	48	30.0	27.2 - 32.9
	1.65	72	24.0	21.3 - 26.6
	1.65	96	18.5	15.9 - 21.1

Source: Post and Schroeder, 1971.

Table I-15. Other Freshwater Toxicity Data for DDT and Metabolites

Organism	Test Duration	Effect	Result (µg/l)	Reference
Cladoceran, *Daphnia magna*	14 days	LC50	0.67	Maki and Johnson, 1975
Cladoceran, *Daphnia magna*	14 days	50% inhibition of total young produced	0.50	Maki and Johnson, 1975
Scud, *Gammarus fasciatus*	120 hours	LC50	0.6	Sanders, 1972
Glass shrimp, *Palaemonetes kadiakensis*	36 hours	LC50	4.5	Ferguson, *et al*. 1965b
Glass shrimp, *Palaemonetes kadiakensis*	120 hours	LC50	1.3	Sanders, 1972
Stonefly (naiad), *Acroneuria pacifica*	30 days	LC50	72	Jensen and Gaufin, 1964
Stonefly (naiad), *Pteronarcys california*	30 days	LC50	265	Jensen and Gaufin, 1964
Planarium, *Polycelis felina*	24 days	Asexual fission inhibition	250	Kouyoumjian and Uglow, 1974
Coho salmon, *Oncorhynchus kisutch*	—	Reduced fry survival	1.09 mg/kg in eggs	Johnson and Pecor, 1969
Coho salmon (juvenile), *Oncorhynchus kisutch*	7 days	Increased cough frequency	5	Schaumburg, 1967
Coho salmon, *Oncorhynchus kisutch*	125 days	Estimated median survival time--160 days	1.27 mg/kg in food	Buhler and Shanks, 1972
Cutthroat trout, *Salmo clarki*	—	Reduced sac fry survival	>0.4 mg/kg in eggs	Cuerrier, *et al*. 1967
Rainbow trout, *Salmo gairdneri*	24 hours	Uncontrolled reflex reaction	100	Peters and Weber, 1977
Rainbow trout, *Salmo gairdneri*	5 hours	Cough response threshold	52-140	Lunn, *et al*. 1976

Table I-15. Other Freshwater Toxicity Data for DDT and Metabolites (Continued, page 2)

Organism	Test Duration	Effect	Result (µg/l)	Reference
Rainbow trout, Salmo gairdneri	—	Reduced sac fry survival	>0.4 mg/kg in eggs	Cuerrier, et al. 1967
Atlantic salmon (gastrulae), Salmo salar	30 days	Retarded behavioral development and impaired balance of alevins	50	Dill and Saunders, 1974
Atlantic salmon, Salmo salar	24 hours	Altered temperature selection	5	Ogilvie and Anderson, 1965
Atlantic salmon, Salmo salar	24 hours	Altered temperature selection for 1 mo.	50	Ogilvie and Miller, 1976
Atlantic salmon, Salmo salar	24 hours	Altered temperature selection	10	Peterson, 1973
Brook trout, Salvelinus fontinalis	24 hours	Lateral line nerve hypersensitivity	100	Anderson, 1968
Brook trout, Salvelinus fontinalis	24 hours	Visual conditioned avoidance inhibition	20	Anderson and Peterson, 1969
Brook trout, Salvelinus fontinalis	—	Reduced sac fry survival	>0.4 mg/kg in eggs	Cuerrier, et al., 1967
Brook trout, Salvelinus fontinalis	24 hours	Altered temperature selection	20	Gardner, 1973
Brook trout, Salvelinus fontinalis	156 days	Slight reduction in sac fry survival	2 mg/kg in food	Macek, 1968
Brook trout, Salvelinus fontinalis	24 hours	Altered temperature selection	10	Miller and Ogilvie, 1975
Brook trout, Salvelinus fontinalis	24 hours	Altered temperature selection	100	Peterson, 1973
Lake trout (fry), Salvelinus namaycush	—	Reduced survival	2.9 mg/kg in fry	Burdick, et al. 1964
Goldfish, Carssius auratus	2.5 hours	Loss of balance and decreased spontaneous electrical activity of the cerebellum	1,000	Aubin and Johanson, 1969

Table I-15. Other Freshwater Toxicity Data for DDT and Metabolites (Continued, page 3)

Organism	Test Duration	Effect	Result (µg/l)	Reference
Goldfish, *Carassius auratus*	4 days	Exploratory behavior inhibition	10	Davy and Kleerekoper, 1973
Goldfish, *Carassius auratus*	7 days	Schooling inhibition	1	Weis and Weis, 1974
Golden shiner, *Notemigonus crysoleucas*	24 hours	Schooling inhibition	15	Bailey, 1973
Golden shiner, *Notemigonus crysoleucas*	36 hours	LC50	29.9	Ferguson, *et al*. 1964
Fathead minnow, *Pimephales promelas*	266 days	Mg^{2+} ATPase inhibition	0.5	Desaiah, *et al*. 1975
Black bullhead, *Ictalurus melas*	36 hours	LC50	16.4	Ferguson, *et al*. 1965a
Mosquitofish, *Gambusia affinis*	36 hours	LC50	21.3	Ferguson, *et al*. 1965a
Mosquitofish, *Gambusia affinis*	40 minutes	Succinic dehydrogenase activity inhibition	9×10^{-9} molar	Moffett and Yarbrough, 1972
Green sunfish, *Lepomis cyanellus*	36 hours	LC50	23.5	Ferguson, *et al*. 1964
Bluegill, *Lepomis macrochirus*	36 hours	LC50	28.7	Ferguson, *et al*. 1964
Bluegill, *Lepomis macrochirus*	16 days	Hyperactive locomotor response	0.008	Ellgaard, *et al*. 1977
Toad (tadpole, 4-5-wk-old), *Bufo woodhousei fowleri*	96 hours	LC50	1,000	Sanders, 1970
Toad (tadpole, 4-5-wk-old), *Bufo woodhousei fowleri*	96 hours	LC50 (TDE)	140	Sanders, 1970
Toad (tadpole, 6-wk-old), *Bufo woodhousei fowleri*	96 hours	LC50	100	Sanders, 1970

Table I-15. Other Freshwater Toxicity Data for DDT and Metabolites (Continued, page 4)

Organism	Test Duration	Effect	Result (µg/l)	Reference
Toad (tadpole, 7-wk-old), <u>Bufo woodhousei fowleri</u>	96 hours	LC50	30	Sanders, 1970
Frog (tadpole), <u>Pseudacris triseriata</u>	96 hours	LC50	800	Sanders, 1970
Frog (tadpole), <u>Pseudacris triseriata</u>	96 hours	LC50 (TDE)	400	Sanders, 1970
Frog (tadpole), <u>Rana clamitans</u>	6 days	Increased pituitary melanocyte-stimulating hormone levels	100	Peaslee, 1970
Turtle, <u>Chrysemys picta</u>	30 minutes	ATPase inhibition	0.53 µM	Phillips and Wells, 1974

Note: Lowest value = 0.008 µg/l.

Only one chronic toxicity test with DDT was found. Jarvinen et al. (1977) reported that the acute toxicity (48 µg/l) was 65 times greater than the chronic toxicity (0.74 µg/l) to the fathead minnow. Other chronic effects which have not been evaluated in any species include long term impact on morphological features, embryological development, physiological and behavioral functions, tropho-dynamic response and other biological attributes pertaining to species specific stress reactions.

5.4 BIRDS

There are many studies on toxicity of DDT and other organochlorines on many bird species. Some are direct laboratory feeding studies, while others attempt to sample birds in the field to determine natural body levels of pollutant. Among the birds most often studied are the gallinacious species.

Hill et al. (1971) fed ad libitiem diets with 25 to 800 ppm DDT to bobwhites and determined the brain levels of DDT, DDE, and DDD. During the experiment, significant weight loss was noted when dietary concentrations reached 400 ppm, but no other toxic effects were reported. At a rate of 800 ppm the birds suffered mild intoxication and a total brain residue of 5.6 ppm to 22.3 ppm was determined; 1600 ppm DDT caused convulsions and death with mean brain levels of 28.4 ppm. The authors reported a wide diversity of lethal brain concentrations of DDT for various bird species, ranging from 23.0 ppm in blue jays to 43.2 ppm in house sparrows.

Stickel (1973) reported that DDT storage in chickens is complicated by its metabolic conversion to DDE and DDD. Brain concentrations appear to be the most rigorous criterion for diagnosis of toxicity (Stickel and Stickel, 1969; Stickel, 1973).

The LC50 values for DDT in various aged mallards were reported by Friend and Trainer (1974). These values ranged from 1200 ppm to 1600 ppm. Greatest mortality was noted among five-day-old ducklings and the lowest mortality among 30-day-old ducklings. Adult females were more resistant than adult males. Among adults, all ducks experienced some weight loss. Those that survived lost about 9 percent of their starting body weight, while those that died lost 24-28 percent.

Heinz (1976) reported that mallard ducklings fed 3 ppm DDE laid eggs containing 5.8 ppm DDE. According to the author, those ducklings that hatched differed in behavior (i.e., response to maternal call and to frightening stimuli) than the controls. Longcore and Stendell (1977) fed DDE to black ducks for two breeding seasons. Following two years of dietary DDE, the mean residue in eggs averaged 6.2 ppm. In another study, black ducks fed 10 ppm and 30 ppm DDE produced eggs containing 46 and 144 ppm residues respectively.

Another approach to the toxicity problem has been to study natural populations. Henny et al. (1977) determined residue levels of DDT in the common flicker and mountain blue bird eggs, a year after application.

The residues of DDT in mountain blue birds were about ten times greater than in common flicker eggs (5.29 ppm vs. 0.58 ppm wet weight). They concluded that the differences were most likely due to disparate diets. The mean level of DDT in the American kestrel eggs collected at the same time was 6.42 ppm, wet weight.

A nationwide monitoring study to determine DDTR residues in wings of adult mallards and black ducks was reported by White (1979). This study revealed DDE to be present in every sample and the levels were unchanged from a similar study conducted four years earlier.

Heath (1969) had conducted a similar nationwide search for DDT, DDE, and DDD residues in the wings of mallards and black ducks bagged in the 1965-66 hunting season. The total number in the sample was 24,000 birds. DDE was the predominant residue followed in order by DDT and DDD. DDE was found in samples from every state, but was notably high in New Jersey, Massachusetts, Connecticut, Rhode Island, and New York.

The U.S. Fish and Wildlife Service has continued this nationwide program which has examined the pesticide burden in migratory waterfowl. Hunters contribute wings from mallard ducks and these are pooled for analysis. According to Fleming (1980), wing pools from Limestone and Madison Counties, Alabama had DDTR levels that averaged 10.8 and 18 times higher respectively than the combined average of all other counties or county groups. The result is an inflated average for Alabama which in 1976, for example, was 3.2 times the national average.

The effect of DDE on egg shell thickness and therefore overall reproductive potential has been studied in many species of birds. DDE has been shown to cause substantial shell-thinning in three major bird groups experimentally fed this isomer (Stickel, 1973);

Order Anseriformes (mallard duck and black duck)
Order Falconiformes (American kestrels)
Order Strigiformes (screech owl).

Captive black ducks fed DDE at 10 and 30 ppm produced eggs with thinner shells which were more susceptible to cracking than non-DDE fed controls (Longcore and Sampson, 1973; Longcore et al., 1971). Eggshells were 18-24 percent thinner at the equator, 28-31 percent thinner at the cap, and 29-38 percent thinner at the apex than controls. The feeding levels of 30 ppm, 10 ppm, and 0 ppm DDE resulted in 21, 10 and 2 percent cracking respectively. The survival rate of treated ducklings was 40-76 percent lower than controls (Longcore et al. 1971; Longcore and Samson, 1973). Longcore and Stendall (1977) fed captive black ducks two ppm DDE for two breeding seasons. Shells of eggs from treated hens were approximately 20 percent thinner than controls. When DDE was removed from the diet, progressively thicker shells resulted and reproductive success improved, but even after two years on untreated feed, these hens laid eggs with shells about 10 percent thinner than control hens.

Similar studies were conducted by Haegele and Hudson (1974) on mallards. A diet of 40 ppm DDE fed for 96 days resulted in eggs with 15-20 percent thinner shells than controls. When DDE treatment was discontinued, the treated birds laid eggs which were still thinner than controls. After 11 months, treated birds laid eggs with shells averaging 7.4 percent thinner than controls.

Results of similar feeding studies in screech owls (McLane and Hall, 1972) were comparable. After two breeding seasons with diets containing 10 ppm DDE, treated birds laid eggs with shells that were 13 percent thinner than untreated birds. Longcore et al. (1971a) also reported on the effect of DDE on the eggshell composition. Black ducks were fed diets containing 10 ppm and 30 ppm DDE and mallards were fed diets with 1, 5, and 10 ppm DDE. Eggshells had increases in the percentages of magnesium, sodium, copper and, decreases in barium, strontium and calcium.

Thin eggshells contribute to cracking and reduced reproductive success, but other effects are also noted when DDT is present in the diets of birds. Porter and Wiemeyer (1969) fed captive sparrow hawks a diet containing dieldrin and DDT. The major effects on reproduction were increased egg disappearance (by breakage and eating of the young by parents), increased egg destruction by the parents, and reduced eggshell thickness (8-10 percent thinner). Similarly, the feeding of DDE to mallards at levels of 10 ppm and 40 ppm resulted in eggshell thinning (13 percent) and cracking (25 percent) as well as marked increases in mortality (35 percent) (Heath et al. 1969). DDD and DDT also impaired reproduction, but less severely than DDE.

Quail fed diets of DDT produced fewer eggs and eggs with thinner shells (Stickei and Rhodes, 1970). Hatchability, however, was not significantly altered.

In field tests, DDT was applied in oil at 2 lbs/acre over a four-year interval on bottomland forest (Robbins et al. 1951). By the fifth spring, there was a 26 percent decrease in breeding bird populations. Over the four year period, the American redstart, parula warbler and red-eyed vireo suffered decreases of 44 percent, 40 percent, and 28 percent, respectively.

Gallinacious species seem to be most resistant to most environmental pollutants and raptor species the most susceptible (Cooke, 1973). In North America and Britain shell thinning is directly associated with population decreases of raptor species.

In a classic paper, Anderson and Hickey (1972) studied over 2000 eggs of 11 species in 14 geographic areas. They found the following results:

1) An apparent decrease in the golden eagle population in the Western North America since the 1890's.
2) Eggshell changes to be rare before 1939 and quite common for sometime thereafter. This coincides with the advent and widespread use of DDT as an insecticide.

3) Shell-thinning had not occurred in 9 of 25 species. Others showed varying decreases in shell thickness.
4) Shell weights decreased by 20 percent or more.
5) Nearly 8 species had regional declines in population and in some cases the decline seemed to be continuing.

Hulbert (1975) discussed avian predator dependent species and noted that evidence has accumulated relating organochlorine insecticides to reproductive failures and population declines. Among those species cited were the kestrel, peregrine, osprey, golden eagle, red shouldered hawk, Cooper's hawk, brown pelican and the black-crowned night heron.

Many researchers have attempted to determine the cause of eggshell thinning. The work of Kolaja and Hinton (1977) is illustrative. It was demonstrated that eggshell thinning in mallard ducks could be correlated with a 35 percent reduction in ATPase activity in the microsomal fraction of eggshell gland epithelium. Since this Ca-ATPase is associated with Ca transport, it was suggested that this inhibition may be responsible for thin eggshells. In an earlier paper, Kolaja and Hinton (1976) had roted that DDT induced shell thinning was accompanied by histopathologic alterations in the shell gland of mallard ducks. Table I-16 presents a summary listing of toxic effects of DDT on various bird species.

5.5 MAMMALS

The data on toxicity to various mammalian species is limited. Aquatic mammals throughout the world accumulate substantial concentrations of many different organochlorine pesticides (Stickel, 1973). Clark and Pronty (1977) fed 166 ppm DDE in mealworm bait to female big brown bats for 54 days. Thereafter, 6 were frozen, and 16 were starved to death. DDE increased in the brains of starving bats; however, tremors and/or convulsions, characteristic of neurotoxicity were not observed. The brain DDE levels reached 132 ppm.

5.6 ALGAE AND FUNGI

Four species of freshwater algae have been reported as sensitive to DDT. DDT levels ranged from 800 μg/l to 0.3 μg/l and effects included alterations to growth morphology and photosynthesis. These data are summarized in Table I-17.

Hodkinson and Dalton (1973) evaluated the effect of DDT on the growth of a variety of river fungi at two incubation temperatures. Generally, the growth rates for the twelve fungal species were enhanced when DDT was added (up to 60 ppm) to the medium. Results presented in Table I-18 do not indicate that a toxic level was reached.

6.0 EPA AMBIENT WATER QUALITY CRITERIA FOR DDT

EPA has proposed ambient water quality criteria for DDTR using guidelines developed earlier (EPA, 1979; EPA, 1978).

Table I-16. Toxicity of DDT to Various Bird and Fish Species

Organism	Effect	Concentration (mg/kg)	Reference
Mallard, Anas platyrhynchos	Eggshell thinning	3*	Haseltine, et al.1974
Mallard, Anas platyrhynchos	Eggshell thinning	3*	Heath, et al. 1969
Black duck, Anas rubripes	Eggshell thinning	3*	Longcore, et al. 1971
Black duck, Anas rubripes	Reduced duckling survival	2.8	Longcore and Sterdell, 1977
Sparrow hawk, Falco sparverius	Eggshell thinning	3	Lincer, 1975
Sparrow hawk, Falco sparverius	Reduced survival	2.8	Porter and Wiemeyer, 1972
Screech owl, Otus asio	Eggshell thinning	2.8	McLane and Hall, 1972
Brown pelican, Pelecanus occidentalis	Eggshell thinning	0.5	Blus, et al. 1972, 1974
Brown pelican, Pelecanus occidentalis	Reduced productivity	0.15	Anderson, et al. 1975
Coho salmon (fingerling), Onchorhynchus kisutch	Reduced survival	6.25	Buhler, et al. 1969
Chinook salmon (fingerling), Onchorhynchus tshawytscha	Reduced survival	6.25	Buhler, et al. 1969
Cutthroat trout, Salmo clarki	Reduced sac fry survival	3	Allison, et al. 1963
Rainbow trout, Salmo gairdneri	Inhibition of Na^+-K^+ ATPase	2.75	Campbell et al. 1974
Rainbow trout, Salmo gairdneri	Reduced phenoxyethanol anesthetic induction and recovery times	11.36	Klaverkamp, et al. 1976
Rainbow trout, Salmo gairdneri	Reduced light intensity discrimination	9	McNicholl and Mackay, 1975
Brown trout, Salmo trutta	Reduced fry survival	3.4	Burdick, et al. 1972
Lake trout, Salvelinus namaycush	Reduced fry survival	6	Burdick, et al. 1972

Table I-17. Freshwater Plant Effects for DDT and Metabolites

Organism	Effect	Concentration (µg/l)	Reference
Alga, *Anacystis nidulans*	Growth	800	Batterton, *et al*. 1972
Alga, *Chlorella* sp.	Growth and morphology	0.3	Sodergren, 1968
Alga, *Scenedesmus quadricaudata*	Growth	100	Stadnyk, *et al*. 1971
Alga, *Selanastrum capricornutum*	Photosynthesis	3.6	Lee, *et al*. 1976

Source: EPA's Ambient Water Quality Criteria for DDT.

Table I-18. Percentage Increase in Fungal Growth in Medium Containing 2, 10, 20 AND 60 mg/l of DDT

Fungus	20°C				5°C			
	DDT Conc. mg/l				DDT Conc. mg/l			
	2	10	20	60	2	10	20	60
Isoachyla sp.	1	2	10	39	3	5	7	12
I. monilifera	0	9	58	138				
Saprolegnia sp.	0	2	10	43				
Pythium sp.	0	4	9	41				
Heliscus submersus	5	9	14	65	1	5	14	41
Clavariopsis aquatica	0	5	12	29				
Tetracladium setigerum	0	6	20	48				
Varicosporium elodeae	0	2	11	48				
Cladosporium cladosporioides	0	4	10	36	4	7	16	46
Aureobasidium pullulans	0	25	35	74				
Cephalosporium acremonium	2	4	17	54				
Cylindrocarpon orthosporium	0	7	12	57				

Note: Mycelial yields determined after 100 hours at 20°C and 400 hours incubation at 5°C.

Source: Hodkinson and Dalton, 1973.

> For DDT and metabolites the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.00023 µg/l as a 24-hour average and the concentration should not exceed 0.41 µg/l at any time.

7.0 FDA REGULATIONS REGARDING DDTR RESIDUES IN FISH

The guidelines concerning FDA regulations for pesticide residues in foods are covered in two publications (FDA, 1978; FDA, 1979). The FDA Guideline Manual (FDA, 1978) states the basis of their authority and the origin of the tolerances as follows:

> Sections 406, 408, 409, and 402 of the Federal Food, Drug, and Cosmetic Act are the applicable provisions in determining whether foods containing pesticide residues comply with the Act.
>
> The Environmental Protection Agency (EPA) is authorized under Sections 408 and 409 to establish tolerances for pesticide residues in raw agricultural commodities and processed foods respectively. Pesticide tolerances established by EPA for raw agricultural commodities are contained in Title 40, Part 180 of the Code of Federal Regulations; pesticide tolerances for processed foods are found in Title 21, Part 193. Where a pesticide chemical has been used on a raw agricultural commodity in conformity with Title 40, Part 180 of the CFR, residues of that pesticide may be present in food processed from such raw agricultural commodity provided the residues have been removed to the extent possible during processing and the concentration of the residue in the processed food when ready to eat is not greater than the tolerance prescribed for the pesticide residue in the raw agricultural commodity, unless otherwise specified in Part 193. This provision does not apply where the raw agricultural commodity does not conform to a prescribed tolerance. In this situation, quantifiable residues in food processed from the raw agricultural commodity adulterate the food under Section 402(a)(2)(c).
>
> Section 406 authorizes EPA to establish tolerances for residues of pesticides as added poisonous or deleterious substances which are required in the production of food or which otherwise cannot be avoided by good manufacturing practice, e.g., unavoidable because of background or environmental factors. In the absence of a tolerance under Section 406, and provided a tolerance is not in effect under Section 408 or 409, FDA may establish an action level for unavoidable pesticide residues in food. The level at which an FDA action level is established is based on EPA's recommendation. (For more information on the subject of pesticide action levels, refer to Sections III and V of these guidelines and 21 CFR 109.6 and 109.7.)
>
> Section 402(a)(2) describes the conditions in which a food containing a pesticide residue shall be deemed adulterated. In

accordance with this section of the Act, such food is considered by FDA to be actionable when:

1) the pesticide residue level exceeds an established tolerance or is at or above an established action level; or

2) there is evidence clearly demonstrating that a pesticide residue is present due to misuse, regardless of whether there exists a tolerance or action level.

The FDA guidelines manual (FDA, 1978) gives the following general criteria for sampling and analytical work to support recommendations for action at the district level:

> The following criteria, unless exceptions are specified in the other criteria, are to be met for all district recommendations:
>
> 1) The sample collected was representative of the shipment in accordance with the sampling instructions contained in Section 443 of the Inspectors Operations Manual; and
>
> 2) The exact portion of food prepared for analysis is specified by the analyst and was in accordance with 40 CFR 180.1(j) or if not appropriate, in accordance with Pesticide Analytical Manual (PAM) Volume I, Section 141; and
>
> 3) An original and check analysis on the quantity of residue was performed and the results obtained from each are in reasonably close agreement (Note: it is not practical to be more precise in stating what constitutes "reasonably close agreement" because this will vary according to pesticide, type of food, analytical method and residue level. Therefore, it becomes a judgement decision that has to be made on a case-by-case basis.); and
>
> 4) The identity and quantity of the residue in either the original or check analysis sample was confirmed by an appropriate method; and
>
> 5) The analytical methods used for the original and check analyses are contained in the PAM, Volume I or II or the AOAC Book of Methods or are otherwise considered by DRG to be suitable for FDA regulatory purposes; and
>
> 6) The district is satisfied that the analytical work supports the reported residue findings of the laboratory and is adequate to sustain scrutiny in a court of law.

In FDA, 1979, the regulations are further explained as follows:

> Action levels for poisonous or deleterious substances are established by the Food and Drug Administration (FDA) to

REFERENCES

Acree, F., Jr., M. Beroza and M.C. Bowman. 1963. J. Agr. Food Chem. 11:278.

Alabaster, J.S. 1969. Int. Pest. Control. 2:29.

Albaugh, D.W. 1972. Bull. Environ. Contam. Toxicol. 8:334.

Albone, E.S., G. Eglington, N.C. Evans, J.M. Hunter and M.M. Rhead. 1972. Environ. Sci. α Technol. 6:914.

Albone, E.S., G. Eglinton, N.C. Evans and M.M. Rhead. 1972a. Nature. 240:420.

Allison, D., B.J. Kallman, O.B. Cope and C.C. VanValin. 1963. Science. 142:958.

Anderson, D.W. and J.J. Hickey. 1972. Eggshell Changes in Certain North American Birds. In: Proc. XV International Ornithological Congress, Laiden.

Anderson, D.W., J.R. Jehl, R.W. Risebrough, L.A. Woods, Jr., L. R. Deweese and W.G. Edgecomb. 1975. Science. 190:806.

Anderson, J.M. 1968. J. Fish. Res. Board Can. 25:2677.

Anderson, J.M. and M.R. Peterson. 1969. Science. 164:440.

Anderson, J.P.E., E.P. Lichtenstein and W.F. Whittingham. 1970. J. Econ. Entomol. 63:1595.

Aubin, A.E. and P.H. Johansen. 1969. Can. J. Zool. 47:163.

Bailey, G.W. and J.L. White. 1964. J. Agr. Food Chem. 21:324.

Bailey, G.W. and J.L. White. 1970. Residue Reviews. 32:29.

Bailey, R.L. 1973. Ph.D. Thesis. Univ. Georgia, Athens, GA.

Bailey, S., P.J. Bunyan, D.M. Jennings, J.D. Norris, P.I. Stanley and J.H. Williams. 1974. Agro. Ecosystems. 1:323.

Baker, R.D. and H.G. Applegate. 1970. Agron. J. 62:509.

Batterton, J.C., G.M. Boush and F. Matsumura. 1972. Science. 176:1141.

Bedford, J.W. and M.J. Zabik. 1973. Arch. Environ. Contam. Toxicol. 1:97.

Blus, L.J., A.A. Belisle and R.M. Prouty. 1974. Pest. Monit. J. I:181.

Blus, L.J., C.D. Gish, A.A. Belisle and R.M. Prouty. 1972. Nature. 235:376.

Bowes, G.W. 1972. Plant Physiol. 49:172.

Bowman, M.C., F. Acree, Jr. and M.L. Corbett. 1960. J. Agr. Food Chem. 8:406.

Bowman, M.C., F. Acree, Jr., C.H. Schmidt and M. Beroza. 1959. J. Econ. Entomol. 52:1038.

Bowman, M.C., F. Acree, Jr., C.S. Lofgren and M. Beroza. 1964. Science. 146:1480.

Bowman, M.C., M.S. Schecter and R.L. Carter. 1965. J. Agr. Food Chem. 13:360.

Buhler, D.R. and W.E. Shanks. 1972. J. Fish Res. Board Can. 27:347.

Buhler, D.R., M.E. Rasmusson and W.E. Shanks. 1969. Toxicol. Appl. Pharmacol. 14:535.

Burdick, G.E., E.J. Harris, H.J. Dean, T.M. Walker, J. Skea and D. Colby. 1964. Trans. Am. Fish. Soc. 93:127.

Burdick, G.E., H.J. Dean, E.J. Harris, J. Skea, R. Karcher and C. Frisa. 1972. NY Fish Game J. 19:97.

Burge, W.D. 1971. J. Agr. Food Chem. 19:375.

Campbell, R.D., T.D. Leadem and D. Johnson. 1974. Bull. Environ. Contam. Toxicol. 11:425.

Castro, T.F. and T. Yoshida. 1971. J. Agr. Food Chem. 19:1168.

Castro, T.F. and T. Yoshida. 1974. Soil Sci. Plant Nutr. 20:363.

Champion, D.F. and S.R. Olsen. 1971. Soil Sci. Soc. Amer. Proc. 35:887.

Chiou, C.T., L.J. Peters and V.H. Freed. 1979. Science. 206:831.

Chisholm, D. and A.W. MacPhee. 1972. J. Econ. Entomol. 65:1010.

Clark, D.R., Jr. and R.M. Peouty. 1977. J. Toxicol. Environ. Health. 2:917.

Cliath, M.M. and W.F. Spencer. 1972. Environ. Sci. and Technol. 6:910.

Cooke, A.S. 1973. Environ. Pollution. 4:85.

Crosby, D.G. et al. 1966. Food Cosmat. Toxicol. 4:503.

Cuerrier, J.P., J.A. Keith and E. Stone. 1967. Naturaliste Can. 94:315.

Davis, B.N.K. 1971. Soil Biol. Biochem. 3:221.

Davis, B.N.K. and M.C. French. 1969. Soil Biol. Biochem. 1:45.

Davy, F.B. and H. Kleerekoper. 1973. Water Resour. Res. 9:900.

Desaiak, D., L.K. Cutkomp, R.B. Koch and A. Jarvinen. 1975. Arch. Environ. Contam. Toxicol. 3:132.

Dill, P.A. and R.C. Sanders. 1974. J. Fish Res. Board Can. 21:1936.

Dimond, J.B., G.Y. Belyea, R.E. Kadunce, A.S. Getchall and J.A. Bleose. 1970. Can. Entomol. 102:1122.

Dziuk, L.J. and F.W. Plapp. 1973. Bull. Environ. Contam. Toxicol. 9:15.

Eberhardt, L.L., R.L. Meeks and T.J. Peferle. 1971. Nature. 230:60.

Edwards, C.A. 1966. Residue Reviews. 13:83.

Edwards, C.A. and K. Jeffs. 1974. Nature. 247:157.

Ekstedt, J. 1975/76. Grundforbattring. 27:179.

Ellgaard, E.G., J.C. Ochsner and J.K. Cox. 1977. Can. J. Zool. 55:1077.

Environmental Protection Agency. 1978. Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life. [43 FR 21506 (May 18, 1978) and 43 FR 29028 (July 5, 1978)].

Environmental Protection Agency. 1979. Ambient Water Quality Criteria for DDT. Environmental Protection Agency Criteria and Standards Division, Office of Water Planning and Standards. Washington, D.C.

Environmental Protection Agency. 1978. Federal Register. May 18, 48, No. 97:21506.

Farmer, W.J., K. Igue, W.F. Spencer and J.P. Martin. 1972. Soil Sci. Soc. Amer. Proc. 36:443.

Farmer, W.J., K. Ingue, W.F. Spencer. 1973. J. Environ. Qual. 2:107.

Ferguson, D.E 1965b. J. Miss. Acad. Sci. 11:235.

Ferguson, D.E. et al. 1965a. J. Miss. Acad. Sci. 11:239.

Ferguson, D.E., D.D. Culley, W.D. Cotton and R.P. Dodds. 1964. Bioscience. 14:43.

Fleming, W.J. 1980. Summary DDT Residues in Waterfowl Wings From Alabama. Letter Fleming to Green. Jan. 3, 1980.

Focht, D.D. 1972. Bull. Environ. Contam. Toxicol. 7:52.

Food and Drug Administration. 1978. Administrative Guidelines Manual No. 7420.08, revised 10/5/78. Washington, D.C.

Food and Drug Administration. 1979. Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed. Washington, D.C.

Frank, R., A.E. Armstrong, R.G. Boelens, H.E. Braun and C.W. Douglas. 1974. Pest. Mon. J. 7:165.

Frank, R., K. Montgomery, H.E. Braun, A.H. Berst and K. Loftus. 1974a. Pest. Mon. J. 8:184.

Fredeen, F.J.H. 1972. Can. Entomologist. 104:945.

Freed, V.H. Transport and Accumulation. In: J.W. Gillett (ed.); Global Distribution of Pesticides. Environ. Health Ser. No. 1, Oregon State Univ.

Friend, M. and D.O. Trainer. 1974. Bull. Environ. Contam. Toxicol. 11:49.

Gardner, D.R. 1973. Pest. Bioch. Phys. 2:437.

Gaufia, A.R. et al. 1965. Water Sewage Works. 12:276.

Gish, C.D. 1970. Pest. Mon. J. 3:241.

Glass, B.L. 1972. J. Agr. Food Chem. 20:324.

Guenzi, W.D. and W.E. Beard. 1976a. J. Environ. Qual. 5:391.

Guenzi, W.D. and W.E. Beard. 1970. Soil Sci. Soc. Amer. Proc. 34:443

Guenzi, W.D. and W.E. Beard. 1976. J. Environ. Qual. 5:243.

Gunther, F.A., W.E. Westlake and P.S. Jaglan. 1968. Residue Reviews. 20:1.

Hamaker, J.W. 1972. Organic Chemicals in the Soil and Environment. Marcel-Dekker, NY, p. 341.

Hamelink, J.L. and R.C. Waybrant. 1976. Trans. Am. Fish. Soc. 105:124.

Hamelink, J.L., R.C. Waybrant and R.C. Ball. 1971. Trans. Am. Fish. Soc. 100:207.

Hansen, D.J., E. Matthews, S.L. Nall, D.P. Duman. 1972. Bull. Environ. Contam. Toxicol. 8:46.

Hargele, M.A. and R.N. Hudson. 1974. Arch. Environ. Contam. Toxicol. 2:356.

Harris, C.R. 1970. Persistence and Behavior of Soil Insecticides. In: Pesticides in the Soil, Michigan St. Univ. p. 58.

Hartley, G.S. 1969. Adv. Chem. Ser. 86:115.

Haseltine, S., K. Vebelhart, T. Peterle, and S. Lustick 1974. Bull. Environ. Contam. Toxicol. 11:139.

Heath, R.G. 1969. Pest. Monit. J. 3:115.

Heath, R.G., J.W. Spann, and J.F. Kreitzer. 1969. Natura 224:47.

Heinz, G.H. 1976. Bull. Environ. Contam. Toxicol. 16:640.

Henderson, C. et al. 1959. Trans. Am. Fish Soc. 88:23.

Henny, C.J., R.A. Olsen, and D.L. Meeker. 1977. Bull. Environ. Contam. Toxicol. 18:115.

Hill, E.F., W.E. Dale, and J.W. Miles. 1971. Toxicol. Appl. Pharms. 20:502.

Hodkinson, M. and S.A. Dalton. 1973. Bull. Environ. Contam. Toxicol. 10:356.

Hubbell, D.H., D.F. Rothwell, W.B. Wheeler, W.B. Tappan, and F.M. Rhoads. 1973. J. Environ. Qual. 2:96.

Hulbert, S.H. 1975. Secondary Effects of Pesticides on Aquatic Ecosystems. Residue Reviews 75:81-148.

Hummon, W.D. 1974. Amer. Midland Naturalist 92:327.

Janke, D. and W. Fritsche. (1978). Zeitschrift fur Allgemeine Mikrobiologie 18:365.

Jarvinen, A.W. et al. 1977. J. Fish. Res. Board Con. 34:2089.

Jensen, L.D. and A.R. Gaufin. 1964. Trans. Am. Fish. Soc. 93:357.

Jensen, S., R. Gothe, and M.O. Kindst. 1972. Nature 240:421.

Johnsen, H.E., and C. Pacor. 1969. Trans N. Am. Wildl. Nat. Resour. Conf. 34:159.

Johnsen, R.E. 1976. Residue Reviews 61:1.

Johnson, B.T., C.R. Saunders, and H.O. Sanders. 1971. J. Fish. Res. Board Can. 28:705.

Juengst, F.W., Jr., and M. Alexander. 1976. J. Agr. Food Chem. 24:111.

Katz, M. 1961. Trans. Am. Fish. Soc. 90:264.

Keil, J.E. and L.E. Priester. 1969. Bull. Environ. Contam. Toxicol. 4:169.

Kiigemagi, U. and L.C. Terriere. 1972. Bull. Environ. Contam. Toxicol. 7:348.

King, S.F. 1962. USDI. Spec. Sci. Rep. Fish. 339:22.

Klaverkamp, J.F., A.L. Higer, and M.L. Yates. 1976. J. Fish. Res. Board Can. 33:1331.

Kolaja, G.J. and D.E. Hinton. 1976. Environ. Pollut. 10:225.

Kolaja, G.J. and D.E. Hinton. 1977. J. Toxicol. Environ. Health 3:699

Kolipinski, M.C. 1971. Pest. Monit. J. 5:281.

Korn, S. and R. Earnest. 1974. Calif. Fish and Game 60:128.

Kouyoumjian, H.H. and R.F. Uglow. 1974. Environ. Pollut. 7:103.

Kuhr, R.J., A.C. Davis and E.F. Taschenberg. 1972. Bull. Environ. Contam. Toxicol. 8:329.

Kynard, B. 1974. Trans. Fish. Soc. 103:557.

Lake Michigan Interstate Pesticide Committee. 1972. U.S. Environ. Prot. Agency, EPA-R3-72-003.

Lichtenstein, E.P. 1965. Research in Pesticides. New York, Academic Press. p. 199.

Lichtenstein, E.P. and K.R. Schulz. 1959. J. Econ. Entomol. 52:124.

Lichtenstein, E.P., J. Katan, and B.N. Anderegg. 1977. J. Agr. Food Chem. 25:43.

Lichtenstein, E.P., L.J. DePew, E.L. Eshbaugh, and J.P. Sleesman. 1960. J. Econ. Entomol. 53:136.

Lichtenstein, E.P., T.W. Fuhremann and K.R. Schulz. 1971. J. Agr. Food Chem. 19:718.

Lincer, J.L. 1975. J. Appl. End. 12:781.

Lincer, J.L., J.M. Solon, J.H. Nair, III. 1970. Trans. Am. Fish Soc. 99:13.

Livingston, R.J. 1977. CRC Critical Rev. in Environ. Control. p. 325.

Longcore, J.R. and F.B. Samson. 1973. J. Wildlife Management. 37:390.

Longcore, J.R. and R.C. Stendell. 1977. Arch. Environ. Contam. Toxicol. 6:293.

Longcore, J.R., F.B. Samson, and T.W. Whittendale, Jr. 1971. Bull. Environ. Contam. Toxicol. 6:485.

Lee, S.S., S.C. Fang, and V.H. Freed. 1976. Pestic. Biochem. Physiol. 6:46

Longcore, J.R., F.B. Samson, J.F. Kreitzer and J.W. Spann. 1971a. Bull. Environ. Contam. Toxicol. 6:345.

Lopez-Gonzales, J.D. and C. Valenzuela-Calahorro. 1970. J. Agr. Food Chem. 18:520.

Lopez-Gonzales, J.D., M.A. Banares Munoz and J. Lopex. (1975). Anales de Quimica 71, 482.

Lunn, C.R., D.P. Toews, and D.J. Pree. 1976. Am. J. Zool. 54:214.

Macek, K.J. and H.D. Sanders. 1970. Trans. Am. Fish. Soc. 99:89.

Macek, K.J. and S. Korn. 1970. J. Fisheries Res. Board of Can. 27:1496.

Macek, K.J. and W.A. McAllister. 1970a. Trans Am. Fish. Soc. 99:20.

Macek, K.J. and W.A. McAllister. 1970. Trans Am. Fish. Soc. 99:89.

Maki, A.W. and H.E. Johnson. 1975. Bull. Environ. Chem. Contam. Toxicol. 13:412.

Marcek, K.J. 1968. J. Fish. Res. Board Can. 25:1781.

Marking, L.L. 1966. "Evaluating p,p-DDT as a Reference Toxicant in Bioassays." An Investigation in Fish Control. U.S. Fish Wildl. Am. Resour. Bull. 14:10.

Marking, L.L. 1966. "Evaluating p,p-DDT as a Reference Toxicant in Bioassays." An Investigation in Fish Control. U.S. Fish Wildl. Am. Resour. Bull. 14:10.

Martin, J.P. 1966. Pesticides and Their Effects on Soil and Water, Soil Sci. Soc. Amer., ASA Spec. Publ. No. 8, Madison, Wisc.

McCall, P.J., R.L. Swann, D.A. Laskowski, S.A. Vrona, S.M. Unger and H.J. Dishburger (Unpublished). "Prediction of Chemical Mobility in Soil from Sorption Coefficients."

McCall, P.J., R.L. Swann, D.A. Laskowski, S.M. Unger, S.A. Vrona and H.J. Dishburger (Unpublisheda). "Prediction of Chemical Mobility in Soil from HPLC Retention Times."

McLane, M.A.R. and L.C. Hall. 1972. Bull. Environ. Contam. Toxicol. 8:65.

McNicholl, P.G. and W.C. MacKay. 1975. J. Fish. Res. Board Am. 32:785.

Menzie, C.M. 1972. Ann. Rev. Entomol. 17:199.

Metcalf, R.L. and J.N. Pitts, Jr. 1969. Advances in Environmental Sciences, Vol. I, New York, Wiley-Interscience.

Metcalf, R.L., G.K. Spangha and I.P. Kapoor. 1971. Environ. Sci. Technol. 5:709.

Metcalf, R.L., I.P. Kapoor, A.S. Hirwe. 1971. Bull. Wld. Hlth. Org. 44:363.

Metcalf, R.L., I.P. Kapoor, P.Y. Lu, C.K. Schuth and P. Sherman (1973). Environ. Health Persp., June, p. 35.

Metcalf, R.L., J.R. Sanborn, P.Y. Lu and D. Nye. 1975. Arch. Environ. Contam. Toxicol. 3:151.

Miles, J.R.W. and C.R. Harris. 1973. Pest. Monit. J. 6:363.

Miles, J.R.W. and C.R. Harris. 1978 J. Econ. Entomol. 71:125.

Miles, J.R.W., C.R. Harris and P. Moy. 1978. J. Econ. Entomol. 71:97.

Miller, D.L. and D.M. Ogilvie. 1975. Bull. Environ. Contam. Toxicol. 14:545.

Miyazaki, S. and A.J. Thorsteinson. 1972. Bull. Environ. Contam. Toxicol. 8:81.

Moffett, G.B. and J.D. Yarbrough. 1972. J. Agr. Food Chem. 20:558.

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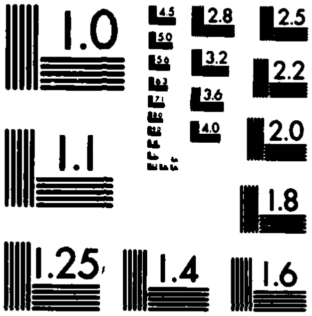

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Moore, R.B. and D.A. Dorward. 1968. J. Phycol. 4 (Suppl.), p.7.

Murphy, P.G. 1970 Bull. Environ. Contam. Toxicol. 5:404.

Nash, R.G. and E.A. Woolson. 1967. Science 157:924.

Nevdorf, S. and M.A.Q. Khan. 1975. Bull. Environ. Contam. Toxicol. 13:443.

Ogilvie, D.M. and D.C. Miller. 1976. Bull. Environ. Contam. Toxicol. 16:86.

Ogilvie, D.M. and J.M. Anderson. 1976. J. Fish. Res. Board Am. 22:503.

Parr, J.F., and S. Smith. 1974. Soil Sci.. 118:45.

Parr, J.F., G.H. Willis and S. Smith. 1970. Soil Science 110:306.

Patil, K.C., F. Matsumura and G.M. Boush. 1970. Appl. Micro. 19:879.

Patil, K.C., F. Matsumura and G.M. Boush. 1972. Environ. Sci. Technol. 6:629.

Peaslee, M.H. 1970. Gen. Comp. Endocrinol. 14:594.

Peterson, R.H. 1973. J. Fish Res. Board Can. 20:1091.

Peters, C.F. and D.D. Weber. 1977. DDT Effect on the Lateral Line Nerve of Steelhead Trout. In: Physiological Response of Marine Biota to Pollutants. Academic Press, NY. p. 75.

Pfaender, F.K. and M. Alexander. 1972. J. Agr. Food Chem. 20:842.

Phillips, J.B. and M.R. Wells. 1974. J. Agr. Food Chem. 22:404.

Pollero, R. and S.C. dePollero. 1978. Bull. Environ. Contam. Toxicol. 19:345.

Porter, R.D. and S.N. Weimeyer. 1969. Science. 165:199.

Porter, R.D. and S.N. Weimeyer. 1972. Bull. Environ. Contam. Toxicol. 8:193.

Post, G. and T.R. Schroeder. 1971. Bull. Environ. Contam. Toxicol. 6:144.

Priester, E.L., Jr. 1965. Ph.D. Thesis, Clemson Univ., Clemson, SC.

QueHee, S.S., R.G. Sutherland, K.S. McKinley and J.G. Saha. 1975. Bull. Environ. Contam. Toxicol. 13:284.

Rawash, I.A., I.A. Gaaboub, F.M. El-Gayar and A.Y. El-Shazli. 1975. Toxicol. 4:133.

Reinert, R.E. 1970. Pest. Monit. J. 3:233.

Reinert, R.E. and H.L. Bergman. 1974. J. Fish. Res. Board Can. 31:1649.

Reinert, R.E. and L.J. Stone. 1974. Proc. 17th Conf. Great Lakes Res. 52.

Rice, C.P. and H.C. Sikka. 1973. J. Agr. Food Chem. 21:148.

Robbins, C.S. P.F. Springer and C.G. Webster. 1951. J. Wildlife Management. 15:213.

Sanborn, J.R., W.F. Childers and R.L. Metcalf. 1975. Bull. Environ. Contam. Toxicol. 13:209.

Sanders, H.O. and O.B. Cope. 1968. Limnol. Oceanog. 13:112.

Sanders, H.O. 1966. Trans. Am. Fish. Soc. 95:165.

Sanders, H.O. 1969. Bur. Sport Fish. Wild. Tech. Paper. 25:18.

Sanders, H.O. 1970. Copeia. No. 2:246.

Sanders, H.O. 1972. Bur. Sport Fish. Wild. Tech. Paper. 66:19.

Schaumberg, F.D. et al. 1967. Water Res. 1:731.

Sethunathan, N. 1973. Residue Reviews. 47:143.

Shin, Y-O, J.J. Chodan and A.R. Wolcott.1970. J. Agr. Food Chem. 18:1129.

Smith, S. and J.F. Parr. 1972. J. Agr. Food Chem. 20:839.

Sodergren, A. 1968. Oikos. 19:126.

Sodergren, A. and B. Svensson. 1973. Bull. Environ. Contam. Toxicol. 9:345.

Spencer, W.F. and M.M. Cliath. 1972. J. Agr. Food Chem. 20:645.

Spencer, W.F. and M.M. Cliath. 1973. J. Environ. Qual. 2:284.

Spencer, W.F. 1970. Pesticides in the Soil; Ecology, Degradation and Movement. Michigan State Univ. 120.

Spencer, W.F. 1975. Residue Reviews. 59:91

Stadnyk, L., R.S. Campbell and B.T. Johnson. 1971. Bull. Environ. Contam. Toxicol. 6:1.

Stickel, L.F. 1973. *Pesticides in Birds and Mammals.* In: Environmental Pollution by Pesticides. C.A. Edwards (ed). Plenum Press, NY and London.

Stickel, L.F. 1968. Organochlorine Pesticides in the Environment. USDI Fish and Wild. Ser. Special Scientific Report Wild. No. 119. Washington, DC.

Stickel, L.F. and L.I. Rhodes. 1970. The Thin Eggshell Problem. Proc. of Symposium: The Biological Impact of Pesticides in the Environment. Environ. Health Sci. Ser. No. 1:31.

Stickel, L.F. and W.H. Stickel. 1969. Industrial Med. and Surgery. 38:44.

Stickel, W.H. 1975. Some Effects of Pollutants in Terrestrial Ecosystems. In: Ecological Toxicology Research. A.D. McIntyre and C.F. Mills. (eds). Plenum Publishing Corp., NY.

Subba-Rao, R.V. and M. Alexander. 1977. J. Agr. Food Chem. 25:327.

Sundaram, K.M.S. 1974. Bimonthly Res. Notes. 30:14.

Swann, R.L., P.J. McCall, D.A. Laskowski and H.J. Dishburger. (Unpublished). Estimation of Soil *Sorption Constants of Organic* Chemicals by HPLC.

Talekar, N.S., L-T Sun, E-M Lee and J-S Chen. 1977. J. Agr. Food Chem. 25:348.

Tooby, E., P.A. Hursey, J.S. Alabaster. 1975. Chem. Ind. 12:523.

Walker, P.G. and C.M. Weiss. 1971. Trans. Am. Fish. Soc. 100:222.

Ware, G.W., B. Estesen, W.C. Kronland and W.P. Cahill. 1977. Bull. Environ. Contam. Toxicol. 17:317.

Weis, P. and J.S. Weis. 1974. Environ. Res. 7:68.

Wheeler, W.B. 1980. Unpublished data.

White, D.H. 1979. Pest. Monit. J. 13:12.

White, J.L. and M.M. Mortland. 1970. Pesticides in the Soil; Ecology Degradation and Movement. Michigan State University. 95.

Willis, G.H., J.F. Parr and S. Smith. 1971. Pest. Mon. J. 4:204.

Wolfe, L., R.G. Zepp, D.F. Paris, G.L. Baughman and R.C. Hollis. 1977. Environ. Sci. Technol. 11:1077.

Yadav, D.V., H.C. Agarwal and M.K.K. Pillai. 1978. Bull. Environ. Contam. Toxicol. 19:300.

Yadav, D.V., M.K.K. Pillai and H.C. Agarwal. 1976. Bull. Environ. Contam. Toxicol. 16:541.

Yang, C.F. and Y.P. Sun. 1977. Arch. Environ. Contam. Toxicol. 6:325.

Young, R.G., L. St. John and D.J. Lisk. 1971. Bull. Environ. Contam. Toxicol. 6:351.

Yule, W.N. 1973. Bull. Environ. Contam. Toxicol. 9:57.

Yule, W.N., M.J. Hildebrand, G.G. Smith and R.S. Fox. 1972. Bull. Environ. Contam. Toxicol. 8:19.

II. SITE SPECIFIC INFORMATION AND ANALYSIS

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II. SITE SPECIFIC INFORMATION AND ANALYSIS

1.0 - A HISTORICAL REVIEW OF DDT MANUFACTURE AND SUBSEQUENT ENVIRONMENTAL IMPACT AT REDSTONE ARSENAL

1.1 MANUFACTURING PLANT HISTORY

Following lease negotiations with Redstone Arsenal the Calabama Chemical Company began the manufacture of DDT in 1947. According to a Department of the Army report (CDIR, 1977) other concerns involved in the overall operation were Solvoy Process Division of Allied Chemical and Dye Corporation and John Powell and Company. Calabama, however, was on the RSA property and responsible for unit operations. Figure II-1 presents a chronology of activities related to initiation of the plant operation and subsequent impact.

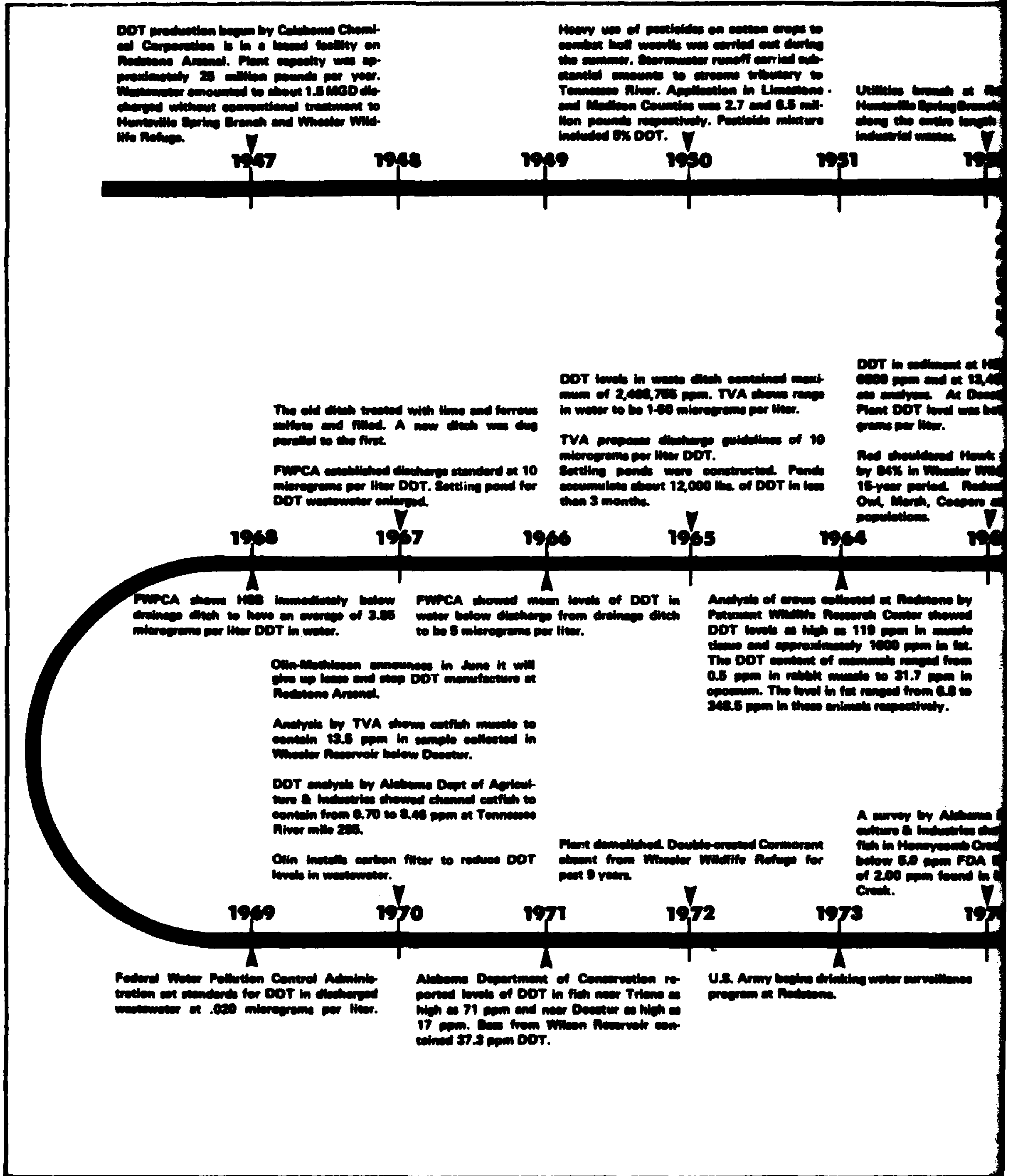
The plant was located in the 5000 section of the Arsenal where process wastewater entered a drainage ditch which discharged to Huntsville Spring Branch. There are no available records regarding DDT production at that time. However, estimated wastewater volume was 1.5 mgd. Treatment of process wastes was not done and residual pesticide entered Huntsville Spring Branch, a tributary to the Tennessee River. Wastewater was characterized as shown in Table II-1. The amount of DDT in the wastewater ranged up to 0.5 mg/l mainly as particulates.

Seven years later in 1954 the Olin Mathieson Chemical Company became the lessee and continued DDT manufacture. No improvements for treatment of wastewaters were carried out until 1965 when a settling pond was constructed. During this time production was estimated at 1 to 2 million pounds per month (USPHS, 1964). Olin kept the facility operating on a 7-day schedule. By 1969, 2,250,000 pounds were being manufactured monthly which was near the 2.5 million production capacity of the plant (AEHA, 1969).

1.2 PRIOR CONTROL EFFORTS

A review of the chronology of waste treatment shows that the settling pond constructed in 1965 was enlarged two years later. Plant personnel estimated that 12,000 pounds of DDT accumulated by sedimentation in four months (AEHA, 1965). Also at the time of the settling pond modification the ditch conveying wastewater from the plant was treated with 70 tons of lime and 400 pounds of $FeSO_4$ and filled in. A new ditch was constructed alongside. This modification was completed to meet water quality standards that had been imposed by the Federal government. These standards for DDT required that concentrations in wastewater discharged to Huntsville Spring Branch not exceed 10 µg/l. The original ditch conveying wastewater had accumulated so much DDT that the ditch itself was a source and posed a problem for Olin in meeting the standards.

In February 1970 Olin installed a carbon filter at the outlet of the settling pond to keep the DDT level at or below the 10 µg/l limit for discharge (AEHA, 1969). Sometime later the same year the Federal Water



DDT production begun by Calabama Chemical Corporation is in a leased facility on Redstone Arsenal. Plant capacity was approximately 25 million pounds per year. Wastewater amounted to about 1.5 MGD discharged without conventional treatment to Huntsville Spring Branch and Wheeler Wildlife Refuge.

Heavy use of pesticides on cotton crops to combat boll weevils was carried out during the summer. Stormwater runoff carried substantial amounts to streams tributary to Tennessee River. Application in Limestone and Madison Counties was 2.7 and 6.5 million pounds respectively. Pesticide mixture included 5% DDT.

Utilities branch at R
Huntsville Spring Branc
along the entire length
industrial wastes.

DDT in sediment at H
6880 ppm and at 13,4
ate analyses. At Dec
Plant DDT level was be
grams per liter.

Red shouldered Hawk
by 84% in Wheeler Wi
15-year period. Redu
Owl, Marsh, Coopers a
populations.

Analysis of crows collected at Redstone by Patuxent Wildlife Research Center showed DDT levels as high as 119 ppm in muscle tissue and approximately 1600 ppm in fat. The DDT content of mammals ranged from 0.5 ppm in rabbit muscle to 31.7 ppm in opossum. The level in fat ranged from 6.8 to 348.5 ppm in these animals respectively.

DDT levels in waste ditch contained maximum of 2,486,785 ppm. TVA shows range in water to be 1-60 micrograms per liter.

TVA proposes discharge guidelines of 10 micrograms per liter DDT.
Settling ponds were constructed. Ponds accumulate about 12,000 lbs. of DDT in less than 3 months.

FWPCA showed mean levels of DDT in water below discharge from drainage ditch to be 5 micrograms per liter.

The old ditch treated with lime and ferrous sulfate and filled. A new ditch was dug parallel to the first.

FWPCA established discharge standard at 10 micrograms per liter DDT. Settling pond for DDT wastewater enlarged.

FWPCA shows HSB immediately below drainage ditch to have an average of 3.85 micrograms per liter DDT in water.

Federal Water Pollution Control Administration set standards for DDT in discharged wastewater at .020 micrograms per liter.

Olin-Mathieson announces in June it will give up lease and stop DDT manufacture at Redstone Arsenal.

Analysis by TVA shows catfish muscle to contain 13.5 ppm in sample collected in Wheeler Reservoir below Decatur.

DDT analysis by Alabama Dept of Agriculture & Industries showed channel catfish to contain from 0.70 to 8.46 ppm at Tennessee River mile 285.

Olin installs carbon filter to reduce DDT levels in wastewater.

Alabama Department of Conservation reported levels of DDT in fish near Triana as high as 71 ppm and near Decatur as high as 17 ppm. Bass from Wilson Reservoir contained 37.3 ppm DDT.

Plant demolished. Double-crested Cormorant absent from Wheeler Wildlife Refuge for past 9 years.

U.S. Army begins drinking water surveillance program at Redstone.

A survey by Alabama
culture & Industries s
fish in Honeycomb Cre
below 5.0 ppm FDA
of 2.00 ppm found in
Creek.

FIGURE II-1. Chronology of Events Resulting from DDT Manufacture at Redstone Arsenal

SOURCE: WATER AND AIR RESEARCH, INC., 1980

51

Utilities branch at Redstone noted that Huntsville Spring Branch was grossly polluted along the entire length with municipal and industrial wastes.

1952

1953

Alabama Department of Conservation conducted biological surveys in selected north Alabama streams to assess impact of heavy pesticide use on crops in the summer of 1950. The Department concluded that the community structure in fish and macroinvertebrates showed alteration from pesticides.

Olin Mathieson Chemical Company purchased Calabama Chemical Co. and continued manufacture of DDT.

1954

1955

1956

1957

1958

Wheeler Wildlife Refuge personnel note a 97.5% reduction in the Double-crested Cormorant population. During a 10 year period from 1949 Cormorants annually visiting the Refuge was reduced from 2000 to 50 birds.

1959

1960

1961

1962

DDT in sediment at HSBM 4.7 estimated at 6600 ppm and at 13,400 ppm in two separate analyses. At Decatur Water Treatment Plant DDT level was between 20-670 micrograms per liter.

Red shouldered Hawk population reduced by 84% in Wheeler Wildlife Refuge within a 15-year period. Reductions also in Barred Owl, Marsh, Coopers and Red-tailed Hawk populations.

1963

64

llected at Redstone by
search Center showed
as 119 ppm in muscle
ately 1600 ppm in fat.
mammals ranged from
muscle to 31.7 ppm in
fat ranged from 6.8 to
nimals respectively.

73

king water surveillance

A survey by Alabama Department of Agriculture & Industries showed DDT content in fish in Honeycomb Creek & Limestone Creek below 5.0 ppm FDA limit. Maximum level of 2.00 ppm found in bluegill in Limestone Creek.

1974

1975

Landfills containing DDT on Redstone (area 5000) were closed.

1976

1977

FDA monitors fish in Tennessee River and selected fish markets. DDT levels in some samples well above 5 ppm limit.

AEHA surveyed land, water, sediments and animal life. Fish were found to have an average of 63.58 ppm DDTR and considered unsafe for consumption.

Water and sediment samples showed high concentrations of DDT.

Abatement program suggested to stop migration of DDT from Redstone to Huntsville Spring Branch. TVA data show catfish at TRM 275-292 contained about 5 ppm. TVA estimate that 4000 tons of DDT in sediments from HSBM 2.45 to 5.9. Ducks collected in Wheeler Refuge showed DDT levels to be comparable to levels found in fish. Total DDTR in waterfowl ranged from 1.2 to 2252 ppm.

1978

1979

Federal task force implements study to determine extent of DDT contamination and alternative actions to prevent further contamination of the Tennessee River, COE Mobile District given responsibility to lead group.

Double-crested Cormorant slowly increasing during past 6 years in Wheeler Refuge.

Redstone puts activated carbon filtration plant on line to abate DDT contamination from drainage ditch.

ne Arsenal

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters,Wheeler Reservoir, Alabama

1 2

Table II-1. Wastewater Characteristics from DDT Manufacture at RSA

Calcium chloride	Monochlorobenzene
Hydrochloric acid	Hypochlorites
DDT	Chloral
	Sulfuric and Sulfonic Acid

Note: DDT levels ranged up to 0.5 mg/l.

Source: Industrial Wastes Survey Redstone Arsenal, 1964 - USPHS.

Quality Administration placed a limit of 20 parts per trillion as the amount of DDT that could be released in process water. Production of DDT stopped by June 1970 as Olin could not treat their wastewater in a manner that would reduce DDT to this level.

Two other pesticides were later manufactured at the site. Trichloroacetonitrite (TCAN) was produced for less than a month and methoxychlor was produced for about six months. In early 1972, the plant was demolished.

Since that time extenesive restoration of the site has been carried out. Short term containment measures were completed in 1977. These included filling and sealing the old settling basin, diversion of drainage around the old plant site, and installation of two dams in the drainage ditch to create sediment retention ponds. In January 1979, a water filtration/carbon adsorption unit was installed to further treat the water leaving the drainage ditch. Later in 1979 surface soils at the old plant site were removed and placed in a state approved landfill located on the Arsenal. Further restoration has included excavation and landfilling of contaminated sediments in the old ditch, stabilization of old disposal sites to preclude surface erosion, and installation and operation of a subsurface water monitoring system. Based on these actions future migration of DDTR from Arsenal property to Huntsville Spring Branch should be negligible.

1.3 HISTORICAL CHRONOLOGY OF CONTAMINATION

The record of events relating to Olin's facility and the spread of DDT in the environment shows that no aquatic surveys were conducted for 16 years following plant startup and operation. As an agricultural chemical DDT was widely used on lands within the drainage basin of the Tennessee River. Pest control on crops such as cotton and soybeans was carried out by application of DDT and other organochlorine insecticides. There was no data during the late 1940's of DDT impact on the environment via biomagnification and bioconcentration through food webs. The risk to man as far as health effects was considered insignificant.

By 1963 the Public Health Service and TVA were conducting surveys to determine the extent of DDT migration and levels of the compound in water and sediment. There was increasing evidence of toxic effects to the biota (USPHS, 1964).

1.3.1 Water Quality Surveys

The utilities branch at Redstone carried out some of the early surveys. Although no data are available, the general conclusion following water and sediment analysis is that Huntsville Spring Branch was grossly polluted and reflected the effect of industrial wastes from industry and Arsenal activities on water quality. Aside from wastes originating from Huntsville, other firms on or near the Arsenal contributed wastewater to Huntsville Spring Branch. Components included chlorine and caustics (Stauffer Chemical), iron and nickel carbonyls (GAF), rocket propellants

(Thiokol), and other residues related to rocket research and production (COE, 1966).

The pollution of Indian Creek and Huntsville Spring Branch (HSB) continued unabated and without apparent concern during the 1950's. Increasing frequency of fish kills and other pollution related events in all probability led to sampling efforts to establish water quality levels. The first of these was initiated by the Public Health Service in 1963 (USPHS, 1964). Table II-2 presents data showing the levels of DDTR in Indian Creek and Huntsville Spring Branch. Some limited information on Wheeler Reservoir near Decatur is also included. It should be remembered that contamination of these surface waters also included beryllium, chromium, cyanide, cadmium, acids and other unknown components related to the rocket research program at Redstone. These substances along with DDT wastewater led to the biological degradation of the Indian Creek - Huntsville Spring Branch system (CDIR, 1977).

Sampling related to DDT residues was sporadic until late 1967 when the Federal Water Pollution Control Administration established a station at Mile Marker 5.4 on Huntsville Spring Branch. Monthly collections were made until May, 1969. Whether these samples represented composites or grabs is not known. The values ranged from 0.3 to 60 ug/l and included analyses for the first four months of 1970 when the program evidently was discontinued.

Following cessation of DDT manufacture no water samples were analyzed for this residue until 1977. These results (Table II-3) show lower DDT values than during the 1960-1970 period. Relatively little significance can be attributed to the data since the sampling sites are not comparable. Analyses also were conducted on Tennessee River water. As the table shows, DDTR did not exceed 0.05 ug/l and most were less than 0.03 ug/l. Since DDT is only slightly soluble in water and highly sorptive on organic and inorganic particulates the main sink is the sediments in aquatic systems.

1.3.2 DDT Levels in Aquatic Sediments

Work on the DDT levels in sediments has principally been carried on by various Federal agencies. These are the Public Health Service, TVA, the Army Environmental Hygiene Agency (AEHA) and the Chemical Demilitarization and Installation Restoration group (CDIR), now designated as the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). Sampling and analysis of sediments was intermittent and was begun in 1963. There seemed to be little to no coordination among agencies with regard to station location or data sharing until perhaps 1978-1979.

A review of the available information presented in the accompanying Tables II-4 to II-6 shows a trend toward increasing levels from Indian Creek Mile 0 (ICM-0) to Huntsville Spring Branch Mile 5+ (HSBM-5+) near the confluence of the DDT drainage ditch. Direct comparisons are difficult as sample sites varied from midchannel to overbank and samples

Table II-2. Concentrations of DDT in Surface Water to 1970 (ug/l)

Date	Location	DDT	DDE	DDD	DDTR	Data Source
11/63	HSBM 5.7	---	0.33	---	0.33	USPHS
11/63	HSBM 4.7	1.6	4.1	---	5.7	USPHS
11/63	ICM 4.6	0.06	---	---	0.06	USPHS
12/63	HSBM 5.7	0.14	---	---	0.14	USPHS
12/63	HSBM 4.7	47	---	---	47	USPHS
12/63	ICM 4.6	0.51	---	---	0.51	USPHS
12/63	HSBM 5.7	0.05	---	---	0.05	USPHS
12/63	HSBM 4.7	135	---	---	135	USPHS
12/63	ICM 4.6	8.6	---	---	8.6	USPHS
12/63	HSBM 5.7	0	---	---	0	USPHS
12/63	HSBM 4.7	15.8	16.0	---	31.8	USPHS
12/63	ICM 4.6	2.6	3.6	---	6.2	USPHS
12/63	TRM 305	.06	---	---	.06	USPHS
12/63	TRM 305	.02	---	---	.02	USPHS
12/63	TRM 305	0	---	---	0	USPHS
12/63	TRM 305	0.67	---	---	0.67	USPHS
1/64	HSBM 5.7	0	---	---	0	USPHS
1/64	HSBM 4.7	11.0	3.4	---	14.4	USPHS
1/64	ICM 4.6	4.6	3.0	---	7.0	USPHS
1/64	HSBM 4.7	0.14	0.08	---	0.22	USPHS
1/64	ICM 4.6	1.8	1.4	---	2.2	USPHS
1/64	HSBM 4.7	0.35	0.02	---	0.37	USPHS
1/64	ICM 4.6	0.04	1.1	---	0.15	USPHS
1/64	TRM 305	0.30	0.12	---	0.42	USPHS
1/64	TRM 305	0.07	0.14	---	0.21	USPHS
9/65	HSBM 4.7	74.0	2.2	2.2	78.4	USPHS
9/65	ICM 4.6	0.8	0.6	---	1.4	USPHS
9/65	HSBM 5.7	3.3	0.1	---	3.4	USPHS
9/65	HSBM 4.7	83.6	1.87	1.92	87.39	COE
9/65	HSBM 4.7	27.96	1.08	0.97	30.01	COE
9/65	HSBM 4.7	110.32	2.90	3.00	116.22	COE
9/65	HSBM 5.75	3.34	0.12	---	3.46	COE
9/65	ICM 4.6	1.3	0.53	2.51	4.34	COE
9/65	ICM 4.6	0.55	0.83	3.11	4.69	COE
9/65	ICM 4.6	0.52	0.24	1.06	1.82	COE
10/67	HSBM 5.4	6.6	---	---	---	FWQA*
11/67	HSBM 5.4	6.4	---	---	---	FWQA*
12/67	HSBM 5.4	2.1	---	---	---	FWQA*
1/68	HSBM 5.4	2.6	---	---	---	FWQA*
2/68	HSBM 5.4	2.9	---	---	---	FWQA*
3/68	HSBM 5.4	2.3	---	---	---	FWQA*
4/68	HSBM 5.4	2.6	---	---	---	FWQA*
5/68	HSBM 5.4	2.3	---	---	---	FWQA*
6/68	HSBM 5.4	3.2	---	---	---	FWQA*

Table II-2. Concentrations of DDT in Surface Water to 1970 (ug/l)
(Continued, page 2)

Date	Location	DDT	DDE	DDD	DDTR	Data Source
7/68	HSBM 5.4	1.2	---	---	---	FWQA*
8/68	HSBM 5.4	1.1	---	---	---	FWQA*
9/68	HSBM 5.4	4.8	---	---	---	FWQA*
10/68	HSBM 5.4	15.1	---	---	---	FWQA*
11/68	HSBM 5.4	6.1	---	---	---	FWQA*
12/68	HSBM 5.4	2.1	---	---	---	FWQA*
1/69	HSBM 5.4	4.4	---	---	---	FWQA*
2/69	HSBM 5.4	1.3	---	---	---	FWQA*
3/69	HSBM 5.4	5.3	---	---	---	FWQA*
4/69	HSBM 5.4	8.2	---	---	---	FWQA*
5/69	HSBM 5.4	17.3	---	---	---	FWQA*
1/70	HSBM 5.4	4.7	---	---	---	FWQA*
2/70	HSBM 5.4	3.6	---	---	---	FWQA*
3/70	HSBM 5.4	3.6	---	---	---	FWQA*
4/70	HSBM 5.4	3.6	---	---	---	FWQA*

*All FWQA data reported as averages.
Range of values from 0.3 to 60 ug/l.

Source: USPHS, 1964; USPHS, 1965; COE, 1966; FWQA, 1970

Table II-3. Concentrations of DDT in Water Subsequent to 1970

Date	Location	DDT	DDE	DDD	DDTR	Data Source
7/77	TRM 102-567	No detectable residue - No detection limits stated.				TVA
10/77	ICM 1	0.16	0.13	0.34	0.63	TVA
10/77	ICM 0	0.04	0.07	0.18	0.29	TVA
10/77	TRM 320	<0.01	0.01	0.03	>0.04-<0.05	TVA
10/77	TRM 311	<0.01	<0.01	<0.01	<0.03	TVA
10/77	TRM 285	<0.01	<0.01	<0.01	<0.03	TVA
10/77	TRM 277	<0.01	<0.01	<0.01	<0.03	TVA
10/77	TRM 272	<0.01	<0.01	<0.01	<0.03	TVA
10 and 11/77	IC-West and North Boundary	at or <1.0 ug/l (19 samples)				CDIR
1977	IC at Triana	---	---	---	9	AEHA
11/77	IC at Mouth	---	---	---	0.3	TVA
11/77	IC 1 Mile above Mouth	---	---	---	0.6	TVA
11/77	TRM 1 Mile below IC	---	---	---	0.04	TVA
11/77	BFCM 0.5	<0.01	0.026	0.072	>0.108-<0.118	TVA
11/77	TRM 333	<0.01	<0.01	<0.01	<0.03	TVA
11/77	IC	<0.01	<0.01	<0.01	<0.03	TVA
11/77	HSB	<0.01	<0.01	<0.01	<0.03	TVA

Note: Values in ug/l.

Source: TVA, 1977; AEHA, 1978; CDIR, 1978.

Table II-4. Concentrations of DDT in Indian Creek Sediments, Mile Segment 0-8, Analyses during 1963-1978

Date	Mile Marker	DDT	DDE	DDD	DDTR	Data Source
10-12/63	1.0	0.8	0.8	---	1.6	USPHS
	4.6	11.6	6.0	---	17.6	USPHS
	4.6	17.0	6.0	---	23.0	TVA
	7.75	2.0	0.72	---	2.72	USPHS
9/65	4.6	9.3	1.2	2.1	12.6	USPHS
9/73	1.0	0.8	---	---	---	AEHA
10/77	0	0.08	0.14	0.24	0.46	TVA
	0.91	1.2	---	---	---	AEHA
	0.91	11.85	---	---	---	AEHA
	0.91	28.90	---	---	---	AEHA
	0.91	41.08	---	---	---	AEHA
	0.91	40.48	---	---	---	AEHA
	0.91	30.80	---	---	---	AEHA
	0.91	41.47	---	---	---	AEHA
	0.91	38.38	---	---	---	AEHA
	0.91	33.89	---	---	---	AEHA
	0.91	35.47	---	---	---	AEHA
	0.91	33.23	---	---	---	AEHA
	0.91	3.03	---	---	---	AEHA
	1.0	0.16	0.13	0.34	0.63	TVA
11/77-3/78	1.0	---	---	---	28.31	CDIR
	1.38	---	---	---	38.14	CDIR
	2.2	---	---	---	70.35	CDIR
	2.4	---	---	---	29.41	CDIR
	4.6	---	---	---	13.35	CDIR
	5.33	---	---	---	4.58	CDIR
6/78	4.6	---	---	---	0.11	TVA(b)
9/78	2.2	0.81	2.9	7.9	11.61	TVA(a)
	2.4	0.06	0.53	1.8	2.39	TVA
	3.9	0.16	1.9	2.2	4.26	TVA

Note: Concentration in ug/gm.

Source: TVA, 1963; USPHS, 1964; USPHS, 1965; AEHA, 1977; TVA, 1977; CDIR; TVA, 1978(a); TVA, 1978(b).

Table II-5. Concentrations of DDT in Huntsville Spring Branch Sediments, Mile Segment 0-2.5, Analyses during 1963-1978

Date	Mile Marker	DDT	DDE	DDD	DDTR	Data Source
10-12/63	2.5	432	136	---	568	USPHS
	2.5	400	---	---	---	TVA
	2.5	2,500	---	---	---	USPHS
9/75	2.5	14.71	3.12	14.62	32.45	USPHS
9/73-3/74	2.5	0.8	---	---	---	USPHS
12/77	0.38	90	---	---	---	AEHA
	1.0	32.66	---	---	---	AEHA
	1.31	59.8	---	---	---	AEHA
1977	1.7	1.48-33.6	---	---	---	TVA
12/77	2.0	1.39	---	---	---	AEHA
1977	2.5	32.5	---	---	---	TVA
6/78	0	---	---	---	27.7	TVA(a)
	0.55	---	---	---	23.9	TVA(a)
	1.0	---	---	---	9.6	TVA(a)
	1.0	0.28	0.31	0.19	0.78	EPA
	1.7	2,040	---	---	---	TVA(a)
	2.0	---	---	---	2,940	TVA
	2.5	---	---	---	4,420	TVA
	2.5	2,100	240	440	1,780	EPA
9/78	1.7	220	19	76	315	TVA(b)
	1.7(a)	0.35	2.0	76	78.35	TVA
	1.7(b)	<0.04	0.06	0.05	0.15	TVA
	1.7(c)	0.015	0.045	0.039	0.099	TVA
	2.5	6.0	0.27	1.5	7.77	TVA

Note: Concentration in μg/gm.

(a) Core = 0-6"
(b) Core = 6-12"
(c) Core = 12-18"

Source: TVA, 1963; USPHS, 1964; USPHS, 1975; AEHA, 1977; TVA, 1977; TVA, 1977; TVA, 1978(a); TVA, 1978(b); EPA, 1978; TVA, 1979.

Table II-6. Concentrations of DDT in Huntsville Spring Branch Sediments, Mile Segment 2.6-5.6, Analyses during 1963-1978

Date	Mile Marker	DDT	DDE	DDD	DDTR	Data Source
10/63	2.55	432	136	---	568	USPHS
10/63	4.7	6,500	---	---	---	USPHS
12/63	2.55	2,500	---	---	---	USPHS
12/63	4.7	13,400	---	---	---	USPHS
9/65	5.3	605.84	384.00	1,847.05	2,836.89	USPHS
	4.7	0.65	---	---	---	USPHS
12/77	4.0	39.8	---	---	---	AEHA
	4.2	19.5	---	---	---	AEHA
	4.2	919	---	---	---	TVA
	4.3	5.11	---	---	---	USPHS
	4.5	934-5,441	---	---	---	TVA
	4.7	1,865	---	---	---	TVA
	4.7	128.54	---	---	---	TVA
	5.3	18,434	---	---	---	AEHA
	5.6	0.38	---	---	---	AEHA
9/78	3.0	3.0	5.7	10.3	19.0	TVA
	3.0	530	97	390	1,017	TVA
	3.0	11	---	---	---	TVA
	3.2	163	58	351	572	TVA
	3.5	5.2	2.6	10	17.8	TVA
	3.5(a)	910	430	2,200	3,540	TVA
	3.5(b)	690	310	1,600	2,600	TVA
	3.5(c)	540	640	2,800	3,980	TVA
	3.5(a)	120	2.1	9.3	131.4	TVA
	3.5(b)	0.30	0.29	1.1	1.69	TVA
	3.5(c)	<0.04	0.05	0.07	0.16	TVA
	3.65	50	64	190	304	EPA
	3.7	0.49	0.75	2.5	3.74	TVA
	3.75	0.079	0.050	0.038	0.167	EPA
	4.0	0.64	4.7	11	16.34	TVA
	4.0	0.13	0.65	1.3	2.08	TVA
	4.0	1,017	---	---	---	TVA

Table II-6. Concentrations of DDT in Huntsville Spring Branch Sediments, Mile Segment 2.6-5.6, Analyses during 1963-1978 (Continued, page 2)

Date	Mile Marker	DDT	DDE	DDD	DDTR	Data Source
9/78	4.2(a)	63	12	54	129	TVA
	4.2(b)	18	1.1	4.4	23.5	TVA
	4.2(c)	5,700	360	1,700	7,760	TVA
	4.2(d)	24,000	1,700	2,600	28,300	TVA
	4.2(a)	12	4.4	12	28.4	TVA
	4.2(b)	3	0.44	4.3	7.87	TVA
	4.2(c)	490	2,000	410	2,900	TVA
	4.2	1,280	230	880	2,390	TVA
	4.2(c)	430	160	920	1,510	TVA
	4.35(c)	820	62	190	1,072	EPA
	4.5	700	110	490	1,300	TVA
	4.5	27	5.7	19	51.7	TVA
	4.5	16.34	---	---	---	TVA
	4.6	100	19	96	215	TVA
	4.7(a)	940	97	1,100	2,137	TVA
	4.7(b)	10,000	720	2,100	12,820	TVA
	4.7(c)	5,000	250	1,200	6,450	TVA
	4.7	0.81	---	---	---	TVA
	4.7	116	20	135	271	TVA
	4.7	0.20	0.16	0.45	0.81	TVA
	4.8	<0.1	<0.1	<0.1	<0.3	TVA
	4.8	1,500	180	490	2,170	TVA
	4.8	0.1	---	---	---	TVA
	5.0(a)	2,300	670	4,300	7,270	TVA
	5.0(b)	36	2.7	3.6	42.3	TVA
	5.0(a)	2,900	660	2,900	6,460	EPA
	5.0	620	86	350	1,056	EPA
	5.5	0.12	0.042	0.058	0.220	EPA
	HSB Loop	75	10	52	137	EPA

Note: Concentration in ug/gm.

(a) Core = 0-6"
(b) Core = 6-12"
(c) Core = 12-18"
(d) Core = 18-24"

Source: USPHS, 1964; USPHS, 1965; AEHA, 1977; TVA, 1978; TVA, 1979; EPA, 1978.

themselves varied from grabs with dredges to coring devices. However, no significant trend with time is apparent in this data.

As might be expected the highest levels of DDT are in Huntsville Spring Branch sediments. Concentrations of DDTR over 28,000 µg/gm were reported in 1978 (TVA, 1979). In October 1977, concentrations up to 0.36 ppm were found in the Tennessee River below Indian Creek (Table II-7).

1.3.3 Fish and Wildlife

Sporadic sampling of the biota has been done with the majority occurring from the mid-1970's. Concerns during the first aquatic surveys carried out in the 1960's originated from fish kills which appeared to be increasing in HSB and IC. In 1964 TVA conducted in situ bioassays with fathead minnows. In an 18-hour test all fish died. Toxic effects at this time were attributed to the discharge from the Stauffer caustic-chlorine plant and the General Aniline and Film Corp. Another brief survey by USPHS in 1964 showed that below area 5000 where DDT and other industrial wastes enter Huntsville Spring Branch the stream was devoid of fish and bottom organisms.

Peak annual population estimates for a number of water birds, raptors, and mammals at Wheeler National Wildlife Refuge from 1943 to 1979 are presented in Tables II-8 and II-9. Declines for several species occurred during the period of the old DDT plant operation. For instance, reductions in Double-crested Cormorant populations were observed in the early 1950's. By 1963 the cormorant population at Wheeler had been reduced to zero. Since 1973, the species has been reported again, though in modest numbers (Huntsville Times, 1979). It is not known whether this or other observed trends resulted from DDT contamination at Wheeler. As is discussed in more detail in section 5.4, areawide or regionwide trends may significantly impact local populations, particularly for migrating species.

In May of 1964 the Patuxent Wildlife Research Center collected crows and various mammals near the Arsenal. Analyses for DDT were made on muscle and fat tissue. Values ranged in bird muscle from 6.9 to 119.3 ppm in 7 samples. As might be expected, higher levels were found in fat with a maximum of 1,602.9 ppm. Table II-10 presents these results. The sample size overall was small, but the evidence for bioaccumulation clearly is apparent.

As evidence of long term effects of organochlorine compounds increased, the surveys in the 1970's focused on DDT residues in fish and wildlife. In September, 1970, the Alabama Department of Conservation reported DDT residues in fish collected in Wheeler Reservoir and vicinity to be above FDA limits of 5 ppm. Those species that exceeded the standard were channel catfish, smallmouth bass and white bass. All species analyzed contained DDT. Bottom feeders, rough and sport fishes were included. Fish from Guntersville Reservoir and Pickwick contained DDT levels ranging to 2.97 ppm. In Wilson Reservoir the highest concentration was observed in channel catfish and smallmouth bass. Levels of DDTR were 8.55 and 6.42 ppm, respectively (see Table II-11).

Table II-7. Concentrations of DDT in Tennessee River and Indian Creek Sediments

Date	Mile Marker	Concentration in μg/gm DDT	DDE	DDD	DDTR	Data Source
7/77	112.5	0.001	0.002	0.002	0.005	TVA(c)
	193.0	0.002	0.003	0.002	0.007	TVA(c)
	283.0	0.006	0.011	0.006	0.023	TVA(c)
	294.0	0.003	0.004	0.003	0.01	TVA(c)
	309.5	0.003	0.004	0.004	0.01	TVA(c)
10/77	272.0	0.01	0.03	0.02	0.06	TVA
	277.0	<0.01	0.03	0.03	<0.07	TVA
	285.0	<0.01	0.06	0.04	<0.11	TVA
	311.0	0.04	0.04	0.04	0.12	TVA
	320.0	0.12	0.10	0.14	0.36	TVA
11/77	333.0	<0.01	<0.01	<0.01	<0.03	TVA
	333.0	0-0.114	-	-	-	CDIR
	SE Causeway*	0.49	-	-	-	AEHA
12/77	SE of Causeway	8.67	-	-	-	AEHA
11/77	NW of Causeway	2.49	-	-	-	AEHA
	NW of Causeway	2.30	-	-	-	AEHA

*Wheeler Reservoir Causeway - Designated as North-South Road across Indian Creek near Mile 6.

Source: TVA, 1977; TVA, 1978(c); CDIR; AEHA, 1977 (Drinking Water Surveillance Program).

Note: TVA, 1978(c) reports 7/77 concentrations as mg/g. Personal Communication with Jim Bobo 10/80 indicates concentration was as ug/g.

Table II-8. Peak Bird Populations[a] - Wheeler National Wildlife Refuge

Calender Year	Common Loon	Pied-Billed Grebe	Horned Grebe	Great Blue Heron	Common Egret	Cattle Egret	King Rail	Sora Rail	Green Heron	Little Blue Heron	Double Crested Cormorant
79	60	100	25	100	8	40	200	100	100		20
78	50	50	10	160	5	15	400	500	25	8	21
77	20	200	25	200	20	30	500	600	35	80	9
76-3/4[b]	20	200	35	70	6	36	400	200	40	12	16
75	35	60	35	75	10	50	400	500	50	30	2
74	20	40	10	55	40	30	200	150	50	40	3
73	10	30	10	65	12	10	200	50	35	25	2
72	15	50	10	50	20	50	250	300	25	25	2
71	10	25	5	50	15	15	150	50	25	40	
70	5	30	5	70	35	10	200	50	20	25	
69	15	20	2	30	10	15	100	8	20	1	
68	10	20	2	200	12	12	200	100	15	10	
67	8	30		50	20	70	200	200	30	30	
66	25	40	4	60	25	75	200	100	100	10	
65	20	50	5	60	150	125	300	120	200	75	
64	10	50	10	80	200	150	200	150	200	100	
63	10	50	5	100	225	50	250	175	250	125	
62	15	60	2	150	200		300	200	250	100	3
61	20	75	1	300	250	3	300	200	225	50	10
60	15	75	10	300	150				225	275	10
59	15	100	10	400	125		300	75	200	300	50
58	8	100		500	250				175	300	75
57	10	100		400	300				175	200	150
56	15	100	5	350	300				175	200	175
55		100		350	300				175	200	150
54-2/3[b]	30	100		400	300				180	200	300
53	10	75		600	350		125		150	250	500
52	10	75		650	400		125		200	300	800
51	5	60	5	800	650		125		200	300	1,000
50		50		1,300	1,300		700	800	400	500	2,000

Table II-8. Peak Bird Populations[a] - Wheeler National Wildlife Refuge (Continued, Page 2)

Calender Year	Common Loon	Pied-Billed Grebe	Horned Grebe	Great Blue Heron	Common Egret	Cattle Egret	King Rail	Sora Rail	Green Heron	Little Blue Heron	Double Crested Cormorant
49		50		1,200	750		800	1,000	400	500	2,500
48	20	150	3	500	750		125	20	400	500	2,500
47	25	250		500	750				400	500	2,500
46		200		800	750		*		400	500	1,000
45		300		1,200	1,800				*	*	1,000
44	*	300		1,000	1,800				*	*	2,600
43		200		1,000	1,400						2,800

Calender Year	Wilson Snipe	Least Sandpiper	Greater Yellowlegs	Lesser Yellowlegs	Killdeer	American Woodcock	Spotted Sandpiper	Pectoral Sandpiper	White Rumped Sandpiper	Semi-Palmated Plover
79	800	500	500	300	1,000	500	40	400	50	150
78	800	1,500	750	600	1,000	600	70	1,100	200	75
77	800	1,000	500	350	1,500	400	40	800	25	250
76	1,000	800	1,200	450	2,000	800	30	400	25	80
75	500	300	500	550	1,300	300	60	400	30	400
74	600	1,000	500	600	2,500	200	300	200	30	25
73	800	200	500	700	1,000	75	80	200	25	100
72	500	300	500	500	1,000	200	50	75		100
71	300	200	600	1,000	1,500	40	20	40		50
70	500	200	500	800	1,000	20	50			
69	800	200	800	1,000	1,000	20	40			
68	500	300	800	1,000	2,000	3	30	50		
67	500		700	700	1,000	10	50	25		50
66	500	100	700	700	700	1	60			
65	600		750	500	800	1	80			
64	600		800	400	800	1	75	75	25	
63	700	100	1,000	250	800	1	75	50		
62	125	150	200	250	800		75	75	10	100
61	150	150	175	250	900		80	75		
60	50	150	175	250	900				5	50

Table II-8. Peak Bird Populations[a] - Wheeler National Wildlife Refuge (Continued, Page 3)

Calender Year	Wilson Snipe	Least Sandpiper	Greater Yellowlegs	Lesser Yellowlegs	Killdeer	American Woodcock	Spotted Sandpiper	Pectoral Sandpiper	White Rumped Sandpiper	Semi-Palmated Plover
59	50	200	250	300	1,000		100	50		50
58	75		200	200	1,000	5	100	100		
57	250	200	250	500	1,000		100	100		
56	250	200	250	500	1,000	10				
55	20	200	100	400	1,200	10	100	100		
54-2/3[b]	50		125	400	1,400	1				
53	75	200	500	700	2,000	10	75	50		
52	50	200	1,000	2,000	2,000	6	75	300		200
51	50	100	1,000	2,000	1,500		75	300		10
50	75	125	800	600	2,500	10	75	100		35
49	50	45	700	500	3,000	20	75	100		*
48	150	50	300	250	3,000	10	75			*
47	325	10	200	200	3,000	20	75	25		25
46-2/3[b]	300		200	*	3,000	*				
45	*		*	*	*	*				
44	*		*	*	*	*	*			
43	*		*	*	*	*	*			

Calendar Year	Turkey Vulture	Black Vulture	Sharp-Shinned Hawk	Coopers Hawk	Red-Tailed Hawk	Red-Shouldered Hawk	Sparrow Hawk	March Hawk	Great Horned Owl	Barn Owl	Barred Owl	Screech Owl	Osprey
79	15	8	10	8	70	5	85	15	14	30	20	170	3
78	7	4	10	8	40	5	45	25	15	34	12	160	2
77	7	8	10	10	45	8	50	25	15	30	15	160	2
76	8	10	12	8	60	10	60	20	14	35	12	70	1
75	5	7	15	12	35	14	35	15	20	35	10	64	2
74	8	5	15	15	40	15	30	20	15	38	10	75	2
73	5	5	20	15	30	12	30	15	25	35	15	100	1
72			25	15	40	15	35	25	12	40	15	200	
71			20	20	30	30	40	15	15		12	100	
70			20	25	15	35	30	12	12		25		2

Table II-8. Peak Bird Populations[a] - Wheeler National Wildlife Refuge (Continued, Page 4)

Calendar Year	Turkey Vulture	Black Vulture	Sharp-Shinned Hawk	Cooper's Hawk	Red-Tailed Hawk	Red-Shouldered Hawk	Sparrow Hawk	Marsh Hawk	Great Horned Owl	Barn Owl	Barred Owl	Screech Owl	Osprey
69			10	20	20	20	15		10		10	45	1
68			20	25	20	30	15		6		20	50	1
67			20	30	20	60	20	25	10		15	50	
66			20	30	25	70		25	4		20		
65			25	35	25	75		30	13		15		
64			50	75	60	80		80	5	30	40		
63			50	75	75	225	120	90	8	30	40	50	
62			60	80	80	250	50	100	10	30	30	50	
61			70	100	100	275	60	125		30	30	50	
60			70	125	100	300	25	125	5			50	
59			70	125	100	300		125			100	50	
58			70	150	75	300	40	150			120		
57			75	175	75	350	50	175	8		125		
56			100	200	100	400	50	175	10		150	75	
55			100	250	100	425	50	200	10		150		
54-2/3[b]			100	200	25	225	50	200	10		150		
53			100	400	25	450	50	200	10		200	120	
52			100	400	25	450	50	200	12		200	120	
51			100	450	20	450		200	8		200	120	
50			100	500		500		300			200	120	
49-2/3[b]			100	150	15	100		100	25		100	120	
48			100	225	15	*		75			100		1
47			100	225				*			100		
46-2/3[b]									*		*		
45	*		*	*	*	*	*	*					*
44	*	*	*	*	*	*	*	*			*	*	*
43	*	*	*	*	*	*	*	*			*	*	*

[a] Greatest number of birds observed on any day during that period.

[b] Data available for partial year only.

*Report indicates present but no numbers given

Source: U.S. Fish & Wildlife Service - 1979.

Table II-9. Peak Mammal Populations[a] - Wheeler National Wildlife Refuge

Calender Year	Cottontail Rabbit	Swamp Rabbit	Raccoon	Opossum	Beaver	River Otter	Muskrat	Wood Chuck
79	2,000	700	1,200	1,700	1,200	14	1,500	350
78	1,900	700	1,100	1,700	1,100	12	1,500	330
77	2,000	750	1,000	1,600	1,000	10	1,200	320
76	1,600	600	900	1,600	800	10	850	275
75	2,000	800	800	1,500	600	10	850	275
74	4,500	2,000	600	1,600	400	10	800	250
73	5,800	2,800	650	1,600	250	8	800	250
72	5,500	3,000	700	1,500	150	8	750	200
71	4,000	3,000	750	1,461	120	8	750	160
70	3,300	2,250	633	1,461	100	10	750	160
69	2,600	2,400	760	1,461	70	10	700	120
68	5,200	2,000	950	1,400	60	6-10	650	100
67	4,330	2,000	1,357	1,460	50	6-10	600	
66	5,200	3,040	1,257	1,358	40	8	600	50
65	5,200	3,040	1,357	1,461	35		480	30
64	5,999	2,777	1,266	1,461	30		400	24
63	5,778	2,667	1,055	1,357	25		350	20
62	5,200	2,500	1,000	1,266	20		300	20
61	5,100	2,300	950	1,266	15		300	18
60	5,600	1,800	950	1,266	12		300	12
59	4,750	1,000	950	1,266	10		240	20
58	3,166	1,000	1,140	1,583	8		240	18
57	3,166	713	950	1,266	8		300	18
56	3,166	625	1,000	1,583	7		300	24
55	2,714	555	1,357	1,728	7		300	20
54	2,375	500	1,580	1,900	7		300	25
53	2,111	250	1,727	1,900	7		300	25
52	1,906	200	1,900	2,300	7		240	25
51	1,520	150	1,400	1,900	8		240	20
50	1,000	100	1,167	1,500	6		240	20
49	1,000	100	1,000	1,200	6		500	20
48								
47	1,000	100	400	1,150	30		500	25
46	400		360		40		580	
45	560		425	1,385	20		2,113	
44	560	275	360	1,415	20		2,270	
43	460	275	130	1,410	5		2,275	

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[a] Greatest number of animals observed on any day during that period.

Table II-10. DDT Content of Wildlife Specimens (1964) - Redstone Arsenal Near Huntsville Spring Branch

Species	DDT Residues (ppm Wet Weight)	
	Muscle	Fat
Crow	21.7	872.9
Crow	51.4	770.1
Crow	52.9	1,602.9
Crow	3.6	109.3
Crow	119.3	773.6
Crow	24.5	625.8
Crow	6.9	510.4
Swamp Rabbit	0.5	2.8
Swamp Rabbit	0.7	not received
Swamp Rabbit	0.6	14.3
Cottontail Rabbit	1.6	50.5
Cottontail Rabbit	0.5	15.8
Cottontail Rabbit	trace	6.8
Opossum	13.3	348.5
Opossum	31.7	132.3
Gray Fox	27.4	50.0

Source: U.S. Fish and Wildlife Service, 1964.

Table II-11. DDT Residues in Fish From the Tennessee River - 1970

Species	Location	DDT	DDE	DDD	DDTR
Channel Catfish	Wilson Res.	3.78	4.77	-	8.55
Smallmouth Bass	Wilson Res.	0.66	2.88	2.88	6.42
Sauger	Guntersville Dam	0.33	1.32	1.32	2.97
Redhorse	Wheeler Res.	0.16	0.62	0.66	1.44
Longear(4)	Wheeler Res.	0.10	0.39	0.35	0.84
Black Redhorse	Unknown	0.43	0.62	0.64	1.69
White Bass(2)	Wheeler Res.	2.4	8.4	11.4	22.2
Shorthead Redhorse	Pickwick Res.	0.44	0.56	0.66	1.66
Spotted Sucker	Wilson Res.	0.270	0.645	0.450	1.365
Largemouth Bass	Wilson Res.	0.54	1.92	1.08	3.54
Largemouth Bass(3)	Guntersville Dam	0.18	0.43	-	0.61
Golden Redhorse	Wilson Res.	0.35	0.70	0.48	1.53
Largemouth Bass	Guntersville Dam	0.065	0.135	-	0.20
Redear(2)	Wilson Res.	0.075	0.180	0.075	0.33
Black Redhorse	Wilson Res.	0.065	0.240	0.060	0.365
Smallmouth Buffalo	Wheeler TRM-295	0.06	0.44	0.34	0.84
Silver Redhorse	Wheeler TRM-295	0.017	0.030	0.031	0.078
Channel Catfish	Wheeler TRM-295	0.36	3.78	4.32	8.46
Channel Catfish	Wheeler TRM-295	0.06	0.35	0.29	0.7

Note: Residue content in edible muscle (PPM)

Source: Alabama Department of Conservation, 1970.

In 1971 the Alabama Department of Agriculture and Industries released a report on pesticide residues in fish from Alabama waters. Table II-12 shows the level of DDT in various fish species in the Tennessee River and other Alabama streams. Results of the survey indicated that for some individual bluegill, shad, bass, and carp, levels exceeded FDA limits. Samples from the Tennessee River contained the highest residue. A value in shad of 195.6 ppm was observed while 73.8 ppm was found in bass. Stations on the Tennessee River were located from Guntersville to Wilson Reservoir. The highest levels were found in areas between Triana and Decatur.

Beginning in 1975 surveys to determine pesticide residues in fish were more frequent. The agencies involved were the Food and Drug Administration, the Army Environmental Hygiene Agency, the Tennessee Valley Authority and the Public Health Service. There was growing concern in the mid-to-late 1970's related to health effects from the consumption of contaminated fish. Table II-13 presents Food and Drug Administration results from analyses on dressed fish in area markets.

In 1977 TVA published the results of several surveys carried out in Huntsville Spring Branch and in the Tennessee River. Table II-14 presents the data and shows elevated levels of DDTR in all species collected in HSB (whole body analysis). Bass, catfish and other edible species were heavily contaminated in the Tennessee River at mile 320-321. Levels as high as 411.6 ppm were observed in catfish. DDTR concentrations decreased downriver to a minimum of <0.1 ppm in samples of sunfish and crappie at Mile 277. Fish at TRM 273, the furthest downstream station, had DDTR levels ranging from 1.2 to 1.8 ppm.

A special AEHA report also released in 1977 contained a few additional results on fish analyses. For example, a goldfish from HSB (whole body) contained 111.4 ppm. Fat bodies extracted from a gar collected in HSB had 2817.98 ppm DDTR. This latter analysis demonstrated the lipid solubility of DDTR in biological material. In other samples where fat bodies were analyzed the results showed DDTR concentrated in this tissue.

Analyses by FDA on fish collected at various points in Wheeler Reservoir are presented in Table II-15. DDTR levels varied from 0.05 to 205.1 ppm. The highest concentrations were found at TRM 321 and 322 near Indian Creek.

An Army report in 1978 contained the results of a study of DDTR in waterfowl. The levels ranged from 0.05 in a Mallard drake to 94.60 ppm in a Mallard hen. Other species included Gadwall and a Wood Duck. Both of these ducks had high levels of residue as Table II-16 shows. These results can be put in perspective by comparison to the average DDT concentration in duck wings. During the 1965-1972 period this was 3 to 5 ppm for samples collected in Alabama.

Two collections of fish were made by TVA in June and September 1978. These data are presented in Table II-17. The residue levels represent

Table II-12. DDT Residues in Various Species of Fish Taken From Alabama Rivers Expressed in PPM Wet Weight Basis - 1971

River		Bluegill	Shad	Bass	Carp	Catfish	Sucker	Crappie	Buffalo
Coosa	Number	13	8	34	28	1	4	1	1
	Mean	.311	1.83	1.383	1.140	.48	.076	.19	.330
	Range	.05-1.20	.07-7.20	.028-6.80	.04-5.80		ND-.08		
Tennessee	Number	13	14	21	9	4	3	2	2
	Mean	2.365	16.46	6.538	10.118	3.415	.473	.510	.475
	Range	.03-14.40	.06-195.6	.07-73.80	.23-4.37	2.53-4.37	.23-.60	.50-.52	.15-.80
Chattahoochee	Number	14	4	19	6	10	3	NS	NS
	Mean	.236	.451	2.84	1.730	.775	.175		
	Range	.068-.46	.25-.89	.06-9.68	.60-5.47	.02-1.71	.08-.339		
Alabama	Number	9	6	11	1	7	2	1	2
	Mean	.263	.575	.768	.800	.729	.965	1.00	.295
	Range	.10-.48	.05-1.20	.10-1.68		.09-1.68	.46-1.47		.16-.43
Warrior	Number	36	17	40	14	9	14	17	7
	Mean	.245	.233	.478	.278	.296	.285	.451	.287
	Range	ND-.77	ND-.677	.027-2.50	.09-.83	.05-1.28	.05-1.28	.03-1.47	.16-.48
Tombigbee	Number	15	9	19	5	12	2	7	5
	Mean	.785	1.218	.533	.926	.551	.698	.276	1.078
	Range	.12-2.10	.216-3.25	.13-1.76	.48-1.78	.08-2.48	.45-.947	.002-.509	.11-2.65

Source: Alabama Department of Agriculture and Industries (1971)

Note: Values based on edible muscle except shad (whole body)

Table II-13. DDT Residues in Dressed Fish From Area Markets - 1975-77

Species	Location	DDT	DDE	DDD	DDTR
Buffalo	Guntersville Dam	0.02	0.09	-	0.11
Carp	Guntersville Dam	-	1.06	-	1.06
Channel Catfish	Guntersville Dam	0.07	0.22	-	0.29
Redhorse	Guntersville Dam	0.05	0.32	-	0.37
White Catfish	Guntersville Dam	0.04	0.09	-	0.13
Yellow Catfish	Guntersville Dam	0.12	0.48	-	0.6
Channel Catfish	Guntersville Dam	0.03	0.04	-	0.07
Catfish	Guntersville Dam	0.27	0.94	-	1.21
White Catfish	Guntersville Dam	0.07	0.18	-	0.25
Blue Catfish*	Decatur	0.04	0.29	-	0.33
Buffalo	Decatur	-	1.31	-	1.31
Blue Catfish	Huntsville	0.13	1.93	-	2.06
Buffalo	Huntsville	0.31	2.62	-	2.93
Shovelbill Catfish	Florence	-	0.85	-	0.85
Channel Catfish	Florence	0.28	2.75	-	3.03
Blue Catfish	Florence	0.67	11.04	-	11.71
Buffalo	Guntersville Dam	0.44	0.43	-	0.87
Carp	Guntersville Dam	-	0.37	-	0.37
Channel Catfish*	Ragland	-	0.77	-	0.77
Channel Catfish*	-	0.08	0.27	-	0.35
Channel Catfish*	Ragland	-	0.73	-	0.73
Catfish	Huntsville	-	0.54	0.55	1.09
Buffalo	Huntsville	-	0.52	-	0.52
Catfish	Huntsville	2.75	31.3	80.7	114.75
Catfish	Huntsville	-	0.28	0.53	0.81
Catfish	Decatur	-	2.82	3.80	6.62
Buffalo	Decatur	-	2.77	3.12	5.89
Catfish	Decatur	-	1.83	2.01	3.84
Catfish	Guntersville Dam	-	1.94	2.41	4.35
Catfish	Guntersville Dam	-	0.37	-	0.37
Catfish	Decatur	-	1.12	1.04	2.16

*Caught outside Tennessee River.

Note: Values in ppm.

Source: Food and Drug Administration, 1977.

Table II-14. DDTR in Fish in Huntsville Spring Branch and Tennessee River - 1977 - Analysis on Whole Body

Fish Species	Location	DDTR (ppm)
Shortnose gar	HSB	193.9
Gizzard shad	HSB	127.0
White bass	HSB	105.5
Black crappie	HSB	63.1
Freshwater drum	HSB	60.3
Bluegill	HSB	21.4
Channel catfish	TRM 320-321	411.6
Channel catfish	TRM 320-321	9.5
Black bass	TRM 320-321	259.7
Black bass	TRM 320-321	103.5
Black bass	TRM 320-321	56.0
Black bass	TRM 320-321	13.4
Black bass	TRM 320-321	8.5
Bluegill	TRM 320-321	35.2
Flathead catfish	TRM 320-321	30.8
Flathead catfish	TRM 320-321	21.2
Flathead catfish	TRM 320-321	14.6
Lepomis sp.	TRM 320-321	10.9
Lepomis sp.	TRM 320-321	7.0
Lepomis sp.	TRM 320-321	2.2
White bass	TRM 320-321	6.3
White bass	Triana to Decatur	88.2
Sunfish	Triana to Decatur	11.3
Sucker	Unknown	8.9
Mixed species	Unknown	3.2
Carp	Triana to Decatur	77.5
Carp	Triana to Decatur	1.7
White bass	Triana to Decatur	25.9
White bass	Triana to Decatur	25.6
Channel catfish	Triana to Decatur	12.7
Smallmouth buffalo	Triana to Decatur	11.0
Smallmouth buffalo	Triana to Decatur	2.3
Sauger	Wheeler Dam to Triana	0.2
Channel catfish	Triana to Guntersville	255.2
Channel catfish	Triana to Guntersville	3.1
Mixed species	Triana to Guntersville	98.4
Mixed species	Triana to Guntersville	73.8
White bass	Triana to Guntersville	61.6
White bass	Triana to Guntersville	10.5
Carp	Triana to Guntersville	30.6
Smallmouth buffalo	Triana to Guntersville	9.1
Black bass	Triana to Guntersville	1.8
Largemouth buffalo	Triana to Guntersville	1.4
Catfish	TRM 273	1.8
Carp	TRM 273	1.3

Table II-14 DDTR in Fish in Huntsville Spring Branch and Tennessee River - 1977 - Analysis on Whole Body (Continued, page 2)

Fish Species	Location	DDTR (ppm)
Sauger	TRM 273	1.2
Catfish	TRM 277	7.2
Sucker	TRM 277	6.8
Bass	TRM 277	1.4
Sauger	TRM 277	0.5
Sunfish	TRM 277	<0.1
Crappie	TRM 277	<0.1
Catfish	TRM 285	3.7
Bass	TRM 285	0.5
Sauger	TRM 285	0.3
Carp	TRM 285	0.3
Sucker	TRM 285	0.2
Sunfish	TRM 285	0.1
Catfish	TRM 311	29.4
Bass	TRM 311	2.7
Crappie	TRM 311	1.0
Sunfish	TRM 311	0.7
Carp	TRM 311	0.6
Catfish	TRM 320	22.8
Bass	TRM 320	19.0
Carp	TRM 320	14.4
Sauger	TRM 320	13.6
Sunfish	TRM 320	4.4

Source: TVA, 1979a.

Table II-15. DDT Residues in Whole Fish Collected Between 1977-79 (FDA)

			Concentration in ppm		
Species	Location	DDT	DDE	DDD	DDTR
Multiple 1	TRM-322	0.58	4.11	5.93	10.62
Multiple 2	TRM-322	0	43.8	161.3	205.1
Multiple 3	TRM-322	0	1.95	3.15	5.1
Multiple 4	TRM-322	0	58.1	130.65	188.75
Multiple 1	TRM-321	0	29.6	49.95	79.55
Multiple 2	TRM-321	0	16.5	29.2	45.7
Multiple 3	TRM-321	0	13.75	48.95	62.7
Multiple 4	TRM-321	0	15.45	48.95	64.4
Multiple 5	TRM-321	0	3.86	5.89	9.75
Multiple 6	TRM-321	0	59.35	119.15	178.5
Bass	TRM-285	---	0.23	0.24	0.47
Sauger	TRM-285	---	0.16	0.09	0.25
Sucker	TRM-285	---	0.15	0.09	0.24
Catfish	TRM-285	---	2.42	1.27	3.69
Carp	TRM-285	---	0.17	0.16	0.33
Bream	TRM-285	---	0.06	0.05	0.11
Carp	TRM-273	---	0.73	0.61	1.34
Sauger	TRM-273	---	0.65	0.60	1.25
Catfish	TRM-273	---	1.09	0.70	1.79
Catfish	TRM-311	5.42	10.94	17.6	33.96
Bream	TRM-311	0	0.32	0.38	0.7
Carp	TRM-311	0	0.38	0.20	0.58
Bass	TRM-311	0	1.54	1.14	2.68
Crappie	TRM-311	0	0.42	0.60	1.02
Catfish	TRM-320	0	9.18	11.75	20.93
Bream	TRM-320	0	1.84	2.61	4.45
Carp	TRM-320	0	5.75	11.30	17.05
Bass	TRM-320	0	7.05	12.01	19.06
Sauger	TRM-320	0	5.07	9.7	14.77
Catfish	TRM-277	0	3.88	3.94	7.82
Sucker	TRM-277	0.51	3.86	2.66	7.03
Crappie	TRM-277	0	0.03	0.02	0.05
Bream	TRM-277	0	0.04	0.02	0.06
Sauger	TRM-277	0	0.23	0.24	0.47
Bass	TRM-277	0	0.78	0.65	1.43
Catfish	Mallard Creek	0	3.77	5.62	9.39

Source: FDA, 1979.

Note: In some cases DDT concentration was shown as 0, in other cases no value for DDT was shown.

Table II-16. DDT Residues in Ducks Collected in Wheeler Wildlife Refuge 1978

Date of Collection: 22 Jan 78	Date of Results: 21 Sep 78
	DDTR ppm
Gadwall Hen	1.55
Gadwall Drake	90.83
Mallard Hen	94.60
Wood Duck Drake	39.74
Mallard Hen	18.66
Mallard Drake	0.051
Mallard Drake	32.43
Mallard Hen	0.28
Mallard Drake	2.45
Gadwall Drake	1.22

Source: U.S. Army, 1978.

Note: Whole body analysis.

Table II-17. Fish Residues-TVA and Army Data - Redstone Arsenal DDT Study

Location	Species	TVA Data[1] (ppm) DDE	DDD	DDT	DDTR	U.S. Army[2] DDTR
TRM 275-292.7	B	0.17	0.21	>0.1	0.48	---
	CC	2.4	2.0	0.72	5.12	---
	SMB	1.0	0.75	0.13	1.88	---
TRM 293-305	B	0.14	0.16	>0.1	>0.31	---
	CC	0.87	0.82	0.15	1.84	---
	SMB	1.2	0.93	0.15	2.28	---
TRM 305-321	WB	---	---	---	---	23.6 & 25.9
	B	2.5	5.3	0.23	8.03	---
	CC	6.6	10.0	0.40	17.0	12.7
	SMB	13.0	10.0	0.62	23.62	2.3 & 10.9
TRM 321	WB	---	---	---	---	10.5
	CC	21	36	1.2	58.2	---
	SMB	20	41	0.77	61.77	---
	LMB	0.91	1.7	0.04	2.65	---
TRM 321-334	WB	---	---	---	---	15.4 & 61.6
	B	3.3	8.2	0.28	11.78	---
	CC	31.0	87.0	1.6	119.6	3.1 & 255.2
	SMB	9.4	7.6	0.49	17.49	1.8 & 9.1
TRM 349	SMB	0.59	0.24	0.22	1.05	---
TRM 352	CC	0.64	0.27	0.18	1.09	---
	LMB	0.08	0.09	0.07	0.24	---
Indian Creek	LMB	3.4	8.2	0.15	11.75	---
	CC	38	85	6.4	129.4	---
	SMB	68	140	4.7	212.7	---

Note: B=Bass (no further identification given), CC=Channel Catfish, SMB=Smallmouth Buffalo, LMB=Largemouth Bass, WB=White Bass, ---=No Data.

[1] Data from June and September 1978 Surveys (TVA, 1978b, 1978d and 1978e)

[2] Data from November 1977 (TVA, 1978f)

those found in muscle and range from 0.24 ppm for largemouth bass at TRM 352 to 212.7 ppm in smallmouth buffalo (Indian Creek). In an independent analysis the Army found concentrations as high as 255 ppm in a channel catfish at TRM 321-334. The data show that contaminated fish were widely dispersed in Wheeler Reservoir.

In January, 1979, fish samples from Triana were analyzed for DDT. The results (Table II-18) show high levels of DDT in most fish.

More recent data on DDT in fish are discussed in Section 5.3 of this appendix.

2.0 CURRENT ENVIRONMENTAL SETTING

2.1 DESCRIPTION OF THE NATURAL SYSTEMS

2.1.1 Tennessee River (Wheeler Reservoir)

Several aquatic ecosystem types occur in the project area. These are the Wheeler Reservoir, flowing and non-flowing portions of several streams, and a spring(s).

The Wheeler Reservoir is a run-of-the-river reservoir along the Tennessee River, and it forms the southern boundary of the Redstone Arsenal. Within the project area it supports no significant vascular flora, although it does currently support a fishery. The Wheeler National Wildlife Refuge is located within its backwaters, and is an important wintering waterfowl refuge. The reservoir is important regionally for commercial transport of such bulky, non-perishable goods as coal. Also, its waters are used by a variety of interests, for recreation, electric power generation, as a water supply, and as a waste receptacle for the cities and industries located along it.

Benthic macroinvertebrates collected by the TVA in Wheeler Reservoir are dominated numerically by chironomids, although molluscs (primarily the Asiatic clam, *Corbicula fluminea*) may dominate the biomass (see Appendix V). *Tubificid oligochaetes* and the larvae of the mayfly *Hexagenia* are also important components of the benthos. Artificial substrate macroinvertebrates were dominated by phytoplanktivorous caddisfly larvae primarily of *Cheumatopsyche* and *Hydropsyche* genera. Chironomids were of lesser importance on the artificial substrates, and were dominated as a group by *Cricotopus*, an aufwuchs feeder. Macroinvertebrate species diversity (base 2) was low to moderate ($\bar{x}$ = 2.62) in the benthos, and low on the artificial substrates ($\bar{x}$ = 0.84).

A total of 115 taxa of fish are known to inhabit the Wheeler National Wildlife Refuge, an area which includes the Wheeler Reservoir and its backwaters (Reeves, n.d.). The most common groups are the herrings, the minnows, the catfish, and the sunfish. These are common forms of the large, Southeastern rivers that are considered mesotrophic to eutrophic.

Table II-18. DDT-Related Compounds in Fresh and Frozen Fish Filets From Triana, Alabama, January 1979

Source and Species	Lab	DDT	DDD	DDE	DDTR
Frozen Freezer Fish:					
Redhorse-Lanier	CDC	0.13	0.41	0.6	1.1
	TVA	<0.3	0.32	0.5	1.0
Buffalo-Malone	CDC	0.8	62.5	21.6	84.9
	TVA	<2.0	53.0	16.0	70.0
Buffalo-Fletcher	CDC	1.0	39.8	10.8	51.6
	TVA	<2.0	27.0	8.7	36.7
Catfish-Caudle	CDC	14.8	201.6	58.0	274.4
	TVA	12.0	200.0	50.0	262.0
White Bass-Fletcher	CDC	0.2	22.6	7.7	30.5
	TVA	<2.0	21.0	6.6	28.6
White Bass-Timmons	CDC	0.12	2.3	2.4	4.82
	TVA	<0.3	2.7	2.4	5.25
White Bass-Vaughn	CDC	1.2	43.0	18.1	62.3
	TVA	<2.0	7.1	2.8	10.9
Fresh Fish:					
Bigmouth Buffalo	CDC	1.2	78.8	30.0	110.0
	TVA	<10.0	95.0	32.0	132.0
Carp	CDC	3.9	152.4	58.2	214.5
	TVA	<10.0	99.0	30.0	134.0
Smallmouth Buffalo	CDC	13.4	157.8	56.9	228.1
	TVA	<10.0	98.0	29.0	132.0
Redhorse	CDC	0.0	11.6	7.5	19.1
	TVA	<2.5	7.8	5.1	14.15
Shortnosed Gar	CDC	10.3	321.1	118.6	450.0
	TVA	<10.0	150.0	45.0	200.0
Spotted Gar	TVA	<13.0	210.0	69.0	285.5

CDC=Center for Disease Control Laboratory.
TVA=Tennessee Valley Authority Laboratory

Note: Samples were split between the two labs, except for the spotted gar sample that was only analyzed by TVA.

Source: TVA, 1979; CDC, 1979.

Zooplankton samples collected in the Tennessee River during late summer/early autumn were dominated by cladocerans; rotifers and cyclopoid copepods were also abundant. Phytoplankton samples collected in the Tennessee River at the same time were mostly dominated by blue-green algae, with significant percentages of diatoms and green algae also present. See Appendix V for occurrence and abundances of phytoplankton and zooplankton taxa collected in this study.

2.1.2 Huntsville Spring Branch and Redstone Arsenal Area

Huntsville Spring Branch--Huntsville Spring Branch originates at a spring located off-site, within the city of Huntsville, and runs through Redstone Arsenal into the Tennessee River. The stream occupies a mature floodplain, which is largely inundated due to the Wheeler Dam. Toward the lower end of HSB, between Indian Creek and HSBM 1.4, the water inundates the floodplain for a depth of several feet. There is no aquatic or wetland vegetation here except for black willows and buttonbushes scattered along the shoreline (see Figure II-2). An algal bloom was visually observed during the summer, 1979, field surveys. Progressing upstream, the water becomes shallower and large stands of buttonbush (Cephalanthus occidentalis) can be found. Some of the buttonbush stands are completely overgrown and dominated by climbing hempweed, Mikania scandens. A few other aquatic plants occur within the buttonbush swamps, including Hibiscus militaris and Ludwigia sp. Muskrat are abundant in these buttonbush swamps.

Upstream of HSBM 3.5, large stands of floodplain and bottomland swamp forests occur. It is useful to consider these two habitats as two ends of a continuum defined by frequency and depth of inundation. The swamp association is flooded to a 2 foot depth, for as much as a year, or longer. This induces the characteristic buttressing of the bases of swampland trees. The floodplain association is usually flooded only long enough for stormwater surges. Since floodplain topography is not uniform, gradations between these two extremes exist. An example of this is transect 1, (Appendix VI) where the ground is apparently too wet to support the more mesic floodplain species, and is not wet enough to allow swamp vegetation to dominate. It is therefore heavily dominated by red maple, which can occur anywhere along the wetland continuum. Transects 4 and 7, (Appendix VI) are representative of the floodplain forest association, while Transect 8, (Appendix VI) is representative of the bottomland swamp forest.

The floodplain forests were found to be among the most diverse of the forest associations on the Redstone Arsenal, supporting at least 20 species of trees, (Appendix VI). They are dominated by green ash, red maple, blue beech, American elm and hackberry. Ground and shrub cover is sparse, and includes poison ivy, violets, peppervine (Ampelopsis arborea), and lizard's tail (Saururus cernuus).

The bottomland hardwood swamp was found to be the least diverse association, being thoroughly dominated, where transected, by water tupelo, Transect 8, (Appendix VI). Some of the water tupelo are quite large, the

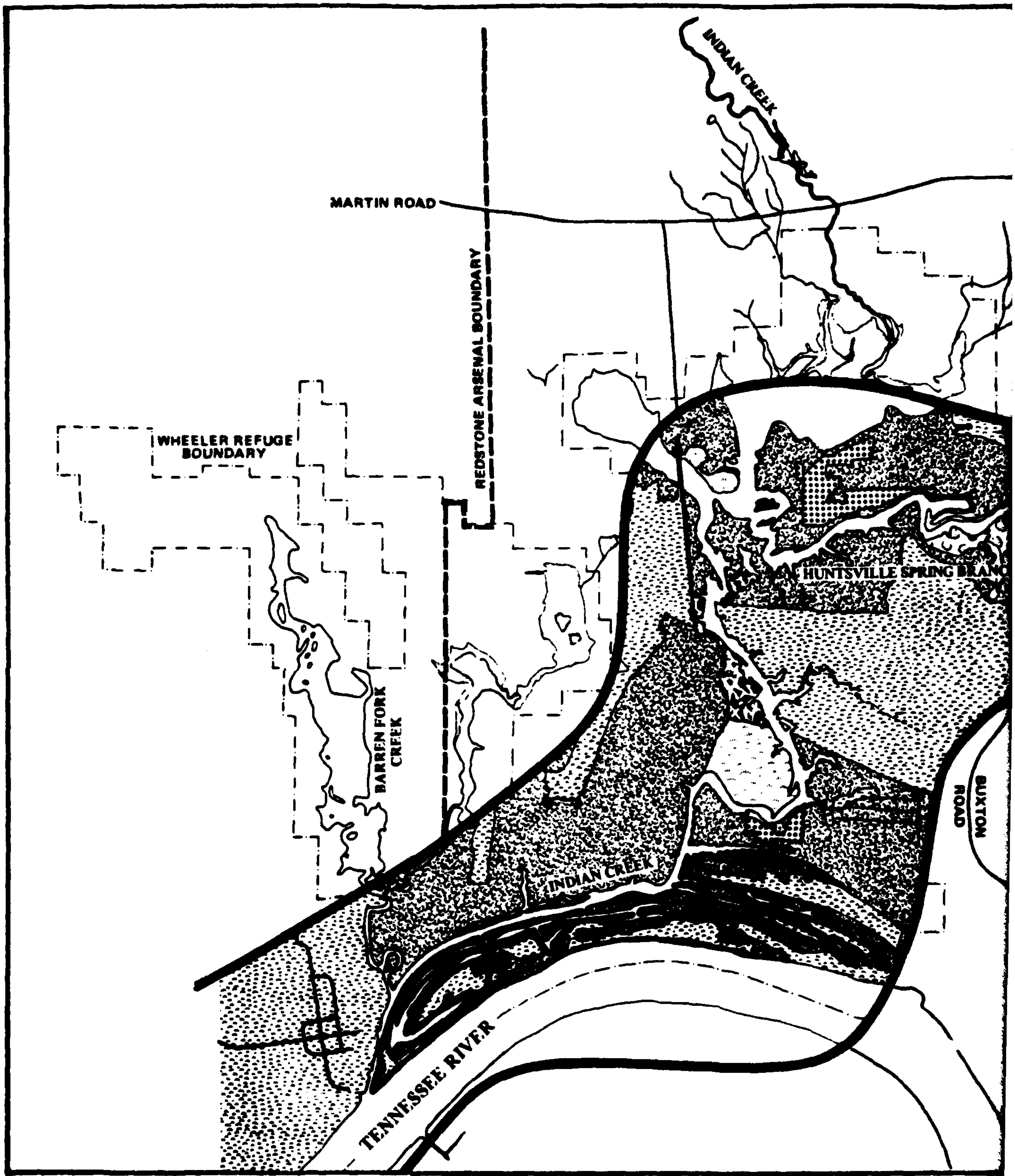
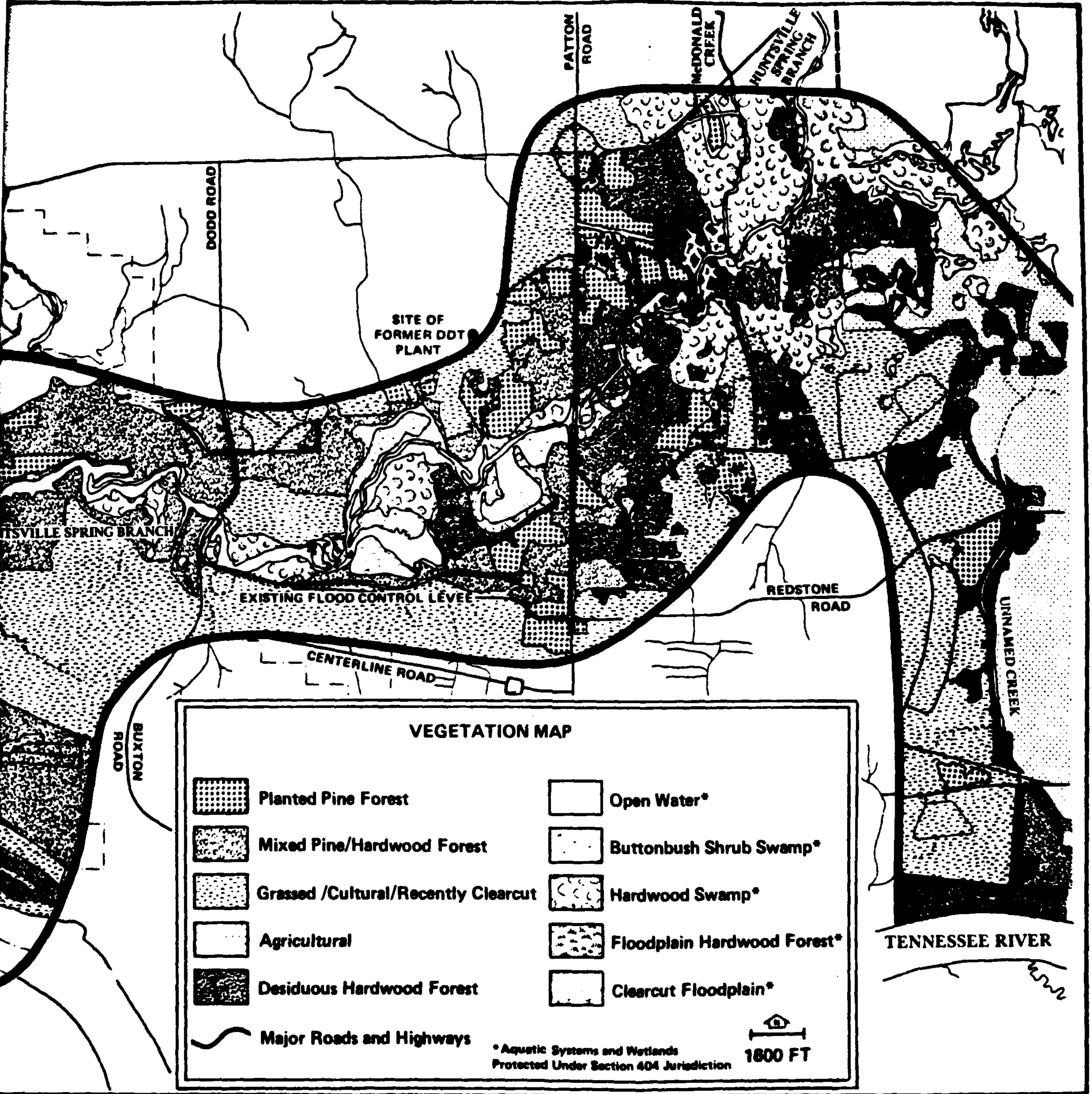


FIGURE II-2. Vegetative Associations Within the Project Study Area

SOURCE: WATER AND AIR RESEARCH, INC., 1980



U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

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largest circumference at breast height being measured at 96.5 inches. Shrubs consist of occasional buttonbush and swamp rose (Rosa palustris). No ground cover was observed under the 12 to 18-inch deep black, standing water. Poison ivy is abundant.

The results of the aquatic biological surveys are listed in Tables II-19, II-20, and II-21. Within Huntsville Spring Branch, phytoplankton density and species richness (number of taxa) increased in progression from above the old DDT ditch downstream to Indian Creek. This appears to be associated with stream widening and current deceleration. The high densities in HSB and IC relative to the Tennessee River are probably a result of nutrient enrichment from upstream wastewater disposal. Zooplankton density paralleled phytoplankton density in Huntsville Spring Branch, but was inconsistent in Indian Creek. Zooplankton species richness was relatively stable throughout both streams.

Artificial substrate macroinvertebrates increased in density progressing downstream from the DDT ditch, paralleling phytoplankton and zooplankton; however, species richness remained relatively constant and diversity decreased. This suggests that artificial substrate macroinvertebrate populations are more a function of food (phyto- and zooplankton) supply than of a toxic stress which would tend to depress macroinvertebrate densities. Macroinvertebrate infauna showed no clear trend in densities; however, there was an increase in species richness and in species diversity. This could be a reflection of the progressively lower levels of sediment DDTR.

Three upland forest associations were encountered. These are planted pine forest, mixed pine and deciduous hardwood forest, and deciduous hardwood forest. The mixed forest generally occurs on higher ground relative to the deciduous forest, which sometimes occurs between a floodplain forest and a mixed forest. Planted pines occur also on the higher ground. All three associations are scattered throughout the Arsenal.

Redstone Arsenal Uplands--The deciduous hardwood forest association is dominated by blue-beech, which is an understory tree, (Appendix VI). Co-dominant canopy trees are cherry bark oak, sweetgum, red maple and willow oak. Shrubs are common, including pawpaw, (Asimina triloba), a wild azalea (Rhododendron sp.), a blueberry (Vaccinium sp.), and parsley-haw (Crataegus marshallii). Ground cover is sparse, consisting of violets (Viola sp.), poison ivy, (Rhus toxicodendron), and muscadine (Vitis rotundifolia). Tree species diversity is intermediate between the floodplain forest and the swamp forest. This association is excellent wildlife habitat due to the diversity of mast-producing tree species. Its inhabitants include deer, turkey, fox, gray squirrel, and numerous woodland birds.

The mixed pine and deciduous hardwood forest is similar to the deciduous hardwood forest, Appendix VI. However, being somewhat drier, pines and red cedar become common to abundant. Tree species diversity is similar for the two. The mixed forest usually has a more open canopy, resulting in more shrub and ground cover. The shrubs include smooth sumac, (Rhus

Table II-19. Total Densities of Phytoplankton, Zooplankton, and Macroinvertebrates Collected from the DDTR Study Area

				Macroinvertebrates ($x10^3/m^2$)	
		Pytoplankton ($x10^6/l$)	Zooplankton ($x10^3/m^3$)	Artificial Substrates	Benthic Substrates
HSBM	5.9	1.28	5.68	2.16	0.68
	5.37	1.96	NA	2.23	2.65
	2.4	7.78	16.23	2.43	0.65
	1.3	110.58	32.17	4.71	1.34
	0.0	2.40	NA[1]	--	--
ICM	4.0	95.88	NA	--	--
	0.0	54.00	5.30	2.65	0.42
TRM	350.0	3.61	22.05	3.62	0.53
	345.2	1.92	32.84	16.31	0.30
	315.0	1.19	--[2]	--	--
	289.9	3.64	--	--	--
BFCM	1.2	17.22	NA	8.62	0.73
ERM	20.7	--	--	--	0.93
UC	0.5	--	--	--	13.06
UC	1.5	--	--	--	17.27
UC	2.8	--	--	--	8.57

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[1] NA = data not quantified and therefore not applicable.
[2] (-) indicates no samples were collected.

Table II-20. Total Numbers of Taxa of Phytoplankton, Zooplankton, and Macroinvertebrates Collected from the DDTR Study Area

		Pytoplankton	Zooplankton	Macroinvertebrates Artificial Substrates	 Benthic Substrates
HSBM	5.9	31	46	5	9
	5.37	38	47	4	11
	2.4	55	45	3	14
	1.3	53	45	4	18
	0.0	44	--	--	--
ICM	4.0	54	35	--	--
	0.0	59	46	4	18
TRM	350.0	47-50	38-42	10	13-16
	345.2	31-39	32-43	8	13-16
	315.0	29-36	--	--	--
	289.9	33-44	--	--	--
BFCM	1.2	57	43	8	11
ERM	20.7	--*	--	--	19
UC	0.5	--	--	--	19
UC	1.5	--	--	--	21
UC	2.8	--	--	--	21

*(-) indicates no samples were collected.

Table II-21. Shannon-Weaver Species Diversity (base 2) for Phytoplankton, Zooplankton, and Macroinvertebrates Collected from the DDTR Study Area

		Pytoplankton	Zooplankton	Macroinvertebrates	
				Artificial Substrates	Benthic Substrates
HSBM	5.9	2.85	2.32	1.73	0.74
	5.37	2.64	3.13	1.07	1.27
	2.4	3.00	3.25	1.07	2.61
	1.3	2.29	2.39	1.07	2.06
	0.0	3.24	--	--	--
ICM	4.0	1.89	1.50	--	--
	0.0	2.36	2.50	0.66	2.80
TRM	350.0	2.87-3.24	2.42-2.51	0.59	2.90
	345.2	2.89-3.25	1.89-2.45	1.10	2.21
	315.0	2.90-3.22	--	--	--
	289.9	2.56-2.78	--	--	--
BFCM	1.2	2.96	2.12	1.10	2.54
ERM	20.7	--*	--	--	2.05
UC	0.5	--	--	--	1.89
UC	1.5	--	--	--	2.28
UC	2.8	--	--	--	2.36

*(-) indicates no samples were collected.

glabra), blackberry (Rubus sp.), and tree saplings. Vines were usually very abundant, including muscadine (Vitis rotundifolia), trumpet-vine (Campsis radicans), peppervine (Ampelopsis arborea), and several kinds of greenbriar (Smilax spp.). This is excellent wildlife habitat, having mast-producing trees, fruit-producing vines, and plenty of cover for resting or nesting.

Planted pine forests probably have the lowest tree species diversity of any association within the project area, although this was not measured. Where the planted forest approaches maturity the canopy coverage approaches 100 percent, which, coupled with the very acidic nature of fallen needles, precludes all but a few other species from surviving. Among these are blackberry (Rubus sp.) and braken fern (Pteridium aquilinum). Where the forest is younger, other shrubs and trees may be common or even dense. These include sweetgum, smooth sumac, and vines. The latter younger forests provide moderate wildlife habitat, while the more mature plantations maintain low wildlife potential. Loblolly and slash pines (Pinus taeda and P. elliottii, respectively) are cultivated in the pine plantations (D. Bryant, personal communication, 1979).

2.1.3 Indian Creek

Downstream of its confluence with HSB, Indian Creek is relatively wide and shallow. No aquatic vegetation was seen, except for occasional buttonbush and black willow along the shoreline. At approximately ICM 2.8, where Indian Creek meets the base of Bradford Mountain, the stream narrows and deepens. There is little or no littoral zone, since the banks are nearly vertical. The floodplain between ICM 3.9-4.7 has been cleared of woody vegetation. Here, herbaceous vegetation carpets the ground wherever prolonged flooding does not occur. A section of floodplain forest shades the west bank between ICM 2.8-3.9. The forests on either side of Indian Creek below ICM 2.8 are of upland character, being either deciduous hardwood or mixed pine and deciduous hardwoods.

Benthos at the mouth of Indian Creek (ICM 0.0) were dominated numerically by chironomids, with oligochaetes being secondary dominants. Total benthic populations were less at the mouth of Indian Creek than at any of the sampled locations within Huntsville Spring Branch, although species diversity was higher. The Asiatic clam, Corbicula fluminea, was present in low numbers at the mouth of Indian Creek, while it was more abundant in the Tennessee River and absent in Huntsville Spring Branch. The fingernail clam, Sphaerium sp., was present in all three locations, but was more common in the Tenneessee River. Sphaerium transversum was found in the vicinity of the Pine Bluff Arsenal in sediments loaded to 100-180 ug/g DDTR (E. Bender, personal communication, 1979).

Hester-Dendy artificial substrate samplers in Indian Creek and Huntsville Spring Branch were populated almost exclusively by chironomids (99.2 percent) and a few tubificids. Above the old DDT ditch the chironomids were apportioned fairly evenly among Chironomus, Dicrotendipes, and Glyptotendipes. These are commonly found in moderate to eutrophic conditions, feeding on phytoplankton and suspended detritus. Below the old DDT ditch, Chironomus disappears and is replaced by Glyptotendipes and Dicrotendipes. Ablabesmyia, a predaceous chironomid, is consistently present in low numbers at all stations except at the mouth of Indian Creek. Ablabesmyia was also absent from the Tennessee River samplers. Caddisfly larvae primarily Cheumatopsyche and Hydropsyche, dominated the Tennessee River samplers. Mayfly larvae were present in low numbers on Tennessee River samplers. Like the benthic samples, no mayfly, stonefly, or caddisfly larvae were found on artificial substrates from Indian Creek and Huntsville Spring Branch. These groups are among those least tolerant to pollution. Since they were absent from above the old DDT ditch, their absence may be due at least as much to the pollution from Huntsville as from the DDTR.

An artesian spring occurs at the northwestern end of the flooded cul-de-sac whose exit into Indian Creek lies opposite the confluence with Huntsville Spring Branch. No aquatic or wetland vegetation was found in or around the spring. In a benthic grab (qualitative) sample were found blind, white troglobitic (cave-adapted) amphipods and isopods, indicating that the spring discharges an underground stream. The amphipod was identified by Dr. John R. Holsinger (personal communication, 1980) as probably being an undescribed species of Stygobromus. It may be described in the future, by Dr. Holsinger, from specimens collected in this study. The isopod was identified by Julian J. Lewis (personal communication, 1980) as probably being Caecidotea bicrenata.

2.1.4 Unnamed Creek

The Unnamed Creek, actually a ditch, runs approximately parallel to the Arsenal's eastern boundary. At approximately UNC mile 3.0, the creek forks. The northern fork exists as a shallow swale approximately 10 feet wide and up to 2 feet deep. This swale is subdivided by a number of small beaver dams, which pool the water and provide habitat for dense patches of aquatic grassbeds formed of smartweed, milfoils and a Ludwigia (see Appendix VI). The impoundments range up to about 50 feet long. The current was negligible during sampling (October, 1979). The benthic substrate is composed mostly of organic detritus, with much silt. The benthos is dominated by oligochaetes, chironomid larvae, and the Asiatic clam (see Appendix VI). The north fork lies within a deciduous hardwood forest dominated by willow oak, sweetgum and hackberry.

The southwestern fork originates within the Thiokol contractor-use area, where it picks up stormwater and small amounts of wastewater from the rocket propellant manufacturing process. The southwestern fork, and the remainder of the creek below the confluence with the north fork, is very different in physical structure and ecological function from the north fork. Most of the creek's flow originates within the southwestern fork. The channel is very deep, up to 15 feet in places, although during sampling the water was less than a foot deep. The banks are very steep, with perhaps a 1:2 slope. Ground vegetation was sparse, and there was no aquatic vegetation. A current was present during sampling. At UNC Mile 1.5 the benthic substrate was mostly clay and silt, although organic detritus was also present. At Mile 0.5 the substrate was composed of coarse materials (sand, pebbles) due to the shallowness and swiftness of the stream. At Mile 1.5 the benthos was dominated by oligochaetes, chironomids and Asiatic clams, like that at Mile 2.8. The benthos at Mile 0.5 was dominated by oligochaetes, chironomids, and fingernail clams, although the chironomids were present here in much lower densities than upstream.

No true floodplain forest is associated with this stream. The associated forest is deciduous hardwoods north of Buxton Road; south, it is composed of mixed pine and deciduous hardwoods, with abundant red cedar. Apparently this was once a small surface channel almost entirely storm-fed. It appears to have been canalized all the way to the Wheeler Reservoir for the purpose of stormwater and wastewater removal. Prior to the original canalization, the creek may have flowed north into the bottomland hardwood swamp forests in the Huntsville Spring Branch floodplain.

The deciduous forest has a dense canopy dominated by willow oak. Commonly found are green ash, hackberry, and overcup oak (see Transect 10, Appendix VI). Shrubs and ground cover are sparse. South of Buxton Road, the stream is lined with high spoil banks. These are vegetated with an open canopy of early successionals dominated by loblolly pines, red cedar, red maple, black cherry and willow oak. Shrubs and ground cover are very dense due to the open nature of the crown canopy (see Appendix VI).

2.1.5 Wheeler Refuge

The Wheeler National Wildlife Refuge contains 37,648 acres in the *Tennessee River Valley* of Northern Alabama. Formed in 1938, it was the first refuge ever superimposed on a hydroelectric impoundment as an experiment to determine the feasibility of attracting migratory waterfowl onto a multiple-purpose impoundment. Presently, approximately 50,000 wild ducks and 30,000 Canada geese winter there. Though designated for waterfowl, the Wheeler Refuge provides habitat for many species of wildlife. Other habitats of interest are a large tupelo swamp designated as a National Landmark, a pure stand of eastern cedar designated as a Research Natural Area, and 1,200 acres of bottomland hardwoods set aside as four public use natural areas.

2.1.6 Species List

Species have been drawn from the published federal lists of species known or suspected to occur within the adjacent Wheeler National Wildlife Refuge. These are listed in Tables II-22 through II-26.

2.1.7 Caves

Eleven caves are known to exist on the Redstone Arsenal (Sproul, 1972). Five of these occur south of Martin Road, within the study area. In addition, there is an entrance to a possible cave at the base of Bradford Mountain, within the Arsenal, and there is one cave off the Arsenal within a half-mile of the proposed out-of-basin diversion route.

Table II-22. Fishes of the Wheeler National Wildlife Refuge[1]

COMMON NAME	SCIENTIFIC NAME	RELATIVE ABUNDANCE[2]
Ohio Lamprey	Ichthyomyzon bdellium	Rare
Chestnut Lamprey	Ichthyomyzon castaneus	Common
Least Brook Lamprey	Lampetra aepyptera	Rare
Lake Sturgeon	Acipenser fulvescens	Undetermined
Shovelnose Sturgeon	Scaphirhynchus platorynchus	Undetermined
Paddlefish	Polyodon spathula	Uncommon
Spotted Gar	Lepisosteus oculatus	Common
Longnose Gar	Lepisosteus osseus	Common
Shortnose Gar	Lepisosteus platostomus	Undetermined
Bowfin	Amia calva	Uncommon
American Eel	Anguilla rostrata	Uncommon
Skipjack Herring	Alosa chrysochloris	Abundant
Gizzard Shad	Dorosoma cepedianum	Abundant
Threadfin Shad	Dorosoma petenense	Abundant
Goldeye	Hiodon alosoides	Rare
Mooneye	Hiodon tergisus	Uncommon
Rainbow Trout	Salmo gairdneri	Uncommon
Redfin Pickerel	Esox americanus americanus	Uncommon
Chain Pickerel	Esox niger	Common
Stoneroller	Campostoma anomalum	Common
Goldfish	Carassius auratus	Uncommon
Rosyside Dace	Clinostomus funduloides	Undetermined
Common Carp	Cyprinus carpio	Abundant
Flame Chub	Hemitremia flammea	Rare
Silvery Minnow	Hybognathus nuchalis	Undetermined
Bigeye Chub	Hybopsis amblops	Undetermined
Blotched Chub	Hybopsis insignis	Undetermined
Silver Chub	Hybopsis storeriana	Undetermined
River Chub	Nocomis micropogon	Undetermined
Golden Shiner	Notemigonus crysoleucas	Common
Rosefin Shiner	Notropis ardens	Undetermined
Emerald Shiner	Notropis atherinoides	Common
Ghost Shiner	Notropis buchanani	Uncommon
Striped Shiner	Notropis chrysocephalus	Common
Ribbon Shiner	Notropis fumeus	Undetermined
Whitetail Shiner	Notropis galacturus	Undetermined
Tennessee Shiner	Notropis leuciodus	Undetermined
Mountain Shiner	Notropis lirus	Undetermined
Rosyface Shiner	Notropis rubellus	Undetermined
Spotfin Shiner	Notropis spilopterus	Undetermined

Table II-22. Fishes of the Wheeler National Wildlife Refuge[1] (Continued, Page 2)

COMMON NAME	SCIENTIFIC NAME	RELATIVE ABUNDANCE[2]
Telescope Shiner	*Notropis telescopus*	Undetermined
Mimic Shiner	*Notropis volucellus*	Undetermined
Steelcolor Shiner	*Notropis whipplei*	Common
Pugnose Minnow	*Opsopoedus emiliae*	Undetermined
Bluntnose Minnow	*Pimephales notatus*	Common
Fathead Minnow	*Pimephales promelas*	Uncommon
Bullhead Minnow	*Pimephales vigilax*	Common
Blacknose Dace	*Rhinichthys atratulus*	Uncommon
Creek Chub	*Semotilus atromaculatus*	Common
River Carpsucker	*Carpiodes carpio*	Uncommon
Quillback	*Carpiodes cyprinus*	Uncommon
Highfin Carpsucker	*Carpiodes velifer*	Uncommon
White Sucker	*Catostomus commersoni*	Uncommon
Creek Chubsucker	*Erimyzon oblongus*	Undetermined
Northern Hogsucker	*Hypentelium nigricans*	Undetermined
Smallmouth Buffalo	*Ictiobus bubalus*	Common
Bigmouth Buffalo	*Ictiobus cyprinellus*	Uncommon
Black Buffalo	*Ictiobus niger*	Uncommon
Spotted Sucker	*Minytrema melanops*	Abundant
Silver Redhorse	*Moxostoma anisurum*	Common
River Redhorse	*Moxostoma carinatum*	Uncommon
Black Redhorse	*Moxostoma duquesnei*	Common
Golden Redhorse	*Moxostoma erythrurum*	Common
Shorthead Redhorse	*Moxostoma macrolepidotum*	Common
Blue Catfish	*Ictalurus furcatus*	Common
Black Bullhead	*Ictalurus melas*	Common
Yellow Bullhead	*Ictalurus natalis*	Uncommon
Brown Bullhead	*Ictalurus nebulosus*	Uncommon
Channel Catfish	*Ictalurus punctatus*	Common
Slender Madtom	*Noturus exilis*	Undetermined
Tadpole Madtom	*Noturus notatus*	Undetermined
Flathead Catfish	*Pylodictis olivaris*	Common
Southern Cavefish	*Typhlichthys subterraneus*	Undetermined
Pirate Perch	*Aphredoderus sayanus*	Undetermined
Blackstripe Topminnow	*Fundulus notatus*	Undetermined
Blackspotted Topminnow	*Fundulus olivaceus*	Common
Mosquitofish	*Gambusia affinis*	Common
Brook Silverside	*Labidesthes sicculus*	Common
White Bass	*Morone chrysops*	Common
Yellow Bass	*Morone mississippiensis*	Common
Striped Bass	*Morone saxatilis*	Undetermined
Rock Bass	*Ambloplites rupestris*	Uncommon
Green Sunfish	*Lepomis cyanellus*	Abundant
Warmouth	*Lepomis gulosus*	Common
Orangespotted Sunfish	*Lepomis humilis*	Common
Bluegill	*Lepomis macrochirus*	Abundant

Table II-22. Fishes of the Wheeler National Wildlife Refuge[1]
(Continued, Page 3)

COMMON NAME	SCIENTIFIC NAME	RELATIVE ABUNDANCE[2]
Longear Sunfish	*Lepomis megalotis*	Common
Redear Sunfish	*Lepomis microlophus*	Common
Smallmouth Bass	*Micropterus dolomieui*	Uncommon
Spotted Bass	*Micropterus punctulatus*	Common
Largemouth Bass	*Micropterus salmoides*	Common
White Crappie	*Pomoxis annularis*	Common
Black Crappie	*Pomoxis nigromaculatus*	Uncommon
Greenside Darter	*Etheostoma blennioides*	Common
Blenny Darter	*Etheostoma blennius*	Undetermined
Rainbow Darter	*Etheostoma caeruleum*	Undetermined
Blackside Snubnose Darter	Etheostoma *duryi*	Uncommon
Fantail Darter	*Etheostoma flabellare*	Undetermined
Blueside Darter	*Etheostoma jessiae*	Undetermined
Stripetail Darter	*Etheostoma kennicotti*	Undetermined
Johnny Darter	*Etheostoma nigrum*	Undetermined
Redline Darter	*Etheostoma rufilineatum*	Undetermined
Tennessee Snubnose Darter	Etheostoma *simoterum*	Undetermined
Spottail Darter	*Etheostoma squamiceps*	Undetermined
Speckled Darter	*Etheostoma stigmaeum*	Undetermined
Tuscumbia Darter	*Etheostoma tuscumbia*	Rare
Banded Darter	*Etheostoma zonale*	Undetermined
Logperch	*Percina caprodes*	Common
Blackside Darter	*Percina maculata*	Undetermined
Dusky Darter	*Percina sciera*	Undetermined
River Darter	*Percina shumardi*	Undetermined
Oachita Darter	*Percina oachitae*	Undetermined
Sauger	*Stizostedion canadense*	Common
Walleye	*Stizostedion vitreum vitreum*	Uncommon
Freshwater Drum	*Aplodinotus grunniens*	Abundant
Banded Sculpin	*Cottus carolinae*	Uncommon

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[1] Taken directly from Reeves, n.d.

[2] Abundant=occurring in large numbers in many locations.
Common=widely distributed, may be quite numerous at certain times of the year or at particular locations.
Uncommon=observed only occasionally, because of restricted habitat or small numbers present.
Rare=present in very small numbers or, where abundant, found in very restricted habitat in only a few locations.
Undetermined=status unknown, these species are expected to occur in the waters of Wheeler Refuge, but their presence and/or numbers have not been validated. Many of the species were placed in this catagory because of a lack of basic information on them within the refuge boundaries.

Table II-23. Amphibians of the Wheeler National Wildlife Refuge[1]

COMMON NAME	SCIENTIFIC NAME
FROGS AND TOADS	
Eastern Narrow-Mouthed Toad	Gastrophryne carolinensis
Eastern Spade Foot Toad	Scaphiopus holbrooki
American Toad	Bufo americanus
Woodhouse's Toad	Bufo woodhousei
Northern Cricket Frog	Acris c. crepitans
Mountain Chorus Frog	Pseudacris brachyphona
Northern Chorus Frog	Pseudacris triseriata feriarum
Greater Gray Tree Frog	Hyla v. versicolor
Lesser Gray Tree Frog	Hyla chrysocelis
Spring Peeper Tree Frog	Hyla c. crucifer
Bullfrog	Rana catesbeiana
Green Frog	Rana clamitans melanota
Southern Leopard Frog	Rana sphenocephala
Pickerel Frog	Rana palustris
SALAMANDERS	
Hellbender	Cryptobranchus a. alleganiensis
Mudpuppy	Necturus m. maculosus
Tiger Salamander	Ambystoma t. tigrinum
Spotted Salamander	Ambystoma maculatum
Marbled Salamander	Ambystoma opacum
Small-Mouthed Salamander	Desmognathus fuscus
Seal Salamander	Desmognathus monticola
Two-Lined Salamander	Eurycea bislineata
Long-Tailed Salamander	Eurycea l. longicauda
Cave Salamander	Eurycea lucifuga
Red Salamander	Pseudotriton r. ruber
Spring Salamander	Gyrinophilus porphyriticus
Tennessee Cave Salamander	Gyrinophilus paleucus
Zigzag Salamander	Plethodon dorsalis
Slimy Salamander	Plethodon g. glutinosus
Green Salamander	Aneides aeneus
Four-Toed Salamander	Hemidactylium scutatum
Eastern Newt	Notophthalmus viridescens

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[1] From Conant, 1958; Smith, 1978; and Speake and Mount, 1974.

Table II-24. Reptiles Possibly Occurring in the Wheeler National Wildlife Refuge[1]

COMMON NAME	SCIENTIFIC NAME
SAURIANS	
American Alligator	Alligator mississippiensis
TURTLES	
Snapping Turtle	Chelydra s. serpentina
Stinkpot	Sternothaerus odoratus
Stripe-Necked Musk Turtle	Sternothaerus minor peltifer
Eastern Mud Turtle	Kinosternon s. subrubrum
Eastern Box Turtle	Terrapene c. carolina
Map Turtle	Graptemys geographica
Ouachita Map Turtle	Graptemys pseudogeographica ouachitensis
Midland Painted Turtle	Chrysemys picta marginata
Southern Painted Turtle	Chrysemys picta dorsalis
Red-Eared Turtle	Chrysemys scripta elegans
Cumberland Turtle	Chrysemys scripta troosti
River Cooter	Chrysemys c. concinna
Slider	Chrysemys concinna hieroglyphica
Smooth Softshell	Trionyx m. muticus
Eastern Spiny Softshell	Trionyx s. spinifer
LIZARDS	
Green Anole	Anolis c. carolinensis
Northern Fence Lizard	Sceloporus undulatus hyacinthinus
Six-Lined Racerunner	Cnemidophorus sexlineatus
Ground Skink	Leiolopisma laterale
Five-Lined Skink	Eumeces fasciatus
Broad Headed Skink	Eumeces laticeps
Southeastern Five-Lined Skink	Eumeces inexpectatus
Eastern Slender Glass Lizard	Ophisaurus attenuatus longicaudus
SNAKES	
Yellow-Bellied Water Snake	Nerodia erythrogaster flavigaster
Midland Water Snake	Nerodia sipedon pleuralis
Northern Water Snake	Nerodia s. sipedon
Queen Snake	Regina septemvittata
Midland Brown Snake	Storeria dekayi wrightorum
Northern Red-Bellied Snake	Storeria o. occipitomaculata
Eastern Garter Snake	Thamnophis s. sirtalis
Eastern Ribbon Snake	Thamnophis s. sauritus
Rough Earth Snake	Haldea striatula
Eastern Earth Snake	Haldea v. valeriae

Table II-24. Reptiles Possibly Occurring in the Wheeler National Wildlife Refuge[1] (Continued, Page 2)

COMMON NAME	SCIENTIFIC NAME
Eastern Hognose Snake	Heterodon platyrhinos
Mississippi Ringneck Snake	Diadophis punctatus stictogenys
Northern Ringneck Snake	Diadophis punctatus edwardsi
Eastern Worm Snake	Carphophis a. amoenus
Midwest Worm Snake	Carphophis amoenus helenae
Western Mud Snake	Farancia abacura reinwardti
Northern Black Racer	Coluber c. constrictor
Eastern Coachwhip	Masticophis f. flagellum
Rough Green Snake	Opheodrys aestivus
Corn Snake	Elaphe g. guttata
Black Rat Snake	Elaphe o. obsoleta
Gray Rat Snake	Elaphe obsoleta spiloides
Black Kingsnake	Lampropeltis getulus niger
Scarlet Kingsnake	Lampropeltis d. doliata
Red Milk Snake	Lampropeltis doliata syspila
Eastern Milk Snake	Lampropeltis doliata triangulum
Mole Snake	Lampropeltis calligaster rhombomaculata
Scarlet Snake	Cemophora coccinea
Southeastern Crowned Snake	Tantilla c. coronata
Northern Copperhead	Agkistrodon contortrix mokeson
Eastern Cottonmouth	Agkistrodon p. piscivorus
Timber Rattlesnake	Crotalus horridus atricaudatus
Carolina Pygmy Rattlesnake	Sistrurus miliarius miliarius

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[1] From Conant, 1958; and Speake and Mount, 1974.

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W[2]
Common Loon	*Gavia immer*	c		c	c[3]
Red-throated Loon	*Gavia stellata*				x
Red-necked Grebe	*Podiceps grisegena*			o	o
Horned Grebe	*Podiceps auritus*	u		c	c
Eared Grebe	*Podiceps caspicus*	x			
Pied-billed Grebe*	*Podilymbus podiceps*	c	u	c	c
White Pelican	*Pelacanus erythrorhynchos*	r		u	r
Double-crested Cormorant	*Phalacrocorax auritus*	r	r	r	r
Anhinga	*Anhinga anhinga*	r	r		
Great Blue Heron	*Ardea herodias*	u	u	c	c
Green Heron*	*Butorides virescens*	c	c	u	
Little Blue Heron	*Florida caerulea*	u	u		
Cattle Egret	*Bubulcus ibis*	u	u	u	
Great Egret	*Casmerodius albus*	u	u	u	r
Snowy Egret	*Leucophoyx thula*	u	u		
Louisiana Heron	*Hydranassa tricolor*	x	x		
Black-crowned Night Heron	*Nycticorax nycticorax*	u	u	u	r
Yellow-crowned Night Heron*	*Nyctanassa violacea*	c	c	u	r
Least Bittern*	*Ixobrychus exilis*	u	u	u	
American Bittern	*Botaurus lentiginosus*	u		u	r
Wood Stork	*Mycteria americana*	x	x		
Glossy Ibis	*Plegadis falcinellus*	r		r	
White Ibis	*Eudocimus albus*	r	r	r	
Mute Swan	*Cygnus olor*	x			
Whistling Swan	*Olor columbianus*	r		u	r
Canada Goose	*Branta canadensis*	u	u	a	a
Brant	*Branta bernicla*				x
Barnacle Goose	*Branta leucopsis*				x
White-fronted Goose	*Anser albifrons*	r		r	r
Snow Goose	*Chen hyperborea*	u		c	c

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 2)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Mallard*	*Anas platyrhynchos*	c	c	a	a
Black Duck*	*Anas rubripes*	u	u	c	c
Gadwall	*Anas strepera*	u	r	c	c
Pintail	*Anas acuta*	u	r	c	c
Green-winged Teal	*Anas carolinensis*	u	r	c	c
Blue-winged Teal	*Anas discors*	c	r	c	u
Cinnamon Teal	*Anas cyanoptera*				x
American Wigeon	*Mareca americana*	u		c	a
Northern Shoveler	*Spatula clypeata*	c	r	c	c
Wood Duck*	*Aix sponsa*	c	c	c	c
Fulvous Whistling Duck, Fulvous Tree Duck	*Dendrocygna bicolor*	x			
Redhead	*Aythya americana*	r		u	u
Ring-necked Duck	*Aythya collaris*	c		c	c
Canvasback	*Aythya valisineria*	c		c	c
Greater Scaup	*Aythya marila*			u	u
Lesser Scaup	*Aythya affinis*	c	r	c	c
Common Goldeneye	*Bucephala clangula*	u		u	u
Bufflehead	*Bucephala albeola*	u		c	c
Common Eider	*Somateria mollissima*				x
King Eider	*Somateria spectabilis*				x
Oldsquaw	*Clangula hyemalis*			u	u
Harlequin Duck	*Histrionicus histrionicus*				x
White-winged Scoter	*Melanitta deglandi*	r		r	u
Surf Scoter	*Melanitta perspicillata*				x
Black Scoter	*Oidemia nigra*				x
Ruddy Duck	*Oxyura jamaicensis*	u		u	c
Masked Duck	*Oxyura dominica*	x			
Hooded Merganser	*Lophodytes cucullatus*	u	u	c	c
Common Merganser	*Mergus merganser*	u		u	u
Red-breasted Merganser	*Mergus serrator*	c		u	u
Turkey Vulture	*Cathartes aura*	u	u	u	u

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 3)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Black Vulture	Coragyps atratus	r	r	r	r
Mississippi Kite	Ictinia misisippiensis	o	o		
Sharp-shinned Hawk*	Accipiter striatus	u	u	u	u
Cooper's Hawk*	Accipiter cooperi	u	u	u	u
Red-tailed Hawk*	Buteo jamaicensis	u	u	c	c
Red-shouldered Hawk*	Buteo lineatus	r	r	r	r
Broad-winged Hawk	Buteo platypterus	u	u		
Swainson's Hawk	Buteo swainsoni			x	x
Rough-legged Hawk	Buteo lagopus			o	o
Golden Eagle	Aquila chrysaetos			o	o
Bald Eagle	Haliaeetus leucocephalus	r		u	u
Marsh Hawk	Circus cyaneus	u		c	c
Osprey	Pandion haliaetus	u		u	
Peregrine Falcon	Falco peregrinus			r	r
Merlin	Falco columbarius	r		u	u
American Kestrel*	Falco sparverius	c	c	c	c
Bobwhite*	Colinus virginianus	c	c	c	c
Ring-necked Pheasant	Phasianus colchicus	x	x	x	x
Wild Turkey*	Meleagris gallopavo	u	u	u	u
King Rail*	Rallus elegans	c	c	c	
Virginia Rail*	Rallus limicola	c	c		
Sora Rail	Porzana carolina	c	c	c	
Yellow Rail	Coturnicops noveboracensis				x
Purple Gallinule	Porphyrula martinica	u	u		
Florida Gallinule	Gallinula chloropus	u	u	u	
Coot*	Fulica americana	c	u	c	c
Semipalmated Plover	Charadrius semipalmatus	c	u	c	
Piping Plover	Charadrius melodus	o		o	
Wilson's Plover	Charadrius wilsonia	x			
Killdeer*	Charadrius vociferus	c	c	c	c

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 4)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Curlew, or Whimbrel	Numenius phaeopus	r	r	r	
Golden Plover	Pluvialis dominica	u		u	
Black-bellied Plover	Squatarola quatarola	u	r	u	
Ruddy Turnstone	Arenaria interpres	o		o	
American Woodcock*	Philohela minor	c	u	c	c
Snipe	Capella gallinago	c	u	c	c
Upland Sandpiper	Bartramia longicauda	r	r	r	
Spotted Sandpiper	Actitis macularia	c	c	c	
Solitary Plover	Tringa solitaria	c	u	c	
Willet	Catoptrophorus semipalmatus	o	o	o	
Greater Yellowlegs	Totanus melanoleucus	c	u	c	u
Lesser Yellowlegs	Totanus flavipes	c	u	c	r
Knot	Calidris canutus			u	
Pectoral Sandpiper	Erolia melanotos	c	u	c	r
White-rumped Sandpiper	Erolia fuscicollis	u	r	u	
Baird's Sandpiper	Erolia bairdii	r		r	
Least Sandpiper	Erolia minutilla	c	u	c	u
Dunlin	Erolia alpina	u		u	
Short-billed Dowitcher	Limnodromus griseus	u		u	
Long-billed Dowitcher	Limnodromus scolopaceus	u		u	
Stilt Sandpiper	Micropalama himantopus	o	r	u	
Semipalmated Sandpiper	Ereunetes pusillus	c	u	c	r
Western Sandpiper	Ereunetes mauri	u	r	u	
Buff-breasted Sandpiper	Tryngites subruficollis	u		u	
Marbled Godwit	Limosa fedoa	o			
Hudsonian Godwit	Limosa haemastica	o			o
Sanderling	Crocethia alba	r		u	
American Avocet	Recurvirostra americana			o	
Black-necked Stilt	Himantopus mexicanus	x		x	
Wilson's Phalarope	Steganopus tricolor	o		o	

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 5)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Northern Phalarope	Lobipes lobatus			x	
Great Black-backed Gull	Larus marinus				o
Herring Gull	Larus argentatus	u	r	c	c
Ring-billed Gull	Larus delawarensis	u	r	c	c
Laughing Gull	Larus atricilla	r	r	r	r
Glaucus Gull	Larus hyperboreus				o
Franklin's Gull	Larus pipixcan	r	r		r
Bonaparte's Gull	Larus philadelphia	u		u	u
Forster's Tern	Sterna forsteri	u	u	u	
Common Tern	Sterna hirundo	u	u	u	
Least Tern	Sterna albifrons	u	u	u	
Caspian Tern	Hydroprogne caspia	u	u	u	
Black Tern	Chlidonias niger	u	u	u	
Rock Dove*	Columba livia	c	c	c	c
White-winged Dove	Zenaida asiatica			x	
Mourning Dove*	Zenaidura macroura	c	c	a	c
Ground Dove	Columbigallina passerina	o	o	o	
Yellow-billed Cuckoo*	Coccyzus americanus	c	c	c	
Black-billed Cuckoo	Coccyzus erythropthalmus	r		r	
Barn Owl*	Tyto alba	c	c	c	c
Screech Owl*	Otus asio	c	c	c	c
Great-horned Owl*	Bubo virginianus	u	u	u	u
Barred Owl*	Strix varia	u	u	u	u
Short-eared Owl	Asio flammeus			u	u
Saw-whet Owl	Aegolius acadicus				x
Chuck-Will's-Widow	Caprimulgus carolinensis	c	c	u	
Whip-Poor-Will	Caprimulgus vociferus	u		u	
Common Nighthawk*	Chordeiles minor	c	c	c	
Chimney Swift*	Chaetura pelagica	c	c	c	c
Ruby-throated Hummingbird*	Archilochus colubris	c	c	c	
Belted Kingfisher*	Megaceryle alcyon	u	u	u	u
Common Flicker*	Colaptes auratus	c	c	c	c

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 6)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Pileated Woodpecker*	Dryocopus pileatus	c	c	c	c
Red-bellied Woodpecker*	Centurus carolinus	c	c	c	c
Red-headed Woodpecker*	Melanerpes erythrocephalus	c	c	c	u
Yellow-bellied Sapsucker	Sphyrapicus varius	u		c	c
Hairy Woodpecker*	Dendrocopos villosus	c	c	c	c
Downy Woodpecker*	Dendrocopos pubescens	c	c	c	c
Kingbird*	Tyrannus tyrannus	c	c	c	
Scissor-tailed Flycatcher	Muscivora forfic			x	
Crested Flycatcher*	Myiarchus crinitus	c	c		
Eastern Phoebe*	Sayornis phoebe	c	c	u	u
Acadian Flycatcher	Empidonax virescens	u	u		
Olive-sided Flycatcher	Nuttallornis borealis	x			
Wood Pewee*	Contopus virens	c	c	u	
Horned Lark*	Eremophila alpestris	u	u	c	c
Tree Swallow	Iridoprocne bicolor	u		u	
Bank Swallow	Riparia riparia	c		c	
Rough-winged Swallow*	Stelgidopteryx ruficollis	c	c	c	
Barn Swallow*	Hirundo rustica	c	c	c	
Cliff Swallow*	Petrochelidon pyrrhonota	c	u	c	
Purple Martin*	Progne subis	c	c		
Blue Jay*	Cyanocitta cristata	c	c	c	c
Common Crow*	Corvus brachyrhynchos	c	u	a	a
Carolina Chickadee*	Parus carolinensis	c	c	c	c
Tufted Titmouse*	Parus bicolor	c	c	c	c
White-breasted Nuthatch	Sitta carolinensis	u		u	u
Red-breasted Nuthatch	Sitta canadensis	r		u	u
Brown-headed Nuthatch	Sitta pusilla			x	
Brown Creeper	Certhia familiaris			c	c
House Wren	Troglodytes aedon	u		u	c
Winter Wren	Troglodytes troglodytes			u	c
Bewick's Wren	Thryomanes bewickii	r	r	u	u

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 7)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Carolina Wren*	*Thryothorus ludovicianus*	c	c	c	c
Long-billed Marsh Wren	*Telmatodytes palustris*			r	r
Short-billed Marsh Wren	*Cistothorus platensis*	r		r	
Mockingbird*	*Mimus polyglottos*	c	c	c	c
Gray Catbird*	*Dumetella carolinensis*	c	c	u	r
Brown Thrasher	*Toxostoma rufum*	c	c	c	c
American Robin*	*Turdus migratorius*	c	c	c	c
Wood Thrush*	*Hylocichla mustelina*	c	c		
Hermit Thrush	*Hylocichla guttata*			c	c
Swainson's Thrush	*Hylocichla ustulata*	u		u	
Gray-cheeked Thrush	*Hylocichla minima*	u		u	
Veery	*Hylocichla fuscescens*	r		r	
Eastern Bluebird*	*Sialia sialis*	u	u	u	u
Blue-gray Gnatcatcher*	*Polioptila caerulea*	c	c	u	
Golden-crowned Kinglet	*Regulus satrapa*	r		c	c
Ruby-crowned Kinglet	*Regulus calendula*	r		c	c
Water Pipit	*Anthus spinoletta*	u		c	c
Sprague's Pipit	*Anthus spragueii*				x
Cedar Waxwing	*Bombycilla garrulus*	u		c	c
Loggerhead Shrike*	*Lanius ludovicianus*	c	u	c	c
Starling*	*Sturnus vulgaris*	c	c	a	a
White-eyed Vireo*	*Vireo griseus*	c	c	c	
Yellow-throated Vireo*	*Vireo flavifrons*	c	c	u	
Solitary Vireo	*Vireo solitarius*	r		u	
Red-eyed Vireo*	*Vireo olivaceus*	c	c	c	
Philadelphia Vireo	*Vireo philadelphicus*	r		u	
Warbling Vireo	*Vireo gilvus*	r		r	
Black-and-white Warbler*	*Mniotilta varia*	c	c	c	
Prothonotary Warbler*	*Protonotaria citrea*	c	c	u	
Swainson's Warbler	*Limnothlypis swainsonii*	r		r	
Worm-eating Warbler	*Helmitheros vermivorus*	u	u		

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 8)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Golden-winged Warbler	Vermivora chrysoptera	u		u	
Blue-winged Warbler	Vermivora pinus	u		u	
Tennessee Warbler	Vermivora peregrina	u		u	
Orange-crowned Warbler	Vermivora celata	u		u	
Nashville Warbler	Vermivora ruficapilla	r		u	
Northern Parula Warbler	Parula americana	u	u	u	
Yellow Warbler*	Dendroica petechia	c	c	c	
Magnolia Warbler	Dendroica magnolia	c		c	
Cape May Warbler	Dendroica tigrina	u		u	
Black-throated Blue Warbler	Dendroica caerulescens	x			
Yellow-rumped Warbler	Dendroica coronata	c		c	c
Black-throated Green Warbler	Dendroica virens	c		c	
Cerulean Warbler*	Dendroica cerulea	u		u	
Blackburnian Warbler	Dendroica fusca	c		c	
Yellow-throated Warbler	Dendroica dominica	u		u	
Bay-breasted Warbler	Dendroica castanea	u		u	
Prairie Warbler	Dendroica discolor	c		c	
Palm Warbler	Dendroica palmarum	c		c	
Ovenbird	Seiurus aurocapillus	c		c	
Northern Waterthrush	Seiurus noveboracensis	u		u	
Louisiana Waterthrush*	Seiurus motacilla	c	c		
Kentucky Warbler	Oporornis formosus	u		u	
Connecticut Warbler	Oporornis agilis	r		r	
Mourning Warbler	Oporonis philadelphia	r		r	
Common Yellowthroat*	Geothlypis trichas	c	c	c	r
Yellow-breasted Chat*	Icteria virens	c	c		
Hooded Warbler*	Wilsonia citrina	c	c	u	
Wilson's Warbler	Wilsonia pusilla	u		u	
Canada Warbler	Wilsonia canadensis	u		u	

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 9)

COMMON NAME	SCIENTIFIC NAME	SF	S	F	W
American Redstart*	*Setophaga ruticilla*	c	c	c	
House Sparrow*	*Passer domesticus*	c	c	c	c
Bobolink	*Dolichonyx oryzivorus*	c		u	
Eastern Meadowlark*	*Sturnella magna*	c	c	c	c
Western Meadowlark	*Sturnella neglecta*			x	o
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	x		x	
Red-wing Blackbird*	*Agelaius phoeniceus*	c	c	a	a
Orchard Oriole*	*Icterus spurius*	c	c		
Northern Oriole	*Icterus galbula*	u	r	u	
Rusty Blackbird	*Euphagus carolinus*	u		c	c
Brewer's Blackbird	*Euphagus cyanocephalus*			u	u
Common Grackle*	*Quiscalus quiscula*	c	c	c	a
Brown-headed Cowbird*	*Molothrus ater*	u	u	c	a
Scarlet Tanager	*Piranga olivacea*	u		u	
Summer Tanager*	*Piranga rubra*	c	c	u	
Cardinal*	*Richmondena cardinalis*	c	c	c	c
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	u	u		r
Blue Grosbeak*	*Guiraca caerulea*	u	u		
Indigo Bunting*	*Passerina cyanea*	c	c	u	r
Dickcissel*	*Spiza americana*	u	u		
Evening Grosbeak	*Hesperiphona vespertina*	r		r	u
Purple Finch	*Carpodacus purpureus*	u		u	c
House Finch	*Carpodacus mexicanus*				x
Pine Siskin	*Spinus pinus*	r		r	u
Goldfinch*	*Spinus tristis*	u	u	c	c
Red Crossbill	*Loxia curvirostra*				x
Rufous-Sided Towhee*	*Pipilo erythrophthalmus*	c	c	c	c
Savannah Sparrow	*Passerculus sandwichensis*	c		c	c
Grasshopper Sparrow*	*Ammodramus savannarum*	u	u	u	u
LeConte's Sparrow	*Passerherbulus caudacutus*	r		r	r
Henslow's Sparrow	*Passerherbulus henslowii*	r		u	u

Table II-25. Birds of the Wheeler National Wildlife Refuge[1]
(Continued, Page 10)

COMMON NAME	SCIENTIFIC NAME	SP	S	F	W
Vesper Sparrow	Pooecetes gramineus	u		c	c
Lark Sparrow	Chondestes grammacus	r	r		
Bachman's Sparrow	Aimophila aestivalis	r	r		r
Dark-eyed Junco	Junco hyemalis	u	r	c	c
Tree Sparrow	Spizella arborea			u	u
Chipping Sparrow	Spizella passerina	c	c	c	c
Field Sparrow*	Spizella pusilla	c	c	c	c
Harris' Sparrow	Zonotrichia querula			x	
White-crowned Sparrow	Zonotrichia leucophrys	u		c	c
White-throated Sparrow	Zonotrichia albicollis	u		c	c
Fox Sparrow	Passerella iliaca	u		c	c
Lincoln's Sparrow	Melospiza lincolnii	r		r	r
Swamp Sparrow	Melospiza georgiana	c		c	c
Song Sparrow	Melospiza melodia	u		c	c
Lapland Longspur	Calcarius lapponicus			r	u

[1] Taken directly from USDI, 1979

[2] SP - Spring
S - Summer
F - Fall
W - Winter

[3] a - abundant
c - common
u - uncommon
o - occasional
r - rare
x - accidental

* nests locally

Table II-26. Mammals Possibly Occurring in the Wheeler National Wildlife Refuge[1]

COMMON NAME	SCIENTIFIC NAME
Opossum	Dipelphis marsupialis
Southeastern Shrew	Sorex longirostris
Least Shrew	Cryptotis parva
Shorttail Shrew	Blarina brevicauda
Eastern Mole	Scalopus aquaticus
Keen Myotis	Myotis keeni
Little Brown Myotis	Myotis lucifugus
Gray Myotis	Myotis grisescens
Indiana Myotis	Myotis sodalis
Silver-Haired Bat	Lasionycteris noctivagans
Eastern Pipistrel	Pipistrellus subflavus
Red Bat	Lasiurus borealis
Big Brown Bat	Eptesicus fuscus
Hoary Bat	Lasiurus cinereus
Seminole Bat	Lasiurus seminolus
Evening Bat	Nycticeius humeralis
Eastern Big-Eared Bat	Plecotus rafinesquei
Mexican Freetail Bat	Tadarida brasiliensis
Northern Black Bear	Ursus a. americanus
Raccoon	Procyon lotor
Longtail Weasel	Mustela frenata
Mink	Mustela vison
River Otter	Lutra canadensis
Spotted Skunk	Spilogale putorius
Striped Skunk	Mephitis mephitis
Coyote	Canis latrans
Red Fox	Vulpes fulva
Gray Fox	Urocyon cinereoargenteus
Florida Panther	Felis concolor coryi
Bobcat	Lynx rufus
Woodchuck	Marmota monax
Eastern Chipmunk	Tamias striatus
Eastern Gray Squirrel	Sciurus carolinensis
Eastern Fox Squirrel	Sciurus niger
Southern Flying Squirrel	Glaucomys volans
Beaver	Castor canadensis
Eastern Harvest Mouse	Reithrodontomys humulis
Oldfield Mouse	Peromyscus polionotus
White-Footed Mouse	Peromyscus leucopus
Cotton Mouse	Peromyscus gossypinus
Golden Mouse	Peromyscus nuttallii
Eastern Woodrat	Neotoma floridana
Rice Rat	Oryzomys palustris

Table II-26. Mammals Possibly Occurring in the Wheeler National Wildlife Refuge[1] (Continued, Page 2)

COMMON NAME	SCIENTIFIC NAME
Hispid Cotton Rat	*Sigmodon hispidus*
Pine Vole	*Pitymys pinetorum*
Muskrat	*Ondatra zibethica*
Norway Rat	*Rattus norvegicus*
Black Rat	*Rattus rattus*
House Mouse	*Mus musculus*
Meadow Jumping Mouse	*Zapus hudsonius*
Woodland Jumping Mouse	*Napaeozapus insignis*
Eastern Cottontail	*Sylvilagus floridanus*
Swamp Rabbit	*Sylvilagus aquaticus*
New England Cottontail	*Sylvilagus transitionalis*
Whitetail Deer	*Odocoileus virginianus*

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[1] From Burt & Gossenheider, 1952.

Information concerning these caves was collected from Sproul (1972) and Varnedoe (1980). The potentially affected caves are listed below.

Name	Alabama Cave Survey Number	Entrance Elevation (msl)
Adams Cave	ALMD 412	630
Five-and-one-half Cave	ALMD 417	781
Fishin' Hole Cave	ALMD 681	571
Redstone Cave	ALMD 682	581
Lehman's Bluff Cave	ALMD 863	561
Muddy Cave	ALMD 1095	580

All but Muddy Cave are relatively dry. None have received detailed biological scrutiny due to the paucity of organisms reported by their few visitors. Muddy cave is known to harbor the troglobitic southern cavefish, Typhlychthes subterraneus.

2.2 ENDANGERED, THREATENED, AND SPECIAL CONCERN BIOTA

Endangered and threatened plants and animals in Alabama were drawn from USDI (1979b), Freeman, et al. (1979), and Boschung (1976). Seven of the bivalves are listed by the USDI (1979b) as endangered. These and the remaining species are listed by the State of Alabama as endangered, threatened, species of special concern, or as being possibly extinct or extirpated from Alabama. A list of the sensitive plant species which may occur within the project area is in Table II-27. Inclusion within the table is based on known occurrences within Madison County. Since field surveys were conducted after autumnal leaf drop, the presence of these species, most of which are herbaceous and cannot be identified when lacking leaves and flowers, could not be ascertained.

A list of sensitive invertebrates possibly occurring within the project area is in Table II-28. For sake of completeness both the Alabama and Federal status is shown. However, it should be noted that only the Federal status is of legal importance in a Federal project. The list includes one freshwater shrimp (Bouchard, 1976), one aquatic snail (Stein, 1976), and 31 species of unionoid bivalves (Stansbery, 1976). The blind shrimp, Palaemonais alabamae, "is known with certainty only from Shelta Cave (in Huntsville). An additional population of Palaemonias from a cave (Bobcat Cave) on the Redstone Arsenal, which may belong to this species, is under study" (Bouchard, p. 10 In: Boschung, et al., 1976). Bobcat Cave is approximately three miles north of the confluence of Indian Creek and Huntsville Spring Branch. The Olive Hydrobiid, Marstonia olivacea, was once "common in streams and springs in and about Huntsville" (Goodrich, 1944), but Thompson (1975) states "If it still survives, it is confined to Big Spring Creek (Huntsville Spring Branch) in the Redstone Arsenal". Thompson also says (Personal Communication, 1980) that the Olive Hydrobiid has been collected in the past below Huntsville's sewage treatment plant effluent, so it apparently can tolerate some nutrient pollution. However, it is unknown whether

Table II-27. Endangered, Threatened and Special Concern Plants Possibly Occurring on Wheeler National Wildlife Refuge

SPECIES	FAMILY	ALABAMA STATUS[1]	FEDERAL STATUS[2]
Trillium pusillum	Liliaceae	E[3]	NL
Panax quinquefolius	Araliaceae	E	NL
Neviusia alabamensis	Rosaceae	E	NL
Carex purpurifera	Cyperaceae	T	NL
Trillium erectum var. sulcatum	Liliaceae	T	NL
Leavenworthia torulosa	Brassicaceae	T	NL
Stylophorum diphyllum	Papaveraceae	T	NL
Athyrium pycnocarpon	Aspidiaceae	SSC	NL
Lycopodium flabelliforme	Lycopodiaceae	SSC	NL
Ophioglossum engelmannii	Ophioglossaceae	SSC	NL
Orchis spectabilis	Orchidaceae	SSC	NL
Plantanthera peramoena	Orchidaceae	SSC	NL
Cotinus obovatus	Anacardiaceae	SSC	NL
Jeffersonia diphylla	Berberidaceae	SSC	NL
Gymnocladius dioica	Fabaceae	SSC	NL
Oxalis grandis	Oxalidaceae	SSC	NL
Actaea pachypoda	Ranunculaceae	SSC	NL
Anemone caroliniana	Ranunculaceae	SSC	NL
Veronica anagallis - aquatica	Scrophulariaceae	SSC	NL
Valeriana pauciflora	Valerianaceae	SSC	NL

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[1] From Freeman, et al., 1979.

[2] USDI, 1979.

[3] E=Endangered; T=Threatened; SSC=Species of Special Concern; NL=Not Listed.

Table II-28. Endangered, Threatened and Special Concern Invertebrates Possibly Occurring on Wheeler National Wildlife Refuge

SPECIES	ALABAMA STATUS[1]	FEDERAL STATUS[2]
Arthropoda: Crustacea		
Palaemonias alabamae	SSC	NL
Mollusca: Gastropoda		
Marstonia olivacea	PE	NL
Mollusca: Bivalvia		
Pegias fabula	E, PE	NL
Quadrula c. cylindrica	E	NL
Fusconaia cuneolus	E	E
Fusconaia cor	E	NL
Fusconaia barnesiana	E	NL
Lexingtonia dolabelloides	E	NL
Plethobasus cicatricosus	E, PE	E
Plethobasus cooperianus	E, PE	E
Pleurobema clava	E, PE	NL
Pleurobema oviforme	E	NL
Pleurobema plenum	E	E
Hemistena lata	E	NL
Ptychobranchus subtentum	E	NL
Dromus dromas	E	E
Actinonaias l. ligamentina	E, PE	NL
Actinonaias pectorosa	E	NL
Oboraria subrotunda	E	NL
Oboraria retusa	E, PE	NL
Potamilus laevissimus	E	NL
Toxolasma l. lividus	E	NL

Table II-28. Endangered, Threatened and Special Concern Invertebrates Possibly Occurring on Wheeler National Wildlife Refuge (Continued, Page 2)

SPECIES	ALABAMA STATUS[1]	FEDERAL STATUS[2]
Mollusca: Bivalvia		
Toxolasma cylindrellus	E	E
Medionidus conradicus	E	NL
Villosa fabalis	E	NL
Villosa t. taeniata	E	NL
Lampsilis orbiculata	SSC	E
Lampsilis ovata	E	NL
Epioblasma triquetra	E	NL
Truncilla truncata	T	NL
Epioblasma brevidens	T	NL
Cumberlandia monodonta	SSC	NL
Plethobasus cyphyus	SSC	NL
Ptychobranchus fasciolaris	SSC	NL

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[1] From Boschung [ed.], 1976.

[2] From USDI, 1979.

[3] E=Endangered; T=Threatened; SSC=Species of Special Concern; NL=Not Listed; PE=Possibly Extinct or Extirpated from Alabama.

this species can tolerate the present high levels of pollution in Huntsville Spring Branch. The Olive Hydrobiid may well be extinct.

The 31 species of bivalves listed were drawn from Stansbery (In: Boschung, et al., 1976. Most of the species have a range or habitat description listed solely as "Tennessee River System", so it is impossible to accurately determine the presence or absence of these taxa within the project study area. However, most have been collected only a few times, often only before the extensive system of TVA dams were installed on the Tennessee River. These dams, plus cultural pollution (eutrophication, siltation), are frequently cited (Stansbery, 1976) as the causes of the extinction or extirpation of Alabama's extraordinarily large unionid fauna. Since all three factors are pronounced within the study area, it is unlikely that any of these bivalves exist there today. None were collected in the macroinvertebrate surveys of Indian Creek, Huntsville Spring Branch, and the Wheeler Reservoir adjacent to the Redstone Arsenal.

Four sensitive taxa of fish (see Table II-29) are found in the area in and around the Redstone Arsenal. The Tuscumbia darter, Etheostoma tuscumbia, occurs in several springs and their spring runs surrounding the Redstone Arsenal, although it has not been collected within Huntsville Spring Branch or within the Arsenal. The flame chub, Hemitremia flammea, is moderately common north of the Tennessee River, typically inhabiting limestone springs and their runs, including several surrounding the Arsenal. It has been extirpated from Huntsville Spring Branch, however, and it is not now known to occur anywhere within the Arsenal. The southern cavefish, Typhlychthes subterraneus, is an obligate troglobite (cave dweller) found in subterranean waters in the Tennessee and Coosa River drainages. "Outside Alabama it has the most extensive range of any North American troglobitic fish" (Ramsey, In: Boschung, 1976). It has been found in Muddy Cave. The whiteline topminnow, Fundulus albolineatus, "probably extinct as a species, is known only from specimens captured in (Huntsville) Spring Creek" (Ramsey, In: Boschung, 1976).

The hellbender, found over a large area of the eastern United States, occurs in Alabama only in the Tennessee River System. Although it has not been collected from the Arsenal's waters, it occurs in the nearby Flint River and Walker Creek. It prefers large, free-flowing streams with rocky bottoms and clear water (Mount, In: Boschung, 1976). "Impoundment, channelization, and pollution are detrimental to hellbenders" (Nickerson and Mays, 1972). It is therefore not likely to occur within the project area. In Alabama, the Tennessee cave salamander, Gyrinophilus pelluceus, is known from several caves in Jackson, Madison and Limestone Counties. However, it has not been collected from within the Arsenal.

In Alabama, the range of the eastern spiny softshell, Trionyx spiniferus spinigerus, is the Tennessee River System. It may not occur within the Arsenal, since its "optimum habitat is a free-flowing creek or stream with a sand-ground bottom. The impoundment of the Tennessee River

Table II-29. Endangered, Threatened and Special Concern Vertebrates Possibly Occurring on Wheeler National Wildlife Refuge

SCIENTIFIC NAME	COMMON NAME	ALABAMA LISTING[1]	FEDERAL LISTING[2]
FISH			
Etheostoma tuscumbia	Tuscumbia Darter	T[3]	NL
Hemitremia flammea	Flame Chub	SSC	NL
Typhlichthys subterraneus	Southern Cavefish	SSC	NL
Fundulus albolineatus	Whiteline Topminnow	SSC	NL
AMPHIBIANS			
Cryptobranchus a. alleganiensis	Hellbender	T	NL
Gyrinophilus palleucus	Tennessee Cave Salamander	SSC	NL
REPTILES			
Alligator mississippiensis	American Alligator	T	E
Trionyx spinferus spinferus	Eastern Spiny Softshell	SSC	NL
BIRDS			
Aquila chrysaetos	Golden Eagle	E	NL
Haliaeetus leucocephalus	Bald Eagle	E	E
Pandion haliaetus	Osprey	E	NL
Falco peregrinus	Peregrine Falcon	E	NL
Dendrocopos borealis	Red-cockaded Woodpecker	E	E
Florida caerulea	Little Blue Heron	SSC	NL
Mycteria americana	Wood Stork	SSC	NL
Nycticorax nycticorax	Black-crowned Night Heron	SSC	NL
Accipiter striatus	Sharp-shinned Hawk	SSC	NL
Accipiter cooperi	Cooper's Hawk	SSC	NL
Buteo lineatus	Red-shouldered Hawk	SSC	NL
Falco columbarius	Merlin	SSC	NL
Thryomanes bewickii	Bewick's Wren	SSC	NL
Limnothlypis swainsonii	Swainsons Warbler	SSC	NL
Aimophila aestivalis	Bachman's Sparrow	SSC	NL
MAMMALS			
Myotis grisescens	Gray Myotis	E	E
Myotis sodalis	Indiana Myotis	E	E
Ursus a. americanus	Northern Black Bear	E	NL
Felis concolor coryi	Florida Panther	E	E
Sorex l. longirostris	Southeastern Shrew	SSC	NL
Myotis a. austroriparius	Southeastern Myotis	SSC	NL
Myotis l. lucifugus	Little Brown Myotis	SSC	NL
Myotis keenii septrionalis	Keen's Myotis	SSC	NL
Plecotus rafinesquii	Rafinesque's Big-eared Bat	SSC	NL
Microtus o. ochrogaster	Prairie Vole	SSC	NL

[1] From Boschung, [ed.], 1976

[2] From USDI, 1979

[3] E=Endangered; T=Threatened; SSC=Species of Special Concern; NL=Not Listed.

throughout its length in Alabama has been detrimental to the eastern spiny softshell, and there are no recent records of the species from the Tennessee River." (Mount, In: Boschung, 1976).

The Golden Eagle, Aquila crysaetos, is seen rarely in Alabama in the winter. It does not breed in Alabama. It inhabits wild country, especially mountains and large forests. It eats a variety of rodents and large birds. Its rarity in Alabama is attributed to illegal shooting (Keeler, In: Boschung, 1976).

The Bald Eagle, Haliaeetus leucocephalus, once was common in the Tennessee River Valley, nesting there in the summer and even wintering there. No recent nests, however, have been found in Alabama. Fish are its main food, supplemented by carrion, small mammals, birds and snakes. Its decline is attributed to pesticides, illegal shooting, and harassment (Keeler, In: Boschung, 1976).

The Osprey, Pandion haliaetus, was formerly a fairly common breeding bird in the Tennessee Valley. It has been rare during the past decade, and, although it has apparently been making a slow comeback since DDT was banned, it still does not breed in the Tennessee Valley (Keeler, In: Boschung, 1976). This species feeds entirely on fish, making it especially susceptible to DDT poisoning.

The Peregrine Falcon, Falco peregrinus, rare in Alabama in winter and on migration, formerly bred along the Tennessee Valley. It feeds primarily on birds, especially waterfowl and shorebirds, thus exposing itself to pesticide poisoning. This is the factor blamed for its catastrophic decline. No recent breeding records are known from Alabama (Keeler, In: Boschung, 1976).

The Little Blue Heron, Florida caerulea, is a resident of the wetlands within the Tennessee Valley, including the project area. This species of special concern, a semi-aquatic wading bird, feeds mainly on frogs, crayfish and small fish. Being exposed to the DDT contamination, it may be accumulating DDT.

The Sharp-shinned Hawk, Accipiter striatus, is a locally common, permanent resident of the northern portion of Alabama, and winters throughout the State. It feeds in open woodlands, primarily on small to medium-sized birds, but occasionally takes mice, frogs, lizards and grasshoppers. Pesticides are given as the probable reason for its decline (Keeler, In: Boschung, 1976).

The Cooper's Hawk, Accipiter cooperi, was a common, year-round resident of Alabama, especially in moderately wooded areas. It feeds primarily on birds, but will also eat rabbits, rodents, amphibians, reptiles and insects. This species also appears to be declining, probably due to the use of pesticides (Keeler, In: Boschung, 1976).

The Red-shouldered Hawk, Buteo lineatus, "was the most common and widespread of all soaring hawks in Alabama until about 1970. Since then the population has experienced a rapid decline....Habitat destruction and pesticides are factors influencing the declining population" (Keeler, In: Boschung, 1976).

Bewick's Wren, Thryomanes bewickii, breeds uncommonly in the Tennessee River Valley and the mountains of Alabama. Its numbers have declined drastically throughout the Southeast since 1958. The causes are poorly understood, although, since it feeds primarily on insects, pesticides may have been a factor. Habitat changes do not appear to be a factor in the decline. North Alabama is on the periphery of its range (Keeler, In: Boschung, 1976).

Swainson's Warbler, Limnothlypis swainsonii, is an uncommon summer resident in the Coastal Plain and Tennessee River Valley of Alabama. It feeds primarily on insects. It breeds in river swamps, particularly where cane (Arundinaria) grows. The project area, particularly along Huntsville Spring Branch, contains significant amounts of this habitat. However, recent evidence indicates the Alabama population is too thinly dispersed for individuals to find mates and breed (Keeler, In: Boschung, 1976). Also, insects do not appear to be very abundant along Huntsville Spring Branch, as evidenced by aquatic macroinvertebrate data, and by direct field observations.

Bachman's Sparrow, Aimophila aestivalis, is a permanent resident everywhere in Alabama where there is suitable habitat, which is dry pine and scrub oak woods, particularly the dry ridges (Keeler, In: Boschung, 1976). This habitat does not occur within the project area.

The Black-crowned Night Heron, Nycticorax nycticorax, is an uncommon, year-round resident of the area (USDI, 1979). Its main food is fish, but it will also feed on a variety of insects, small rodents and reptiles, amphibians, and aquatic crustaceans.

The Merlin, Falco columbarius, is an occasional autumn and winter visitor to the area (USDI, 1975). It feeds primarily on small birds up to the size of pigeons, and will also eat small mammals and large insects (Keeler, In: Boschung, 1976).

The American alligator, Alligator mississippiensis, apparently did not originally inhabit the project area. However, several saurians (alligators or tropical caimans) have been sighted at the Wheeler Refuge. These are believed to be released pets (Speake and Mount, 1974).

Two species of endangered mammals are known to occur on the Wheeler Refuge (Atkeson, Personal Communication, 1979), and thus possibly in the study area. These are the gray bat, Myotis grisescens, and the Indiana bat, Myotis sodalis. Of critical concern to the gray bat are suitable maternity caves, of which there are two in northern Alabama. Neither cave is located on Redstone Arsenal property (Dusi, 1976). The distribution of the Indiana bat in Alabama is not well documented. Both feed over water on insects. Commercialization of caves and cave vandalization are cited as the primary causes of their decline.

2.3 GEOLOGY AND PHYSIOGRAPHY

A considerable amount of general information has been drawn together in the publication "Environmental Geology and Hydrology, Huntsville and Madison County, Alabama", published as Atlas Series 8 by the Geological Survey of Alabama in 1975. This publication states "The hills east of Huntsville dominate Madison County's topography. These uplands are the Appalachian plateau - part of the Appalachian Mountains. The western edge of the area, the Cumberland escarpment, joins with the Interior Low Plateaus area at its base-the flatter, rolling lands of Madison County". There are some pronounced hills or small mountains within the Arsenal property, which are comprised of rocks that have not eroded away.

The ground surface is generally underlain with unconsolidated soil materials which are generally transported accumulations resulting from rock weathering and deposited by an ancestral stream. Near Huntsville Spring Branch arm of Wheeler Lake, these materials generally lie on the Tuscumbia Limestone which averages 150 feet in thickness. This is underlain by the Fort Payne Limestone which, because it contains beds of chert, is usually called the Fort Payne Chert. The formation is generally 155 to 185 feet thick. It is principally the limestones which serve as the aquifers in the area.

The unconsolidated surficial materials (called Regolith), transmit some water, but less freely than do the underlying limestone members, where the water generally moves through solution passages, mostly located along fracture lines.

Much, if not all, of the area is karstic, which is defined as "an irregular limestone region with sinks, underground streams, and caverns". This condition is caused by the dissolving-away of calcium carbonate and other minerals from the rock by the water that has been flowing in passages through the rock. Over geologic time the result is subsidence features such as sinkholes, or even declines in the earth's surface elevation over large areas which lead to the development of aimless internal drainage patterns to the underground aquifers rather than a ubiquitous pattern of surface drainage out of the area by organized stream patterns.

The construction of surface impoundments on the land surface in karst terrains can lead to new sinkhole collapses due to the increased loading on the Regolith caused by the weight of the water. The resulting new sinkholes may provide a source of groundwater contamination, as older sinkholes often do.

2.4 HYDROLOGY

2.4.1 Surface Water Hydrology

The dominating factor in the surface water resources of the study area is the Tennessee River. Average flow in the river just downstream of Indian Creek is 43,200 cfs. Average annual flow in Indian Creek below its confluence with Huntsville Spring Branch is about 220 cfs (Geological Survey of Alabama, 1973). The surface water hydrology of Huntsville Spring Branch and Indian Creek is detailed in Section 4.1 of this appendix.

2.4.2 Groundwater Hydrology

In preparation for the hydrologic study in Atlas Series 8 (Geological Survey of Alabama, 1975), many wells were inventoried, and a potentiometric surface map was prepared. However, at the time the Atlas was put together, there were very few well records available in or near Redstone Arsenal, so that there was little control for the construction of the potentiometric surface map in the Arsenal area. In such areas surface topography was used to guide the contouring. Thus, the contours in the southern part of the Arsenal can only be considered as approximate.

Atlas Series 8 includes a generalized map giving the estimated thickness of the Regolith, which in the vicinity of Wheeler Lake Arm ranges from 20 to 80 feet in thickness, with most of the area 40 to 80 feet in thickness. South of the Wheeler Lake Arm, along the line of Dodd Road, the Regolith thickness is given at 20 to 40 feet. This is also the thickness estimated along the eastern boundary of the Arsenal, from Huntsville Spring Branch southward to the Tennessee River.

Prior to the publication of the Atlas Series 8 map in 1975, 22 wells in or near Redstone Arsenal had been inventoried by USGS and the Alabama State Geological Survey. Water level data were available for these sometimes from as early as the 1960's, as given in Table II-30.

Subsequent to the publication of the Atlas Series 8 map, additional wells were drilled in 1976. In 1978 the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), located at Aberdeen Proving Ground, Maryland, contracted for the construction of 24 wells in the Redstone area, particularly in conjunction with the monitoring of leachate from landfills. In 1979 a contract was let for the construction of 30 more wells of which four twin deep and shallow sets were paired in order to evaluate the relationship of water level in the Regolith to that in the underlying rock. Data on these wells are contained in Table II-31. The wells in each of the pairs were located within a few hundred feet of each other. Most of the wells drilled in 1978 and 1979 bottomed in the Regolith. The wells were located on dry land sites for ready access for sampling and level measurements.

Table II-32 contains the paired water level data for five sites. It is seen that, with one exception, water levels in Regolith wells were 1.6 to 4.9 feet higher than those in the limestone wells. Thus, it appears that water levels for either type of well can be used to construct a potentiometric surface map that would be correct to within plus or minus 5 feet.

Table II-30. Water Well Records at Redstone Arsenal, 1951-1974

Well Number	Date Drilled	Completion Depth (ft.)	Ground Surface Elevation (ft.)	Depth to Bedrock (ft.)	Date Measured	Groundwater Elevation (ft.)
W-2	1951	289	614.0	54.0	Oct. 1956	441.0
W-17	----	74	630.0	65.0	----	591.0
I	1971	66.0	615.0[1]	58.0	----	<549.0
L	1962	58.4	570.0[1]	38.5	----	545.0
M-3-74	1974	34.5	580.0[1]	NE	----	561.0
M-6-74	1974	28.5	580.0[1]	NE	----	553.0
M-7-74	1974	30.5	580.0[1]	20.5	----	571.2
M-8-74	1974	33.5	580.0[1]	23.5	----	562.0
M-9-74	1974	32.6	580.0[1]	27.0	----	553.0
M-14-74	1974	32.8	580.0[1]	27.0	----	575.6
M-15-74	1974	27.0	580.0[1]	NE	----	559.6
M-16-74	1974	32.7	580.0[1]	27.0	----	573.0
M-17-74	1974	38.7	580.0[1]	28.7	----	558.5
M-18-74	1974	39.2	580.0[1]	29.2	----	550.5
M-19-74	1974	32.9	580.0[1]	22.9	----	575.0
M-22-74	1974	30.0	580.0[1]	NE	----	553.0
Q-178	1955	74.0	595.0	37.0	May 1956	571.0
Q-186	----	54.0	590.0	54.0	----	568.0
Q-190	----	----	597.0	----	----	592.0
Q-191	----	----	601.0	----	----	580.0
Q-192	----	----	600.0	----	----	577.0
Q-195	----	----	608.0[1]	----	----	586.0

Note: NE = Not Encountered.

[1] Estimated from topographic map of Redstone Arsenal.

Table II-31. Water Well Records at Redstone Arsenal, 1976-1979

Well Number	Date Drilled	Completion Depth (ft.)	Ground Surface Elevation (ft.)	Depth to Bedrock (ft.)	Date Measured	Groundwater Elevation (ft.)
Q-6	1976	22.5	570.0[1]	NE	---	555
Q-13	1976	16.5	570.0[1]	NE	---	558
N-1	1976	23.6	570.0[1]	14.0	---	559.5
N-3	1976	23.7	570.0[1]	12.0	---	561.0
N-4	1976	22.8	570.0[1]	8.5	---	562.0
N-8	1976	7.5	570.0[1]	NE	---	565.5
P	1976	33.0	580.0[1]	28.0	---	<547
Q-1	1976	19.5	570.0[1]	NE	---	562
O-2	1976	36.0	570.0[1]	NE	---	553
O-3	1976	12.0	570.0[1]	NE	---	564
J	1976	34.5	580.0[1]	NE	---	<545.5
RS-015	Nov. 78	66.4	606.27	66.4	Dec. 1978	580.77
RS-016	Nov. 78	55.0	616.86	55.0	Dec. 1978	580.06
RS-020	Nov. 78	26.0	566.46	NE	Dec. 1978	564.36
RS-021	Nov. 78	30.0	574.16	NE	Dec. 1978	566.36
RS-022	Nov. 78	41.0	567.05	NE	Dec. 1978	559.35
RS-023	Nov. 78	18.3	563.0[1]	18.3	Dec. 1978	559.2
RS-024	Nov. 78	26.0	562.0[1]	NE	Dec. 1978	553.9
RS-025	Nov. 78	24.8	570.78	24.8	Dec. 1978	568.98
RS-026	Nov. 78	26.4	573.78	26.4	Dec. 1978	569.18
RS-027	Nov. 78	24.9	572.40	24.9	Dec. 1978	571.40
RS-028	Nov. 78	21.6	576.95	21.6	Dec. 1978	571.65
RS-029	Nov. 78	29.4	579.10	27.4	Dec. 1978	569.10
RS-030	Nov. 78	36.0	584.21	NE	Dec. 1978	569.91
RS-031	Dec. 78	56.0	609.01	NE	Dec. 1978	573.71
RS-032	Dec. 78	46.0	604.94	NE	Dec. 1978	585.44
RS-033	Dec. 78	41.0	609.52	NE	Dec. 1978	584.22
RS-034	Dec. 78	26.0	606.60	NE	Dec. 1978	604.4
RS-035	Dec. 78	36.0	619.98	NE	Dec. 1978	605.08
RS-036	Dec. 78	31.0	616.79	NE	Dec. 1978	608.09
RS-037	Dec. 78	51.0	627.84	NE	Dec. 1978	614.14
RS-038	Nov. 78	52.5	625.69	NE	Dec. 1978	614.99
RS-039	Dec. 78	46.0	634.77	NE	Dec. 1978	616.77

Table II-31. Water Well Records at Redstone Arsenal, 1976-1979
(Continued, page 2)

Well Number	Date Drilled	Completion Depth (ft.)	Ground Surface Elevation (ft.)	Depth to Bedrock (ft.)	Date Measured	Groundwater Elevation (ft.)
RS-040	Sep. 79	31.0	565.5	NE	Nov. 1979	563.4
RS-041	Sep. 79	12.5	568.28	12.5	Nov. 1979	566.18
RS-042	Sep. 79	11.5	566.85	11.5	Nov. 1979	563.90
RS-043	Nov. 79	23.0	567.80	13.0	Nov. 1979	562.30
RS-044	Oct. 79	70.0	629.83	70.0	Nov. 1979	568.83
RS-045	Sep. 79	31.0	572.14	NE	Nov. 1979	560.34
RS-046	Oct. 79	30.2	573.42	30.2	Nov. 1979	560.5
RS-047	Nov. 79	62.2	615.80	62.2	Nov. 1979	559.2
RS-048	Sep. 79	23.6	587.34	23.6	Nov. 1979	581.34
RS-049	Sep. 79	38.9	583.42	38.9	Nov. 1979	578.92
RS-050	Sep. 79	33.4	588.24	33.4	Nov. 1979	572.1
RS-051	Nov. 79	46	582.09	36.0	Nov. 1979	569.4
RS-052	Sep. 79	35.0	616.63	NE	Nov. 1979	586.93
RS-053	Sep. 79	36.4	610.89	36.4	Nov. 1979	584.0
RS-054	Sep. 79	56.8	613.56	56.8	Nov. 1979	591.16
RS-055	Nov. 79	53	611.85	53.0	Nov. 1979	579.1
RS-056	Oct. 79	87	579.50	27.0	Nov. 1979	562.8
RS-057	Oct. 79	47	592.12	37.0	Nov. 1979	558.2
RS-058	Oct. 79	61	589.99	51.0	Nov. 1979	561.5
RS-067	Nov. 79	58	608.89	48.0	Nov. 1979	564.2
RS-068	Sep. 79	51	568.52	16.0	Nov. 1979	562.5
RS-069	Sep. 79	74	566.01	14.0	Nov. 1979	562.8
RS-070	Sep. 79	48	571.12	38.0	Nov. 1979	564.3
RS-071	Sep. 79	77	517.18	NE	Nov. 1979	573.8

NE = Not Encountered

[1] Estimated from topographic map of Redstone Arsenal.

Table II-32. Comparison of Water Level Elevations in Deep and Shallow Well Pairs at Redstone Arsenal

Well Numbers		Non-Pumping Water Level, ft. MSL		
Shallow Well (Regolith)	Deep Well (Limestone)	Shallow Well (Regolith)	Deep Well (Limestone)	Differential Head-(ft)
Wells Drilled in 1979 at Four Separate Locations				
RS-042	RS-043	563.9	562.3	+1.6
RS-047	RS-067	559.2	564.2	-5.0
RS-050	RS-051	572.1	569.4	+2.7
RS-053	RS-055	584.0	579.1	+4.9
Wells Drilled in 1976 at Fire Station No. 2				
	1		559.5	
8	3	565.5	561.0	+4.5
	4		562.0	

It also appears that, in general, water in the Regolith is moving downward toward the underlying limestone aquifers, rather than vice versa. The differential head values are small enough to indicate reasonably good hydraulic communication between the Regolith and the limestone (Hudson, 1976).

The water level profile in Huntsville Spring Branch is nearly flat in the reach between Dodd Road and Patton Road. It is also flat from Dodd Road to Indian Creek which in turn is essentially flat all the way to its mouth at Triana. The summer Wheeler Lake level is controlled to elevation 556, and that in winter some five feet lower. Prevailing levels would be at or near these elevations except during floods, either of Tennessee River or of Huntsville Spring Branch.

A potentiometric surface map was drawn using all available data (Figure II-3). There are no wells in the vicinity immediately south of the levee south of Huntsville Spring Branch across the Arsenal Test Range area. However, Arsenal personnel state that every winter the water levels are customarily at or a little above the ground surface. Throughout much of this area, the ground surface is quite generally at or near elevation 560. The 560 topographic contour may thus be taken as the boundary of that potentiometric surface level. Further south, there are topographic highs that doubtless recharge the Regolith and the underlying limestone, between Huntsville Spring Branch arm and the Tennessee River, and there is some well information and surficial evidence (swamps) to indicate that there is a 570 contour.

Comparing the 560 and other contours with levels in Wheeler Reservoir at 556, it appears certain that the surface waters in the Arm comprise the sink into which groundwater discharges from both the north and south sides of the Arm. The upward discharge differential head is about four feet.

High flood stages in the Tennessee River could reverse the differential head between the surface water and the potentiometric surface from time to time. Review of a stage-duration curve of the water levels in Tennessee River at Triana (probably the best available location to establish the levels to be expected along Huntsville Spring Branch) showed that the water levels in the river exceeded elevation 560 approximately 2 percent of the time. It is considered that such exceedances would be so transient as to have no material effect with regard to the vertical transport by the groundwater caused by reversals of the head differential between surface water and groundwater.

The conclusion is inescapable that the DDTR in the bottom of Huntsville Spring Branch poses no threat to the underlying groundwater. Soluble contaminants not bound to earth materials could move downward from terrestrial deposits a short distance, but are almost certain to move laterally toward Huntsville Spring Branch.

A report "Public and Private Water Supply Investigation, Redstone Arsenal and Vicinity" dated October 1, 1979 was prepared by personnel of EPA Region IV at Atlanta. The report described an investigation of ground and surface water supplies, performed to determine if any of the

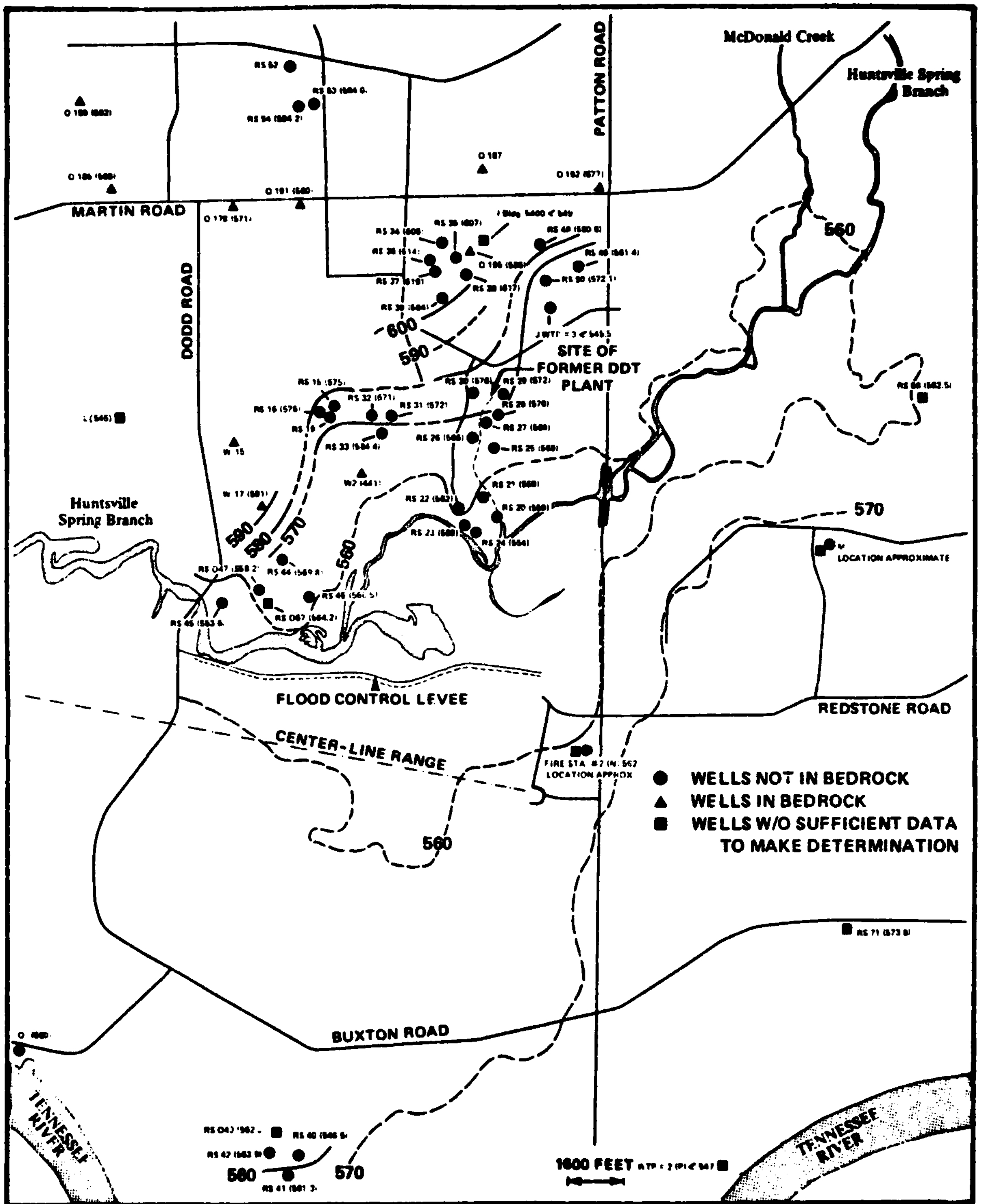

FIGURE II-3. Potentiometric Surface Map 1978-79

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama

area public or private water supplies were contaminated with DDT (including its analogs) or heavy metals. This report concluded that "None of the potable water supplies investigated during this study were found to be contaminated with DDT or its metabolites. However, low levels of other pesticides were detected at some of the water supplies."

In a later survey, EPA (1980) reported detectable DDTR in 21 of 21 wells located in four areas of Redstone Arsenal. Concentration patterns indicated uniform widespread contamination not related to old DDT plant site or disposal areas. Sample contamination problems were suspected.

2.5 CULTURAL RESOURCES

In the project area, two distinct settlement zones may be defined for the prehistoric period:

1) The Tennessee River Valley zone
2) The Upland Settlement zone

The differences between occupation of the zones are dramatic and pertain to every time period subsequent to the Paleo-Indian era. During some periods, such as the Archaic and Woodland, settlement occurred in both zones, although the types of sites and exploitation strategies in each differed. During these periods, river valley and upland occupation was characterized by a shifting settlement pattern, but as a whole encompassed a single settlement/subsistence system.

The pattern of human use of the area around Huntsville Spring Branch begins with fragmentary evidence of Paleo-Indian occupation, primarily as hunting camps or other limited activity, near the most reliable water sources in the area.

During the Archaic period, the uplands were exploited to a limited degree, with small temporary encampments located on swamp margins and near small streams in the interior. Larger, more stable base camps were located in the Tennessee River Valley. This pattern of shifting settlement probably reflects alternating periods of population aggregation and dispersion with larger groups coming together at the River Valley base camps and seasonally dispersing into small groups of nuclear families to exploit the uplands.

Later, during the Woodland period, the River settlement zone continued to be the area of maximum population with the appearance of large base camps, mound and village sites, and isolated mounds. Exploitation of the upland zone persisted with the presence of limited activity sites. However, a major change during this period was marked by large base camps in the upland zone. The relationships between the upland base camps and river valley mound and village sites remains to be explained.

In the Mississippian period, it appears the upland zone was shunned, but river valley settlement continued with the development of mound and village sites. It may be that use of the highlands in the form of limited activity sites associated with the river valley settlements may lie outside the project area, or may contain artifacts not sufficiently unique to be diagnostic of a Mississippian occupation, or may not be detectable by present research methods.

Occupation of the project area during the historic period consists primarily of settlement by agriculturalists. Most of the sites are former farm houses, and at several, the remains of the former structures and outbuildings are evident on the surface. These sites are either on or near to soil that is well-suited for agriculture.

The sites in the project area are fairly abundant at about 17 discovered sites per square mile. Analysis of environmental factors indicate that the sites tend to cluster in the following manner:

1) They tend to be on higher ground relative to the surrounding terrain, with bottomland knolls particularly favored

2) They tend to be found between the 565 and 580 foot elevations

3) They tend to be 0 to 2 meters above the nearest water source

4) They tend to be within 50 meters of a water source

5) They tend to be on or near soils well suited for horticulture.

Thus we can conclude that the Wheeler Basin is characterized by an intensive prehistoric occupation, and any elevated knoll within a short distance from water is likely to yield evidence of prehistoric activity.

3.0 DDTR DISTRIBUTION

3.1 DDTR IN SEDIMENTS

3.1.1 Indian Creek and Huntsville Spring Branch

Introduction--Significant contamination with DDTR resulting from past waste discharges from the Olin DDT manufacturing facility, occurs in the sediments throughout both Huntsville Spring Branch and Indian Creek. The area of highest contamination, however, is confined primarily to the channel and near overbank downstream from the old waste ditch outfall a distance of 2.7 miles to just upstream of Dodd Road.

It is estimated that over 837 tons of DDTR as DDT is contained in the sediments of the channel, overbank and ponded areas of Indian Creek and Huntsville Spring Branch. Approximately 804 tons or 96 percent of the total is contained within the sediments of Huntsville Spring Branch between Dodd and Patton Roads. Only 25 tons, or 3 percent of the total, is contained in Huntsville Spring Branch from Mile 0 to 2.4, and 8.5 tons, or 1 percent of the total is contained in the sediments of Indian Creek. Less than 1 ton of DDTR as DDT is dispersed over the floodplain to the south and east of Indian Creek and Huntsville Spring Branch.

A summary of the DDTR concentrations found in the sediments of Indian Creek, Barren Fork Creek (BFC) and Huntsville Spring Branch is shown in

Table II-33 and illustrated in Figures II-4 thru 11. Sediment concentrations of DDTR range from a minimum of from >0.037 to <0.086 ppm as DDT in the 6 to 12 inch depth horizon at Mile 3.5 in the flood plain of Huntsville Spring Branch to a maximum of 30,200 ppm as DDT, or over 3 percent by weight, in the 6 to 12 inch depth horizon in the main channel of Huntsville Spring Branch at Mile 4.5, approximately 1 mile downstream of the old waste ditch outfall.

Figure II-12 illustrates the mean and range of surface sediment DDTR concentrations found in the Tennessee River and a number of major tributaries upstream and downstream of its confluence with Indian Creek as well as concentrations found at location in Indian Creek and Huntsville Spring Branch. As this Figure illustrates, DDTR levels in both Indian Creek and Huntsville Spring Branch are considerably above those found elsewhere in this stretch of the Tennessee River.

Methodology--Sediment samples were taken by TVA between August 14-30, 1979 at locations upstream, downstream and in the immediate vicinity of the "old waste ditch" in the channel overbank and ponded areas and floodplain of Huntsville Spring Branch, as well as at selected locations in the channel and floodplain of Indian Creek and at one location in Barren Fork Creek. Where field conditions would permit, samples were obtained at each of four depth horizons: 0 to 6 inches, 6 to 12 inches, 12 to 24 inches, and >24 inches below the sediment:water interface or soil surface. Figures II-13 and II-14 illustrates the locations at which cores were taken in Indian Creek, Huntsville Spring Branch as well as the maximum depth to which individual cores penetrated the sediment.

The locations of TVA core sampling transects and individual core samples were located on 1 inch equals 800 feet scale Redstone Arsenal Site maps using information supplied by TVA, inspection of aerial photographs, transect cross sections and field notes. The approximate midpoints between adjacent sampling transects were located along the channel centerline and a bisector drawn between adjacent transects located in order to segment the system for subsequent analysis.

Areas were classified into one of four major hydrologic categories: channel, overbank, ponded, and floodplain. The following criteria, with some modifications for special situations, were employed:

- o Channel Areas--areas confined by well-defined banks as determined from the transect profiles and generally occupied by flowing water.
- o Overbank Areas--areas outside of well-defined channel banks, with or without a permanent vegetative cover, periodically inundated as a result of reservoir operations on the Tennessee River and upstream streamflow conditions.
- o Ponded Areas--areas generally inundated with standing water and hydraulically connected to a stream channel.
- o Floodplain Areas--areas below the 100-year flood elevation as determined by TVA in the course of this study.

Table II-33. Summary of Stream Bottom and Overbank Sediment DDTR Concentrations in Indian Creek, Barren Fork Creek and Huntsville Spring Branch, August 1979.

Location	Depth Horizon	No. Samples	Sediment DDTR Concentration[1] (ppm as DDT)	
			Mean	Range
ICM 0-5	0-6"	18	17.8	<1.01 - 30.8
	6-12"	10	8.88	4.65 - 15.2
	12-24"	10	5.83	<0.81 - 15.8
	>24"	3	0.61	<0.16 - 1.51
	Overall		8.75	<0.16 - 30.8
HSBM 0-2.4	0-6"	15	97.8	<2.26 - 403
	6-12"	14	9.99	<0.13 - 42.1
	12-24"	8	3.30	<0.37 - 9.77
	>24"	2	0.72	<0.66 - 0.78
	Overall		38.1	<0.13 - 403
HSBM 2.4-5.4	0-6"	54	1,360	<0.86 - 14,700
	6-12"	45	2,160	<0.09 - 30,200
	12-24"	28	299	<0.19 - 2,730
	>24"	3	1,820	<0.38 - 12,100
	Overall		1,540	<0.09 - 30,200
HSBM >5.4	0-6"	3	0.63	0.63
	6-24"	3	0.48	0.48
	12-24"	3	0.30	0.30
	Overall		0.47	0.30 - 0.63
Floodplain[2]	0-6"	11	0.95	<0.13 - 2,420
BFC	Overall		<0.94	<0.94

NOTES:

[1] All less than values assumed equal to stated value.

[2] Mean excludes station HSB FP 1, floodplain station near mouth of "Old Waste Ditch", and includes "Floodplain" stations in Indian Creek.

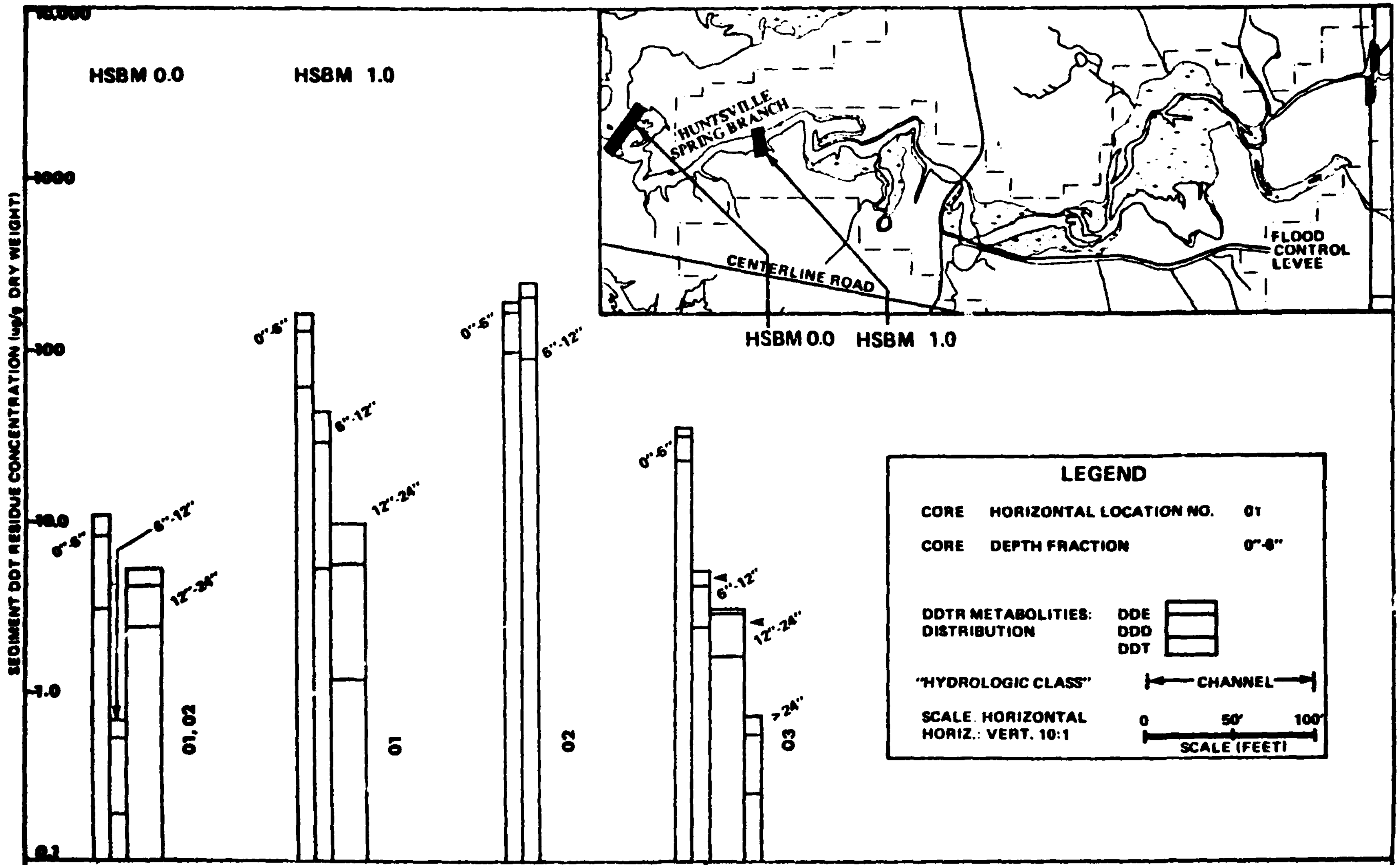

FIGURE II-4A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 0.0 and 1.0

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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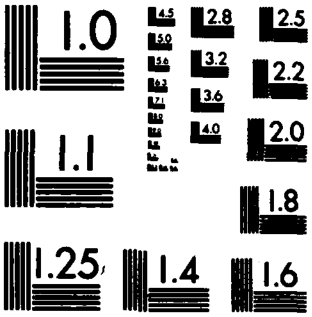

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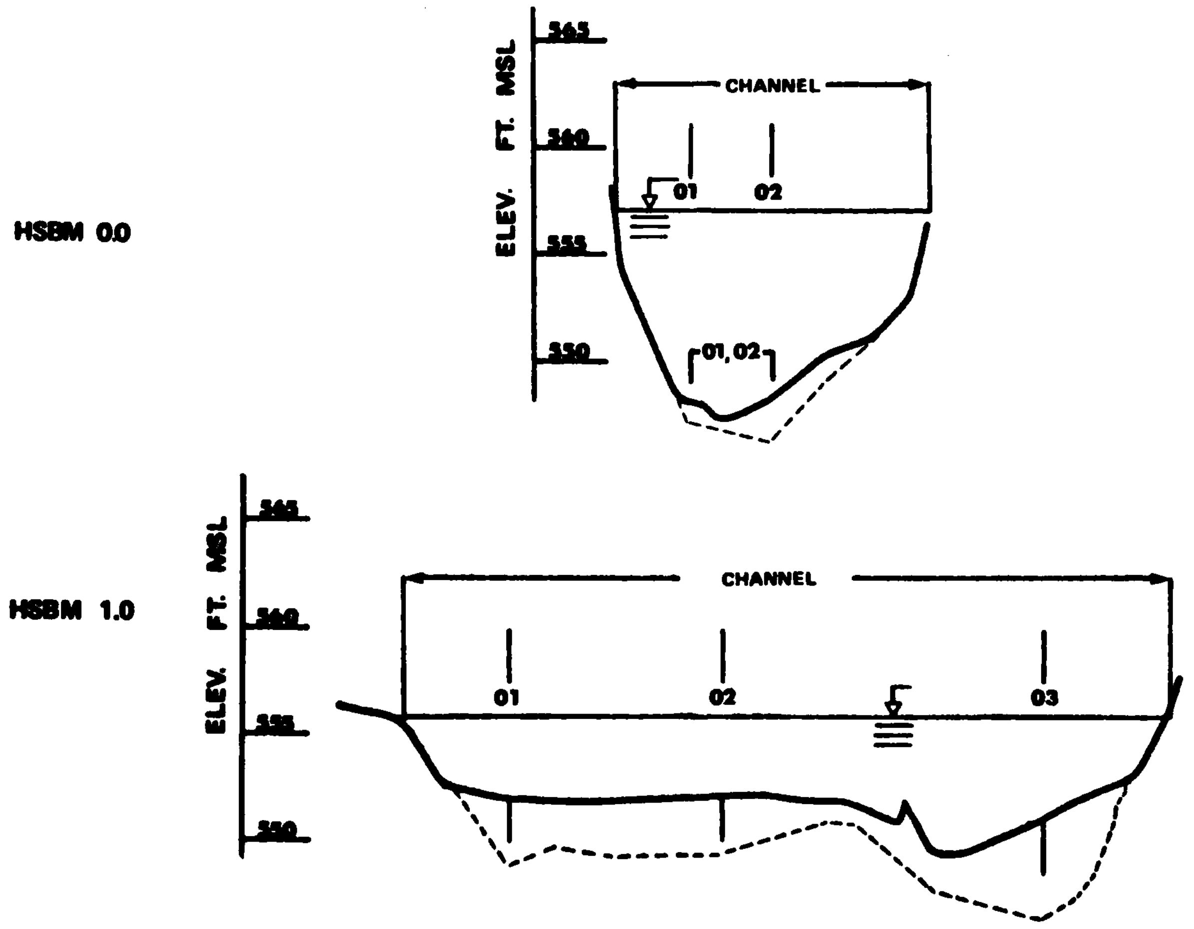

FIGURE II-4B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 0.0 and 1.0

SOURCE. WATER AND AIR RESEARCH, INC., 1980

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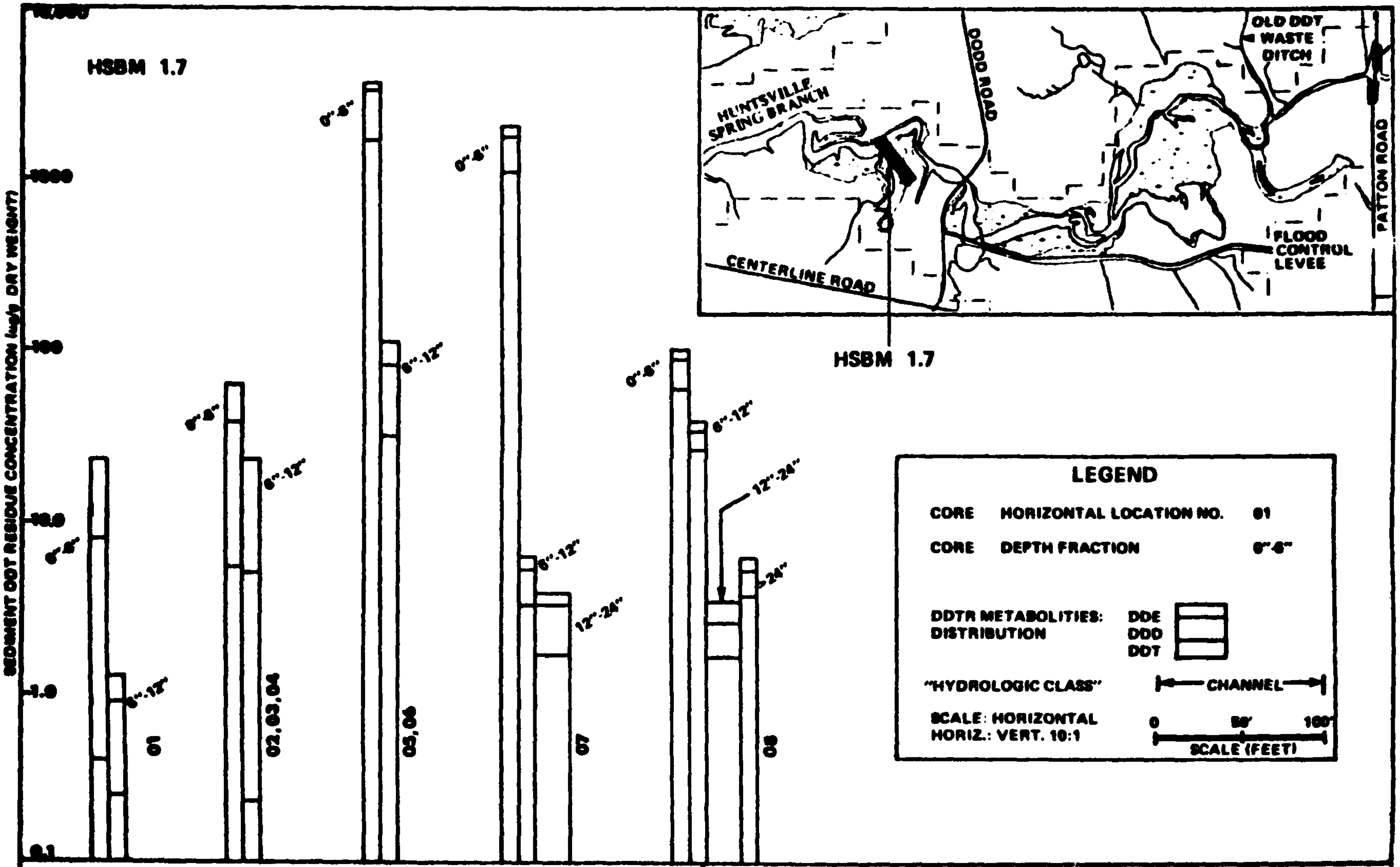

FIGURE II-5A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 1.7

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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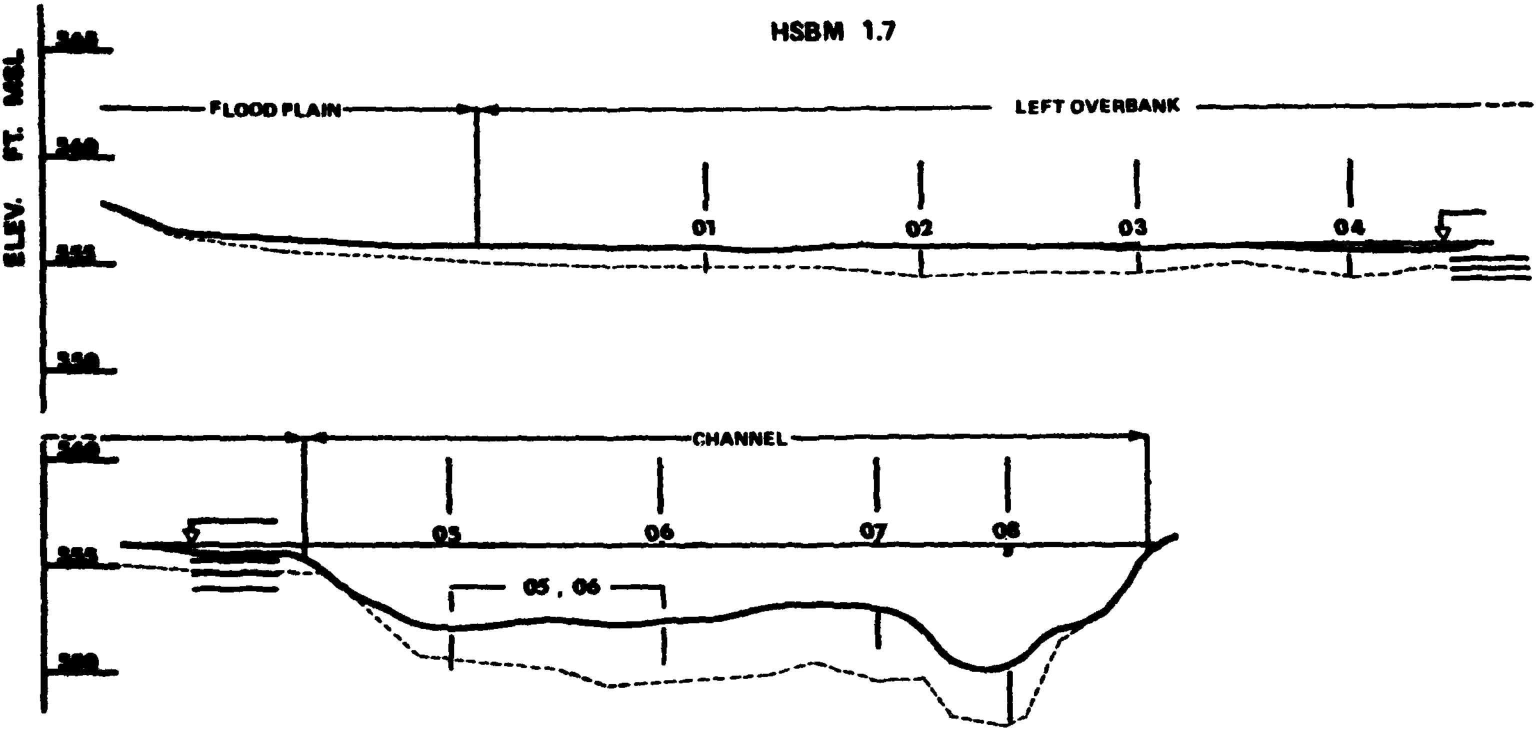

FIGURE II-5B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 1.7

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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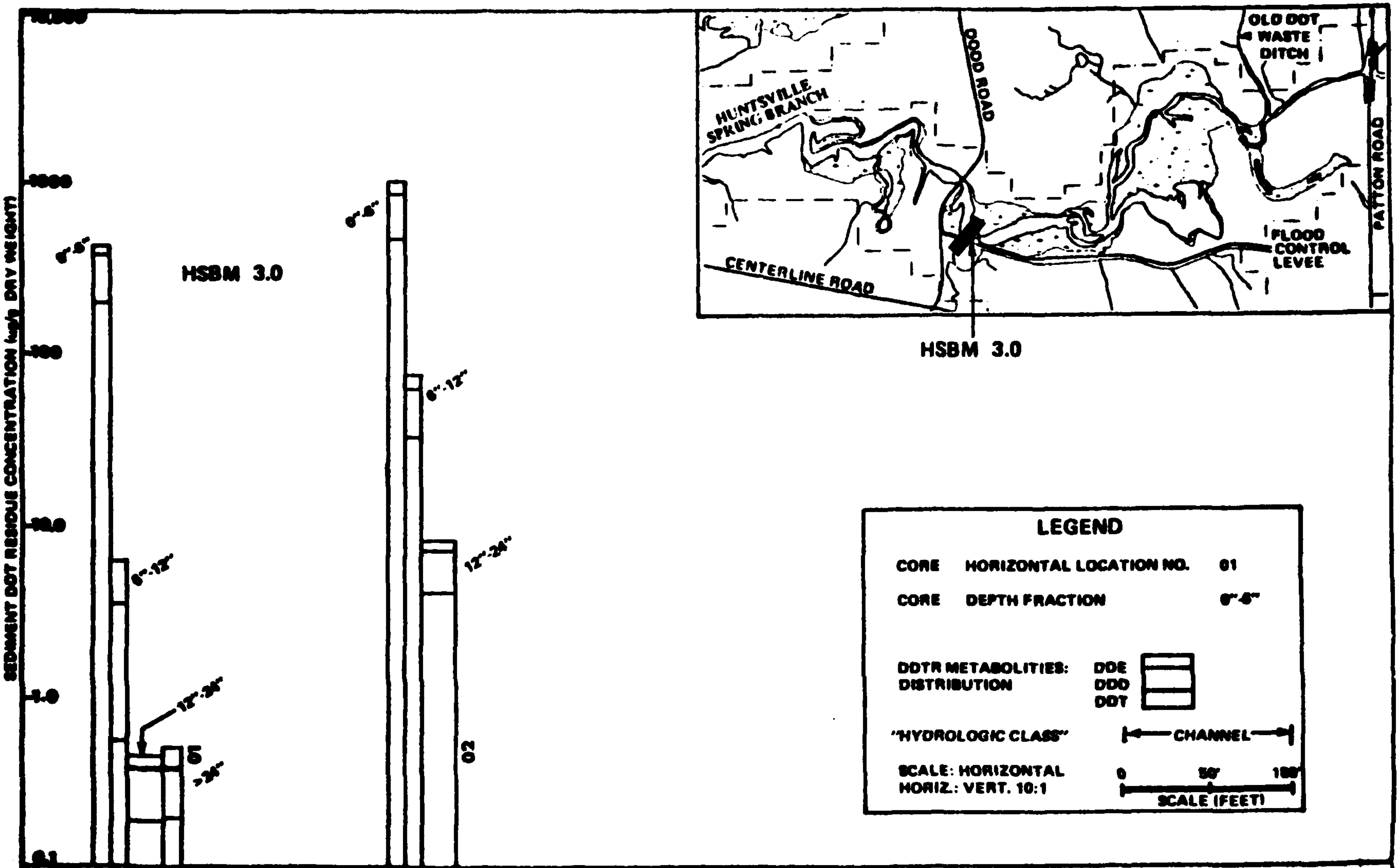

FIGURE II-6A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 3.0

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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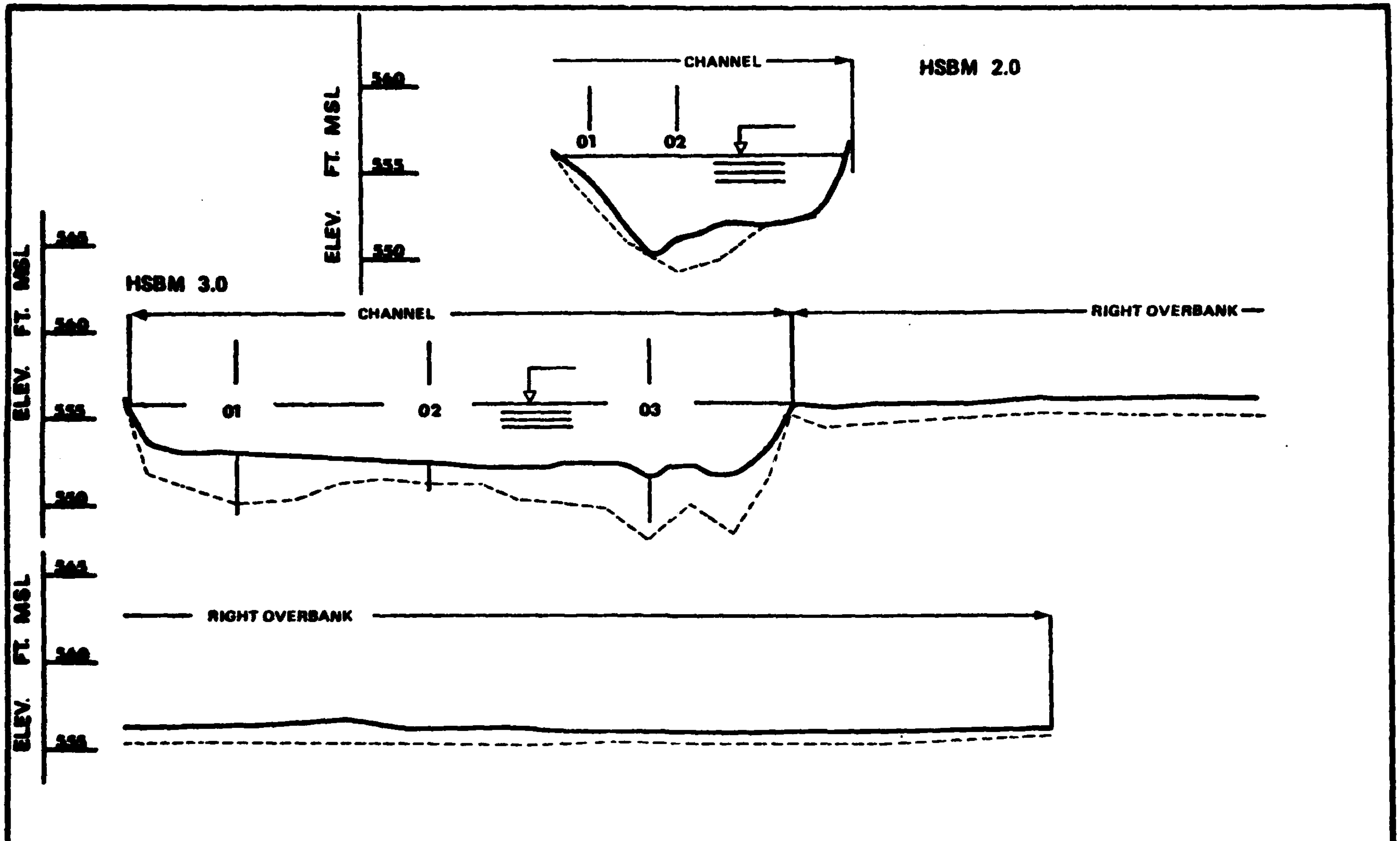

FIGURE II-6B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 2.0

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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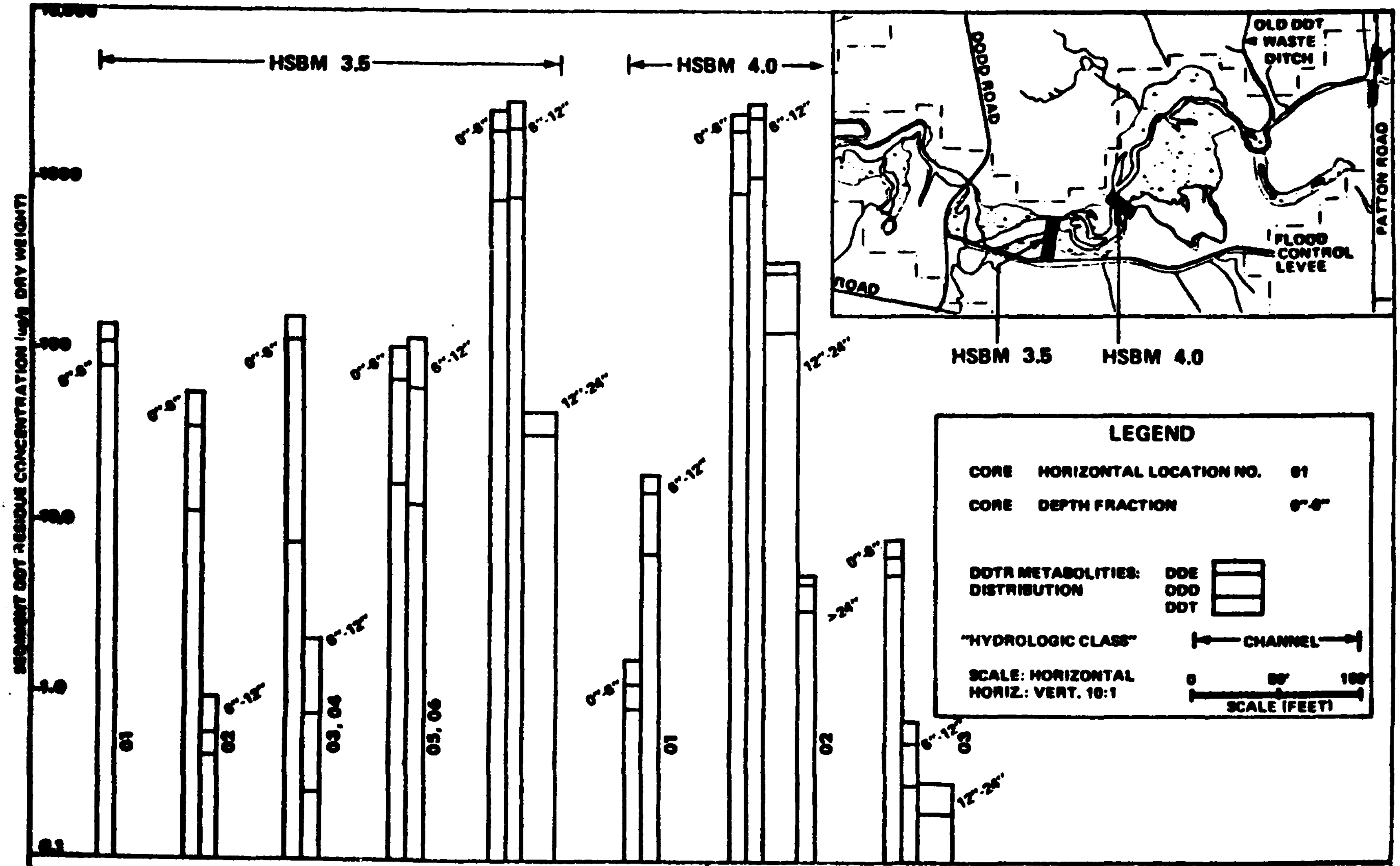

FIGURE II-7A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 3.5 and 4.0

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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Wheeler Reservoir, Alabama

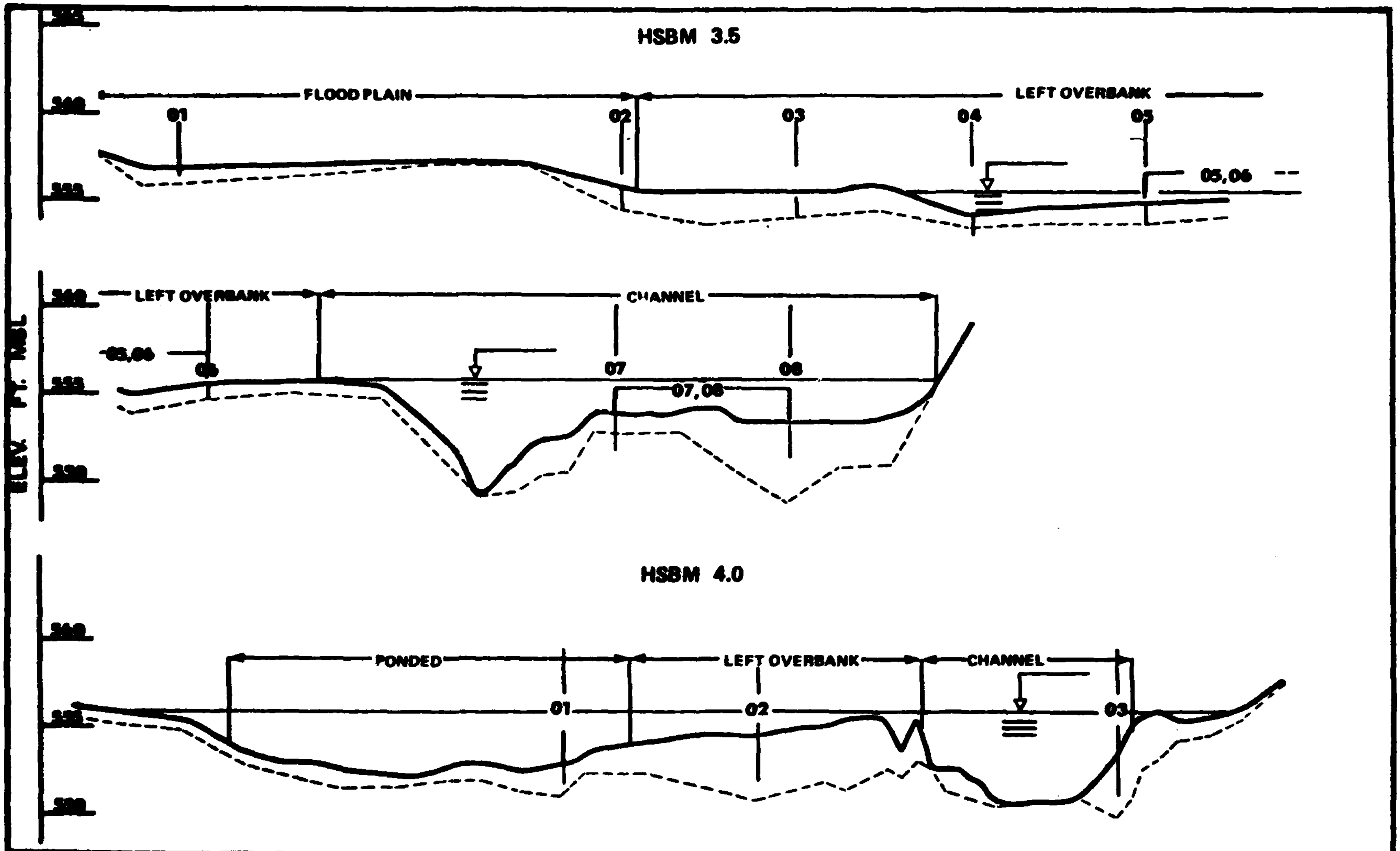

FIGURE II-7B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 3.5 and 4.0

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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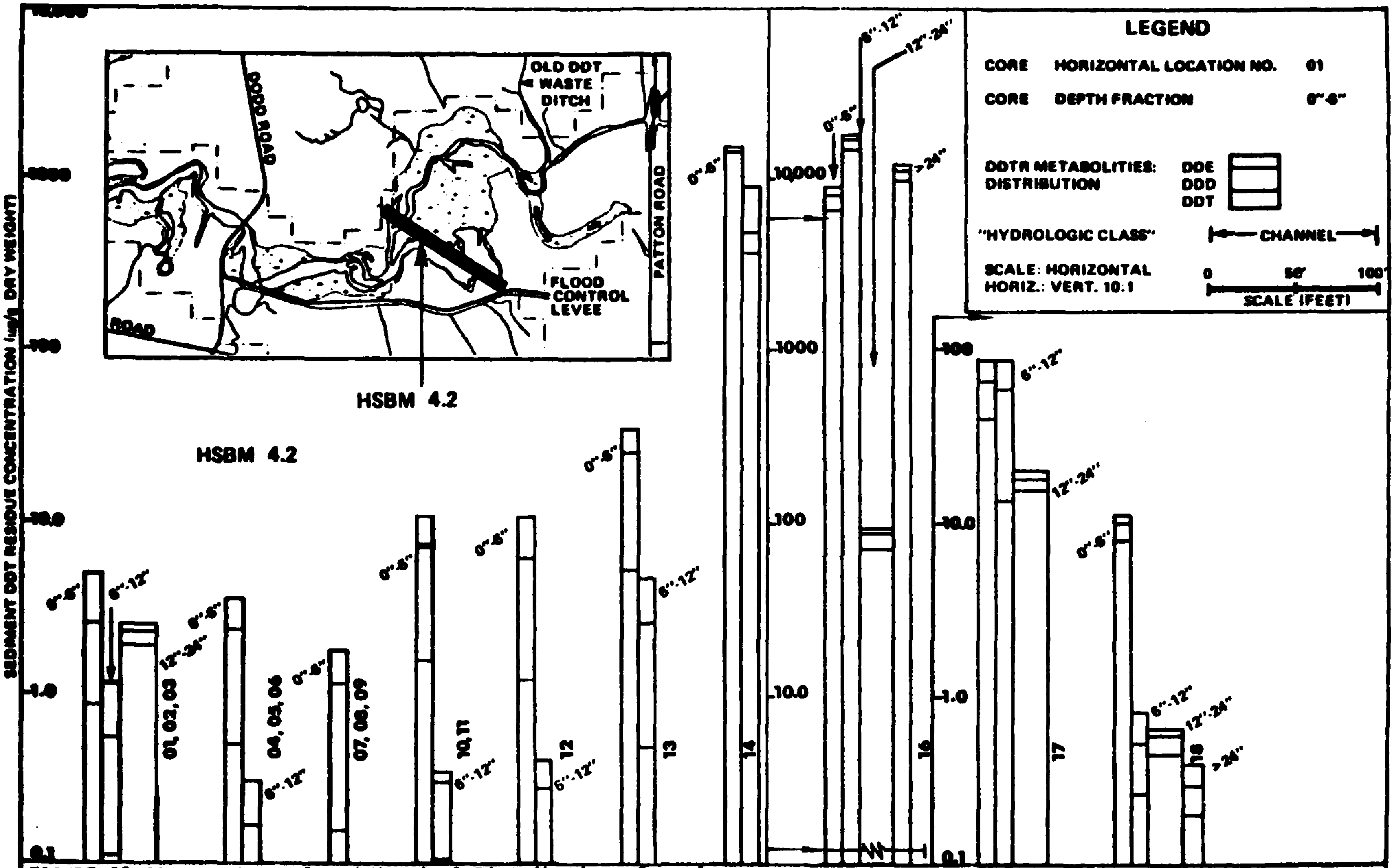

FIGURE II-8A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 4.2

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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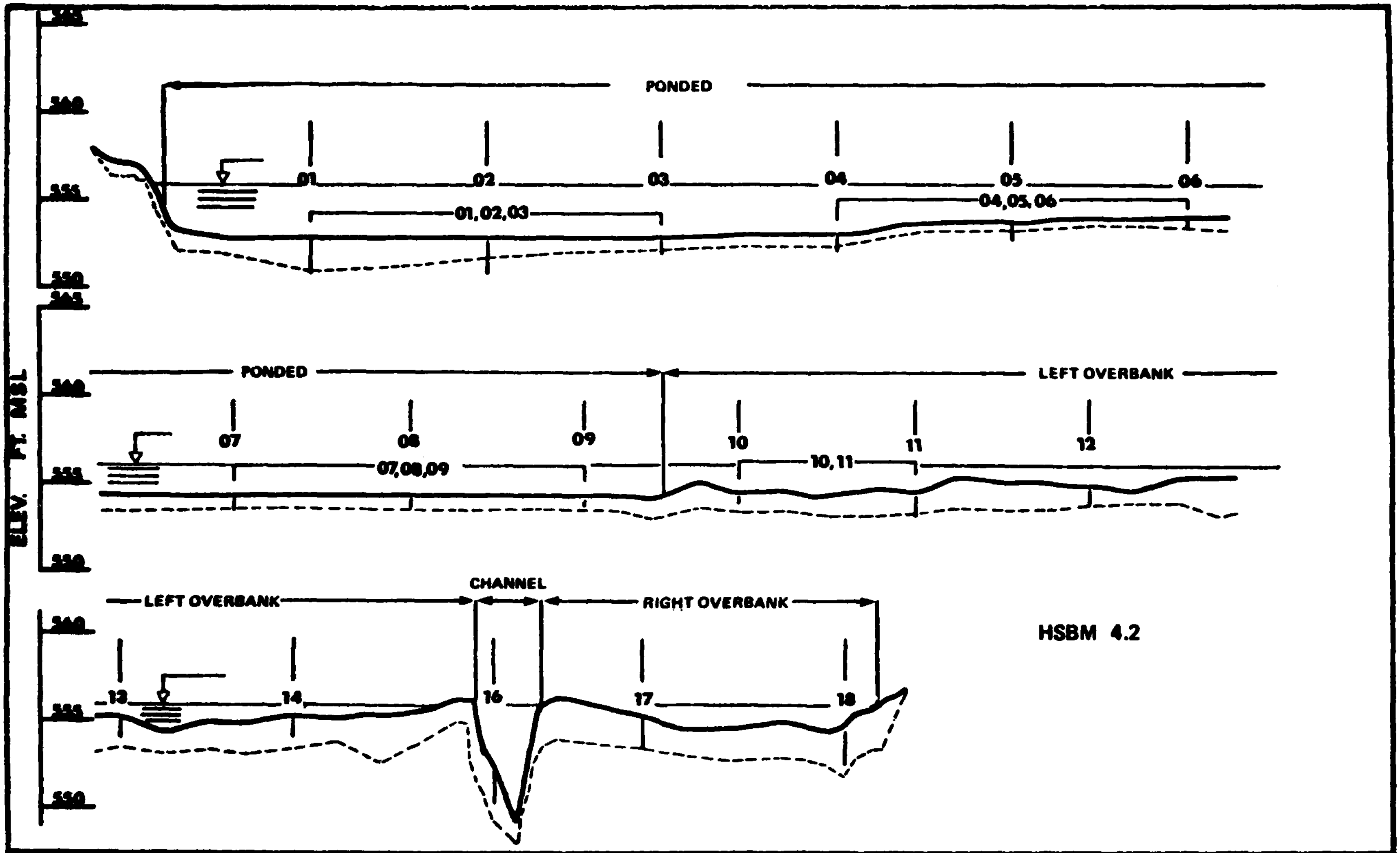

FIGURE II-8B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 4.2

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

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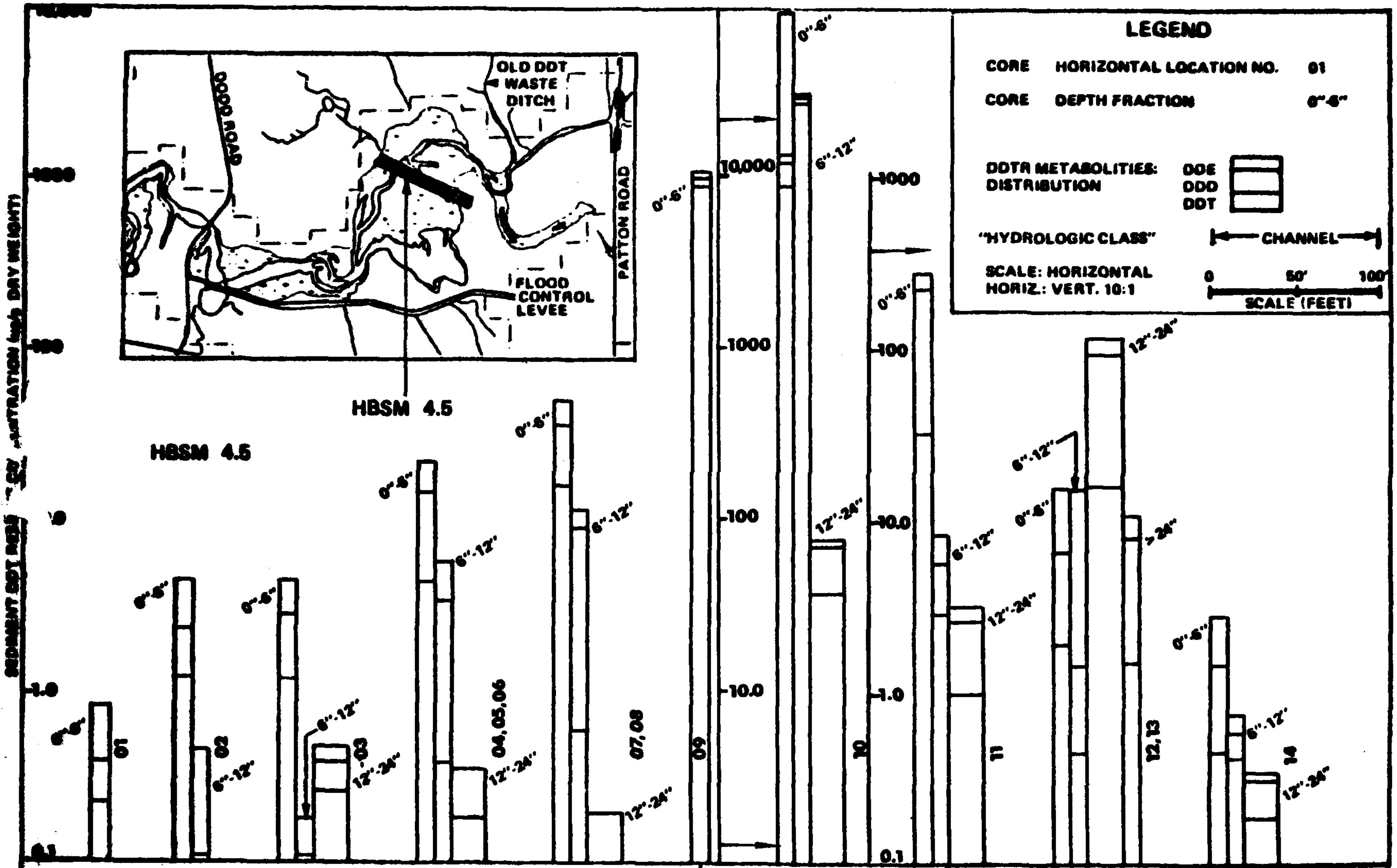

FIGURE II-9A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 4.5

SOURCE: WATER AND AIR RESEARCH, INC. 1980

U.S. ARMY CORPS OF ENGINEERS,
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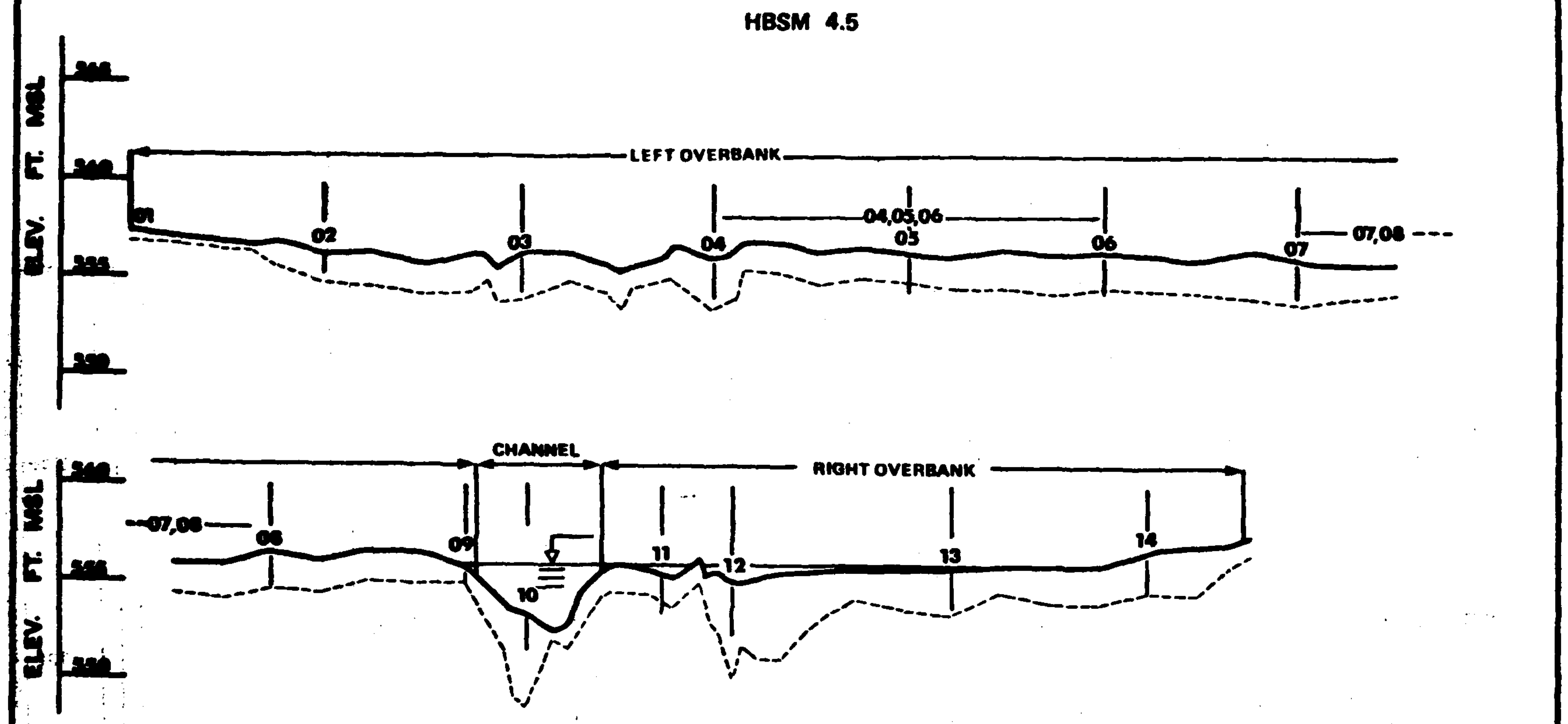

FIGURE II-9B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 4.5

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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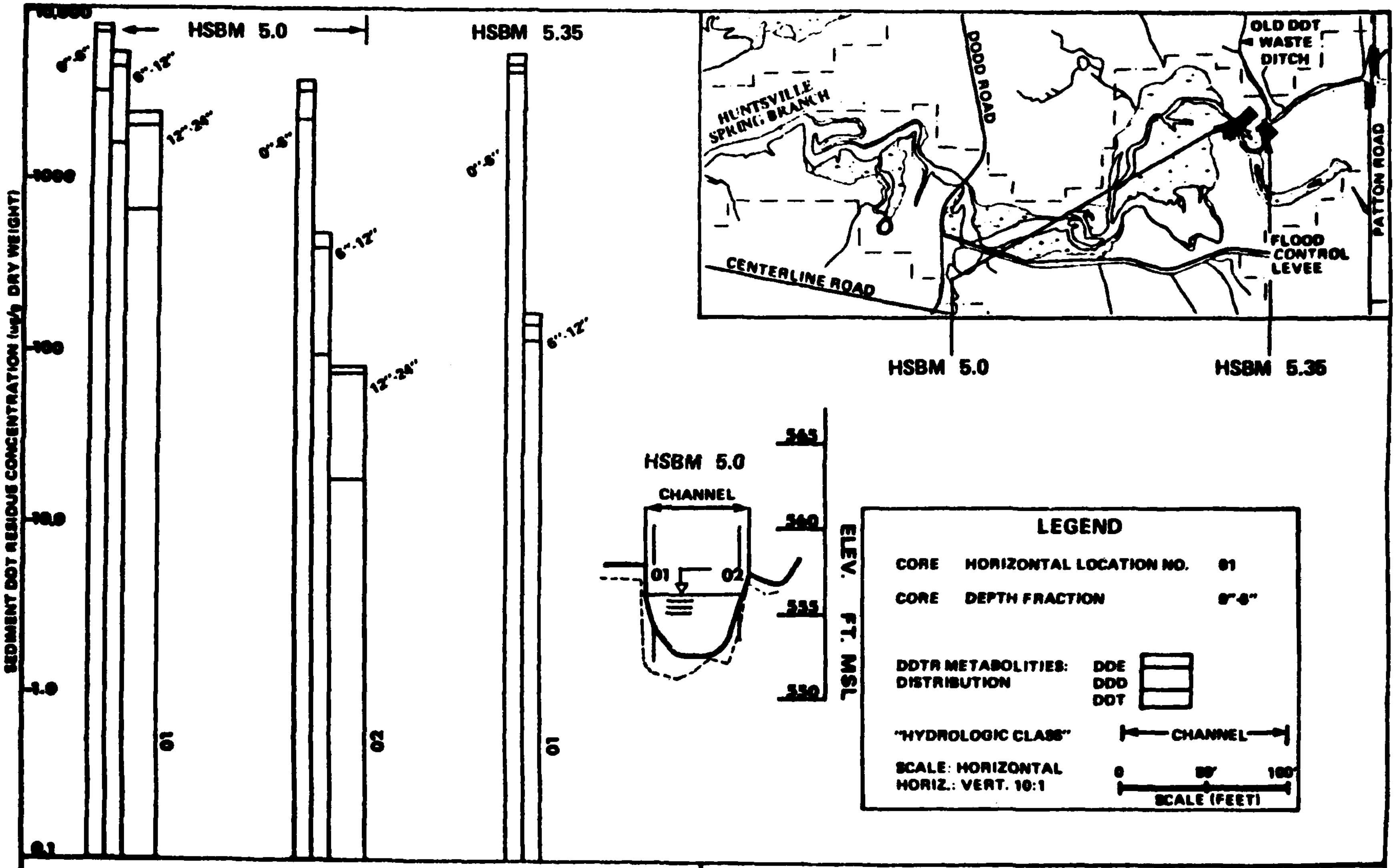

FIGURE II-10. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 5.0 and 5.35

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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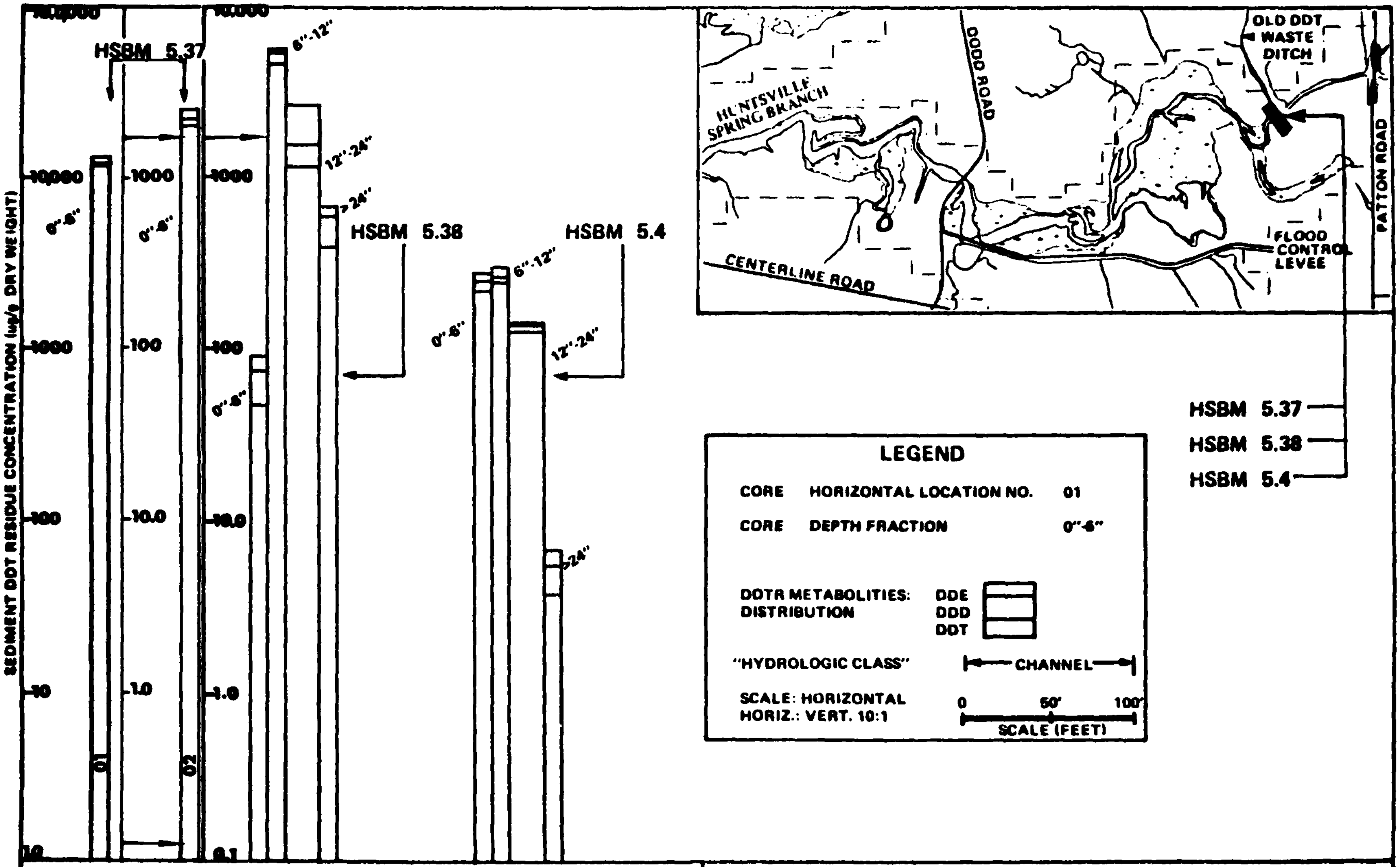

FIGURE II-11. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 5.37, 5.38 and 5.4

SOURCE: WATER AND AIR RESEARCH, INC. 1980

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Mean and range of DDTR in channel surface sediments in the Tennessee River and tributaries Wilson, Wheeler, and Guntersville Reservoirs, Alabama.

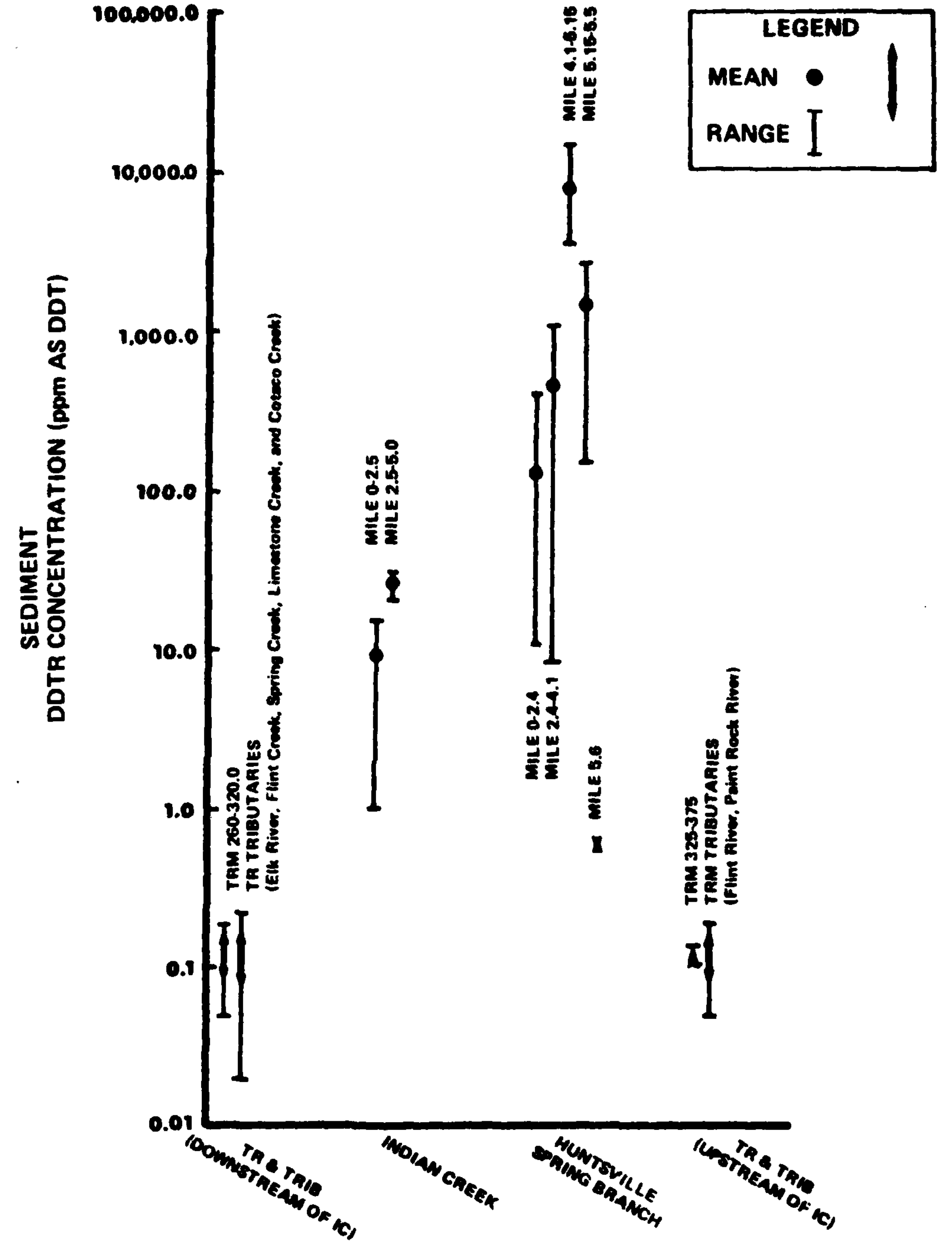

FIGURE II-12. Mean and Range of DDTR in Channel Surface Sediments in the Tennessee River and Tributaries, Indian Creek, and Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

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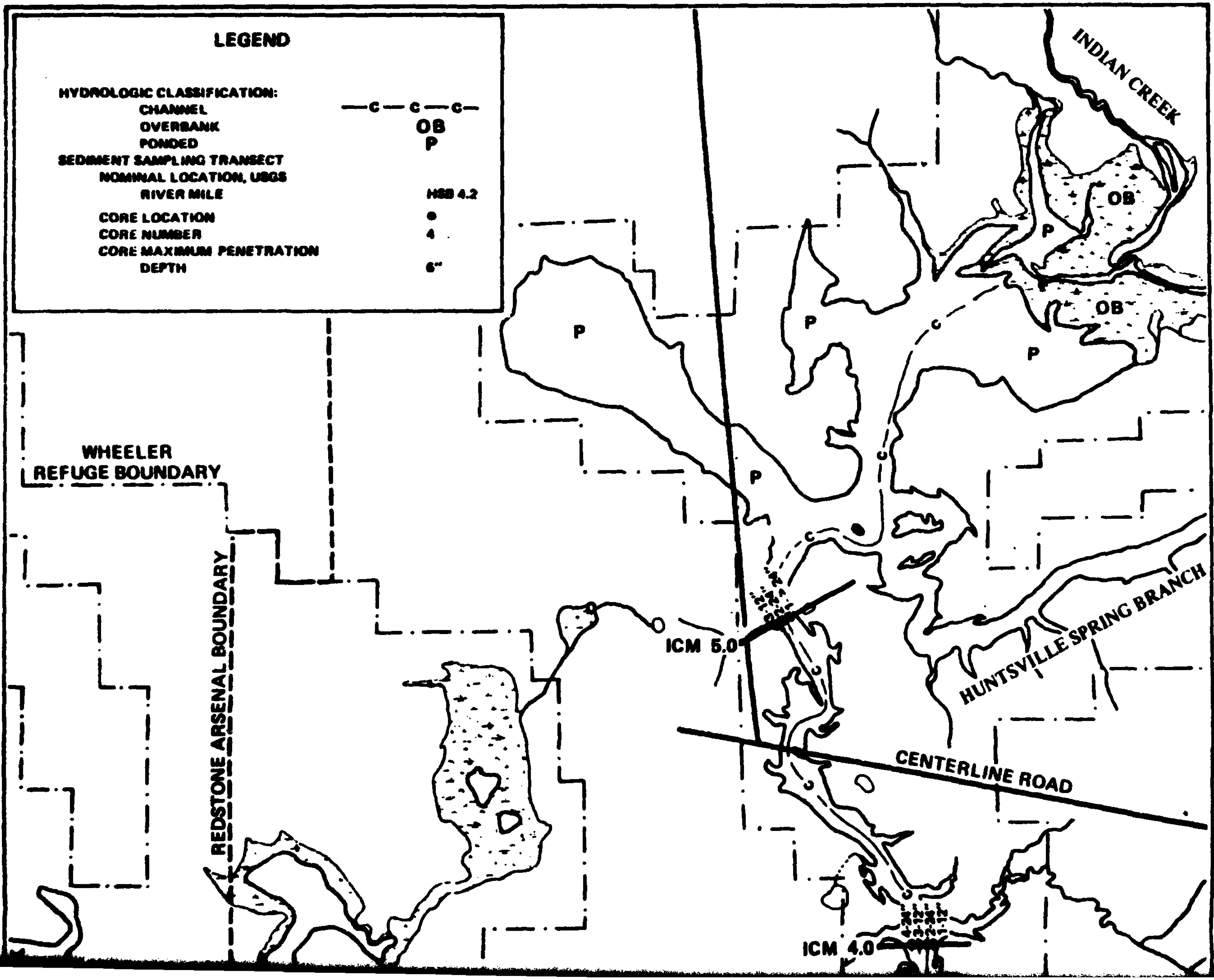
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OVERBANK OB
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RIVER MILE HSB 4.2
CORE LOCATION ●
CORE NUMBER 4
CORE MAXIMUM PENETRATION
DEPTH 6"
INDIAN CREEK
OB
OB
P
P
P
P
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HUNTSVILLE SPRING BRANCH
CENTERLINE ROAD
ICM 5.0
ICM 4.0
WHEELER
REFUGE BOUNDARY
REDSTONE ARSENAL BOUNDARY

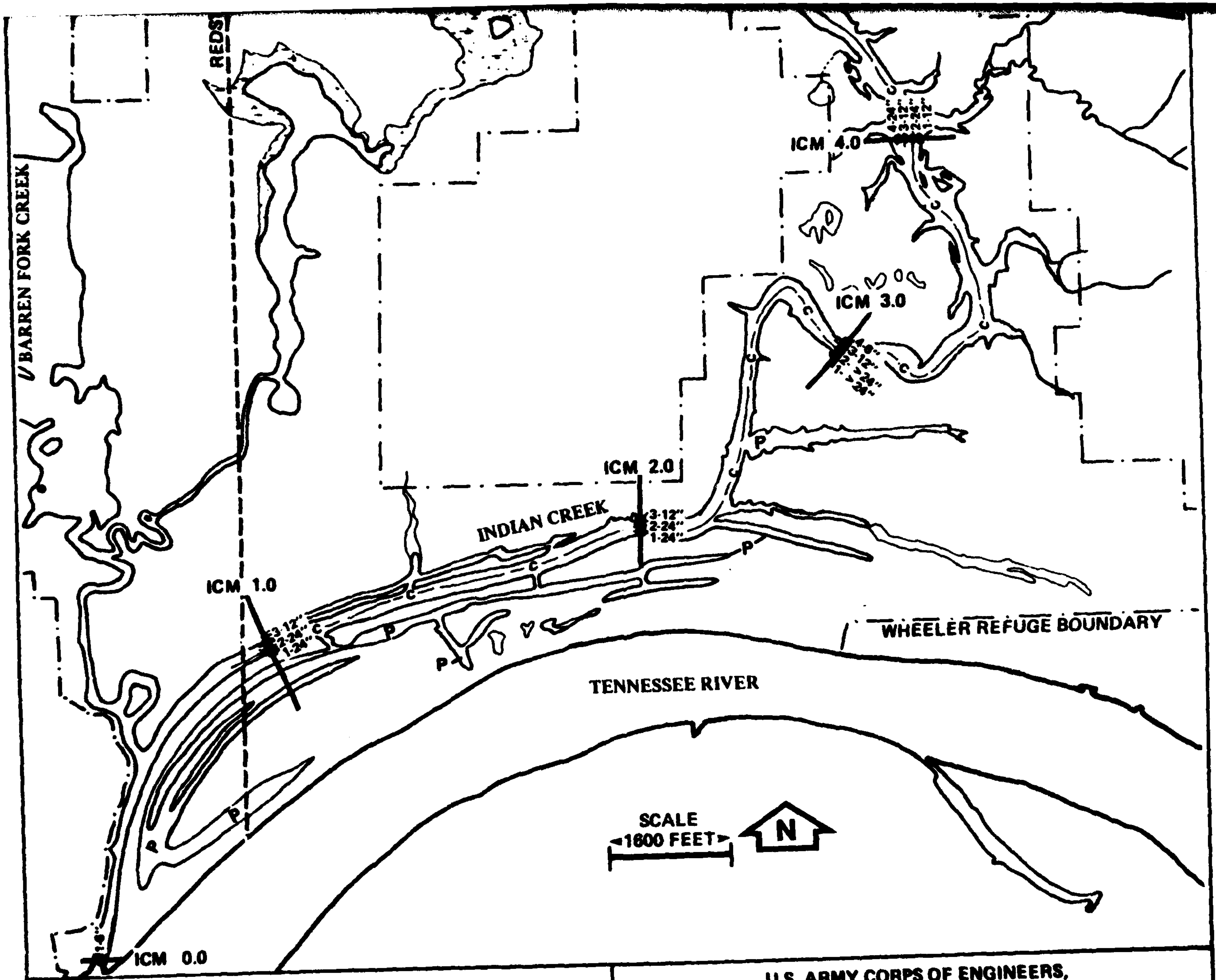

FIGURE II-13. Locations of Sediment Sampling Transects in Indian Creek

SOURCE: WATER AND AIR RESEARCH, INC. 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT
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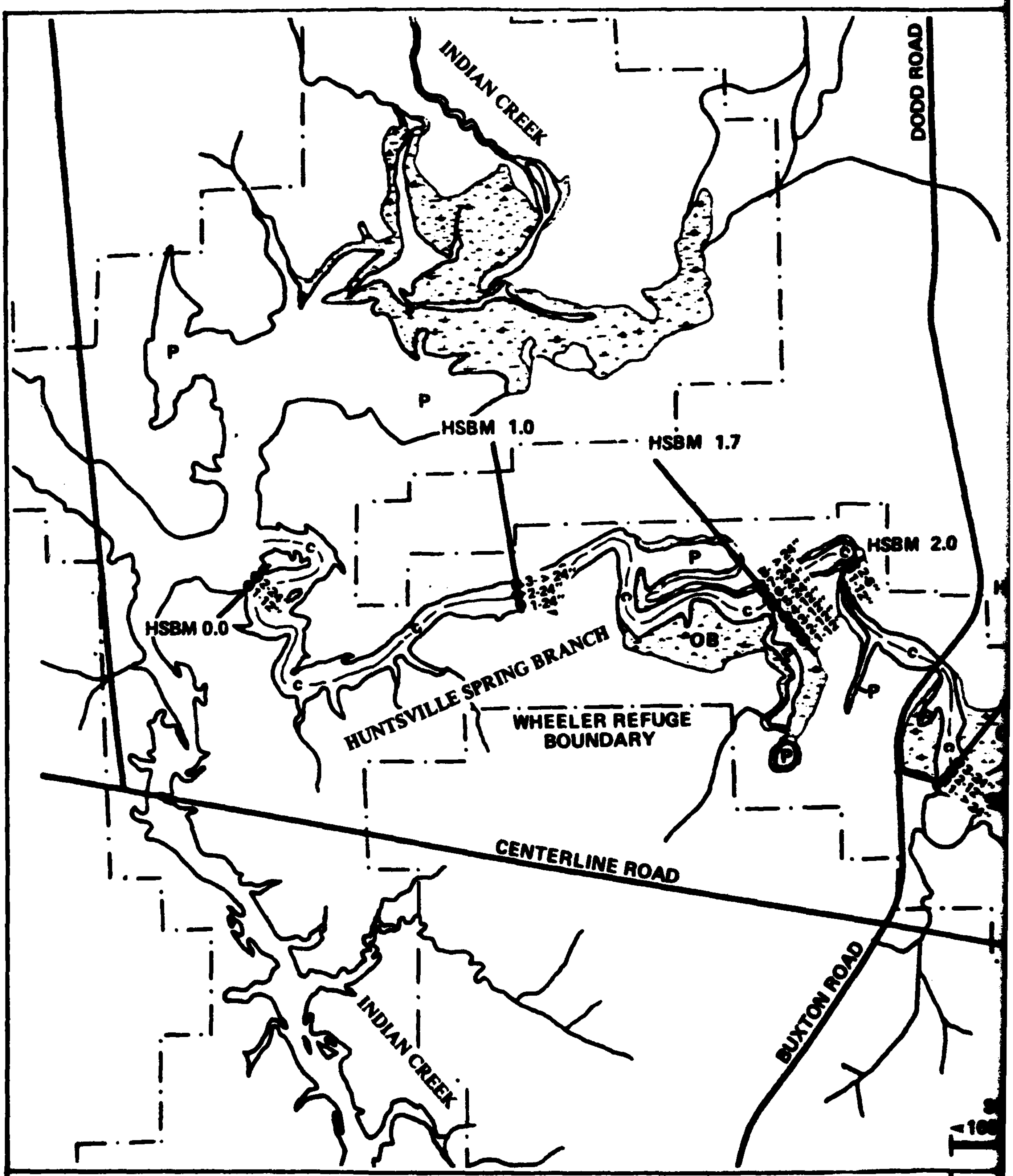
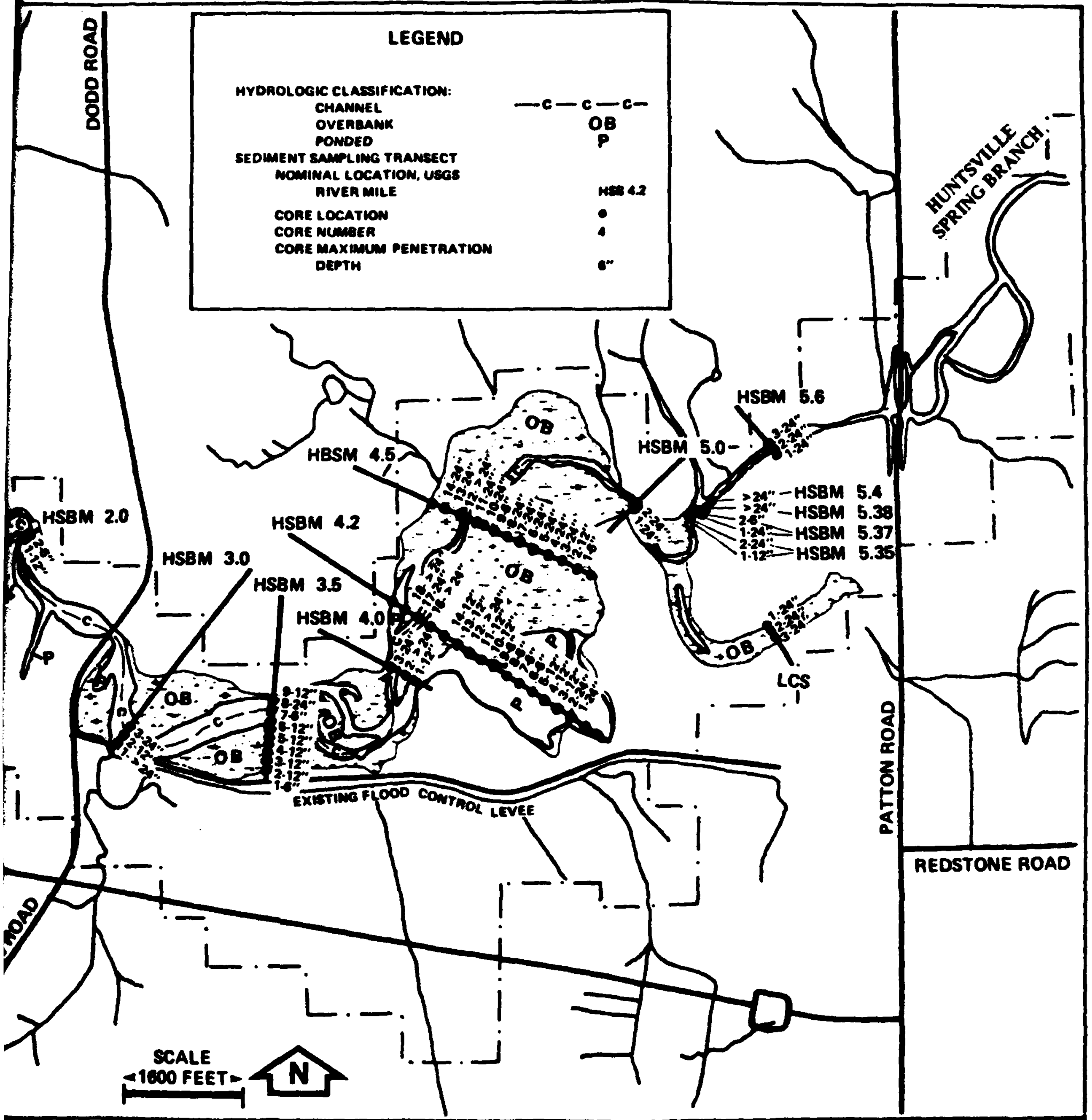


FIGURE II-14. Locations of Sediment Sampling Transects in Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980



Branch

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Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters, Wheeler Reservoir, Alabama

The total surface area assigned to each transect as well as surface areas in each of the above-mentioned hydrolgic categories were determined for both left and right banks (facing downstream) in Indian Creek and Huntsville Spring Branch using planimetric methods and 1" = 800' scale location maps.

The width along each transect in each hydrologic class was determined from transect profiles supplied by TVA. Individual cores were then classified as to the hydrologic category into which they were located. A surface area was assigned to each individual core as follows:

$$a = (A_i)(b/B)$$

where: a = surface area assigned to core
A_i = surface area assigned to hydrologic category i
B = width along the transect assigned to hydrologic category i
b = width along the transect assigned to an individual core, in hydrologic category i.

The volume of sediment represented by each individual core depth horizon was then determined. Low and high estimates were made as follows:

o Low Estimate--based on the probe data provided by TVA, the distance along each transect, in each hydrologic category assigned to each core in each of the four depth horizons: 0-6", 6-12", 12-24", and >24", was determined as follows:

$$v = a(\Sigma\ell/b)\Delta d$$

where: v = sediment volume assigned to core depth horizon, low estimate
$\Sigma\ell$ = total transect width in depth horizon assigned to core
Δd = depth increment in horizon (6" was assumed for >24" depth horizon)

o High Estimate--since the entire floodplain of Indian Creek - Huntsville Spring Branch is underlain by alluvial and residual soils to depths generally in excess of 20 feet, the interpretation of the probe data may be somewhat ambiguous. Thus, a volume of sediment attributable to each core based simply on the depth increment of each horizon was determined as follows:

$$V = a\ \Delta d$$

where: V = sediment volume assigned to core, depth horizon, high estimate.

The total quantity of each DDTR isomer attributable to each core-depth horizon was determined as follows:

$$m = V\ \gamma_d\ c$$

where: m = mass of the isomer attributed to volume represented by core depth horizon

γ_d = estimated unit dry weight of the sediment in the depth horizon
c = isomer concentration, ppm.

The unit dry weight of the sediment in each depth horizon was calculated using the following equation and data supplied by TVA from laterally composited, disturbed core samples:

$$\gamma_d = \gamma_s/(W\ \gamma_s + 1.0)$$

where: W = moisture content
γ_s = estimated unit weight of solids

$$= \frac{(1.03)(2.70)}{f(2.70-1.03)+1.03}$$

f = volatile solids fraction

The areal distribution of DDTR was calculated by summing over the depth horizons and isomers as follows:

$$(m/a)_{DDTR} = \Sigma\ \Sigma\ \Delta d\ \gamma_d\ c$$

DDTR and individual metabolite totals and subtotals were determined both as straight sums and as the equivalent weight of DDT. For ease of isomer and metabolite comparisons results are generally reported as DDT. In situations where reported results were below analytical detection limits a range of values was determined assuming:

(a) all less than values equal 0.0, and
(b) all less than values equal the stated value (i.e., reported detection limit.)

In general sediment DDTR levels in Indian Creek and Huntsville Spring Branch were significantly above detection limits for most isomers, thus, unless otherwise reported, only upper limits are reported.

In situations where isomer concentration data existed for a vertical or lateral composite or subcomposite as well as for all but one individual core in the composite, the isomer concentrations in the missing core were determined as follows (see Table II-34):

$$c_c = (W\ \bar{c}) - \Sigma\ c$$

where: c_c = calculated concentration
W = weight factor = number of cores in the composite
$\bar{c}$ = lateral or vertical composite concentration
c = individual core measured concentration.

In areas in Indian Creek and Huntsville Spring Branch within the influence of Wheeler Reservoir but not sampled in the course of this study, concentration and depth of contamination had to be estimated. Data was derived either from previous survey information (TVA, 1977) or estimated from samples taken in the course of this survey (see Table II-35).

Table II-34. Calculated DDT Residue Sediment Concentrations (ppm)

				Calculated DDT Residue Sediment Concentrations (ppm)					
River	Mile	Nominal Horizontal Location	Depth Horizon	o,p'-DDT	p,p'-DDT	o,p'-DDD	p,p'-DDD	o,p'-DDE	p,p'-DDE
HSB	1.0	2	0"-6"	1.76	106.00	15.00	52.90	11.10	11.10
HSB	1.0	2	6"-12"	1.23	96.00	23.70	85.50	28.00	21.80
HSB	1.0	2	12"-24"	<0.02	<0.02	<0.02	<0.02	0.34	<0.02
HSB	3.0	2	0"-6"	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
HSB	3.0	2	6"-12"	<0.02	0.45	3.37	<0.02	<0.02	<0.02
HSB	4.2	10	0"-6"	0.22	1.38	2.34	3.11	0.71	2.31
HSB	4.2	10	6"-12"	0.01	0.06	0.08	0.10	0.03	0.03
HSB	4.2	11	0"-6"	0.22	1.38	2.34	3.11	0.71	2.31
HSB	4.2	11	6"-12"	0.01	0.06	0.08	0.10	0.03	0.03
HSB	4.2	14	0"-6"	154.00	1390.00	15.00	54.30	<0.02	38.80
HSB	4.2	14	6"-12"	<0.02	500.00	154.00	79.00	29.40	114.00
HSB	5.35	1	0"-6"	538.00	4000.00	201.00	205.00	121.00	526.00
HSB	5.38	1	6"-12"	478.00	4460.00	333.00	281.00	<0.02	257.00
HSB	5.40	1	6"-12"	31.50	223.00	8.80	4.00	0.87	7.06

Table II-35. Estimated DDT Residue Sediment Concentrations (ppm)

River	Mile	Nominal Horizontal Location	Depth Horizon	Estimated DDT Residue Sediment Concentrations (ppm)					
				o,p'-DDT	p,p'-DDT	o,p'-DDD	p,p'-DDD	o,p'-DDE	p,p'-DDE
IC	1.0	-1	0"-24"	0.03	0.77	1.14	1.38	1.25	1.33
IC	1.0	4	0"-24"	0.03	0.77	1.14	1.38	1.25	1.33
IC	1.0	5	0"-24"	0.03	0.77	1.14	1.38	1.25	1.33
IC	2.0	-2	0"-GT24"	0.06	0.45	0.64	0.98	0.60	1.08
IC	2.0	-1	0"-GT24"	0.06	0.45	0.64	0.98	0.60	1.08
IC	2.0	4	0"-GT24"	0.06	0.45	0.64	0.98	0.60	1.08
IC	2.0	5	0"-GT24"	0.06	0.45	0.64	0.98	0.60	1.08
IC	3.0	-1	0"-GT24"	0.12	2.29	1.47	3.15	1.32	2.47
IC	3.0	5	0"-GT24"	0.12	2.29	1.47	3.15	1.32	2.47
IC	4.0	-1	0"-GT24"	0.07	1.81	0.57	1.36	0.86	0.96
IC	4.0	6	0"-GT24"	0.07	1.81	0.57	1.35	0.86	0.96
IC	4.0	7	0"-GT24"	0.07	1.81	0.57	1.35	0.86	0.96
IC	5.0	-1	0"-GT24"	0.16	4.75	1.51	4.13	1.53	2.03
IC	5.0	4	0"-GT24"	0.16	4.75	1.51	4.13	1.53	2.03
IC	5.75	1	0"-GT24"	0.16	0.85	0.29	0.80	0.30	0.40
IC	5.75	2	0"-GT24"	0.16	0.85	0.29	0.80	0.30	0.40
IC	5.75	3	0"-GT24"	0.16	0.84	0.29	0.78	0.29	0.39
IC	5.75	4	0"-GT24"	0.16	0.85	0.29	0.80	0.30	0.40
IC	5.75	5	0"-GT24"	0.16	0.85	0.29	0.80	0.30	0.40
HSB	0.0	-1	0"-24"	0.85	1.98	0.58	1.53	0.39	0.50
HSB	0.0	3	0"-24"	0.85	1.98	0.58	1.53	0.39	0.50
HSB	1.0	-2	0"-GT24	49.50	170.50	32.90	43.09	5.14	13.85
HSB	1.0	-1	0"-GT24	0.07	0.34	1.23	0.95	0.35	1.26
HSB	1.0	4	0"-GT24	0.07	0.34	1.23	0.95	0.35	1.26
HSB	1.0	5	0"-GT24	49.50	170.50	32.90	43.09	5.14	13.85
HSB	1.7	-1	0"-12"	49.50	170.50	32.90	43.09	5.14	13.85
HSB	1.7	9	0"-12"	0.07	0.34	1.23	0.95	0.35	1.26
HSB	2.0	-2	0"-12"	49.50	170.50	32.90	43.09	5.14	13.85

Table II-35. Estimated DDT Residue Sediment Concentrations (ppm) (Continued, Page 2)

River	Mile	Nominal Horizontal Location	Depth Horizon	Estimated DDT Residue Sediment Concentrations (ppm)					
				o,p'-DDT	p,p'-DDT	o,p'-DDD	p,p'-DDD	o,p'-DDE	p,p'-DDE
HSB	2.0	3	0"-12"	0.16	5.26	0.66	0.83	0.08	0.19
HSB	3.0	-2	0"-12"	1.43	88.20	16.79	55.26	10.00	15.69
HSB	3.0	-1	0"-12"	0.13	1.68	3.28	1.45	0.85	3.13
HSB	3.0	4	0"-12"	1.01	1.99	6.46	3.83	1.28	4.41
HSB	3.5	-1	0"-24"	5.23	81.30	40.40	92.50	17.80	48.60
HSB	3.5	10	0"-12"	1.01	1.99	6.46	3.83	1.28	4.41
HSB	4.0	4	0"-12"	0.05	1.05	7.22	11.70	2.32	5.78
HSB	5.0	-1	0"-24"	3.86	32.50	5.73	3.40	1.41	4.96
HSB	5.0	3	0"-24"	77.70	966.00	397.00	819.00	90.10	264.00
HSB	5.0	4	0"-24"	0.61	6.86	11.40	21.60	4.05	6.83
HSB	5.35	2	0"-24"	279.00	2050.00	106.00	112.00	62.30	271.00

General Extent of DDTR Contamination--Surficial sediments in the channel, overbank, ponded and floodplain areas of Indian Creek-Huntsville Spring Branch contain DDT residue levels ranging from <1 lb/acre to >46 tons/acre as DDT. Figure II-15 illustrates the extent of the DDTR contamination in HSB upstream of Mile 1.5 and downstream of Patton Road. As this figure illustrates, the most highly contaminated areas occur downstream of the old waste ditch outfall a distance of approximately 1.5 miles and within and 250-500 feet on either side of the main stream channel. DDTR levels in excess of 5 tons/acre or over 5 orders of magnitude above levels found in the adjacent flood plain and upstream channel sediments occur extensively throughout this area. DDTR levels in the main channel as far downstream as Dodd Road, 2.7 miles downstream of the old outfall, exceed 0.5 tons/acre over much of the channel bottom. Channel sediments downstream of Dodd Road in Huntsville Spring Branch contain DDTR at levels ranging from 0.025-0.5 tons/acre. Channel deposits in this stretch appear to be most heavily contaminated in the shallower areas which do not appear to be actively scouring. For example, at Mile 1.7, three-quarters of a mile downstream of Dodd Road, the highest DDTR levels in the channel occur in an area 50 to 250 feet to the left of the channel thalweg at depths 2 to 3 feet shallower than the deepest point in the channel where DDTR levels range from 0.25-0.5 pounds per acre vs. 40 pounds per acre at the thalweg. Channel deposits in Indian Creek downstream of the confluence with Huntsville Spring Branch contain DDTR levels ranging from <3 lb/acre at the confluence with the Tennessee River to nearly 0.1 ton/acre at Mile 5.0, 0.4 miles upstream of the channel constriction at Centerline Road and 0.2 miles downstream of the confluence with HSB.

The overbank areas within the HSB drainage basin are contaminated with DDTR at levels ranging from approximately 0.005 to over 5 tons/acre. As mentioned above, the most heavily contaminated overbank areas occur in a strip 250 to 500 feet wide paralleling the main channel from approximately 1000 feet upstream of the old outfall downstream a distance of 1.5 miles to below Mile 4.0. DDTR levels in this band range from >0.05 to <10 tons/acre. The level of contamination, however, is inversely proportional to the distance from the main channel. The lateral distribution in this stretch does not appear to be symmetric with respect to the channel, with areas to the south of the main channel contaminated for greater distance than those to the north, reflecting the broader width of the floodplain and overbank to the south. Downstream of Mile 4.0, overbank areas do not appear to be nearly as heavily contaminated with DDTR, with levels in the range of 5 to 50 lb/acre. These levels are comparable to those found in Indian Creek downstream of Mile 3.0. At no overbank location sampled in HSB (no similar stations were sampled in Indian Creek) were surficial sediment DDTR levels below 4 lb/acre.

Off channel ponded areas in HSB which are inundated at normal pool stage in Wheeler Reservoir, generally contained DDTR levels 5-10 times those found in adjacent overbank areas. DDTR levels generally range from 10-24 lb/acre, although at Mile 4.0 levels in excess of 50 lb/acre were observed 500 feet from the confluence with the heavily contaminated main channel. Nevertheless, DDTR levels in all ponded areas sampled in the course of this study contain DDTR levels 2-3 orders of magnitude lower than those observed in the adjacent channel deposits. Although no off

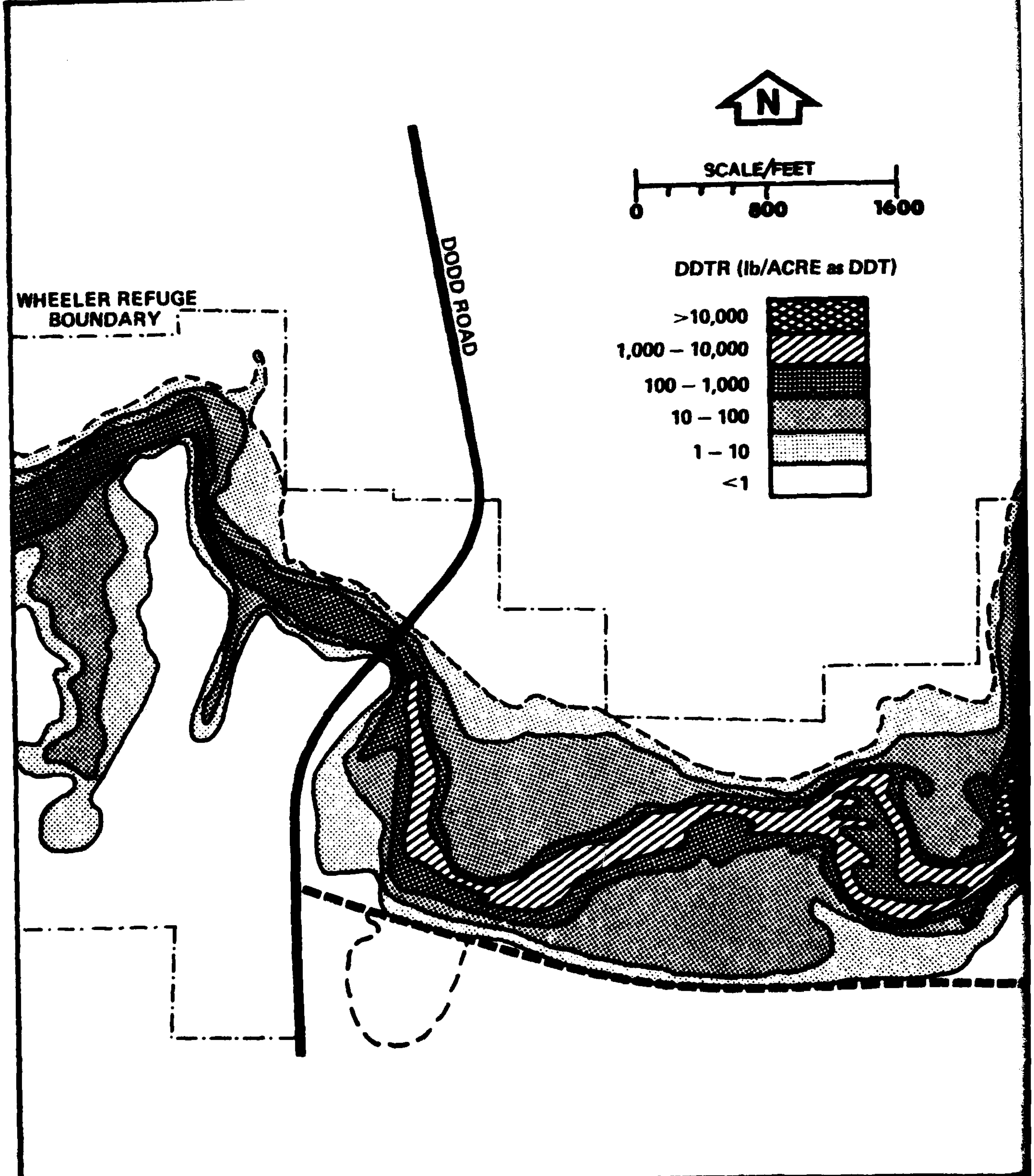
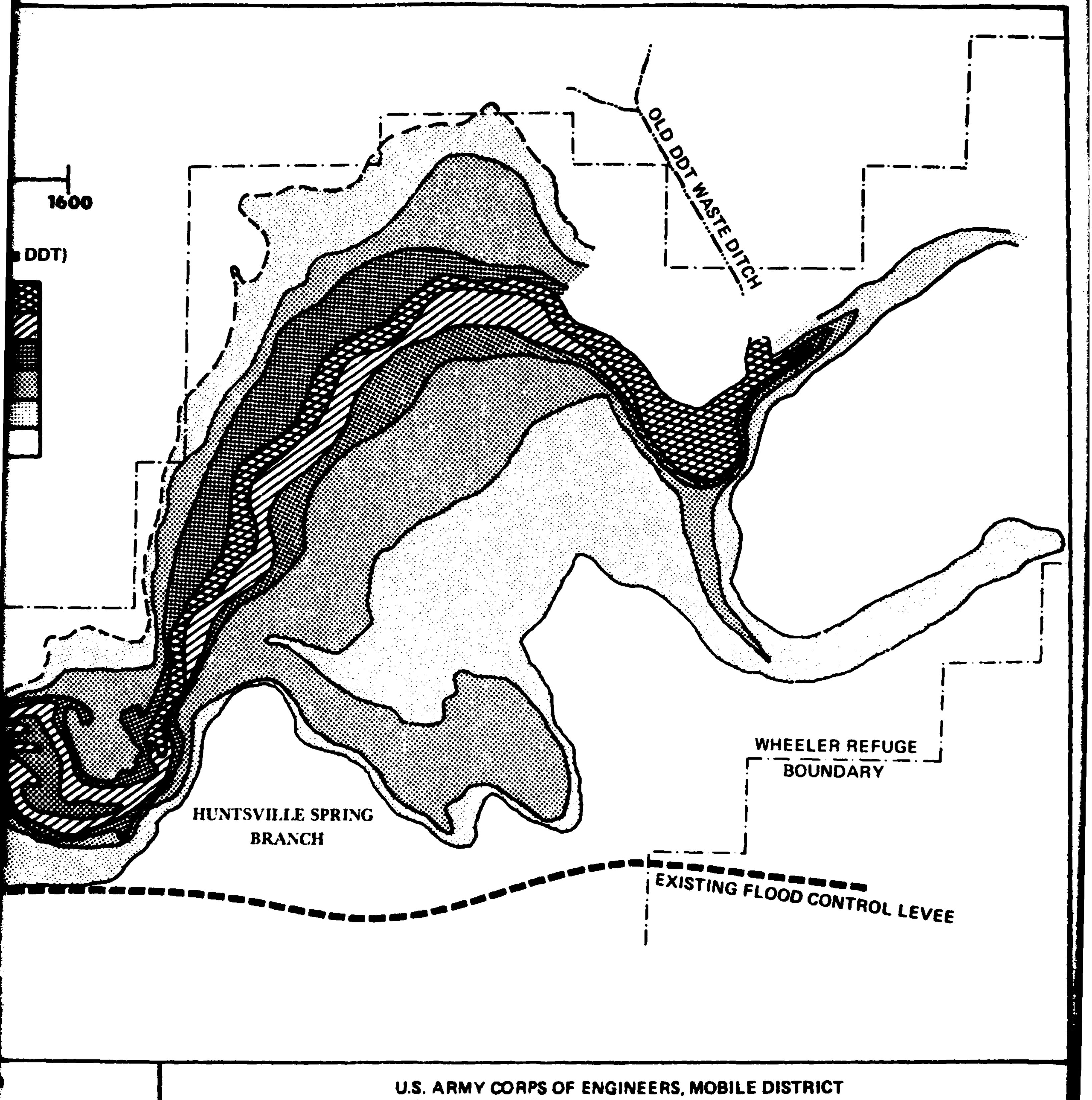


FIGURE II-15. Extent of DDT Residue Contamination of Surface Sediments in Huntsville Spring Branch Between Mile 1.5 and 5.6

SOURCE: WATER AND AIR RESEARCH, INC. 1980



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channel cores were obtained in Indian Creek in the course of this study, previous surveys indicate that a similar relationship occurs between ponded and adjacent channel DDTR levels (TVA, 1977).

With the exception of floodplain areas within 0.5 miles of the old waste ditch outfall, surface (0-6") soils within the floodplain of Indian Creek and Huntsville Spring Branch generally contain DDTR levels below 1 lb/acre. DDTR levels in BFC are on the order of <10 lb/acre. These areas contain a relatively minor portion, i.e.<< 1 percent, of the total DDTR contaminating the sediments of IC-HSB.

The vertical distribution of the DDTR in the channel and overbank areas is dependent upon the distance from the old waste ditch outfall. Figure II-16 illustrates the DDTR sediment concentrations at four cross-sections in HSB, at Miles 5.0, 4.5, 3.5 and at Mile 1.7, 0.4 miles downstream of Dodd Road. Upstream of Mile 3.5 evidence of significant DDTR contamination at depths >24" exist. Although there is some indication of highly contaminated sediments being covered by less contaminated deposits, this does not appear to be a significant process as over 85 percent of the DDTR in the channel sediments upstream of Dodd Road occurs within 12 inches of the sediment:water interface.

As mentioned above, of the estimated 837 tons of DDTR contained in the sediments of IC-HSB, 804 tons or over 95 percent is contained within the 2.7 mile stretch of HSB between Dodd Road and Patton Road. Of this total, 257 tons or 32 percent resides in the channel bottom deposits, 544 tons or 67 percent resides in the overbank sediments and the remaining 3.4 tons or <1 percent of the total occurs in the off channel ponded area sediments (see Table II-36).

The longitudinal, lateral, and vertical distribution of DDTR in the sediments of HSB upstream of Dodd Road exhibit a somewhat complex pattern as a result of repeated transport and deposition. Although over two-thirds of the DDTR upstream of Dodd Road occurs in the overbank areas outside of the main channel, at least 473 tons or over 87 percent occurs within 400 feet and 508 tons or over 90 percent occurs within 500 feet of the channel. Furthermore, over 99 percent of the total DDTR in the overbank occurs upstream of Mile 3.5. Over 460 tons or 85 percent of the total DDTR in the overbank occurs within 12 inches and over 99 percent occurs within 2 feet of the surface.

Figure II-17 illustrates the relationship between the mass of DDTR and the associated volume of sediment in channel, overbank and ponded areas of IC and HSB as well as the overall mass-volume relationship. Removal of ±99 percent of the DDTR contaminated sediments from IC and HSB would require the displacement of over 6 million cubic yards. However, the fact that the DDTR contamination is not uniformly distributed accounts for the sharp break in the mass-volume distribution curve.

Nearly half of the DDTR contaminating the surficial sediments of the IC-HSB system occurs within only 0.06 million cubic yards in the channel and near overbank areas of HSB between Miles 4.0 and 5.4. This volume of sediment constitutes less than 1 percent of the total volume of DDTR contaminated sediment in the IC-HSB system. The next 25 percent of the

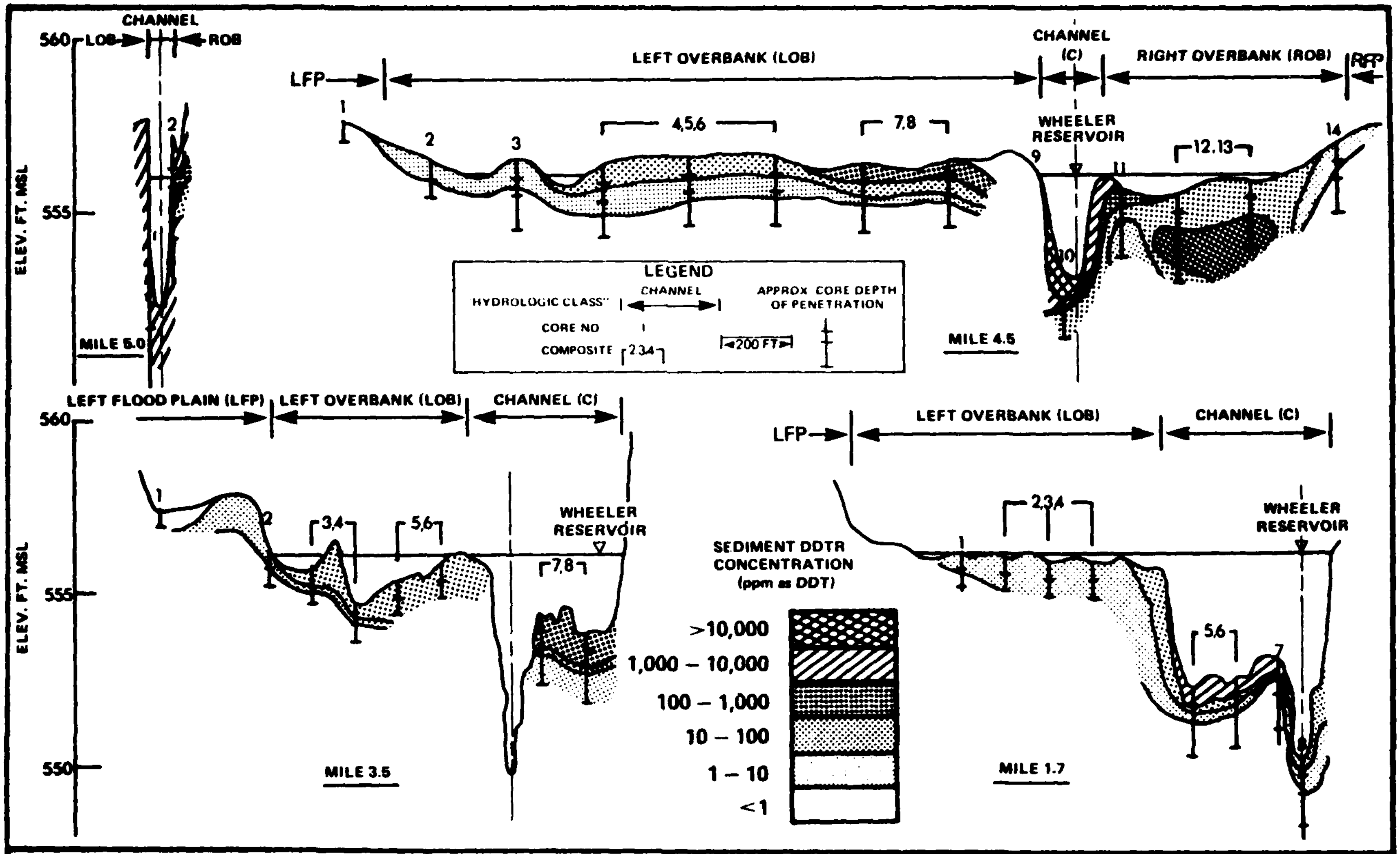

FIGURE II-16. Horizontal and Vertical Extent of DDT Residue Contamination in the Surface Sediments at Four Locations in Huntsville Spring Branch, Miles 5.0, 4.5, 3.5 and 1.7

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Table II-36. Mass Distribution of DDTR in the Sediments of Indian Creek and Huntsville Spring Branch as a Function of Hydrologic Category, August, 1979

Location	Depth	Hydrologic Category Channel Tons as DDT	Overbank Tons as DDT	Ponded Tons as DDT	Total Tons as DDT
HSBM 2.4-5.6	0-6"	102	271	1.7	375
	6-12"	118	193	1.2	311
	12-24"	58	80	0.5	86
	>24"	31	0.87	NEGL	32
	Overall	257	544	3.4	804
HSBM 0-2.4	0-6"	17	0.85	0.73	19
	6-12"	5.9	0.35	0.73	7.0
	12-24"	0.79	NEGL	0.04	0.83
	>24"	0.03	NEGL	0.02	0.05
	Overall	23	1.2	1.5	26
ICM 0-5.0	0-6"	4.5	NEGL	0.04	4.5
	6-12"	2.1	NEGL	0.04	2.1
	12-24"	1.3	NEGL	0.08	1.4
	>24"	0.04	NEGL	NEGL	0.04
	Overall	8.5	NEGL	0.02	8.5

NOTE: Includes estimated data.

NEGL - Negligible

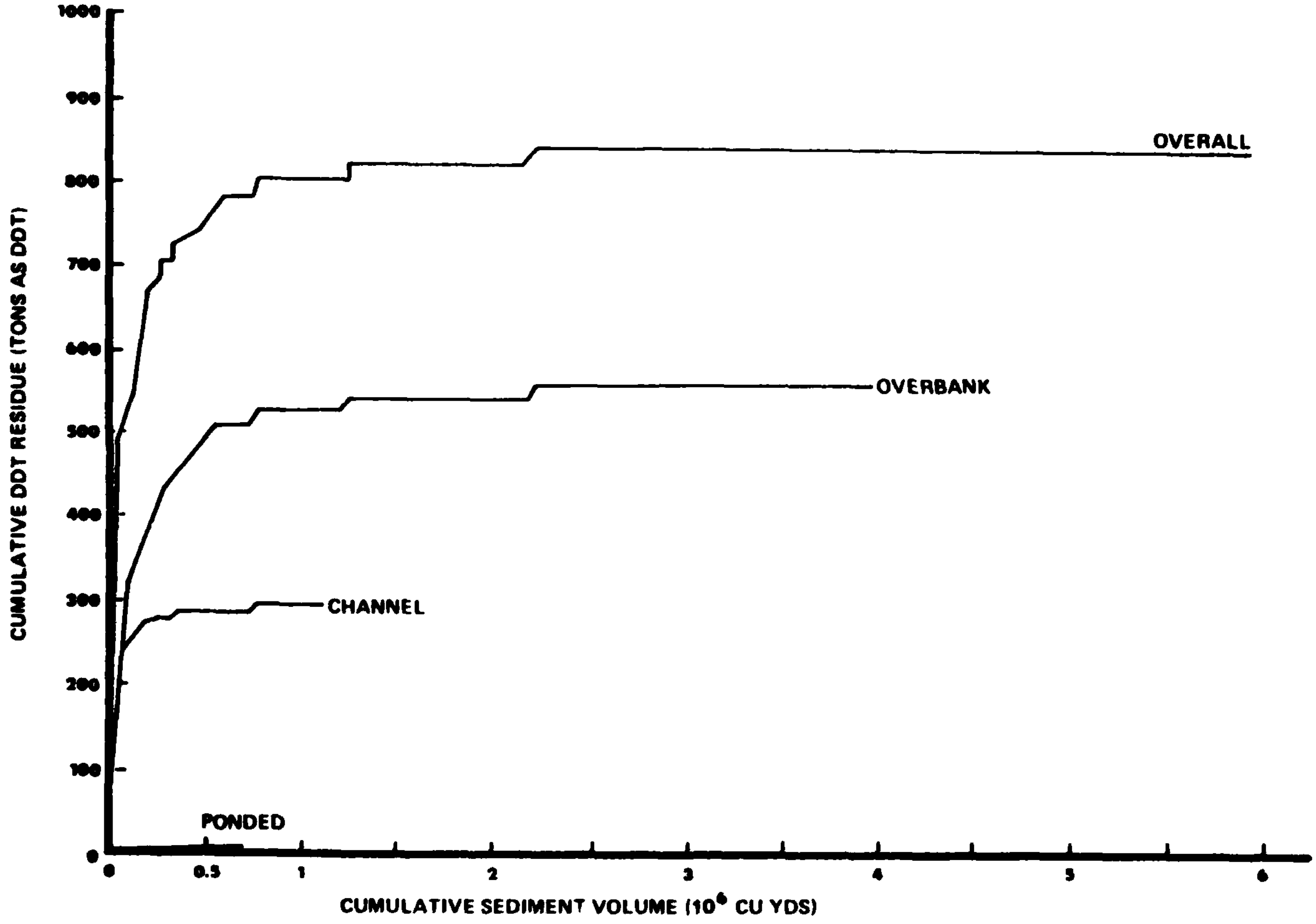

FIGURE II-17. Distribution of DDT Residue in the Contaminated Surface Sediments of Indian Creek and Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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DDT residue contaminates an additional 0.14 million cubic yards. Just under 95 percent of the DDTR is associated with approximately 1.0 million cubic yards of sediment, the bulk of which occurs in the channel and near overbank deposits in HSB upstream of the confluence with IC and downstream of the old waste ditch outfall. The next 3 percent of the DDTR contaminates a volume of sediment approximately equal to the volume contaminated by 95 percent of the total DDTR.

Physically, the surface sediments throughout most of Indian Creek and Huntsville Spring Branch range from clay to clay loam to sandy clay. Channel sediments throughout most of Indian Creek downstream of the confluence with HSB are clays with over 75 percent fines. Sediments in HSB exhibit greater variation in general than those in IC. Nevertheless, the distribution of DDTR in the sediments of both IC and HSB does not appear to correlate closely with any of the physical characteristics of the sediments.

Over 50 percent of the total DDTR in the sediments of IC and HSB, or over 493 tons, occurs as either the o,p- or p,p-isomer of DDT. The remaining 344 tons exists as one or the other of the metabolites, DDD or DDE. Overall, DDD is the primary metabolite, constituting over two-thirds of the metabolized fraction or 235 tons. Approximately 110 tons occurs as DDE, the other major metabolite.

The distributional patterns of DDT and each of the metabolites are all different from each other as well as that of the sum, i.e., DDTR. The relative concentration of DDT is related to the total DDTR concentration. Higher relative DDT concentrations are correlated with higher DDTR concentrations as shown in Figures II-18 thru II-20 for channel, overbank and ponded area sediments.

Figure II-21 illustrates the relative contribution of DDT and each of the major metabolites to the total DDTR is the surface 0-6" sediments as a function of distance from the outfall. DDT constitutes 60 percent of the DDTR in HSB upstream of Dodd Road, 45 percent downstream to the confluence with IC and only 27 percent of the DDTR in Indian Creek. In HSB upstream of Dodd Road at depths >24" over 80 percent of the DDTR is DDT.

Figure II-22 illustrates the relative contributions of DDT and the metabolites, as well as each of the separate isomers, in the surface 0-6" sediments along the sampling transect at HSB Mile 4.2. The relative distribution of each of the metabolites across this transect follows a pattern analogous to that of the longitudinal distribution, with DDT constituting most of the DDTR in the heavily contaminated channel and near overbank sediments, with DDD and finally DDE predominately as one moves to areas further from the heaviest contamination. This figure also illustrates the relative distribution of the o,p- and p,p-isomers. In general it appears that the p,p-isomer is predominate regardless of the metabolite.

3.1.2 Tennessee River and Tributaries

A summary of DDTR concentrations in sediments in the Tennessee River and tributaries is shown in Table II-37. Detectable quantities of DDTR were

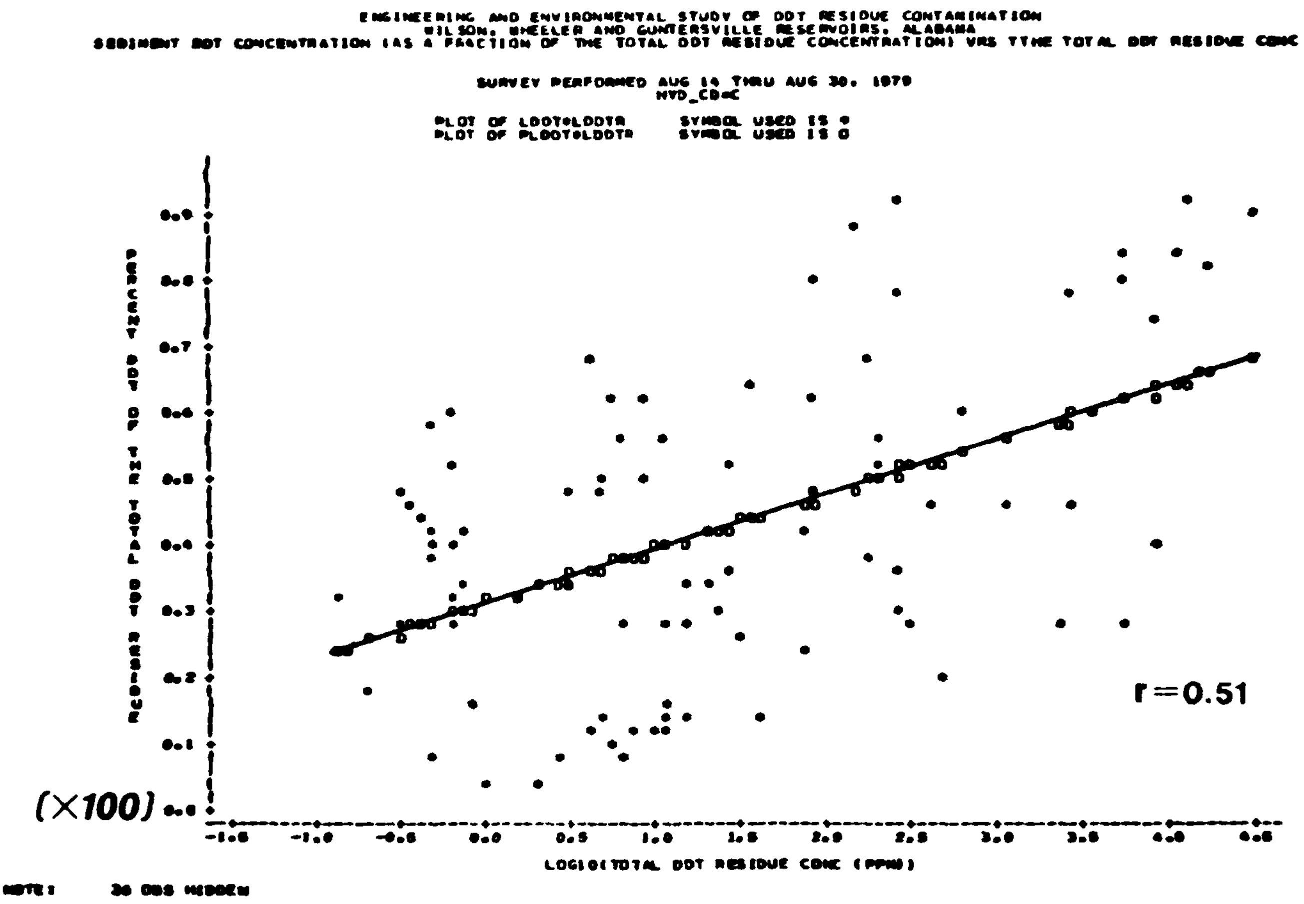

FIGURE II-18. Relative DDT Concentration as a Function of Total DDT Residue Concentration in the Channel Sediments of Indian Creek and Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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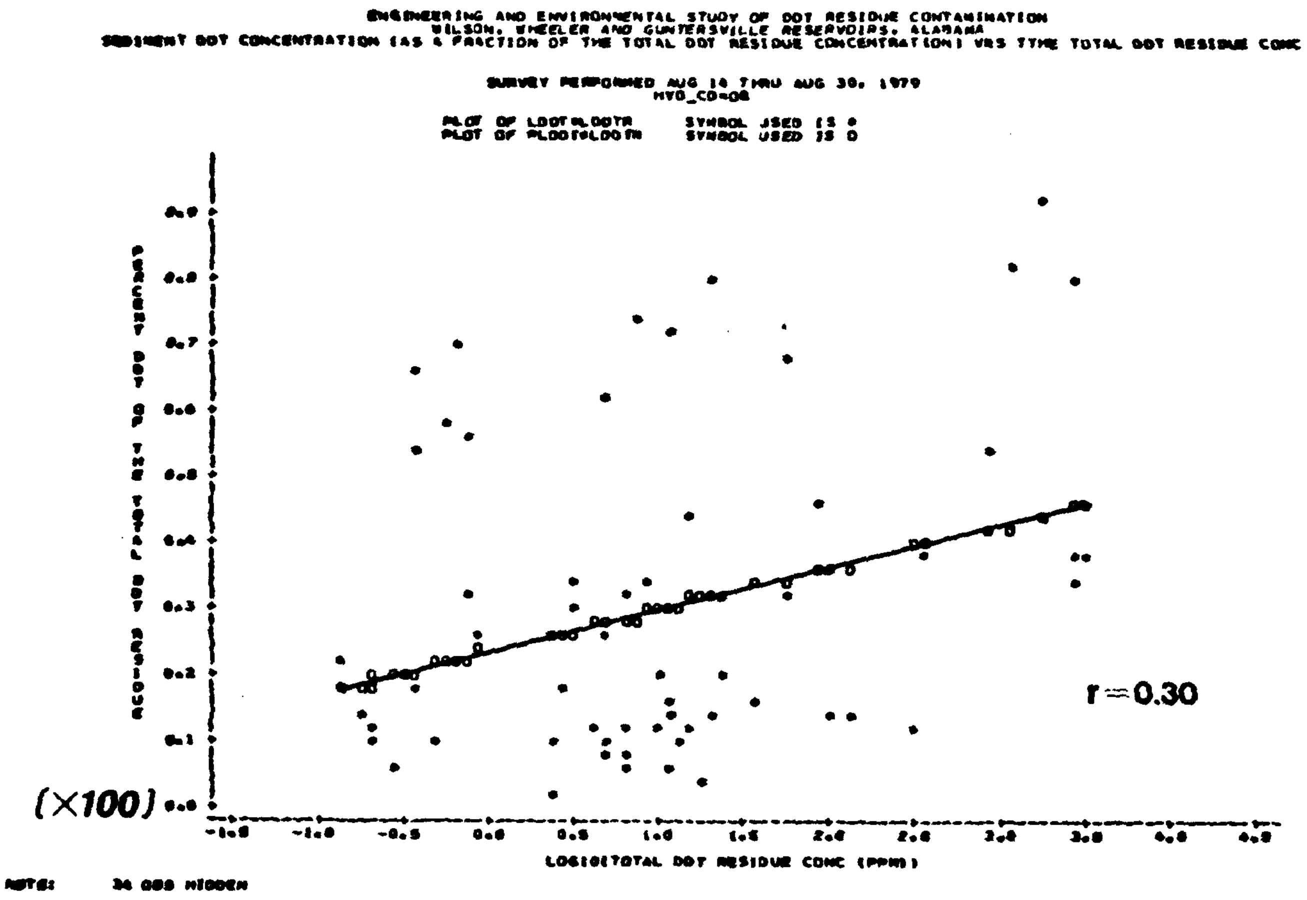

FIGURE II-19. Relative DDT Concentration as a Function of Total DDT Residue Concentration in the Overbank Sediments of Indian Creek and Huntsville Spring Branch

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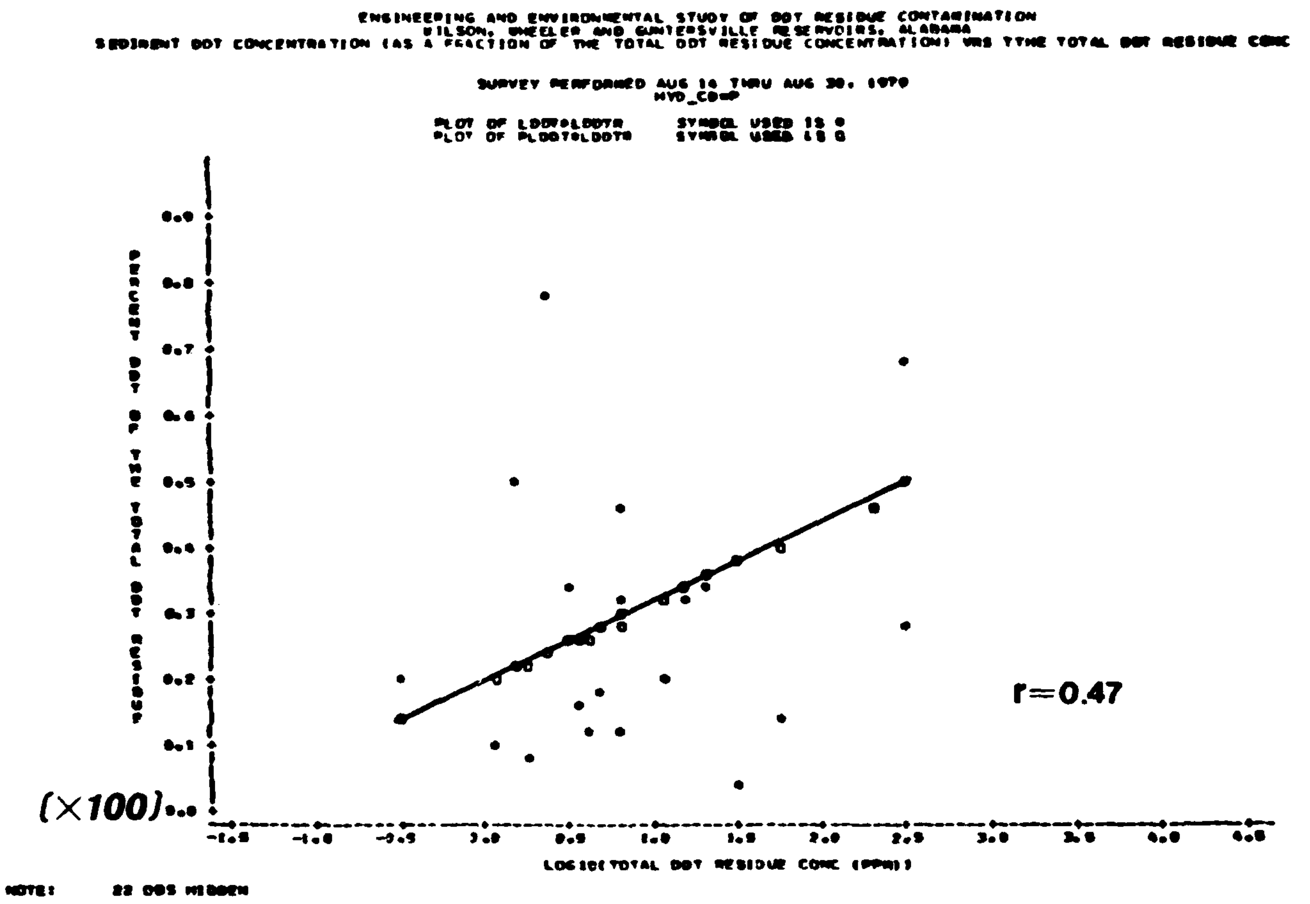

FIGURE II-20. Relative DDT Concentration as a Function of Total DDT Residue Concentration in the Ponded Area Sediments of Indian Creek and Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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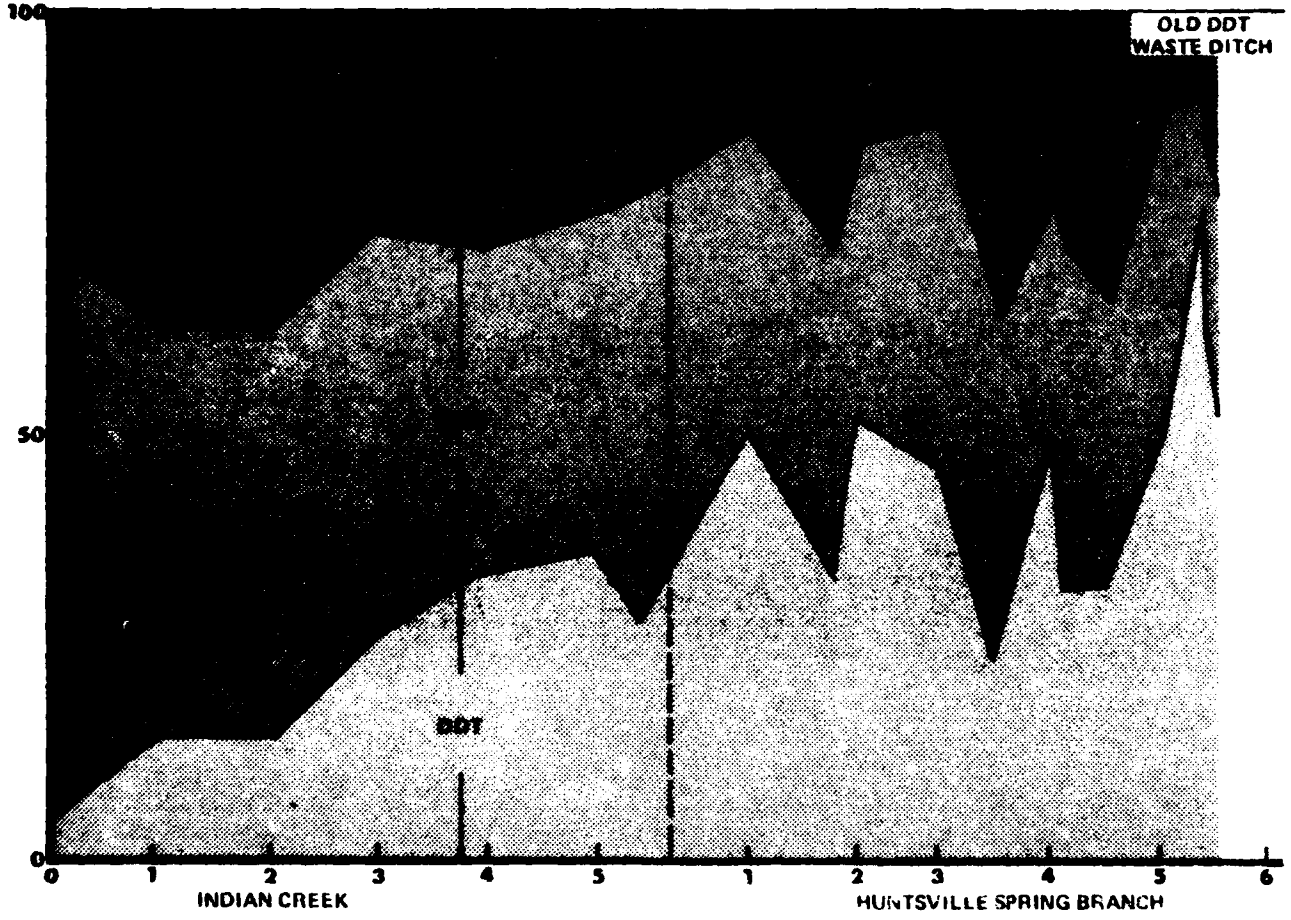

FIGURE II-21. Average Relative Metabolite Composition of the DDT Residue in the Surface 0-6" Sediments in Indian Creek and Huntsville Spring Branch

SOURCE. WATER AND AIR RESEARCH, INC., 1980

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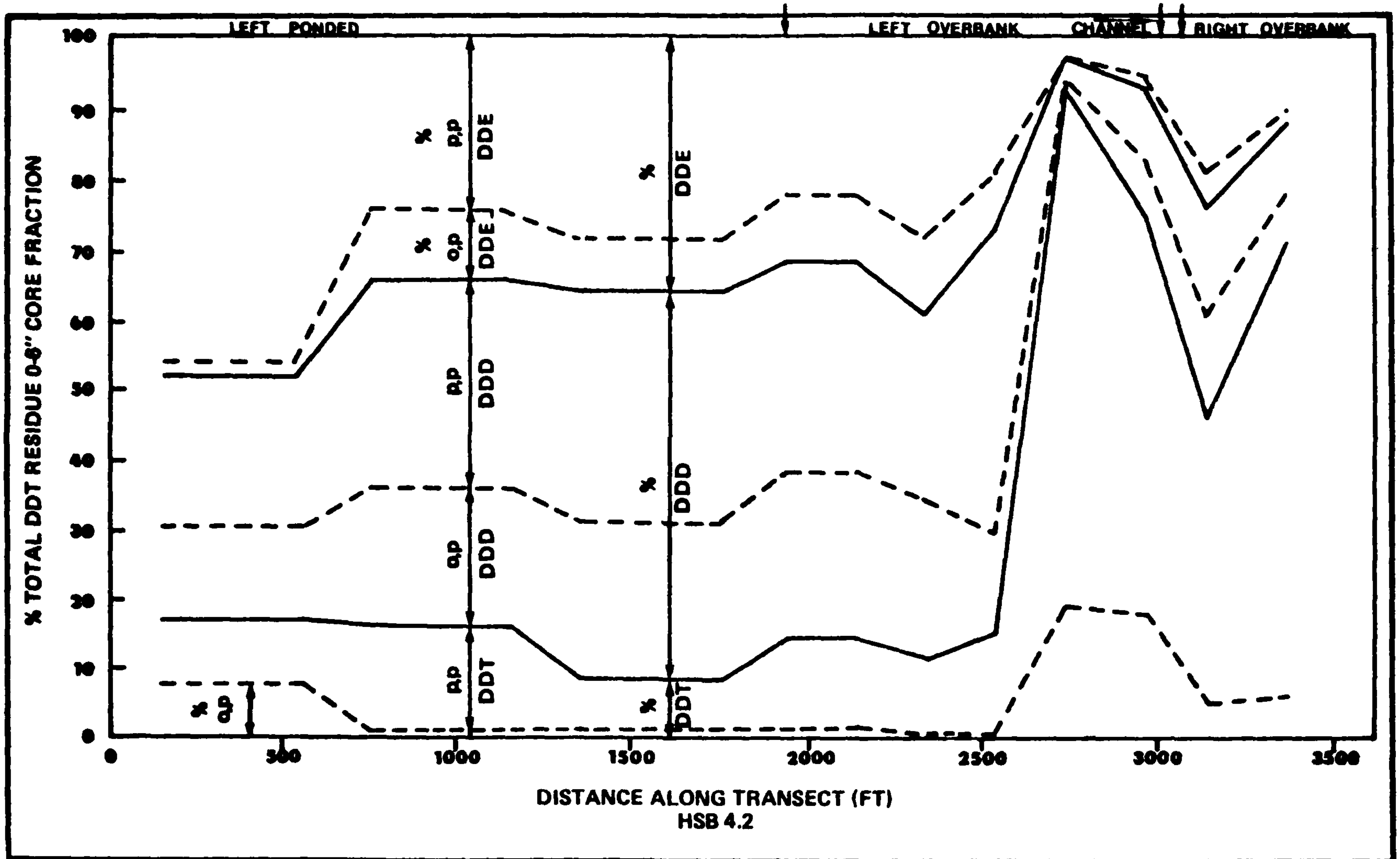

FIGURE 22. Relative Metabolite and Isomer Composition of the DDT Residue in the Surface 0-6" Sediments along the Sampling Transect at HSBM 4.2 (see Figure II-8)

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Table II-37. DDTR in Sediments in the Tennessee River and Major Tributaries

Location	Mile	Date Sampled	DDTR, ppm
Upstream of Indian Creek - Guntersville Reservoir			
Tennessee River	400	08/01/1979	--
Tennessee River	395	12/10/1979	--
Tennessee River	375	08/02/1979	<0.14
Tennessee River	375	12/10/1979	--
Tennessee River	350	08/01/1979	<0.14
Upstream of Indian Creek - Wheeler Reservoir			
Paint Rock River	3.9	08/01/1979	>0.02-<0.11
Paint Rock River	1.9	08/01/1979	<0.14
Flint River	2.5	08/01/1979	<0.14
Flint River	1.2	08/01/1979	<0.14
Tennessee River	345	08/01/1979	--
Tennessee River	343.9	12/06/1979	--
Tennessee River	340	08/01/1979	--
Tennessee River	335	08/01/1979	--
Tennessee River	333.6	12/06/1979	--
Tennessee River	331	12/06/1979	--
Tennessee River	330	08/01/1979	--
Tennessee River	326	12/04/1979	--
Tennessee River	325	08/01/1979	<0.14
Downstream of Indian Creek - Wheeler Reservoir			
Cotaco Creek	7.7	08/02/1979	<0.14
Cotaco Creek	3.8	08/02/1979	<0.14
Limestone Creek	3.0	08/02/1979	>0.03-<0.16
Limestone Creek	1.5	08/02/1979	>0.05-<0.16
Flint Creek	13.3	08/02/1979	**
Flint Creek	6.7	08/02/1979	<0.14
Spring Creek	2.0	07/30/1979	>0.17-<0.22
Spring Creek	1.0	07/30/1979	>0.03-<0.14
Elk River	15.0	08/02/1979	<0.14
Elk River	10.0	08/02/1979	<0.14
Elk River	5.0	08/02/1979	<0.14
Tennessee River	320.8	12/14/1979	<0.10
Tennessee River	315	07/31/1979	--
Tennessee River	314	12/04/1979	--
Tennessee River	310	07/31/1979	--
Tennessee River	309.7	12/06/1979	--

Table II-37. DDTR in Sediments in the Tennessee River and Major Tributaries (Continued, Page 2)

Location	Mile	Date Sampled	DDTR, ppm
Tennessee River	305.7	12/06/1979	--
Tennessee River	305	07/31/1979	--
Tennessee River	300	07/31/1979	>0.09-<0.18
Tennessee River	295	07/31/1979	>0.09-<0.18
Tennessee River	290	07/31/1979	>0.07-<0.16
Tennessee River	285	07/31/1979	>0.10-<0.19
Tennessee River	280	07/30/1979	>0.10-<0.19
Tennessee River	275	07/30/1979	>0.09-<0.18
Downstream of Indian Creek - Wilson Reservoir			
Tennessee River	270	07/30/1979	>0.08-<0.17
Tennessee River	265	07/30/1979	>0.08-<0.17
Tennessee River	260	08/03/1979	>0.05-<0.16

Notes:

1) "--" indicates insufficient fine grained sediment (i.e. passing a #4 sieve) retrieved for analysis.

2) "*" indicates site not sampled due to inaccessibility

3) All less than values assume individual less than isomer concentrations equal to stated value.

4) All greater than values assume individual less than isomer concentrations equal to zero.

found in three of the seven tributaries in amounts ranging from 0.02 to 0.17 ppm. Considering "less than" values, the maximum amounts that could have been present were 0.11 to 0.22 ppm. If no isomer was detected, the DDTR detection limit was generally reported as <0.14 ppm.

Samples were taken in the Tennessee River from Mile 260 in Wilson Reservoir to Mile 375 in Guntersville Reservoir. Detectable quantities of DDTR were found in all nine samples from TRM 260 to TRM 300. The average actually detected was 0.08 ppm with a range of 0.05 to 0.10 ppm. Considering "less than" values these levels could be as much as 0.18 (0.16-0.19) ppm.

No DDTR was detected in either of the two sediment samples taken in Guntersville Reservoir at TRM 350 and 375. Nor was DDTR detected in either of the samples taken at TRM 320.8 and 325 in Wheeler Reservoir upstream of the confluence with IC.

The DDTR was estimated for Wilson Reservoir, Wheeler Reservoir (TRM 275-300), Limestone Creek, Paint Rock River, and Spring Creek. No estimate was made for areas where no DDTR was detected. The amount of DDTR was calculated assuming a six inch depth of sediment, measured sediment densities, bottom area at high pool, i.e. elev. 556, and measured DDTR values. The results are as follows:

	Total DDTR, lbs	
Wilson Reservoir	>1,360	<3,230
Tennessee River 275-300	>4,200	<8,400
Paint Rock River	> 2.5	< 14
Limestone Creek	> 103	< 412
Spring Creek	> 162	< 292

3.2 DISTRIBUTION OF DDTR IN WATER

The quantity of DDTR suspended or dissolved in the water column at a given instant is a relatively minor fraction of the total quantity of DDTR in the IC-HSB-TR system. For example, based on the range of DDTR concentrations observed, in Wheeler Reservoir and its major tributaries during the course of this study, including IC and HSB, less than 1 ton of DDTR as DDT is likely to ever be in suspension at a given point in time. If the DDTR were uniformly distributed, nearly 0.3 tons would have to be in the water columns to reach analytical detection limits reported in this study.

Maximum DDTR concentrations observed during this study occurred at HSB at Dodd Road during storm event sampling on 1/18/80. A total DDTR concentration of 17.8μg/l as DDT was observed, of which over 80 percent was associated with suspended material >1μ. DDTR levels measured in the waters of the TR and tributaries were generally below or only slightly above analytical detection limits. This fact, coupled with the relatively small data base precludes more precise estimate of DDTR in the water column.

3.3 BIOTA

3.3.1 Plankton

The inclusion of inorganic particulates in both the phytoplankton and zooplankton samples made separation of these components impossible. Therefore, the amount of DDTR in suspended solids was used and the reader is referred to Section 3.2. for this information.

3.3.2 DDTR in Macroinvertebrates

The macroinvertebrate DDTR values are reported based on a unit weight of organism (μg DDTR/gm organism). The total weight of organisms in the sample is reported also but no indication is given of how much bottom area was sampled. Examination of the field notes shows that grabs at a single station varied from 1 to 9. This data has been used to estimate the amount of DDTR in the benthic community in the HSB-IC system and in Wheeler Reservoir. Because of the wide difference in DDTR concentrations, the areas have been divided and the DDTR in macroinvertebrates estimated separately for each area. The total DDTR in macroinvertebrates is calculated using the total area of the reach in question, the weight of macroinvertebrates in a sample, and the average DDTR concentration in the reach.

The results are as follows:

	lbs. DDTR
Huntsville Spring Branch	12.6
Indian Creek	1.3
Tennessee River Mile 275-340	.40
TOTAL	14.3

3.3.3 Vertebrates (Except Fish)

Samples were collected from various vertebrates in the study area. These were turtles, snakes, Green Herons and Wood Ducks. A separate report by the Patuxent Wildlife Research Center (O'Shea, 1980) documented levels in Mallard ducks, crows, and two species of rabbits. Other small mammals (shrews and muskrats) were also assessed for the DDTR level. There are no available population estimates for these species, so only relative amounts can be calculated. For the purpose of this section, the amount of DDTR in birds and mammals will be estimated with the following assumptions:

1) The level of DDTR employed in the calculation is based on the maximum mean value;

2) The biomass for birds is an estimate considered to be a conservative value; and

3) The overall estimate of DDTR in the vertebrate population is based on the area of Wheeler National Wildlife Refuge.

For migratory birds, approximately 50,000 ducks and 30,000 Canada geese utilize the Refuge during the winter period. Utilizing a 4 ppm DDTR level for Mallard ducks as the base residue amount (O'Shea, 1980); and an average weight of 5 pounds per bird then waterfowl populations of this size would contain 1.6 pounds of DDTR. If the assumption is made that all other bird species contain the 4 ppm DDTR, then per 100,000 individuals (1 pound average) the amount would be 0.4 pounds. The amount of DDTR in birds at a very conservative estimate is about 2 pounds.

In mammals, an estimate of 25 pounds of biomass per acre is considered appropriate (Marion, 1980). The Wheeler Wildlife Refuge contains 37,648 acres. Analysis by TVA shows that shrews contained the highest level (52 ppm) in the Huntsville Spring Branch area. Using this concentration at 10 percent of the per acre biomass and 90 percent at 1 ppm, then the amount of DDTR in Wheeler Refuge incorporated in the mammal population is 6 pounds. This amount is considered a high estimate and in actuality the level is probably lower.

3.3.4 DDTR in Fish

Because of the many variables involved it is not possible to obtain a precise value for the total amount of DDTR in Fish in Wheeler Reservoir. The average standing crop of fish has been estimated from 56 samples taken from 1949 to 1979 by TVA to be 504 pounds per acre. This number has ranged over the years and by location in the reservoir from 118 to 1180 pounds per acre. Also, the average DDTR value for all fish species is not known since only 3 or 4 species have been tested to any extent. Nevertheless, if the assumption is made that the standing crop throughout Wheeler Reservoir is 504 pounds per acre and that the average DDTR concentration across all species is 1 ppm, the total amount of DDTR in fish in Wheeler Reservoir (including tributaries) would be 34 lbs. If the average DDTR concentration was assumed to be 10 ppm, a figure that should be an upper limit, the total amount of DDTR in fish would be 340 pounds.

3.4 OVERALL DISTRIBUTION OF DDTR

The overall distribution of DDTR in the study area is as follows:

Substrate	Location	Tons of DDTR	Percent of Total
Sediments	IC and HSB	837	99.4
Sediments	TRM 275-300	2.1-4.2	0.25-0.50
Sediments	Wilson Res.	0.68-1.6	0.08-0.19
Sediments	Other TR Tribs.	0.13-0.36	0.015-0.043
Water	Wheeler Res.	<0.3-1	<0.036-0.12
Fish	Wheeler Res.	0.017-0.17	0.002-0.020
Macroinvertebrates	Wheeler Res.	0.007	<0.001
Mammals	Wheeler Refuge	0.003	<0.001
Birds	Wheeler Refuge	0.001	<0.001
TOTAL		840-844	100

4.0 ENVIRONMENTAL TRANSPORT OF DDTR

4.1 PHYSICAL TRANSPORT OF DDTR

4.1.1 Introduction

Fluvial transport appears to be the major process dispersing the DDTR contamination occurring in the sediments of HSB and IC through the biosphere. DDTR is currently being transported out of the IC-HSB drainage basin at a rate of 0.31 to 1.3 tons per year, or 0.04 to 0.2 percent per year of the total quantity contained within the sediments of the IC-HSB system.

4.1.2 Methodology

In the course of this study a considerable data base relating to the transport of DDTR within and out of the IC-HSB drainage basin has been generated by TVA. An extensive network of hydrologic and water quality monitoring stations was established upstream and downstream of the area of highest DDTR contamination and an intensive field sampling program was carried out from August, 1979 through April, 1980. The locations of the rain gauge, stream gauging stations, water quality sampling stations and bedload sampling stations used in the course of this study are shown in Figure II-23.

All rain gauge and stage records were supplied by TVA for the period of record. Streamflow data was obtained from field notes also supplied by TVA. Suspended solids data for size fractions passing a 1u (nom.) glass fiber and retained on a 0.45u membrane filter; passing a 63u sieve and retained on a 1u (nom.) glass fiber filter; and retained on a 63u sieve, were supplied by TVA. Volatile suspended solids data for fractions passing a 63u sieve and retained on a glass fiber filter; and retained on a 63u sieve were also supplied by TVA. DDT residue data for fractions passing a 1u (nom.) glass fiber filter (i.e.,"dissolved/suspended") and retained on a 1u (nom.) glass giver filter and passing a 63u sieve (i.e, "suspended") were also supplied by TVA.

A screening procedure was developed to determine the primary factors affecting the transport of DDTR within and out of the IC-HSB drainage system. This procedure utilized the CORR (Correlation Matrix), STEPWISE (Stepwise Regression) and GLM (General Linear Model) procedures of SAS (Statistical Analysis System) (SAS, 1979). The first step involved the identification of those factors directly or indirectly affecting the fluvial transport of DDTR. Those factors identified, and quantified to the extent possible, included:

sampling location
discharge
mean cross sectional velocity
season

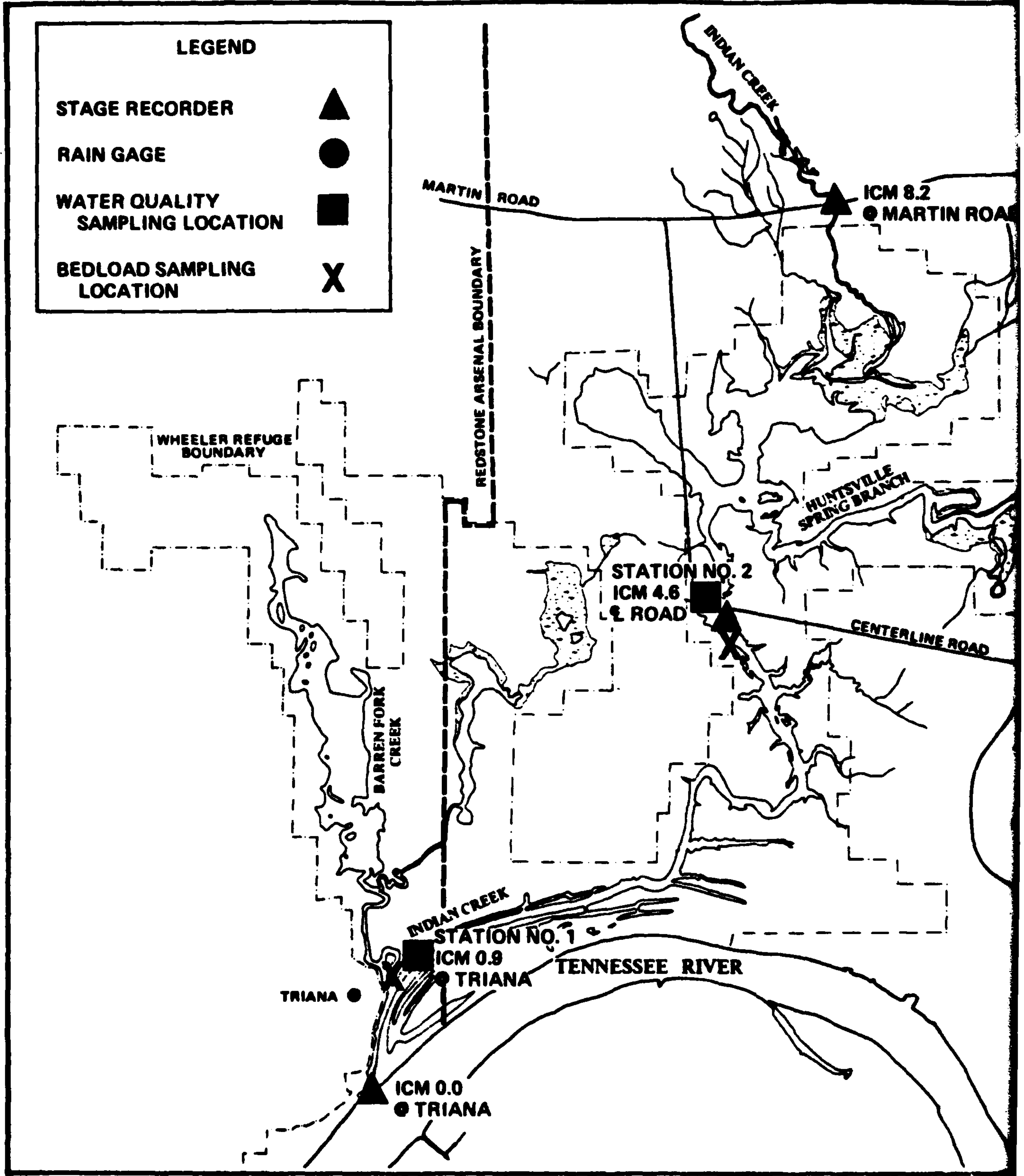
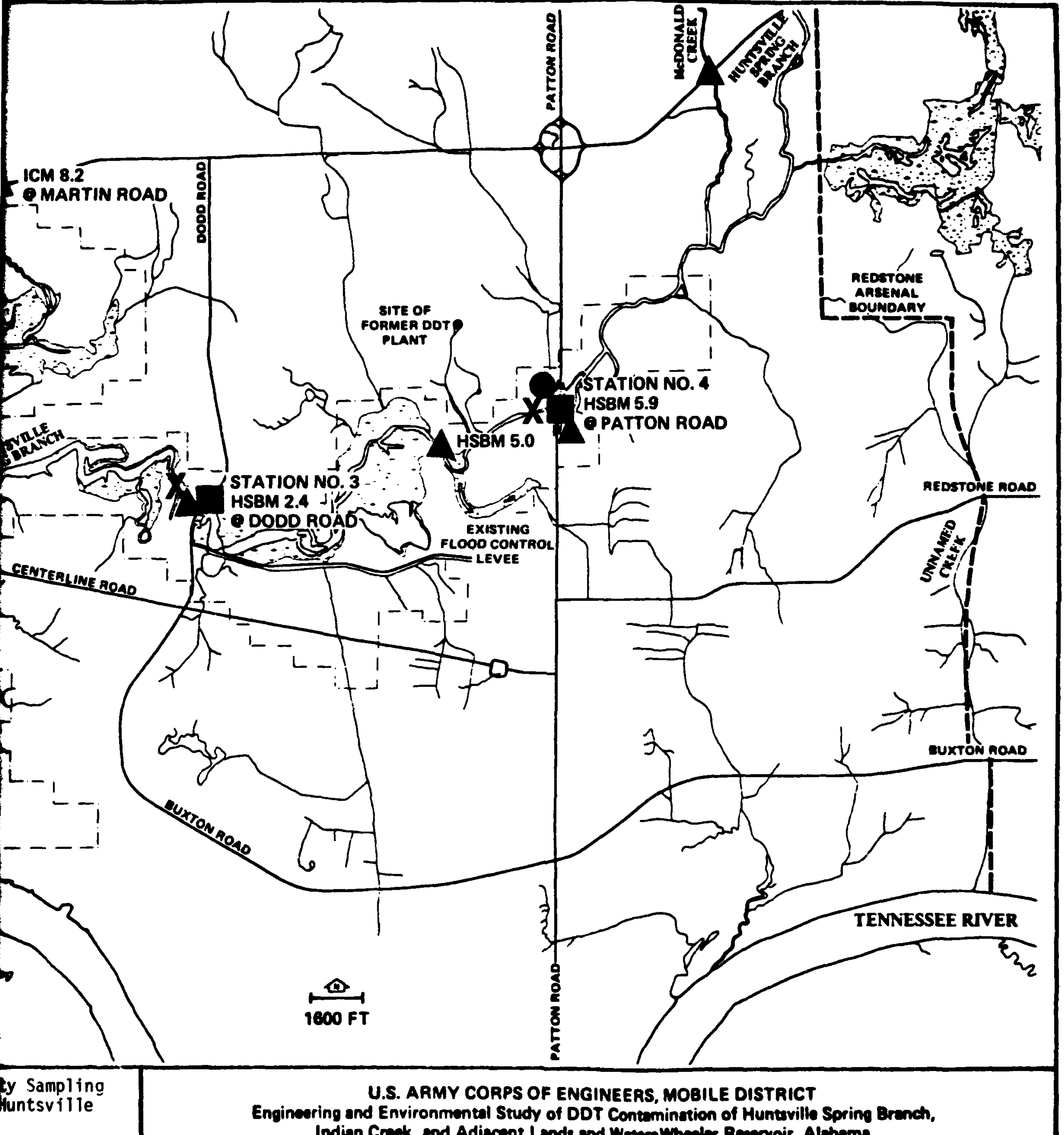


FIGURE II-23. Locations of Rain Gage, Stream Gaging Stations, Water Quality Sampling Stations and Bedload Sampling Stations in Indian Creek and Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980



ty Sampling
Huntsville

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2

relative position in the runoff hydrograph (i.e.,rising or falling)
event related parameters, including the sampled event,
  the type of event (i.e, headwater flood or tailwater flood), and
  event anticedent conditions (stage, streamflow and rainfall related)
suspended solids load, and
volatile suspended solids load.

Each of the individual metabolites, DDT, DDD and DDE as well as the total DDTR load were treated as dependent parameters. A separate line of model development was followed for both the "suspended" and "dissolved/suspended" DDTR components. All less than individual isomer concentrations, as well as missing values, were assumed equal to zero. For ease of metabolite and between location comparisons, all metabolites as well as total DDTR were converted to equivalent weight as DDT. All DDTR concentrations were converted to loading rates and the logrithmic transformation employed in subsequent analyses.

The sampling location was heated as a class type variable so that the observations from each of the sampling locations could be pooled in the model building process, thus reducing somewhat the impact of site specific sampling protocal errors.

Discharge data was obtained directly from field notes. All reverse flows (i.e., streamflow in an upstream direction), as well as streamflow data which was deemed to be biased low because a significant overbank flow component had been neglected, were treated as missing values in the subsequent analysis of the data. A correction was applied to measured streamflow data utilizing a second order curvilinear interpolation procedure in order to account for unsteady streamflow conditions and the time lag between discharge measurement and water quality sampling. The logrithmic transformation of the corrected discharge was employed in subsequent analyses.

Mean cross-sectional velocity at the sampled cross section at the time of DDTR water quality sampling was calculated from the corrected streamflow data and a stage-cross sectional area relationship derived for each sampled cross section. The logrithmic transformation of velocity was employed in all subsequent analyses.

Sampling was carried out during both summer (May-Oct) and winter (Nov-April) seasons, the seasons being defined on the basis of Wheeler Reservoir operations. However, problems encounter during the summer sampling program precluded the utilization of this date in subsequent analyses or the determination of its significance as a factor affecting DDTR transport. All estimates of summer season DDTR transport, therefore, are based on winter season sampling results.

Based on the evaluation of the streamflow data, the relative hydrographic position at which an observation was made was classified as either rising, falling or base flow. However, no base flow measurements were obtained during this study.

Streamflow event related parameters identified in this study included the event sampled, type of event and event anticedent conditions. The event sampled was treated as a class type variable to determine if a significant component of the error could be accounted for simply by event-event sampling protocol. Runoff events were classified as either headwater or tailwater based on whether or not a significant component of the downstream streamflow was contributed by flow original outside of the IC-HSB drainage basin. The criteria employed in this classification was whether or not the stage in the TR at Whitesbuge equalled or exceed in the elevation of the saddle of the sill separately the HSB drainage basin from the Unnamed Creek basin, i.e., elevation 564. Event anticedent conditions based on inter-event baseflow periods, inter-event low stage periods as well as inter-event rainfall periods were examined.

Suspended solids data was obtained for each of three separate size classes; material retained on a 63u sieve representing sands, detritus, etc., material retained on a 1u (nom.) glass fiber filter and passing a 63u sieve representing silts and medium and coarse clays; and material retained on a 0.45u membrane filter and passing a 1u (nom.) glass fiber filter representing primarily fine clays. Meaningful partial sums as well as total suspended solids were determined. All less than concentrations were taken as equal to half the stated value. All suspended solid concentrations were converted to loading rates and the logirithmic transformation employed in subsequent analyses.

Volatile suspended solids data was obtained for each of two separate size classes: material retained on a 63u sieve and material passing a 63u sieve and retained on a 1u (nom.) glass fiber filter. Volatile suspended solids ws treated in a maneer analogous to suspended solids data.

The general, ranked correlation coefficient matrix of Pearson Correlation coefficients was employed to determine which of the competing, redundant predictive parameters were most closely correlated to DDTR transport. Of all the suspended solids and volatile suspended solids fractions suspended (as well as dissolved/suspended) DDTR transport was most closely correlated to the corresponding suspended and volatile suspended solids transport (i.e., that portion ≥1u and <63u). Thus, only the suspended and volatile suspended solids fractions in the size range >1u and <63u were employed in subsequent regression modelling. Similarly, the type of event (i.e. headwater or tailwater) as well as rainfall-related anticedent event parameters were the only event related parameters utilized.

The STEPWISE procedure of SAS was employed to determine the most significant main effect and interaction terms to be employed in the subsequent regression models. Finally, the GLM procedure was utilized to develop the final somewhat simplified empirical model used in subsequent data analysis.

Suspended and volatile suspended solids loading-streamflow relationships were developed utilizing multiple regression techniques and the GLM procedure of SAS. Separate regression models were developed for each size fraction as well as for meaningful partial and total sums. Sampling location was treated as a class type variable in a manner analogous to that employed in modeling DDTR transport.

An attempt was made to measure bedload DDTR and solids transport at selected locations in IC and HSB. However, as this component of both the total DDTR load as well as the toal suspended solids load was determined to be negligible, bedload sampling was discontinued during the winter season sampling period.

4.1.3 Discussion

A summary of the seasonal streamflow duration relationships developed by TVA are shown in Table II-38 and illustrated in Figures II-24 through II-28. These relationships were developed neglecting reverse flows. Seasonal stage duration relationships at Whitesburg, TRM 333.3 for the period of record 1/1950 through 12/1979 are illustrated in Figure II-29. A summary of "suspended" DDTR loading rate regression models for the DDT, DDD and DDE metabolites as well as Total DDTR loading rates is shown in Table II-39. The corresponding regression models for the "dissolved/suspended" DDTR loading rates are summarized in Table II-40. The regression models for the suspended solids and volatile suspended solids loading rates are summarized in Table II-41.

Predicted seasonal and annual suspended and volatile suspended solids loads at each of the sampling locations are summarized in Tables II-42 and II-43, in seasonal and relative terms, respectively. Also included in these summary tables are the 95 percent confidence limits about the predicted mean values. Based on these figures total suspended sediment yield from the HSB drainage basin is not significantly different from that of the IC drainage basin, i.e., 29-64 and 39-70 tons/sq.mi/yr, respectively. Suspended sediment yield from the IC/HSB drainage basin during winter (November-April) is over four times greater than during the summer (May-October). Silts and medium and coarse clays comprise over 92 percent of the total annual sediment load at the mouth of IC, fine clays comprise approximately 6 percent and sands the remaining 2 percent. The silt and medium and coarse clay component of the annual sediment load at Patton Road on HSB upstream of the highest DDTR contamination is about 88 percent, fine clays comprising less than 2 percent and sands over 10 percent of the total. In general, fine clay component of the total suspended sediment load, although relatively minor, increases in the downstream direction whereas the coarser component of the suspended sediment load decreases.

As indicated in Table II-39 the suspended DDTR transport rate in the IC-HSB system is predicted reasonably well, r=0.90, by considering sampling location, discharge, the type of runoff event (i.e., headwater or tailwater) and the transport rate of the corresponding suspended solids size fraction (i.e., <63u and>1u). Predicted seasonal and annual suspended DDTR transport rates through and out of the IC-HSB drainage system are summarized in Table II-44, and illustrated in Figures II-30 through II-32. These predictions are based upon the empirically derived

Table II-38. Summary of Flow Duration Computations

Percent of Time Equalled or Exceeded	ICM 8 Madison, AL DA = 49 mi^2		Station 4 HSBM 5.9 DA = 72.9 mi^2		Station 3 HSBM 2.4 DA = 83.9 mi^2		Station 2 ICM 4.6 DA = 153 mi^2		Station 1 ICM 0.9 DA = 157 mi^2	
	Summer (cfs)	Winter (cfs)	Summer (cfs)	Winter (cfs)	Summer (cfs)	Winter (cfs)	Summer (cfs)	Winter (cfs)	Summer (cfs)	Winter (cfs)
1	430	1200	1320	3630	1380	2720	1990	3990	2020	4090
3	175	600	433	1400	541	1350	788	2320	802	2370
5	110	400	254	831	304	921	459	1570	468	1600
10	65	240	137	416	153	559	245	897	250	917
20	42	150	89	237	97	377	156	589	159	601
30	33	120	80	201	87	275	134	444	137	454
40	27	90	69	151	74	169	112	296	114	303
50	22	70	61	120	65	133	96	232	98	238
60	19	53	56	98	59	108	86	183	88	187
70	17	40	53	81	56	88	80	144	81	147
80	15	25	50	63	53	67	74	102	75	104
90	13	18	49	55	51	58	69	83	70	84
100	6	6	41	41	42	42	50	50	50	51
Seasonal Avg.	32.7	101	88.6	206	96.8	232	143	375	145	383
Annual Avg.	67		148		164		259		264	
Total Runoff[1]	18.5		27.4		26.6		22.0		22.9	
STP	--		6.14		5.34		2.93		2.85	
Net Runoff	18.5		21.3		21.3		20.0		20.0	

NOTES:

(1) {(SQ+WQ)/2}*365*.0372÷DA

(2) STP = 33x365x.0372÷DA

(3) STP-Study of Huntsville Sewage Treatment Plant No. 1 Discharge (inches/yr)
DA-Drainage Area (mi^2)
SQ-Average Summer Discharge (cfs)
SW-Average Winter Discharge (cfs)

(4) Runoff and STP in inches/yr

5) Summer: May-October

6) Winter: November-April

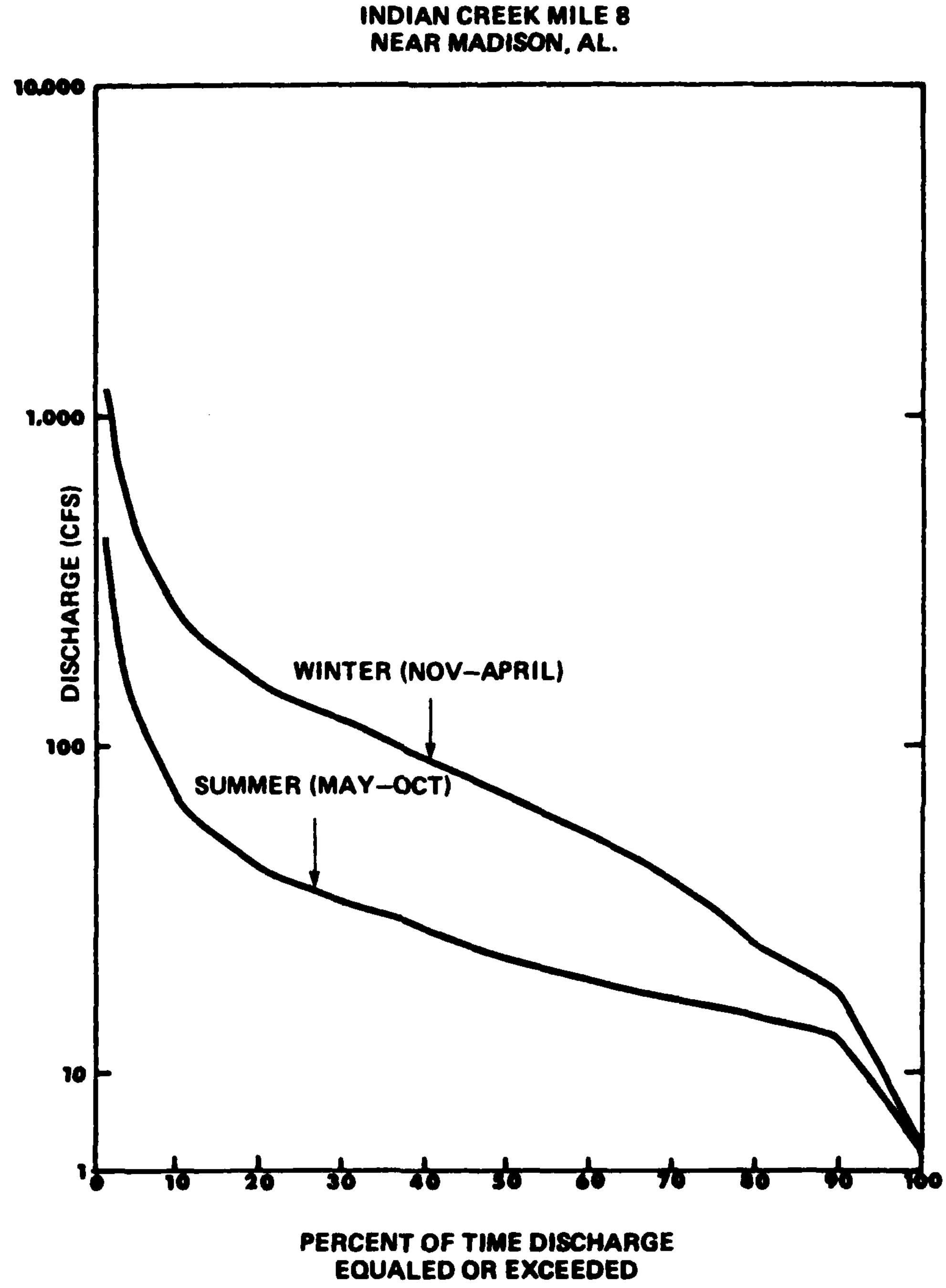

FIGURE II-24. Seasonal Flow-Duration Relationship at IC Mile 8 Madison, Alabama

SOURCE: TVA, 1980

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HUNTSVILLE SPRING BRANCH MILE 5.9

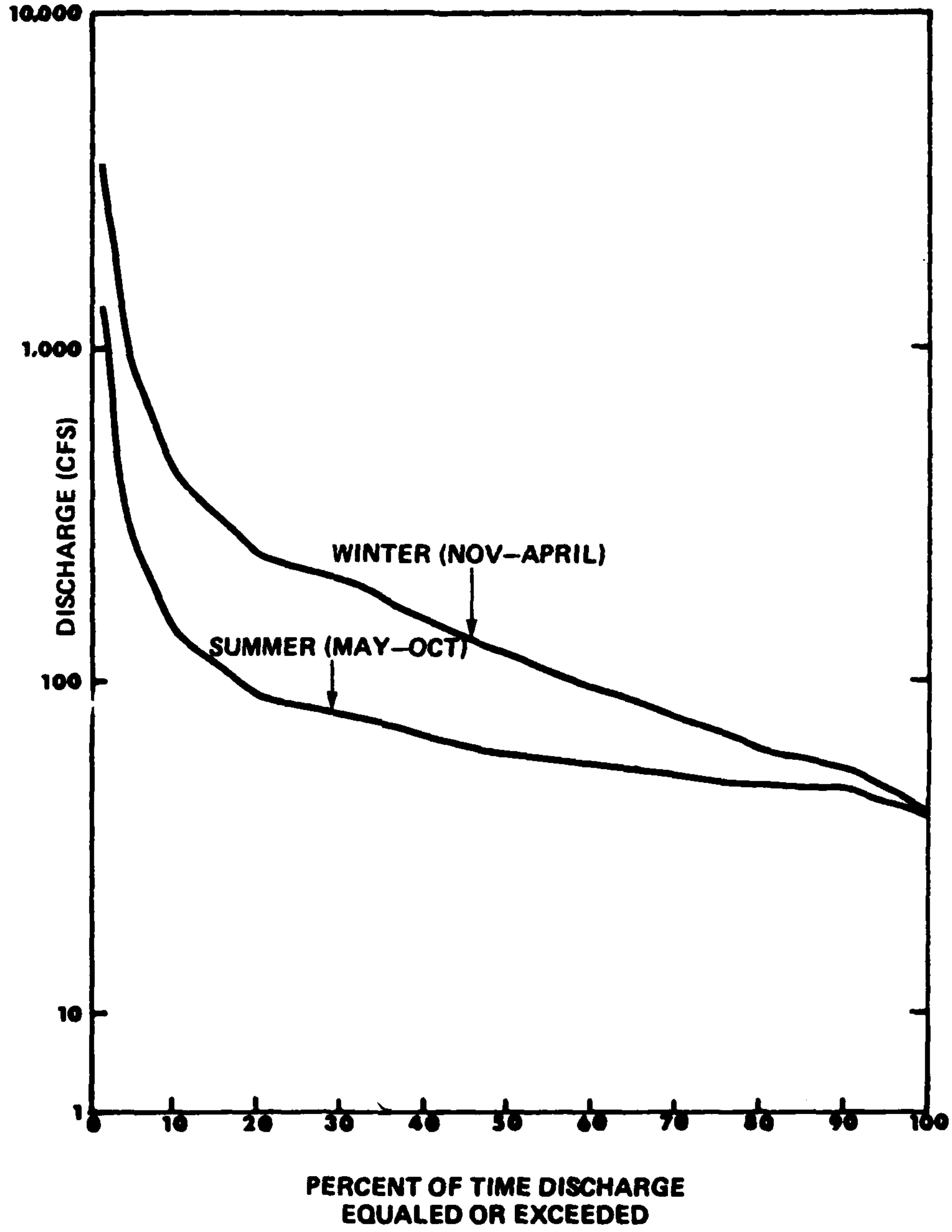

FIGURE II-25. Estimated Seasonal Flow-Duration Relationship at HSBM 5.9, Patton Road SOURCE: TVA, 1980	**U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT** **Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama**

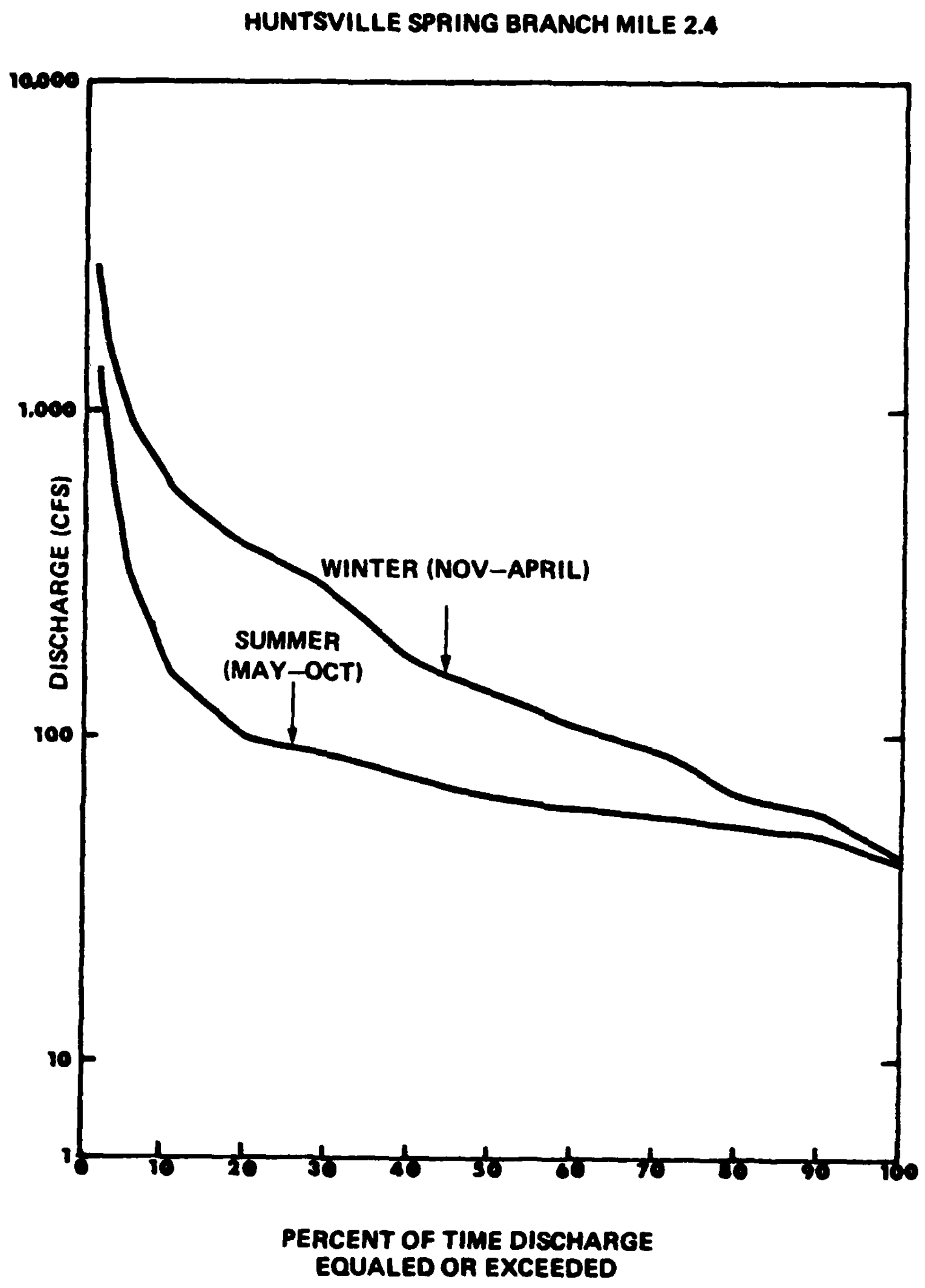

FIGURE II-26. Estimated Seasonal Flow-Duration Relationship at HSBM 2.4, Dodd Road

SOURCE: TVA, 1980

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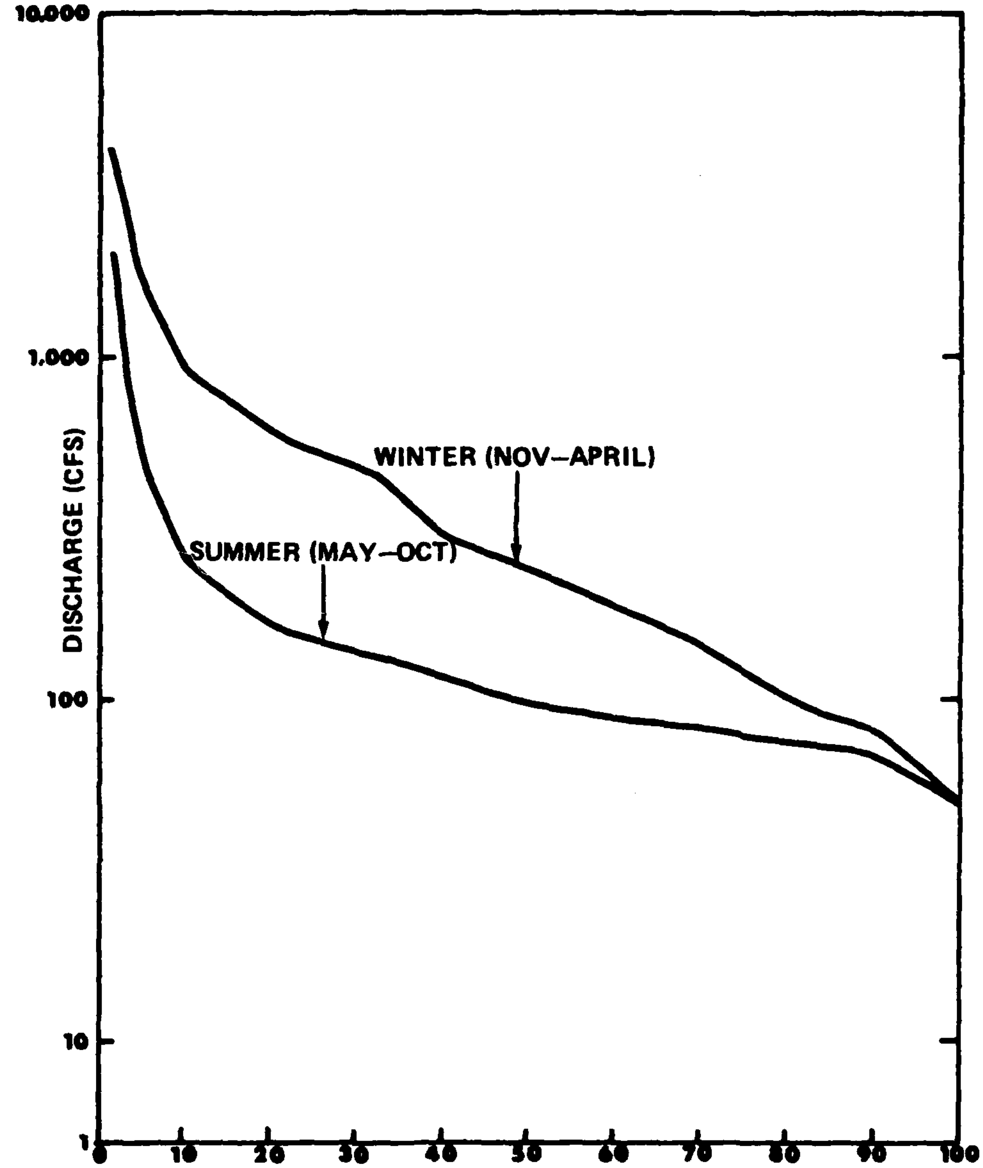
INDIAN CREEK MILE 4.6



PERCENT OF TIME DISCHARGE
EQUALED OR EXCEEDED

FIGURE II-27. Estimated Seasonal Flow-Duration Relationship at ICM 4.6, Centerline Road

SOURCE: TVA, 1980

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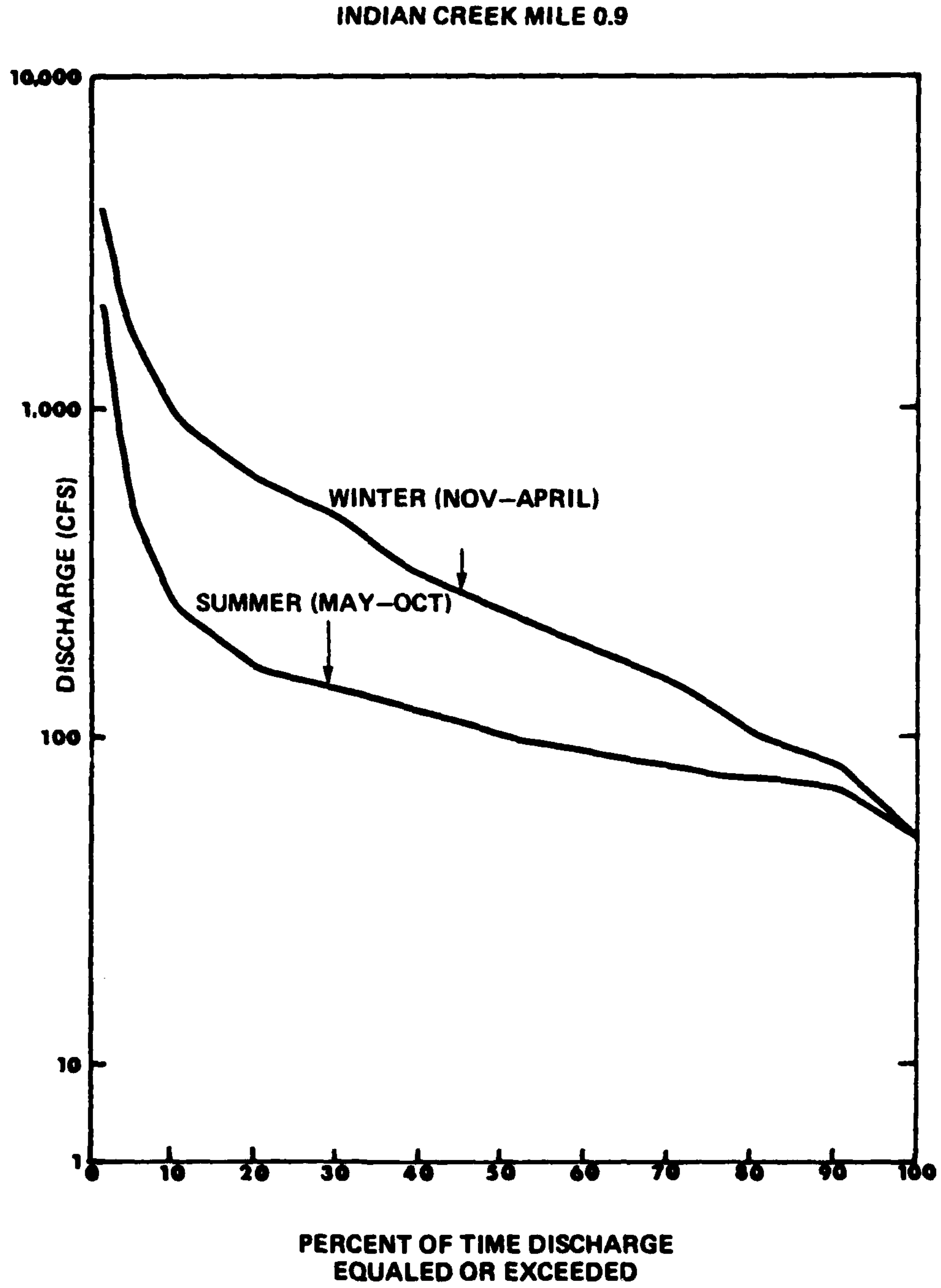

FIGURE II-28. Estimated Seasonal Flow-Duration Relationship at ICM 0.9, Triana, Alabama

SOURCE: TVA, 1980

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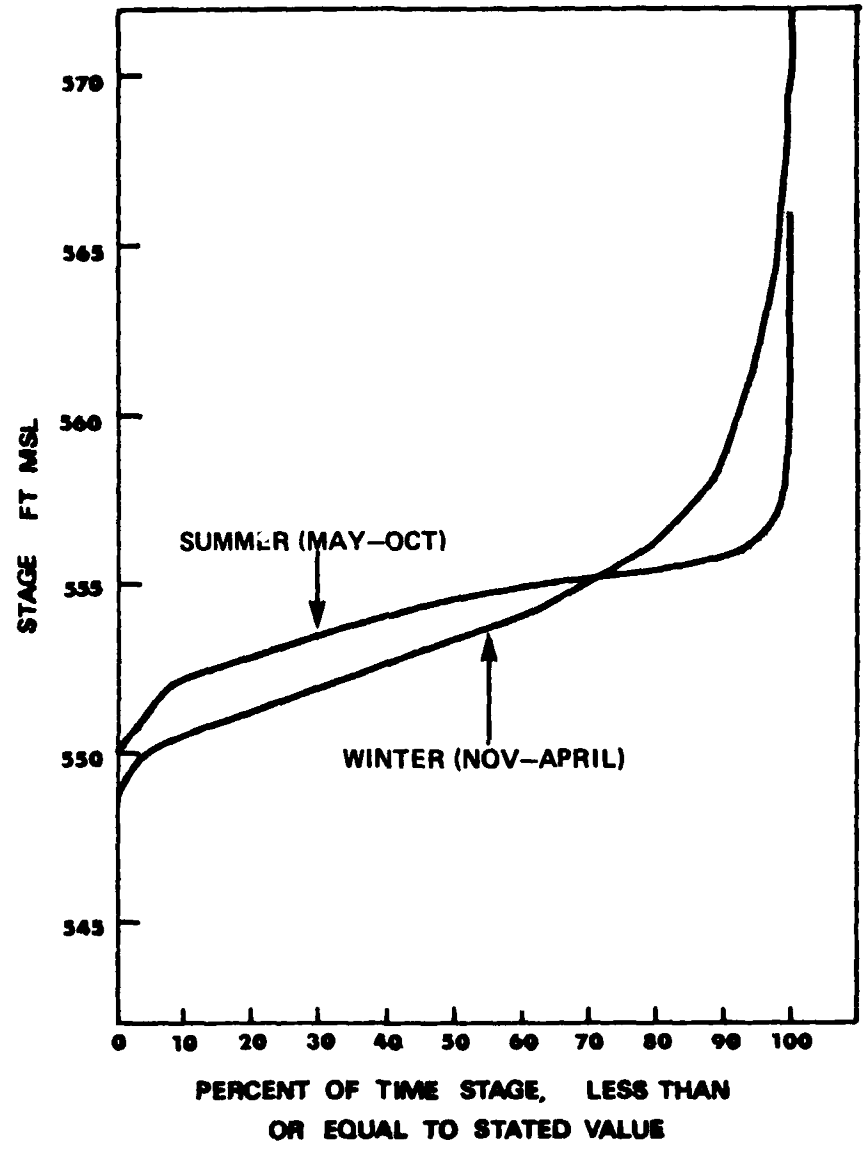

FIGURE II-29. Seasonal Stage-Duration Relationship at TRM 333 Whitesburg, Alabama

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Table II-39. Summary of Winter Season Suspended (i.e. Passing a 63μ Sieve and Retained on a ∿1μ Glass Fiber Filter) DDTR Loading Multiple Regression Analysis at Sampling Locations in Indian Creek and Huntsville Spring Branch^1

Dependent Variable	n	r^2	Mean Sqr. Error	Independent Variables	$\hat{\beta}$	Standard Error $\hat{\beta}$
DDTR Load	86	0.809	0.0741	Intercept^2	-0.337	0.579
				Discharge	-1.31	0.260
				Sus. Solids Load	1.53	0.155
				Flood Type:		
				Headwater	0.268	0.105
				Tailwater	0	--
				Sampling Loc. #1	1.50	0.156
				Sampling Loc. #2	1.74	0.152
				Sampling Loc. #3	1.84	0.148
				Sampling Loc. #4	0	--
DDT Load	80	0.748	0.123	Intercept^2	0.107	0.753
				Discharge	-1.11	0.346
				Sus. Solids Load	1.70	0.206
				Flood Type:		
				Headwater	0.190	0.140
				Tailwater	0	--
				Sampling Loc. #1	-0.473	0.103
				Sampling Loc. #2^2	-0.148	0.0928
				Sampling Loc. #3	0	--
				Sampling Loc. #4	--	--

Table II-39. Summary of Winter Season Suspended (i.e. Passing a 63μ Sieve and Retained on a ~1μ Glass Fiber Filter) DDTR Loading Multiple Regression Analysis at Sampling Locations in Indian Creek and Huntsville Spring Branch (Continued, Page 2)[1]

Dependent Variable	n	r^2	Mean Sqr. Error	Independent Variables	$\hat{\beta}$	Standard Error $\hat{\beta}$
DDD Load	85	0.776	0.0713	Intercept[2]	-0.154	0.569
				Discharge	-1.39	0.258
				Sus. Solids Load	1.49	0.154
				Flood Type:		
				Headwater	0.265	0.103
				Tailwater	0	--
				Sampling Loc. #1	1.35	0.174
				Sampling Loc. #2	1.56	0.171
				Sampling Loc. #3	1.65	0.167
				Sampling Loc. #4	0	--
DDE Load	86	0.802	0.0529	Intercept[2]	-0.764	0.489
				Discharge	-1.12	0.220
				Sus. Solids Load	1.34	0.131
				Flood Type:		
				Headwater	0.253	0.0886
				Tailwater	0	--
				Sampling Loc. #1	1.41	0.132
				Sampling Loc. #2	1.32	0.128
				Sampling Loc. #3	1.34	0.125
				Sampling Loc. #4	0	--

Table II-39. Summary of Winter Season Suspended (i.e. Passing a 63μ Sieve and Retained on a ~1μ Glass Fiber Filter) DDTR Loading Multiple Regression Analysis at Sampling Locations in Indian Creek and Huntsville Spring Branch[1] (Continued, Page 3)

Notes:

1) All regression models of the form:

$$\log y = \alpha + \beta_1 \log x_1 + \beta_2 \log x_2 + \beta_{3,\mathrm{FLOOD}} + \beta_{4,\mathrm{STA}}$$

where: y = DDT residue load passing a 63μ sieve and retained on a 1μ (nom.) glass fiber filter, (lb/day as DDT or as metabolite)
x_1 = Stream discharge (cfs)
x_2 = Suspended solids load passing a 63μ sieve and retained on a 1μ (nom.) glass fiber filter, (tons/day)
$\beta_{3,\mathrm{FLOOD}}$ = Constant dependent upon type of hydrologic event (i.e. class variable)
$\beta_{4,\mathrm{STA}}$ = Constant dependent upon sampling location (i.e. class variable)

Sampling Location #1 = Indian Creek, Mile 0.9 at Triana, AL
Sampling Location #2 = Indian Creek, Mile 4.6 at Centerline Road
Sampling Location #3 = Huntsville Spring Branch, Mile 2.4 at Dodd Road
Sampling Location #4 = Huntsville Spring Branch, Mile 5.9 at Patton Road

2) $p > 0.05$ for H_0: $\{\alpha \text{ or } \beta = 0\}$.

3) "-" indicates insufficient data for analysis.

4) All less than or missing individual DDTR isomer concentration values assumed equal to 0.

Table II-40. Summary of Winter Season Dissolved ($\lesssim$ 1μ) DDTR Loading Multiple Regression Analysis at Sampling Locations in Indian Creek and Huntsville Spring Branch^1

Dependent Variable	n	r^2	Mean Sqr. Error	Independent Variables	$\hat{\beta}$	Standard Error $\hat{\beta}$
DDTR Load	107	0.866	0.0716	Intercept^2	-0.317	0.424
				Discharge	-0.344	0.158
				Vol. Sus. Solids	0.572	0.0692
				Sampling Loc. #1	1.31	0.0823
				Sampling Loc. #2	1.57	0.0764
				Sampling Loc. #3	0.38	0.0704
				Sampling Loc. #4	0	--
DDT Load	59	0.457	0.119	Intercept^2	-1.50	0.793
				Discharge^2	-0.171	0.298
				Vol. Sus. Solids	0.627	0.135
				Sampling Loc. #1^2	0.669	0.368
				Sampling Loc. #2	0.956	0.366
				Sampling Loc. #3	0.802	0.360
				Sampling Loc. #4	0	--
DDD Load	107	0.856	0.0702	Intercept^2	-0.268	0.420
				Discharge	-0.363	0.156
				Vol. Sus. Solids	0.562	0.0684
				Sampling Loc. #1	1.24	0.0815
				Sampling Loc. #2	1.48	0.0757
				Sampling Loc. #3	1.31	0.0697
				Sampling Loc. #4	0	--
DDE Load	86	0.826	0.0371	Intercept	-1.96	0.325
				Discharge^2	0.0308	0.121
				Vol. Sus. Solids	0.581	0.0561
				Sampling Loc. #1	1.04	0.119
				Sampling Loc. #2	1.21	0.119
				Sampling Loc. #3	1.04	0.117
				Sampling Loc. #4	0	--

Table II-40. Summary of Winter Season Dissolved ($\lesssim 1\mu$) DDTR Loading Multiple Regression Analysis at Sampling Locations in Indian Creek and Huntsville Spring Branch[1] (Continued, Page 2)

Notes:

1) All multiple regression models of the form:

$$\log y = \alpha + \beta_1 \log x_1 + \beta_2 \log x_2 + \beta_{3,STA}$$

where: y = DDT residue load passing a 1μ (nom.) glass fiber filter (lb/day as DDT)
x_1 = Stream discharge (cfs)
x_2 = Volatile suspended solids load passing a 63μ sieve and retained on a 1μ (nom.) glass fiber filter (tons/day)
$\beta_{3,STA}$ = Constant, dependent upon sampling location (i.e. class variable)

Sampling Location #1 = Indian Creek, Mile 0.9 at Triana, AL
Sampling Location #2 = Indian Creek, Mile 4.6 at Centerline Road
Sampling Location #3 = Huntsville Spring Branch, Mile 2.4 at Dodd Road
Sampling Location #4 = Huntsville Spring Branch, Mile 5.9 at Patton Road.

2) $p>0.05$ for H_0: $\{\alpha \text{ or } \beta = 0\}$.

3) "-" indicates insufficient data for analysis.

4) All less than or missing individual DDTR isomer concentration values assumed equal to 0.

Table II-41. Summary of Winter Season Suspended Solids and Volatile Suspended Solids Ratings at Sampling Locations in Indian Creek and Huntsville Spring Branch[1]

Dependent Variable	n	r^2	Mean Sqr. Error	Independent Variables	$\hat{\beta}$	Standard Error $\hat{\beta}$
<u>Suspended Solids Load:</u>						
$>0.45\mu$ and $\lesssim 1\mu$	110	0.757	0.133	Intercept	-6.30	0.433
				Discharge	2.49	0.140
				Sampling Loc. #1	0.233	0.112
				Sampling Loc. #2[2]	-0.0693	0.103
				Sampling Loc. #3[2]	0.117	0.0946
				Sampling Loc. #4	0	--
$\gtrsim 1\mu$ and $<63\mu$	111	0.714	0.0573	Intercept	-2.30	0.284
				Discharge	1.46	0.0921
				Sampling Loc. #1[2]	0.0694	0.0735
				Sampling Loc. #2[2]	0.00813	0.0675
				Sampling Loc. #3[2]	0.0340	0.0621
				Sampling Loc. #4	0	--
$>63\mu$	111	0.460	0.259	Intercept	-3.18	0.605
				Discharge	1.43	0.196
				Sampling Loc. #1	-0.631	0.156
				Sampling Loc. #2[2]	-0.420	0.143
				Sampling Loc. #3[2]	-0.262	0.132
				Sampling Loc. #4	0	--

Table II-41. Summary of Winter Season Suspended Solids and Volatile Suspended Solids Ratings at Sampling Locations in Indican Creek and Huntsville Spring Branch[1] (Continued, Page 2)

Dependent Variable	n	r^2	Mean Sqr. Error	Independent Variables	$\hat{\beta}$	Standard Error $\hat{\beta}$
Total $>0.45\mu$	111	0.768	0.0523	Intercept	-2.61	0.272
				Discharge	1.60	0.0880
				Sampling Loc. #1^2	0.0513	0.0702
				Sampling Loc. #2^2	-0.0281	0.0642
				Sampling Loc. #3^2	0.0180	0.0593
				Sampling Loc. #4	0	--
<u>Volatile Suspended Solids Load:</u>						
$\gtrsim 1\mu$ and $<63\mu$	39	0.592	0.142	Intercept	-4.07	0.447
				Discharge	1.73	0.145
				Sampling Loc. #1^2	0.0805	0.115
				Sampling Loc. #2^2	0.0073	0.106
				Sampling Loc. #3^2	0.0868	0.0976
				Sampling Loc. #4	0	--
$>63\mu$	33	0.437	0.291	Intercept	-3.61	0.689
				Discharge	1.41	0.225
				Sampling Loc. #1	-0.618	0.184
				Sampling Loc. #2	-0.574	0.159
				Sampling Loc. #3	-0.319	0.148
				Sampling Loc. #4	0	--
Total $\gtrsim 1\mu$	33	0.642	0.134	Intercept	-4.14	0.467
				Discharge	1.81	0.153
				Sampling Loc. #1^2	-0.0208	0.125
				Sampling Loc. #2^2	-0.0949	0.108
				Sampling Loc. #3^2	-0.0561	0.101
				Sampling Loc. #4	0	--

Table II-41. Summary of Winter Season Suspended Solids and Volatile Suspended Solids Ratings at Sampling Locations in Indian Creek and Huntsville Spring Branch[1] (Continued, Page 3)

Notes:

1) All regression models of the form:

$$\log y = \alpha + \beta_1 \log x_1 + \beta_{2,STA}$$

where: y = Suspended or volatile suspended solids load, (tons/day)
x_1 = Stream discharge (cfs)
$\beta_{2,STA}$ = Constant dependent upon sampling location (i.e. class variable)

Sampling Location #1 = Indian Creek, Mile 0.9 at Triana, AL
Sampling Location #2 = Indian Creek, Mile 4.6 at Centerline Road
Sampling Location #3 = Huntsville Spring Branch, Mile 2.4 at Dodd Road
Sampling Location #4 = Huntsville Spring Branch, Mile 5.9 at Patton Road

2) $p>0.05$ for H_0: $\{\alpha \text{ or } \beta = 0\}$.

3) "-" indicates insufficient data for analysis.

4) All "less than" suspended solids concentrations assumed equal to one-half stated value.

Table II-42. Summary of Predicted Winter (November-April), Summer[1] (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch

Sampling Location		Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons/yr/sq. mi.)		
No.	River Mile	Winter (Nov.-April) (95% CI)	Summer (May-Oct.) (95% CI)	Annual Average (95% CI)
Suspended Solids Load Passing a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	410 (270-610)	37 (21-66)	450 (290-680)
2	ICM 4.6	190 (120-300)	17 (09-33)	210 (130-330)
3	HSBM 2.4	94 (56-160)	6 (03-13)	100 (59-170)
4	HSBM 5.9	51 (29-91)	6 (03-14)	57 (32-110)
Suspended Solids Load Passing a 63μ Sieve, Retained on a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	6100 (4700-8000)	1500 (1000-2200)	7600 (5700-10,000)
2	ICM 4.6	5100 (3800-6900)	1300 (820-1900)	6400 (4600-8800)
3	HSBM 2.4	2800 (2000-3900)	560 (330-940)	3400 (2300-4800)
4	HSBM 5.9	2100 (1400-3100)	630 (380-1100)	2700 (1800-4200)
Suspended Solids Load Retained on a 63μ Sieve				
1	ICM 0.9	140 (78-240)	35 (15-77)	180 (93-320)
2	ICM 4.6	220 (120-400)	54 (22-140)	270 (140-540)
3	HSBM 2.4	160 (79-330)	33 (11-100)	190 (90-430)
4	HSBM 5.9	240 (110-540)	74 (25-220)	310 (130-760)

Table II-42. Summary of Predicted Winter (November-April), Summer[1] (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch (Continued, Page 2)

Sampling Location		Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons)		
No.	River Mile	Winter (Nov.-April) (95% CI)	Summer (May-Oct.) (95% CI)	Annual
Total Suspended Solids				
1	ICM 0.9	6700 (5100-8900)	1600 (1000-2300)	8200 (6100-11,000)
2	ICM 4.6	5500 (4000-7600)	1400 (850-2100)	6900 (4900-9700)
3	HSBM 2.4	3100 (2100-4400)	570 (340-1100)	3700 (2400-5400)
4	HSBM 5.9	2400 (1600-3700)	710 (400-1300)	3100 (2000-5100)
Volatile Suspended Solids Passing a 63μ Sieve, Retained on a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	550 (360-840)	100 (57-190)	650 (420-1000)
2	ICM 4.6	450 (290-710)	84 (43-170)	530 (330-880)
3	HSBM 2.4	240 (140-400)	36 (15-81)	280 (160-480)
4	HSBM 5.9	160 (86-290)	37 (17-83)	200 (100-370)
Volatile Suspended Solids Retained on a 63μ Sieve				
1	ICM 0.9	47 (24-91)	12 (4.9-30)	59 (29-120)
2	ICM 4.6	51 (5.0-100)	13 (4.6-36)	64 (9.6-140)
3	HSBM 2.4	10 (2.9-35)	47 (21-100)	60 (24-140)
4	HSBM 5.9	81 (33-200)	25 (7.5-86)	100 (40-290)

Table II-42. Summary of Predicted Winter (November-April), Summer[1] (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch (Continued, Page 3)

Sampling Location No.	River Mile	Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons) Winter (Nov.-April) (95% CI)	Summer (May-Oct.) (95% CI)	Annual
Volatile Suspended Solids Retained on a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	600 (380-940)	100 (57-190)	700 (440-1100)
2	ICM 4.6	490 (310-770)	84 (42-170)	570 (350-940)
3	HSBM 2.4	300 (170-510)	40 (17-94)	340 (190-600)
4	HSBM 5.9	200 (110-380)	45 (20-100)	200 (130-480)

Notes: 1) Predicted summer season suspended solids and volatile suspended solids loadings based on winter season sampling results only.

Table II-43. Summary of Predicted Winter (November-April), Summer (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch

Sampling Location No.	River Mile	Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons/yr/sq. mi.) Winter (Nov.-April) Average (95% CI)	Summer (May-Oct.) Average (95% CI)	Annual Average (95% CI)
Suspended Solids Load Passing a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	5.2 (3.4-7.8)	0.47 (0.27-0.84)	2.9 (1.8-4.3)
2	ICM 4.6	2.5 (1.6-3.9)	0.22 (0.12-0.43)	1.4 (0.85-2.2)
3	HSBM 2.4	2.2 (1.3-3.8)	0.14 (0.072-0.31)	1.2 (0.70-2.0)
4	HSBM 5.9	1.4 (0.80-2.5)	0.16 (0.08-0.38)	0.78 (0.88-3.0)
Suspended Solids Load Passing a 63μ Sieve, Retained on a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	78 (60-100)	19 (13-28)	48 (36-64)
2	ICM 4.6	67 (50-90)	17 (11-25)	42 (30-58)
3	HSBM 2.4	67 (48-93)	13 (7.9-22)	41 (41-57)
4	HSBM 5.9	58 (38-85)	17 (10-30)	37 (25-58)
Suspended Solids Load Retained on a 63μ Sieve				
1	ICM 0.9	1.8 (1.0-3.1)	0.45 (0.19-0.98)	1.1 (0.59-2.0)
2	ICM 4.6	2.9 (1.6-5.2)	0.71 (0.29-1.8)	1.8 (0.92-3.5)
3	HSBM 2.4	3.8 (1.9-7.9)	0.79 (0.26-2.4)	2.3 (1.1-5.1)
4	HSBM 5.9	6.6 (3.0-15)	2.0 (0.69-6.0)	4.3 (1.8-10)

Table II-42. Summary of Predicted Winter (November-April), Summer[1] (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch (Continued, Page 3)

Sampling Location No.	River Mile	Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons) Winter (Nov.-April) (95% CI)	Summer (May-Oct.) (95% CI)	Annual
Volatile Suspended Solids Retained on a Glass Fiber Filter (∿1μ)				
1	ICM 0.9	600 (380-940)	100 (57-190)	700 (440-1100)
2	ICM 4.6	490 (310-770)	84 (42-170)	570 (350-940)
3	HSBM 2.4	300 (170-510)	40 (17-94)	340 (190-600)
4	HSBM 5.9	200 (110-380)	45 (20-100)	200 (130-480)

Notes: 1) Predicted summer season suspended solids and volatile suspended solids loadings based on winter season sampling results only.

Table II-43. Summary of Predicted Winter (November-April), Summer (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch

Sampling Location No.	River Mile	Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons/yr/sq. mi.) Winter (Nov.-April) Average (95% CI)	Summer (May-Oct.) Average (95% CI)	Annual Average (95% CI)
Suspended Solids Load Passing a Glass Fiber Filter (~1μ)				
1	ICM 0.9	5.2 (3.4-7.8)	0.47 (0.27-0.84)	2.9 (1.8-4.3)
2	ICM 4.6	2.5 (1.6-3.9)	0.22 (0.12-0.43)	1.4 (0.85-2.2)
3	HSBM 2.4	2.2 (1.3-3.8)	0.14 (0.072-0.31)	1.2 (0.70-2.0)
4	HSBM 5.9	1.4 (0.80-2.5)	0.16 (0.08-0.38)	0.78 (0.88-3.0)
Suspended Solids Load Passing a 63μ Sieve, Retained on a Glass Fiber Filter (~1μ)				
1	ICM 0.9	78 (60-100)	19 (13-28)	48 (36-64)
2	ICM 4.6	67 (50-90)	17 (11-25)	42 (30-58)
3	HSBM 2.4	67 (48-93)	13 (7.9-22)	41 (41-57)
4	HSBM 5.9	58 (38-85)	17 (10-30)	37 (25-58)
Suspended Solids Load Retained on a 63μ Sieve				
1	ICM 0.9	1.8 (1.0-3.1)	0.45 (0.19-0.98)	1.1 (0.59-2.0)
2	ICM 4.6	2.9 (1.6-5.2)	0.71 (0.29-1.8)	1.8 (0.92-3.5)
3	HSBM 2.4	3.8 (1.9-7.9)	0.79 (0.26-2.4)	2.3 (1.1-5.1)
4	HSBM 5.9	6.6 (3.0-15)	2.0 (0.69-6.0)	4.3 (1.8-10)

Table II-43. Summary of Predicted Winter (November-April), Summer (May-October) and Annual Suspended Solids and Volatile Suspended Solids Loadings at Four Locations in Indian Creek and Huntsville Spring Branch (Continued, Page 2)

Sampling Location No.	River Mile	Predicted Suspended Solids and Volatile Suspended Solids Loading (Tons/yr/sq. mi.) Winter (Nov.-April) Average (95% CI)	Summer (May-Oct.) Average (95% CI)	Annual Average (95% CI)
Total Suspended Solids				
1	ICM 0.9	85 (65-110)	20 (13-29)	52 (39-70)
2	ICM 4.6	72 (52-99)	18 (11-28)	45 (32-63)
3	HSBM 2.4	74 (50-105)	14 (8.1-26)	44 (29-64)
4	HSBM 5.9	66 (44-102)	19 (11-36)	42 (27-70)
Volatile Suspended Solids Passing a 63μ Sieve, Retained on a Glass Fiber Filter ($\sim 1\mu$)				
1	ICM 0.9	7.0 (4.6-11)	1.3 (0.73-2.4)	4.1 (2.7-6.4)
2	ICM 4.6	5.9 (3.8-9.3)	1.1 (0.56-2.2)	3.5 (2.2-5.8)
3	HSBM 2.4	5.7 (3.3-9.5)	0.86 (0.36-1.9)	3.3 (1.9-5.7)
4	HSBM 5.9	4.4 (2.4-8.0)	1.0 (0.47-2.3)	2.7 (1.4-5.1)
Volatile Suspended Solids Retained on a 63μ Sieve				
1	ICM 0.9	0.60 (0.31-1.2)	0.15 (0.062-0.38)	0.38 (0.18-0.76)
2	ICM 4.6	0.67 (0.065-1.3)	0.17 (0.060-2.2)	0.42 (0.063-1.92)
3	HSBM 2.4	0.24 (0.069-0.83)	1.1 (0.5-2.4)	0.72 (0.29-1.6)
4	HSBM 5.9	2.2 (0.91-5.5)	0.69 (0.21-2.4)	1.4 (0.55-4.0)
Volatile Suspended Solids Retained on a Glass Fiber Filter ($\sim 1\mu$)				
1	ICM 0.9	7.6 (4.8-12)	1.3 (0.73-2.4)	4.5 (2.8-7.0)
2	ICM 4.6	6.4 (4.1-10)	1.1 (0.55-2.2)	3.7 (2.3-6.1)
3	HSBM 2.4	7.2 (4.1-12)	1.0 (0.41-2.2)	4.1 (2.3-7.2)
4	HSBM 5.9	5.5 (3.0-10)	1.2 (0.55-2.7)	2.7 (1.8-6.6)

Table II-44. Summary of Predicted Winter (November-April), Summer[1] (May-October) and Annual DDTR Loadings at Four Locations in Indian Creek and Huntsville Spring Branch

Sampling Location		Predicted Seasonal DDTR Loading (tons/yr as DDT)		
		Winter (Nov.-April)	Summer (May-Oct.)	Annual
No.	River Mile	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Dissolved/Suspended DDTR Passing a Glass Fiber Filter (∼1μ)				
1	ICM 0.9	0.44 (0.25-0.75)	0.23 (0.11-0.51)	0.34 (0.18-0.63)
2	ICM 4.6	0.71 (0.39-1.3)	0.38 (0.16-0.93)	0.54 (0.28-1.1)
3	HSBM 2.4	0.36 (0.19-0.75)	0.17 (0.060-0.48)	0.28 (0.13-0.61)
4	HSBM 5.9	0.01 (0.006-0.03)	0.008 (0.003-0.02)	0.01 (0.004-0.02)
Suspended DDTR Passing a 63μ Sieve and Retained on a Glass Fiber Filter (∼1μ)				
1	ICM 0.9	0.43 (0.20-0.89)	0.18 (0.059-0.52)	0.30 (0.13-0.71)
2	ICM 4.6	0.57 (0.25-1.3)	0.25 (0.070-0.79)	0.45 (0.16-1.1)
3	HSBM 2.4	0.55 (0.21-1.4)	0.15 (0.033-0.60)	0.34 (0.12-1.0)
4	HSBM 5.9	0.006 (0.001-0.02)	0.003 (0.0005-0.02)	0.004 (0.0009-0.02)
Total DDTR Passing a 63μ Sieve				
1	ICM 0.9	0.86 (0.46-1.6)	0.41 (0.17-1.0)	0.64 (0.31-1.3)
2	ICM 4.6	1.3 (0.64-2.6)	0.63 (0.23-1.7)	0.99 (0.44-2.2)
3	HSBM 2.4	0.93 (0.40-2.1)	0.32 (0.093-1.1)	0.62 (0.25-1.6)
4	HSBM 5.9	0.02 (0.007-0.05)	0.01 (0.003-0.04)	0.01 (0.006-0.05)

NOTES: 1) Predicted summer season DDTR loadings based on winter season sampling results only.

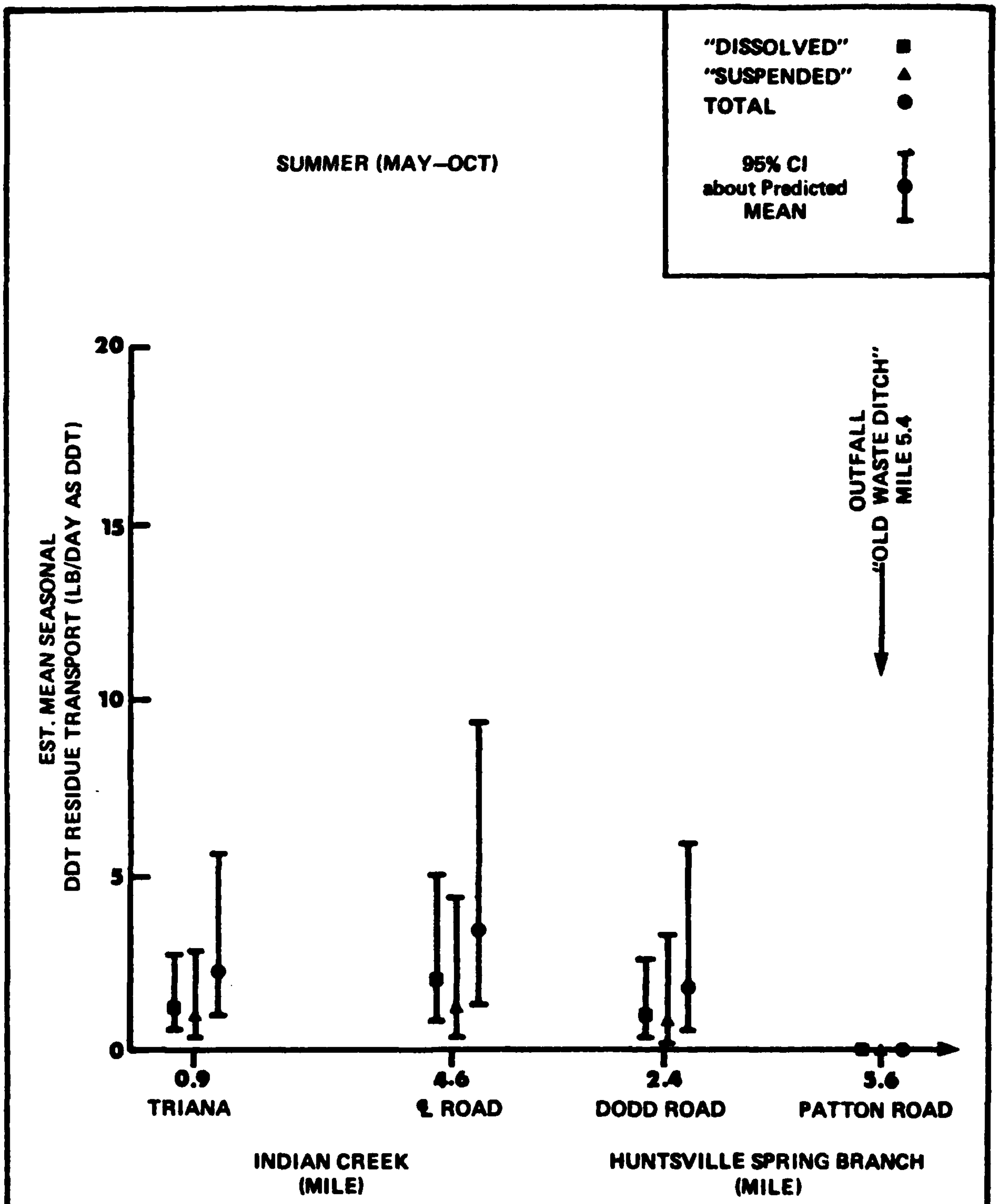

FIGURE II-30. Predicted Mean Summer Season (May-October) "Suspended", "Dissolved" and Total DDTR Loadings at Four Locations in IC and HSB

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama

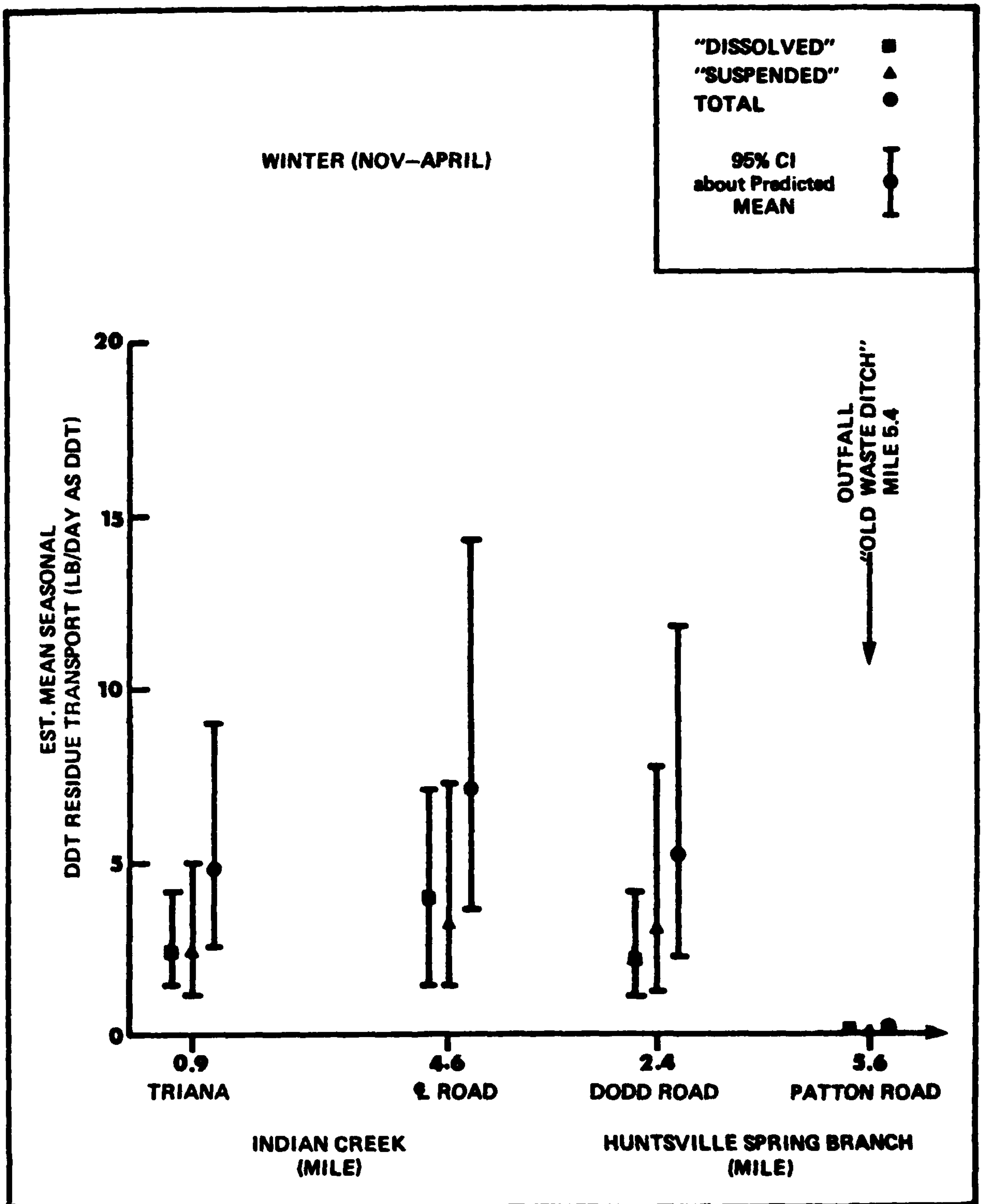

FIGURE II-31. Predicted Mean Winter Season (November-April) "Suspended", "Dissolved" and Total DDTR Loadings at Four Locations in IC and HSB

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama

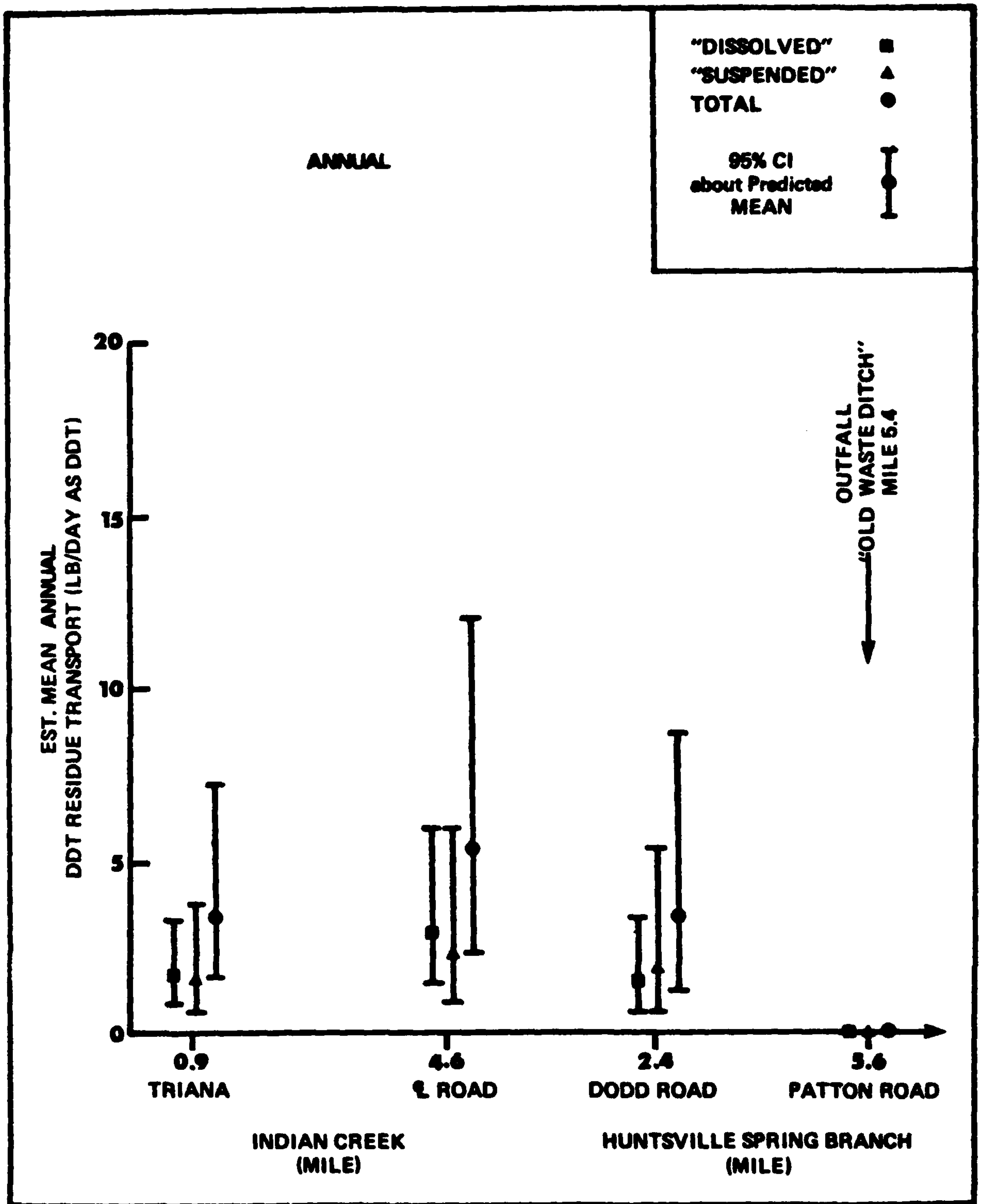

FIGURE II-32. Predicted Mean Annual "Suspended", "Dissolved" and Total DDTR Loadings at Four Locations in IC and HSB

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama

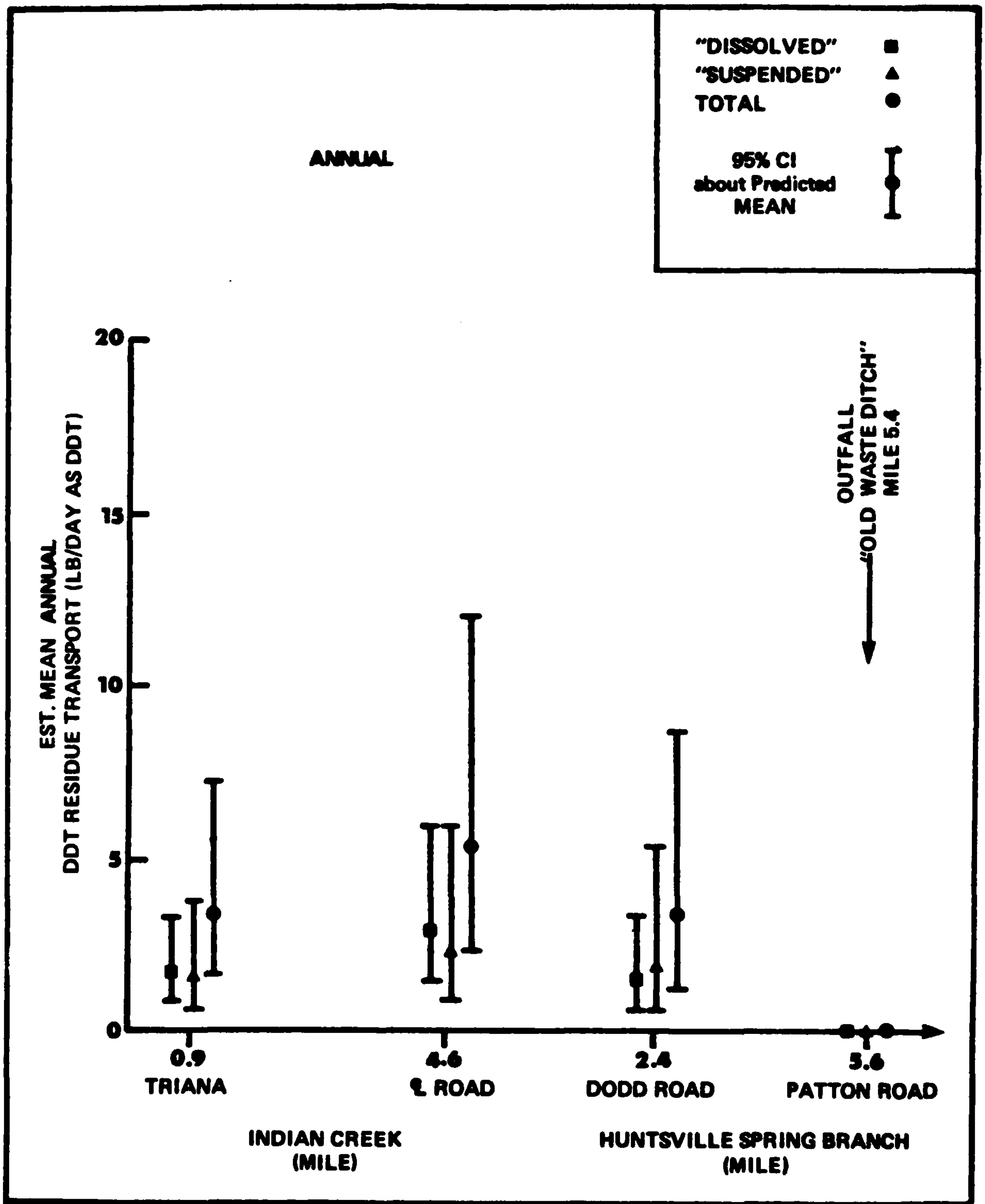

FIGURE II-32. Predicted Mean Annual "Suspended", "Dissolved" and Total DDTR Loadings at Four Locations in IC and HSB

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Wheeler Reservoir, Alabama

DDTR transport model, mean seasonal discharge as determined from the seasonal flow duration relationships, predicted seasonal suspended solids transport rates as well as seasonal estimates of the frequency with which headwater and tailwater events occur in the sampled reaches of the IC-HSB drainage basin. Also included in the suspended DDTR load summary tables are approximate 95 percent confidence limits about the predicted mean loadings. These intervals were developed by taking into account the uncertainty in the estimates of seasonal suspended solids transport as well as in the DDTR transport model.

The transport rate of the dissolved/suspended component of the DDTR load in the IC-HSB system is modeled by a somewhat simpler relationship than is the suspended DDTR component (see Tables II-39 and 40). Sampling location, discharge and the volatile suspended solids loading rate (<63u and>lu) predict the dissolved/suspended DDTR transport rate reasonably well, r=0.93. Predicted seasonal dissolved/suspended DDTR transport as well as approximate 95 percent confidence limits are also summarized in Table II-44 and illustrated in Figures II-30 through II-32.

4.1.4 Conclusions

Based on the figures shown in Table II-44, DDTR is currently being transported out of the IC-HSB drainage basin by means of fluvial transport processes at an average annual rate of 0.64 (0.31-1.3) tons per year as DDT. In other words, less than 0.08 (0.04-0.2) percent per year of the total quantity of DDTR contained within the sediment of the IC-HSB systems are being transported through and from the system by means of fluvial transport processes. Over two thirds of this load, or 0.43 (0.23-0.80) tons is transported during the winter season (i.e., November through April) with the remaining 0.21 (0.09-0.50) tons being transported during the summer months. The DDTR load to the Tennessee River is approximately equally divided between suspended and dissolved/suspended fractions, i.e. 47 and 53 percent, respectively. As a result of low velocities and the fine grained material comprising the channel bed in the lower reaches of HSB an IC as well as the association of DDTR with clay minerals, the bedload component of the DDTR load out of the IC-HSB drainage system is negligible.

An examination of the predicted DDTR transport loadings indicates that the net source of the DDTR being transported through the IC-HSB system is the stretch of HSB upstream of Dodd and downstream of Patton Roads. DDTR is being transported downstream of this location at an average annual rate of 0.62 (0.25-1.6) tons per year as DDT. Approximately three quarters of this load, or 0.47 (0.20-1.1) tons, is transported during the winter months, a slightly higher percentage than that transported during a comparable period out of IC. Nearly 55 percent of the annual DDTR load transported past Dodd Road in HSB is associated with suspended material <63u and>lu, as compared to 47 percent at the mouth of IC.

Less than 2 percent of the DDTR transported out of the IC-HSB drainage system derives from sources in the HSB basin upstream of Patton Road and the area of heaviest DDTR contamination. Although data corresponding to that available in HSB does not exist for IC, the relative contribution to the annual DDTR load exported to the Tennessee River from sources in the IC drainage basin upstream of the confluence with HSB is certainly less than 60 percent and more likely on the order of about 3 percent.

Examination of the estimated confidence limits about the predicted mean seasonal and annual fluvial DDTR transport rates indicates that the suspended DDTR loading rates downstream of Dodd Road could vary as much as an order of magnitude. Dissolved DDTR loadings can be predicted with somewhat greater confidence, and may vary over a range of about 1:5. A greater degree of relative uncertainty exists in predicting DDTR loads at Patton Road, HSBM 5.9 upstream of the area of heaviest DDTR contamination. Adding to the uncertainty in estimating seasonal and annual DDTR transport rates from and through the IC-HSB system is due to the fact that these estimates result from extrapolations of the empirically derived models.

Examination of Figures II-44 in which the seasonal, suspended, dissolved/suspended and total DDTR loading rates are graphically displayed along with attendant 95 percent confidence intervals indicates that, although there is a significant increase in DDTR transport between Patton and Dodd Roads in HSB, little can be stated with any degree of confidence concerning DDTR deposition or resuspension rates downstream of Dodd Road. Nevertheless, during the winter months there is an apparent decrease in the suspended DDTR load of 0.12 tons per year and an increase of 0.08 tons per year of the DDTR load which is dissolved or associated with fine clays or colloidal material or a net deposition rate of 0.7 tons per year in HSB downstream of Dodd Road and IC upstream of Mile 0.9. During the summer months there is an apparent net increase in the DDTR transport rates of about 0.09 tons per year downstream of Dodd Road. On an annual basis, approximately 0.04 tons per year of suspended DDTR is being deposited in IC-HSB downstream of Dodd Road and an increase of 0.06 tons per year of the DDTR load associated with fine clays, colloidal material or dissolved. Thus, on an annual basis the transport of DDTR through the IC-HSB system downstream of the most heavily contaminated stretch of HSB appear to be of steady state.

As indicated in Table II-45, DDD is the primary metabolite component of both the suspended and the dissolved/suspended DDTR loads being transported past all sampling locations. Nearly three quarters, 74 percent, of the total annual DDTR load exported out of the IC-HSB system is DDD. The metabolite DDE and DDT are transported in roughly equal percentages, i.e., 14 percent DDE and 12 percent DDT, out of IC-HSB. The metabolite distributions of the suspended and dissolved/suspended DDTR loads are somewhat different the DDE (and to a lesser extent DDT) components of the suspended DDTR fraction 5-6 times that of the dissolved/suspended DDTR fraction. The metabolite composition of the suspended DDTR load compares reasonably well to the average DDTR composition of the surface 0-6" sediments in IC downstream of the confluence with HSB, i.e. 30 percent DDT, 41 percent DDD and 27 percent DDE. The greatest deficiency occurs in the DDT component. The dissolved/suspended DDTR load appears to be deficient in both the DDT

Table II-45. *Summary of the Relative Contributions of the Three Primary DDTR Metabolites, DDT, DDD and DDE, to the Predicted Winter (November-April), Summer (May-October) and Annual Total DDTR Loadings at Four Locations in Indian Creek and Huntsville Spring Branch*

Sampling Location		Percent of Predicted Seasonal Total DDTR Loading								
		Winter (Nov-April)			Summer (May-October)			Annual		
No.	River Mile	DDT	DDD	DDE	DDT	DDD	DDE	DDT	DDD	DDE
Dissolved/Suspended DDTR Passing a Glass Fiber Filter ($\sim 1\mu$)										
1	ICM 0.9	11	84	4	8	87	3	10	86	4
2	ICM 4.6	10	86	4	7	90	3	9	88	3
3	HSBM 2.4	8	87	5	6	91	4	8	88	4
4	HSBM 5.9	12	75	12	9	81	10	11	77	11
Suspended DDTR Passing a 63μ Sieve and Retained On a Glass Fiber Filter ($\sim 1\mu$)										
1	ICM 0.9	15	59	26	9	64	27	13	61	26
2	ICM 4.6	18	58	24	11	63	26	17	59	24
3	HSBM 2.4	17	62	21	10	67	23	16	63	21
4	HSBM 5.9	0	59	41	0	60	40	0	59	41

and DDE components, relative to the surface sediments in IC. The metabolite distribution of the DDTR load does not appear to vary significantly in the IC-HSB downstream of the most heavily contaminated stretch of HSB.

4.2 BIOLOGICAL TRANSPORT OF DDTR

4.2.1 Plankton

The transport of DDT in an aquatic system will occur principally through sorption to particulates. These may be inorganic in nature such as clays or bioparticulates of various size classes. An objective of the study was to determine the magnitude of DDTR transport by plankton. Considering the waters of Indian Creek and Huntsville Spring Branch as a point source of DDTR to the main body of Wheeler Reservoir, a series of sampling stations were set up to determine transport by the plankton component. Stations ranged along Huntsville Spring Branch from Mile 0 to 5.9, and in Indian Creek from Mile 0 to 4.6. Stations in the Reservoir were located above and below the confluence of Indian Creek.

As part 5.1 of this appendix shows, results are masked by the inability to separate plankton from inorganic particulates in the sample. These inorganic suspended solids account for some of the DDTR in the sample. The total suspended solid fraction was employed as a means of determining movement of pesticide by this mechanism. TVA data show that the DDTR ascribed to phytoplankton began to rise at HSBM 5.37. This location is immediately downstream from the former waste ditch and represents a heavily contaminated site. A peak was observed at HSBM 2.4 and then levels declined. Based on arithmetic means the maximum amount was 10.5 ug/gm. At HSBM 0.0 the concentration had dropped to about half this level. At ICM 0.0, the entry of the creek waters to Wheeler Reservoir, the concentration was 2.4 ug/gm and 0.21 ug/gm in two discrete September samples.

Within the Reservoir the concentration was 0.2 ug/gm on an average at stations above and below Indian Creek confluence.

Zooplankton collections exhibit a similar distribution pattern to phytoplankton. Beginning at HSBM 5.9 increasing levels of DDTR were observed downstream. A maximum of 1,065 µg/gm occurred at HSBM 2.4 with a gradual decline to 332 at HSBM 0.0. The concentrations are based on arithmetic means of all samples collected from September through December, 1979. Indian Creek shows a distribution similar to that of HSB. At mile point 4.6 an average of 338.7 µg/gm was noted with a reduction to 48.1 µg/gm at ICM 0.0. In the Tennessee River levels varied from 0.17 µg/gm to 4.6 µg/gm with the maximum at the upper and lower extremes of Wheeler Reservoir. As with phytoplankton, the variation in DDTR with the two creeks could be a function of clays or other inorganic particulates retained in the net and may not be a reflection of the amount of residue in zooplankton. Calculation of the amount transported by suspended solids has been included in Section 4.1.1.

The suspended solid fraction plays an important role in biomagnification. Figures II-33 and II-34 show pathways for bioconcentration and biomagnification of DDT within food webs. Particulates in the water will be ingested by invertebrates and vertebrates and be transported within the Tennessee River system by this means. Therefore, the total suspended particulate fraction may be a significant factor in contamination of some organisms.

4.2.2 Macroinvertebrates

Transport of DDT by macroinvertebrates will be via movement within the aquatic or to the terrestrial environment. The former occurs by drifting while the latter mainly takes place by emergence of adults. Neither of these mechanisms could account for the movement of any substantial amount of DDT within the study area. The emergence of adult insects which serve as food for birds and other vertebrates could be considered a type of migration in a secondary sense since ingestion by birds increases the distance a discrete amount of pesticide would move. Overall, the amount of DDT in macroinvertebrates is small (see Section 3.3.2) compared to that in sediments and movement via these organisms will be limited. That is, spread of DDT from a contaminated area such as HSB-IC will be very localized.

4.2.3 Vertebrates (except fish)

DDT in birds has the potential of migration for a considerable distance away from the main area of contamination. An examination of Table II-49 shows, however, that Green Herons and Wood Ducks had the highest levels in the Huntsville Spring Branch-Indian Creek area (TRM 321 and TRM 330). Since these two species are local residents the transport of DDT via these birds is probably limited to the HSB-IC system. Much the same pattern is evident in the remaining species studied. The data show that for turtles, snakes, shrews and muskrats highest levels of DDTR were in animals localized where pesticide levels are highest.

The level of DDTR in vertebrates is reflected by their diet. Figures II-35 through II-37 contain the food habits of species inhabiting the study area. The Green Heron, for example, has a diet consisting of crayfish, fish and insects. Fish, as will be noted later in this section, are mobile and have the capacity to migrate out from the contaminated area. The data show a relative low level of DDTR in herons downriver and upriver from the HSB-IC system leading to a tentative conclusion that DDT is still mainly localized in these two tributaries. A similar pattern seems evident with the other vertebrates listed in Table II-46.

There will be transport of DDTR by migratory birds, especially waterfowl using Wheeler Wildlife Refuge. The recent work completed by Patuxent Wildlife Research Center documents DDTR in Mallard ducks and duck wings (see Section 5.0). These birds primarily consume aquatic plants although they also have a limited diet of aquatic invertebrates. The Patuxent study (O'Shea, 1980) shows a geometric mean of 4 ppm in mallards based on

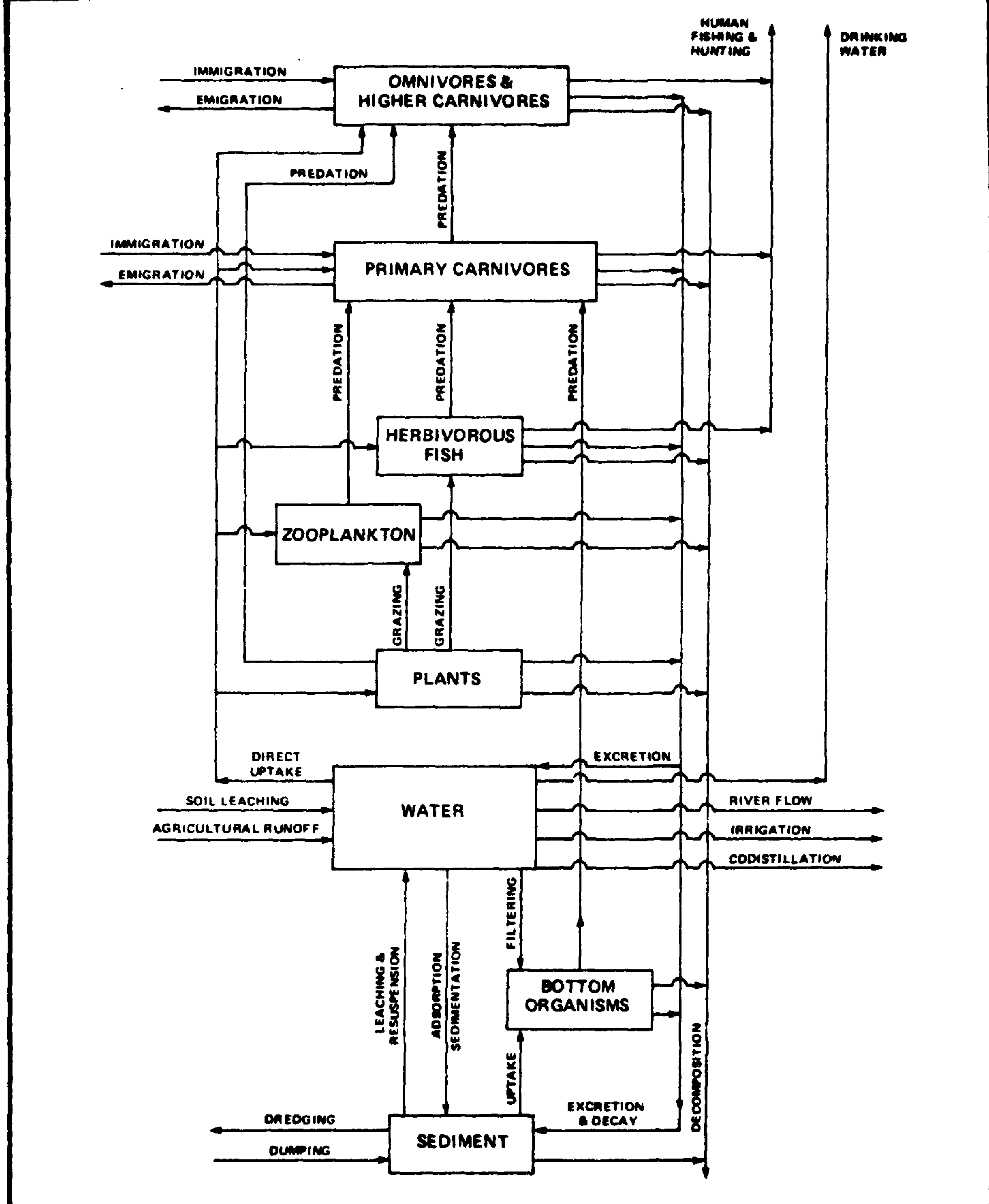

FIGURE I-33. Transport of DDT in an Ecosystem - Adapted from AEHA, 1977

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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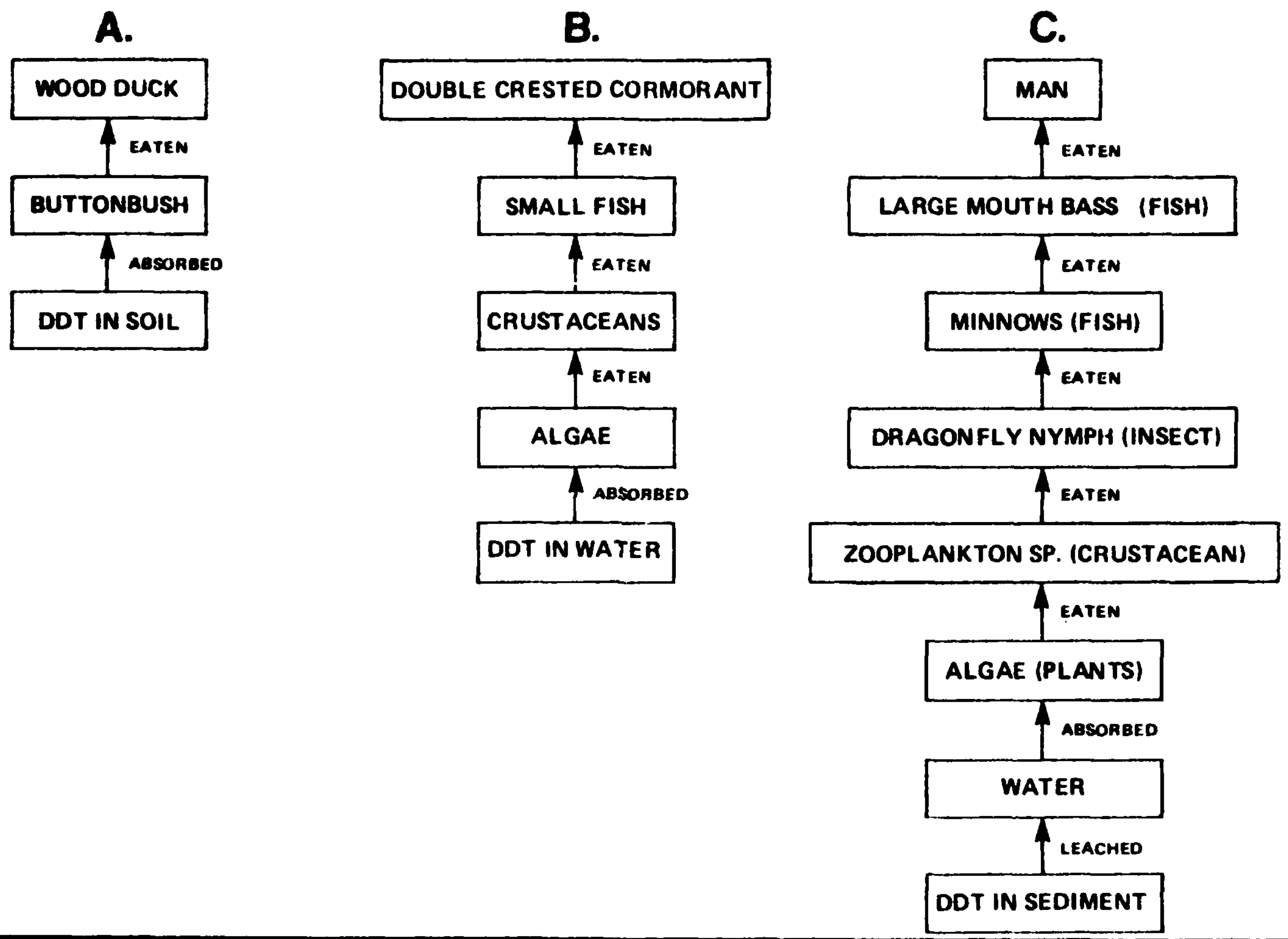

FIGURE II-34. Incorporation of DDT into the Food Web

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

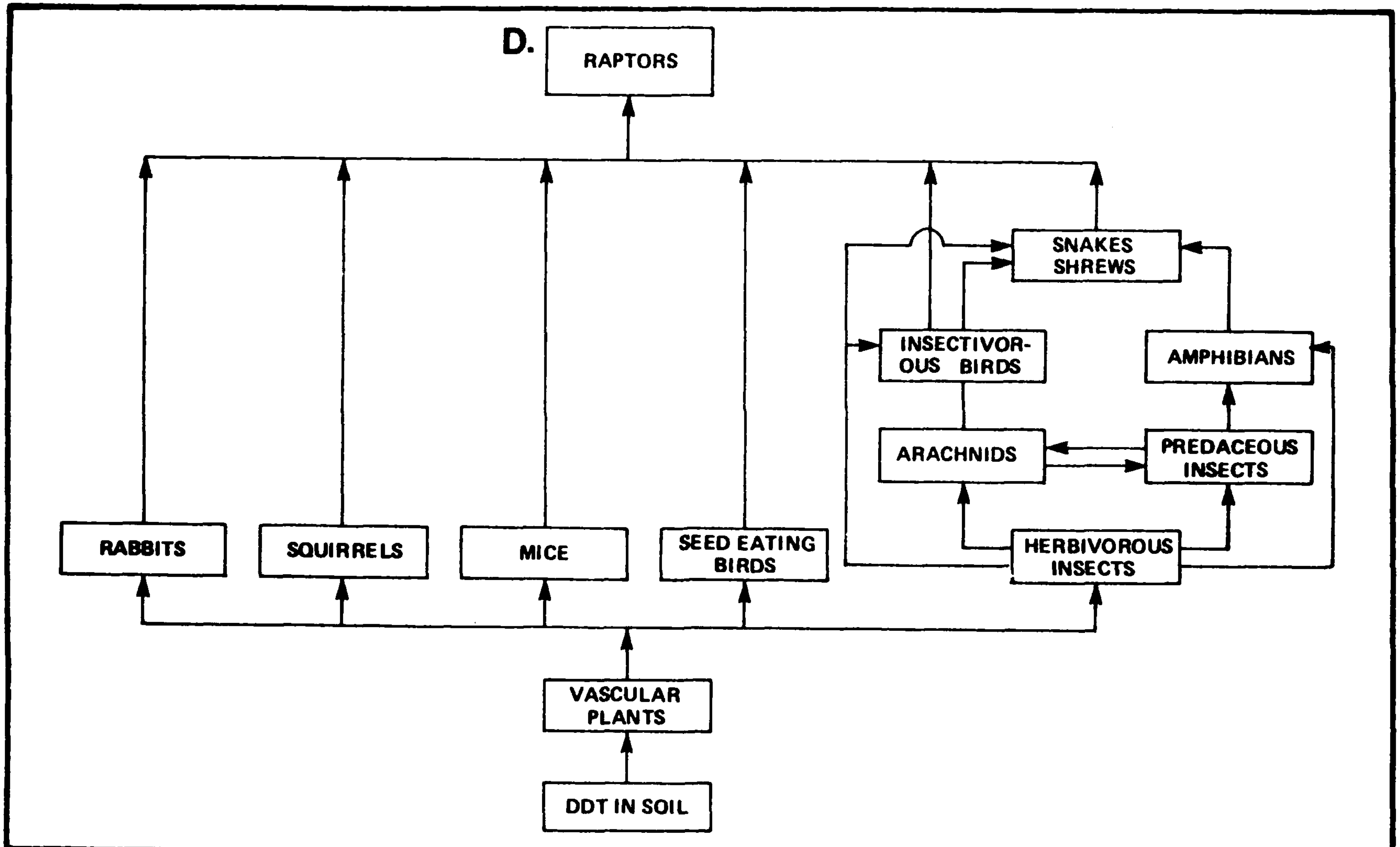

FIGURE II-34.(Continued). Incorporation of DDT into the Food Web

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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REFERENCES FOR FIGURES II-35, II-36, II-37

1. Adams, C.C., and T.L. Hankinson, 1928. The Ecology and Economics of Oneida Lake Fish. Roosevelt Wildlife Annals 1(3 and 4): 235-548.

2. Bent, A.C. 1926. Life History of North American Marsh Birds. Dover Publication, Inc., New York, NY. 392 pp.

3. Bent, A.C. 1927. Life History of North American Shore Birds. Part I. Dover Publications, Inc., New York, NY. 420 pp.

4. Bent, A.C. 1929. Life History of North American Shore Birds. Part II. Dover Publications, Inc., New York, NY. 412 pp.

5. Bent, A.C. 1951. Life History of North American Wildfowl. Dover Publications, Inc., New York, NY. Vol. I. 224 pp., 46 pl. Vol. II. 316 pp, 60 pl.

6. Carlander, K.D. 1969. Handbook of Freshwater Biology. Vol. I. Iowa State University Press, Ames, Iowa. 752 pp.

7. Carlander, K.D. 1977. Handbook of Freshwater Fishery Biology. Vol. II. Iowa State University Press, Ames, Iowa. 431 pp.

8. Carr, A.F. 1940. A Contribution to the Herpetology of Florida. University of Florida Publication, Gainesville, FL. Biological Series 3. 118 pp.

9. Carr, A.F. 1952. Handbook of Turtles. Comstock Publishing Associates. Ithaca, N.Y. 542 pp.

10. Grzimek, B. and L. Werner. 1974. Grzimek's Animal Life Encyclopedia. Van Nostrand Reinhold Company. New York, N.Y. Vol. 5. 555 pp.

11. Heubeck, E.K. 1967. A Survey of the Parasites of the Cattle Egret (Bibulcus ibis). M.S. Thesis. University of Florida, Gainesville, FL. 41 pp.

12. Howell, A.H. 1932. Florida Bird Life. Coward-McCann, Inc., New York, N.Y. 579 pp.

13. Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. American Wildlife and Plants: A Guide to Wildlife Food Habits. Dover Publications, Inc., New York, N.Y. 500 pp.

14. McLane, W.M. 1955. The Fishes of St. John River System. Ph.D. Thesis. University of Florida, Gainesville, FL. Unpublished. 362 pp.

15. Sprunt, A., Jr. 1954. Florida Bird Life. Coward-McCann, Inc. New York, NY. pp. 527.

16. Wright, A.H. and A.A. Wright. 1957. Handbook of Snakes of the United States and Canada. Comstock Publishing Associates. Ithaca, N.Y. (2 Vol.) 1105 pp.

N.I. = NO INFORMATION
A = ADULTS
Y = YOUNG
● = AGE NOT SPECIFIED
■ = PREDOMINANTLY EATEN
* UNSPECIFIED

FISH	reference	FOOD	FISH (SMALL)	Bass, Largemouth	Bass, Yellow	Bluegill	Carp	Catfish, Channel	Catfish, White	Crappies	Minnows	Mosquitofish	Perch	Shad, Gizzard	Sunfish	Trout	Fish eggs	AMPHIBIANS	Frogs	Tadpoles	CRUSTACEANS	Amphipods	Copepods	Crayfish	Fish lice	INSECTS	Insect (larvae)	Caddisfly (Larvae)	Diptera	Mayfly (larvae)	Mosquito (larvae)	INVERTEBRATES*	Chironomids	Leeches	MOLLUSKS	Clams	Crabs	Snails	OLIGOCHAETES	Earthworms	PROTOZOANS	Cladocerans	Rotifers	ZOOPLANKTON	PLANTS	Algae	Diatoms	Duckweed	Phytoplankton	Zooplankton	Organic Detritus
Bass, Largemouth	1.7		A		A			A			Y		A	A		A			A		Y	Y	Y	A		AY							Y									Y	Y			Y					
Bass, Rock	1.7		A								A										AY	A	Y	A			A			●			Y		A				A							Y					
Bass, Smallmouth	1.7		AY																	A	Y		Y	A		A	Y		A				AY									Y	Y								
Bass, Spotted	7		A																		Y			A		AY							Y																		
Bass, Striped	14		●			●															●																														
Bass, White	1, 10		●								A										●			A			●						●		A																
Bass, Yellow	10		●																		●																														
Bluegill	7		A																		AY		Y	A	A	AY																Y	Y		AY	A					
Bowfin	1.6		■																●					■		●								●	●					●											
Buffalo, Bigmouth	6																				●		●										●									●								●	
Buffalo, Smallmouth	6																						AY			A																AY				A		A			
Bullhead, Black	6		A																A		AY					A	Y																			Y					A
Carp	1.6																				●					●	■						●			●			●			●			●				●	●	●
Carpsucker	6																						●										●										●			●					●
Catfish, Blue	6		●																					●		●																								●	●
Catfish, Channel	1.6		A								A										AY					Y									●										A						
Catfish, Flathead	6		A	A					A															A		AY																									
Chub, Silver	6																				A		Y			A				A			AY									Y									
Crappie, Black	7		A								A										Y		Y			A			Y				Y									AY							A	A	
Crappie, White	7		A											A							AY	Y	Y			AY				A			AY									Y	Y							Y	
Darter, River	10		●														●				●						●					●							●												
Darter, Tuscumbia	10																				●						●																								
Drum, Freshwater	N.I																																																		
Gar, Longnose	6		A																		Y						Y																								
Gar, Shortnose	6		●			A	A						A		A						Y			A		A					Y																				
Gar, Spotted	6		●																			●		●		●																									
Goldfish	6																																																●		
Herring, Skipjack	6		A																							Y																									
Lamprey	6		■																																																
Madtom, Tadpole	6																																●		●							●				●					●

FIGURE II-35. Food Habits of Freshwater Fish

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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N.I. = NO INFORMATION
A = ADULTS
Y = YOUNG
● = AGE NOT SPECIFIED
■ = PREDOMINANTLY EATEN
* UNSPECIFIED

FISH	reference	FOOD	FISH (SMALL)	Bass, Largemouth	Bass, Yellow	Bluegill	Carp	Catfish, Channel	Catfish, White	Crappies	Minnows	Mosquitofish	Perch	Shad, Gizzard	Sunfish	Trout	Fish eggs	AMPHIBIANS	Frogs	Tadpoles	CRUSTACEANS	Amphipods	Copepods	Crayfish	Fish lice	INSECTS	Insect (larvae)	Caddisfly (Larvae)	Diptera	Mayfly (larvae)	Mosquito (larvae)	INVERTEBRATES *	Chironomids	Leeches	MOLLUSKS	Clams	Crabs	Snails	OLIGOCHAETES	Earthworms	PROTOZOANS	Cladocerans	Rotifers	ZOOPLANKTON	PLANTS	Algae	Diatoms	Duckweed	Phytoplankton	Zooplankton	Organic Detritus
Minnows, Bullhead	1, 6																				●					●	●												●							●	●				●
Mooneye	6		●																							●																									
Mosquitofish	6		●																				●								●															●			●	●	
Paddlefish	6		●																							●				●																			■	■	
Perch, Yellow	1, 10		●								●						●				●	●		●			●					●							●	●						●					
Pickerel, Grass	6		A																		Y	Y	A	A			AY															AY									
Redhorse, Golden	6																											●		●			●			●			●												●
Redhorse, Silver	6																											●		●			●																		●
Sauger	10		●														●				●						●					●							●												
Shad, Gizzard	6																				Y					A													A		Y		Y			A	A		A	A	●
Shad, Threadfin	6																									●			●												●								●	●	●
Shiner, Common	6																				●					●																	●			●					
Shiner, Emerald	6																				●	●				●		●		●																					
Shiner, Golden	1, 7																				Y					●	A	●																		●	●		AY	A	
Silverside, Brook	1,14		●																		●	●	●			●			●				●									●			●				●	●	
Stoneroller	1, 7																									●	■																			■	●				●
Sucker, Spotted	N.I.																																																		
Sunfish, Green	7		●				A			A		A		A			A							A		A						A																		Y	
Sunfish, Longear	1, 7		●														A				Y	A		A		AY		●		●								A	A							A					
Sunfish, Orange Spotted	6		●																							●																									
Sunfish, Redear	7		●																				●			●												●				●				●					
Topminnow, Black Spotted	N.I.																																																		
Walleye	10		●														●				●						●					●							●												
Warmouth	7		A																		Y			A		A																									

FIGURE II-35 (Continued). Food Habits of Freshwater Fish

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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N.I. = NO INFORMATION
# = % OF DIET
■ = EATEN OFTEN
▲ = EATEN RARELY
* UNSPECIFIED

FOOD	reference	AMPHIBIANS	Frogs	Salamanders	Toads	MAMMALS	Rabbits	Rats	Rhodents	Squirrels	BIRDS	CARRION	CRUSTACEANS	Crayfish	FISH	INSECTS	Ants	Beetles	Caddisflies	Caterpillars	Dragonflies
SHORE BIRDS, GULLS, TERNS																					
Killdeer	3, 4, 13												▲	▲		98	10	37		10	
Plover, Semi-Palmated	13												■			■					
Sandpiper, Least	13												■				■	■	■		■
Sandpiper, Pectoral	13												■			■					
Sandpiper, Spotted	13												■				■	■	■		■
Sandpiper, White Rumped	13												■		■	■					
Snipe, Wilson	13												■		■			■			
Woodcock, American	13												▲			▲		▲		▲	
Yellowlegs, Greater	13												■		■	■					
Yellowlegs, Lesser	3, 4, 13 15												▲				▲	▲	30	▲	
RAPTORIAL BIRDS																					
Hawk, Cooper's	13								▲		■										
Hawk, Marsh	13	■							■		■										
Hawk, Red-Shouldered	13						■		■		■										
Hawk, Red-Tailed	13						■		■		■										
Hawk, Sharp-Shinned	13								▲		■										
Hawk, Sparrow	N.I.																				
Osprey	13														■						
Owl, Barn	13		■				■	■		■	■			■		■					
Owl, Barred	13		■				■	■		■	■			■		■					
Owl, Great Horned	13		■				■	■		■	■			■		■					
Owl, Screech	13		■				■	■		■	■			■		■					
Vulture, Black	13											■									
Vulture, Turkey	13											■									
SNAKES & TURTLES																					
Snake, Water	8,16		■	■	■									■	■						
Turtle, Snapping	8, 9											20			34						

FIGURE II-36. Food Habits of Birds and Selected Vertebrates

SOURCE: WATER AND AIR RESEARCH, INC., 1980

INSECTS	Ants	Beetles	Caddisflies	Caterpillars	Dragonflies	Flies	Grasshoppers	Water Boatman	INVERTEBRATES*	MOLLUSKS	Crabs	Snails	REPTILES	Lizards	Snakes	SPIDERS	VERTEBRATES	WORMS	PLANTS	Bristlegrass	Bulrush	Burreed	Clover	Knotweed	Panic Grass	Pondweed	Ragweed	Sawgrass	Sedge	Smartweed	Spike Rush	Violet	Watermilfoil	Widgeongrass	Wildmillet
98	10	37		10			10			▲	▲					▲		▲	2																
■										■								■																	
	■	■	■		■					■								■																	
■										■								■			1		1		1	1				1			1	1	
	■	■	■		■					■								■																	
■										■								■											1					1	
		■				■						■						■		1	4	1			4	1	1	1		1	1				1
▲		▲		▲		▲										▲		90		1				1	1		1		1			1			
■												■						■																	
	▲	▲	30	▲			▲	38		▲		5						5																	
													■																						
														■	■																				
														■	■																				
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FOOD HABI

MAMMALS	FOOD reference	AMPHIBIANS	Frogs	MAMMALS	Mice	BIRDS	Bird Eggs	CRUSTACEANS	Crayfish	EARTHWORMS	FISH	INSECTS	Ants	Beetles	Caddisflies	Caterpillars	Flies	Grasshoppers	Mosquitoes	Moths	INVERTEBRATES*	MOLLUSKS	Mussels	Snails	REPTILES	Snakes
Bat, Gray	13											■	■	■	■		■		■	■						
Bat, Indiana	N.I.																									
Beaver	13																									
Muskrat	13								■		■	■											■	■		
Opossum	13	■					■					■									■					
Otter, River	13		■						■		■			■												■
Raccoon	13	■	■						■			■						■								
Rabbit, Cottontail	13																									
Rabbit, Swamp	N.I.																									
Shrew	13				■					■		■	■	■		■	■	■						■		
Woodchuck	13																									

KEY

N.I. = NO INFORMATION
\# = % OF DIET
■ = EATEN OFTEN
▲ = EATEN RARELY
*UNSPECIFIED

MARSH & WATER BIRDS	FOOD reference	AMPHIBIANS	Frogs	Salamanders	MAMMALS	Mice	Moles	Shrew	BIRDS	CRUSTACEANS	Crabs	Crayfish	Shrimp	FISH	INSECTS	Beetles	Caterpillars	Dragonflies	Flies	Grasshoppers	Wasps	MOLLUSKS	Clams	Mussels	Snails	REPTILES
Cormorant, Double Crested	12,13,15		▲							▲	▲			99												
Duck, Wood	5, 15									▲					2	1	▲	3	▲	▲	▲					
Egret, Cattle	11, 13														■		■			■						
Egret, Common	2, 13,15		■	▲		▲	▲				■	■	■	■	■					■					■	
Grebe, Horned	13, 15									17		■	■	33	50	■			■		■	■			■	
Grebe, Pied Billed	13, 15									■		27		24	46							■				
Heron, Great Blue	2, 13,15	▲	▲			5		▲	▲	▲		8		68	8											
Heron, Green	2, 12, 13, 15											45		35	20											
Heron, Little Blue	2, 13, 15		▲							▲	▲	■	▲	▲	▲					▲						
Loon, Common	13		▲								▲			■	▲							▲				
Rail, King	13											▲		▲	■	■		■		■					▲	
Rail, Sora	13, 15									▲					■	■						■			▲	

FIGURE II-37. Food Habits of Marsh and Water Birds and Selected Small Mammals

SOURCE: WATER AND AIR RESEARCH, INC., 1980

FOOD HABITS

INVERTEBRATES*	MOLLUSKS	Mussels	Snails	REPTILES	Snakes	SPIDERS	PLANTS	Alfalfa	Ash bark & wood	Bulrush	Carrot	Cattail	Clover	Clubmoss	Cordgrass	Corn	Cutgrass	Blackgum	Bluegrass	Grape	Grasses	Greenbrier	Holly	Honeysuckle	Mulberry	Oak/Acorns	Oats	Palmetto	Panic Grass	Pecan	Persimmon	Pine bark & wood	Reedgrass	Sawgrass	Sweet gum bark & wood	Soybeans	Vegetables	Wheat
		■	■						8	18		8			4		1												8			8	1	1	18			
■					■									1		1		1		4					1	1					4							
								8			4		9			4 1			1	8		8	1			18	4	18		1	8					8		18
			■			■		4					18								8			1												4	8	

*UNSPECIFIED

Wasps	MOLLUSKS	Clams	Mussels	Snails	REPTILES	Lizards	Snakes	Turtles	SPIDERS	WORMS	PLANTS	Acorns & Beechnuts	Algae	Bayberry	Bulrush	Burreed	Buttonbush	Composites	Coontail	Cordgrass	Cypress Cones	Duckweed	Grasses	Naiad	Panicgrass	Paspalum	Pondweed	Rice	Seeds (Misc.)	Sedges	Smartweed	Spike Rush	Widgeongrass
▲									▲	▲		6				2	2	2	3		9	10	8				7		10	9	5		
				■		▲	▲																										
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U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters,Wheeler Reservoir, Alabama

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Table II-46. DDTR (ppm) in Vertebrates Collected Within the Study Area During Late Summer - Early Fall 1979

Location	Green Heron	Wood duck	Snapping Turtle	Water Snake	Shrew	Muskrat
TRM 271	0.802	---	0.061	0.28	7.7	0.067
TRM 299	0.20	0.42	0.072	0.28	4.7	0.056
TRM 309	---	<0.1	---	---	---	---
TRM 311	0.70	---	0.18	---	2.1	0.090
TRM 317	---	1.8	---	---	---	---
TRM 321	---	0.45	---	---	---	---
HSB	4.3	3.5	0.45	1.8	52	0.26
TRM 330	2.5	---	0.054	0.053	0.63	0.075
TRM 402	0.09	0.062	0.053	0.056	0.73	0.10

Note: Except for wood ducks these data are believed to have a significantly low bias. See the Quality Assurance Section of this report.

Values in ppm on Wheeler Wildlife Refuge expressed as means of sample groups. Wood Duck eggs collected from two locations on Wheeler Wildlife Refuge by Fish and Wildlife personnel had a mean DDTR level of 0.216 ppm and 2.2 ppm respectively.

whole body analyses. Although no population data are available the DDT transport out of the system per 1,000 birds is estimated at 0.01 pounds (assuming all contain 4 ppm) and have an average weight of 2.6 pounds (Bellrose, 1976). On this basis 96.5 thousand birds would be required to export one pound of DDTR. In a relative sense, then, the amount of pesticide transported by migratory birds is small compared with the reservoir of DDT in the HSB-IC area. The small amount transported does not imply a correlation with impact, however. The DDT burden in waterfowl may affect reproduction via classic egg shell thinning.

Total biomass for mammals inhabiting the floodplain habitat along the HSB-IC system approximates 25 lbs/acre (Marion, 1980). Total area of the overbank is 332 acres which provides a total of 8300 pounds of biomass. Using an assumption that 10 percent is made up of shrews and 90 percent by other species the following amounts are attributed to each group.

1) shrews - 830 lbs
2) others - 7470 lbs.

The current study results showed shrews contained on an average 52 ppm DDTR in the area most highly contaminated. Using this level of DDTR the amount in shrews is 0.04 pounds. Using a 1 ppm estimate for all other mammals, this amount is 0.01 pounds.

These calculations show that the absolute amount of pesticide presently incorporated in the mammals in the HSB-IC area is too low to be a significant factor in overall DDTR transport.

4.2.4 Fish

In Section 3.3.4 of this appendix it was estimated that the total amount of DDTR in fish in Wheeler Reservoir was 34 to 340 pounds. Two fish samplings were made in September 1979 to measure standing crop in Indian Creek-Huntsville Spring Branch. The average result for the two was 151.8 pounds per acre with 54 percent of the fish being young-of-year. DDTR analyses on whole body samples of young-of-year fish showed 56.9 ppm. Adult fish in Indian Creek averaged 153 ppm (whole body analyses). Using these figures plus the area of Indian Creek-Huntsville Spring Branch to HSBM 5.6 gives a total of 4.0 pounds of DDTR in fish in this area. This information does not allow one to predict with precision the annual net transport of DDTR to the Tennessee River by fish. That depends on the rate of movement of contaminated fish out into the river. Fish movement studies in Wheeler Reservoir for 5 species showed that the percent of fish found more than five miles from their release point after 60 days ranged from 20 to 65 (TVA, 1978). If it is assumed that 50 percent of the contaminated fish in the Indian Creek-Huntsville Spring Branch area leave every 60 days, the total DDTR transport to the Tennessee River would be 12 pounds per year.

5.0 CURRENT CONTAMINATION LEVELS IN BIOTA

5.1 PLANKTON

Samples were obtained of the two major fractions of the plankton and analyzed for DDTR. Interpretation of the results for the phytoplankton and zooplankton is masked by inorganic particulates which are included in these samples. Adsorption on clays readily occurs with DDTR and therefore analysis of a sample of plankton which contains clays enters a bias to the results. That is to say that the level of DDTR in a plankton sample cannot be all attributed to bioparticulates. For this reason the more realistic approach is to base the interpretation on total suspended solids. This has been the approach utilized for this Section, and reference to Section 4.0 of this Appendix is suggested for this information. However, general trends may be observed in Table II-47.

5.2 MACROINVERTEBRATES

Benthic macroinvertebrates were collected within the study area using a Ponar dredge. Stations above and below the DDT waste ditch (HSBM 5.4) were sampled in Huntsville Spring Branch. Collections were made from Indian Creek from Mile 0.0, 0.8 and 4.6. In the Tennessee River samples were taken at two locations below the confluence of Indian Creek (TRM 321) and two upriver from this point. Comparisons of the results are somewhat confounded by collections in various time periods ranging from August to December. Factoring out this variable, DDTR levels below the old waste ditch at Mile 5.37 were three orders of magnitude greater than upstream values. Table II-50 is a summary presentation of DDTR levels in the biota excluding vertebrates. The data show trends in concentration as cited above for HSB. Indian Creek is similar with a range (based on means) from 24.4 µg/g at Mile 0.0 to 355 µg/g at Mile 4.6. Analyses of other tributaries above and below the principal source (IC) show that macroinvertebrates contain the highest levels of DDTR in the HSB-IC system.

Levels in the Tennessee River macroinvertebrates show a marked reduction. At TRM 315 DDTR is 0.5 µg/g. Lower concentrations were observed upriver at TRM 345 and 350 (0.02 and 0.03 µg/g, respectively). Levels in other tributaries ranged from 0.05 to 2.06 µg/g. Barren Fork Creek represented the maximum (2.06 µg/g) and was the most proximate to the HSB-IC system.

5.3 FISH

5.3.1 Results of Surveys Made in 1979-80

A major impact of the DDTR residues is contamination of fish. Historical data discussed in Section 1.0 suggests that fish, particularly in the Indian Creek area, have had DDTR concentrations above the FDA limit of 5 ppm (µg/g). In 1979 fish sampling was done in the study area on three occasions. A summary of this data for channel catfish is shown in Table II-48. The data show a very marked downward trend during the year. This variation may be due to (1) actual decreases in average DDTR levels,

Table II -47. DDTR Residues in Selected Biota Within the Study Area

Location	Collection Date	Sample Type (Species)	Average Total (DDTR (μg/g)
Barren Fork Creek 1.20		Aufwuchs	0.212
Huntsville Spring Branch 0.00		"	7.04
Huntsville Spring Branch 1.30		"	49.5
Huntsville Spring Branch 2.40		"	38.2
Huntsville Spring Branch 5.37		"	0.27
Huntsville Spring Branch 5.90		"	0.148
Indian Creek 0.00		"	0.899
Indian Creek 4.00		"	2.72
Tennessee River 289.90		"	0.162
Tennessee River 315.00		"	0.069
Tennessee River 315.00		"	0.350
Tennessee River 345.00		"	0.042
Tennessee River 350.00	10/24/79	"	0.034
Tennessee River 350.00	11/1/79	"	0.029
Barren Fork Creek 1.20	9/12/79	Benthic Macroinvertebrates	2.061
Elk River 20.70	10/18/79		0.710
Flint River 22.70	10/25/79		0.048
Huntsville Spring Branch 2.40	12/15/79	"	256.0
Huntsville Spring Branch 4.30	8/30/79	"	2.50
Huntsville Spring Branch 5.37	10/30/79	"	2,710.0
Huntsville Spring Branch 5.90	12/16/79	"	5.96
Indian Creek 0.00	8/29/79	"	24.4
Indian Creek 0.80	12/16/79	"	177.0
Indian Creek 4.60	12/15/79	"	355.0
Limestone Creek 18.00	10/23/79	"	0.371
Tennessee River 289.90	12/6/79	"	0.129
Tennessee River 315.0	8/29/79	"	0.499
Tennessee River 345.30	9/5/79	"	0.020
Tennessee River 350.0	9/17/79	"	0.033
Huntsville Spring Branch 2.50	10/18/79	*Cephalanthus*	0.265
Huntsville Spring Branch 4.50		"	0.224
Huntsville Spring Branch 5.60		"	0.008
Indian Creek 4.20		"	0.100
Indian Creek 6.70		"	0.023
Indian Creek 7.00		"	0.041
Tennessee River 293.0	10/22/79	"	0.011
Tennessee River 305.10	10/25/79	"	0.097
Tennessee River 328.50		"	0.007
Tennessee River 359.00		"	0.005
Huntsville Spring Branch 2.50	10/18/79	*Hibiscus*	0.786
Huntsville Spring Branch 4.50		"	0.455
Indian Creek 4.20		"	0.171
Indian Creek 6.70		"	0.072
Indian Creek 7.00		"	0.036
Tennessee River 293.00	10/22/79	"	0.006
Tennessee River 305.10	10/25/79	"	0.016

Table II -47. DDTR Residues in Selected Biota Within the Study Area (Continued, page 2)

Location	Collection Date	Sample Type (Species)	Average Total (DDTR (ug/g)
Tennessee River 328.50		Hibiscus	0.007
Tennessee River 359.00		"	0.004
Huntsville Spring Branch 4.50	10/18/79	Lemna-Spirodela	5.60
Huntsville Spring Branch 5.60		Duckweed	0.071
Barren Fork Creek 1.20	9/24/79	Zooplankton	52.0
Huntsville Spring Branch 0.00	9/25/79	"	332.0
Huntsville Spring Branch 1.30		"	577.0
Huntsville Spring Branch 2.40	9/24/79	"	935.0
Huntsville Spring Branch 2.40	12/15/79	"	1,065.0
Huntsville Spring Branch 5.37	9/25/79	"	175.0
Huntsville Spring Branch 5.90	9/25/79	"	9.66
Huntsville Spring Branch 5.90	12/15/79	"	1.70
Indian Creek 0.00	9/5/79	"	48.1
Indian Creek 0.80	12/15/79	"	3.03
Indian Creek 4.00	9/5/79	"	190.0
Indian Creek 4.00	9/25/79	"	168.0
Indian Creek 4.60	12/15/79	"	339.0
Tennessee River 289.90	9/28/79	"	4.641
Tennessee River 315.00	9/25/79	"	0.567
Tennessee River 345.00	9/27/79	"	0.173
Tennessee River 350.00	9/27/79	"	4.611
Barren Fork Creek 1.20	9/24/79	Phytoplankton	0.567
Huntsville Spring Branch 0.00	9/25/79	"	5.68
Huntsville Spring Branch 1.30	9/24/79	"	7.07
Huntsville Spring Branch 2.40	9/24/79	"	10.5
Huntsville Spring Branch 5.30	9/25/79	"	3.26
Huntsville Spring Branch 5.90	9/25/79	"	0.250
Indian Creek 0.00	9/5/79	"	2.44
Indian Creek 0.00	9/24/79	"	0.207
Indian Creek 4.00	9/5/79	"	4.15
Indian Creek 4.00	9/24/79	"	3.311
Tennessee River 289.9	9/28/79	"	0.200
Tennessee River 315.0	9/27/79	"	0.200
Tennessee River 345.20	9/27/79	"	0.200
Tennessee River 350.00	9/27/79	"	0.200

Table II-48. Comparison of DDTR Concentrations in Channel Catfish Fillets in 1979

Location	April	May	July-Oct.
TRM-270	---	2.6	1.3
TRM-275	---	9.3	1.8
TRM-280	---	10.	0.7
TRM-285	---	6.7	---
TRM-290	---	9.	2.0
TRM-295	---	3.5	1.9
TRM-300	---	16.	12.5
TRM-305		65.	12.8
TRM-310		31.	1.2
TRM-315	133	16.	9.1
TRM-320		70.	9.6
TRM-325		28.[1]	0.3
TRM-330	390	71.	0.35
TRM-335		4.6[2]	0.35
TRM-340	---	17.[1]	1.2
TRM-345	---	1.9[2]	1.2
TRM-350	---	2.9[3]	---
TRM-355	---	1.7	---

Concentrations in ug/g

TRM 270 in Wilson Reservoir
TRM 350-355 in Guntersville Reservoir
All other sites in Wheeler Reservoir

Unless otherwise noted all samples are six fish composites.

[1] Five fish composite
[2] Four fish composite
[3] Three fish composite

Source: April and May data are from Tennessee Valley Authority. July - Sept. data were collected as part of the current study (see Appendix V - TVA Task 1)
TVA, 1979b.

(2) seasonal cycles in DDTR concentrations, (3) extensive migration of contaminated fish, and/or (4) laboratory variations related to differences in analytical procedures or analytical inaccuracy.

The spring 1979 data indicate substantial contamination of channel catfish from TRM 275 to TRM 340. The late summer-fall data, collected during this study, indicate a much more limited area of contamination from about TRM 300 to the mouth of Indian Creek (TRM 321).

The quality control data generated with these studies has been examined. In all cases samples were split with the EPA laboratory in Athens, Georgia. In the May study, the TVA laboratory results averaged 2.6 times higher than the EPA results. In the fall study, the analyses were conducted by Stewart Laboratories, Inc. (SLI) under contract to TVA. The results averaged 21 percent lower than the EPA results (see the attached Quality Assurance Report for details on the fall results). Assuming that the EPA laboratory held constant throughout this period, one would expect the May results to average 3.3 times the fall results. In fact, the relative error between the fifteen matched pairs of samples in the May and fall data is 126 percent which is equivalent to an average ratio of 4.41 between the May and fall results. The differences noted between laboratories may have been due to slight differences in the analytical procedures utilized or to analytical inaccuracy.

All data from the first 1979 fish survey (April-May) are shown in Table II-49. As noted previously, channel catfish DDTR values are very high. Smallmouth buffalo and white bass also exceeded FDA criteria of 5.0 ppm. Largemouth bass outside of Indian Creek were not contaminated above the FDA limit.

In the second 1979 sampling (May) only channel catfish were sampled and these values were previously presented and discussed.

A summary of results from the third 1979 sampling (fall) is presented in Table II-50. Several items are worth noting. Overall, channel catfish, and possibly blue catfish, are the most susceptible food fish of those tested to DDTR contamination. Smallmouth buffalo are next most susceptible. The situation regarding largemouth bass is not clear. The test results indicate that some contamination is occurring both upstream and downstream of Indian Creek from TRM 315 to TRM 340. The upstream contamination appears to be due to fish migration or movement. Channel catfish and smallmouth buffalo showed no contamination in the Tennessee River upstream of Indian Creek in this sampling.

Bluegill were sampled at all locations and no composite sample showed DDTR above 5 ppm. One composite sample was above 1 ppm and that was from Indian Creek Mile 2 where the composite concentration measured 4.2 ppm with individual fish values ranging from 2.1 to 6.6 ppm. Because of the variance in analytical results, it cannot be statistically concluded that the composite value is below 5 ppm.

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UNCLASSIFIED DACW01-79-C-0224 F/G 13/3 NL

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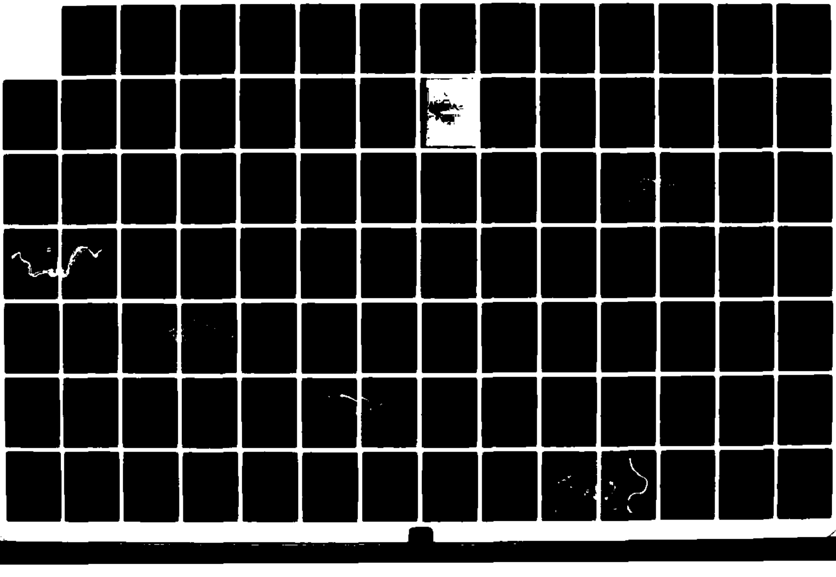

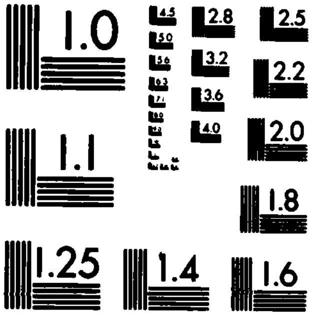

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table II-49. DDT Residue in Fish Samples from Wheeler Reservoir, April-May, 1979

Sample Identification	Location	Concentration, µg/g DDT	DDD	DDE	DDTR
6 Channel Catfish, 4/12/79	TRM 305-321.5	2.1	90	41	133
6 Smallmouth Buffalo, 4/12/79	TRM 305-321.5	0.12	9.8	3.9	13.8
6 White Bass, 4/12/79	TRM 305-321.5	0.55	7.4	3.1	11.05
5 Largemouth Bass, 5/1/79	TRM 305.0-321.4	0.10	0.95	0.82	1.87
6 Channel Catfish, 4/12/79	TRM 322-333.5	<0.01	276	114	390
6 Smallmouth Buffalo, 4/12/79	TRM 322-333.5	0.52	4.0	3.9	8.42
6 White Bass, 4/12/79	TRM 322-333.5	0.55	50	22	72.55
2 Largemouth Bass, 5/1/79	TRM 321.5-334.0	<0.01	1.7	0.88	2.58
6 Channel Catfish, 4/12/79	Indian Creek	0.57	35	14	49.57
6 Smallmouth Buffalo, 4/12/79	Indian Creek	0.07	5.8	2.8	8.67
6 White Bass, 4/12/79	Indian Creek	0.11	4.2	2.3	6.61
1 Largemouth Bass, 5/1/79	Indian Creek	0.10	6.0	2.7	8.80

Table II -50. Summary of DDTR Results of July-October 1979 Fish Survey

Location	Channel Catfish	Smallmouth Buffalo	Largemouth Bass	Bluegill
CCM 2	56(3.3-139)	0.15	0.35[2]	0.25
ERM 5	1.2(0.4-2.3)	1.35	0.05	0.05
ERM 10	0.55	1.1	0.05	0.05
ERM 15	0.4	0.25	0.05	0.05
FCM 5	3.75(0.15-19.1)	0.25	0.15	0.2
FRM 1	0.5(0.1-2.6)	---	0.05	0.05
ICM 2	186(15.5-627)	16.2(2.2-44)	1.4[2]	4.2(2.1-6.6)
LCM 3	4.3	5.4(0.25-1.1)	0.15[2]	0.15
PRRM 1	0.2(0.2-2.6)	0.4	0.05	0.05
SCM 1	1.95	1.1	0.05	0.05
TRM 260	0.6	---	0.1	0.05
TRM 265	---	---	0.05	0.1
TRM 270	1.3	1.6	0.15	0.2
TRM 275	1.8(1.2-10.1)	3.9	0.05[2]	0.15
TRM 280	0.7	2.8	0.05[2]	0.1
TRM 285	---	0.7	0.25	0.05
TRM 290	2.0(0.45-2.2)	5.1(0.25-4.5)	0.15	0.05
TRM 295	1.9	2.1	0.10	0.05
TRM 300	12.5(1.4-46.3)	0.9	0.4	0.05[2]
TRM 305	12.8(1.3-21.0)	0.3	0.15[2]	0.05[2]
TRM 310	1.2	3.2	0.15[2]	0.2
TRM 315	[4]9.1(3.0-40.0)	2.75	9.2[2](0.5-3.1)[1]	0.25
TRM 320	9.6(0.8-22.0)	1.2	2.8	0.7
TRM 325	0.3	1.3	6.0	0.15
TRM 330	0.35	0.9	2.3(0.55-16.1)	0.1
TRM 335	0.35	0.6	7.3(1.9-11.9)	0.05
TRM 340	1.2	0.7	0.8[3]	0.1
TRM 345	1.2(0.8-3.7)	0.5	1.5	0.05
TRM 350	---	---	0.25	0.05
TRM 375	0.15	0.5	0.05	0.05
TRM 400	---	0.6	0.05	0.05

Table II-50. Summary of DDTR Results of July-October 1979 Fish Survey (Continued, page 2)

Location	White Crappie	White Bass	Gizzard Shad	Blue Catfish
CCM 2	0.1	---	---	---
ERM 5	0.05[2]	0.9	---	---
ERM 10	0.05	---	---	---
ERM 15	0.05	0.4	---	---
FCM 5	0.15	---	---	---
FRM 1	0.1	---	---	---
ICM 2	3.5	---	100(40-179)	---
LCM 3	0.15	---	---	---
PRRM 1	0.2	---	---	---
SCM 1	---	1.6	---	---
TRM 260	---	---	0.6	---
TRM 265	---	---	---	0.4
TRM 270	0.1	---	---	---
TRM 275	0.05	---	0.15	---
TRM 280	---	---	---	---
TRM 285	---	0.15	---	3.9
TRM 290	0.05	---	---	---
TRM 295	0.05	0.8	---	---
TRM 300	0.05[2]	---	---	---
TRM 305	---	---	---	---
TRM 310	0.15	---	---	---
TRM 315	---	---	2.8(0.1-37.0)	---
TRM 320	---	---	---	---
TRM 325	---	---	8.1(0.05-32.1)	---
TRM 330	---	---	---	---
TRM 335	---	---	---	---
TRM 340	0.15	---	---	---
TRM 345	0.1	---	1.55	---
TRM 350	0.05	0.2	---	0.6
TRM 375	---	---	---	---
TRM 400	---	---	0.15[2]	---

Notes: First number is DDTR concentration in a six fish composite. Concentration in ug/g

Numbers in parenthesis are range of results from individual fish analyses.

Fillet samples for all except gizzard shad.

TRM 260-270 in Wilson Reservoir

TRM 350-400 in Guntersville Reservoir

All other sites in Wheeler Reservoir

[1] Only two individuals analyzed.
[2] Results may be low - run on 12 December. See Quality Assurance Document.
[3] EPA got 9.4 for this sample.
[4] EPA got 25.4 for this sample.

Limited sampling for white crappie and white bass showed no values exceeding 5 ppm. However, white crappie at Indian Creek Mile 2 cannot be statistically judged as below 5 ppm.

Some analyses were performed on whole body fish samples rather than fillet samples. Actually the fillets and the remaining carcass were analyzed separately and the whole body DDTR value calculated as the weighted average of the two results. In Table II-51 the average and range of the whole body DDTR results are compared to the composite fillet results. In most cases the whole body concentrations are much higher than the fillet concentrations. The whole body analyses were performed in an effort to determine the relationship between whole body and fillet results so that historical whole body data could be more meaningfully compared to current fillet data. The data indicate that no fixed relationship exists between the two results, particularly across species. This may be due in part to the wide variance that exists between blind split whole body samples (see the Quality Assurance Report).

In hopes of further clarifying the situation regarding the level of contamination of fish in the TR system a sampling and analysis program was conducted in June-July 1980 and the results are summarized in Table II-52. Channel catfish, smallmouth buffalo, and largemouth bass were sampled. Complete results are given in Appendix VI. Attempts were made to collect largemouth bass at more than two stations but either no or insufficient samples were obtained. Analyses were first conducted on filet composites of six fish. Analyses were performed by WAR with split samples run at three other laboratories; EPA, TVA, and SLI. No differences in results was detected between the laboratories (see Quality Assurance Document, Appendix VI). Later analyses were performed on all individual fish samples by WAR with samples being split with EPA. Again, no differences in results between laboratories were detected.

These results indicate that channel catfish have DDTR levels above 5 ppm from TRM 275 to 340 (essentially throughout Wheeler Reservoir). The contamination levels generally agreed with those found in the May 1979 sampling.

Channel catfish were sampled in three tributaries of Wheeler Reservoir. At Flint Creek Mile 5, unusually high levels of contamination were found. The reason for this is unknown.

Smallmouth buffalo were sampled between TRM 280 and 340. Below IC (TRM 280-320) 17 of the 30 fish (57%) analyzed had DDTR levels equal to or above 5 ppm. Above IC none of 6 fish were contaminated above 5 ppm.

Of 12 largemouth bass tested from TRM 285 and 345, only one had DDTR levels above 5 ppm.

The June-July 1980 data indicate a more severe contamination problem than the July-October 1979 data, particularly as regards channel catfish. However, three of the four surveys conducted in 1979-80 indicated significant contamination of channel catfish in the TR. More limited

Table II -51. Summary of Whole Body Fish Analyses, Fall 1979

	Concentration DDTR, ug/g		
	Indian Creek Mile 2	Tenn. River Mile 315	Tenn. River Mile 345
Channel Catfish			
Whole Body Average	367	39.9	4.5
Whole Body Range[1]	40-601	7.2-102.5	1.9-9.8
Filet Composite	186	9.1	1.2
Largemouth Bass			
Whole Body Average	48.4	184.4	25.3
Whole Body Range[1]	24.9-69.4	184.4[2]	0.8-79.0
Fillet Composite	1.4[2]	9.2[2]	1.5
Bluegill			
Whole Body Average	19.7	3.8	0.8
Whole Body Range[1]	5.4-40.6	0.9-8.4	0.0-2.6
Fillet Composite	4.2	0.25	0.5

[1] For all samples except largemouth bass at TRM 315 (2 individual fish available) the range is for five or six individual fish samples.

[2] This value may be low. Processed on 12 December 1979. See Quality Assurance Document.

Table II-52. Summary of DDTR Results of June-July 1980 Fish Survey

Location	Species	Composite Sample	Individual Fish Samples Average	Individual Fish Samples Range
TRM 275	CC	9.3	11	4.5-25
TRM 280	CC	8.5	8.0	5.5-13
TRM 285	CC	15	9.5	2.8-19
TRM 290	CC	15	13	3.5-22
TRM 295	CC	15	14	4.7-31
TRM 300	CC	9.0	11	3.0-18
TRM 305	CC	10	14	9.7-22
TRM 310	CC	9.2	9.2	3.8-17
TRM 315	CC	5.4	7.6	3.3-13
TRM 320	CC	120	120	13-360
TRM 325	CC	100	190	0.74-1100
TRM 330	CC	34	32	2-140
TRM 340	CC	25	33	1.5-180
FCM 5	CC	50	45	10-150
LCM 3	CC	14	13	2-28
SCM 1	CC	5.8	5.0	2.6-9.1
TRM 280	SMB	6.4	3.9	2.3-6.8
TRM 290	SMB	12	10	3.4-21
TRM 300	SMB	6.3	5.0	1.3-10
TRM 310	SMB	4.3	4.0	1.4-6.1
TRM 320	SMB	25	24	0.43-48
TRM 330&340	SMB	0.89	0.95	0.25-2.5
TRM 285	LMB	0.38	0.36	0.11-0.80
TRM 345	LMB	2.1	2.4	0.35-7.4

Concentrations in ug/g

CC=Channel Catfish, SMB=Smallmouth Buffalo, LMB=Largemouth Bass.

Six individual fish were taken at each sampling location. All analyses were in fillet samples.

data on smallmouth buffalo indicate that this species is contaminated particularly at and downstream of IC. Data on largemouth bass showed lesser overall contamination levels but some individual fish had relatively high DDTR levels.

5.3.2 Method of Contamination

Clarification regarding both the source and mechanism of DDTR contamination of fish in the TR is important in assessing any proposed clean-up plans. Several possibilities exist: 1) DDTR in the TR could be coming from the IC-HSB system and possibly other sources, 2) Fish in the TR could be becoming contaminated due to low level concentrations of DDTR in the water and/or sediments of the TR, 3) Fish in the TR could be becoming contaminated due to migration in and out of the IC-HSB system.

Sediment analyses clearly show the IC-HSB system as being a major source of DDTR. Further, it has been shown that at least some DDTR is being transported out of the IC-HSB system to the TR. Sediment and water analyses for the TR and tributaries indicate no other significant source of DDTR. The only indication of another source of significant DDTR contamination is the elevated DDTR levels in fish sampled in July-August 1980 from Flint Creek Mile 5. No explanation for this is known. Thus, the best evidence seems to be that the HSB-IC system is a major source of contamination and possibly the only significant source.

The mechanism of contamination of fish in the TR is important not only in understanding the present situation but also in predicting the effectiveness of any clean-up procedure. Of particular importance is whether contamination is occurring by migration of fish from IC and HSB or in situ due to exposure to very low levels of DDTR in sediments and/or water. An examination of the pattern of contamination for individual fish in the June-July 1980 survey gives some indication of the mechanisms involved. Below IC from TRM 315 to 275 (9 samples) the average DDTR in individual channel catfish was 10.8 ppm with a range of 2.8 to 3.1. Of the 54 individual fish from this area, 44, or 81 percent, had DDTR levels greater than 5 ppm. At TRM 320 (1 mile from the mouth of IC) all fish had DDTR levels above 13 ppm. Above Indian Creek (TRM 325-340) 50 percent of the individuals had DDTR levels greater than 5 ppm. Thus, a more consistent pattern of contamination was found below IC in the TR. Above IC the variation in DDTR values between individual fish was much greater than below IC. The isolated occurrences of very high values (>100 ppm) suggests an upstream migration from the IC-HSB area.

Further evidence of possible mechanisms involved can be obtained by examining the low values at each location. Below IC from TRM 315 to 275 the average of the lowest value found at each location is 4.5 ppm DDTR whereas above IC the lowest values average 1.4 ppm DDTR. This suggests that there is sufficient DDTR in the TR downstream of IC to produce a base level of contamination in channel catfish very near the FDA limit. Upstream, base levels are much lower and contamination by migration is indicated.

TVA has conducted fish tagging and movement studies in Wheeler Reservoir (TVA, 1978g). Sufficient recoveries were made for six species to relate distance from release point as a function of time since release. A summary of the data is as follows:

Distance from Release Point after 50 Days (miles)

Species	20% of Fish >	5% of Fish >
Channel catfish	7.6	13.9
Blue catfish	4.7	12.7
Flathead catfish	5.8	8.4
White crappie	8.8	21.2
White bass	22.7	38.3

For all species except flathead catfish, 5 percent of the population would be expected to be more than 12.7 miles from the release point after 50 days. The white crappie and white bass moved longer distances than the catfish.

Thus while there is some evidence to support the hypothesis that migration is contributing to contamination upstream of IC, evidence also exists that, downstream of IC, DDTR in the Tennessee River is contributing to fish contamination. Six sediment samples from Wheeler Reservoir (TRM 275-300) and three samples from Wilson Reservoir (TRM 260-270) all contained low but detectable amounts of DDTR. The highest DDTR concentration detected was only 21 percent above analytical detection limits. Sediment samples upstream of Indian Creek (TRM 325, 350, and 375) had no detectable DDTR. This suggests that the source of the DDTR is IC. However, data on total DDTR in water do not implicate IC as the sole source of DDTR. In July-August 1979 five samples of near bottom waters from TRM 270 to 350 showed no DDTR. However, in December 1979, a second sampling showed detectable amounts of total DDTR in near bottom waters (0.08 to 1.9 ug/l) in 7 of 10 samples with 4 of the positive samples coming from above IC.

The higher base levels of DDTR in channel catfish below IC indicate some *in situ* contamination in that area. Some laboratory work has been done in an attempt to understand the uptake mechanisms involved. Macek and Korn (1970) studied DDTR uptake from food and water by fingerling brook trout and concluded that food was the most significant DDTR uptake route. However, Murphy (1971) using the mosquito fish, *Gambusia*, reported that direct uptake of DDT from water is of considerable importance especially for small fish. In a later study on fathead minnows Jarvinen (1976) concluded that the DDT bioconcentration factor from water was 100,000 whereas it was only 1.2 from food. If the 100,000 bioconcentration factor is valid for fish in the TR, a water concentration of 0.05 ug/l would be sufficient to produce a 5 ppm level in fish. A 0.05 ug/l level in water is very low, below the analytical detection limit utilized in the current survey.

Studies in Oklahoma showed that catfish less than 300 mm. long fed primarily on invertebrates while larger sizes were piscivorous (Jearld and Brown, 1971). Walburg (1975) noted that catfish 15-19 mm. long fed primarily on microcrustacea and larger fish ate both microcrustacea and aquatic insects. Fish larger than 35 mm. fed primarily on insects. The preferred species were chironomids and immature mayflies. Both these forms inhabit sediments.

At present there is insufficient information available to fully explain either why channel catfish seem to be more contaminated than other species tested or precisely how the contamination occurs.

5.4 BIRDS

Analyses were conducted to ascertain the level of DDTR in selected birds inhabiting the studv area. Those species were Green Herons and Wood Ducks which are local residents and therefore reflect, at least in a relative sense, acute exposure to the pesticide.

Table II-46 is a summary of data showing the amount of residue expressed as means in vertebrates (excluding fish) collected in the study area. Mean DDTR values for individuals inhabiting the Huntsville Spring Branch-Indian Creek environment were higher than for individuals from other areas. Green Herons from Huntsville Spring Branch and TRM 330 had 4.3 and 2.5 ppm which was almost an order of magnitude higher than levels in herons from the remainder of the study area. (DDTR concentrations for

Green Herons are believed to be biased low--see Quality Assurance Section of this report). Wood Ducks showed a similar pattern. Two collections of Wood Duck eggs on Wheeler Wildlife Refuge contained an average of 0.2 and 2 ppm of DDTR.

The Patuxent Wildlife Research Center, a part of the Fish and Wildlife Service, has been concerned about DDT contamination of migratory waterfowl utilizing the Wheeler Refuge. They indicate that waterfowl wintering at the Refuge migrate from as far north as Ontario and impaired reproduction caused by DDTR is likely (O'Shea, et al., 1980).

Personnel from the Patuxent Research Center have made recent collections of biota in the study area. Mallard ducks had geometric mean and maximum DDTR values of 4.0 and 480 ppm for carcass samples; 0.67 and 150 ppm for muscle samples. Data from the National Pesticide Monitoring Program on duck wings shows high residue levels in samples from Alabama. Fleming (1980) reports on DDTR in mallard wings collected during the 1978-1979 season. Wing pools from Limestone and Madison counties which include Wheeler Reservoir had residues that averaged 10.8 and 18 times higher respectively than the combined average of all other (Alabama) counties surveyed. These results are presented in Table II-53.

Crows were also included in these recent Fish and Wildlife Service samples and contained geometric mean and maximum DDTR concentrations of 4.0 and 48 ppm respectively in muscle tissue. O'Shea et al. (1980)

Table II-53. DDTR in Mallard Wings from Alabama 1978-79 Hunting Season[1]

County	Statistic	DDTR Concentration, ppm Wet Weight			
		Immature Female	Immature Male	Adult Female	Adult Male
Lauderdale Colbert Lawrence	Mean N	0.36 1	--- ---	0.31 1	--- ---
Limestone	Mean N	0.95 2	1.04 4	0.02 1	7.1 3
Madison	Mean N	3.43 2	4.84 2	--- ---	6.09 1
Jackson Marshall Morgan	Mean N	0.52 1	--- ---	0.33 1	0.44 2
Green Sumter Choctaw	Mean N	--- ---	0.48 2	--- ---	--- ---
Clarke Wilcox Washington	Mean N	0.03 1	0.02 1	0.07 1	0.17 2
Mobile Baldwin	Mean N	--- ---	0.06 1	--- ---	0.19 1
N. County Pool	Mean N	0.81 1	0.127 3	0.69 2	--- ---
S. County Pool	Mean N	0.08 2	--- ---	0.7 1	--- ---
Controls[1]	Mean N	0.07 5	--- ---	--- ---	--- ---

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[1] Each sample consisted of 5 wings.

[2] Control wing pools were comprised of wings from 5 juveniles, without regard to sex. Wings were obtained from pen-raised mallards.

Source: Fleming (1980)

interpret this data as indicating a potential for greater effects higher in the food web of species in the Wheeler Refuge especially in fish eating birds. These authors cite the decline of the Double-crested Cormorant at Wheeler Wildlife Refuge (see Section 1.3.3 for population trends).

However, Wheeler Wildlife Refuge personnel have indicated that populations of the Double-crested Cormorant have been increasing in recent years (Huntsville Times, 1979). The reason for the success of this species may be a combination of factors. There is qualitative evidence from Wheeler Refuge personnel that the increase in numbers of the Double-crested Cormorant is related to a decrease of exposure to DDT. There is also some evidence that the resurgence of the species is a phenomenon occurring in the midcontinent of the United States. Populations of cormorants have been low for years in this section of the country and have been on the "Blue List" published by American Birds for this reason. (This list published annually includes species of birds which appear to be declining in number, either in species range proportion or regionally.).

In reviewing the Blue List for past years, regional population trends are revealed about cormorants. The Blue List for 1977 (Arbib, 1976) states that delisting was favored by coastal region respondents, while strong sentiment remained in the midcontinent for retention. At that time it was stated that inland pesticide pollution had been a factor in population declines while marine breeding cormorants were not so affected.

In 1978 (Arbib, 1977) the species was retained on the Blue List but observer opinions were markedly geographic. Those along the eastern seaboard and west coast were unanimous in favor of deletion; the midcontinent was virtually solid for retention.

The following year (Arbib, 1978) the same regional differences were apparent. "Nesting season reports seemed to suggest an improvement in the fortunes of this species, which would seem to contradict the 58 percent of observers now favoring retention. Strongest for retention were Ontario, Niagara-Champlain, middle western prairies, and northern Rocky Mountain regions. West of the great plains no region favors retention."

The current 1980 List (Arbib, 1979) contains the Double-crested Cormorant with a statement saying the species continued to show declines in some areas and modest to good gains elsewhere. The greatest support for continued listing came from the midwestern prairie region, however the Great Lakes region reported that the species was "doing very well currently. Numbers are up and increasing each year. Most significantly, breeding is up."

Mr. Dan Bystrack (1980) who is in charge of the Breeding Bird Survey at the Migratory Bird and Habitat Research Laboratory at Laurel, Maryland feels that part of the population declines for this bird is related to a nesting site problem. He indicated that inland birds prefer to nest in dead trees and breeding success may be correlated with a paucity of sites. The increase or decrease in cormorants at Wheeler Refuge in relation to the midcontinent region depends to a large extent on the migratory patterns of these birds. Mr. Tom Atkeson (1980) states that the Wheeler Refuge population does not breed locally and therefore represents migrants. He could not be definitive concerning the lessened impact of DDT on cormorants at Wheeler, but did feel that the reduction of cormorants was due to use of pesticides nationally and the curtailment of their use has been a large factor in the successful increase in these birds at Wheeler Refuge. There can not be a separation as to local effects at Wheeler, however.

5.5 MAMMALS

Collections of shrews and muskrats were made from TRM 271 to 402. The results from these samples are presented in Table II-46 and show shrews to contain elevated levels of DDTR. Maximum concentration was 52 ppm in Huntsville Spring Branch. Lowest amounts were upriver and averages 0.68 ppm. Shrews collected from TRM 271 to 311 also contained DDTR in the part per million (ppm) range (2-7) which may represent residues from agricultural use formerly used in the drainage basin.

Muskrats contained much lower levels than shrews and the difference in food habits of these species probably accounts for this result. The range of DDTR in muskrats varied from 0.056 to 0.26 ppm with the highest concentration in samples from Huntsville Spring Branch.

It should be noted that the DDTR results for shrews and muskrats are believed to be biased low (see the Quality Assurance Section of this report).

Samples of cottontail and swamp rabbits collected by the Fish and Wildlife Service (O'Shea et al., 1980) contained geometric mean and maximum concentrations in muscle tissue of 0.27, 0.52 and 0.25, 0.58 ppm respectively. On a lipid weight basis the maximum DDTR was 79 ppm in both species and the authors point out that this concentration exceeds established tolerances for human consumption.

5.6 OTHER VERTEBRATES

Snapping turtles and water snakes constituted other aquatic related vertebrates that were analyzed for DDTR. Both of these species contained maximum levels in Huntsville Spring Branch (0.45 and 1.8 ppm respectively). DDTR in turtles varied from 0.053 ppm at TRM 402 to 0.45 ppm in Huntsville Spring Branch.

5.7 VASCULAR PLANTS

Two rooted aquatic vascular plants were included in the sampling. These were buttonbush (Cephalanthus occidentalis) and halberd-leaved marshmallow (Hibiscus militaris). The floodplain of Huntsville Spring Branch and Indian Creek is abundant with buttonbush growths and the plant is a food source for species of waterfowl, especially wood ducks. Duckweeds consisting of mixed species of <u>Lemna</u> and <u>Spirodela polyrhiza</u> were also collected for analysis. Based on arithmetic means buttonbush samples ranged from 0.005 ppm at TRM 359 to 0.265 ppm in Huntsville Spring Branch at mile 2.5 (see Table II-50). <u>Hibiscus</u> exhibited a similar trend with a low of 0.004 ppm at TRM 359 to 0.786 ppm at HSB Mile 2.5. Duckweed was sampled only at HSB Mile 4.5 and 5.6. These values varied from 5.6 to 0.07 ppm, respectively.

REFERENCES

Alabama Department of Agriculture and Industries. 1971. Pesticide Residue content (including PCB) of Fish, Water and Sediment Samples Collected in 1971 From Aquatic Sites in Alabama Under Terms of a Contract with Alabama Department of Conservations Game and Fish Division.

Alabama Department of Conservation. 1970. Letter - Spencer to Hooper. Pesticide Residues in Fish from the Tennessee River.

American Environmental Health Association. 1977a. Drinking Water Surveillance Program. Part of unidentified report.

Arbib, R. 1976. The Blue List for 1977. American Birds 30(6):1031-1039.

Arbib, R. 1977. The Blue List for 1978. American Birds 31(6):1087-1096.

Arbib, R. 1978. The Blue List for 1979. American Birds 32(6):1106-1113.

Arbib, R. 1979. The Blue List for 1980. American Birds 33(6):830-835.

Atkeson, T. 1979. Personal Communication. Director, Wheeler National Wildlife Refuge, AL.

Atkeson, T.Z. 1980. Personal Communication.

Bellrose, F.C. 1976. Ducks, Geese and Swans of North America. Stackpole Books, Harrisburg, PA.

Boschung, H. (ed.). 1976. Endangered and Threatened Plants and Animals of Alabama: A Symposium. Bull. Alabama Mus. Nat. Hist., University, Alabama, University, AL., 93 pp.

Bouchard, R.W. 1976. Crayfishes and Shrimps. p. 13-20. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University, AL., 92 pp.

Bryant, D. 1979. Personal Communication. Arsenal Forester, Redstone Arsenal, Huntsville, AL.

Burt, W.H. and R.P. Grossenheider. 1952. A Field Guide to the Mammals. Field Marks of All Species Found North of the Mexican Boundary. Houghton Mifflin Co., Boston, MA., 284 pp.

Bystruck, D. 1980. Personal Communication.

Center for Disease Control. 1979. Letter - Kreiss to Foster: DDT Levels in Fish.

Chemical Demilitarization and Installation Restoration. 1977. Sampling and Analysis Data Redstone Arsenal, AL.

Chemical Demilitarization and Installation Restoration. 1978. DDT Contamination Data by Group Location.

Conant, R. 1958. A Field Guide to Reptiles and Amphibians of the U.S. and Canada east of the 100th Meridian. Houghton Mifflin Co., Boston, 366 pp.

Department of Defense. 1977. Installation Assessment of Redstone Arsenal, AL. Record Evaluation Report No. 118.

Dusi, J.L. 1976. Mammals. p. 88-92. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University, AL., 92 pp.

Environmental Protection Agency. 1978. Letter - Bennett to Holley: DDT Residues in Sediments.

Environmental Protection Agency. 1979. Public and Private Water Supply Investigation, Redstone Arsenal and Vicinity, Huntsville, Alabama Area, Oct. 1, 1979. Environmental Protection Agency, Atlanta, GA.

Environmental Protection Agency. 1980. Phase II, Monitoring Well Investigation, Redstone Arsenal, Huntsville, Alabama, Feb. 5, 1980. Environmental Protection Agency, Atlanta, GA.

Food and Drug Administration. 1977. Memo - Boston to Lawrence: DDT Levels in Fish.

Food and Drug Administration. 1979a. Letter - Blough to Hildreth: Analysis of Fish Taken From Tennessee River in Northern Alabama.

Food and Drug Administration. 1979b. Letter - Cruse to State of Alabama Dept. of Public Health: Analytical Results of Samples Taken by FDA From Fish Markets in the Area of the Tennessee River.

Federal Water Quality Administration. 1970. Levels of DDT Pollution from Olin Matheson Corp., Redstone Arsenal, AL.

Fleming, W.J. III. 1980. Letter to L.R. Green COE - Mobile District. Report Summaries of DDT Residues in Woodducks and Eggs and in Waterfowl Wings.

Freeman, J.D., A.S. Causey, J.W. Short and R.L. Haynes. 1979. Endangered, Threatened and Special Concern Plants of Alabama. Dept. of Botany and Microbiology, Dept. Ser. No. 3, Auburn Univ., Auburn, AL., 25 pp.

Geological Survey of Alabama. 1973. Environmental Geology and Hydrology, Madison County, Alabama, Triana Area. Geological Survey of Alabama, University, AL.

Goodrich, C. 1944. Certain Operculates of the Coosa River System. Nautilus 58:1-10.

Holsinger, J.R. 1980. Personal Communication. Professor Biology, Old Dominion Univ., Norfolk, VA.

Hudson, H.E., Jr. 1976. Differential-Head -- Lake Level Relationships in the Middle-Gulf Area, Florida. Groundwater, Vol. 14, No. 5. Sept.-Oct.

Huntsville Times. 1979. DDT Effects on Wheeler Wildlife Refuge, Oct. 28.

Jarvinen, A.W., M. J. Hoffman, and T.W. Thorslund. 1976. Toxicity of DDT Food and Water Exposure to Fathead Minnows. U.S. Environmental Research Laboratory. EPA-600-3-76-114. Duluth, MN.

Jearld, A., Jr. and B.E. Brown. 1971. Food of the Channel Catfish (Ictalurus punctatus) in a Southern Great Plains Reservoir. The American Midland Naturalist. (86) 1:110-115.

Keeler, J.E. 1976. Birds. p. 80-87. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University AL., 92 pp.

Lewis, J.J. 1980. Personal Communication. Graduate Student, Univ. Louisville, KY.

Macek, K.J. and S. Korn. 1970. Significance of the Food Chain in DDT Accumulation by Fish. J. Fish. Res. Board Can. 27:1496-1498.

Marion, Wayne. 1980. Personal Communication. Univ. of Fla.

Mount, R.H. 1976. Amphibians and Reptiles. p. 66-79. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University, AL., 92 pp.

Murphy, P.G. 1971. The Effect of Size on the Uptake of DDT from Water by Fish. Bull. Env. Contamination and Toxicology. 6(1):20-23.

Nickerson, M.A. and C.E. Mays. 1972. The Hellbenders. Milwaukee Mus. Publ. in Biol. and Geol., No. 1, viii:106 pp.

O'shea, T.J., W.J. Fleming III, E. Cromartie. 1980. DDT Contamination at Wheeler National Wildlife Refuge. Science 209:509-510.

Ramsey, J.S. 1976. Freshwater Fishes. p. 53-65. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University, AL., 92 pp.

Reeves, W.C. n.d. Fishes of the Wheeler National Wildlife Refuge. Alabama Game and Fish Div., mimeograph, 6 pp.

SAS Institute, Inc. 1979. SAS User's Guide, 1979 Ed. SAS Institute, Inc., Raleigh, NC.

Smith, H.M. 1978. A Guide to Field Identification Amphibians of North America. Golden Press, NY, 160 pp.

Speake, D.W. and R. Mount. 1974. Amphibians and Reptiles of the Wheeler National Wildlife Refuge. USDI, Fish and Wildlife Serv., Bur. Sport Fish. and Wildl.

Sproul, A.E., Jr. 1972. Findings of the Speleological Survey of Redstone Arsenal, Huntsville, Alabama. U.S. Army Report ATSMM-TA, 5 pp.

Stansbery, D.H. 1976. Naiad Mollusks. p. 42-52. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University, AL., 92 pp.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., NY. 481 pp.

Stein, C.B. 1976. Gastropods. p. 21-41. In: Boschung, H. Endangered and Threatened Plants and Animals of Alabama. Bull. Alabama Mus. Nat. Hist., University, AL., 92 pp.

Tennessee Valley Authority. 1963. Memorandum - Davidson to Derryberry: Waste Disposal Practices at Redstone Arsenal.

Tennessee Valley Authority. 1966. Memo - Morris to Davidson: Redstone Arsenal Waste Discharges.

Tennessee Valley Authority. 1977. Memo - Holley to Crossman: DDT Determinations (in Water, Sediment and Clams).

Tennessee Valley Authority. 1978a. Letter - Moore to Traina: Report on DDT Residues in Sediment and Fish in the Vicinity of Redstone Arsenal (November 15).

Tennessee Valley Authority. 1978b. Memo - Holley to Brooks: DDT Analysis of Sediment and Fish (October 13).

Tennessee Valley Authority. 1978c. Memorandum - Barnes to Ruane. Pesticide Residue Monitoring, Pilot Program.

Tennessee Valley Authority. 1978d. Memo - Holley to Brooks: DDT Determination of Fish (July 3)

Tennessee Valley Authority. 1978e. Memo - Holley to Brooks: DDT Determination of Fish (August 11)

Tennessee Valley Authority. 1978f. Letter - Brooks to Hutchinson: DDT Residues in Fish Collected by TVA in 1977 (December 6)

Tennessee Valley Authority. 1978g. Browns Ferry Nuclear Plant Preoperational Fisheries Resource Report. Chapter 3. Prepared by Division of Forestry, Fisheries, and Wildlife Development, Tennessee Valley Authority, Norris, TN.

Tennessee Valley Authority. 1979a. Letter - Brye to Hildreth: Attachment Appendix E, Fish Collection and Analysis (July 9).

Tennessee Valley Authority. 1979b. Letter - Moore to Traina: DDT Concentration in Fish and Sediment Collected in September 1978 and January 1979.

Thompson, E.G. 1975. Final Report on Endangered/Threatened Mollusk Species of Streams of the Coastal Plain Region of Southeastern United States. Unpubl. Report submitted to the Office of Endangered Species, Fish and Wildlife Serv., U.S. Dept. of Interior, Washington, DC.

U.S. Army Corps of Engineers, Mobile District. 1966. Industrial Waste, Stream Pollution Survey, Redstone Arsenal, AL, Final Report.

U.S. Army Environmental Hygiene Agency. 1965. DDT Pollution at Redstone Arsenal.

U.S. Army Environmental Hygiene Agency. 1970. Sanitary Engineering Survey and Industrial Waste Special Study, 24-030-70/71. Redstone Arsenal, AL. 20 April-1May, 1970.

U.S. Army Environmental Hygiene Agency. 1978. Water Quality Engineering Special Study 24-0044-78. Evaluation of Environmental Degradation from Prior DDT Waste Disposal, Redstone Arsenal, AL.

U.S. Department of Interior. 1979a. Birds of the Wheeler National Wildlife Refuge. USDI, Fish and Wildlife Serv. Pamphlet RF43660-2, Aug. 1979.

U.S. Department of Interior. 1979b. Endangered and Threatened Wildlife and Plants. Federal Register, Vol. 44(12):3636-3654.

U.S. Department of the Army. 1978. Letter - Dall to Traina: DDT Levels in Ducks.

U.S. Fish and Wildlife Service. 1974. Letter - Towns to Thoman, dated July 7, 1964.

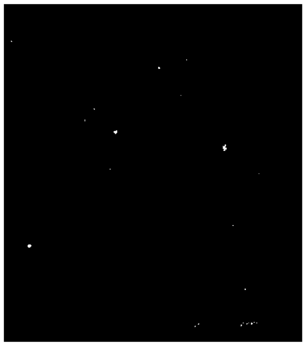
U.S. Fish and Wildlife Service. 1979. Population Surveys of Birds in Wheeler Wildlife Refuge.

U.S. Public Health Service. 1964. Stream Pollution, Industrial Wastes Survey, Redstone Arsenal, AL.

U.S. Public Health Service. 1965. Letters from Rogers to Henry: Results of Analysis for Water and Mud Samples from Redstone Arsenal and Results of Analysis for Chloral, Monochlorobenzene and DDT on samples of water from Indian Creek and Redstone.

Varnedoe, W.W., Jr. 1980. Alabama Cave Survey. Photocopied notes. Alabama Cave Survey, 5000 Ketova Way, Hunstville, AL.

Walburg, C.H. 1975. Food of Young-of-Year Channel Catfish in Lewis and Clark Lake, a Missouri River Reservoir. The American Midland Naturalist. 93(1):218-221.



III. APPENDIX III: ALTERNATIVES FOR MITIGATION OF DDT CONTAMINATION IN HUNTSVILLE SPRING BRANCH AND INDIAN CREEK

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III. APPENDIX III: ALTERNATIVES FOR MITIGATION OF DDT CONTAMINATION IN HUNTSVILLE SPRING BRANCH AND INDIAN CREEK

1.0 INTRODUCTION

Six alternatives are presented for mitigation of DDTR contamination in HSB and IC. They are:

A) Natural Restoration,
B) Dredging and Disposal,
C) Out-of-Basin Diversion and Removal of Contaminated Sediments,
D) Out-of-Basin Diversion and Containment of Contaminated Sediments,
E) Within-Basin Diversion and Removal of Contaminated Sediments, and
F) Within-Basin Diversion and Containment of Contaminated Sediments.

These alternatives do not deal with DDTR contamination in the TR. Concentrations of DDTR in the TR sediments are approximately two orders of magnitude below those in IC, ranging from nondetectable to 0.2 ppm compared to typical concentrations of 10 to 30 ppm in IC sediments. Because of these low concentrations and the large area over which lowlevel contamination is dispersed in the TR, mitigation alternatives there are impractical. A thorough discussion of the areal distribution of DDTR contamination appears in Appendix II. The relatively high (10 to 30 ppm) concentrations of DDTR in IC channel sediments warrant consideration of mitigation alternatives in IC upstream to the HSB confluence. It is apparent that this level of contamination is a major source of DDTR in fish inhabiting IC and the TR (see Appendix II, Section 5.3 for a thorough discussion of this subject). Due to the flows encountered in IC and the infeasibility of containment alternatives there, the only practical means of dealing with this contamination is by dredging the sediments. With the exception of the natural restoration alternative, all alternatives presented include the option to dredge IC in addition to mitigating contamination in HSB.

Presentation of the alternatives will begin with a discussion of relevant properties of DDT and physical characteristics of the site. These considerations are of paramount importance in assessing the effectiveness and environmental acceptability of the alternatives.

Alternatives B through F are centered around one or more of four major physical actions; dredging and disposal, an out-of-basin diversion of HSB, a within-basin diversion of HSB, and in-place containment of contaminated sediments. Other methods for containment, stabilization, and detoxification of contaminated sediments which were evaluated but dismissed for various reasons are discussed in Section 6.2. To avoid redundancy in discussing the alternatives, the four major proposed actions will be discussed first on an individual basis.

Areawide environmental monitoring and legislation, regulations, and permitting associated with the alternatives will be discussed in two separate sections following discussion of the four major physical actions.

The theory, design, construction, and cost of each alternative will then be discussed in the following section. Discussion of major actions associated with each alternative will be referenced to the earlier discussions of the action. In the case of dredging, the action will be modified according to the areal extent required for each alternative, with costs adjusted accordingly.

Following discussion of the alternatives will be separate sections dealing with cultural resources impacts, environmental impacts, and predicted effectiveness associated with the alternatives.

2.0 CHARACTERISTICS OF DDT-SEDIMENT ASSOCIATION

2.1 INTRODUCTION

The approach taken in this study is to design a technically feasible and environmentally sound course of action with respect to alternatives for removal, containment, and disposal of DDTR-contaminated sediments. The effectiveness of each alternative is dependent on the properties of DDTR and the sediments with which it is associated. An in-depth discussion of the physical and chemical properties of DDTR is given in Appendix I. The purpose of this section is to describe those properties which form the basis of the removal, containment, and disposal alternatives presented; and to cite laboratory and field evidence in the literature to substantiate the predicted effectiveness of proposed alternatives.

2.2 LITERATURE REVIEW

All DDTR isomers are extremely hydrophobic, their solubility in water being on the order of 1.2 ppb (Harris, 1970). When present in an aqueous medium, DDTR will adsorb strongly to solid materials by hydrogen bonding and van der Walls forces (Choi and Chen, 1976; Huang and Liao, 1970; Mang et al., 1978). In aquatic systems, the major adsorbents for DDTR are clay minerals, iron and manganese hydrated oxides, and organic material (Mang et al., 1978).

Numerous studies have been conducted to investigate the leaching characteristics of DDTR from dredged materials and through soils. Huang and Liao (1970) found that very little DDTR could be leached from a montmorillonite clay into distilled water. Mang et al. (1978) studied the leaching potential of six DDTR isomers in dredged material and through soils using laboratory columns. Though present in significant concentrations in the solid phase, concentrations of all six isomers in the interstitial water were below detection limits of the analytical technique used. Detection limits for the various isomers ranged from 8 to 26 ppb. Yu and Chen (1978) analyzed liquid and solid phase concentrations of 6 DDTR isomers in 40 samples taken from various dredged material disposal areas. Though present in the solid phase at concentrations up to 850 ppb, DDTR was not detectable in the liquid phase. The authors concluded that DDTR is transported only by adsorption and transport with sediment particles, and that it will not leach out from dredged material

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Other investigations of DDTR migration into the water column from contaminated sediments and during actual or simulated aquatic disposal confirm the strong tendency of DDTR to remain associated with the solid phase in an aqueous medium. Burks and Engler (1978) reported that no soluble chlorinated hydrocarbon pesticides were found at the detection limits (0.01 ppb) during simulated aquatic disposal tests performed in laboratory columns. Krizek et al. (1976) reported DDTR concentrations of 0.5 ppb in supernatant water overlying dredged slurries with an average of about 100 ppb DDTR. A similar study by Krizek et al. (1973) showed DDTR concentrations of 1 to 2 ppb in water overlying dredged material with DDTR concentrations ranging from 20 to 200 ppb. Elutriate tests on Houston ship channel sediments containing 12 and 34 ppm of o, p' and p, p' DDT isomers, respectively, showed elutriate concentrations of the isomers less than 2 ppt (Lee et al. 1975). Similar results were reported for sediments sampled at various locations throughout the United States, regardless of their organic contents.

Elutriate tests on HSB and IC channel sediments, performed under Task 4 of the TVA workplan showed much higher DDTR concentrations in the elutriate than did the studies cited above. Elutriate total DDTR concentrations for 16 sediment samples taken from HSB and IC ranged from 0.57 to 465 ppb, with a mean of 79 ppb. No significant correlation exists between elutriate and sediment DDTR concentrations for those samples. The high elutriate concentrations are a result of both high concentrations of DDTR in the sediments and fine-grain suspended sediment passing the glass fiber filter and remaining suspended after centrifuging. DDTR reported in the elutriate is associated with these suspended fines, as the solubility of DDT in water is only about 1.2 ppb. Though the elutriate test gives no quantitative indication of the concentration of DDTR to be expected in the water column near or downstream from the dredge, they do indicate the potential for significant suspension of fine-grain sediments and DDTR into the water column during dredging and the need for minimizing that potential.

In a study conducted by McCall et al. (1979), the mobility of DDT and various other chemicals in soil was correlated with soil sorption coefficients of the chemicals. Soil sorption coefficients were estimated using reverse phase high performance liquid chromatography (Swann et al., 1979). Data from laboratory column leaching tests were used to develop the following mathematical relationship:

$$R = \frac{1}{K_d(1-f^{2/3})d_s}$$

where $R = \frac{\text{cm. moved by chemical}}{\text{cm. of water entering soil}}$

$$\frac{\text{g chemical/g soil}}{\text{g chemical/g water}},$$

f = pore fraction of the soil, and

d_s = bulk density of the solids.

The soil sorption coefficient, K_d, was observed to increase with increasing percentages of fine-grained material and organic matter in the soil. Sorption coefficients for DDT were given for three soils, all of which had significantly lower percentages of organics and fine-grained material than the sediments in HSB or IC. The smallest of the three given sorption coefficients was selected to give a conservative calculation of maximum leaching potential of DDTR from material dredged in HSB and IC or contained within HSB. Using the value of 1,070 for K_d, a soil pore fraction of 0.35, and a bulk density of 2.65 for soil solids, R was determined to be 7.006×10^{-4}. This indicates that in order for DDT to migrate 1 inch through the sediments, 1,427 inches of water must pass through the sediments. This figure becomes even more significant when the very slow permeability of the clayey sediments is considered. In addition to the mathematical expression, results of column leaching tests conducted during the study indicated non-detectable leaching of DDT in all three soil types with elution of 20 inches of water through the columns. Eight other chemicals analyzed demonstrated variable but significant leaching characteristics.

2.3 CHARACTERISTICS OF SEDIMENTS IN THE STUDY AREA

Sediments in cores taken from HSB and IC under Task IV of TVA's workplan are largely fine-grained, with an average of 78 percent of each sample passing the 63 sieve. Volatile solids content of the sediment samples averaged 7.5 percent. The average <u>in situ</u> void ratio of submerged sediments was 1.45, corresponding to 38 percent water by weight. When dewatered to a 15 percent water content, the void ratio of the sediments would be decreased to 0.35.

Surface soils in the proposed borrow and disposal areas are silty clays with clayey subsoils, primarily of the Melvin, Etowah, Tupelo, Decatur, Capshaw, and Cumberland series (U.S. Department of Agriculture, 1958). Typically 75 to 95 percent of these soils will pass the 63 sieve. Based on soil borings in the vicinity (Dept. of the Army, 1977; U.S. Army Corps of Engineers, 1960), surface soils are typically underlain by 10 to 30 feet of inorganic clays of varying plasticity.

2.4 SUMMARY AND DISCUSSION

Due to its hydrophobic and high absorptive properties, DDTR will be strongly associated with solid materials in an aqueous medium, particularly with clays and organic matter. DDTR-contaminated sediments in HSB and IC are predominantly clays, with approximately 7.5 percent volatile solids. The nature of these sediments indicates that DDTR will remain strongly adsorbed to them and will be transported only if the sediments are transported.

Alternatives involving dredging in flowing reaches of HSB and IC should be designed to minimize suspension of contaminated sediments into the water column. By controlling turbidity, downstream transport of DDTR during dredging will also be controlled. Turbidity generation during dredging is discussed in Section 3.4.7 of this Appendix.

The close association of DDTR with sediment particles is responsible for its nearly total inability to leach through soils or dredged material. This fact is well documented in the literature. With this in mind, it is evident that any containment or disposal method which will effectively contain the contaminated sediments will also effectively contain the DDTR. An important factor in developing the proposed alternatives is the predominance of clays in the study area. Contaminated sediments, soils underlying proposed disposal area, and soils to be used for dike construction and covering contaminated sediments are largely clays or silty clays. The impermeability of the clays to the passage of water together with the strong affinity of DDTR for the clay particles indicates that that migration of DDTR from a properly designed and constructed disposal or containment area will be negligible.

3.0 DREDGING AND DISPOSAL

3.1 INTRODUCTION

DDTR contamination in HSB and IC is closely associated with the sediments, as discussed in detail in Section 2.0 of this Appendix. In its present state, DDTR is available to the immediate biosphere and is subject to further dispersal by hydraulic transport with the sediments during elevated flow conditions in HSB and IC. By physically removing the contaminated sediments and disposing of them in a manner designed to effectively isolate them, the long-term potential for bioavailability and further dispersal of DDTR in the environment would be greatly diminished.

A primary concern in removing the contaminated sediments is not to create adverse impacts by suspending them and increasing DDTR transport downstream during the dredging operation. The dredging methods presented in this alternative are designed to minimize sediment suspension within technically and economically feasible means. Disposal alternatives are designed to immobilize and isolate the sediments, thereby effectively isolating DDTR from the biosphere.

3.1.1 Site Characteristics

HSB flows westward from the original DDTR source (old DDT waste ditch, HSB Mile 5.4) to its confluence with IC (see Figure III-1). IC flows southward from its confluence with HSB at IC Mile 5.4 to IC Mile 3.5, then westward and southward to its confluence with the TR. Stage levels in these reaches of HSB and IC are controlled by the Wheeler Reservoir pool on the TR. Depths indicated below are for high pool stage (approximately elevation 556).

Between HSB Miles 5.6 and 3.9, the channel is well defined and 60 to 140 feet in width. Channel depths are typically 3 to 6 feet. A wide,

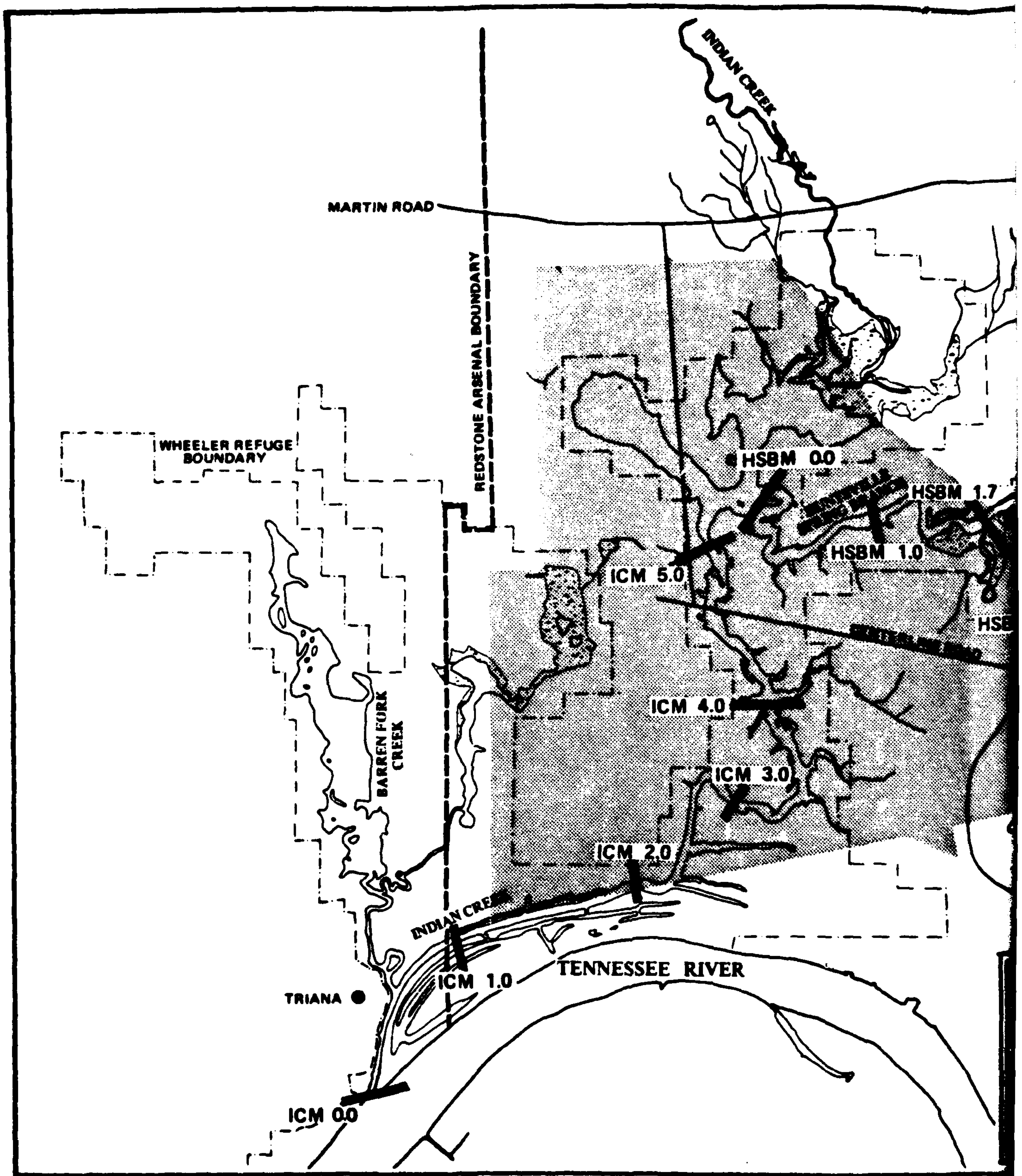
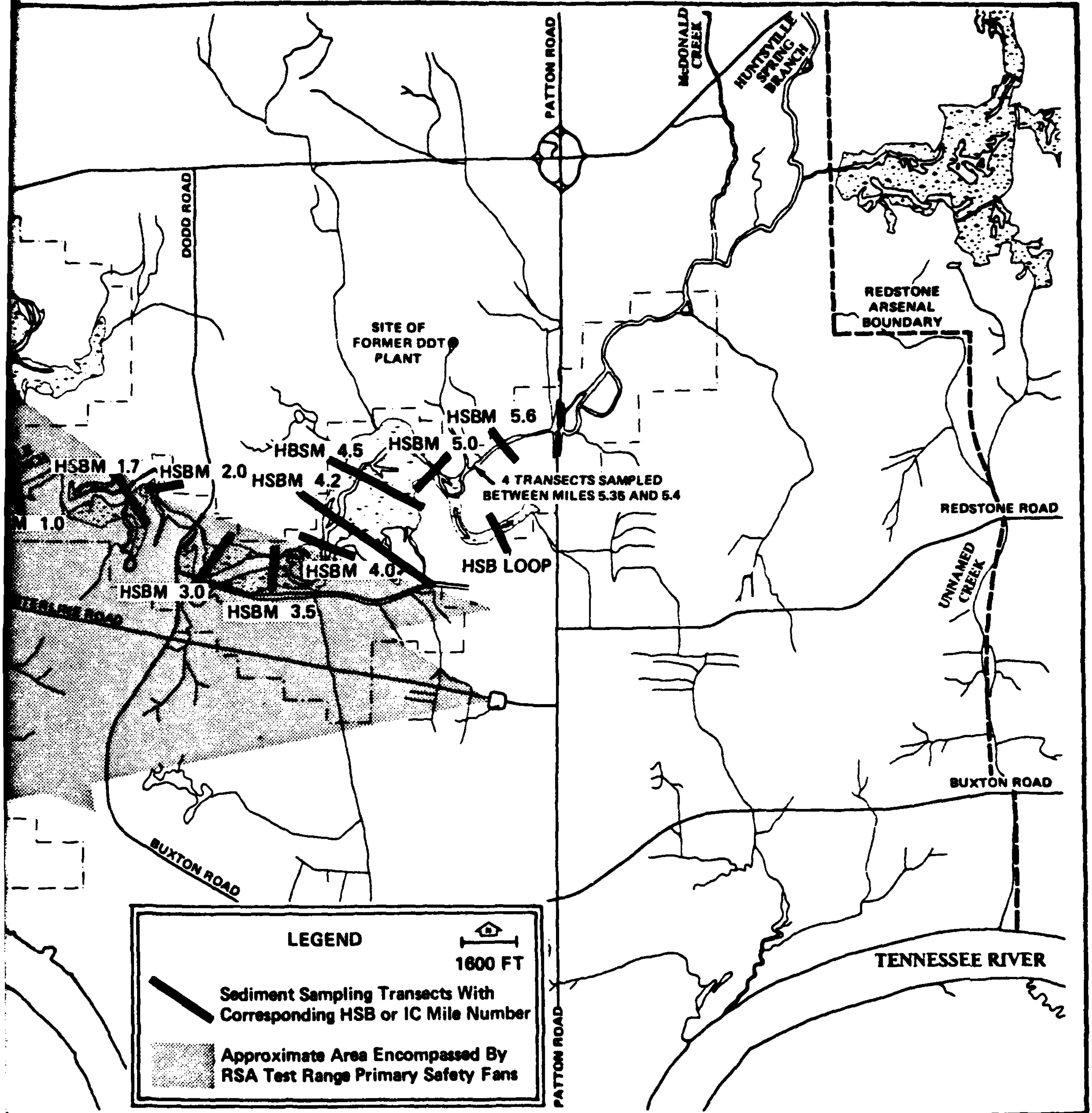


FIGURE III-1. General Site Map - Huntsville Spring Branch, Indian Creek, and Vicinity

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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wooded overbank area exists on either side of the channel in this reach, extending as far as 800 feet to the north and 2,000 feet to the south. This area is inundated only during maximum pool stage in Wheeler Reservoir or during flood conditions. Several deep permanently ponded areas branch off of the main channel. The channel bottom in this reach is heavily littered with trees, branches, and stumps. Bottom sediments consist typically of course to fine clayey sands with coarse detritus at the surface and some pockets of soft clays.

Between HSB Miles 3.9 and 2.4 (Dodd Road), the channel widens considerably, assuming a braided form with vegetated bars. Channel widths range from 100 to 375 feet in this reach, and depths are generally 2 to 4 feet. Tree litter is more widely dispersed and bottom sediments are fine-grained, consisting mostly of clays and silty clays. Several large, wooded overbank areas exist on either side of the channel.

From HSB Mile 2.7 (Dodd Road) to 0.0 (HSB-IC confluence), channel widths vary from 150 to 400 feet, with numerous ponded areas branching off of the main channel. Channel depths vary from 3 to 10 feet, with the deeper areas being near the HSB-IC confluence. Overbank areas are narrow, with the exception of one large area on the south bank, west of Dodd Road. Several small streams enter from the south, draining the northwest portion of Test Area 1. Channel sediments in this reach are fine-grained, consisting mostly of clays.

The IC channel between Miles 5.4 (HSB-IC confluence) and 2.2 varies from 200 to 400 feet in width and 6 to 10 feet in depth. Several small streams enter the channel from the east. Overbank areas in this reach are generally narrow, and bottom sediments consist mostly of clays.

Between IC Miles 2.2 and 0.0, the channel is well defined and nearly uniform, being 150 to 200 feet in width and 10 to 20 feet in depth. Overbank areas are narrow, and numerous long ponded areas extend in a parallel alignment with the TR. Bottom sediments in this reach consist mostly of clays.

3.1.2 Areal Distribution of DDTR

The distribution of DDTR in HSB and IC is determined from the results of Task IV of the TVA work plan. Sediment cores were taken along transects shown in Figure III-1. Results of the core analyses indicate that DDTR contamination is almost entirely confined to the upper 2 feet of sediment. The areal distribution of DDTR between HSB Miles 1.5 and 5.6 is illustrated in Figure III-2. Table III-1 summarizes the areal distribution of DDTR in HSB and IC.. Reaches A, B and C are so designated because of their marked differences in total areal concentration of DDTR. A detailed discussion of the areal distribution of DDTR contamination appears in Appendix II, Section 3.1.1.

As indicated in Table III-1, the majority of DDTR is contained in the channel sediments and in the area designated "critical overbank" adjacent to the channel between HSB Miles 3.8 and 4.7 (illustrated in Figure III-7). The designation as "critical" is warranted by the high DDTR levels observed in sediment core samples from that portion of the overbank (typical range: 100-15,000 ppm). These concentrations indicate

Table III-1. Estimated Percentages of Total[1] DDTR Contained in Designated Hydrologic Areas of Huntsville Spring Branch and Indian Creek

Reach	Miles Included	Area Hydrologic Designation	Surface Area (sq yd)	Volume of Sediment Contained in 3-ft Depth Over Designated Area (cu yd)	Estimated Mass of DDTR in Designated Area (lbs)	Estimated % of Total DDTR in Designated Area	Typical Range of DDTR Concentration Encountered In Designated Area (ppm)
A	HSB Miles 5.6-2.4	Channel[2]	228,000	228,000	503,000	30.0	100-30,000
		Critical Overbank[3]	121,600	121,600	1,016,000	60.6	100-15,000
		Noncritical Overbank[4]	1,122,400	1,122,400	71,500	4.3	5-40
		Ponded[5]	293,000	293,000	7,100	0.4	1-5
B	HSB Miles 2.4-0.0	Channel	408,000	408,000	56,800	3.4	10-400
		Overbank	313,000	313,000	2,380	0.1	2-7
		Ponded	231,000	231,000	3,040	0.2	1-5
C	IC Miles 0.0-5.4	Channel	615,000	615,000	17,040	1.0	10-30
		Overbank	50,000	50,000	12	0.0	0-1
		Ponded	614,000	614,000	65	0.0	0-1

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1. "Total" refers to the total estimated DDTR contained in HSB and IC.
2. Channel areas are designated as the inundated areas in the active flow regime at a pool elevation of approximately 555 feet. The channel is nearly bank-full at this elevation and is typified by well-defined banks and the absence of vegetation occurring in the overbank.
3. The immediate floodplain in HSB and IC inundated by high pool stage in the Wheeler Reservoir is designated as overbank. High DDTR levels in sediment cores from the critical overbank indicate that this area may contain the majority of DDTR in the HSB-IC system.
4. DDTR levels in the noncritical overbank are typically orders of magnitude less than those observed in the critical overbank, but still sufficiently high to warrant consideration of mitigation alternatives there.
5. Sloughs in HSB and IC which are permanently inundated but not subjected to normal channel flow are designated as ponded.

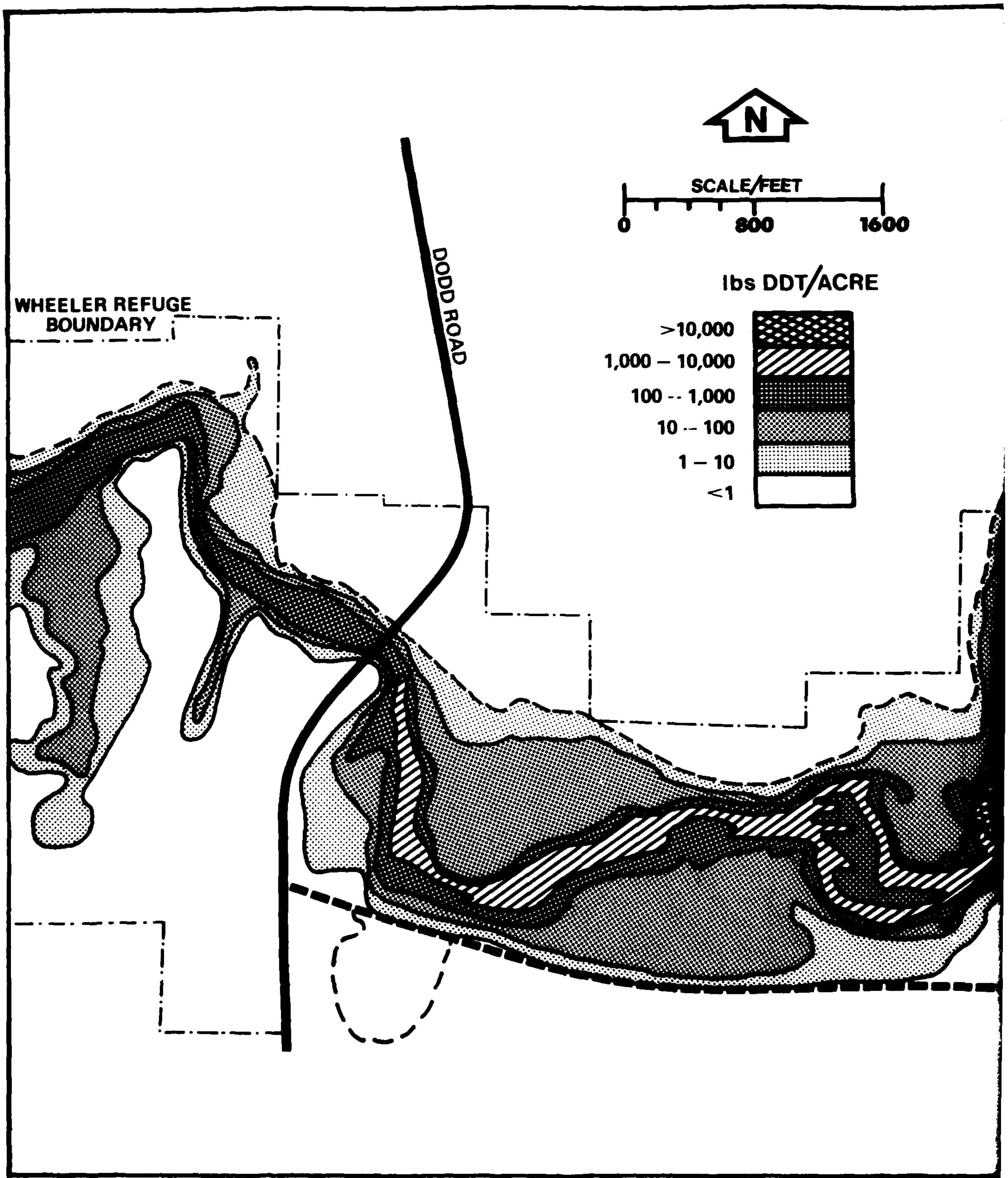
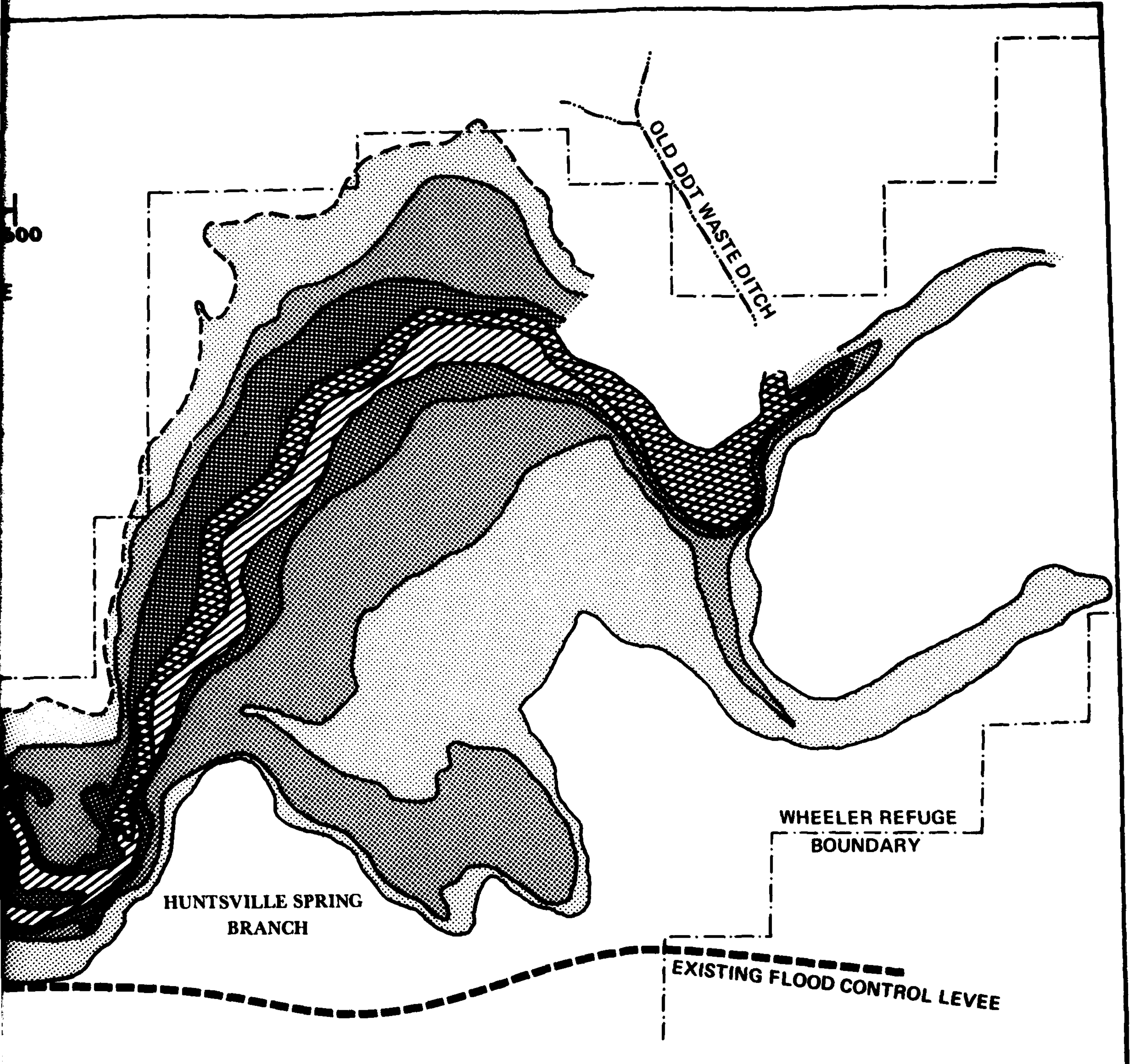


FIGURE III-2. Extent of DDTR Residue Contamination of Surface Sediments in Huntsville Spring Branch Between Miles 1.5 and 5.6

SOURCE: WATER AND AIR RESEARCH, INC.



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that the critical overbank may contain a majority of the total DDTR in the HSB-IC system, therefore mitigation of contamination there is of prime concern. Contamination of the non-critical overbank of Reach A is typically 5-40 ppm DDTR, sufficient to warrant consideration of removing those sediments.

DDTR concentrations in Reaches B and C and all ponded areas are generally less than 7 ppm. Dredging these areas would involve removal of approximately 1,450,000 cubic yards of sediments. These areas are not in the active flow regime of HSB or IC, therefore DDTR transport from them should be minimal. For these reasons the areas are not considered for dredging. Once the major source of DDTR in the system is removed by dredging the channel and designated overbank areas, contamination in the ponded areas should be mitigated by deposition of relatively uncontaminated sediment.

Three dredging plans are designated in Table III-2 according to which reaches of HSB and IC are included, i.e., the level of contamination desired to be removed from the system.

Due to the spacing of the sediment sampling transects, spacing of cores along the transects, and limited definition of core locations with respect to hydrologic designation, little lateral control was available in designating the dredging areas. Before a final dredging program short of total dredging (i.e. Dredging Plan III plus entire overbank of Reach A) can be accurately designed or implemented, additional sediment sampling should be conducted to better define the areal distribution of DDTR contamination and identify "hot spots".

3.1.3 Approach for Implementation

Evaluation of existing equipment and conditions to be encountered at the site indicate that hydraulic dredging is the most feasible means of removing DDTR-contaminated sediment from flowing reaches of HSB and IC. This subject is discussed in detail in Section 3-2 of this Appendix. Dredging would be preceded by snagging and clearing of trees, stumps, and other debris from the channel and its immediate banks. Dredged material would be pumped hydraulically to an on-site temporary dredged material disposal area (TDMDA) designed to provide complete containment of the sediments and adequate treatment of the return water to HSB. The TDMDA would consist of a system of dikes constructed on a cleared site in the vicinity of HSB.

Following completion of the dredging operation, the dredged material would have to be dewatered before a permanent disposal plan could be implemented. Permanent disposal in the TDMDA appears to be the most feasible means of ultimate disposal. This basically involves sealing the area with an impermeable cover once the sediments are dewatered. Factors favoring the environmental acceptability of this disposal technique are discussed in Section 2.0 of this Appendix. Another option considered is to dispose of the dewatered material in an abandoned mine, prepared in such a manner as to effectively isolate the contaminated sediments.

If it is desired to remove low-level contaminated material in the overbank of Reach A, this would involve clearing all vegetation from the area, grubbing all root systems, and removing the sediments to a depth of

Table III-2. Areal Dredging Plans for Dredging Huntsville Spring Branch and Indian Creek Channel Sediments

Dredging Plan	Reaches Included[1]	Miles Included	Volume of Sediment To Be Removed (cu. yd.)[2]	Estimated % of Total[3] DDTR Contained in Volume
I	A	HSB Mile 5.6-2.4	228,000 - hydraulic 121,600 - dragline	90.6
II	A,B	HSB Mile 5.6-0.0	636,000 - hydraulic 121,600 - dragline	94.0
III	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 121,600 - dragline	95.0
III plus Noncritical overbank	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 1,244,000 - dragline	99.3

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[1] Reaches designated in Table III-1 and shown in Figure III-7.

[2] Figures based on removing 3 ft. of sediment from the channel

[3] "Total" refers to the total estimated DDTR contained in HSB and IC

about 3 feet with a dragline. Cooperation of TVA in maintaining the Wheeler Reservoir pool at a low enough level to allow dewatering of the area prior to clearing and removing the sediments would facilitate implementation of this option and disposal of the sediments. The most feasible means of disposal is to place these sediments in separate diked sections of the TDMDA and on top of the dewatered dredged material before applying final cover to the disposal site. Disposal of the overbank material in an abandoned mine is also considered.

3.2 SURVEY OF CURRENT DREDGING TECHNOLOGY

3.2.1 Introduction

Dredges are classified into three general groups according to the physical means by which they remove sediment; mechanical dredges, hydraulic dredges, and pneumatic dredges.

Mechanical Dredges-- Dragline, clamshell, dipper, and bucket chain dredges are the principal types of mechanical dredges. Considerable disturbance and suspension of sediment in the water column is encountered in the operation of these dredges due to the interaction of the digging mechanism with the sediment-water interface, washing of material from the bucket on ascent, and outflow of entrapped water as the bucket clears the water surface. Because of their potential for turbidity generation and subsequent downstream transport of DDTR, mechanical dredges were excluded from consideration for dredging flowing reaches of HSB and IC.

Attempts have been made to minimize the secondary pollution characteristics of clamshell dredges by making the bucket watertight. This system will completely contain the water and sediments and is reported to result in a 30-60 percent reduction in turbidity generation compared to conventional clamshell dredges (Barnard, 1978; U.S. Army Corps of Engineers, 1978). Substantial turbidity still results from bucket impact on the bottom and its withdrawal from the sediments. Debris caught in its jaws can also cause release of the dredged material from the bucket on ascent. Due to these operating characteristics of the watertight bucket, it too was excluded from consideration for dredging in flowing reaches of HSB or IC.

Dragline or clamshell dredges are suitable for removing contaminated material in the HSB overbank areas, provided the Wheeler Reservoir pool is maintained at a low enough level to isolate overbank removal activity from flowing water in HSB. Clearing and grubbing of the overbank would be necessary before or concurrent with removal of sediments.

Hydraulic Dredges--A number of small hydraulic dredges are available, some of which are specifically designed to minimize turbidity at the dredge head. The primary operational differences between these dredges are in the design of the cutterhead and the mechanism of positioning. Dredge heads for small hydraulic dredges generally fall into the following categories:

a) conventional rotating basket cutterhead,
b) horizontal rotating cutter,
c) dustpan suction, and

d) specialized rotating cutterheads.

Positioning and mobility of the dredge is usually accomplished by

a) straight-line winching on a single cable,
b) alternate lateral passes with stem spuds or anchors, cables, and swing winches, or
c) unconventional cable positioning systems allowing flexibility of advance direction and swing width.

Conventional cutterhead dredges are generally positioned with stem spuds, cables, and swing winches. The cutterhead is an open "basket"-type, positioned at the end of a rigid ladder. Of the dredge head types listed, they have the greatest potential for turbidity generation. The primary advantage of a conventional rotating cutterhead is its ability to cut through hard, compact bottom materials.

Horizontal rotating cutterheads are designed for dredging fine or granular, loosely-consolidated sediments with a minimum of turbidity generation. Dredges with this type of head are usually limited to straight-line winching along a single anchored cable. The cutter width is usually 8 or 9 feet and the maximum depth of the cut is typically 18 to 24 inches. This type of dredge head is equipped with a shroud partially covering the cutter mechanism to lessen turbidity effects.

Dustpan suction dredge heads have wide, shallow openings and rely on hydraulic suction to remove loose, free-flowing sediments. Dustpan suction systems function efficiently only in loose, unconsolidated sediments, which they can dredge with little generation of turbidity. The most common positioning system for this type of dredge is straight-line winching on a single cable.

Several manufacturers of small dredges have developed dredge heads which do not fall into any of the conventional categories listed previously. These specialized dredge heads are indicated in Table III-3 and are discussed in the individual dredge descriptions.

Pneumatic Dredges-- Pneumatic dredges evolved in Europe and Japan. The dredge head consists of two or more large steel chambers with a sediment intake opening at the lower end. Two pipes enter the top of each chamber, one for removing the sediment-water mixture and another for introducing and releasing compressed air. When the dredge head is lowered to the bottom with atmospheric pressure in the chamber, hydrostatic pressure forces the sediment-water mixture through the inlet once it is opened. If the dredging depth is too shallow to provide sufficient pressure differential to fill the chamber, a vacuum can be pulled on the chamber through the compressed air line. When the chamber is full, the inlet valve is closed and compressed air is introduced through a valve at the top of the chamber. Air pressure acts as a piston to force the material through the discharge pipe, which extends near the chamber bottom. When the chamber is empty, the compressed air line is vented to the atmosphere, releasing the pressure in the chamber. The inlet valve is then opened to refill the chamber and the cycle is repeated. Use of two or three chambers allows continuous operation of the dredge by alternating intake and discharge cycles among the chambers.

TABLE II

General Dredge Class	Dredge Model No.	Manufacturer/ Distributor	Dimensions, LxW (ft)	Draft (in)	Trans-port Width (ft)	Weight (lbs,	Dredge Head Type	Produc-tion Capacity (yd^3/hr solids)
Pneumatic Dredges	Oozer Dredge	TJK, Inc. North Hollywood CA	82 x 33[1]	87[1]	INP[2]	INP[2]	Two-chamber pneumatic suction head with optional cutter, ladder mounted.	325-450
	Pneuma Dredge	Pneuma North America Libertyville IL	40 x 20[1]	30[1]	INP[2]	INP[2]	Three-chamber pneumatic suction head with optional cutter. Suspended from cable; no ladder.	400
Low-Turbidity Hydraulic Dredges	Waterless Dredge Model 8-180	Waterless Dredge Co. Mattoon IL	33.5 x 12.5	18	8	23,500	Two 4-ft. auger-type rotary cutters mounted one above the other, parallel to the ladder, and partially enclosed by a shroud.	150-200
	Mud Master Dredge Model HPC-250 SM	Dredgemasters International Hendersonville TN	34 x 12	33	8	35,000	(i) Conventional rotating cutter (ii) Horizontal auger (iii) Dustpan suction	120-150
	Mud Cat Dredge Model MC-915	National Car Rental System St. Louis Park MN	39 x 9	21	9	21,000	Twin horizontal augers with a total 9 ft. cutting width, partially enclosed by a shroud.	120
	Delta Dredge Model 212	Delta Dredging Co. St. Louis MO	40 x 16	32	8	31,000	Dual horizontal, counter-rotating cutter discs	100-120
Conventional Cutterhead Hydraulic Dredges	Dixie Dredge Model CS-8E	Dixie Dredge Corp. St. Louis MO	28 x 11	35	11	37,420	Conventional basket-type cutterhead.	45-105
	Ellicott Dragon Series Dredge Model 770	Ellicott Machine Corp. Baltimore MD	42 x 21	36	10	148,000	Conventional basket-type cutterhead	450-550
	IHC Beaver Model 500	IHC Holland Rotterdam Netherlands	46 x 19.5	39	10	INP[2]	Conventional basket-type cutterhead	INP[2]
	Eagle Iron Works 8 in. Cutterhead Dredge	Eagle Iron Works Des Moines IA	46 x 18	24	10	85,200	Conventional basket-type cutterhead	115
	M&S Dredge Model D-24-1	M&S Development, Inc. Greenbush MI	46 x 10	INP[2]	10	30,000	Conventional basket-type cutterhead	140

[1] Figures shown are for existing barge arrangement. The dredge head can be transported separately and used on other barges.

[2] INP - Information Not Published in manufacturer's literature.

[3] For dustpan suction head.

[4] For conventional cutterhead.

[5] NA - Not applicable

[6] Maximum depth shown is for 14 ft. ladder. Longer ladder lengths are available.

[7] Maximum depth shown is for 27 ft. ladder. Longer ladder lengths are available.

[8] Maximum depth shown is for 20 ft. ladder. Extensions up to 10 ft. are available.

[9] Maximum depth shown is for 17 ft. ladder. Extensions are available.

TABLE III-3. Comparison of Dredges Considered for Dredging Huntsville Spring Branch and Indian Creek Channel Sediments

SOURCE: WATER AND AIR RESEARCH, INC.

TABLE III-3

Type	Production Capacity (yd^3/hr solids)	Dredging Depth, min/max (ft)	Propulsion or Positioning System	Dredge Pump Size (hp)	Operating Dredge Pump Flowrate (gpm)	Dredge Pump Location, Barge (B) or Submerged (S)	Maximum Discharge Distance Without Boosters (ft., horizontal)	Inlet Diameter (in)	Discharge Diameter (in)	Maximum Swing Width (in)	Maximum Depth of Cut (in)	Range of Solids Content In Discharge (% by volume)
tic optional nted.	325-450	0/33^{1}	Conventional spuds and swing winches.	INP^{2}	INP^{2}	S	3000	INP^{2}	INP^{2}	INP^{2}	INP^{2}	30-70
matic optional from	400	0/150	Self-propelled or conventional swing winch system	INP^{2}	INP^{2}	S	3000	INP^{2}	10	INP^{2}	INP^{2}	30-80
ype rotary e above el to the lly en- d.	150-200	0/16	Cables, swing winches in various arrangements	200	2500 @ 90 head	S	1300	12	8	500	36	30-50
rotating ger tion	120-150	INP^{2}/18	(i) conventional spuds and swing winches (ii) single cable and winch (iii) 4 corner winches and cables	275	3000-4000	S	2000	12	10	INP^{2}	30^{3} 24^{4}	15-25
gers with ting width, by a	120	2/15	Single cable and winch	175	2000	B	1500	8	6	NA^{5}	18	10-30
counter- iscs	100-120	3/16	Anchors and swing winches	INP^{2}	INP^{2}	S	2000	INP^{2}	12	INP^{2}	8-10	20-40
et-type	45-105	INP^{2}/14^{6}	Conventional spuds and swing winches	175	2000-3000	S	1900	8	8	INP^{2}	26	INP^{2}
et-type	450-550	4/20^{7}	Conventional spuds and swing winches	520	INP^{2}	B	8000	14	14	92	INP^{2}	INP^{2}
et-type	INP^{2}	INP^{2}/26	Conventional spuds and swing winches	355	INP^{2}	B	INP^{2}	14	14	INP^{2}	INP^{2}	INP^{2}
et-type	115	INP^{2}/21^{8}	Conventional spuds and swing winches	350	2700	B	1200	10	8	90	INP^{2}	15-25
et-type	140	INP^{2}/14^{9}	Conventional spuds and swing winches	203	2500	S	INP^{2}	8	8	INP^{2}	INP^{2}	INP^{2}

ges.

The dredge head is suspended from a barge-mounted crane or ladder. Compressors, air distributors, and the dredge head are individual components which do not require a specialized barge and consequently can be mounted on nearly any water craft of appropriate size. Land-based operation using a conventional crane is also possible.

By using air instead of water to move sediments through the discharge line, pneumatic dredges can attain solids concentrations of 60 to 80 percent by volume. Turbidity levels during operation are reported to be low, with minimal disturbance of bottom sediments. Use of this type of dredge is best suited for unconsolidated, free-caving sediments, though specialized cutterheads can be attached for dredging in more difficult material.

3.2.2 Dredges Evaluated for Removing Channels Sediments in Huntsville Spring Branch and Indian Creek

Following an extensive review of current small dredge technology, eleven dredges were selected for further evaluation. These dredges, along with their major physical and operational characteristics, are listed in Table III-3.

Pneumatic Dredges--

Pneuma Dredge--Pneuma North America's portable dredging unit is a pneumatic dredge, the basic operation of which is discussed in the introduction to this section. The dredge head consists of three in-line cylinders. Operation of the intake and discharge ports is controlled electronically and can be sequenced to discharge in a range suitable for the type of material being dredged. An air distributor unit regulates the inflow and discharge of compressed air to each cylinder during the operation cycle, assuring continuous, uniform discharge flow.

The Pneuma Dredge is capable of pumping 60 to 80 percent solids, by volume, with minimal generation of turbidity. By raising or lowering the pump unit as necessary, contours of the bottom can be followed. The dredge can be mounted on a self-propelled barge, eliminating the need for swing wires and anchors if such operating conditions are desired for a particular application. Recent modifications of the Pneuma Dredge extend its applicability to shallow water operation by providing vacuum suction to fill the cylinders when dredging depths are insufficient to provide the necessary hydrostatic pressure. A cutterhead mechanism, designed to minimize turbidity, is available for dredging in materials which are not free-caving.

Low turbidity levels associated with the Pneuma Dredge's operation are attributed to its lack of external moving parts. The dredge has been used successfully in prior operations requiring low turbidity generation, including removal of PCB-contaminated sediments from the Duwamish Waterway, Seattle Harbor, Washington. EPA monitoring of that dredging operation indicated exceptionally low turbidity levels in the vicinity of the operating dredge pump.

Oozer Dredge--The operational principle of the Oozer Pump is basically the same as the Pneuma, except that it employs two pneumatic chambers instead of three. The Oozer Pump can be mounted on a conventional dredge ladder or suspended from a cable. It was specifically designed for dredging polluted sediments at a high solids content with minimal turbidity generation.

The Oozer Pump Dredge Taian Maru is probably the most sophisticated equipment presently available for dredging polluted sediments. It is equipped with two underwater television cameras mounted near the suction inlet to visually monitor turbidity. Changes in turbidity levels are recorded by a highly sensitive turbidimeter. Five electronic sediment detectors located near the suction inlet are capable of measuring the thickness of sediment layers of varying density. Other accessory equipment includes a flow direction and speed meter, gas detector, gas shield and collector, sediment and water sample collectors, and an optional cutterhead attachment. Secondary and booster pumping can be performed by Oozer Pumps if the solids content of the slurry is too high for conventional hydraulic pumps.

In four and one-half years of operation, between 1974 and 1978, the Taian Maru pumped approximately 1.3 million cubic yards of contaminated sediments from Japanese waters. In all dredging projects, turbidity generation was carefully monitored and maintained at a minimum level.

The Oozer Pump has not yet been transported to the United States. A United States representative of the Japanese manufacturer has indicated that transport of the Oozer to the United States is possible, should a situation arise requiring its capabilities (Jensen, 1980). The Oozer Pump unit could be shipped alone and fitted to a barge once here, though at a considerable expense.

Low-Turbidity Hydraulic Dredges--

Waterless Dredge, Model 8-180--The Waterless Dredge was specifically developed for dredging industrial and municipal unconsolidated sludges at a high solids concentration. According to the manufacturer (Searles, 1980), the dredge has consistently attained solids percentages in its discharge within 2 to 5 percent of the in-situ solids concentration when dredging these materials. Solids concentrations of 30 to 50 percent by volume in the discharge slurry are reported. Turbidity associated with operation of the dredge is reported to be minimal.

The cutterhead consists of two 4-foot rotating augers mounted parallel to each other and the cutter ladder, and enclosed within a shroud. The cutterhead is designed to rotate through a 180 degree arc, and on each alternate swing is rolled over so that the opening faces the direction of swing advance. Material filling the shrouded cutterhead area displaces water and theoretically makes only the material itself available to the dredge pump inlet. Variable-speed hydraulic drives enable operation to match the excavation of material with the pumping rate, minimizing turbidity generation and maximizing solids content of the discharge.

Additional advantage is reported to be gained with respect to solids concentration and turbidity control by submerging the dredge pump. Submergence eliminates cavitation and allows enlargement of the pump inlet, reducing inlet velocities to 5 to 6 feet per second compared to 12 to 14 feet per second for most conventional suction dredges with barge-mounted pump. The low inlet velocity allows a thicker, more viscuous material to be pumped while lessening water entrainment (Searles, 1980).

Mobility of the dredge is provided by a system of cables and winches. Utilizing a stern cable connected by a sheave to a rear cross cable, and two forward-directed swing cables, swing widths up to 500 feet can be attained.

Outer hull sections of the Waterless Dredge swing up, allowing for an 8 foot transport width and easy mobility on a single truck.

Mud Master Dredge, Model HPC-250SM--The Mud Master Series of compact dredges is designed for versatility in a wide range of dredging applications. The dredge head, main pump, and main engine are all mounted on a central frame assembly suspended between two hull sections. Outer hull configurations available include rectangular pontoons, wedge-shaped pontoons for operating in confined areas, and floating sections with amphibious tracks. An optional road package is available with the first two hull types which allows transport of the dredge on a single truck.

The main dredge pump is designed to operate underwater to improve pump efficiency and production of the dredge. Three interchangeable ladder head configurations are available; a conventional rotating cutterhead, a shrouded revolving horizontal cutter, and an open suction dustpan head. Turbidity levels associated with the latter two dredge heads are reported by the manufacturer to be low.

Hauling and positioning systems available include a conventional swing winch system with spuds, a four-corner cable positioning system, and a single-cable hauling system. The first system is used in conjunction with the rotating cutterhead for hard digging, the second can be used with all three head configurations, and the last is designed for use with the revolving horizontal cutter or dustpan suction head.

MudCat Dredge, Model MC-915--MudCat Dredges have been widely used for dredging fine-grained sediments in shallow waterways and basins. Largest of the MudCat Series, Model MC-915 has a nine-foot wide horizontal cutterhead with dual augers that dislodge material and move it toward a central pump inlet. A mud shield surrounds the auger, minimizing mixing of disturbed sediments and the surrounding water, and aiding in channeling sediment to the pump inlet. This arrangement is reported to result in low turbidity generation during operation of the dredge.

The cutterhead assembly of the MudCat can be rotated up to 45 degrees to conform with or shape bottom profiles. Maximum cutting depth is 18 inches. Solids concentration in the discharge slurry varies from 10 to 30 percent.

Propulsion of the dredge is provided by winching along a single-cable system anchored by trees or deadman anchors, limiting its mobility to a linear path. Average advance speed along the cable is 8 to 12 feet per minute. Upon completion of each dredging pass, the MudCat must be winched over by pullover cables to begin the next pass. Sediments which protrude above water level can be dredged by raising the cutterhead and dragging the material into the water with the mud shield. This process is time consuming, but is within the operation capabilities of the dredge.

The MudCat is easily transported on a single truck and can be launched at the site by a small crane.

Delta Dredge, Model 212--This compact dredge utilizes two disc-shaped, horizontal counter-rotating cutters which cut a relatively shallow 7-1/2 foot wide swath. The cutters reverse direction on alternate swings. The discharge pump is submerged to improve operating efficiency. According to the manufacturer, the dredge discharges a high percentage of solids and turbidity generation is low due to the low-speed operation of the cutters.

Swing and stern winches are operated independently to provide mobility during dredge operation. Since the counter-rotating cutter design requires low crowding power (i.e., power to advance the dredge head through the material), stern spuds are not necessary and large anchors are not required.

Hull construction consists of four parallel pontoons with steel grate decking. The outer two pontoons fold upwards, providing for an 8 foot transport width and easy mobility on a single flatbed truck.

Conventional Cutterhead Hydraulic Dredges--The five conventional cutterhead dredges evaluated are not discussed individually, as they all possess the same basic design and operating characteristics. Each employs a conventional basket-type cutterhead mounted on a ladder. Differences in physical dimensions and production capabilities for these dredges are indicated in Table III-3.

3.2.3 Discussion

Several key factors should be considered in selecting equipment to dredge HSB or IC channels. The first concern is the characteristics of the bottom sediments to be dredged. Field observations made on January 30, 1980 indicate that between HSB Miles 5.6 and 3.9 the bottom sediments in some areas of the channel are well consolidated and in some areas are heavily armored by coarse detritus and/or sediments at the surface. Hand penetration of the sediments with a 1-1/4 inch steel piston corer could only be accomplished to a depth of two to four inches in most places. These conditions indicate that reasonable progress through this material could not be made by any of the pneumatic or low-turbidity hydraulic dredges due to a lack of, or operating characteristics of, the cutterhead. A conventional basket-type cutterhead dredge would probably be required to dredge this reach. Between HSB Mile 3.9 and IC Mile 0.0 the sediments are finer-grained and less consolidated, though some pockets of difficult material were encountered. It is expected that reasonable progress could be made here with any of the dredges, though the pneumatic dredges would most likely have to be equipped with a cutterhead. The pneumatic and low-turbidity dredges would encounter some difficult digging in this reach, and their production rates would probably not be nearly as high as that of a conventional cutterhead dredge.

Another important consideration is the magnitude of turbidity generated by the dredge in comparison to that generated by the snagging and clearing operation. The reach of HSB most heavily covered with tree debris, HSB Miles 5.6 to 3.9, is also the reach most heavily contaminated with DDTR. An estimated 20 percent of the channel bottom in this area is covered with tree debris, much of which extends into the sediments. Clearing this material from the channel is expected to generate significant turbidity. Downstream from HSB Mile 3.9 tree debris coverage is not as extensive as upstream, but is still sufficient to pose turbidity problems with its removal.

Snagging should be carried on coincident with dredging in the channel. Though this may result in higher suspended sediment and DDTR concentrations in the water column than if the two actions were conducted separately, the net downstream transport of sediment and DDTR during the project should be minimized. Higher suspended sediment concentrations will enhance flocculent settling of clay-size particles and overall sedimentation may be greater than if the two actions were conducted at different times. Concurrent snagging and dredging will also minimize the duration of elevated DDTR levels in the water column.

A certain amount of downstream transport of suspended sediment and DDTR will be unavoidable during the proposed dredging operation. The net transport of DDTR downstream due to dredging can be put in perspective by comparison with the downstream transport that would occur naturally under elevated flow conditions. A dredging operation that would move no more DDTR downstream than would move due to existing channel scour might be considered acceptable, as further DDTR transport after the dredging operation would be greatly diminished once the contaminated sediments were removed.

Finally, careful consideration should be given the characteristics of the turbidity plume, the flow velocity expected during dredging, and possibilities for reducing the flow velocity by various means. These parameters determine how much of the sediment suspended by the dredge will eventually settle out downstream to be dredged later, and how much will be transported out of the reach being dredged.

Quantification of the turbidity considerations discussed above would be extremely difficult using a strictly theoretical approach, due to the many variables and site-specific conditions involved. Turbidity associated with operation of the pneumatic or low-turbidity hydraulic dredges can be assumed small compared to that generated by snagging and clearing the channel. In order to obtain a conservative estimate of DDTR transport downstream during operation of a conventional cutterhead dredge, assumptions are made as to the expected turbidity level downstream from the dredge, the average DDTR concentration in the suspended sediment, the average discharge of HSB during dredging, and the duration of the dredging project. Based on these assumptions, the total amount of DDTR leaving HSB during the dredging of HSB Miles 5.6 to 0.0 is estimated.

Data obtained from two dredging projects (Barnard, 1978) indicated near-bottom suspended sediment levels of 336, 205, and 125 mg/l at distances of 100, 200 and 1,000 feet, respectively, downstream from a conventional cutterhead dredging fine-grained sediment in a current of less than 5 cm/sec. Background suspended sediment levels were 1 to 30 mg/l. Near-bottom suspended sediment levels are the highest encountered in the water column downstream from an operating cutterhead (Barnard, 1978). Current velocity in HSB during base flow conditions is generally less than 5 cm/sec.; therefore, the conditions at these dredging projects approximate those to be encountered in HSB. A dredge would be operating at a mean distance of 15,000 feet upstream of the IC confluence while dredging in HSB. Considering this distance and the near-bottom suspended sediment levels observed for the shorter distances, an average suspended sediment elevation of 50 mg/l over background is assumed for the flow leaving HSB. The DDTR concentration of the suspended sediment is assumed to be the overall average DDTR concentration of the sediments dredged, i.e., the total mass of DDTR divided by the total mass of sediment dredged or 231 ppm. A base flow of 50 cfs is assumed for HSB, and a production rate of 350 cubic yards per hour is assumed for the dredge. These assumptions should give a conservative upper limit estimate of DDTR transport out of HSB, especially when one considers that the great majority of DDTR is located in the upstream-most two miles of the reach to be dredged and material suspended while dredging there will have a greater distance in which to settle out and be recovered downstream.

Other flow considerations during the dredging operation will tend to reduce downstream sediment transport. At an operating rate of 8000 gpm (17.8 cfs), an Ellicott 770 or similar capacity dredge would be pumping from 25 to in excess of 100 percent of the base flow in HSB. The return water discharge from the TDMDA will upstream from the dredge, but since it will be operating on a 24-hour basis and the dredge will be operating on 8 to 10 hour shifts, an overall reduction in flow of 10 to 12 cfs will be realized. This will significantly reduce the downstream velocity of HSB during dredging and decrease downstream sediment transport. The City of Huntsville's 201 Facilities Plan recommends rerouting the discharge from Huntsville Sewage Treatment Plant No. 1 from HSB directly to the Tennessee River (Black, Crow, and Eidsness, 1976). The average daily flow from that plant in 1976 was 7.4 MGD (11.5 cfs), a significant portion of the base flow in HSB. Design flow of the plant in 1976 was 10 MGD (15.5 cfs).

Based on the above assumptions, a total of 236 pounds of DDTR is estimated to be entering IC from the dredging of HSB. This amounts to 0.04 percent of the total amount of DDTR removed during dredging, assuming a 99 to 100 percent removal efficiency. Assuming an eight-hour work shift and 70 percent production efficiency for the dredge (i.e., 30 percent down-time), this amounts to 0.7 pounds per day of DDTR entering IC.

For comparison with DDTR transport to be expected under natural conditions, the total mass of DDTR estimated to be leaving HSB annually due to natural flow in the channel is in excess of 1.4 tons, or 2,800 pounds (see Appendix II, Section 4.1). The dredging of HSB would take approximately one year, and according to these calculations would transport less DDTR out of HSB than would be transported substantially by one year of natural flow conditions. This estimate assumes, of course, that dredging is conducted only during base flow conditions. It is recognized that storm flows through the HSB channel may transport sediments disturbed by snagging and dredging to a greater extent than these predictions indicate. The magnitude of this type of transport cannot be predicted from existing information. If the IC channel is to be dredged, DDTR transport into the TR resulting from that operation should be much less than that estimated for HSB, due to the lower DDTR concentrations in the IC sediments and lower flow velocities there.

While these estimations are by no means precise, they should give a reasonable indication of the magnitude of DDTR transport expected to result from dredging HSB or IC. Since this is an area of critical concern, it should be addressed in a more comprehensive manner in the final engineering phase of the project. A reliable (though costly) method of predicting DDTR transport downstream during dredging would be to implement a short pilot dredging study in HSB and monitor DDTR transport at various distances downstream from snagging and dredging operations. A less direct but more economical approach would be to monitor the turbidity-generating characteristics of a cutterhead dredge operating at another site in similar sediments. This information could be combined with the results of settling column analyses of the HSB sediments to estimate how much contaminated sediment would settle out and how much would be transported a specified distance downstream.

Considering the nature of the HSB bottom sediments, the estimated transport of DDTR caused by a conventional cutterhead, the unavoidable turbidity to be generated by snagging and clearing ahead of the dredge, and economic factors; a conventional cutterhead dredge appears to be the best choice for dredging the HSB and IC channels. As previously noted, the nature of the bottom sediments in the most highly contaminated reach of HSB (HSB Miles 5.6 to 3.9) preclude the use of pneumatic or low-turbidity hydraulic dredges and probably require a conventional cutterhead. Employing a low-turbidity dredge downstream from HSB Mile 3.9 would probably result in a drastic decrease in production rate due to the generally smaller pumping capacity of those dredges and the slower progress expected through the difficult sediments. This would result in a significant cost increase for the dredging project with little relative gain in overall environmental acceptability.

3.3 TEMPORARY DREDGED MATERIAL DISPOSAL AREA (TDMDA)

3.3.1 Introduction

To implement a dredging alternative it will be necessary to site a temporary dredged material disposal area within reasonable pumping distance from the areas to be dredged. The disposal area must be carefully designed to assure containment of the contaminated sediments and to provide for adequate treatment of the overflow water.

The approach used is to site and design one large disposal area as opposed to two or more smaller ones. Though this tends to increase dredge pumping costs, advantages would be gained with respect to facilitating construction and operation of the site, localization of the DDTR contamination, long-term control of ownership, and long-term integrity and monitoring. It was also considered desirable to locate the temporary disposal area near the majority of the present contamination rather than at a distant site in an uncontaminated region. In addition to facilitating pumping to the site, this would maintain localization of the DDTR contamination. Ideally, the site should be located hydraulically and topographically upgradient from the present contaminated area.

3.3.2 Selection Criteria and Site Evaluation

The criteria used for temporary disposal site selection are presented in Table III-4. Seven candidate disposal sites were selected on the basis of proximity to HSB and topographic suitability alone. The locations of these sites are shown in Figure III-3. Of the seven sites, six are within the RSA boundary and one is adjacent to the eastern RSA boundary. Extending the limits for disposal site consideration further from RSA would provide few, if any, additional sites due to the surrounding development and generally unsuitable topography. A summary and brief evaluation of the seven sites is presented in Table III-5.

Sites 4 and 5 were discarded due to the unavoidable impact those locations would have on the operation of Test Area 1. Use of these sites would require that Test Area 1 be either relocated or shut down while the site is in use. Site 3 is only large enough to accomodate Dredging Plan I, and is reported by RSA Facilities Engineers to have mustard gas landfilled on the eastern portion of it. Site 2 will also only accommodate Dredging Plan I and has the further disadvantage of a 30 inch industrial water main crossing it.

Field observation of Site 6 revealed evidence of recent sinkhole activity in the southwest corner of that area, indicated in Figure III-3. A sinkhole approximately 20 by 30 feet was observed, with other indications of subsidence in the immediate vicinity. This activity had been reported by NASA officials at the Marshall Space Flight Center, who indicated that they had experienced sinkhole problems when constructing additions to their buildings directly across Dodd Road from Site 6. A large depression was also noted in the northwest area of Site 6. Though no other surface features were noted that would indicate instability in the remainder of Site 6, use of that site as a disposal area is highly questionable and should be subject to a rigorous geological investigation.

Site 1 is acceptable for temporary dredged material disposal with regard to all criteria established. Sufficient area is available to accommodate disposal for any of the three dredging plans. No apparent serious conflicts exist between use of the site and present operations at RSA. The site is both hydrologically and topographically upgradient from the most contaminated reach of HSB, being approximately one mile upstream from the

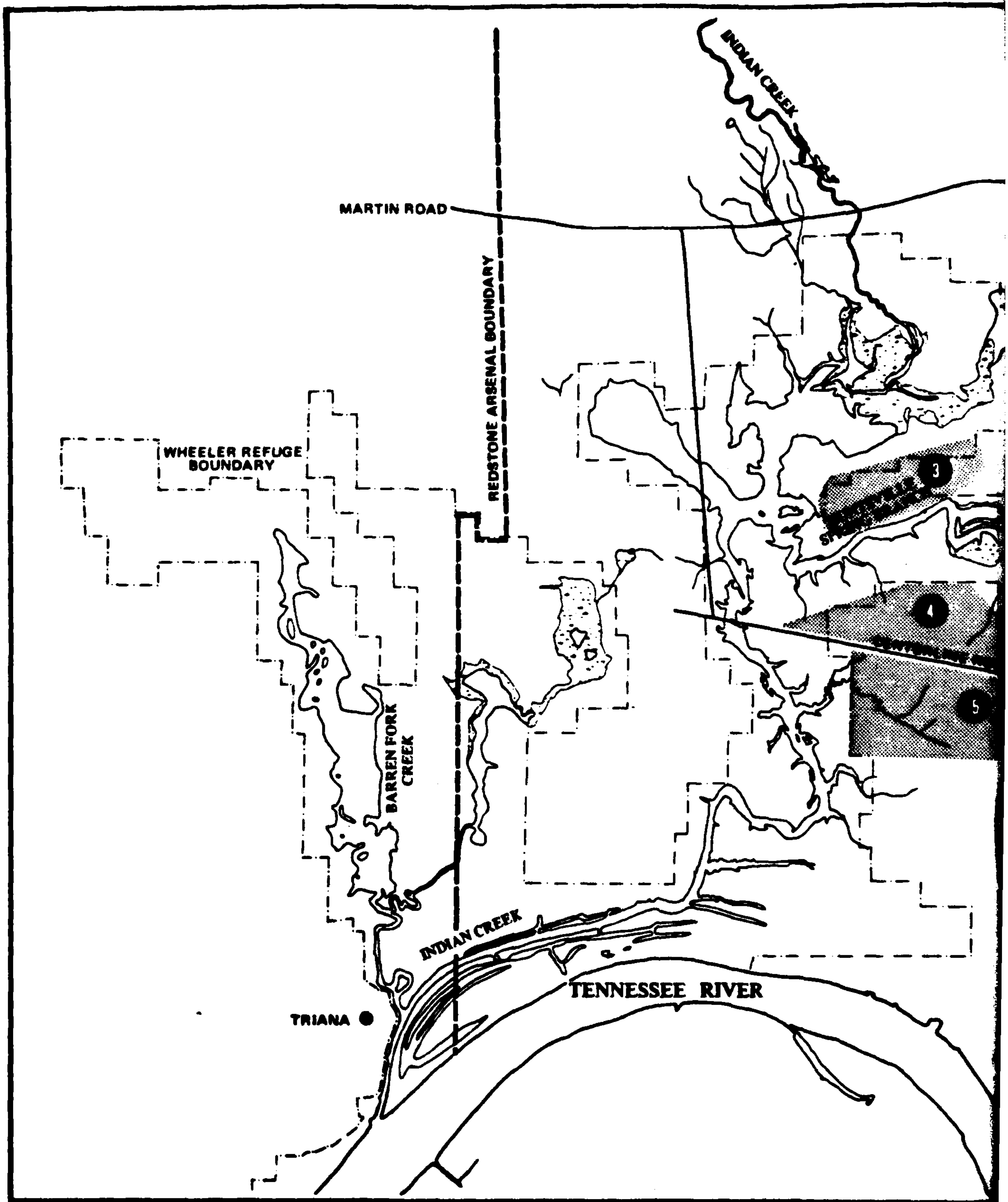

FIGURE III-3. Sites Considered for Temporary Disposal of Dredged Material

SOURCE: WATER AND AIR RESEARCH, INC., 1980

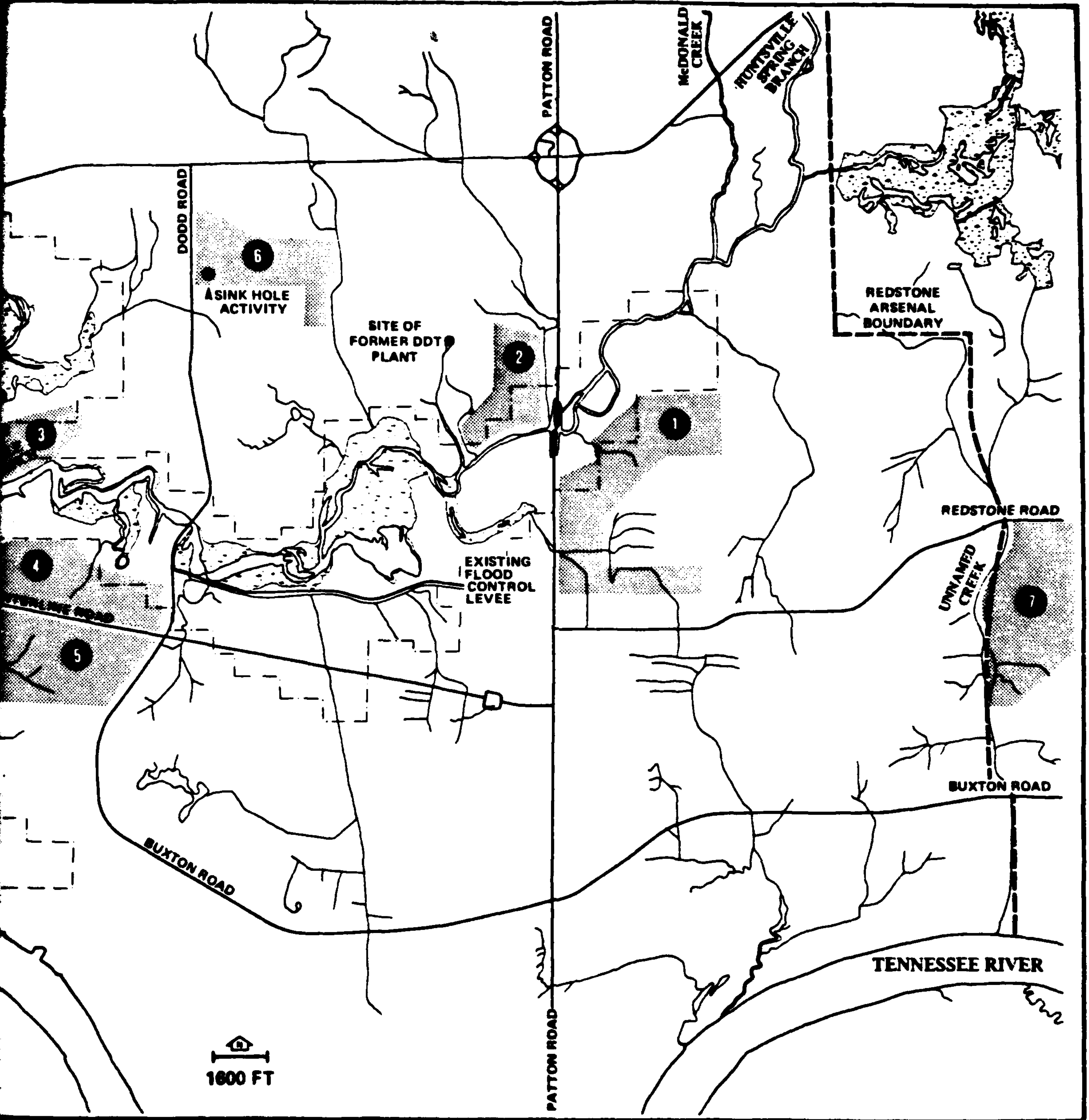

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Table III-4. Criteria for Selection of Temporary Dredged Material Disposal Areas

	Ideal	Acceptable	Unacceptable
Proximity to HSB	Adjacent	Within 2-3 mi.	>3 mi.
Soil Type	Impermeable clays	Relatively impermeable sandy clays	Sandy or gravelly permeable soils
Elevation	Site not inundated by 100 yr. flood	Site dike crests not overtopped by 100 yr. flood	Dikes overtopped by 100 yr. flood
Area	>300 acres	100-300 acres	<100 acres
Relief	0 10 ft.	10-40 ft.	>40 ft.
Proximity to Groundwater	>20 ft.	3-20 ft.	0-3 ft.
Depth to Bedrock	>40 ft.	20 40 ft.	<20 ft.
Impact on RSA	None	Moderate impacts which could be mitigated	Serious impact or curtailment of operations due to location of site

Table III-5. Comparison of Candidate Temporary Dredged Material Disposal Sites

Disposal Site	Approximate Area Available (acres)	General Soil Type Present	Maximum Relief (ft.)	Approximate Pumping Distance From HSB Mile 2.4 Dodd Rd. (mi.)	Approximate Average Elevation (ft.)
1	300	Silty clay loam underlain by plastic clayey subsoil	15	3.5	565
2	140	Silty clay loam underlain by plastic clayey subsoil	15	2.5	565
3	130	Silty to sandy loam underlain by plastic clayey subsoil	20	1.5	570
4	250	Silty clay loam underlain by plastic clayey subsoil	10	0.5	565
5	270	Silty clay loam underlain by plastic clayey subsoil	10	1.0	565
6	160	Silty to sandy clay loam underlain by plastic clayey subsoil	35	2.5	610
7	200	Silty to sandy clay loam underlain by plastic clayey subsoils	30	6.5	570

Table III-5. Comparison of Candidate Temporary Dredged Material Disposal Sites (Continued, Page 2)

Disposal Site	Approximate Average Elevation of Water Table (ft.)	Vegetative Cover	Elev. of 100-yr. Flood Stage (ft.)	Approximate Depth to Bedrock (ft.)	Facilities or Utilities to be Relocated
1	560	Wooded	575	20-30	None
2	560	Wooded	575	20-30	30 in. industrial water main crosses site
3	560	Wooded	575	20-40	None
4	560	Bare or grasses with some wooded areas	575	20-40	None
5	560	Bare or grasses	575	20-40	None
6	590-600	Wooded	575	20-40	36 in. sewer main and a small communications cable cross site
7	565	Grasses	575	20-40	None

Table III-5. Comparison of Candidate Temporary Dredged Material Disposal Sites (Continued, Page 3)

Disposal Site	Present Ownership	Use of Site Feasible with Present RSA Operations [1]	Evaluation of Site Suitability
1	RSA	Yes	Acceptable with regard to all criteria.
2	RSA	Yes	Marginally suitable; area could only accommodate Dredging Plan I; water main would have to be relocated.
3	RSA	Yes	Unsuitable due to limited size and presence of landfilled wastes.
4	RSA	No	Unsuitable due to conflict with Test Area 1 operation.
5	RSA	No	Unsuitable due to conflict with Test Area 1 operation.
6	RSA	Yes	Questionable due to sinkhole activity on western side and high relief.
7	Private	Yes	Suitable, but would incur high dredging costs due to distance from HSB.

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[1] Site use feasability based on communication with Redstone Arsenal Facilities Engineers, January 10, 1980.

old DDT ditch. The predominant soil type is silty clays at the surface underlain by a plastic clayey subsoil. Soil borings from wells drilled in the vicinity (Department of the Army, 1977) indicate a regolith thickness of at least 20 feet consisting almost entirely of clays. All preliminary disposal site designs are located on this site.

Site 7 is acceptable with regard to the established criteria with the exception of distance from HSB. Being three miles more distant from the dredging area than Site 1, use of Site 7 would raise dredging costs an estimated 4 million dollars. The majority of this cost increase would be in the purchase of three additional booster pumps with accessory equipment and pipeline, costs of operating and maintaining the three boosters, and acquisition of the land from private ownership. Use of Site 7 should only be considered if the additional costs incurred are offset by an equal or greater benefit derived from RSA's use of the land occupied by Site 1.

3.3.3 TDMDA Design and Construction

Required Containment Volume--Disposal sites are sized for each of the three areal dredging plans. The amount of material to be dredged from the channel is based on dredging 2 feet of sediment and allowing 1 foot of overdredging, assuming the dredge follows the contour of the channel bottom by the method described in Section 3.4.5.

Determination of the required containment volume is obtained using the method of Lacasse *et al*. (1977). The calculation considers the effects of solids bulking due to hydraulic transport, the efficiency of the dredging operation, and the degree of overdredging allowed. Required containment volumes calculated using this approach are greater than the *in situ* volumes desired to be removed by a factor of 1.43. Containment volumes obtained for the three dredging plans are shown in Table III-6. Solids removal efficiency is not considered in the design containment volume, as the high level of treatment required can be more effectively accomplished by a separate return water treatment facility.

Subsurface Exploration and Soil Tests--An extensive program of surface and subsurface exploration and soil testing is necessary to assure the integrity of the main containment dike, and to assure that contaminated dredged material will not migrate downward from the site due to vertical drainage or sinkhole collapse. Such a program begins with field observations and a review of information already available from past construction projects in the area. This preliminary phase was conducted and the information obtained is used for the general design criteria presented in this report. An extensive boring and soil testing program should be initiated early in the final engineering phase.

Existing fill structures examined in the vicinity of the proposed disposal area include Patton Road adjacent to Site 1, the flood levee north of Test Area 1, and the fill road to the Thiokol burning pit in the swampy area near the HSB-McDonald Creek confluence. While some of these fill structures were not in the immediate vicinity of the proposed disposal area, they were selected as "worst case" soil conditions typical of

Table III-6. Containment Volumes Required for Areal Dredging Plans

Dredging Plan	Channel Areas Dredged	Required (cu.yd.)
I	HSB Mile 5.6 to Dodd Road	326,000
II	HSB Mile 5.6 to HSB Mile 0.0	908,000
III	HSB Mile 5.6 to IC Mile 0.0	1,786,000

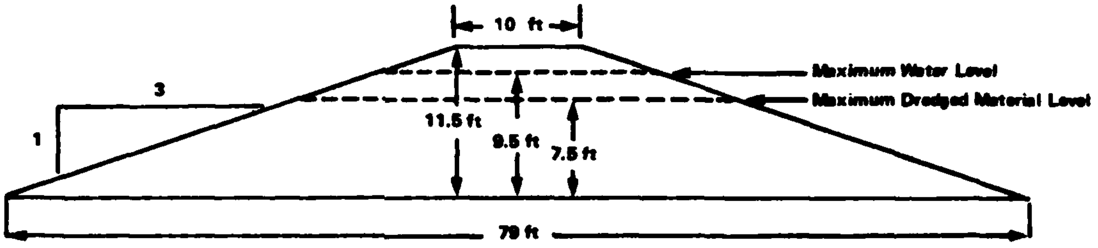
the area. No evidence of subsidence or instability was observed in any of these structures.

Soil boring information available from previous construction projects consists of logs from 34 borings taken along the first 2 miles of the Martin Road extension route east of Patton Road, and 24 borings in four potential borrow sites selected for construction of that road (U.S. Army Corps of Engineers, 1960). The Martin Road borings indicate typical subsurface strata consisting of a surface layer 5 to 20 feet thick of inorganic clays of low to medium plasticity, underlain by 10 to 30 feet of inorganic clays of high plasticity. A few small isolated pockets of clayey sands and clayey gravels were encountered at intermediate depths. No formations existed at the surface which would indicate excessive permeability or other features leading to dike instability. The four borrow sites are located east of Patton Road, west of HSB, and north of the Martin Road alignment. All borings in these sites indicate homogenous inorganic clays of low to medium plasticity ranging in depth from 12 to 20 feet.

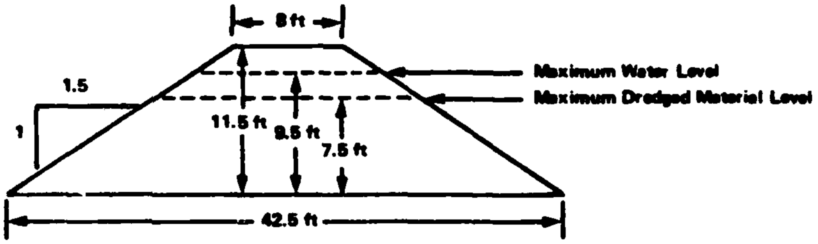
Subsurface exploration and soil testing should be initiated early in the final engineering phase. Soil borings 20 to 40 feet deep along the proposed main dike centerline will be necessary, with additional borings and test pits in the central containment/borrow area. Some borings should be extended to refusal depths. A boring spacing of 700 to 1000 feet is sufficient if relatively uniform subsurface conditions are encountered. The spacing should be reduced where alluvial soils, variable subsurface conditions, swampy areas, or suspected sinkhole areas are encountered. These areas represent the critical design case and should not be overlooked in an effort to reduce costs associated with drilling in difficult areas. Bulk and undisturbed samples would be obtained from the borings. Standard or cone penetration testing should be conducted in the field at each boring site. Laboratory testing should include, but not necessarily be limited to, classification, compaction, consolidation, permeability, and strength testing.

Design Criteria and Specifications--Main dikes of the disposal areas are designed with an 11.5 foot crest height above the containment area floor. This allows for a maximum of 7.5 foot of unconsolidated spoil, a 2 foot minimum freeboard, and a 2 foot minimum ponding depth (see Figure III-4). Depths of fine-grained dredged materials in excess of 7.5 feet cannot be dewatered in a reasonable amount of time by the dewatering methods proposed.

The containment area will be divided by longitudinal cross dikes to provide for separate primary disposal cells with high length-to-width ratios (see Figure III-5). This design will minimize short circuiting and facilitate dewatering by attaining a nearly uniform distribution and slope of the dredged material and allowing access to the cells for trenching. Flow from each primary disposal cell will empty into an equilization basin via a 48 inch pipe weir. Pipe weirs will also interconnect adjacent cells so that they may be used in series for maximum settling efficiency. The site will be graded to an elevation calculated such that the excavated fill will be sufficient for dike construction.



MAIN DIKE



INTERIOR DIKE

FIGURE III-4. Typical Dike Cross-Sections for the Temporary Dredged Material Disposal Area (TDMDA)

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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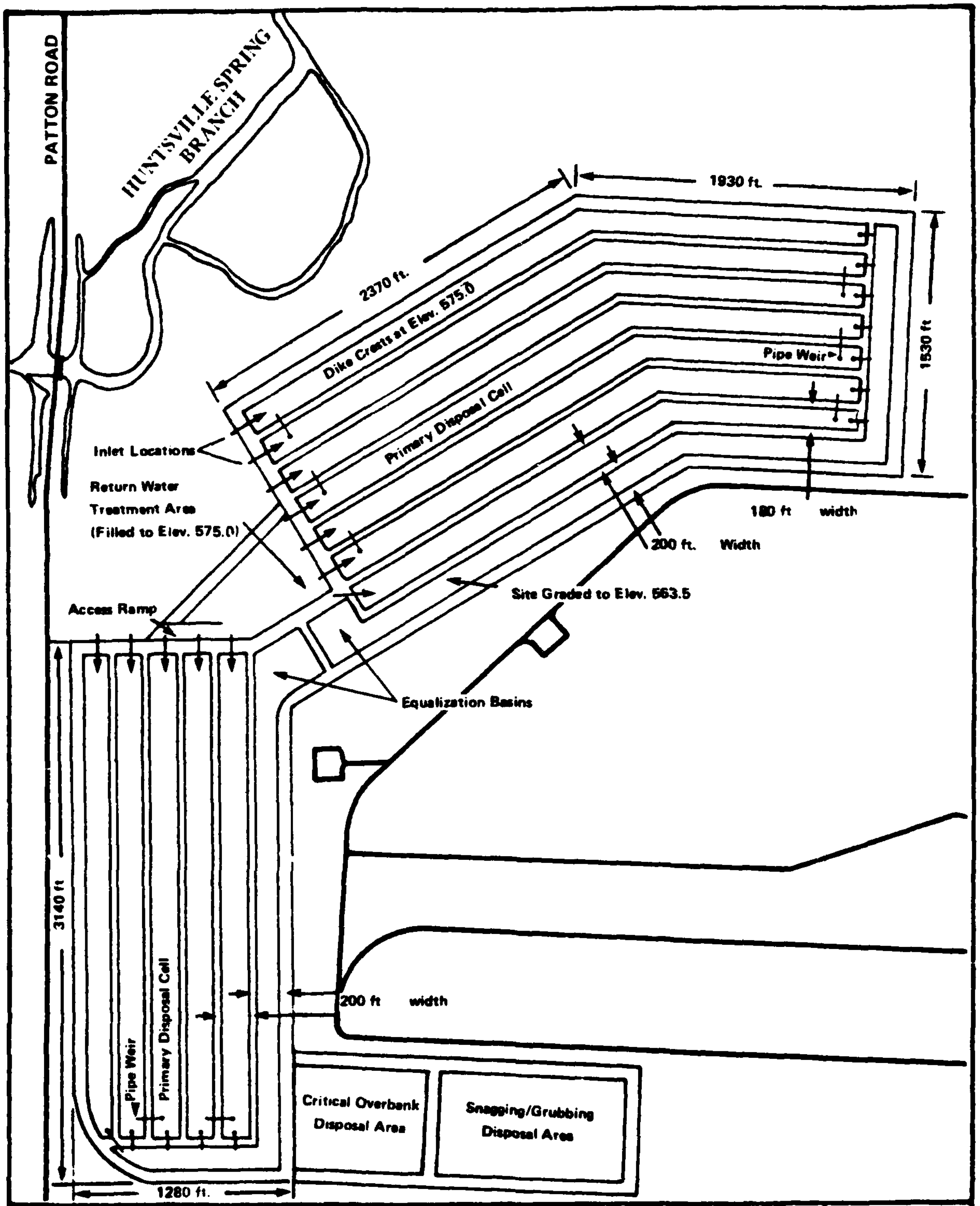

FIGURE III-5. Temporary Dredged Material Disposal Area Site Plan

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Equalization basins are also designed with high length-to-width ratios to minimize short-circuiting and improve settling efficiency. The design criteria used is to provide sufficient storage for one day's dredging overflow and runoff from a precipitation event of 24-hour duration with a recurrence interval of 100 years, while providing a minimum 4-foot depth for settling and storage of settled solids. The design rainfall for Madison County is approximately 8 inches (U.S. Department of Agriculture, 1973). If the design criteria are exceeded, the temporary storage can be provided by raising the weir level of the pipe weirs and impounding the excess runoff in the primary disposal areas. Water from the equalization basin will be pumped to the return water treatment facility to assure a regulated, uniform flow.

Separate disposal cells will be provided for landfilling of critical overbank material and for tree material, root systems, and other debris removed in snagging and grubbing operations (see Figure III-5). Precipitation incident on these areas will be pumped to the adjacent equalization basin. The snagging disposal area can be expanded to the east as necessary to accommodate the amount of material removed.

A 3:1 sideslope is used for all main dike sections. This provides for a conservative design in the absence of detailed soil and subsurface engineering tests which would be necessary to safely design a more economical dike of smaller cross-section. These tests would, of course, be performed in the final engineering phase, and the dike designed accordingly. A crest width of 10 feet will provide access for dike inspection and equipment used in containment area operation. The main dike crest height is 11.5 feet.

A 1.5:1 sideslope is used for all interior dike sections. The smaller cross-section is adequate since interior dikes will generally have water or sediment on both sides, resulting in less stress; and the consequences of failure are not severe, as spilled material would be contained by the main dike. A top width of 8 feet will provide access for inspection and equipment. The crest height is 11.5 feet. Interior and exterior dike sections are illustrated in Figure III-4.

A preliminary site plan of the temporary disposal area for Dredging Plan III is shown in Figure III-5. Disposal areas for Dredging Plans I and II would be of similar design but scaled down to the smaller containment volumes required. Site and dike crest elevations were computed solely on the basis of providing sufficient fill to construct the dikes. Dike crest elevations are at 575 feet, the approximate elevation of the 100-year flood on the TR. If the 100-year flood is to be used as the design criteria, the procedure ordinarily followed is to allow an additional 2 feet of freeboard in excess of the design flood elevation. With the conservative design cross-section of the main dike and the rough fill calculations used, this would require either grading the site to a lower elevation or using off-site borrow material to gain the additional elevation. This is not considered necessary, as the actual design cross-section and fill computations determined in the final engineering phase may allow the additional height to be gained without using off-site borrow material or a lower site grade.

Construction--All dikes will be constructed with material excavated from the site. This material consists almost entirely of clays and is well-suited for construction of the dikes. Existing drainage which crosses the site must be rerouted around its periphery. The site will be cleared of vegetation, and grubbed of all root systems. Topsoil will be stripped and stockpiled for future use during site closure. The interior of the site will be graded to an elevation calculated to provide sufficient material for all dike construction. An estimated 812,000 cubic yards of fill will be required for dike construction. All exterior dike slopes will be seeded and mulched. Excavated material judged unsuitable for exterior dike construction may be used for interior dikes or as fill for the return water treatment area. Groundwater and leachate monitoring systems as described in Section 3.6 will be installed.

3.3.4 TDMDA Operation

Primary Disposal of Dredged Material--During the early phases of dredging, dredged material can be discharged to the two disposal cells nearest the equalization basins (Figure III-5) and passed through a series of disposal cells via the interconnecting pipe weirs. This will minimize the surface loading rate, maximize sedimentation, and decrease the loading on the return water treatment system. As cells become full, the capacity to utilize them in series will be decreased. Eventually they must be used on an individual basis, discharging directly to the equalization basin. Upon completion of dredging, all cells will be decanted and the dewatering program will be initiated.

Return Water Treatment System--Treatment of the return water will be necessary before it is discharged to HSB. The proposed treatment system is designed for complete solids removal with carbon adsorption to remove soluble DDTR. A flow diagram of the treatment process is shown in Figure III-6. Disposal areas sized for Dredging Plans I and II will require 2 MGD capacity and that sized for Dredging Plan III will require 3 MGD, assuming a maximum dredge pumping rate of 8100 gpm on 5-day, 8-hour shifts, 70 percent operational efficiency (i.e, 30 percent down-time), and continuous operation of the facility.

The proposed system utilizes feed pumps to draw untreated water from the equalization basin. Feed systems add a polymer coagulant to the flow before discharging to an earthen clarification pond. Solids in the pond are pumped back periodically to a primary disposal cell with a small Mud Cat dredge. From the clarification pond, flow is pumped via two feed pumps through multimedia filters followed by dual carbon adsorbers. The effluent is then discharged to HSB, with some being held in a small pond to provide backwash water for the filters.

Operation of the treatment system on a 24-hour basis will probably be required. Upon completion of the dredging program, the plant will have to operate on an intermittent basis to treat runoff from the disposal site. The plant is proposed to be leased from the manufacturer for the duration of disposal site operation. Spent carbon will be regenerated off-site.

Dewatering Dredged Material--Dewatering of the dredged material will be necessary before an ultimate disposal option can be carried out, be it

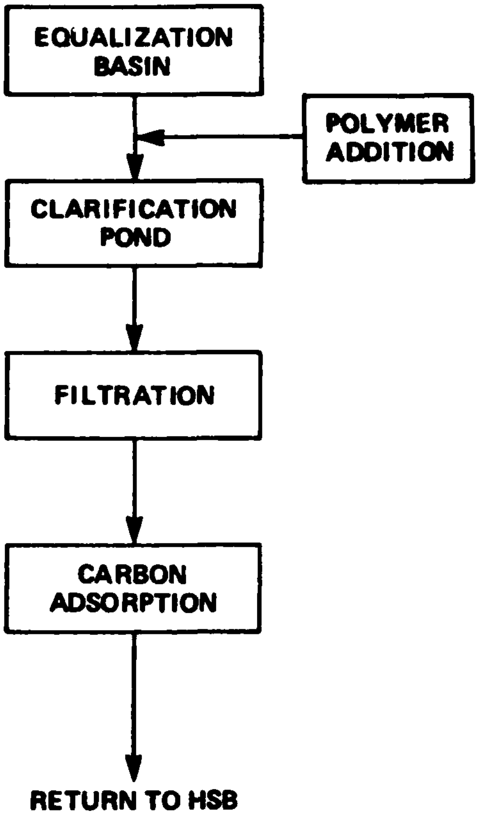

FIGURE III-6. Flow Diagram for Treatment of Dredge Return Water

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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on-site application of a stable impermeable cover, or transportation of the material to off-site mine disposal. Since the disposal area is designed to contain water, precipitation incident on it will tend to remain ponded if no dewatering measures are taken. Ponded water will be removed only by evaporation, as downward percolation out of the disposal area is restricted by the impermeability of the underlying clays. If no other means of removing the water is provided, the perched water table in the dredged material will be recharged and dewatering will not occur.

A series of studies conducted by the U.S. Army Engineer Waterways Experiment Station under the Dredged Material Research Program concluded that natural evaporative drying with progressive trenching is the most efficient and cost-effective method of dewatering fine-grained dredged material (Johnson et al., 1977; Palermo, 1977; Bartos, 1977; Haliburton, 1978). Other methods investigated were the use of underdrains, horizontal or vertical sand drains, mechanical agitation, electro-osmosis, and vacuum well pointing. While some of these methods produce higher rates of dewatering, they incur high capital and operating costs and are not cost-effective unless constraints, such as time available, preclude natural dewatering (Johnson et al., 1977; Haliburton, 1978).

By constructing surface trenches to provide adequate drainage for removal of precipitation, the water table in the dredged material is gradually lowered through evaporative drying. The formation of desiccation cracks at the surface of the material enhances evaporative drying by providing additional surface area for evaporation and pathways for surface drainage to the trenches. As the depth of the cracks increases with drying, the surface trenches must be progressively deepened so that their flowline elevation is always lower than the base of the desiccation cracks to prevent ponding in the cracks. Construction of trenches much deeper than the bottom of the adjacent desiccation crust is difficult due to slumping caused by the high water content of the underlying dredged material.

The earliest time at which surface trenching can be initiated is at the end of the free water decant phase, termed the "decant point". Prior to this time, evaporation rates are controlled by the free water surface and will not be increased by trenching (Haliburton, 1978). The decant point is reached in 1 to 6 months, depending on the nature of the dredged material, physical properties of the disposal site, and climatological conditions. It is observed in the field by formation of a thin drying crust with widely spaced desiccation cracks. If drainage conditions in the disposal area at the decant point are good enough to remove precipitation quickly and prevent ponding, the trenching program need not be implemented at that time. Drainage conditions must be monitored closely and trenching should be initiated at the first sign of persistent standing water or ponding in the desiccation cracks.

When conditions suggest that trenching be initiated, trenches should be constructed in such a manner as to maximize surface drainage. The actual configuration used is based on the topography of the disposal site. The high length-to-width ratio of the disposal areas should minimize short-circuiting and provide for uniform settling of solids, resulting in an even distribution of dredged material across the cross-section. With proper operation of the disposal site assuring this condition, two peripheral trenches near the dikes on either side of the disposal cells will probably suffice for providing surface drainage (Palermo, 1980). These trenches can be constructed by a small dragline with a boom length of 40 to 60 feet. The track width of this equipment is typically 9 to 10 feet, therefore some reworking of the interior dikes may be required to provide for safe operation and mobility on the dikes.

A detailed procedure for peripheral trenching is given by Haliburton (1978). The basic procedure consists of digging a sump at the outlet weir, then constructing peripheral trenches to the sump. Additional trenching cycles are initiated at the first sign of prolonged ponding in the desiccation cracks. Estimated trenching intervals for dewatering fine-grained dredged materials with a 2 to 5 inch initial crust using peripheral dragline trenching are bimonthly for the first four months, and every four months thereafter.

Though the drawdown rate of the water table in fine-grained dredged material is site-specific, previous field measurements indicate that an estimate of 0.1 feet per month is realistic (Palermo, 1977; Haliburton, 1978). The dewatering program should be continued at least until an adequate crust thickness is formed to support the weight of equipment required for application of the final cover, if that option is taken. This will require a minimum of 2 feet of crust. If additional stability is required, the dewatering program will have to be extended accordingly. If transportation to a mine disposal site is desired, the dredged material should be dewatered throughout most of its depth before removal, as interruption of existing drainage by earlier removal will inhibit further dewatering.

3.3.5 Miscellaneous Considerations

The entire disposal area should be fenced to limit access by persons or animals. A buffer area of 200 feet should be left between active areas of the site and the fence. The site boundary should be posted at regular intervals with appropriate signs.

A drainage system must be provided for the site, designed to separate runoff from contaminated and uncontaminated areas. Contaminated runoff must pass through the return water treatment system.

Inspections of the main dike should be made on a regular basis.

3.4 DREDGING HUNTSVILLE SPRING BRANCH AND INDIAN CREEK SEDIMENTS

3.4.1 Overview

Channel dredging will proceed in the following sequence:

1) construct necessary access roads along HSB,
2) clear trees and other debris from the channel and bank edges with a crawler-mounted crane operating from the access road and a small barge-mounted crane operating in areas inaccessible from the road,
3) dispose of the cleared debris in a landfill, and

4) hydraulically dredge the channel sediments and transport material via pipeline to the temporary disposal area.

For removing overbank material in Reach A of HSB, the following approach will be used:

1) clear vegetation from the overbank,
2) grub all root systems,
3) remove contaminated sediment with a dragline,
4) construct haul roads as necessary as operation progresses into overbank,
5) dispose of contaminated tree material in landfill, and
6) dispose of contaminated sediment in separate cells of the TDMDA and on top of dewatered dredged material in the TDMDA, or in an off-site mine.

Before bringing equipment into the area it may be necessary to survey for and remove live ordnance which may be in the area as a result of RSA's testing operations.

3.4.2 Access Roads

The locations of access roads for the three areal dredging plans are shown in Figure III-7. Approximately 4 miles of road are required for Reach A, 6 miles for Reach B, and 5.5 miles for Reach C. A width of 35 feet is used to allow two-way traffic and turning room for haul vehicles. A buffer of 20 to 30 feet should be left between the access roads and the stream, cleared only where necessary for stream access or equipment operation. This buffer will minimize the potential for bank erosion and aid in sediment control during road construction. When clearing the bank, some larger trees near the channel should be topped to a height of 6 feet or so to provide anchorage for the dredge swing cables without crossing and blocking the access road. Culverts will be placed as necessary to provide drainage into HSB from sloughs and streams. If the bearing strength of the sediments is insufficient for road construction, surface sediments may have to be removed and replaced with suitable fill. Contaminated sediments in the critical overbank area along the access road alignment will have to be excavated prior to or coincident with access road construction. Access roads will be surfaced with gravel.

Sediment loading to the adjacent stream during access road construction can be minimized by stabilizing exposed surfaces as soon as is practical. This would include gravelling the road surface and seeding and mulching shoulders. If additional sediment control is deemed necessary, silt fences may be installed around active construction areas.

The possibility of dredging Indian Creek without an access road should be considered. This would not be expected to result in cost savings, as reduced snagging and dredging production rates and increased floating pipeline requirements would probably offset the savings in road costs. Snagging would be implemented by a self-propelled barge-mounted crane, unloading at various accessible points along IC. The entire discharge line would have to be on floats, as would the booster pumps. Some

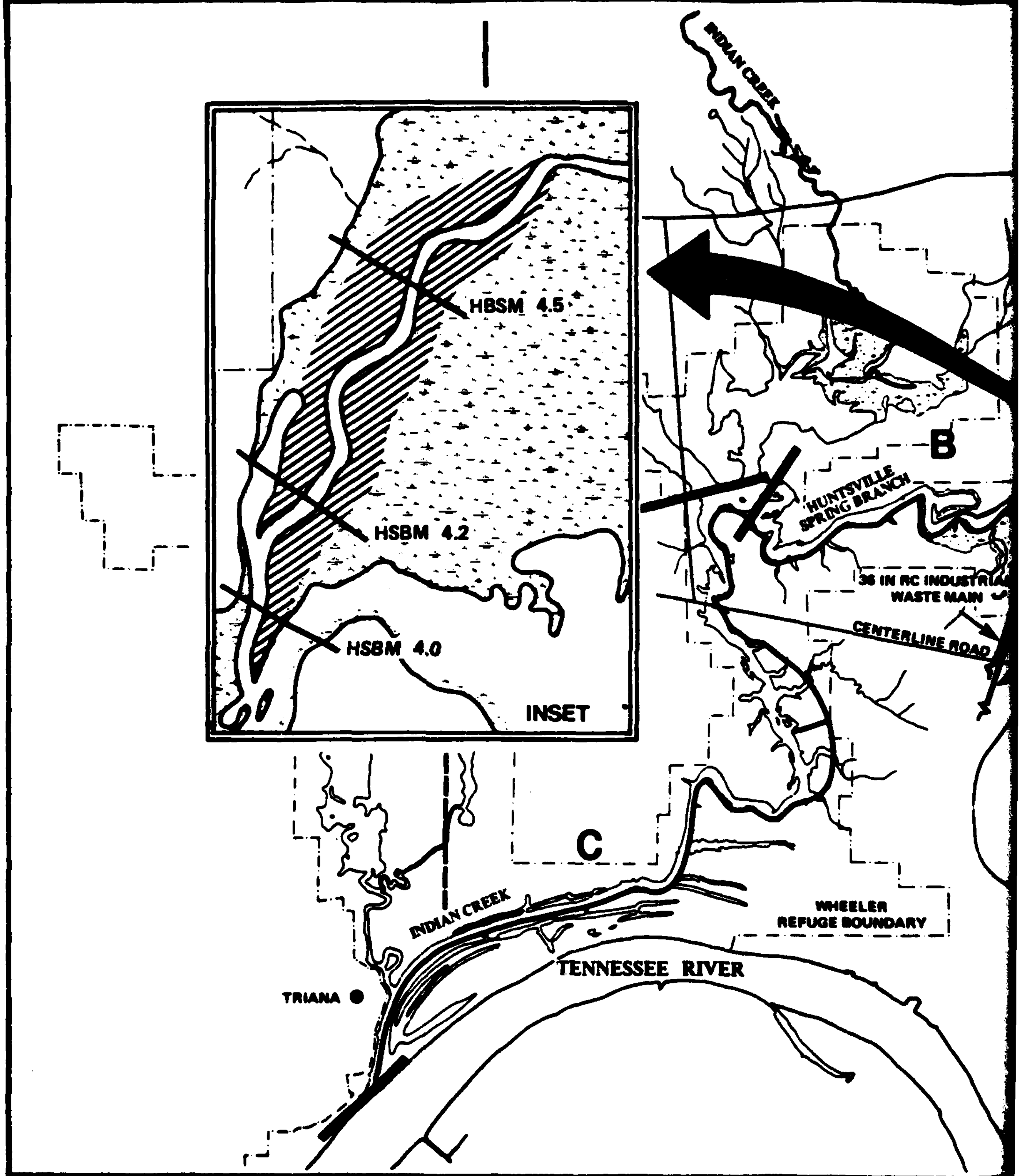
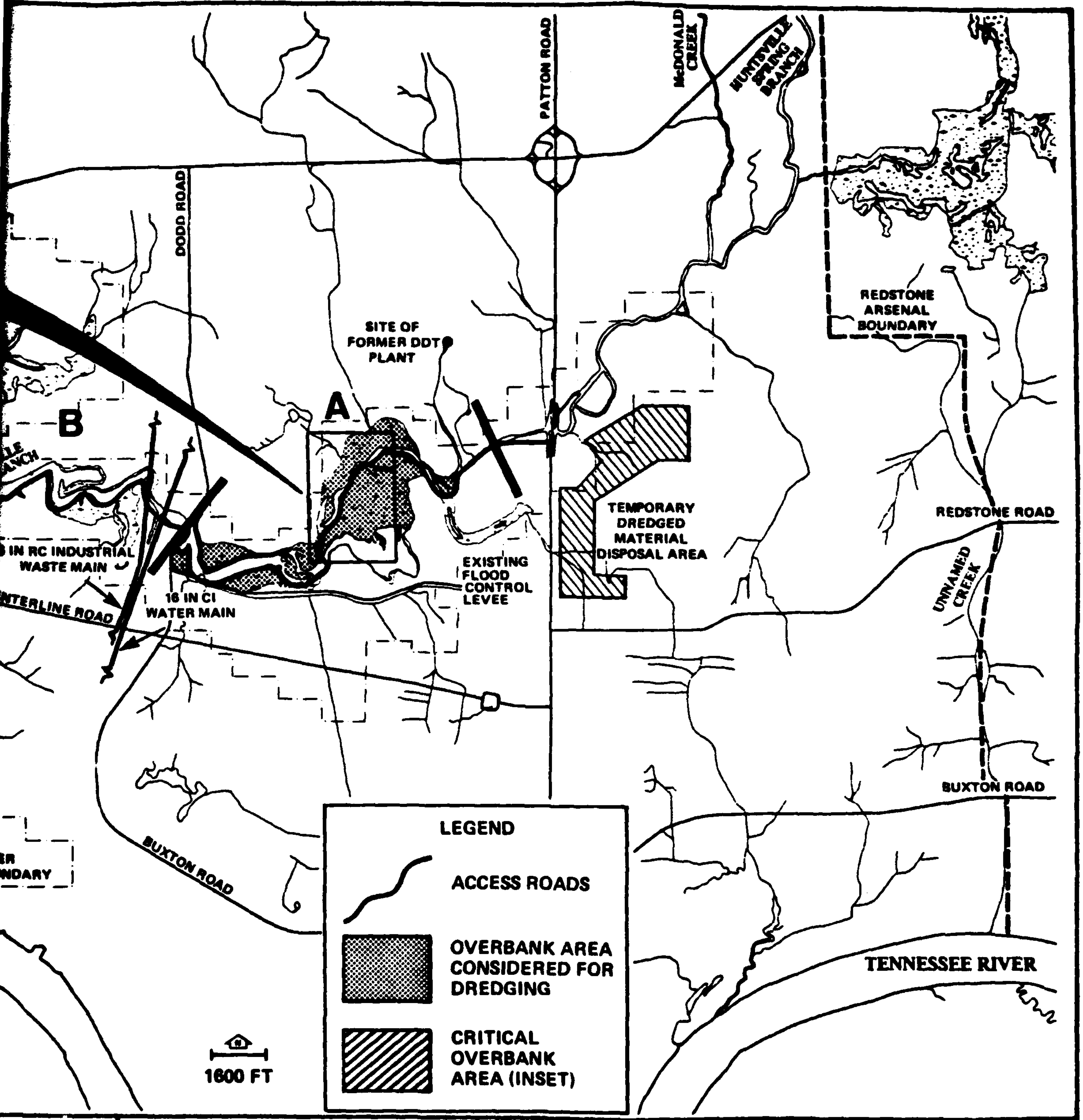


FIGURE III-7. Areal Plan for Hydraulic Dredging in Huntsville Spring Branch and Indian Creek

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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clearing may be required along lower IC for powerline installation to serve the booster pumps. This approach is not feasible for HSB, as shallow depths there preclude use of a self-propelled barge.

All access roads will be abandoned upon completion of any mitigation alternative.

3.4.3 Snagging and Clearing Channel

All trees and debris must be removed from the channel bottom to allow operation of the dredge. Trees on the immediate banks which protrude over or into the water must also be removed. Between HSB Miles 5.6 and 3.9, both banks are accessible to a crawler-mounted, grapple-equipped crane with a boom length of 160 feet operating from the access road on the south bank. Beginning at HSB Mile 5.6, the crane will proceed in a downstream direction, loading trees and debris into trucks for hauling to a landfill adjacent to the TDMDA (see Figure III-5). Snagging should stay ahead of dredging only to the extent necessary to avoid delays or conflicts. This will leave a minimal amount of disturbed contaminated sediment exposed in the event elevated flow conditions are encountered.

Downstream from HSB Mile 3.9, a barge-mounted hydraulic crane will be necessary for clearing areas inaccessible from the access roads. Due to the shallow depths in HSB, the barge will have to be mobilized and positioned with a cable and winch system to avoid sediment suspension by prop-wash. The cable arrangement described for the Waterless Dredge in Section 3.2.2 will allow the barge to swing across the entire channel.

IC can be snagged either from the access road or with a self-propelled barge.

3.4.4 Utilities Relocation

Two pipes cross the HSB channel just west of Dodd Road, a 16 inch cast iron water main and a 36 inch reinforced concentrate industrial water main (see Figure III-7). Though their exact depth has not been determined, it is expected that both pipes will have to be buried to a greater depth in the channel or relocated before that area is dredged.

3.4.5 Channel Dredging

A conventional basket cutterhead dredge such as the 14-inch Ellicott 770 will be employed to dredge HSB and IC channel sediments, as discussed in Section 3.2.3. Dredging will commence at HSB Mile 5.6 as soon as sufficient channel is cleared and proceed downstream, following the snagging operation. The dredge will be launched by crane from Patton Road into HSB. Some clearing may be required between Patton Road and HSB Mile 5.6 to allow passage of the dredge. A general equipment list for the three dredging plans is given in Table III-7.

Due to the long discharge distance to the TDMDA (12.5 miles from IC Mile 0.0) a total of 11 booster pumps will be required in the discharge line. Use of electric boosters is recommended, as they are much more easily adapted to an integrated central control system to maintain steady

Table III-7. General Equipment List for Dredging Huntsville and Indian Creek Channels[1]

Item	Quantity Required for Each Dredging Plan I	II	III
14 in. cutterhead dredge	1	1	1
14 in. floating discharge pipe	2,000 ft.	2,000 ft.	2,000 ft.
14 in. fixed discharge pipe	21,000	34,000	63,000
14 in. booster pumps	4	7	12
Service boat and motor	1	1	1
Temporary Power Line (43 kv)	3 miles	5.5 miles	11 miles

[1] Figures are based on using the Ellicott 770 dredge operating at 8100 GPM with a 350 cu. yd./hr. solids output and a discharge distance of 1.1 miles between booster pumps.

flow in the discharge line (Stribling, 1980). Flow monitoring and control for all boosters could be performed at a single location with this type of system. The 14-inch Ellicott boosters upon which dredging costs are based have a discharge range of approximately 6000 feet when pumping at a rate of 400 cubic yards solids per hour. Costing for the dredging project includes the outright purchase of twelve, 14-inch electric boosters (1 spare included), as no dredging contractor would have this equipment capability. Boosters would be skid-mounted and set up along the access roads approximately 1.1 miles apart. A temporary power line carrying primary voltage (43 kv) would be required along the access road to provide power for the boosters. A transformer at each booster would be required to step the voltage down to the 4,160 volts required for the boosters. Spacing power poles at 175 foot intervals and installing conventional street lights on each would provide adequate lighting along the access road for evening shift work and pipeline inspection.

The dredge discharge line should be a polyethylene pipe of 14 inch inside diameter, such as the Phillips Driscopipe. This pipe typically comes in 38 foot sections which can be fused together by a thermal pressure system leased from the manufacturer, forming a permanent joint stronger than the pipe itself (Hoover, 1980). Mechanical joints can also be used where pipe breakdown is required by fusing flanges onto the pipe ends. Permanently fusing three, 38 foot sections together and using flange joints between the resulting 114 foot lengths would minimize the possibility of leakage at mechanical joints, while maintaining a reasonable length of pipe to work with and allowing breakdown of the pipe in the event of clogging. In addition to permanent jointing, other advantages of polyethylene pipe are lightness, flexibility (can bend over and around land forms), and positive flotation (buoyant even when filled with water). Operating flotation for the pipe is provided by three, 19 foot by 10 inch diameter floats per 100 feet of discharge line, allowing for an overloaded condition of 65 percent solids by weight (Hoover, 1980).

Unconventional systems should be considered for positioning the dredge. Advantages may be gained both in turbidity reduction and production rate. The conventional stepping method of swinging alternately on port and starboard spuds makes a zig-zag cut along the bottom, with the cutterhead passing over some areas twice and leaving "windrows" of material between cuts near the outer edges of the swing (Barnard, 1978). Aside from lowering dredge production, contaminated material may be left in the windrows where it would be subject to scour and transport downstream. Modifications of the conventional stepping method have been developed to allow the dredge to swing in successive concentric arcs, eliminating windrows and excessive duplicate coverage. Among these are the spud carriage system and the Wagger system (Barnard, 1978).

The conventional approach to channel dredging is to take level cuts. Since the channel profiles in HSB and IC are irregular, it would be advantageous to follow the channel contour while dredging, as only the top 3 feet of sediment is to be removed. This would result in higher production, as multiple swings in the same position would not be necessary, and the total volume of sediment dredged would be considerably reduced. Electronic equipment is available which would allow the dredge operator to follow the bottom contour. Motorola's Position Determining

System Division, Scottsdale, AZ, has indicated that production of such a unit is entirely within their capabilities, though it is not presently in production (Sanders, 1980). The unit would consist of two depth sounders mounted on a small boom in front of the dredge, one reading the depth of the dredge head, and the other reading the bottom depth ahead of the cut. A processer would take readings from the two depth sounders and output it on a visual display showing the position of the dredge head with respect to the bottom. Production of the unit would require approximately 90 to 120 days.

An alternative to the electronic sounding system would be to survey the channel bottom and place grade stakes where necessary to determine the depth of cut. The dredge ladder must be equipped with an inclinometer which converts the ladder angle to depth of the dredge head below the surface. Since this method is expected to be more time consuming, less accurate, and equally or more costly; the electronic sounding system is preferred.

Design and costing of the dredging alternative is based on 8-10 hour work shifts, 5 days per week. Intermittant operation such as this is not desirable from a production standpoint but cannot be avoided due to unavoidable conflicts with Test and Evaluation Directorate (T and ED) operations on Test Range 1 during normal working hours. If a 24-hour operation were possible, costs for treatment of return water would increase by a factor of 2.5, resulting in a cost increase of approximately 17 million dollars. Even if a 24-hour dredging were possible, it is doubtful that the increased production efficiency would offset the increased treatment costs.

Active dredging in HSB and IC should be terminated when flow rises significantly above base flow. The point at which sediment (and DDTR) transport becomes excessive would be determined by turbidity monitoring downstream from the dredge (see Section 3.6).

3.4.6 Overbank Removal

The critical overbank area indicated in Figure III-7 consists of approximately 25 acres and contains an estimated 61 percent of the total DDTR in the HSB-IC system. Its removal will require excavation and disposal of 121,600 cubic yards of sediment. The non-critical overbank areas of Reach A contain approximately 4.3 percent of the total DDTR in the HSB-IC system. In order to remove this 4.3 percent, approximately 235 acres of overbank will have to be cleared and grubbed, and 1,136,800 cubic yards of sediment will have to be excavated. This volume is nearly equal to that involved in Dredging Plan III.

Removal of the overbank sediments will require clearing all vegetation and grubbing all root systems in the overbank areas indicated on Figure III-7. Disposal of cleared uncontaminated timber and debris will be provided by the contractor hired for clearing. Removal of the contaminated sediments to a depth of 3 feet can be accomplished simultaneously with grubbing by a small dragline, operating on mats if necessary. Root material will be disposed of in a landfill adjacent to the TDMDA (Figure III-5). Sediments from the critical overbank area will be disposed of in the diked portion of the TDMDA indicated in Figure III-5. Sediments from the non-critical overbank will be disposed of by landfilling in the TDMDA or by containment in an abandoned mine. Both disposal options are discussed in Section 3.5. Access roads will be constructed as necessary to haul material out of the overbank area.

Work in the overbank area will be governed by the water level in Wheeler Reservoir. Inundation of the overbank will require temporary curtailment of work there. The critical overbank should be dredged during the months of November through May, as this is the period when the Wheeler Reservoir is generally at or below elevation 552. This will permit excavation of the sediments with a minimum of ponded water, as the elevation after excavation will be above the water level in HSB. Cooperation of TVA may be enlisted to extend this period somewhat by beginning the drawdown of Wheeler Reservoir prior to the present date of July 1. It would also be advantageous to maintain the maximum pool stage at 555 feet rather than 556 feet while work in the overbank area is in progress. This will minimize down-time due to high water and will significantly reduce the potential for agitated overbank sediments to enter HSB. These adjustments in the Wheeler Reservoir schedule are possible from a technical standpoint. Adverse impacts of these changes would be largely economic and recreational in nature, i.e., shortening of marina seasons, restricted boat access, etc. Environmental, navigational, and power generation impacts would be minimal (Brye, 1980).

Work in the overbank area should be conducted in such a manner as to minimize the potential for suspended sediment and DDTR loading to HSB. Sections of the overbank should be grubbed and excavated leaving a 10 to 20 yard wide strip intact along the HSB channel. This would confine ponded water and disturbed sediment to the dredged area, provided the overbank is not inundated. The narrow strip could then be removed during low pool stage when the excavated areas are either dried out or could be easily drained without releasing heavy sediment loads. Additional sediment control may be gained by utilizing silt fences around active clearing and excavation sites if necessary.

3.4.8 Turbidity Control

The most effective means of minimizing turbidity generated by a conventional cutterhead dredge is to carefully control its operation. The following operational procedures are recommended (Barnard, 1978):

- Cutterhead rotation, swing speed, and inlet pumping rates should be matched so that the cutter does not remove significantly more or less material than can be pumped at the inlet.
- Large sets and excessively thick cuts should be avoided, as they tend to dislodge more material than can be pumped.
- The swinging mechanism of the dredge should be designed for total coverage of the bottom, eliminating the formation of windrows between cuts and their potential for increasing sediment suspension.

- Steep channel slopes should be formed in steps rather than with a straight box cut to reduce turbidity generated by slumping on the slope.

- Dragging of positioning anchors should be avoided.

- Pipelines should be flushed with water before being broken down to add or remove sections.

The use of silt curtains was investigated for controlling downstream sediment transport during dredging. Silt curtains do not contain turbid water, they merely divert its flow under the curtain, minimizing turbidity in the upper water column outside the curtain. Though small reductions in downstream turbidity may be gained by employing a silt curtain in HSB, its utility as a sediment control measure is questionable due to the shallow depths there. The average depth of 3 to 5 feet in HSB would require an extremely short skirt length, and turbid flow under the curtain would remain relatively close to the surface.

Water depths in IC may be sufficient to deploy a silt curtain there, though its utility would again be questionable. The curtain would have to be deployed at some distance downstream from the dredge to avoid frequent curtain movement. Since the turbidity plume downstream from the dredge is expected to be concentrated near the bottom, it is doubtful that the use of the curtain would have a significant effect on overall turbidity reduction. Test deployment of a silt curtain at the beginning of HSB or IC dredging may be desirable to fully evaluate its capabilities.

Low-level impoundment structures were also investigated for controlling downstream sediment transport during dredging in HSB.

The relatively flat topography would permit the impoundment of HSB at Mile 0.0 only to an elevation of 556 feet without causing excessive inundation upstream. This level of impoundment may increase sedimentation behind the dam during low pool stage in the Wheeler Reservoir. However, the majority of the turbidity plume is expected to settle out in HSB or IC without such a structure since dredging will be conducted only under base flow conditions. The advantage gained by installing an impoundment structure may be negated by the adverse effects of prolonged elevated water levels on work in the overbank areas.

3.4.8 Work Scheduling

Work schedules in HSB and IC will have to be coordinated with operations of the T and ED at Test Area 1. Based on past operation of Test Area 1, the following estimates of work stoppage during normal work time (0800 to 1630 hours, Monday through Friday) can be expected if range operations are not curtailed during dredging (U.S. Army, 1980):

1) eastern half of Reach A, 0 percent;
2) western half of Reach A, 25 percent;
3) Reach B and Reach C north of Centerline Road, 65 percent; and
4) Reach C south of Centerline Road, 61 percent.

Based on these estimates a evening shift from 1620 to 2430 hours would be required in Reaches B and C if Test Area 1 operations are not to be seriously impacted. Work in Reach A can be conducted during normal work hours without serious impact on range operations, provided contractor personnel can be evacuated during hazardous tests. As this will result in an estimated 25 percent work stoppage in the western half of Reach A, work in that reach may be more productive on an evening shift.

The duration of the dredging project is dependent on the production capacity and efficiency of the dredge selected. Assuming the Ellicott Dragon 770 is selected and averages 350 cubic yards per hour solids production with a 70 percent production efficiency over a 40-hour week, the project duration would be 0.5, 1.3, and 2.6 years for Dredging Plans I, II, and III, respectively. Preliminary engineering, permitting, mobilization, set-up, and disposal site construction would require an additional 3.0 to 3.5 years. Use of a dredge with a smaller production capacity would increase the dredging time accordingly. Use of multiple dredges or a dredge with a higher production capacity would increase return water treatment costs significantly as discussed in Section 3.4.5.

3.5 PERMANENT DISPOSAL OF DREDGED MATERIAL

3.5.1 Use of TDMDA as a Permanent Landfill

The physical factors which determine the effectiveness and environmental acceptability of this disposal method are discussed in Section 2.0 of this Appendix. The TDMDA would be used as permanent landfill and closed as such after the dredged material is dewatered. Initial site preparation would remain unchanged. Groundwater and leachate monitoring systems, as described in Section 7.0, will be installed regardless of whether this option is taken.

Closure of the site cannot be initiated until the dredged material is dewatered sufficiently for long-term stability and access by earth-moving equipment. If overbank sediments are deposited on top of the dewatered dredged material they should not require dewatering. If the option is taken to remove noncritical overbank sediments in Reach A, diking in the TDMDA for the critical overbank disposal area could be expanded eastward to accommodate overbank sediments removed in the early phase of the project. In later stages of the project, overbank sediments may be deposited on top of dredged material in the primary disposal cells once dewatering of those cells is sufficiently complete. Individual primary disposal cells should be filled and completed as soon as is practical during dredging so that overbank removal is not excessively postponed by dewatering time requirements.

Grading and compaction of the contaminated material will preceed cover application. Dike sections above the final grade of contaminated material can be used for the final clay cover, provided undesirable materials are excluded. Additional clay material from off-site borrow areas may be required. Preliminary investigation indicates that adequate borrow sites are available within a 3 or 4 mile radius of the TDMDA. This distance is used in computing hauling costs for borrow material. If sites more distant than 3 or 4 miles are used, hauling costs would be increased proportional to the haul distance. The final cover will consist of a minimum of 6 inches of compacted clay with a permeability less than or equal to 10^{-7} cm/sec., underlying 18 inches of soil capable of supporting shallowrooted vegetation. The final grade of the site will be 2 percent, sloped approximately from the site centerline. A durable, shallow-rooted grass or other suitable vegetative cover will be established and maintained. Mowing will be required at least once or twice a year to prevent deep-rooted plant growth from penetrating the clay cover. Provisions must be made for long-term monitoring of leachate and groundwater, and periodic site inspections. The site will remain ✓ fenced and posted.

3.5.2 Mine Disposal

Three abandoned mine sites are considered for permanent disposal of the dewatered dredged material. The sites are among those previously investigated by TVA for disposal of low-level radioactive waste (TVA, 1979a). Principal features of the mines are shown in Table III-8, and their approximate locations in Figure III-8.

The Guntersville Mine is limited in size, having an estimated storage capacity of only 100,000 to 150,000 cubic yards. This storage volume is insufficient for any of the dredging plans proposed in this alternative. Use of the site would be limited to one of the smaller dredging plans associated with alternative D or F if dredging in Reaches B and C is omitted. Some initial preparation of the mine would be required to isolate a large, flowing solution feature near its center. Such isolation should not impede water flow through the feature, but instead isolate it laterally from the rest of the mine.

The dimensions and available area of the Rockwood Aggregate Mine are not known. It appears to have no advantage over the Gager Mine for use as a disposal site and need not be investigated further unless a problem develops with use or acquisition of the Gager Mine.

There appears to be ample storage volume in the Gager Mine for all contaminated sediments being considered for removal. Storage may be limited to the upper level, as the lower level is reported to be wet. No significant solution features were reported during TVA's evaluation of the mine (TVA, 1979a). Though the upper level is mostly dry, some standing water and evidence of small solution channels were reported there (Byerly, 1973).

If a mine disposal option is implemented, a thorough survey and evaluation of the Gager Mine will be required. Any condition which might jeopardize long-term containment of the sediments will have to be corrected before disposal operations commence. Dewatered contaminated sediments will be transported to the mine in covered dump trucks with sealed tailgates. Trucks will proceed as far as possible into the mine, with final placement of the sediments being accomplished by front end loaders and conveyer systems. Closure of the site consists of sealing off the contaminated areas of the mine by building masonry partitions between existing pillars. Hydrologic features of the area must be investigated to determine suitable locations for monitoring.

Table III-8. Candidate Sites for Mine Disposal of DDTR-Contaminated Sediments

	Guntersville Mine	Gager Mine	Rockwood Aggregate Mine
Location	N. Shore, Honeycomb Creek Embayment, Gunterville Lake AL, Mt. Carmel 7-1/2' quad.	Sherwood, Franklin Co. TN, Sinking Cove 7-1/2' quad.	Rockwood, Franklin Co. AL, Isbell 7-1/2' quad.
Haul Distance From HSB at Patton Rd. (mi.)	27	88	30
Ownership/Contact	TVA/Buster Smith, P&SVS, Muscle Shoals, Ext. 2223	W.T. Griffin/ W.T. Griffin, Jr., Rt. 1, Box 222, Stanley NC 28164	Alabama Limestone Inc., Rt. 3, Box 95, Russellville AL (205) 332-3700
Present Use	Abandoned; Civil Defence Storage and Shelter	Abandoned	Abandoned
Approximate Area Mined (acres)	5	60	NK
Ceiling Height (ft.)	35	Up to 65	NK
No. of Levels	1	2	1
Geologic Formation	NK	St. Genevieve-Gasper	Bangor
Bedding Attitude	Horizontal	Horizontal	Horizontal
Topographical Setting	Escarpment face. Large surface solution features nearby	Escarpment face	Face of low ridge
Overburden (ft.)	100	R00+	200-250

Note: NK = Not known.

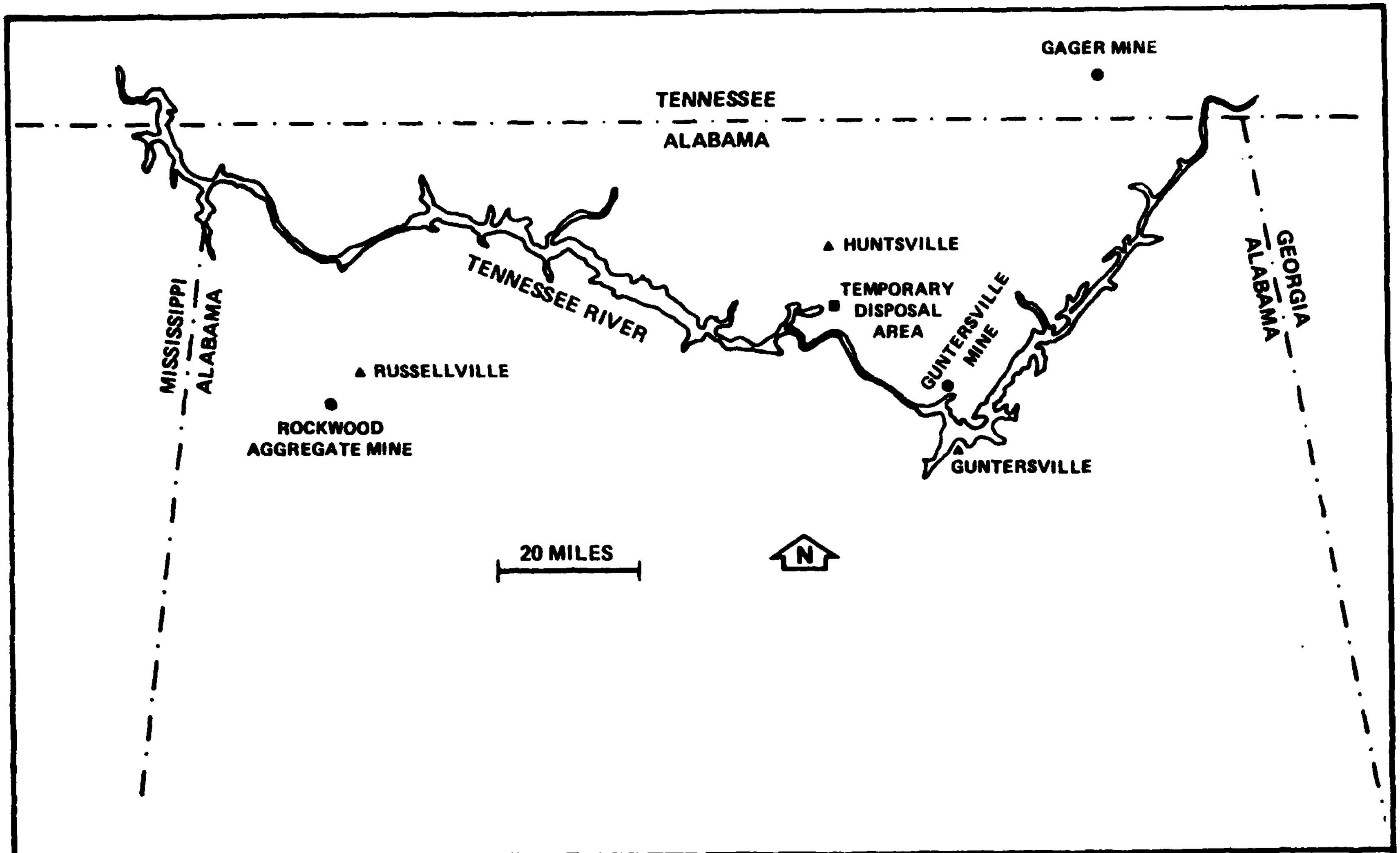

FIGURE III-8. Locations of Candidate Mine Disposal Sites

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Wheeler Reservoir, Alabama

3.5.3 Incineration

Several studies have demonstrated the effectiveness of incineration as a method for disposal of DDTR wastes (Shih *et al*., 1975; Ferguson *et al*., 1975; Duvall and Rubey, 1976; General Electric Co., 1977; Environmental Protection Service, 1978). The successful destruction of DDT and its toxic decomposition products is reported for DDT wastes in solid, semisolid, liquid and liquid emulsion phases of varying composition and concentration. Due to high capital, fuel, and operating costs, incineration is most suitable for concentrated DDTR wastes.

Operating conditions for safe incineration of organic pesticides have been established by EPA in recent tests (Ferguson *et al*., 1975). These tests indicate that a range of combustion temperatures and retention times will provide a minimum of 99.99 percent destruction of DDTR and other organic pesticides, as shown in Figure III-9. Pesticide formulations tested included powders, granules, pellets, and emulsifiable concentrates. Other EPA-sponsored tests on incineration of DDT reference standards reported destruction of those samples to be below gas chromatograph detection limits at the operating conditions indicated by Point A, Figure III-9 (Duvall and Rubey, 1976). In separate tests conducted by the U.S. Army, incineration of DDT in oil solutions and emulsifiable concentrates provided a minimum of 99.99 percent destruction at the operating conditions indicated by Point B, Figure III-9 (Shih *et al*., 1975).

EPA presently recommends that organic pesticides be incinerated at 1000°C (1830°F) with a 2 second retention time, though other operating conditions are acceptable if they provide the same level of destruction (U.S. Environmental Protection Agency, 1974). Additional regulations concerning the incineration of pesticides are proposed under 40 CFR Part 250, Hazardous Waste Guidelines and Regulations, as set forth by the Resource Conservation and Recovery Act (U.S. Environmental Protection Agency, 1978).

DDT and other industrial chlorinated hydrocarbon wastes have been successfully disposed of by thermal destruction in a cement kiln (Environmental Protection Service, 1978). Cement kilns are operated between 1370 and 1450°C with a retention time of about 10 seconds, providing conditions for complete combustion of DDTR (Battelle Memorial Institute, 1978). Toxic emissions during the test burn were negligible. Additional benefits were realized in lower fuel consumption and addition of chloride ion to the process, decreasing the amount of calcium chloride normally added. Though this disposal method appears practical for disposal of relatively concentrated or combustible DDTR wastes, it is not feasible for disposal of contaminated sediments in HSB or IC. The large volume of inert material in the sediments would present transportation problems and would most likely be unacceptable for the cement manufacturing process.

Incineration of large volumes of river sediments was recently investigated as a possible method for disposal of PCB-contaminated sediments in the Hudson River (General Electric Co., 1977). PCB's were successfully volatilized from the sediments by a progressive temperature

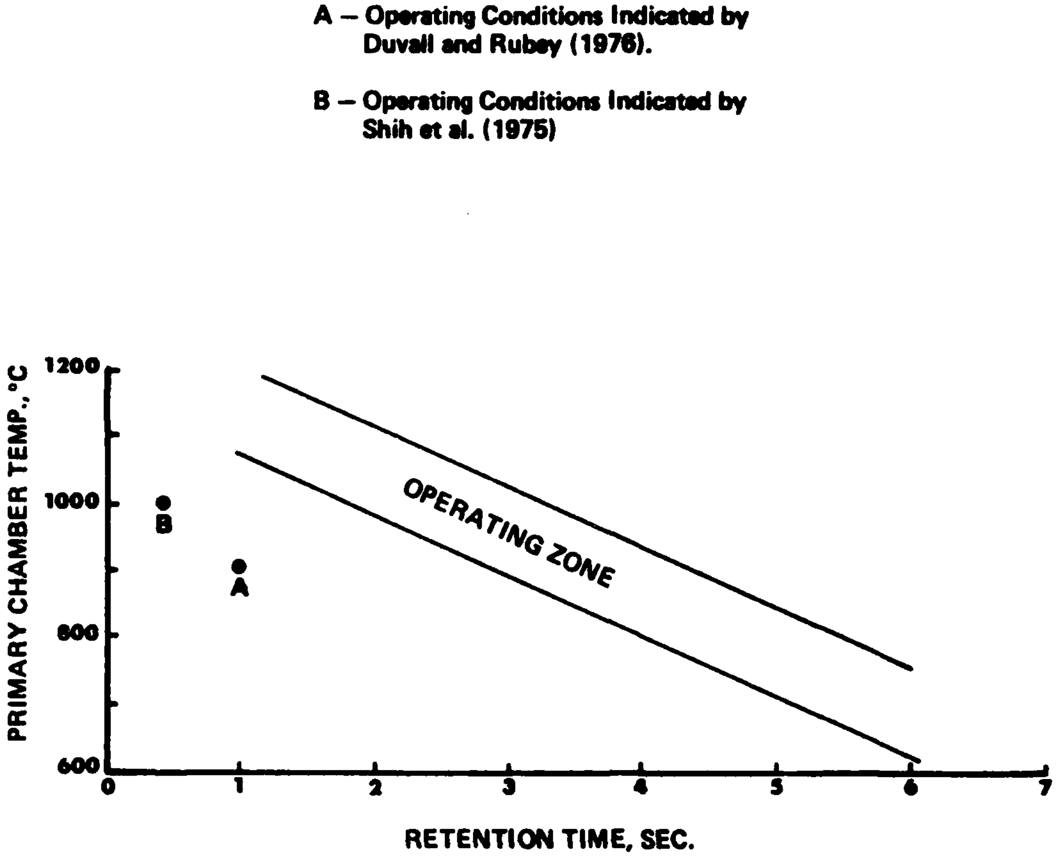

FIGURE III-9. Operating Conditions Generally Acceptable for Incineration of Organic Pesticides

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama

buildup from 427°C (800°F) to 610°C (1130°F) between the first and fourth hearths of a small multiple hearth incinerator. PCB's in the vapor phase were destroyed in the afterburner at temperatures greater than 982°C (1800°F) and 0.5 second retention time. These operating conditions are similar to those reported for DDTR destruction. From the test burn it was concluded that thermal treatment of river sediments, though effective, was infeasible due to the high cost involved. Fuel costs alone were estimated at $10 per cubic yard in 1977, a figure which would more than triple at projected year-end fuel costs. Using a conservative estimate of $30 per cubic yard for fuel costs required to incinerate HSB and IC sediments, total fuel costs of approximately 6.3, 17.4, and 34.5 million dollars would be required for Dredging Plans I, II, and III, respectively. Capital, operating, peripheral equipment and material transporting costs are estimated at 4.2, 11.5, and 22.7 million dollars respectively.

3.5.4 Off-Site Secure Landfill

The possibility of permanent disposal in an existing hazardous waste landfill was investigated. A facility of adequate capacity is operated by Chemical Waste Management, Inc. in Livingston, Alabama. Estimated costs at this facility for transportation and disposal of sediments from Dredging Plans I, II, and III are approximately 16, 44, and 87 million dollars, respectively.

Another option considered was construction of an off-site secure landfill for permanent disposal. Several sites suitable for landfilling DDTR-contaminated sediments were identified in a TVA report on landfilling alternatives for low-level radioactive waste disposal (TVA, 1979b). Haul distances to the sites from HSB at Patton Road range from 100 to 150 miles. The estimated cost of implementing this alternative is 8.0, 14.0, and 26.0 million dollars for Dredging Plans I, II, and III, respectively.

3.5.5 Discussion

The total estimated costs for all disposal options considered are summarized in Table III-9. Time base for the cost estimates is 1980.

Use of an existing hazardous waste landfill was eliminated on a cost basis alone. Incineration is considered a poor alternative because of the high costs with respect to other options and the excessive energy consumption.

Constructing a new secure landfill does not hold any significant advantages over permanent disposal in the TDMDA. It has the distinct disadvantage of moving a large quantity of contaminated sediment from a contaminated area to an uncontaminated area, in addition to the higher costs incurred. This option was eliminated for these reasons.

Permanent disposal in the TDMDA will provide an acceptable degree of isolation for the contaminated sediments. It has the advantages of maintaining DDTR contamination in a localized area and low cost. The

Table III-[illegible]. Summary of Cost Estimates for Implementation of Permanent Disposal Options

	Estimated Cost for Each Dredging Plan (Millions of Dollars)			
	I	II	III	III Plus Reach A Overbank
A. Permanent Disposal in Temporary Dredged Material Disposal Area	1.2	2.7	6.2	14.2
B. Mine Disposal (Gager Mine)	3.0	7.8	15.0	34.2
C. Incineration	10.5	28.9	57.2	116.9
D. Disposal in Existing Hazardous Waste Landfill (Livingstone, AL)	16.0	44.0	87.0	174.0
E. Construct New Secure Landfill	8.0	14.0	26.0	43.0

only significant disadvantage posed would be the loss of that area for future operations or construction at RSA.

Mine disposal may also provide for secure permanent disposal of the contaminated sediments, though at a significantly higher cost than disposal in the TDMDA. A disadvantage of this disposal option would be the potential for leakage of contaminated material from haul trucks.

3.6 MONITORING PROGRAM

3.6.1 Dredging Operation

Monitoring of the dredging operation will be necessary to insure accuracy and control of sediment dredging. An intensive in-stream water quality sampling program should be conducted during the first week of dredging. Samples should be spaced in a uniform, reasonably compact grid downstream from the dredge and taken at regular depth intervals at each location. The entire grid should be sampled on several different occasions. Parameters analyzed should include total DDTR and suspended solids. Such a program will accurately define the turbidity-generating characteristics of the dredge as well as establish the most desirable points for further in-stream sampling.

Automatic water sampling should be conducted at the determined sampling locations for the duration of the dredging program, both upstream and downstream from the dredge. A sampling interval of one or two hours is recommended. Turbidity should be determined at each location from composite samples daily under base flow conditions and more frequently during elevated flow. Turbidity may correlate with suspended solids or DDTR thus giving a quick estimate of the degree to which these parameters are being elevated in the turbidity plume under varying conditions. Total DDTR and suspended sediment at each location should be determined from samples composited twice weekly. Discharge records from the TVA gaging station at HSB Mile 12.2 may be used to obtain a rough estimate of loading from concentrations determined in sampling. Monthly analysis of heavy metals in individual and composite samples is recommended.

Bottom sediment samples should be taken at various locations in newly dredged areas. Sediment cores should be analyzed for total DDTR in various depth fractions to verify the effectiveness of the dredging program and identify possible hot spots passed over by the dredge. Influent and effluent to the return water treatment facility should be sampled daily during active dredging to monitor plant performance. Daily sampling should also be conducted during intermittant operation to treat site runoff. Parameters measured would be identical to those stated above for in-stream water quality sampling.

3.6.2 Long-Term Disposal Site Monitoring

The TDMDA groundwater monitoring system should consist of a minimum of 3 to 6 wells located hydraulically downgradient from the site and drilled to different depths. A minimum of 1 to 3 wells should be located hydraulically upgradient from the site to monitor background conditions of water flowing under it. The leachate monitoring system must be installed in such a manner as to assure the integrity of the soil barriers and collect samples between the bottom of the disposal area and the top of the water table. The parameters analyzed and the frequency of sampling will most likely be governed by the volume of sample attainable from the system. Singular analysis for total DDTR would be the minimal requirement.

A groundwater monitoring system for the mine disposal site should consist of at least 3 wells located hydraulically downgradient from the site and one hydraulically upgradient. Exact location of the wells should be based on a hydrologic survey of the area. Total DDTR, suspended solids, and water level data should be recorded at each location.

Inspection of the TDMDA should be conducted daily as a check on main dike integrity and overall site operation. If the TDMDA is used as a permanent landfill, inspections of the site should be conducted on a once or twice yearly basis to check the integrity of the soil cover and fence. If burrowing animals are found to inhabit the area, a trapping program may have to be initiated. Inspection of the mine disposal site should be conducted yearly to check the integrity of the masonry partitions.

Where applicable, samples should be collected and analyzed several months prior to dredging or disposal to establish background conditions.

4.0 OUT OF BASIN DIVERSION OF HUNTSVILLE SPRING BRANCH

4.1 INTRODUCTION

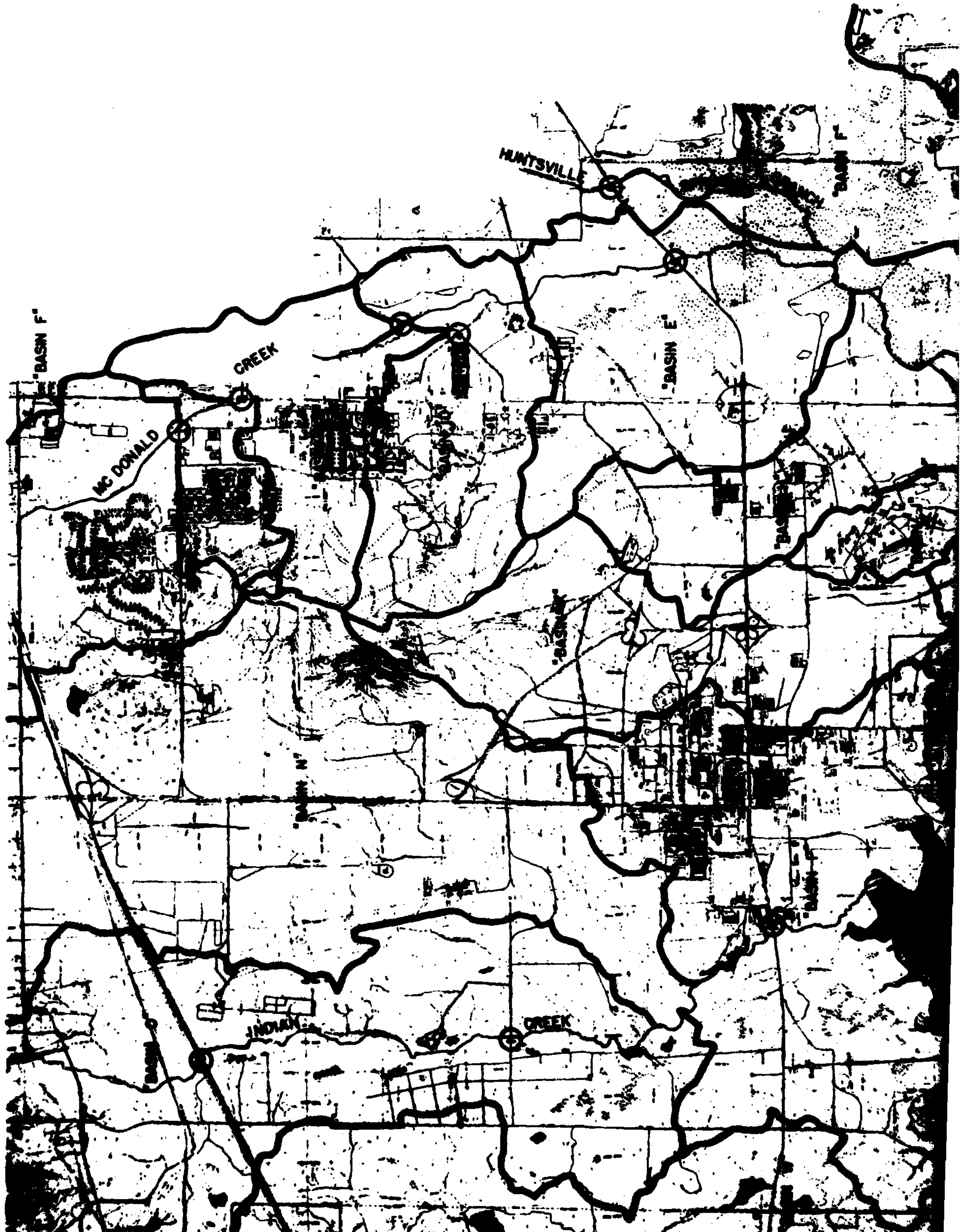
The diversion of HSB from a point upstream from the contaminated area directly to the TR would greatly reduce hydraulic transport of DDTR out of HSB. Headwater flow in the contaminated HSB channel will be limited to that created by local runoff from several small drainage basins lying to the north (Figure III-10). Such a diversion will facilitate further actions for mitigation of DDTR contamination in HSB. Removal alternatives can be implemented with negligible downstream transport of DDTR under the reduced flow conditions. Alternatives to contain contaminated HSB sediments in place can also be implemented in conjunction with an out-of-basin diversion of HSB.

4.2 DIVERSION ALIGNMENT

Two alignment corridors were considered for an out-of-basin diversion of HSB, as shown in Figure III-11. Corridor 2 was eliminated after consultation with personnel at RSA's Test and Evaluation Directorate (T and ED) indicated that use of that corridor would significantly impact flight testing operations and would require extensive relocation of utilities. Corridor 1 was selected for the alignment because of its minimal impact on RSA operations, the minimal amount of utilities relocation involved, and the hydrologic suitability of the corridor as the most direct route between HSB and the TR. Details of the proposed

BASIN KEY MAP

REDSTONE ARSENAL, ALABAMA



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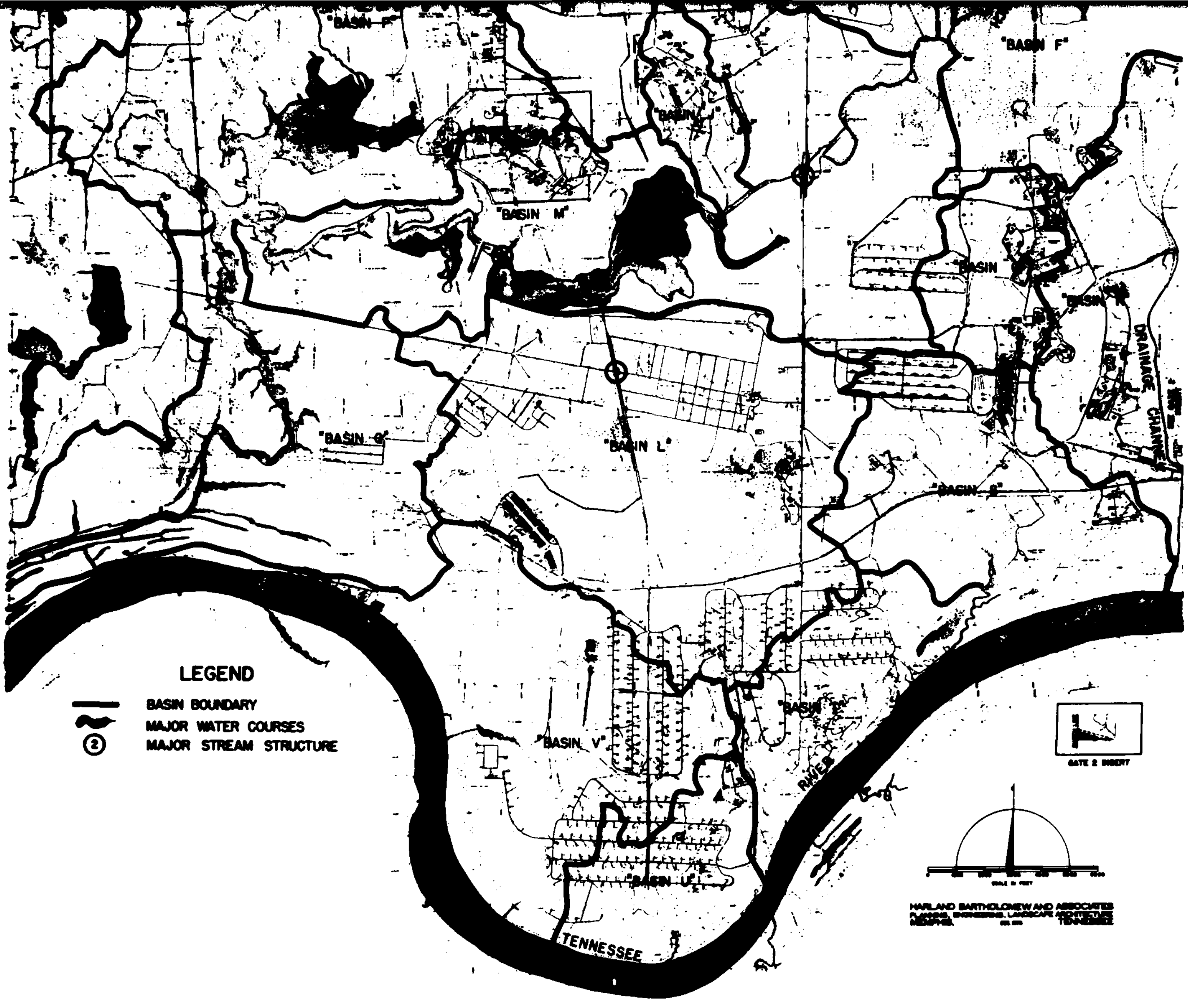

FIGURE III-10. Drainge Basins on Redstone Arsenal

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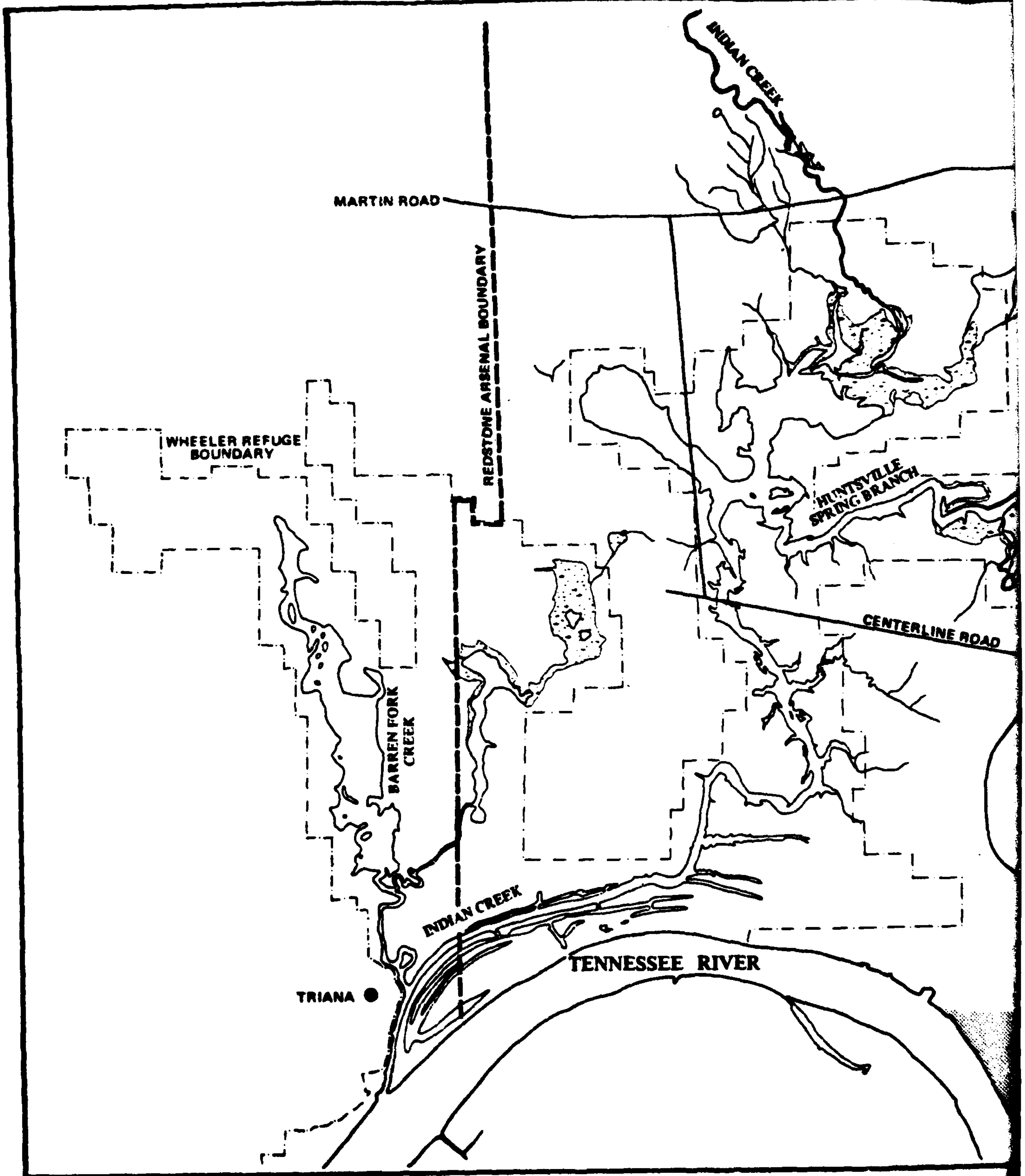
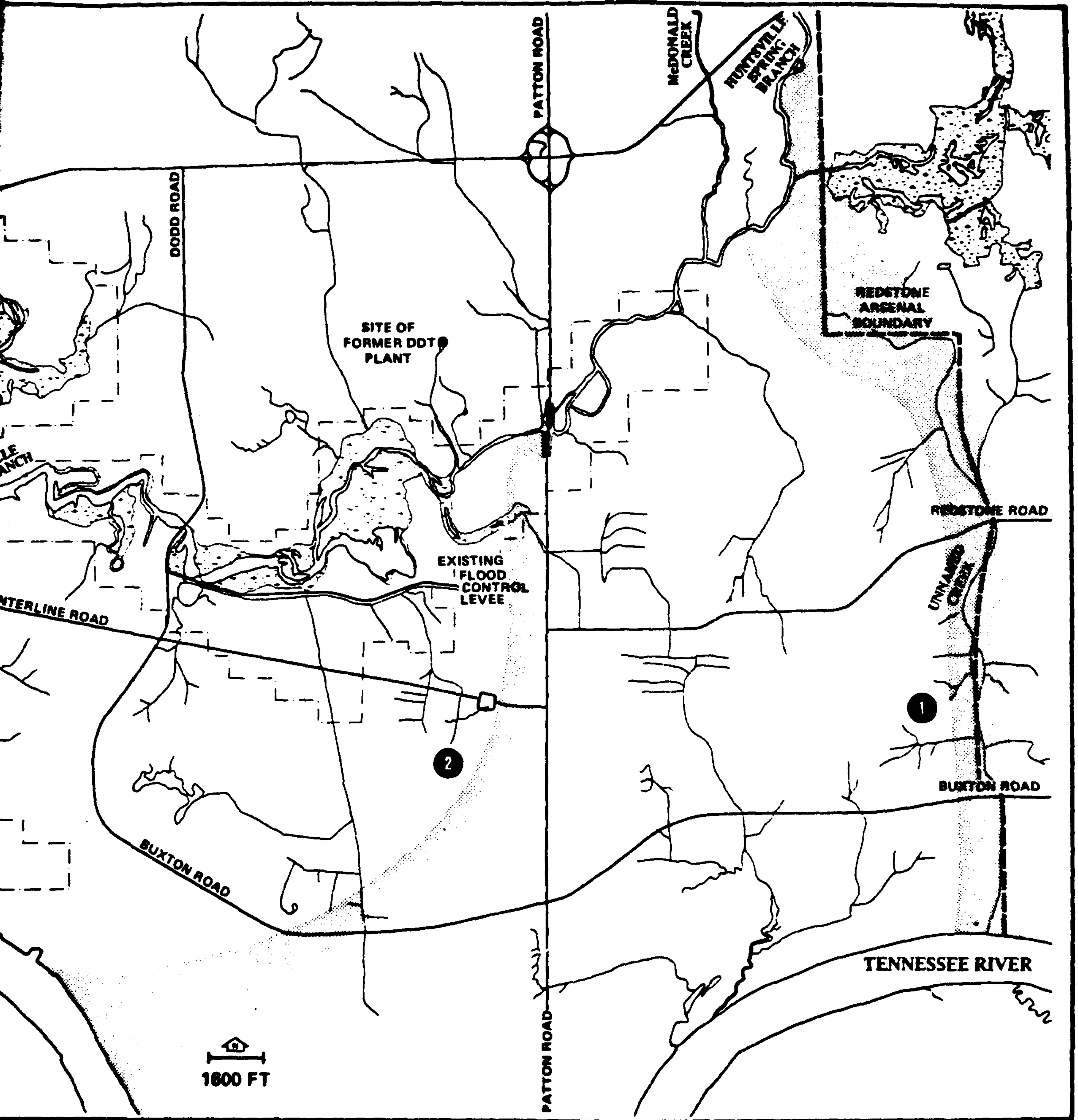


FIGURE III-11. Alignment Corridors Considered for Out-of-Basin Diversion of Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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alignment within the corridor are shown in Figure III-12.

Optimal alignment of the diversion channel depends on a number of parameters such as; topography, land acquisition, geology, interaction with utilities and structures, and costs. To simplify selection of an optimal alignment, the alignment corridor is divided into six sectors as shown in Figure III-12. Sectors are delineated on the basis of whether or not alternate alignments are considered within the sector.

Improvement of the existing HSB channel between Sector A and Martin Road is desirable in order to connect the diversion channel with the HSB channel improvement undertaken by the City of Huntsville upstream of Martin Road. Failure to do so would result in a constriction of the channel between the City of Huntsville's improved channel and the beginning of the diversion channel, which would create backwater effects during flood conditions. By eliminating this constriction, additional flood protection is provided for the City of Huntsville. However, since this is not directly related to mitigation of DDTR contamination, improvement of this reach is not considered as part of this alternative.

Two alignments are considered within Sectors A, C, and D. The general features of these alternate alignments, as well as the alignments for Sectors B and E, are given in Table III-10. The total estimated costs given for the channel sectors are only rough approximations due to assumptions used for the extent of bedrock encountered and costs of acquiring private land. Selection of the optimal alignment will require more accurate costing of these parameters, based on extensive soil borings and negotiations with the private landowners involved. Alignments in Sectors B and E are considered optimal and should require no major adjustments.

4.3 DIVERSION DESIGN AND CONSTRUCTION

4.3.1 Design Criteria

The out-of-basin diversion channel is designed for the 100-year headwater flood in HSB, a flow of approximately 20,500 cfs (see Appendix V, TVA Task 6 Data). The uniform slope of the diversion channel was fixed by the existing channel bottom elevations at the diversion point and TR confluence. Depth of flow in the channel was selected by developing flood contours for various flow depths in the channel. A maximum flow depth of 12.5 feet was determined to cause minimal inundation of the channel floodplain. Width of the channel was selected such that no significant increases in upstream channel depths would be experienced during design flow conditions. Backwater effects of preliminary channel designs were determined by computing backwater curves using the standard step method, assuming steady flow conditions in the channel (Chow, 1959). A channel width of 300 feet was selected to give the desired flow conditions. A typical cross-section of the diversion channel is illustrated in Figure III-13.

A cut-off channel between McDonald Creek (MC) and the HSB diversion is necessary to provide a hydraulically efficient route between those channels during elevated flow conditions (see Figure III-12.) A design

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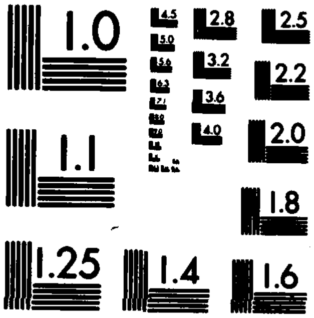

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Table III-10. Comparison of Out-of-Basin Diversion Alignment Sectors

Sector	A-1	A-2	B
Approximate Channel Length (ft)	7,300	6,500	3,500
Land Acquisition	Largely private ownership; high cost of acquisition	RSA ownership; no acquisition costs	RSA ownership; no acquisition costs
Topography	Relatively flat	Relatively flat	Relatively flat
Bedrock[1]	Bedrock not likely to be encountered	Excavation of an estimated 6 ft. of bedrock required for a consierable distance	Some bedrock may be encountered
Utility Relocation or Structure Replacement Required	3,600 feet of 12-inch CMP sewer outfall	3,600 feet of 12-inch CMP sewer outfall	None
Total Estimated Cost[2] (millions of dollars)	6.2	13.0	11.4

Table III-10. Comparison of Out-of-Basin Diversion Alignment Sectors (Continued, Page 2)

Sector	C-1	C-2	D-1
Approximate Channel Length (ft)	4,600	4,200	5,000
Land Acquisition	Some private ownership; acquisition costs involved	RSA ownership; no acquisition costs	Some private ownership; acquisition costs involved
Topography	Alignment skirts hillside; relatively flat	Alignment cuts into hillside; 15 to 25 ft. of relief encountered	Relatively flat
Bedrock[1]	Some bedrock likely to be encountered	Excavation of an estimated 6 to 8 ft. of bedrock required for a considerable distance	Bedrock not likely to be encountered
Utility Relocation or Structure Replacement Required	1,600 ft. of VCP sewer; 5 manholes; 1 entry gate relocated; 1 lift station; 2,350 ft. of 12 in. force main; bridge at Redstone Road Pond	1 entry gate relocated	2800 ft. of 12 in. CI force main
Total Estimated Cost[2] (millions of dollars)	12.4	19.5	6.6

Table III-10. Comparison of Out-of-Basin Diversion Alignment Sectors (Continued, Page 3)

Sector	D-2	E
Approximate Channel Length (ft)	5,150	4,700
Land Acquisition	Largely RSA ownership; minimal acquisition costs involved	Largely RSA ownership; minimal acquisition costs involved
Topography	Relatively flat	Moderate; 10 to 15 ft. of relief encountered
Bedrock[1]	Bedrock not likely to be encountered	Bedrock not likely to be encountered
Utility Relocation or Structure Replacement Required	800 ft. of 12 in. CI force main relocated	2 highway bridges replaced; 1 railroad bridge replaced; 300 ft. of 8 in. CI water main relocated
Total Estimated Cost[2] **(millions of dollars)**	8.0	4.8

Notes: [1] Bedrock information derived from boring logs of wells RS068, RS069, and RS070 (Redstone Arsenal, 1979)

[2] Detailed costing appears in Section 9.0 of this Appendix.

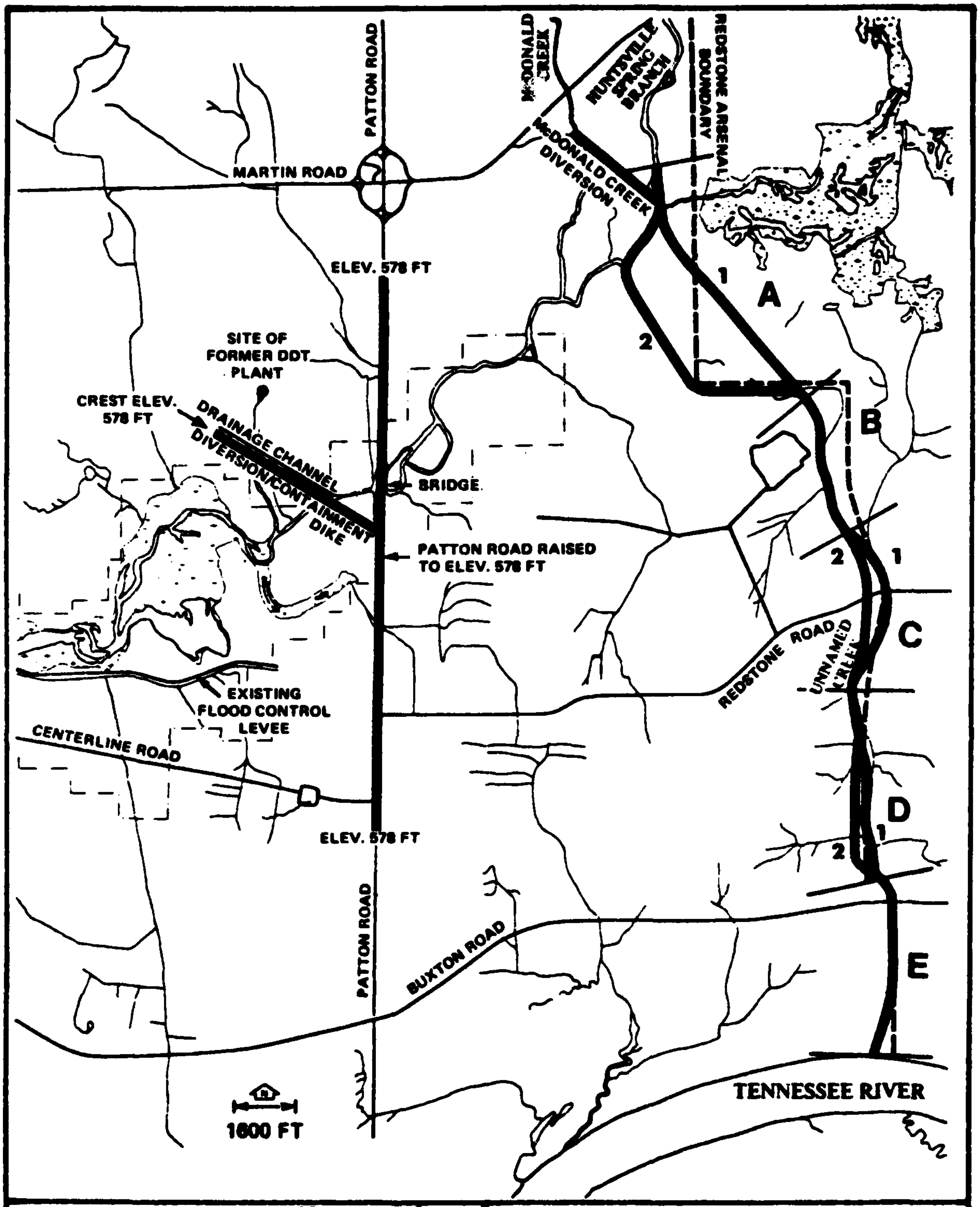

FIGURE III-12. Proposed Alignment for Out-of-Basin Diversion of Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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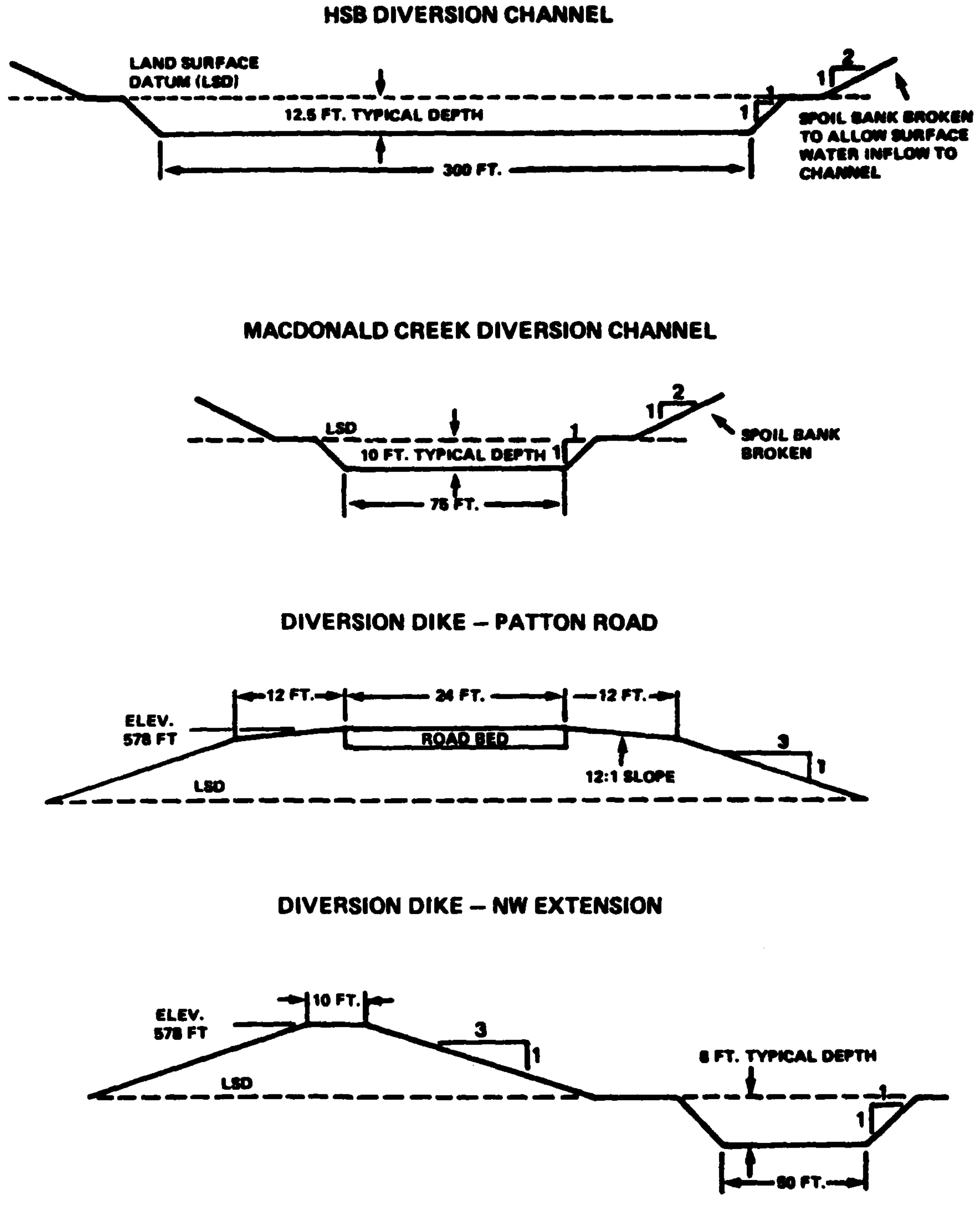

FIGURE III-13. Typical Cross-Section of Out-of-Basin Diversion Channels and Diversion Dikes

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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approach similar to that used for the main diversion channel resulted in the design cross-section illustrated in Figure III-13.

A diversion/containment dike will be constructed by raising Patton Road and constructing a dike between Patton Road south of HSB and high ground to the northwest, as shown in Figure III-12. A bridge will be built over the existing HSB channel at Patton Road so that runoff from basins J and H (Figure III-10) can flow via the HSB channel to the diversion channel. The raising of Patton Road will serve a two-fold purpose, as it will constitute part of the diversion/containment dike and will provide access to the southern portion of RSA under flood conditions. Dike elevations are designed for the 100-year flood stage on the TR south of RSA, approximately 575 feet. Backwater from the TR during a flood will reach the diversion dike via the diversion channel sooner than via IC and the old HSB channel, due to the former channel's greater hydraulic conductivity and more direct alignment. The dike is designed not to be overtopped by the 100-year flood stage on the TR, as overtopping would subject the contaminated area to heavy hydraulic scour. The design crest elevation of the dike system is 578 feet, allowing 3 feet of freeboard in the design flood. No overflow structures will be necessary in the dike. A conservative 3:1 sideslope is used for all dike designs in the absence of detailed geotechnical information. Cross-sections for the dike are illustrated in Figure III-13.

4.3.2 Subsurface Exploration and Soil Tests

Soil borings along the proposed channel alignment will be necessary to determine subsurface conditions and the extent of bedrock excavation required. The depth of the borings should be 20 to 40 feet and in no case be shallower than the proposed channel bottom. Some borings should be extended to refusal depth. A spacing of 700 to 1000 feet will be adequate if uniform conditions are encountered. Abrupt changes in soil conditions or bedrock elevation may necessitate closer spacing. Soil tests should be performed on samples taken from the borings to determine the suitability of material to be excavated for dike construction. These tests should include, but not necessarily be limited to; classification, compaction, consolidation, permeability, and strength testing. Standard or cone penetration tests should be conducted in the field at each boring location along the dike alignment. A detailed topographic survey of the proposed channel corridor will be required if accurate computation of excavation volumes is desired.

A boring program similar to the one outlined above should be conducted along the proposed centerline of the diversion/containment dike. Boring spacing should be reduced where variable or swampy conditions are encountered.

4.3.3 Construction

Clearing and grubbing of the entire diversion corridor will be required before channel excavation. The majority of excavation could be accomplished with pans (self-loading scrapers), though dragline excavation may prove to be more economical due to its lower fuel consumption. Draglines will be required in swampy areas (particularly Reach A), when groundwater is contacted, or where surface water flows into the excavation site. Costing estimates for the diversion are based on using draglines for all channel excavation. Channel lengths for the individual sectors are given in Table III-10. Excavated material will be hauled away for dike construction as necessary, or cast to the side of the channel in a manner that will not prevent adjacent surface flow from entering the diversion channel. The total volumes of excavation for the diversion channel and McDonald Creek cut-off channels are estimated to be 4,045,000 and 61,000 cubic yards, respectively.

In order to meet existing terrain at elevation 578 feet, Patton Road will have to be raised to that elevation for a length of 14,200 feet, as shown in Figure III-12. The total length of the dike west of Patton Road is 4,800 feet. Estimated fill volumes required for the two dikes are 447,500 cubic yards and 150,700 cubic yards for the Patton Road and northwest extension dikes, respectively. All dike slopes and channel sides above water will be seeded and mulched for stability. A gravel road will be constructed along the crest of the dike west of Patton Road.

Utilities or structures requiring relocation or replacing during channel construction are indicated in Table III-12. Construction associated with the raising of Patton Road will require relocation of the following utilities: (1) one buried telephone cable west of Patton Road, (2) one elevated telephone cable west of Patton Road, and (3) one 12 inch CI water main west of Patton Road. A 36 inch RC industrial water main lying approximately 600 feet to the west of Patton Road will not require relocation, though its location should be noted and marked. Personnel from RSA and Southern Central Bell Telephone Company have indicated that there are no power or telephone lines intersecting or adjacent to the proposed alignment corridor. Construction plans for the proposed outfall to the TR for the City of Huntsville's Treatment Plant No. 1 may have to be modified or coordinated with construction of the diversion. Approximate locations of all utilities and structures requiring relocation or replacement with respect to this alternative are shown in Figure III-14.

The completed diversion will be in the TR backwater, thus it will be subject to sedimentation associated with the backwater. It is not expected that sedimentation or bank erosion will cause significant channel maintenance problems. For the purpose of costing, channel maintenance has been assumed negligible.

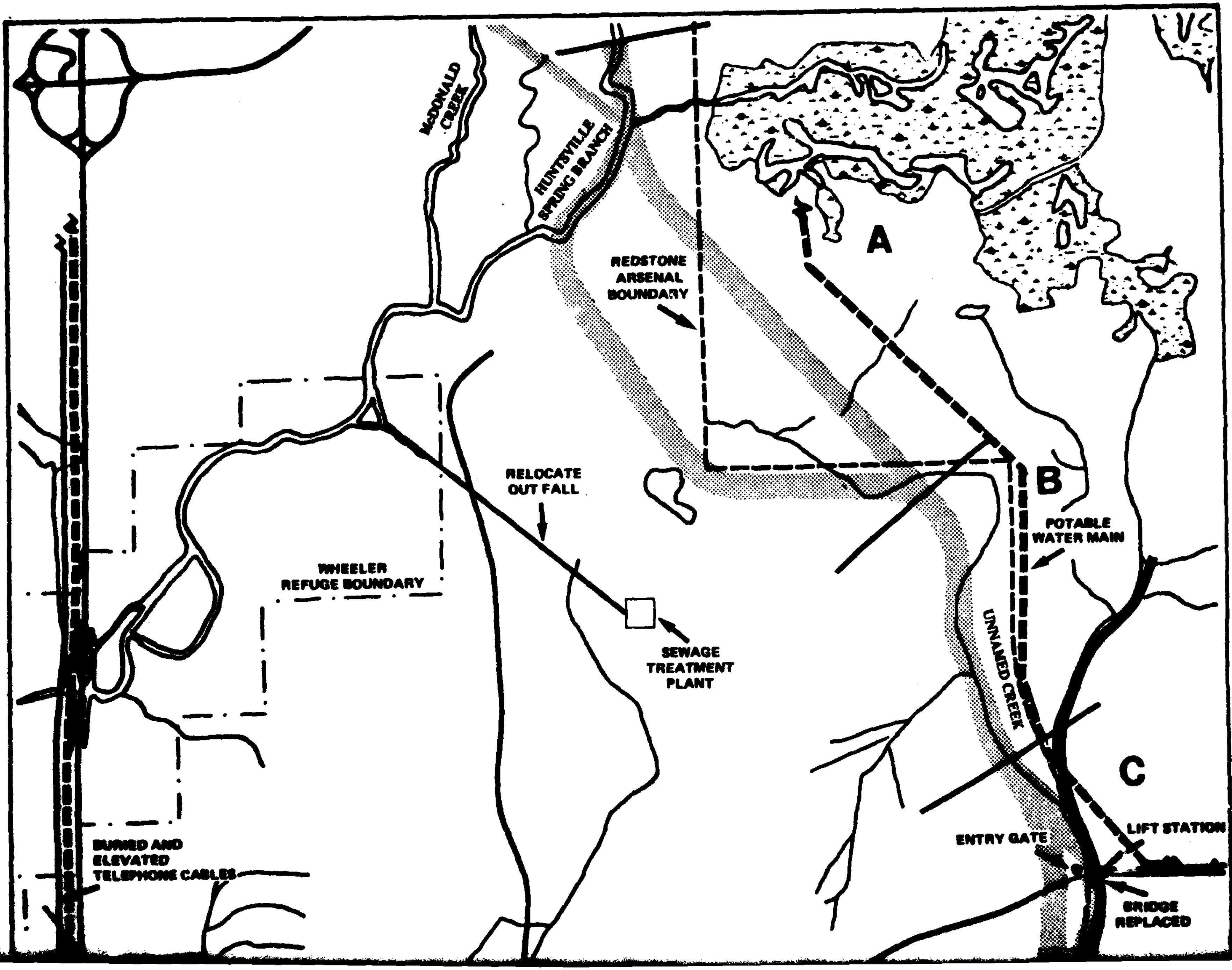
4.3.4 Work Scheduling

Little or no restriction on work hours is expected for any construction associated with the out-of-basin diversion of HSB, as the areas involved do not seriously conflict with RSA operations (U.S. Army, 1980).

5.0 WITHIN-BASIN DIVERSION OF HSB

5.1 INTRODUCTION

A within-basin diversion is proposed to bypass the HSB channel around the most heavily contaminated area between HSB Miles 4.1 and 5.6. With a


McDONALD CREEK
HUNTSVILLE SPRING BRANCH
A
REDSTONE ARSENAL BOUNDARY
B
POTABLE WATER MAIN
RELOCATE OUT FALL
WHEELER REFUGE BOUNDARY
SEWAGE TREATMENT PLANT
UNNAMED CREEK
C
LIFT STATION
ENTRY GATE
BRIDGE REPLACED
BURIED AND ELEVATED TELEPHONE CABLES

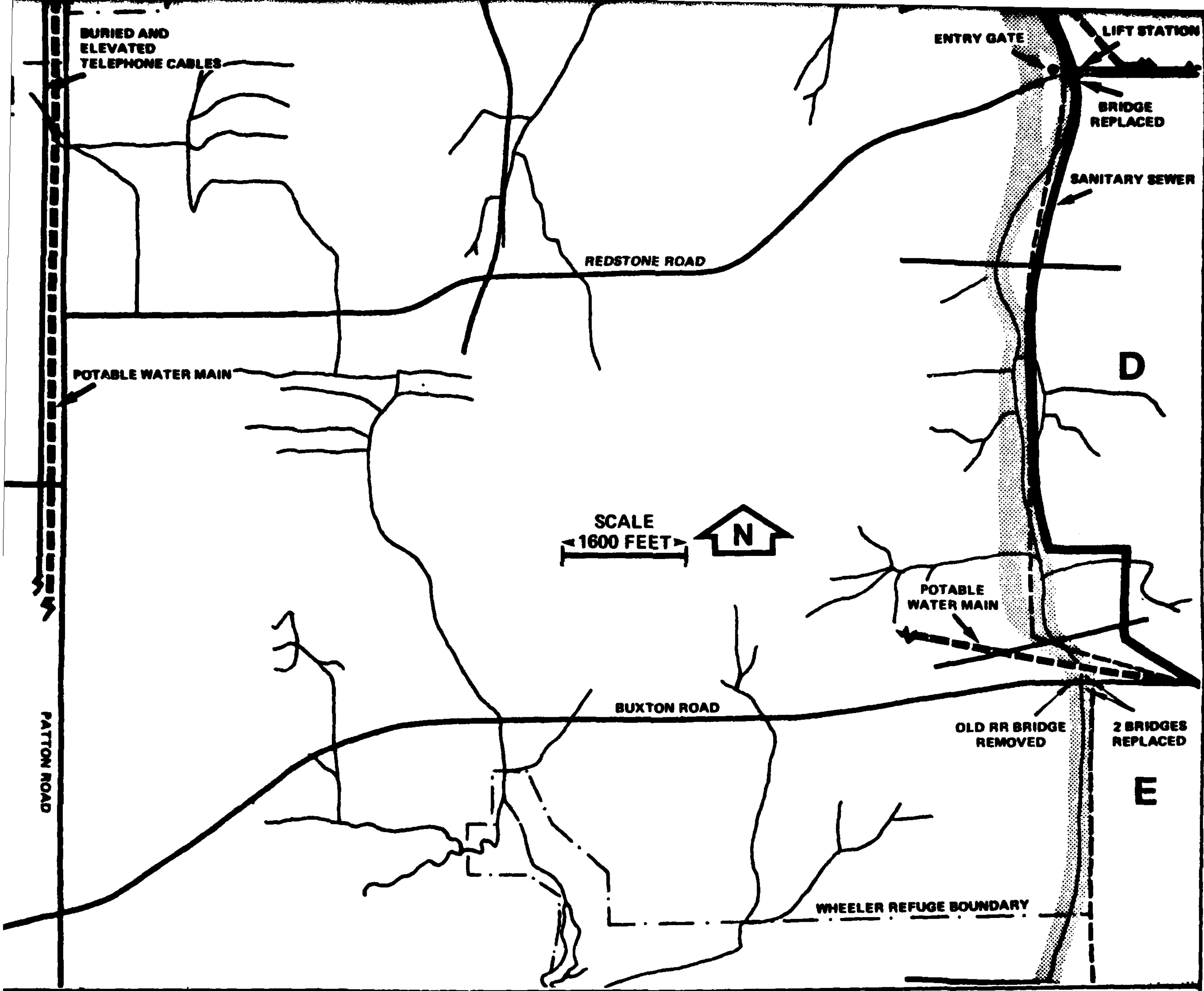


FIGURE III-14. Utilities and Structures Requiring Relocation or Replacement for Construction of the Out-of-Basin Diversion

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containment dike as illustrated in Figure III-15, such a diversion will eliminate hydraulic transport of DDTR from this heavily contaminated area. Further removal or containment actions within the diked area will also be facilitated. The flow of HSB will reenter the existing channel at HSB Mile 2.4. Mitigating actions downstream from Mile 4.1 will consist of dredging the HSB and IC channels. Extending the containment dike further downstream (i.e., to Mile 2.4) would provide little benefit, as the majority of contaminated sediments between Miles 4.1 and 2.4 would be either removed during channel excavation or covered by the dike itself. Routing the diversion further south to avoid this would result in encroachment into Test Area 1.

5.2 DIVERSION ALIGNMENT

Consideration was given to four alignment corridors, shown in Figure III-16. Corridors 2, 3, and 4 would impose serious impacts on T and ED's flight testing operations, and were eliminated for that reason. Corridor 1 encroaches on the safety fan of Test Area 1 (see Figure III-1), but remains to the north of the flood control levee. Though minor work stoppage during construction can be expected due to operations at Test Area 1, use of this alignment is generally compatible with T and ED operations.

5.3 DIVERSION DESIGN AND CONSTRUCTION

5.3.1 Design Criteria

Criteria for design of the within-basin diversion are identical to those discussed for the *out-of-basin diversion in Section* 4.3.1. The resultant channel design is shown in Figure III-17. A backwater curve computed for this channel under design flow conditions indicated that backwater effects would be less severe than those encountered under existing conditions.

The containment dike associated with the within-basin diversion (Figure III-15) is designed not to be overtopped by the 100-year flood stage on the TR of approximately 575 feet. The crest elevation of the dike is 578 feet, allowing 3 feet of freeboard over the design flood stage. A 3:1 sideslope is used in the absence of detailed geotechnical information. A typical cross-section of the containment dike is illustrated in Figure III-17. The cross-section used for the drainage channels on the northeast and northwest sides of the containment dike is shown in Figure III-17. Design is based on the 10-year, 90-minute precipitation event, or a rainfall rate of 2.7 inches per hour (U.S. Soil Conservation Service, 1973). The duration of the design storm corresponds to the estimated time of concentration of Basin K, the largest basin drained by either channel. A recurrence interval of 10 years is adequate since flows in excess of this storm will be contained by the adjacent dikes and hillside.

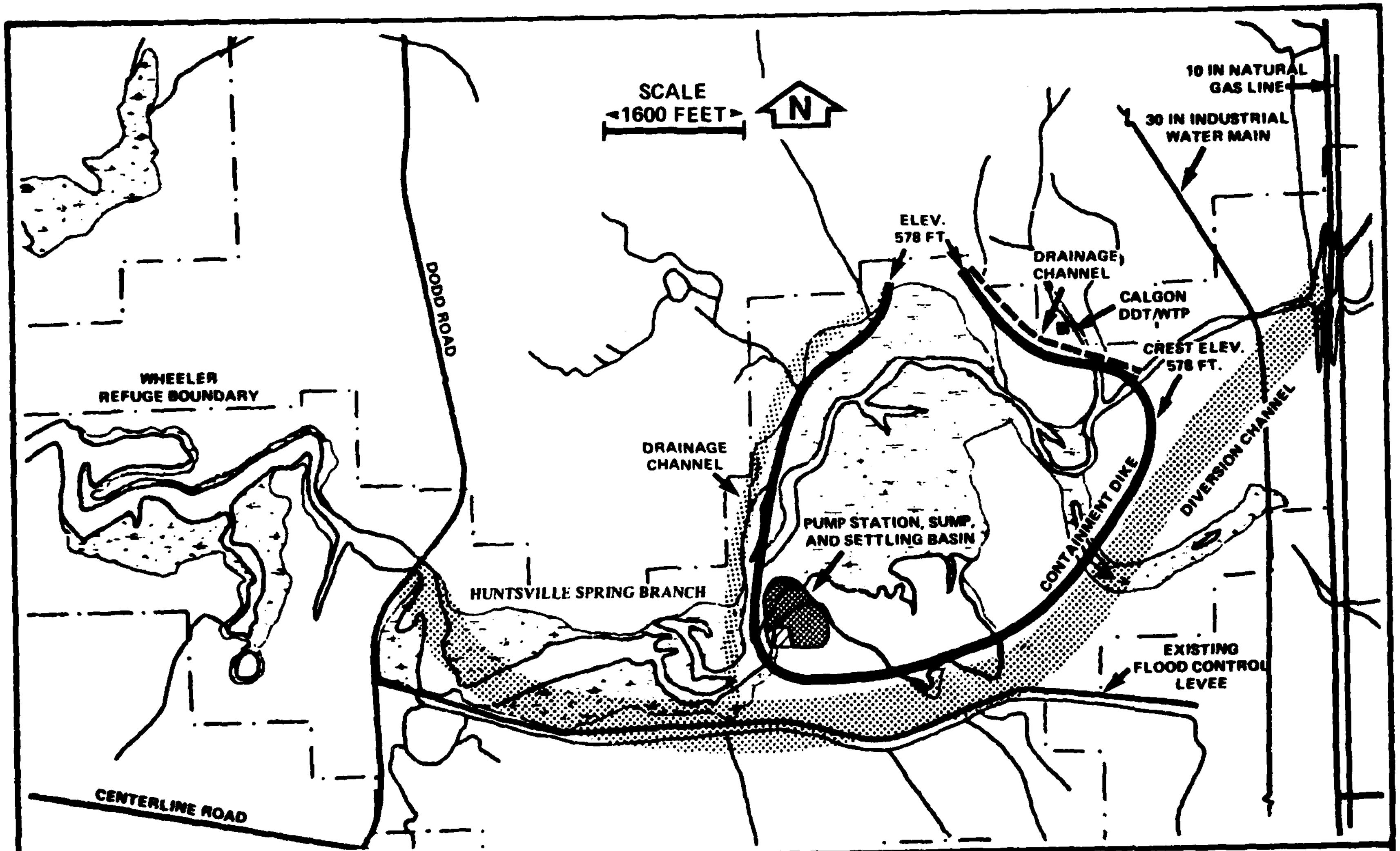

FIGURE III-15. Proposed Alignment of the Within-Basin Diversion and Diversion/Containment Dike

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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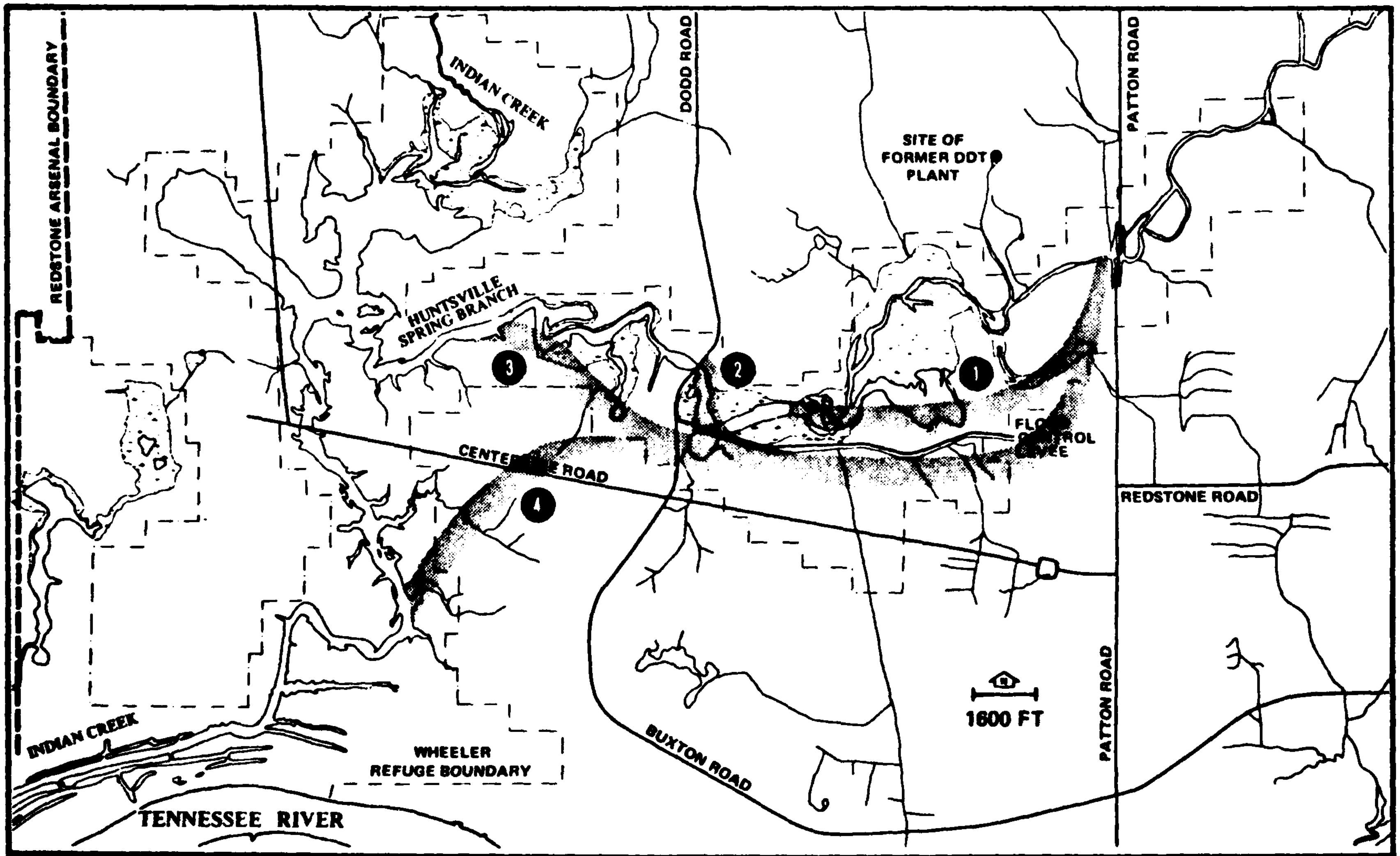

FIGURE III-16. Alignment Corridors Considered for Within-Basin Diversion of Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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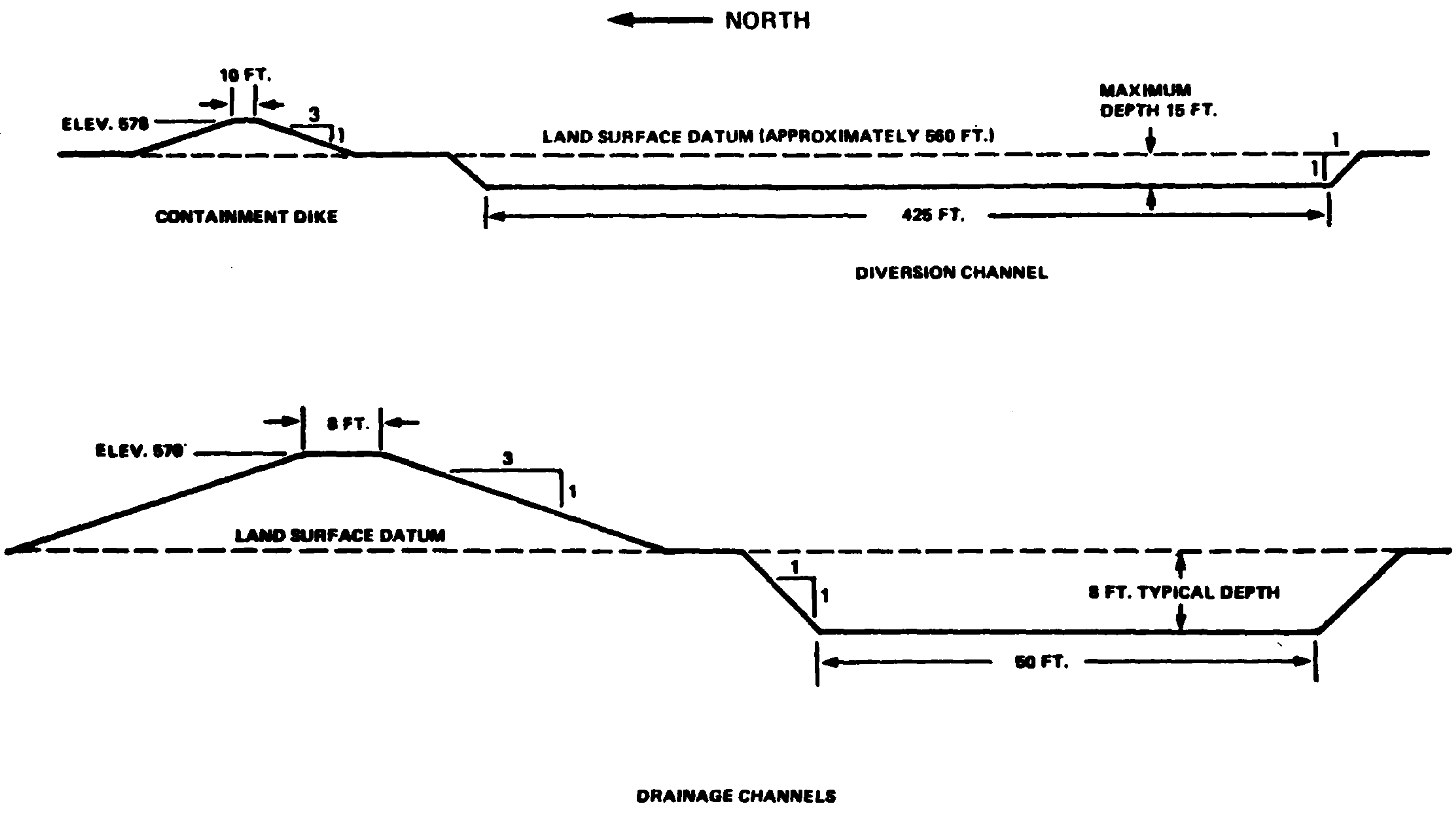

FIGURE III-17. Typical Cross-Section of the Within-Basin Diversion Channel, Containment Dike, and Drainage Channels

SOURCE: WATER AND AIR RESEARCH, INC.

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5.3.2 Subsurface Exploration and Soil Tests

Soil boring and testing as described for the out-of-basin diversion in Section 4.3.2 of this Appendix will be required.

5.3.3 Construction

Due to the generally poor bearing capacity of surface soils in the diversion corridor and the close proximity of the water table to the surface, excavation of the diversion channel can best be implemented with draglines. Clearing and grubbing of the corridor will be required before excavation. Minor departures from the normal operating schedule of Wheeler Reservoir such as described in Section 3.4.6 should be requested of TVA to facilitate work in the overbank areas. This would involve maintaining a high pool elevation of 555 feet, rather than 556 feet to prevent overbank inundation, and initiating summer drawdown early to lengthen the period that overbank sediments can be excavated above water level. Suitable excavated material will be used for construction of the containment dike. This material may require a considerable period of dewatering by natural drainage and evaporation before being reworked to construct the dike. Material judged unsuitable for construction of the dike can be used for interior dike construction in the TDMDA. The total length of the channel is approximately 13,500 feet, requiring excavation of approximately 1,177,500 cubic yards.

The total length of the containment dike is approximately 13,000 feet. All dike slopes will be seeded and mulched, and a gravel road will be constructed on the dike crest. Dike sections across the existing HSB channel will be completed following completion of the diversion. A permanent pumping station with a total capacity of 4.0 MGD will be installed as shown in Figure III-15 to remove local runoff from the containment area. Total fill required for the containment dike is approximately 1,783,500 cubic yards. Though the majority of this fill can be obtained from material excavated from the diversion channel, some off-site borrow will be required. Preliminary investigation indicates that adequate borrow for the construction of the dike can be obtained within a 3 or 4 mile radius of the site. Borrow hauling costs are based on this assumption. If sites more distant than 4 miles are used, hauling costs would be increased proportional to the additional distance.

Utilities requiring relocation are limited to one 36-inch RC industrial water main situated in an approximate north-south alignment 600 feet west of Patton Road (Figure III-15) and a 10-inch natural gas line just east of Patton Road. Plans for the new forced sewer main to be constructed on the east side of Patton Road in 1981 must also be considered.

Portions of the existing flood control levee north of Test Area 1 that are disturbed by construction of the diversion will be relocated south of the diversion to maintain continuity of that levee.

The completed diversion will be in the TR backwater, thus it will be subject to sedimentation associated with the backwater. Neither sedimentation nor bank erosion are expected to cause significant channel maintenance cost. For the purpose of costing, channel maintenance has been assumed negligible.

5.3.4 Work Scheduling

The westernmost extreme of construction activity barely encroaches on the safety fan of Test Area 1 (see Figure III-1). Work stoppage within that portion of the safety fan is estimated at 25 percent of normal working hours (U.S. Army, 1980). Due to the limited amount of activity involved in the restricted area, work stoppage should be minimal and a normal work shift can be employed throughout the project.

6.0 IN-PLACE CONTAINMENT, STABILIZATION, OR DETOXIFICATION OF CONTAMINATED SEDIMENTS

6.1 INTRODUCTION

Containment, stabilization, or detoxification of contaminated sediments in situ can be effectively implemented only in conjunction with a diversion of flow in HSB. Containment or stabilization techniques should stop the migration of DDTR from HSB and diminish its bioavailability in order to be effective in the long term. In order for detoxification to be effective, DDTR must be broken down into harmless decomposition products to an extent sufficient to significantly reduce its bioavailability. Several methods were evaluated. Enclosing the highly contaminated areas of HSB within a dike and applying cover material over the channel sediments was found to be most effective. Containment alternatives based on this approach are discussed for the within-basin and out-of-basin diversions.

6.2 METHODS CONSIDERED

6.2.1 Stabilization Systems

In-place stabilization of sludges and sediments has been developed by the Takenaka Komuten Co. Ltd., of Japan. Termed the Takenaka Sludge Treatment (TST) system, it is marketed in the United States by TJK, Inc. of North Hollywood, California. The process basically consists of concreting sediments in situ by mixing them with portland cement and proprietary additives. Consideration of this technology was dismissed for several reasons, the principal ones being lack of documentation on the long-term stability of the fixed material, and lack of current acceptance by EPA as a disposal technology for contaminated sediments. Additional disadvantages are:

1) the leaching characteristics of DDTR from the fixed material would be difficult to assess;

2) if attempted in submerged sediments the top 2 to 4 inches of sediment would remain unconsolidated;

3) sediments adjacent to the shore would be difficult to fix due to the design of the equipment; and,

4) the fixed sediments would not provide a suitable substrate for aquatic or terrestrial habitat (U.S. Army Corps of Engineers, 1978; Dawson and Goodier, 1977).

The use of sorbents to stabilize sediments has been reviewed by Dawson and Goodier (1977), by Munnecke (1979) and by Kearney, et al. (1969). Woodchips, charcoal, and activated carbon have been applied to tie up pesticide residues. Such systems have not been tested on a large scale, therefore no data is available on their effectiveness and no equipment has been designed to make such an application.

6.2.2 Impoundment Structures

Impoundment structures considered fall into two general categories, low-level and high-level impoundments.

Low-level structures would consist of either level concrete-covered earthen dams or dikes with overflow weirs, and would impound HSB to an elevation not exceeding 556 feet. Their purpose would be to maintain a minimum ponded depth to promote settling of suspended solids and restrict downstream DDTR migration. Such structures were determined to be ineffective in the absence of a diversion of HSB, as the relatively flat topography will not allow sufficient impoundment storage to create an effective sediment trap for the flows encountered.

Low-level structures were designed in conjunction with both diversion alternatives. These structures were predicted to be reasonably effective in restricting DDTR migration from the bypassed areas, as flows would be greatly diminished by the diversion of HSB. Though marginally effective as a containment technique, this approach is unacceptable from an environmental standpoint. During normal periods of high pool elevation in the Wheeler Reservoir, highly contaminated areas in HSB would be accessible to fish from IC and the TR. As discussed in Appendix I, algae, zooplankton, and macroinvertebrates concentrate DDTR, providing a means for further contamination up the food chain. Planktonic species would be discharged downstream over weirs or low-level dams, as would benthic species during migratory periods. Though possibly small in magnitude, this mechanism would provide for a chronic source of DDTR contamination in the food chain downstream from the low-level structures. Large impounded areas would also attract and be permanently accessible to birds and mammals in the Wheeler Refuge.

High-level structures would impound contaminated areas to an elevation of 578 feet with an overflow weir discharging downstream. This would be feasible only between HSB Miles 2.4 and 5.8, as nearly complete enclosure of the area is required due to the low topography. The impounded area would not be inundated by the 100-year flood, therefore passage of fish into the area from downstream would be virtually eliminated. Hydraulic transport of DDTR-contaminated sediments would also be controlled. Use of this approach was ruled out for two reasons; chronic DDTR contamination by biotransport as described above for low-level structures, and the fact that it offers no significant advantage over dry containment alternatives.

6.2.3 Containment Dikes and Earthen Cover

This approach can be implemented only in conjunction with a diversion of HSB for obvious reasons. Though effective when combined, neither of these techniques is effective as a containment measure when employed alone. If the contaminated area is diked but not covered, the exposed sediments will be subject to limited fluvial transport and some DDTR contamination may leave the area via the required pumping station. The potential for bioaccumulation and transport would also exist. If the contaminated area is covered but not diked, flows resulting from local inflow and fluctuations of the Wheeler Reservoir pool would jeopardize the long-term integrity of the applied cover. Used in combination, containment dikes and earthen cover will effectively isolate DDTR-contaminated sediments in place and, with proper management, will provide for their long-term isolation. Two such containment options are proposed, one for each diversion.

6.2.4 In-Place Detoxification

Detoxification of the contaminated sediments in situ by both chemical/physical and biological means was explored. Microbial systems are capable of transforming DDT to DDE in both aerobic and anaerobic systems. In an anaerobic environment, microorganisms can transform DDE into DBP (4,4'-dichlorobenzophenone). Further degradation must take place aerobically in order to break the aromatic ring structure (Johnsen, 1976). Due to the time required and the infeasibility of setting up and controlling such a degradation pathway on a large scale, microbial degradation does not appear to be a viable mitigation alternative.

Chemical/physical treatments of pesticide residues were reviewed by Munnecke (1979). These include oxidation reduction, hydrolysis, solvent extraction and a combination of ultraviolet and ozone treatment. None of the methods reviewed presented viable mitigation alternatives due to introduction of toxic additives or degradation products into the system and/or the infeasibility of implementation of a large scale.

6.3 CONTAINMENT ALTERNATIVES PROPOSED

6.3.1 Containment With Out-Of-Basin Diversion of HSB

Introduction--The highly contaminated sediments between HSB Miles 2.4 and 5.6 will be partially isolated by the out-of-basin diversion dike arrangement discussed in Section 4.0 and shown in Figure III-12. Flow from HSB and runoff from basins J and H (Figure III-10) to the north of the contaminated area will be diverted by these structures to the out-of-basin diversion channel. If no additional containment is provided, the contaminated area would still be subjected to runoff from basins K and M (Figure III-10) and flows resulting from fluctuations of the Wheeler Reservoir pool. A dike and interception channel constructed along the northern edge of the contaminated area, as shown in Figure III-18, would exclude these flows from the area and further isolate DDTR contamination upstream of Dodd Road. A settling basin, pumping station, and floodgate would be required to handle runoff from

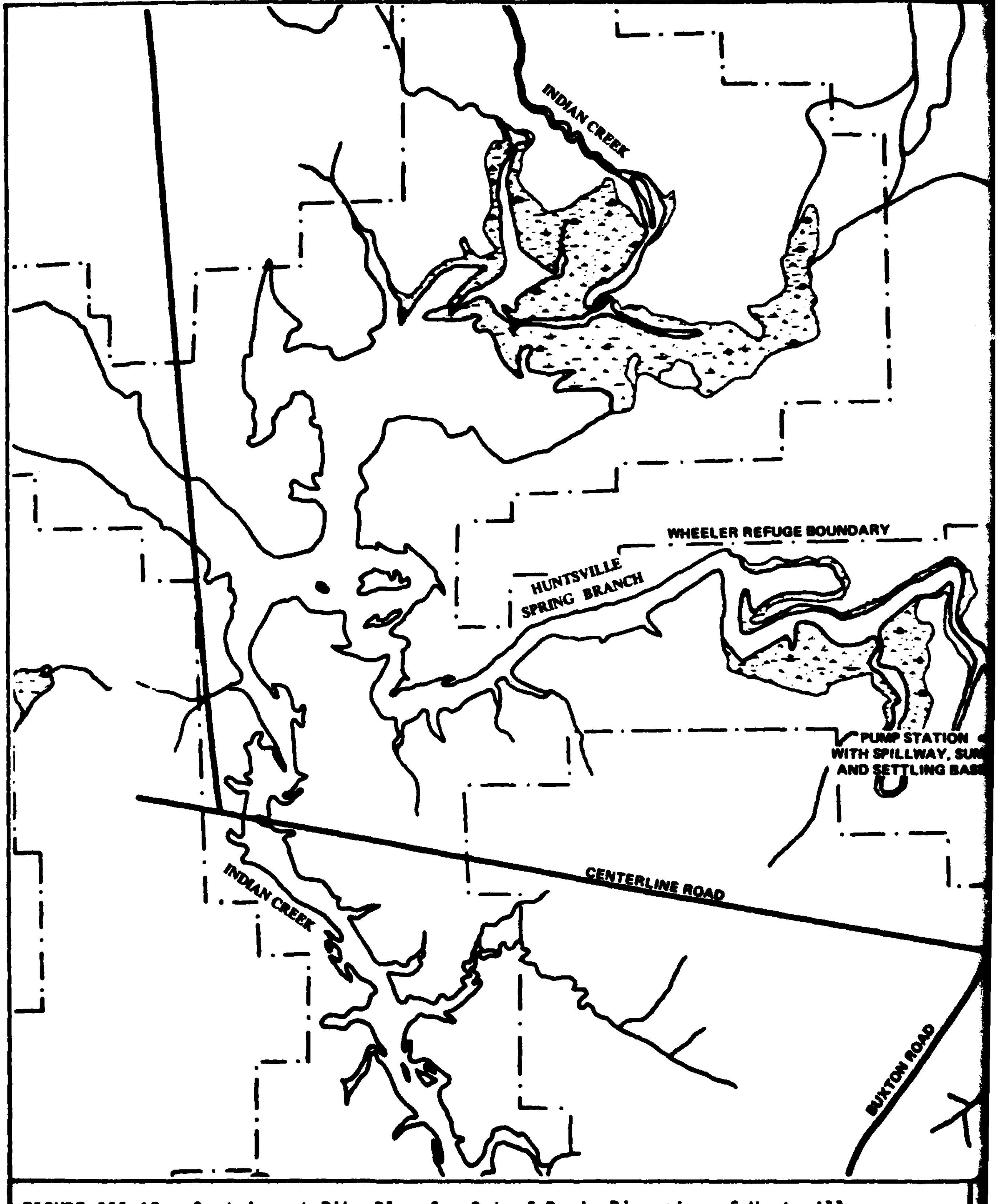
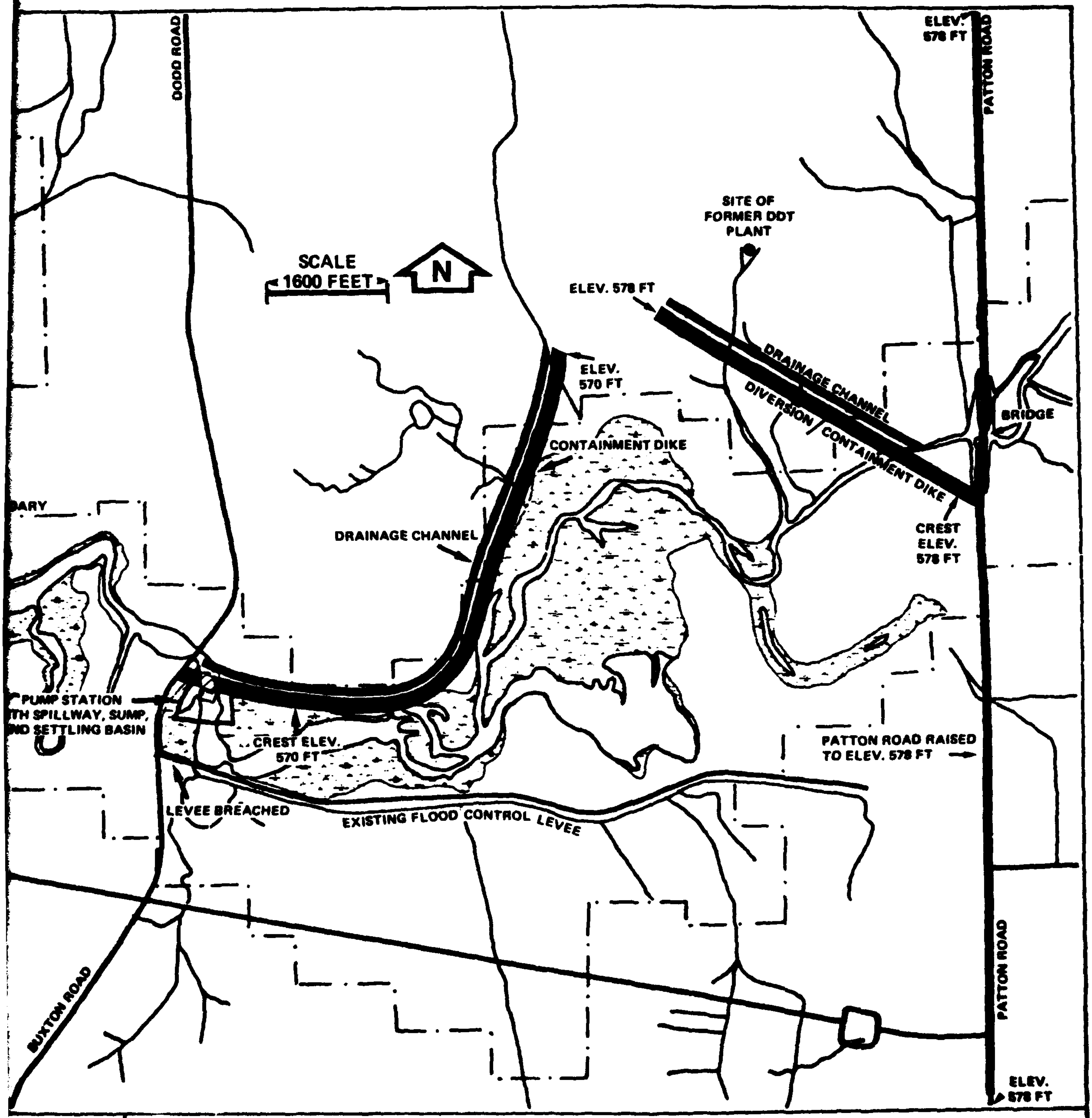


FIGURE III-18. Containment Dike Plan for Out-of-Basin Diversion of Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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the area. A further degree of isolation will be gained by applying cover material over contaminated sediments in the HSB channel and overbank.

Design and Construction--Design Criteria--Crest elevation of the containment dike will be 570 feet. Elevations in excess of this would be useless, as the area floods from the south when the Wheeler Reservoir pool exceeds an elevation of 568 feet. The existing flood control levee on the north side of Test Area 1 can be abandoned, as its purpose will be served by the containment dike. A typical cross-section of the dike and drainage channel is shown in Figure III-19. The dike and channel should be constructed into the hillside to an extent sufficient to provide fill for the dike and adequate slope along the length of the channel. Channel design is based on the 10-year, 90-minute precipitation event, or a rainfall rate of 2.7 inches per hour (U.S. Soil Conservation Service, 1973). The duration of the design storm corresponds to the estimated time of concentration of basin K, the largest basin drained by the channel. A recurrence interval of 10 years is adequate since flows in excess of this will be contained by the adjacent dike and hillside. Cover applied to the contaminated sediments will consist of a minimum of 6 inches of compacted clay underlying 18 inches of soil suitable for supporting stabilizing shallow rooted vegetation.

Subsurface Exploration and Soil Tests--Soil borings along the dike centerline will be necessary to determine subsurface conditions and develop final design criteria for the dike. These should be 20 to 40 feet deep, with some extended to refusal depth. A spacing of 700 to 1000 feet will be adequate if uniform conditions are encountered. Variable subsurface conditions or soft areas will require closer spacing. Additional borings in the adjacent hillside will be necessary to determine suitability of that material for construction of the dike. Soil tests on samples taken from the borings should include, but not necessarily be limited to: classification, compaction, consolidation, permeability, and strength testing. Standard or cone penetration testing should be conducted in the field at each boring location.

Construction of Dike and Interception Channel--Dike construction in this area can be accomplished with conventional earth-moving equipment, such as draglines and pans. The alignment corridor is largely wooded, requiring clearing and grubbing. Where the dike crosses swampy areas or the existing HSB channel, surface sediments may have to be removed and replaced with suitable fill material. All channel areas above elevation 556 and all dike slopes will be seeded. A gravel road with one or more turnouts will be constructed on the dike crest to allow observation of the site and inspection of the dike. The total dike length is 8,000 feet, requiring placement of approximately 153,700 cubic yards. Channel construction will require excavation of approximately 86,500 cubic yards, most of which should be suitable for dike construction. Additional fill for dike construction can be hauled from the out-of-basin diversion channel.

Pumping Station and Floodgate--Capacity required for the pumping station is 2.0 MGD with an additional 2 MGD reserve capacity. This capacity is computed based on removing runoff resulting from the 100-year 6-hour storm over a period of 7 to 10 days. Since the pumping station on the

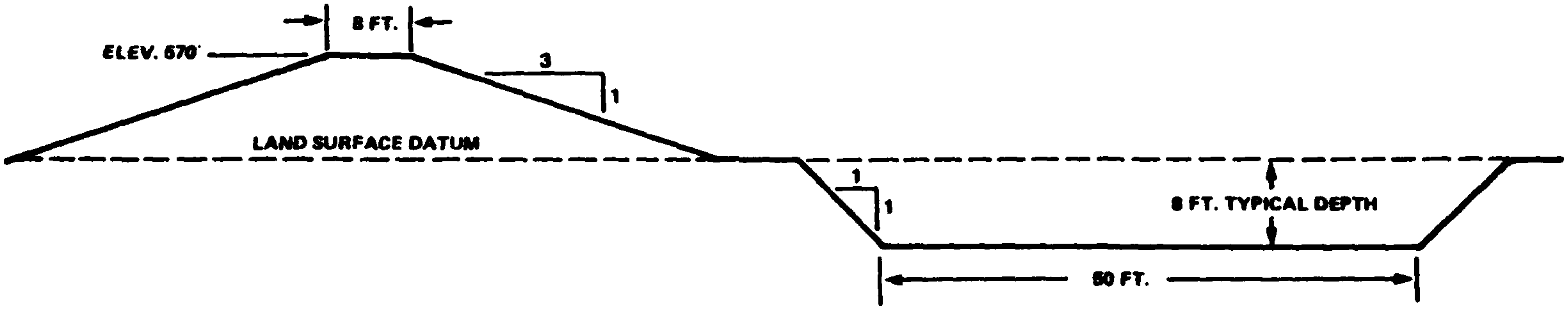

FIGURE III-19. Typical Cross-Section of Western Runoff Diversion Dike and Drainage Channel for Containment with Out-of-Basin Diversion

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of
Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

existing Test Area 1 flood control levee will no longer be necessary, these pumps can be utilized in the containment dike pumping station. Additional capacity will be added as required. The old levee will be breached or partially removed to allow runoff from Test Area 1 to be pumped by the new station.

In the event that the contained area is completely inundated by a flood, it would remain inundated to an elevation of approximately 568 feet after the flood recedes. Since energy requirements to remove this volume of water by pumping would be excessive, a floodgate will be constructed near the pumping station to discharge flood waters from the area.

Cover Application--Application of cover to the HSB channel will commence at the easternmost end and proceed downstream. Sufficient cover must be applied to provide a stable road base for equipment operation in addition to the desired final cover specifications. The channel bottom will have to be cleared of large trees and debris before cover is applied. This can be accomplished with a grapple-equipped crane operating from the leading edge of the cover. Debris will be hauled to the snagging disposal area at the TDMDA.

Excess material will be available from excavation of the out-of-basin diversion to provide ample borrow for covering the HSB channel. Boring logs recorded during installation of groundwater monitoring wells in the vicinity of the diversion alignment indicate that a large portion of materials excavated will be clays suitable for cover application (U.S. Army, 1980). Substandard materials can be used for initial or final fill. A minimum of 6 inches of slowly-permeable compacted clay must be maintained with continuity over the channel. An additional 18 inches of soil suitable for supporting shallow-rooted vegetation will be placed over the compacted clay cover. Grade along the channel should be maintained to provide drainage to the settling basin at the west end. Using an estimate of three feet for the total average cover thickness, covering the HSB channel within the contained area will require 228,000 cubic yards of fill. The final soil cover will be seeded with a durable, shallow-rooted vegetative cover. Maintenance of the cover will include mowing at least once yearly to prevent deep-rooted plants from becoming established and penetrating the clay cover. Periodic inspections of the site will be necessary to check the integrity of the cover and ascertain if measures need to be taken against access by burrowing animals.

Covering the critical overbank sediments between HSB Miles 3.8 and 4.7 will require clearing and grubbing of 25 acres. After grading and compaction of the overbank sediments, 81,100 cubic yards of suitable fill will be required to provide for a 24 inch cover as described above. If non-critical overbank sediments are not covered, a trench should be excavated around the periphery of the critical area to a depth of 3 to 4 feet and backfilled with clay to maintain the integrity of the clay cover at the edge. Elevation differences between the overbank and channel should be graded to gentle slopes before covering.

For covering non-critical overbank sediments within the contained area, 758,000 cubic yards of fill would have to be hauled and placed, and approximately 235 acres cleared and grubbed. This would increase the overall cost of this alternative by approximately 14 million dollars. Cover would be applied in the same manner as described above for critical overbank sediments.

Work Scheduling--Work schedules in the containment area will have to be coordinated with operations of the T and ED at Test Area 1. Based on past operation of Test Area 1, work stoppage will not be necessary upstream from HSB Mile 3.9, but will amount to 25 percent of normal working hours (0800 to 1630, Monday through Friday) downstream from Mile 3.9 (U.S. Army, 1980). The work stoppage will have to be figured into construction costs or be circumvented by employing an evening shift.

6.3.2 Containment With Within-Basin Diversion Of HSB

Introduction--A within-basin diversion will require a dike on the north side of the channel to divert and exclude flow in HSB from the old channel. By raising this dike and extending it such that the most highly contaminated area is completely enclosed, as shown in Figure III-15, that area will be isolated from surrounding surface water. Precipitation incident on the enclosed area can be removed by a pumping station. Application of a stable cover over the contaminated channel sediments will provide a further degree of DDTR isolation within the containment area.

Design and Construction--Since the containment dike for the within-basin diversion is an integral part of the diversion, its design and construction is discussed with the diversion in Section 5.0 of this Appendix.

Cover Application--Application of cover over the HSB channel sediments will be carried out in the same manner as described for the out-of-basin diversion containment (Section 6.3.1). The only difference will be in areal extent, the channel being covered downstream to HSB Mile 4.0 rather than Mile 2.5. Assuming an average of three feet of cover will be applied over the total channel area within the containment dike, approximately 106,000 cubic yards of cover material will be required. Critical and non-critical overbank areas will require 110,000 and 868,000 of fill, respectively. Preliminary investigation indicates that adequate borrow for application of the cover can be obtained within a 3 or 4 mile radius of the site. Borrow hauling costs are based on this assumption. If sites more distant than 4 miles are used, hauling costs would be increased proportional to the haul distance.

Work Scheduling--Work scheduling associated with the containment are discussed in Section 5.0 of this Appendix.

7.0 AREAWIDE ENVIRONMENTAL MONITORING

A program of areawide environmental monitoring will be required following implementation of any alternative in order to assess the effectiveness of the alternative by monitoring conditions during the preliminary recovery period. The proposed program would cover a period of four years following completion of clean-up activities, after which additional monitoring would be implemented as determined necessary.

The basic area-wide monitoring program should consist of a survey and DDTR analysis of selected fish species at various locations in IC and the TR two or three times yearly. A sediment survey should be conducted twice yearly at various locations in HSB, IC, and the TR. Sediment cores should be analyzed for total DDTR in various depth fractions. Water at various locations in HSB and IC should be analyzed monthly for suspended sediment and total DDTR. An annual survey of macroinvertebrates in HSB and IC would be limited to identification and counting. Representive non-fish vertebrates in and around HSB and IC should be identified and counted yearly with limited DDTR analysis on selected individuals.

8.0 LEGISLATION, REGULATIONS, AND PERMITTING

Actions proposed under alternatives for mitigation of DDTR in HSB and IC may be subject to regulation under the following legislation:

1) Clean Water Act of 1977,
2) River and Harbor Act of 1899,
3) National Environmental Policy Act of 1969,
4) Fish and Wildlife Coordination Act of 1934,
5) Resource Conservation and Recovery Act of 1976,
6) Hazardous Waste Transportation Act of 1974,
7) Endangered Species Act of 1973,
8) Section 26a of the Tennessee Valley Authority Act,
9) Various Historic and Archaeological Data Preservation Laws,
10) Alabama Hazardous Wastes Management Act of 1978,
11) Alabama Air Pollution Control Act of 1971,
12) Occupational Safety and Health Administration Legislation,
13) Executive Order 11988, and
14) Executive Order 11990.

8.1 CLEAN WATER ACT OF 1977

Permits are issued by the U.S. Army Corps of Engineers (USCOE) under Section 404 of the Clean Water Act (PL 95-217) to regulate the discharge of dredged material into navigable waters. USCOE Permit Program Regulations are discussed in detail in 33 CFR, Parts 320 through 329, appearing in the Federal Register (42 FR 37121, July 19, 1977). Interpretation of these regulations indicates that HSB and IC would be classified as navigable waters and that the discharge of dredged material includes overflow from contained land disposal areas. Temporary dredged material disposal areas would thus be subject to permitting under Section 404 of PL 95-217. In addition, NPDES permitting under Section 402 may be required for the return water discharge. The selection and operation of the disposal area must be in accordance with guidelines developed jointly by the Administrator of the EPA and Secretary of the Army, published as 40 CFR Part 230 in the Federal Register (40 FR 41291, September 5, 1975) and updated in 40 CFR Part 231 (44 FR 58082, October 9, 1979). Use of any designated disposal site is subject to approval by the Administrator of EPA.

Section 401 of the Clean Water Act (PL 95-217, 33 USC 1341) requires applicants for a Federal license or permit to conduct an activity which may result in the discharge of a pollutant into waters of the United States to obtain a certification from the state in which the discharge originates that the discharge will comply with the applicable effluent limitations and water quality standards. Such certification would be required for the return water discharge from the temporary disposal area.

8.2 RIVER AND HARBOR ACT OF 1899

The construction of any dam or dike across any navigable water of the United States is prohibited without Congressional consent and approval of the plans by the Chief of Engineers and Secretary of the Army under Section 9 of the River and Harbor Act (30 Stat. 1151; 33 USC 401). If the navigable portions of the water involved lie entirely within the limits of a single state, such structures may be built upon approval by the legislature of that state, provided its location and plans are approved by the Chief of Engineers and Secretary of the Army. The instrument of authorization is in the form of a permit. Such permitting may be required for diversion, containment, or dewatering dikes proposed in the alternatives.

Section 10 of the River and Harbor Act (30 Stat. 1151; 33 USC 403) prohibits obstruction or alteration of any navigable water, including excavating or depositing materials in such waters and altering the course or capacity of such waters, without authorization by the Chief of Engineers and Secretary of the Army in the form of a permit or letter of permission. This section would be applicable to all dredging and channel excavation actions.

8.3 NATIONAL ENVIRONMENTAL POLICY ACT OF 1969

Under Section 102(2)(c) of the National Environmental Policy Act (NEPA), all federal agencies proposing major actions which could significantly affect the quality of the environment must submit to the President's Council on Environmental Quality (CEQ) an Environmental Impact Statement (EIS) which addresses:

1) The environmental impact of the proposed actions,
2) Adverse environmental effects which cannot be avoided should the proposal be implemented,
3) Alternatives to the proposed action,
4) The relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity, and
5) Irreversible and irretrievable commitments of resources resulting from implementation of the proposed action.

The lead Federal Agency will determine whether an EIS is required for a permit application. If it is required, the applicant must furnish the District Engineer with all information necessary for preparation of an EIS. Public comment may be invited by the District Engineer in preparation of a draft EIS. Public notice must be issued summarizing the actions and announcing the availability of the draft EIS. A public hearing may be held prior to preparation of a final EIS. If the conventional EIS process is expected to result in excessive delay of the project, an abbreviated NEPA filing procedure is allowed for in the CEQ guidelines on EIS preparation.

8.4 FISH AND WILDLIFE COORDINATION ACT OF 1934

Under the Fish and Wildlife Coordination Act, any federal agency proposing to control or modify a body of water must first consult with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service (if appropriate), and the appropriate state agency with administrative control over wildlife resources in the project area.

8.5 RESOURCES CONSERVATION AND RECOVERY ACT OF 1976 (PL 94-580)

The Resources Conservation and Recovery Act (RCRA) provides funding and technical assistance for developing plans and facilities to recover resources from waste materials, and for regulation and "cradle to grave" management of hazardous wastes. Regulations set forth by RCRA (40 CFR Parts 260-265) appear in Volume 45, No. 98 of the Federal Register (May 19, 1980). Additional proposed regulations appear as 40 CFR Part 250 in the Federal Register (43 FR 58946, December 18, 1978).

Part 261 of RCRA discusses identification and listing of hazardous wastes. Two mechanisms are established for determining whether a particular waste is classified as hazardous; one, a set of characteristics of hazardous wastes, the other a specific list of hazardous wastes. Contaminated sediments from HSB and IC are not included under Subpart C of Part 261, Characteristics of Hazardous Wastes. Subpart D, Lists of Hazardous Wastes, is open to interpretation as to whether or not sediments dredged from HSB and IC would be included. The RCRA regulations do not specifically addressd the disposal of dredged material or other high volume wastes, originally proposed to be classified and regulated as "special wastes" because of their bulk. In the event that the dredged sediments are required to be regulated under RCRA, compliance with the following parts of the regulations will have to be addressed.

Part 262 pertains to standards applicable to generators of hazardous waste. Most notable in this subpart are the items requiring shipping manifests for transportation of hazardous wastes and various identification codes, container requirements, and labeling practices. Little, if any, of Part 262 appears relevant to on-site handling of DDTR-contaminated sediments.

Standards applicable to transporters of hazardous waste appear in Part 263. These regulations are consistent with DOT's regulations on transportation of hazardous waste under the Hazardous Materials Transportation Act (Title 49, Subchapter C), discussed in Section 8.7.

Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities are delineated in Part 264. Interim status standards appear in Part 265. The handling and disposal of dredged contaminated sediments associated with the proposed alternatives is in general compliance with these preliminary Phase I regulations. Additional regulations under these parts will be promulgated in late 1980. If the additional regulations are consistent with proposed regulations (published in the Federal Register, 43 FR 58946, December 18, 1978), disposal plans associated with the alternatives should be in general compliance; with the exception of the following two proposed standards:

1) A facility shall not be located in the 500-year floodplain [Item 250.43-1(d)], and

2) Landfills must have a liner system as described in Item 250.45-2(b)(13).

The conditions which assure the environmental acceptability of the proposed disposal plans without meeting these two standards are discussed in Section 2.0 of this Appendix.

8.6 HAZARDOUS MATERIALS TRANSPORTATION ACT OF 1974

The Hazardous Materials Transportation Act (HMTA) was developed by the U.S. Department of Transportation to regulate transportation of hazardous materials. Though DDT is listed in these regulations as a hazardous material (Section 172.101), no reference is made to bulk sediments or dredged material contaminated with DDT. DDT is classified as an ORM-A waste. Wastes in this classification do not require shipping papers for transportation (Section 172.200). Specific items relating to the transport of DDT wastes under Section 172.101 are that no labelling is required and there is no limit on the net quantity of material transported in one package. Interpretation of the regulations indicate that if the contaminated sediments are to be transported, hauling in covered dump trucks with sealed tailgates will be within these regulations. The Federal Highway Administration is responsible for enforcement of the regulations if transport by road is involved, and should be contacted regarding official interpretation of the regulations.

8.7 ENDANGERED SPECIES ACT OF 1973

Under this Act, actions authorized or implemented by Federal agencies must be conducted in such a manner as to conserve threatened or endangered species. The implementing agency must take action as necessary to insure that the existence of endangered or threatened species is not jeopardized and habitat critical to those species is not destroyed or modified. Additional coordination with the Fish and Wildlife Service will be necessary regarding requirements of this Act.

8.8 SECTION 26a OF THE TENNESSEE VALLEY AUTHORITY ACT

This section of the TVA Act stipulates that plans for construction, operation, and maintenance of projects within the Tennessee River system requiring dams or other obstructions affecting navigation, flood control, or public lands or reservations must be submitted to and approved by the Tennessee Valley Authority Board. Upon approval of such plans, deviation from them is prohibited without approval of appropriate modifications to the original plans.

8.9 VARIOUS HISTORIC AND ARCHAEOLOGICAL DATA PRESERVATION LAWS

8.9.1 Antiquities Act of 1906

This Act provides for the preservation of historic and prehistoric remains (antiquities) on Federal lands, establishes penalties for unauthorized destruction or appropriation of federally owned antiquities, and establishes a permit system for the scientific investigation of antiquities on Federal lands.

8.9.2 Historic Sites Act of 1935

The Secretary of the Interior is designated by this Act as responsible for establishing the National Survey of Historic Sites and Buildings. The Act requires the preservation of properties of "national historical or archaeological significance" and the designation of national historic landmarks. Interagency, intergovernmental and interdisciplinary efforts for the preservation of such resources are also authorized by the Act.

8.9.3 National Historic Preservation Act of 1966, as Amended

This Act establishes a national policy of historic preservation, including encouragement by providing matching grants for state and private efforts. Of particular importance is Section 106 of the Act, which describes certain procedures to be followed by Federal agencies implementing projects which may affect significant properties. Under Section 106, the responsible agency is directed to consult with the State Historic Preservation Officer (SHPO) and, where necessary, the Office of Archaeology and Historic Preservation to determine the significance of the property. Once the significance is determined, the agency must consult with SHPO and the Advisory Council to develop mitigation plans.

8.9.4 Preservation of Historic and Archaeological Data Act of 1974, Amending the Reservoir Salvage Act of 1960

The Reservoir Salvage Act provided for the preservation of Historical or archaeological data that may be lost or destroyed by construction of federally funded or licensed dams, reservoirs, and attendant facilities. This Act was amended by the Preservation of Historic and Archaeological Data Act of 1974. Under this later act, whenever a Federal project or federally licensed project alters terrain to the extent that signifdicant historical or archaeological data is threatened, the Secretary of the Interior may take whatever actions are necessary to recover and preserve the data prior to commencement of the project. The cost of data recovery are restricted by this act to 1 percent of the total project cost. This 1 percent limitation does not apply to identification studies and planning required by other Acts, nor to mitigation costs other than data recovery. If data recovery costs exceed the 1 percent limitation, supplemental funding or alternative mitigation methods must be developed. The loss of significant data not mitigated by the 1 percent limitation or supplmental funding must be addressed as unavoidable adverse impacts in the Environmental Impact Statement.

8.9.5 Archaeological Resources Protection Act of 1979

This Act requires that any person removing any archaeological resource located on public or Indian lands must first obtain a permit from the Federal land manager. Compliance with Section 106 of the National Historic Preservation Act of 1966 is not required with issuance of a permit under the Archaeological Resources Protection Act. The Act states that ownership of archaeological resources excavated or removed from public lands will remain the property of the United States, establishes regulations governing the removal of archaeological resources, and specifies civil and criminal penalties for violators of the Act. Provisions are also made for cooperation and communication between Federal agencies, private individuals, and professional archaeologists.

8.10 ALABAMA HAZARDOUS WASTES MANAGEMENT ACT OF 1978

Regulations promulgated pursuant to this Act incorporate all requirements of the final and proposed regulations under RCRA. The Alabama regulations do impose permit and other legal obligations in addition to the RCRA requirements. If the DDTR-contaminated sediments are classified as a hazardous waste by the State of Alabama, the Alabama regulations will have to be addressed and these additional requirements met. Most noteworthy are Sections 12(e) and 12(f), requiring both construction and operating permits for disposal facilities; and Section 7, requiring dedication of disposal lands for "perpetuity" (200 years as opposed to RCRA's 30-year post closure care requirement).

8.11 ALABAMA AIR POLLUTION CONTROL ACT OF 1971

Regulations of the Alabama Air Pollution Control Commission, promulgated persuant to this Act, regulate open burning and particulate emissions such as fugitive dust (Chapters 3 and 4). These regulations should have minimal impact on proposed alternatives.

8.12 OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

OSHA Legislation 29 CFR 1900 et. seq. sets limits on worker exposure to airborne concentrations of DDT and monochlorobenzene. Though airborne concentrations are not expected to be significant during dredging and construction, this must be verified on-site.

8.13 EXECUTIVE ORDER 11988

Executive Order 1198 directs Federal agencies to "restore and preserve the natural and beneficial values served by floodplains" in Federal activities related to land management or use, and for Federally funded or implemented construction projects. If an agency allows or conducts an action in a floodplain, alternatives must be considered to avoid adverse impacts and incompatable development in the floodplain. Regulations were to be adopted or amended as necessary by the agencies to comply with this order.

8.14 EXECUTIVE ORDER 11990

Executive Order 11990 orders each Federal agency to take actions necessary to "minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands" in Federal activities related to land management or use, and for federally funded or implemented construction projects. If a project is to be implemented in a wetland, it must be demonstrated that there is no practiceable alternative and that the proposed action mitigates to the extent possible, harm to the wetlands. Economic, environmental, and other relevant factors may be considered in making this judgement.

9.0 PROPOSED ALTERNATIVES

9.1 ALTERNATIVE A: NATURAL RESTORATION

An obvious alternative is to allow the presently contaminated system to restore itself naturally. Key factors in this assessment are questions concerning how long natural restoration would require, whether conditions will get worse before they get better, and whether the contamination will spread over an even wider area.

If natural restoration is to be successful, one of three things must occur. Either (1) the DDTR must be degraded to harmless compounds, (2) the DDTR must become isolated in some manner from the rest of the environment, or (3) the DDTR must be flushed out of the system.

A review of the literature regarding the persistence of DDTR, particularly in the concentrations found in Huntsville Spring Branch, strongly indicates the half-life of this material may be on the order of at least 20 to 30 years. At a 20-year half-life, 60 years from now there would still be 105 tons of DDTR left. At a 30-year half-life, 209 tons would be left after 60 years. Either amount would be far more than is currently in the lower reaches of Huntsville Spring Branch and Indian Creek. Hence, it appears that natural degradation cannot be expected to significantly "clean up" the problem in the foreseeable future.

The most promising scenario for success of the natural restoration alternative is that the system will somehow isolate the current contaminated sediments. The most likely mechanism to accomplish this is natural silting over of contaminated areas. To date, this does not appear to be occurring at a very rapid rate. Currently, about 47 percent of the DDTR is in the top 6 inches of sediment and about 86 percent is in the top 1 foot. Hence, natural isolation by silting-in does not appear to have been too successful in the last 10 years since the DDTR manufacturing plant closed.

Another possible means by which the natural restoration alternative might be successful would be for the DDTR in Huntsville Spring Branch and Indian Creek to be flushed out as dissolved and suspended material into the Tennessee River. Current DDTR distributions, plus the best estimates of the rate at which DDTR is moving out of Indian Creek, suggest that natural flushing would take hundreds of years. Even if this were to occur, the positive effects on the HSB-IC system would be more than offset by the negative impacts on the Tennessee River.

Several potential negative aspects of the natural restoration alternative should be noted. Currently, only 1 percent of the total DDTR is in Indian Creek, yet, this is enough to cause substantial contamination of some fish species in that area. If left uncontrolled, there appears to be a significant risk that Indian Creek DDTR levels could be maintained or even increased from the vast storehouse of DDTR sitting upstream. Even if only insignificant amounts of DDTR are moving under normal flow conditions, there is the possibility that infrequent, but large, storm events could flush slugs of DDTR out of Huntsville Spring Branch.

An even worse possibility is that the DDTR has been slowly working its way out of Huntsville Spring Branch and continues to do so at a rate faster than it is degraded downstream. Given sufficient time, enough of it may enter the Tennessee River to more substantially impact an even larger system.

The information available currently is not sufficient to allow one to determine with certainty whether the DDTR effects are increasing or decreasing. Some trends in bird population estimates suggest a decrease in effects. The Double-crested Cormorant population of the Wheeler National Wildlife Refuge declined rapidly from over 2,000 (peak population number) in 1944 to 50 in 1959. Between 1963 and 1972 these birds were not observed on the Refuge. Since 1973 there has been a gradual increase again in these birds to a peak population (greatest number of birds observed on any day during the period) of 21 in 1979. However, as noted in Section 5.4 of this Appendix, this may be due more to regional factors than to local conditions. American Woodcocks, Least Sandpipers, and Pectoral Sandpipers are also increasing (Table II-8). According to the peak population records of the Wildlife Refuge (Table II-8), Pied-billed Grebes, Sora Rails, and Vultures are making possible comebacks. However, this trend is not definite for these species due to the short time span since closure of the DDT plant. Also, population variations may be more the result of region or areawide conditions.

In contrast to this, there has not been a recovery for the following top carnivores: Barred Owl, Cooper's Hawk, Marsh Hawk, Red-Shouldered Hawk, and the Sharp-Shinned Hawk. Table II-8 also shows a marked reduction in Swamp Rabbits after the DDT plant was closed from 3,000 in 1971 and 1972 to 700 for the last two years. The reason for this decline is unknown.

The short-term risk of the natural restoration alternative is relatively low in that the situation does not appear to be rapidly worsening. Thus, it would be possible to tentatively select natural restoration plus continued monitoring and status reports. This would allow additional time during which more definitive information could be gathered to determine contamination trends.

If the natural restoration alternative is selected, either on a temporary or permanent basis, a monitoring program should be initiated to determine its effectiveness. Of particular interest would be whether the contamination is getting worse or better with the passage of time. As a minimum the monitoring program should provide answers to the following questions.

1) What is the background DDTR level in TR sediments and how are sediments in the TR downstream of the IC confluence comparing with background on a continual basis?

2) What is the transport rate of sediment and DDTR out of HSB and IC?

3) What is occurring with regard to DDTR levels in fish inhabiting the TR?

Initial sediment sampling in the TR should extend upstream and downstream sufficient distances to accurately establish background sediment DDTR concentrations. Once background levels are established, the sampling area could be reduced and particular emphasis placed on sampling in Wheeler Reservoir below IC where problems are likely to first appear should the situation worsen. Sediment sampling in the TR should be conducted on a yearly basis. Sediments in IC should also be sampled for DDTR yearly along several transects, the majority of which should be in the lower reaches near the TR. Sediments in HSB need not be sampled at less than two or three year intervals since it is unlikely that significant changes could be detected in such a contaminated system at shorter intervals.

DDTR transport out of IC can best be determined by automatic sampling at a transect located near the IC-TR confluence. Samples collected every three to four hours should be composited at three to seven day intervals and analyzed for suspended solids and DDTR. Flow can be determined from upstream gaging stations on IC and HSB. DDTR transport out of HSB can be estimated in a similar manner.

Water sampling should be conducted on a yearly basis. Water in the TR, and IC should be sampled and analyzed for DDTR.

Fish sampling efforts should be concentrated in the TR, with limited sampling in IC. The sampling area should be extended both upstream and downstream to insure that background conditions can be established. Sampling should be conducted a minimum of twice yearly. Species sampled and analyzed for total DDTR should include but not necessarily be limited to channel catfish, smallmouth buffalo, and largemouth bass.

Surveys and sampling of other biota are of secondary importance but should be conducted to obtain a more complete assessment of the system. This is not meant to imply that other biota are environmentally unimportant. The priority indicated is based on items of information which relate most directly to determining whether the situation regarding DDTR contamination is improving or getting worse.
The exact cost would be highly dependent on the precise scope of work finally agreed upon but has been estimated at $600,000 per year.

The selection of the natural restoration alternative would have the advantage of providing time during which new and/or currently unproven technology could be developed which could concievably result in a more cost-effective mitigation plan. However, there is no guarantee that such a plan would materialize.

Electrical fish barriers could be utilized with this or other alternatives to limit the movement of contaminated fish between IC and the TR. Such barriers have been shown to be effective in preventing upstream movement of adult salmon, but did not prevent downstream movement of salmon fingerlings (Burrows, 1957). The effectiveness of such a barrier to fish native to the TR is unknown. Such a barrier would require the presence of electrodes suspended in the stream. Such an arrangement would preclude boat traffic both physically and because of the electrical hazard.

In summary, the success of the natural restoration alternative depends on natural actions that range in probability from very unlikely to, at best, possible. On the positive side, it appears that conditions are not rapidly changing and the tentative selection of this alternative would not present a high risk for a significantly worsened situation.

9.2 ALTERNATIVE B: DREDGING AND DISPOSAL

9.2.1 Methodology and Implementation for Alternative B

See Section 3.0.

9.2.2 Cost Estimates for Alternative B

Mitigation of Cultural Resources Impact--An intensive cultural resources survey should be made of the dredging impact area over an 8 week period at a cost of $80,000. The cost and time for testing and full scale excavation by professional archaeologists of all National Register eligible properties within this area that cannot be avoided cannot be accurately estimated at this time. At least 15 months and $725,000 will be involved.

General--The detailed cost estimates presented below for Alternate B in Table III-11 assume that Reaches A, B, and C (Figure III-7) are dredged, i.e., the contaminated channel is dredged from HSB Mile 5.6 to IC Mile 0.0. Cost estimates for hydraulic dredging are based on a unit cost of $2.25 per cubic yard for the prime mover (dredge) and $0.75 per cubic yard for each booster in operation. Channel snagging costs are based on required equipment and personnel, with assumptions for production rates in various reaches. It must be noted that significant variations in the cost estimates can be expected if options other than those assumed are implemented. A summary of cost estimates for all three dredging plans and the estimated effect of various options on the total cost of the project are shown in Table III-12. The time base for all cost estimates is 1980. This estimated implementation timeline and

Table III-11. Detailed Cost Estimates for Alternative B, Dredging and Disposal (for Dredging Plan III)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(a) Temporary Dredged Material Disposal Area (TDMDA)				
(i) Construction				
-Site Acquisition	---	---	---	0
-Soil Borings and Testing	1 boring & tests	38	1,026	39,000
-Clearing and Grubbing	acre	187	2,500	468,000
-Excavation and Grading	cu. yd.	962,600	2	1,925,000
-Dike Construction	cu. yd.	812,000	3.5	2,842,000
-Place Fill for Return Water Treatment Area	cu. yd.	100,000	3	300,000
-48-in. Pipe Weirs, Purchase and Install	each	24	5,500	132,000
-Seeding, Mulching, Fertilizing, Exterior Dikes	acre	18	1,300	23,000
-Groundwater Monitoring System	1-50 ft. Well	8	600	5,000
-Leachate Monitoring System	ft.	2,000	12	24,000
-Return Water Treatment System	L.S.[1]	---	---	6,000,000
-Earthern Clarification Basin (for above system)	L.S.	---	---	74,000
-Fencing Around Site	ft.	19,500	12	234,000
-Access Road (1,000 ft. x 40 ft.)	sq. yd.	4,450	5	22,000
-Reroute Existing Drainage	ft.	4,000	2.5	10,000
SUBTOTAL				12,098,000
(ii) Operation				
-Reworking Interior Dikes For Crane Access	cu. yd.	14,000	2	28,000
-Small Dragline for Trenching[2]	L.S.	---	---	473,000
-Return Water Treatment System Operating Costs	L.S.	---	---	5,055,000
-Mud Cat Dredge for Solids Removal in Clarification Basin[3]	L.S.	---	---	122,000
-Sump and Piping for Draining, Snagging & Grubbing Disposal Area	L.S.	---	---	8,000
SUBTOTAL				5,686,000
SUBTOTAL TDMDA COST				17,784,000
-20% Contingency				3,577,000
-15% Engineering Design, Supervision and Administrative Costs				2,668,000
TOTAL TDMDA COST				24,008,000

Table III-11. Detailed Cost Estimates for Alternative B, Dredging and Disposal (for Dredging Plan III) (Continued, Page 2)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(b) Snagging HSB and IC Channel[4]				5,704,000
(c) Hydraulic Dredging				
-Access Roads				
-Clearing and Construction	sq. yd.	323,000	5	1,615,000
-Additional fill for Low Areas	cu. yd.	50,000	4	200,000
-Culverts and Installation	each	100	850	85,000
-Temporary Power Line and Lighting	L.S.	---	---	1,309,000
-Power Consumption (electrical)	kwh	14,000,000	0.05	700,000
-Depth Ranging System	L.S.	---	---	50,000
-Booster Pump Purchase[5]	each	12	206,000	2,472,000
-Polyethylene 14 ID Discharge Pipe[6] (including connections)	ft.	63,000	27.50	1,733,000
-Floatation for Discharge Pipe	ft.	2,000	10	20,000
-Mobilization and Demobilization (dredge and boosters)	L.S.	---	---	80,000
-Lifting Dredge over Dodd and Centerline Road Bridges	L.S.	---	---	15,000
-Channel Dredging and Pumping to TDMDA	L.S.	---	---	8,899,000
-Dredge Monitoring	L.S.	---	---	750,000
SUBTOTAL				17,928,000
-20% Contingency				3,586,000
-15% Engineering Design, Supervision and Administrative Costs				2,689,000
TOTAL HYDRAULIC DREDGING COSTS				24,203,000
(d) Critical Overbank Removal				
-Additional Sediment Sampling	L.S.	---	---	100,000
-Clearing and Grubbing	acre	25	2,500	63,000
-Access Road Construction	sq. yd.	20,000	5	100,000
-Dragline Dredging[7]	cu. yd.	121,600	5	608,000
-Hauling to TDMDA	cu. yd.	121,600	4	486,000
-Placement/Grading in TDMDA	cu. yd.	121,600	1	122,000
-Final Grading of Overbank	sq. yd.	121,600	1	122,000
-Seeding, Mulching, Fertilizing of Overbank	acre	25	1,300	33,000
SUBTOTAL				1,634,000
-20% Contingency				327,000
-15% Engineering Design, Supervision, and Administrative Costs				245,000
TOTAL CRITICAL OVERBANK REMOVAL COSTS				2,206,000

Table III-11. Detailed Cost Estimates for Alternative B, Dredging and Disposal (for Dredging Plan III) (Continued, Page 3)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(e) Option for Noncritical Overbank Removal				
-Clearing and Grubbing	acre	235	2,500	588,000
-Access Road Construction	sq. yd.	85,000	5	425,000
-Dragline Dredging[7]	cu. yd.	1,136,800	5	5,684,000
-Hauling to TDMDA	cu. yd.	1,136,800	4	4,547,000
-Placement/Grading in TDMDA	cu. yd.	1,136,800	1	1,137,800
-Final Grading of Overbank	sq. yd.	1,136,800	1	1,137,800
-Seeding, Mulching, Fertilizing of Overbank	acre	235	1,300	306,000
SUBTOTAL				13,824,000
-20% Contingency				2,765,000
-15% Engineering Design, Supervision, and Administrative Costs				2,074,000
TOTAL				18,663,000
(f) Permanent Disposal of Dredged Material (closure of TDMDA as a landfill)				
-Grading, Compacting Dredged Material	sq. yd.	905,100	1.5	1,358,000
-Hauling, Placement, Compaction, and Grading of Cover Material	cu. yd.	603,400	5	3,017,000
-Seeding, Mulching, Fertilizing Site	acre	187	1300	243,000
SUBTOTAL				4,618,000
-20% Contingency				924,000
-15% Engineering Design, Supervision and Administrative Costs				693,000
TOTAL PERMANENT DISPOSAL COSTS				6,235,000
(g) Cultural Resources Activities	L.S.	---	---	805,000
OPERATION AND MAINTENANCE COSTS				
(a) TDMDA Long-Term Maintenance	yr	30	50,000	1,500,000
(b) Monitoring				
-Disposal Site Monitoring	yr	30	50,000	1,500,000
-Areawide Monitoring	yr	4	500,000	2,000,000

Table III-11. Detailed Cost Estimates for Alternative B, Dredging and Disposal (for Dredging Plan III) (Continued, Page 4)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
TOTAL COST OF PROJECT (excluding noncritical overbank removal)				68,161,000
(including noncritical overbank removal)				86,824,000

[0] Includes operation and maintenance costs.
[1] Lump sum.
[2] Includes purchase, operating, and maintenance costs of 35-ton crane for entire dewatering period (3 years).
[3] Includes purchase and operation of Mud Cat Dredge Model SP810 for operational life of treatment plant (5 years).
[4] Includes contingency, engineering, and administrative costs.
[5] Includes integrated central control system.
[6] Cost based on using Phillips Driscopipe.
[7] Assuming overbank is excavated uniformly to a 3.0-ft. depth.

Table III-12. Cost Summary for Alternative B (As Detailed in Table III-11 for Dredging Plan III)

Dredging Plan	Reaches Included*	Total Estimated Cost (Millions of Dollars)
I	A	27.04
II	A,B	38.66
III	A,B,C	68.16

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option	+ 18.66
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal (Plan III)	+ 15.51
(Including Disposal of Noncritical Overbank Sediments)	+ 43.37

annual expenditures for Alternative B are given in Figure III-20 and Table III-13, respectively.

9.3 ALTERNATIVE C: OUT-OF-BASIN DIVERSION AND REMOVAL OF CONTAMINATED SEDIMENTS

9.3.1 Introduction

This alternative combines the major actions of dredging and disposal and out-of-basin diversion of HSB. Diversion of HSB directly to the TR will greatly reduce fluvial transport of DDTR from HSB and moderate its transport in IC. The diversion alone will not provide for adequate mitigation of DDTR contamination in the HSB-IC system. Contaminated sediments would still be subject to fluvial transport from local runoff and from flows created by fluctuations in the Wheeler Reservoir pool. Significant potential for biotransport would also exist if contaminated sediments were left exposed.

Removal of contaminated sediments from HSB and IC, coupled with a suitable disposal technique, will provide for isolation of the majority of DDTR. Minimal transport of DDTR would occur during the removal operation due to the greatly reduced flows afforded by the diversion. Two options are discussed for removal of contaminated sediments, hydraulic dredging and dragline dredging. Dragline dredging would require construction of a containment dike and drainage channel as illustrated in Figure III-18. The turbidity-generating characteristics of the dragline dredge which excluded it from consideration for dredging flowing reaches of HSB and IC will not present a problem within the diked containment area. Removal of contaminated sediment downstream from the containment area would be by hydraulic dredging.

9.3.2 Out-Of-Basin Diversion

The out-of-basin diversion is discussed in Section 4.0 of this Appendix.

9.3.3 Dredging and Disposal

Hydraulic Dredging--The hydraulic dredging of HSB and IC and alternatives for disposal of contaminated sediments is discussed in Section 3.0 of this Appendix.

Dragline Dredging--

Introduction--Dragline Dredging of HSB upstream from Mile 2.4 (Dodd Road) may be advantageous if the channel can be dewatered to such an extent that ponded water is nearly eliminated. Downstream from HSB Mile 2.4 the topography is such that the channel would probably be inundated several

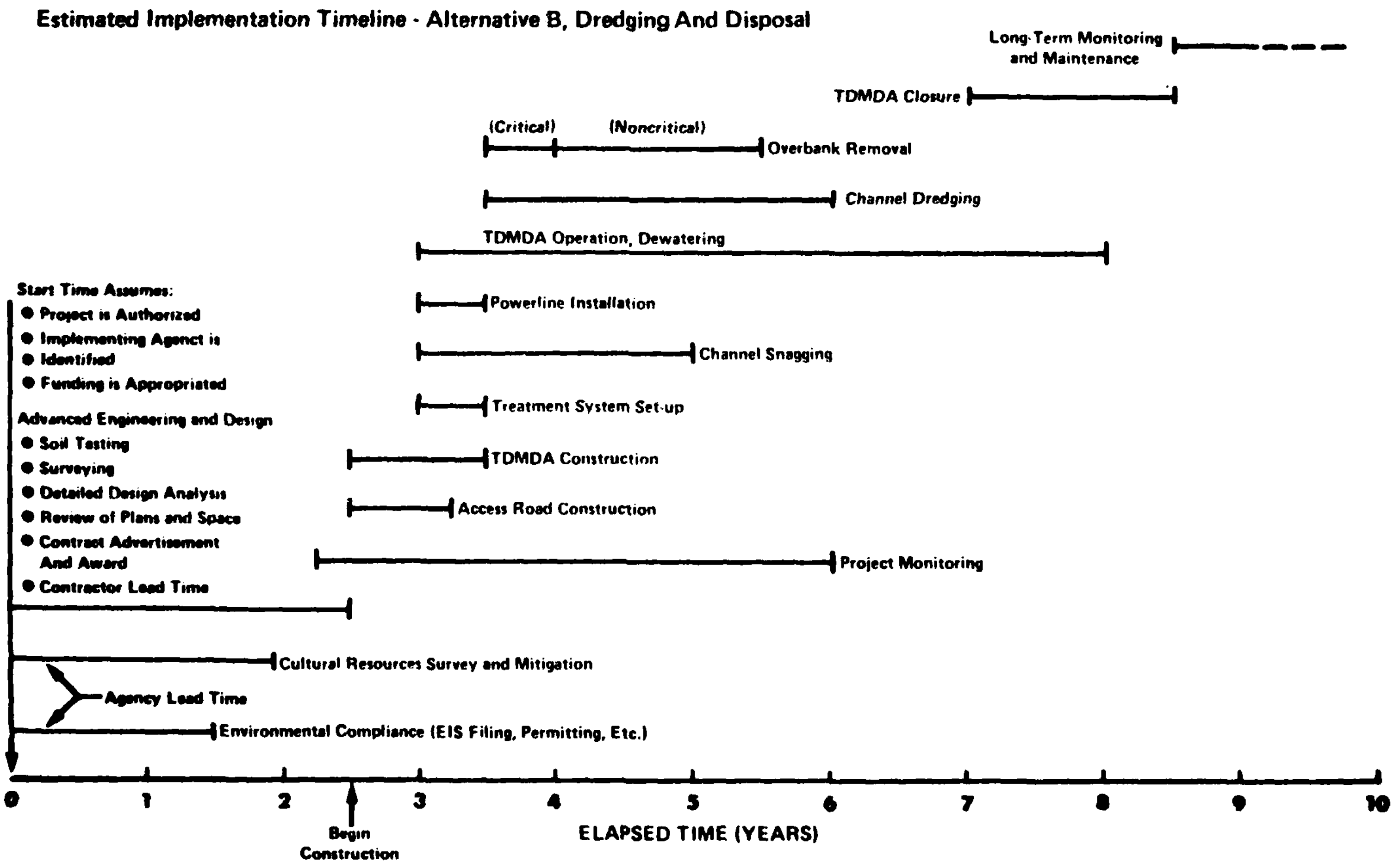

FIGURE III-20. Estimated Implementation Timeline, Alternative B

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of
Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

Table III-13. Estimated Annual Expenditures - Alternative B

Year After Start Time	Estimated Annual Expenditures (Millions of Dollars-1980) Without Noncritical Overbank Mitigation	With Noncritical Overbank Mitigation
1	2.9	3.7
2	2.9	3.7
3	6.6	7.0
4	22.7	22.7
5	11.1	22.4
6	8.2	14.0
7	1.4	1.4
8	5.1	5.1
9	1.8	1.8
10-13	0.6	0.6
14-26	0.1	0.1
Average Annual Expenditure, 1980 Dollars (assuming an interest rate of 7.125% and a project life of 50 years):	5.02	6.39

times during dragline dredging, substantially increasing down-time and dewatering costs. Dewatering requirements for the dragline-dredged sediments would be greatly reduced or eliminated altogether, as sediments would be removed at their in situ water content. This would allow closure of portions of the temporary disposal area soon after termination of dredging and would eliminate some dewatering costs. If the option for permanent disposal in an off-site abandoned mine is chosen, temporary disposal of dragline-dredged sediments may be eliminated altogether. Dragline dredging would also permit visual inspection of the accuracy and completeness of dredging.

Implementation of the dragline option will depend on the hydrologic conditions present in the HSB channel once the out-of-basin diversion is completed. A dewatering dike with sump and pumping station would have to be constructed across HSB to exclude the effects of the Wheeler Reservoir pool from the channel. The channel slope should allow for drainage of the majority of water from HSB. Ponded areas would persist in low areas but can be dewatered as they are encountered during dredging. Some recharge into the channel can be expected from groundwater, though this should be minimal due to the slow permeability of the fine-grained sediments. Groundwater and precipitation recharge can be handled by the pumping station.

Temporary Disposal of Dredged Material--A temporary disposal area will be selected and designed as described in Section 3.3. Dragline-dredged sediments will be placed in the two northern-most primary disposal cells (see Figure III-5). These cells will be sloped toward their outlets to facilitate drainage.

Dredged material will be transported to the temporary disposal area in trucks equipped with sealed tailgates. Methods for handling material within the site will be determined by its water content. It is expected that wide-tracked, low ground-pressure equipment will be operable on the dredged material shortly after its placement.

Placement and handling of the the material must be performed in such a manner as to assure adequate drainage of precipitation and pore water from the cells. Placement of wetter materials in relatively thin lifts may be desirable to increase their rate of dewatering.

If permanent disposal in the TDMDA is chosen, closure of the dragline disposal cells may be implemented soon after completion of dragline dredging. The time at which closure may be implemented will depend on the water content of the material and meteorological conditions encountered at the site.

Hydraulic dredging of IC and lower HSB will be implemented concurrently with dragline dredging of upper HSB, therefore the required capacity of the return water treatment system will not be changed. A significant savings may be realized, however, in the shorter duration of the hydraulic dredging program. Upon completion of hydraulic dredging, only

1 MGD capacity will be required to treat runoff from the site and the lease on the additional 2 MGD capacity may be terminated.

Implementation--Access roads will have to be constructed as described in Section 3.4.2. The width of these roads east of Dodd Road will be increased to 50 feet to accommodate the higher traffic volume necessary for hauling dredged sediments.

A dewatering dike with pumping station will be constructed as shown in Figure III-18. Contaminated sediments along the dike alignment should be excavated between November and February when Wheeler Reservoir is generally below elevation 552. If necessary, minor deviations from normal reservoir operating procedure such as discussed in Section 3.4.6 may be requested of TVA to facilitate work in the overbank. In order to save pumping costs and maximize dewatering of the area, the final dike section should be closed off at the end of December when Wheeler Reservoir is at its lowest elevation of 550 feet.

Water pumped from the sump may require treatment in the return water treatment system of the TDMDA. If monitoring of the water indicates this, the hydraulic dredge discharge pipe can be used to pump water to the TDMDA. Access roads will be constructed as shown in Figure III-7 for Reach A.

Dragline dredging will commence at the sump and proceed upstream. Tree material and other debris on the channel bottom can be removed concurrently with the sediments by equipping the dragline with a grapple operated on a separate cable. These materials will be loaded into separate trucks and disposed of in the snagging disposal area (Figure III-5). All haul trucks must be equipped with sealed tailgates and top covers.

As ponded areas are encountered in the HSB channel, they may be drained by excavating small channels between them and the lower elevation of the dredged area downstream. If this is not adequate, some pumping may be required. As these wetter sediments are placed in the disposal area, their stability can be increased by mixing with drier sediments previously excavated or by spreading in thin layers over drier sediments.

Dragline dredging between HSB Miles 2.8 and 3.9 will be hampered by the inability to reach some areas from the access roads due to the width of the channel. Maximum reach of most conventional dragline equipment is 150 feet. The dragline will have to work its way into these areas using mats or fill placed in dredged areas to allow mobility,. If fill is used it may have to be hauled from an off-site borrow area. The total area inaccessible from the access roads, assuming a maximum reach of 150 feet is about 31,000 square yards, or 13 percent of the channel area.

Upstream from HSB Mile 3.9 the entire channel will be accessible from the south access road.

Removal of critical and non-critical overbank areas in Reach A will be accomplished in the manner described in Section 3.4.6 of this Appendix.

Hydraulic Dredging Downstream From HSB Mile 2.4--Contaminated sediments in IC and lower HSB will be hydraulically dredged as described in Section 3.4 of this Appendix.

Permanent Disposal of Dredged Material--Permanent disposal will be implemented in the same manner as described in Section 3.5 of this Appendix.

9.3.4 Cost Estimates

Mitigation of Cultural Resources Impact--The high site probability in the diversion corridor necessitates an intensive cultural resources survey over a three week period at a cost of about $15,000. Testing of sites and excavation of all National Register eligible sites that cannot be avoided is estimated to take at least one year and $580,000.

An intensive cultural resources survey should be made of the dredging impact area over an 8-week period at a cost of $80,000. The cost and time for testing and full scale excavation by professional archaeologists of all National Register eligible properties within this area that cannot be avoided cannot be accurately estimated at this time. At least 15 months and $725,000 will be involved.

Total cultural resources activities associated with this alternative will take approximately two years at an estimated cost of $3,040,000.

General--A detailed cost estimate for Alternative C is shown in Table III-14. Cost estimates for the out-of-basin diversion are based on the lowest cost routings in each alignment sector, i.e., sectors A-1, B, C-1, D-1, and E (see Figure III-7). The removal of all contaminated channel sediments in Reaches A, B, and C (Figure III-7) is also assumed. A cost summary and the estimated cost effect of various options are given in Table III-15. The time base for all cost estimates is 1980. The estimated implementation timeline and annual expenditures for Alternative C are given in Figure III-21 and Table III-16, respectively.

9.4 ALTERNATIVE D: OUT-OF-BASIN DIVERSION AND CONTAINMENT OF CONTAMINATED SEDIMENTS

9.4.1 Introduction

This alternative utilizes containment techniques to mitigate contamination in Reach A, dredging in Reaches B and C, and an out-of-basin diversion of HSB. As noted previously, the out-of-basin diversion will greatly reduce fluvial transport of DDTR from HSB and moderate its transport in IC, but will not provide for adequate mitigation of DDTR contamination in the HSB-IC system. Contaminated sediments would still be subject to fluvial transport by local runoff or flows created by Wheeler Reservoir fluctuations, and to biotransport.

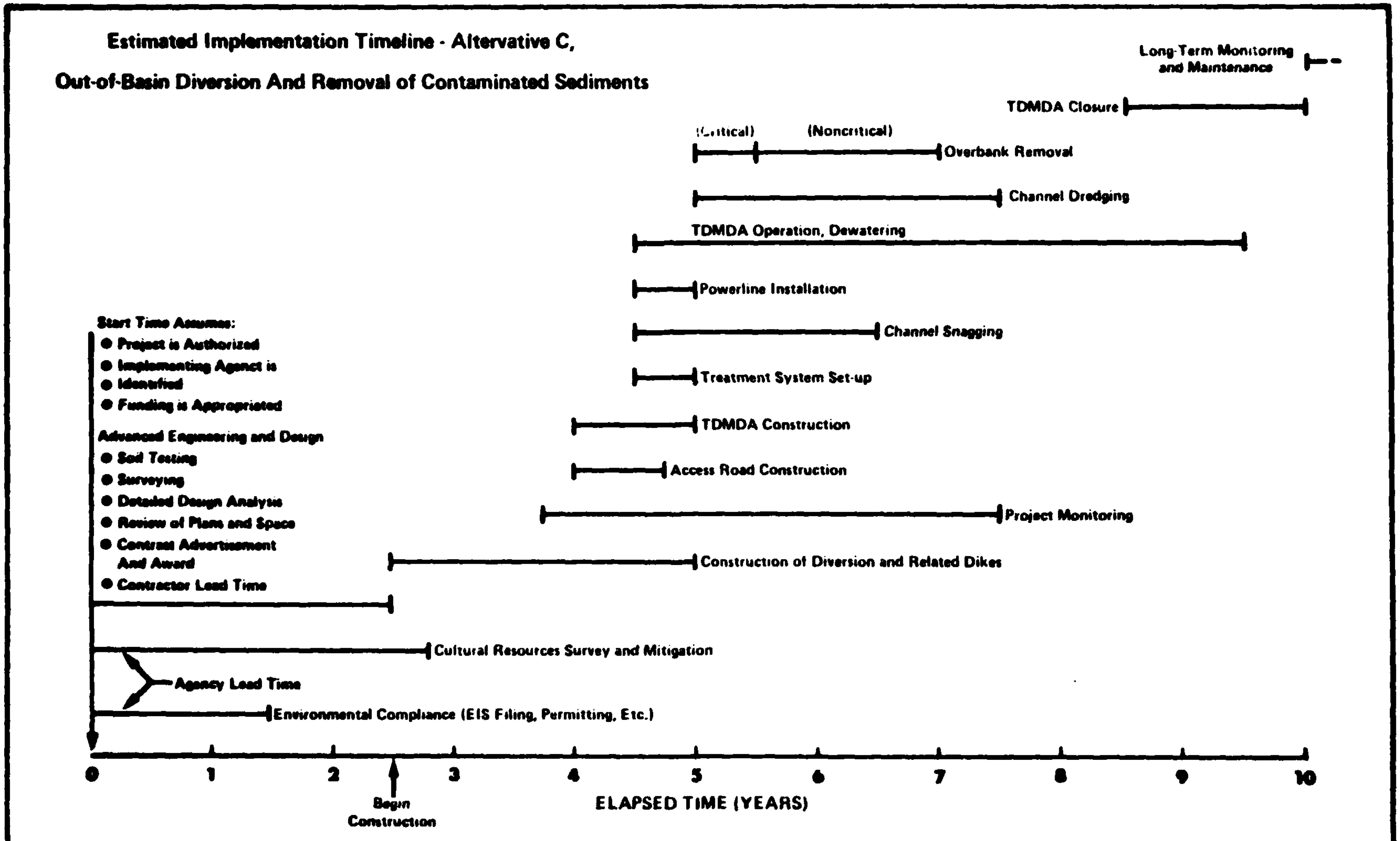

FIGURE III-21. Estimated Implementation Timeline, Alternative C

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of
Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

Table III-14. Detailed Cost Estimates for Alternative C, Out-of-Basin Diversion and Removal of Contaminated Sediments

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(a) Out-of-Basin Diversion Channel[1]				
-Clearing and Grubbing	acre	429	2,500	1,073,000
-Channel Excavation				
-Bedrock	cu. yd.	281,900	50	14,095,000
-Unconsolidated	cu. yd.	3,763,100	3.5	13,171,000
-Soil Borings and Tests	1 boring & test	44	1,026	45,000
-Land Acquisition	acre	235	1,500	353,000
-Utility/Structure Relocation or Replacement				
Sector A-1				
-Relocate STP Outfall, 3600 ft. of 12-in. CMP	ft.	3,600	30	108,000
Sector C-1				
-Install 1600 ft. of 18-in. VCP	ft.	1,600	25	40,000
-Relocate Existing Lift Station	L.S.	---	---	25,000
-Remove Existing Manholes	each	5	350	2,000
-Install Cast Concrete Manholes	each	4	1,500	6,000
-Sewage Pumping During Construction	L.S.	---	---	15,000
-Relocate and Repave Entry Gate No. 3	L.S.	---	---	45,000
-Relocate 2350 ft. of 12-in. CI Force Main	ft.	2,350	30	71,000
-Remove Existing Bridge at Redstone Road	L.S.	---	---	30,000
-Replace Existing Bridge at Redstone Road	ft.	350	720	252,000
Sector D-1				
-Relocate 2800 ft. of 12-in. CI Force Main	ft.	2,800	30	84,000
Sector E-1				
-Remove Existing Highway Bridges	L.S.	---	---	60,000
-Remove Existing Railroad Bridge	L.S.	---	---	25,000
-Construct Two 2-Lane Concrete Bridges at Buxton Road	ft.	650	720	468,000
-Provide for Water Diversion During Construction and Relocate 8-in. CI Water Main on New Bridge	ft.	300	50	15,000
-Seeding, Mulching, Fertilizing	acre	464	1,300	603,000
SUBTOTAL				30,586,000
(b) McDonald Creek Diversion				
-Clearing and Grubbing	acre	27	2,500	68,000
-Channel Excavation (assuming no bedrock is encountered)	cu. yd.	61,000	3.5	214,000

Table III-14. Detailed Cost Estimates for Alternative C, Out-of-Basin Diversion and Removal of Contaminated Sediments (Continued, Page 2)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
-Soil Borings and Tests	1 boring & tests	8	1,026	8,000
-Seeding, Mulching, Fertilizing	acre	22	1,300	29,000
SUBTOTAL				319,000
(c) Raising Patton Road				
-Haul Fill for Roadbed	cu. yd.	447,500	4	1,790,000
-Place Fill for Roadbed	cu. yd.	447,500	3.5	1,566,000
-Soil Borings and Tests	1 boring & tests	20	1,026	21,000
-Remove Existing Bridge	L.S.	---	---	30,000
-Pave Patton Road	sq. yd.	33,500	8	268,000
-Seeding, Mulching, and Fertilizing	acre	43	1,300	56,000
-Fencing	ft.	25,000	12	300,000
-Drainage Structures (box culverts)	L.S.	---	---	15,000
-Construct New Bridge	ft.	350	720	252,000
-Raise Telephone Line Manholes	L.S.	---	---	5,000
-Relocate 12,500 ft. of 12-in. CI Water Main	ft.	12,500	30	375,000
-Relocate Power Lines	L.S.	---	---	20,000
SUBTOTAL				4,698,000
(d) Containment/Diversion Dike NW of Patton Road				
-Clearing and Grubbing	acre	11	2,500	28,000
-Channel Excavation	cu. yd.	60,000	3.5	210,000
-Haul Fill for Dike	cu. yd.	90,700	4.0	363,000
-Dike Construction	cu. yd.	150,700	3.5	527,000
-Soil Borings and Tests	1 boring & tests	8	1,025	8,000
-Seeding, Mulching, and Fertilizing	acre	15	1,300	20,000
SUBTOTAL				1,156,000
SUBTOTAL FOR OUT-OF-BASIN DIVERSION				36,759,000
-20% Contingency				7,352,000
-15% Engineering Design, Supervision, and Administrative Costs				5,514,000
TOTAL FOR OUT-OF-BASIN DIVERSION				49,625,000
(e) Snagging HSB and IC Channel[2]				5,704,000
(f) TDMDA Construction and Operation[3]				24,008,000
(g) Critical Overbank Removal[4]				2,206,000
(h) Hydraulic Dredging of HSB and IC Channel[5]				24,203,000

Table III-14. Detailed Cost Estimates for Alternative C, Out-of-Basin Diversion and Removal of Contaminated Sediments (Continued, Page 3)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(i) Option for Dragline Dredging Between HSB Miles 2.4 and 5.6				
(i) Dike and Drainage Channel for Diverting Runoff from Basins K and M Around Area to be Dragline Dredged				
-Clearing and Grubbing	acre	36	2,500	90,000
-Channel Excavation	cu. yd.	86,500	3.5	303,000
-Haul Fill for Dike	cu. yd.	67,200	4	269,000
-Dike Construction	cu. yd.	153,700	3.5	538,000
-Soil Borings and Tests	1 boring & tests	13	1,026	13,000
-Seeding, Mulching, and Fertilizing	acre	31	1,300	40,000
SUBTOTAL				1,253,000
(ii) Pumping Station				
-2 Pumps, 2 MGD Capacity Each @ 40 ft. Total Head	each	2	15,000	30,000
-Pump Housing Plus Pads	L.S.	---	---	25,000
-Piping, 12 in.	ft.	800	25	20,000
-Electrical Costs and Maintenance	L.S.	---	---	80,000
-Concrete Sump	cu. yd.	32	115	4,000
-Sedimentation Basin (9 Acres x 5 ft.)	cu. yd.	72,600	3.5	254,000
SUBTOTAL				413,000
(iii) Dragline Dredging Costs				
-Access Roads (50-ft. width)				
-Clearing and Construction	sq. yd.	115,600	5	578,000
-Additional Fill for Low Areas	cu. yd.	7,000	4	28,000
-Culverts and Installation	each	25	850	21,000
-Dragline Dredging Sediments				
-Areas Within Boom Reach of Shore	cu. yd.	203,800	5	1,019,000
-Areas Dredged from Mats or Fill	cu. yd.	30,500	15	458,000
-Hauling Sediments to TDMDA	cu. yd.	234,300	4	937,000
SUBTOTAL				3,041,000
(iv) Hydraulic Dredging from HSB Mile 2.4 to IC Mile 0.0[6]				16,285,000
(v) Dredge Monitoring				750,000
SUBTOTAL FOR DRAGLINE DREDGING OPTION				21,742,000

Table III-14. Detailed Cost Estimates for Alternative C, Out-of-Basin Diversion and Removal of Contaminated Sediments (Continued, Page 4)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
-20% Contingency				4,348,000
-15% Engineering Design, Supervision and Administrative Costs				3,261,000
TOTAL FOR DRAGLINE DREDGING OPTION				29,352,000
(j) Permanent Disposal[7] (Closure of TDMDA as Landfill)				6,235,000
(k) Cultural Resources Activities	L.S.	---	---	1,400,000
Operation and Maintenance Costs				
(a) TDMDA Long-Term Maintenance	yr	30	50,000	1,500,000
(b) Monitoring				
-Disposal Site Monitoring	yr	30	50,000	1,500,000
-Areawide Monitoring	yr	4	500,000	2,000,000
TOTAL COST OF PROJECT				
-All Hydraulic Dredging				118,381,000
-With Dragline Option				130,530,000

---

[1] Costs shown are a summary of the projected least-cost alignment, which includes sectors A-1, B, C-1, D-1, and E (see Figure III-17).

[2] Includes contingency and engineering costs.

[3] TDMDA costs are itemized in Table III-11, part (a).

[4] Critical overbank removal costs are summarized in Table III-11, part (d).

[5] Hydraulic dredging costs are itemized in Table III-11, part (c).

[6] This cost is adjusted for deleting the dredging of HSB Miles 2.4 to 5.6.

[7] Permanent disposal costs are itemized in Table III-11, part (f).

Table III-15. Cost Summary for Alternative C (As Detailed in Table III-14)

Dredging Method(s) Utilized	Total Estimated Cost (Millions of Dollars)
All Hydraulic Dredging	118.38
Dragline Dredging Between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	123.53

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option in Reach A	+ 18.66
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 15.04
(Including Disposal of Overbank Sediments)	+ 43.37
-Delete Hydraulic Dredging of Reach C	- 17.94
-Delete Hydraulic Dredging of Reaches B and C	- 26.93
-Use Alternate Sector Routings to Keep Diversion within RSA Boundaries (i.e., Sectors A-2, B, C-2, D-2, and E)	+ 8.22*

*Cost increase is attributed almost entirely to the increased amount of bedrock expected to be encountered during excavation of the channel.

Table III-16. Estimated Annual Expenditures - Alternative C

Year After Start Time	Estimated Annual Expenditures (Millions of Dollars-1980) Without Noncritical Overbank Mitigation	Estimated Annual Expenditures (Millions of Dollars-1980) With Noncritical Overbank Mitigation
1	5.2	6.0
2	5.2	6.0
3	11.6	12.0
4	17.6	17.6
5	38.1	38.1
6	13.1	18.9
7	9.7	21.1
8	4.8	4.8
9	3.2	3.2
10	4.4	4.4
11-14	0.6	0.6
15-40	0.1	0.1
Average Annual Expenditure, 1980 Dollars (assuming an interest rate of 7.125% and a project life of 50 years):	8.71	10.09

Construction of containment dikes as shown in Figure III-18 will isolate the most highly contaminated sediments from normal Wheeler Reservoir pool fluctuations and runoff from drainage basins to the north. By applying a suitable cover over sediments in the HSB channel within the diked area, DDTR contamination there would no longer be subject to local fluvial transport and would be effectively isolated from biota. The cover would consist of an uncontaminated, slowly permeable, fine-grained material stabilized in such a manner as to insure long-term integrity.

This alternative can be effectively implemented only in conjunction with an out-of-basin diversion of HSB for obvious reasons. Mitigation of DDTR contamination in HSB downstream from Dodd Road and in IC under this alternative will be by hydraulic dredging. Utilizing containment techniques in HSB downstream from Dodd Road is impractical because of the difficulty involved in routing runoff from basins H, J, and K, and M (Figure III-10) to IC without utilizing the HSB channel.

9.4.2 Out-Of-Basin Diversion

The out-of-basin diversion is discussed in Section 4.0 of this Appendix.

9.4.3 Containment Methods

Containment associated with the out-of-basin diversion is discussed in Section 6.3.1 of this Appendix.

9.4.4 Dredging and Disposal

Dredging under this alternative will be limited to HSB downstream from Dodd Road and IC. Hydraulic dredging will be implemented as described in Section 3.0 of this Appendix with the following exceptions:

1) Dredging HSB Miles 2.4 to 5.6 will be eliminated.
2) The total volume of sediment to be removed will be reduced from 834,000 to 682,000 cubic yards.

9.4.5 Cost Estimates

Mitigation of Cultural Resources Impact--The high site probability in the diversion corridor necessitates an intensive cultural resources survey over a three week period at a cost of about $15,000. Testing of sites and excavation of all National Register eligible sites that cannot be avoided is estimated to take at least one year and $580,000.

An intensive cultural resources survey should be made of the dredging impact area over an 8-week period at a cost of $80,000. The cost and time for testing and full scale excavation by professional archaeologists of all National Register eligible properties within this area that cannot be avoided cannot be accurately estimated at this time. At least 15 months and $725,000 will be involved.

Total cultural resources activities associated with this alternative will take approximately 2.5 years at an estimated cost of $1,400,000.

General--Detailed cost estimates for Alternative D are given in Table III-17. Cost for the out-of-basin diversion is based on the least cost alignment in each sector. The removal of contaminated channel sediments in Reaches B and C (Figure III-7) downstream from the containment area is also assumed. A cost summary and the estimated cost effect of various options are given in Table III-18. The time base for all cost estimates is 1980. The estimated implementation timeline and annual expenditures for Alternative D are given in Figure III-22 and Table III-19, respectively.

9.5 ALTERNATIVE E: WITHIN-BASIN DIVERSION AND REMOVAL OF CONTAMINATED SEDIMENTS

9.5.1 Introduction

Alternative E combines the within-basin diversion of HSB with dredging and disposal. A within-basin diversion as shown in Figure III-15 will bypass the flow of HSB around the area of heaviest DDTR contamination. The containment dike constructed with the diversion will partially contain the enclosed sediments by isolating them from surrounding surface water flows. This action alone will not offer a complete solution for DDTR contamination within the diked area, as local runoff will transport DDTR-contaminated sediment to the sump where it may be pumped over the dike into HSB. Exposed sediments would also be subject to bioavailability and transport.

By removing the HSB channel sediments from the diked area and disposing of them in a proper manner, the majority of heavily contaminated sediments will be effectively isolated. Since control can be exercised over the water level within the containment dike, sediments can be removed hydraulically by a cutterhead dredge or in the dry by a dragline. Turbidity generated by either dredging method can be effectively controlled within the containment area. DDTR contamination in HSB downstream from the diversion and in IC will be removed by hydraulic dredging.

9.5.2 Within-Basin Diversion

The within-basin diversion is discussed in Section 5.0 of this Appendix.

9.5.3 Dredging and Disposal

Hydraulic Dredging--The hydraulic dredging of HSB and IC and alternatives for disposal of contaminated sediments is discussed in Section 3.0 of this Appendix. Water within the contained area would have to be maintained at an adequate level to allow operation of the dredge.

Dragline Dredging--Dragline dredging within the containment area will be feasible if the channel is pumped and maintained dry. This option is

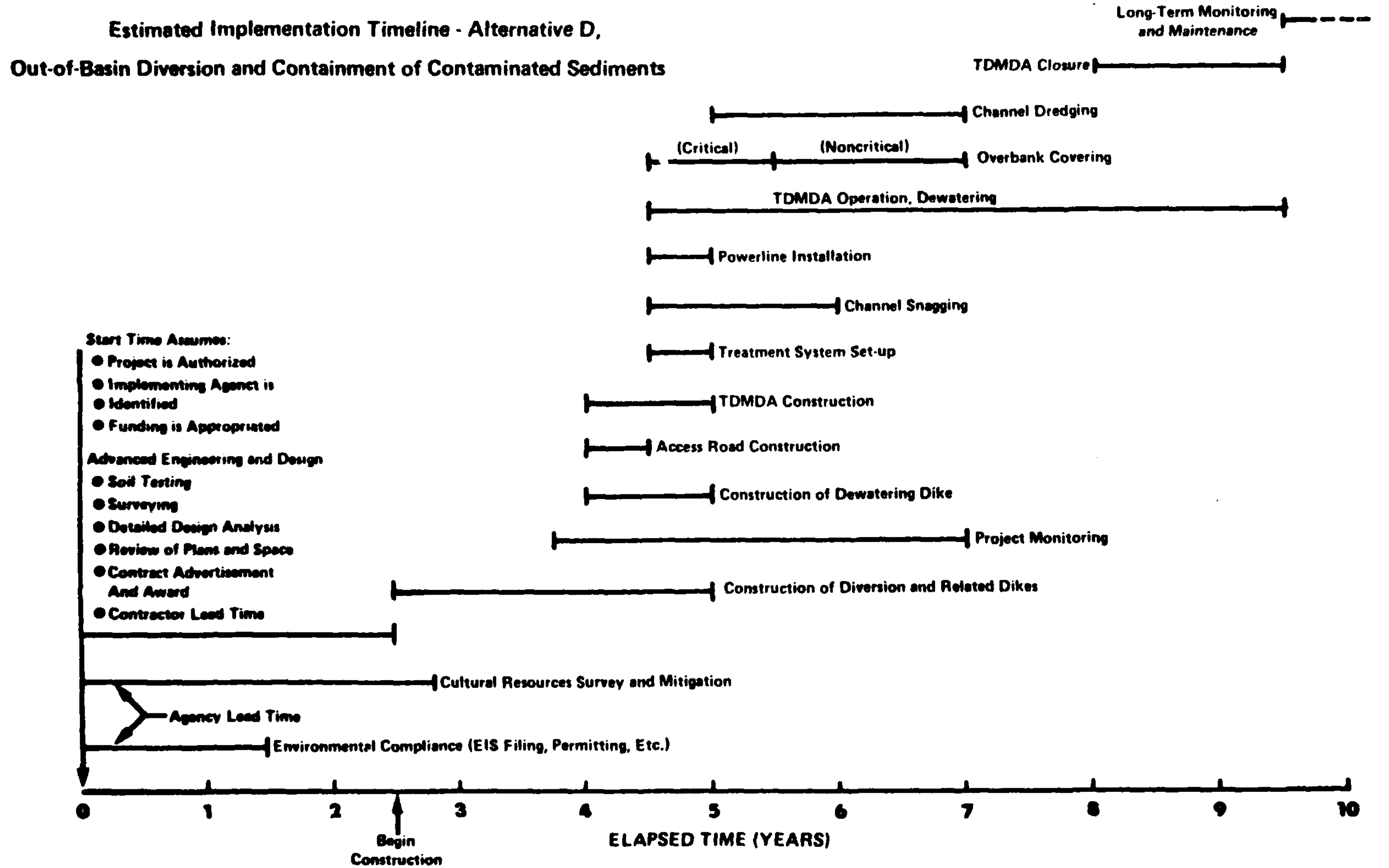

FIGURE III-22. Estimated Implementation Timeline, Alternative D

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
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Engineering and Environmental Study of DDT Contamination of
Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

Table III-17. Detailed Cost Estimates for Alternative D, Out-of-Basin Diversion and Containment of Contaminated Sediments

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(a) Out-of-Basin Diversion[1]				49,625,000
(b) Dike and Drainage Channel for Diverting Runoff from Basins K and M Around Containment Area[2]				1,692,000
(c) Snagging HSB and IC Channel				5,704,000
(d) TDMDA Construction and Operating Costs[3]				24,008,000
(e) Hydraulic Dredging from HSB Mile 2.4 to IC Mile 0.0[4]				22,995,000
(f) Pumping Station[3]				558,000
(g) Covering Channel Sediments Between HSB Miles 2.4 and 5.6				
-Hauling Cover Material From Out-of-Basin Diversion	cu. yd.	228,000	4	912,000
-Placement and Compaction of Cover Material	cu. yd.	228,000	3.5	798,000
-Seeding, Mulching, Fertilizing Cover	acre	47	1,300	61,000
SUBTOTAL				1,771,000
-20% Contingency				354,000
-15% Engineering Design, Supervision and Administrative Costs				266,000
TOTAL				2,391,000
(h) Covering Critical Overbank				
-Additional Sediment Sampling	L.S.	---	---	100,000
-Clearing and Grubbing	acre	25	2,500	63,000
-Hauling Cover Material from Out-of-Basin Diversion	cu. yd.	81,100	4	324,000
-Placement and Compaction of Cover Material	cu. yd.	81,100	3.5	284,000
-Seeding, Mulching, Fertilizing Cover	acre	25	1,300	33,000
SUBTOTAL				804,000
-20% Contingency				161,000
-15% Engineering Design, Supervision, and Administrative Costs				121,000
TOTAL				1,085,000

Table III-17. Detailed Cost Estimates for Alternative D, Out-of-Basin Diversion and Containment of Contaminated Sediments (Continued, Page 2)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(i) Option For Noncritical Overbank Covering				
-Clearing and Grubbing	acre	235	2,500	588,000
-Hauling Cover Material From Out-of-Basin Diversion	cu. yd.	757,900	4	3,032,000
-Placement and Compaction of Cover Material	cu. yd.	757,900	3.5	2,653,000
-Seeding, Mulching, Fertilizing Cover	acre	235	1,300	306,000
SUBTOTAL				6,579,000
-20% Contingency				1,316,000
-15% Engineering Design, Supervision, and Administrative Costs				987,000
TOTAL				8,882,000
(j) Permanent Disposal of Dredged Material in TDMDA[6]				6,235,000
(k) Cultural Resources Activities	L.S.	---	---	1,400,000
Operation and Maintenance Costs				
(a) TDMDA Long-Term Maintenance	yr	30	50,000	1,500,000
(b) Pumping Station Long-Term Maintenance	yr	30	10,000	300,000
(c) Monitoring				
-Disposal Site Monitoring	yr	30	50,000	1,500,000
-Areawide Monitoring	yr	4	500,000	2,000,000
TOTAL COST OF PROJECT				
(Excluding Overbank Covering Option)				120,993,000
(Including Overbank Covering Option)				129,875,000

---

[1] See Table III-14, parts (a)–(d) for itemized costs of out-of-basin diversion.
[2] Itemized costs appear in Table III-14, part (i)(i).
[3] TDMDA costs are itemized in Table III-11, part (a).
[4] Total hydraulic dredging costs are summarized in Table III-11, part (c).
[5] See Table III-14, part (i)(ii) for itemized pumping station costs.
[6] See Table III-11, part (f) for itemized permanent disposal costs.

Table III-18. Cost Summary for Alternative D (As Detailed in Table III-17)

Areal Extent of Cover Application Within Containment	Total Estimated Cost (Millions of Dollars)
Channel and Critical Overbank Only	120.99
Channel and Entire Overbank	129.88

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 12.40
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63
-Use Alternate Sector Routings to Keep Diversion Within RSA Boundaries	+ 8.22

Table III-19. Estimated Annual Expenditures - Alternative D

Year After Start Time	Estimated Annual Expenditures (Millions of Dollars-1980 Without Noncritical Overbank Mitigation	 With Noncritical Overbank Mitigation
1	5.3	5.7
2	5.3	5.7
3	11.7	11.9
4	17.7	17.7
5	42.1	42.1
6	14.8	17.7
7	9.5	15.0
8	1.4	1.4
9	5.1	5.1
10	2.5	2.5
11-14	0.6	0.6
15-40	0.1	0.1
Average Annual Expenditure, 1980 Dollars (assuming an interest rate of 7.125% and a project life of 50 years):	8.90	9.55

discussed in Section 9.3.3 of this Appendix. Under this alternative, dragline dredging will be limited to the contained area of the HSB channel between HSB Miles 4.0 and 5.6 and will involve removal of approximately 82,500 cubic yards of channel sediments.

9.5.4 Cost Estimates for Alternative E

Mitigation of Cultural Resources Impact--An intensive survey of the impacted area would take 3 weeks and cost about $15,000. Subsequent testing and excavation of National Register eligible sites could take place in eight months at a cost of about $350,000.

An intensive cultural resources survey should be made of the dredging impact area over an 8-week period at a cost of $80,000. The cost and time for testing and full scale excavation by professional archaeologists of all National Register eligible properties within this area that cannot be avoided cannot be accurately estimated at this time. At least 15 months and $725,000 will be involved.

Total cultural resources activities associated with this alternative will take approximately 2.5 years at an estmiated cost of $1,170,000.

General--Detailed cost estimates for Alternative E are given below in Table III-20. Costs of dredging all contaminated sediments in Reaches A, B, and C (Figure III-7) are included in the project estimate. A cost summary and the estimated effect of various options on the total cost are given in Table III-21. The time base for all cost estimates is 1980. The estimated implementation timeline and annual expenditures for Alternative E are given in Figure III-23 and Table III-22, respectively.

9.6 ALTERNATIVE F: WITHIN-BASIN DIVERSION AND CONTAINMENT OF CONTAMINATED SEDIMENTS

9.6.1 Introduction

Alternative E utilizes the within-basin diversion, containment techniques to mitigate contamination upstream of HSB Mile 3.9, and dredging and disposal of contaminated sediments below Mile 3.9. The within-basin diversion shown in Figure III-15 will divert flow in HSB around the area of heaviest DDTR contamination and contain that area within a dike. Further action will be necessary to prevent the transport of DDTR when local runoff is pumped over the dike, and to reduce the potential for bioavailability and biotransport of exposed DDTR.

Application of an inert cover to channel sediments will provide an acceptable degree of long-term, in-place isolation of DDTR. The containment dike will facilitate dewatering the channel prior to cover application and will help assure the long-term integrity of the cover by isolating it from most surface water flow. Contamination in HSB downstream from the diversion and in IC will be removed by hydraulic dredging. An option is also presented to use the diked contaminated area for disposal of dredged sediments.

Table III-20. Detailed Cost Estimates for Alternative E, Within-Basin Diversion and Removal of Contaminated Sediments

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(a) Within-Basin Diversion and Diversion/Containment Dike				
-Clearing and Grubbing	acre	222	2,500	555,000
-Channel Excavation (assuming no bedrock is encountered)[1]	cu. yd.	1,177,500	3.5	4,121,000
-Soil Borings and Tests	1 boring & tests	45	1,026	46,000
-Haul Fill From Borrow Area for Dike Construction	cu. yd.	559,000	4	2,236,000
-Dike Construction	cu. yd.	1,736,500	3.5	6,078,000
-Channel for Draining Basin K	cu. yd.	52,800	3.5	185,000
-Relocate 30-in. RC Industrial Water Main	ft.	750	8	6,000
-Pumping Station[2]	L.S.	---	---	620,000
-Seeding, Mulching, Fertilizing Channel and Dike	acre	241	1,300	313,000
SUBTOTAL				13,540,000
-20% Contingency				2,708,000
-15% Engineering, Legal, and Administrative Costs				2,031,000
TOTAL FOR WITHIN-BASIN DIVERSION				18,279,000
(b) Snagging HSB and IC Channels				5,704,000
(c) TDMDA Construction and Operation[3]				24,008,000
(d) Critical Overbank Removal[4]				2,206,000
(e) Hydraulic Dredging of HSB and IC Channels[5]				24,203,000
(f) Option for Dragline Dredging Between HSB Miles 4.0 and 5.6				
(i) Dragline Dredging Costs				
-Access Road				
-Clearing and Construction	sq. yd.	44,000	5	220,000
-Culverts and Installation	each	12	850	10,000
-Dragline Dredging Sediments				
-Areas within Boom Reach of Shore	cu. yd.	82,500	5	413,000
-Areas Dredged from Mats or Fill	cu. yd.	0	15	0
-Hauling Sediments to TDMDA	cu. yd.	82,500	4	330,000
-Hydraulic Dredging from HSB Mile 4.0 to IC Mile 0.0[6]				16,769,000
-Dredge Monitoring	L.S.	---	---	750,000
SUBTOTAL				18,492,000
-20% Contingency				3,928,000
-15% Engineering Design, Supervision, and Administrative Costs				2,774,000

Table III-20. Detailed Cost Estimates for Alternative E, Within-Basin Diversion and Removal of Contaminated Sediments (Continued, Page 2)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
TOTAL FOR DRAGLINE DREDGING				24,964,000
(g) Permanent Disposal in TDMDA[7]				6,235,000
(h) Cultural Resources Activities	L.S.	---	---	1,170,000
Operation and Maintenance Costs				
(a) TDMDA Long-Term Maintenance	yr	30	50,000	1,500,000
(b) Monitoring				
-Disposal Site Monitoring	yr	30	50,000	1,500,000
-Areawide Monitoring	yr	4	500,000	2,000,000
TOTAL COST OF PROJECT				
-All Hydraulic Dredging				87,305,000
-With Dragline Option				88,066,000

[1] Suitable excavated channel material to be used for dike construction.
[2] See Table III-14, part (i)(ii) for itemized costs of pumping station.
[3] See Table III-11, part (a) for itemized TDMDA costs.
[4] See Table III-11, part (d) for itemized critical overbank removal costs.
[5] See Table III-11, part (c) for itemized hydraulic dredging costs.
[6] Cost shown is adjusted for deleting the dredging of HSB Miles 4.0 to 5.6.
[7] See Table III-11, part (e) for itemized permanent disposal costs.

Table III-21. Cost Summary for Alternative E (As Detailed in Table III-20)

Dredging Method(s) Utilized	Total Estimated Cost (Millions of Dollars)
All Hydraulic Dredging	87.31
Dragline Dredging Between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	88.07
Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):	
-Implement Noncritical Overbank Removal Option in Reach A	+ 18.66
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 16.51
(Including Disposal of Overbank Sediments)	+ 43.37
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63

Table III-22. Estimated Annual Expenditures - Alternative E

Year After Start Time	Estimated Annual Expenditures (Millions of Dollars-1980) Without Noncritical Overbank Mitigation	With Noncritical Overbank Mitigation
1	3.8	4.6
2	3.8	4.6
3	6.1	6.5
4	13.1	13.1
5	26.6	26.6
6	11.1	22.5
7	8.3	14.0
8	1.4	1.4
9	5.1	5.1
10	1.8	1.8
11-14	0.6	0.6
15-40	0.1	0.1
Average Annual Expenditure, 1980 Dollars (assuming an interest rate of 7.125% and a project life of 50 years):	6.39	7.76

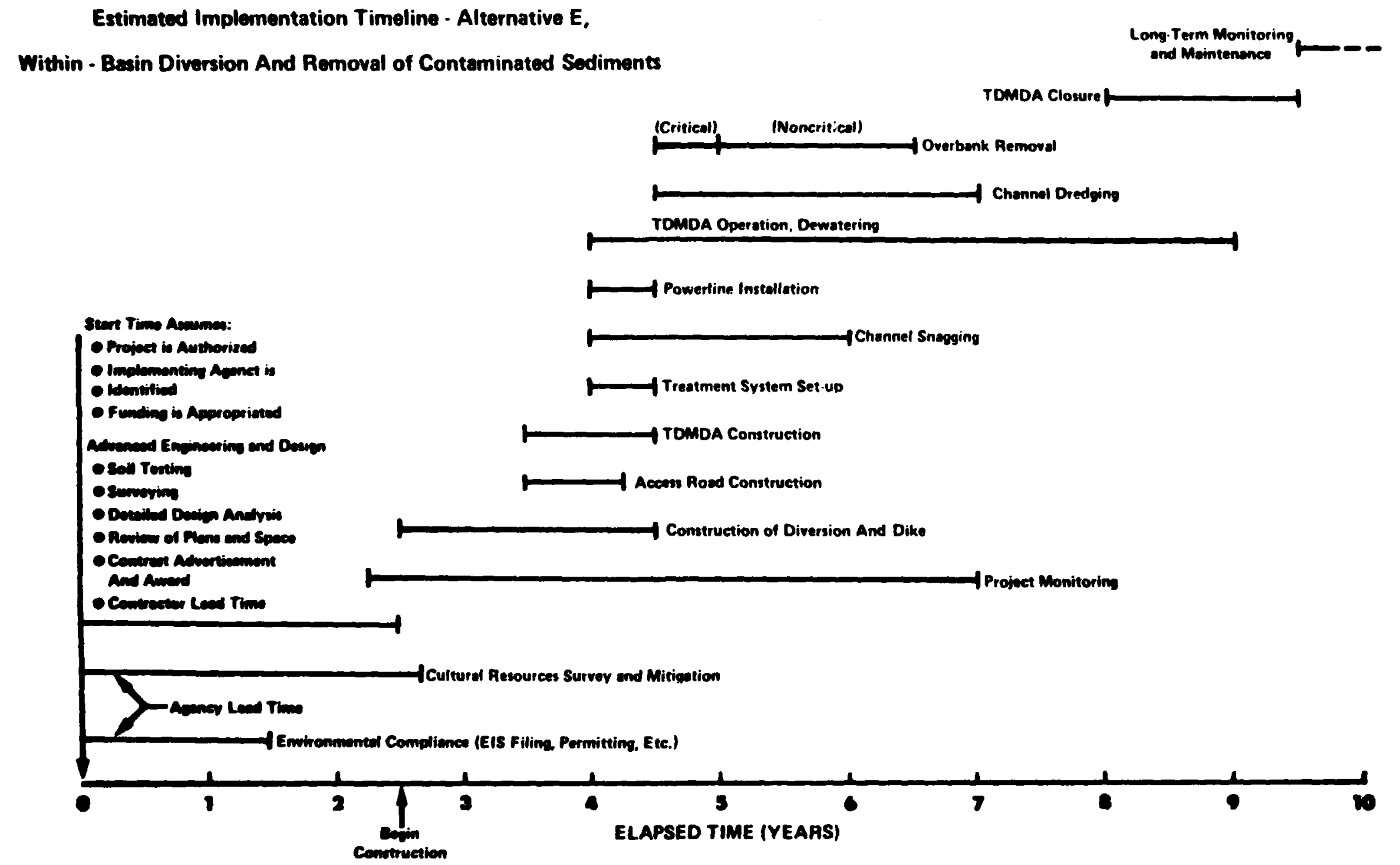

FIGURE III-23. Estimated Implementation Timeline, Alternative E

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Wheeler Reservoir, Alabama

9.6.2 Within-Basin Diversion

The within-basin diversion is discussed in Section 5.0 of this Appendix.

9.6.3 Containment Methods

In-Place Cover--Containment by covering contaminated sediments with excavated clay is discussed in Section 6.3.2 of this Appendix.

Use of the Containment Area as a Disposal Site For Dredged Material--One additional containment option is proposed, that of using the diked containment area of the within-basin diversion as a disposal area for sediments dredged from the HSB and IC. This approach would cover highly contaminated sediments in the containment area with less contaminated dredged sediments. Though this alternative could theoretically be implemented with either the out-of-basin or the within-basin diversions, it is proposed only for the latter due to the much lower construction costs of that diversion.

Disposal site design, construction, and operation would be similar to that described for the TDMDA in Section 3.3, with the site plan modification illustrated in Figure III-20. Clearing and grubbing of the entire area within the containment dike would be required. The primary containment area must be graded to an approximately level elevation, filling the HSB channel in the process. Contaminated material grubbed from the site would be disposed of in the low (formerly ponded) area adjacent to the primary containment area (see Figure III-24). Water from the grubbing disposal area would be discharged to the equalization basin by pump.

The total primary containment area is approximately 140 acres and will accommodate the unconsolidated dredged material at an average final depth of 5.5 feet. Design crest elevation of the interior dikes allows for a minimum 2 feet ponded depth and 2 feet of freeboard. Approximately 228,000 cubic yards of fill will be required for construction of interior dikes, amounting to 1.0 feet of cut over the primary containment area. Use of this material for dike construction is dependent on the degree of dewatering that can be attained at the site prior to construction. If the water table within the containment area remains too high to allow the 1 foot cut, off-site borrow material will have to be used for interior dike construction.

Dewatering of the dredged material and final closure of the site would be conducted in the same manner as described in Sections 3.4 and 3.5 of this Appendix, respectively.

Implementation of this alternative will be dependent on the availability of suitable fill for construction of the dikes and the final cover. Borrow requirements are approximately as follows:

Diversion/Containment Dike (This yardage is required in	606,000 cubic yards

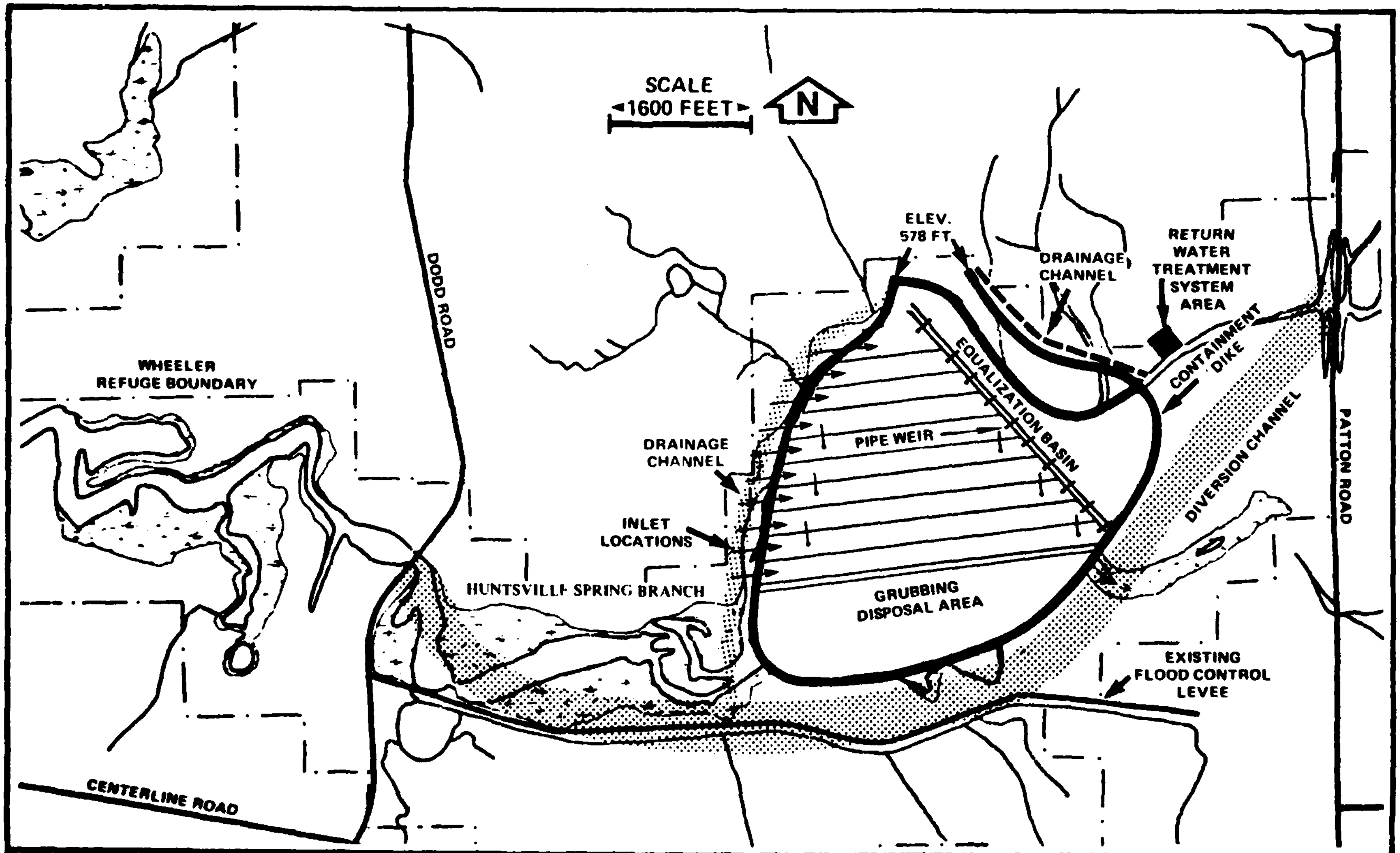

FIGURE III-24. Use of the Within-Basin Diversion Containment Area for Disposal of Dredged Material

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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Wheeler Reservoir, Alabama

excess of that excavated from the within basin diversion channel.)		
Interior Dikes		228,000 cubic yards
Final Cover		1,050,000 cubic yards
	TOTAL	1,884,000 cubic yards

The total cost of this alternative will be reduced considerably if as much of this fill as possible can be obtained on-site. The closest apparent source of borrow is the hills to the north of the containment area. This area is reported to contain former sanitary landfills and other RSA wastes, and has been tentatively designated by RSA officials as unsuitable for borrow. Extensive boring of this area is recommended in order to reconsider its suitability for borrow material. The cost savings of using on-site fill as opposed to truck-hauling fill from off-site is estimated to be five million dollars.

9.6.4 Dredging and Disposal

Contaminated sediments downstream from the containment area would be hydraulically dredged as discussed in Section 3.0.

9.6.5 Cost Estimates for Alternative F

Mitigation of Cultural Resources Impact--An intensive survey of the impacted area by the diversion would take 3 weeks and cost about $15,000. Subsequent testing and excavation of National Register eligible sites could take place in eight months at a cost of about $350,000.

An intensive cultural resources survey should be made of the dredging impact area over an 8 week period at a cost of $80,000. The cost and time for testing and full scale excavation by professional archaeologists of all National Register eligible properties within this area than cannot be avoided cannot be accurately estimated at this time. At least 15 months and $725,000 will be involved.

Total cultural resources activities associated with this alternative will take approximately 2.5 years at an estimated cost of $1,170,000.

General--Detailed cost estimates for Alternative F are shown below in Table III-23. Costs of dredging all contaminated sediments in Reaches A, B, and C (Figure III-7) are included in the estimate. Estimates for the option to use the within-basin diversion containment area as a dredged material disposal site are based on using off-site borrow for construction and closure of the facility. A cost summary and the estimated effect of various options on the total cost are given in Table III-24. The time base for all cost estimates is 1980. The estimated implementation timeline and annual expenditures for Alternative F are given in Figure III-25, and Table III-25, respectively.

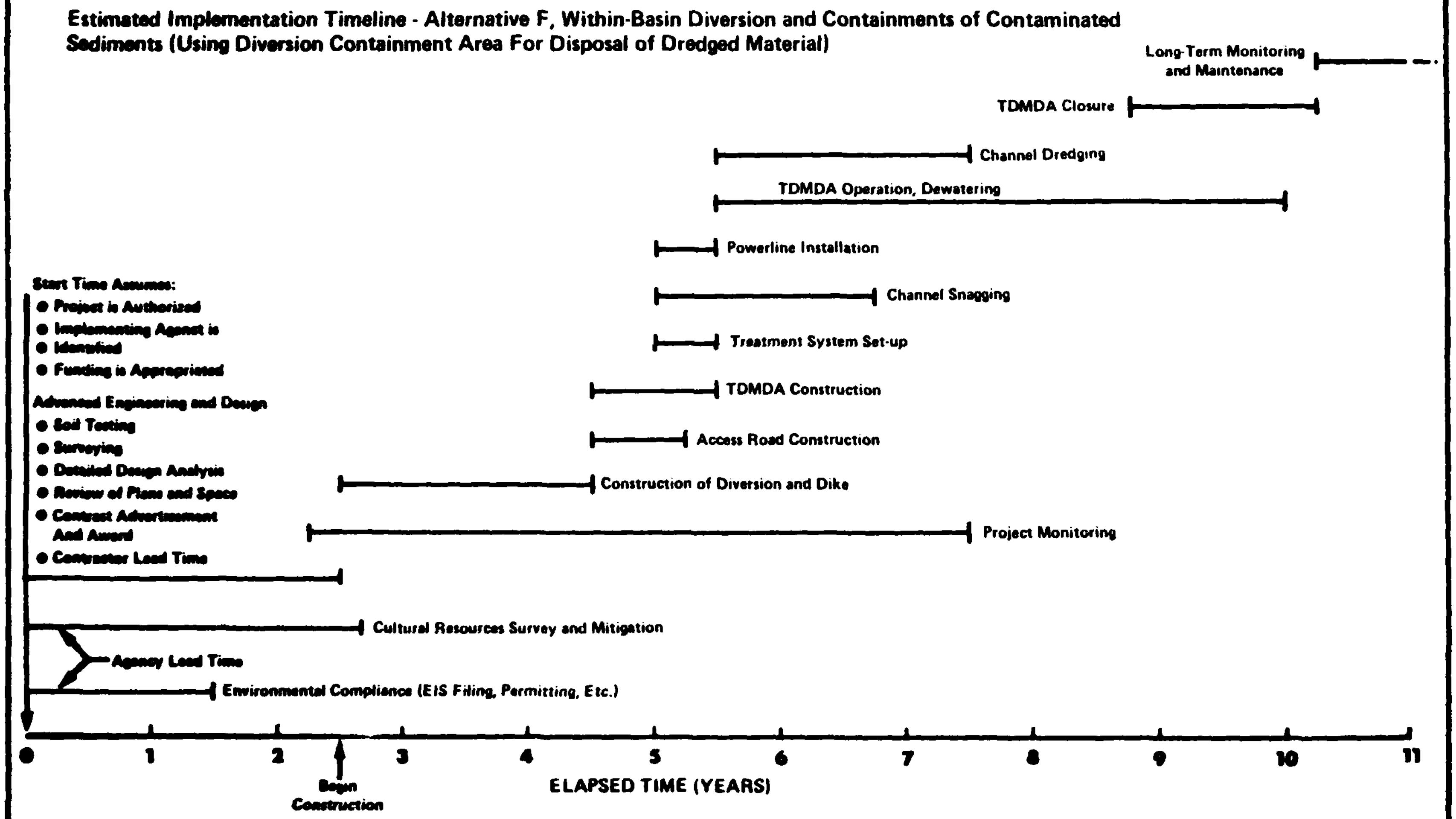

FIGURE III-25. Estimated Implementation Timeline, Alternative F

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
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Engineering and Environmental Study of DDT Contamination of
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Wheeler Reservoir, Alabama

Table III-23. Detailed Cost Estimates for Alternative F, Within-Basin Diversion and Containment of Contaminated Sediments

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(1) Using TDMDA				
(a) Within-Basin Diversion and Diversion/Containment Dike[1]				18,279,000
(b) Snagging HSB and IC Channels				5,704,000
(c) TDMDA Construction and Operation[2]				24,008,000
(d) Hydraulic Dredging from HSB Mile 4.0 to IC Mile 0.0[3]				23,648,000
(e) Covering Channel Sediments Between HSB Miles 4.0 and 5.6				
-Hauling Cover Material from Out-of-Basin Diversion	cu. yd.	94,500	4	378,000
-Placement and Compaction of Cover Material	cu. yd.	94,500	3.5	331,000
-Seeding, Mulching, Fertilizing Cover	acre	17	50	22,000
SUBTOTAL				731,000
-20% Contingency				146,000
-15% Engineering, Legal, and Administrative Costs				110,000
TOTAL				987,000
(f) Covering of Critical Overbank[4]				1,085,000
(g) Option for Noncritical Overbank Covering				
-Clearing and Grubbing	acre	160	2,500	400,000
-Hauling Cover Material from Off-Site Borrow Area	cu. yd.	516,300	4	2,065,000
-Placement and Compaction of Cover Material	cu. yd.	516,300	3.5	1,807,000
-Seeding, Mulching, Fertilizing Cover	acre	160	1,300	208,000
SUBTOTAL				4,480,000
-20% Contingency				896,000
-15% Engineering, Legal, and Administrative Costs				672,000
TOTAL				6,048,000
(g) Permanent Disposal of Dredged Material in TDMDA[5]				6,235,000
SUBTOTAL USING TDMDA (Excluding Overbank Covering Option)				79,946,000

Table III-23. Detailed Cost Estimates for Alternative F, Within-Basin Diversion and Containment of Contaminated Sediments (Continued, Page 2)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
(2) Option to Use Containment Area for Dredged Material Disposal				
(a) Within-Basin Diversion and Diversion/Containment Dike				18,279,000
(b) Snagging HSB and IC Channels (Adjusted for Deleting HSB Miles 4.0-5.6)				5,294,000
(c) Disposal Site Preparation				
-Site Acquisition	---	---	---	0
-Soil Borings and Testing	1 boring & tests	20	1,026	21,000
-Clearing and Grubbing	acre	325	2,500	813,000
-Site Grading	sq. yd.	1,573,000	1.5	2,360,000
-Dike Construction (Assuming Off-Site Borrow Material)	cu. yd.	223,000	7.5	1,673,000
-48-in. Pipe Weirs, Purchase and Install	each	15	5,500	83,000
-Groundwater Monitoring System	1 50-ft. Well	8	600	5,000
-Leachate Monitoring System	ft.	2,000	12	24,000
-Return Water Treatment System	L.S.	---	---	6,000,000
-Earthern Clarification Basin (For Above System)	L.S.	---	---	74,000
-Fencing	ft.	16,400	12	197,000
-Access Road (1800 ft. x 40 ft.)	sq. yd.	8,000	5	40,000
SUBTOTAL				11,290,000
-20% Contingency				2,258,000
-15% Engineering Design, Supervision and Administrative Costs				1,694,000
TOTAL				15,242,000
(d) Disposal Site Operating Cost				7,676,000
(e) Hydraulic Dredging, HSB Mile 4.0 to IC Mile 0.0[6]				21,019,000
(f) Disposal Site Closure				
-Grading, Compacting Site	sq. yd.	1,573,000	1.5	2,360,000
-Hauling, Placement, Compaction, and Grading of Cover Material	cu. yd.	1,048,700	7.5	7,865,000
-Seeding, Mulching, Fertilizing Site	acre	325	1,300	423,000
SUBTOTAL				10,648,000

Table III-23. Detailed Cost Estimates for Alternative F, Within-Basin Diversion and Containment of Contaminated Sediments (Continued, Page 3)

Description	Unit	No. of Units	Unit Cost ($)	Estimated Cost ($)
-20% Contingency				2,130,000
-15% Engineering Design, Supervision, and Administrative Costs				1,597,000
TOTAL				14,375,000
SUBTOTAL FOR ALTERNATIVE TO USE CONTAINMENT AREA AS DISPOSAL SITE				81,885,000
(3) Cultural Resources Activities	L.S.			1,170,000
Operation and Maintenance Costs				
(a) Disposal Site Long-Term Maintenance Costs	yr	30	50,000	1,500,000
(b) Pumping Station Long-Term Maintenance Costs	yr	30	10,000	300,000
(c) Monitoring				
-Disposal Site Monitoring	yr	30	50,000	1,500,000
-AreaWide Monitoring	yr	4	500,000	2,000,000
TOTAL COST USING TDMDA				
(Excluding Noncritical Overbank Covering Option)				86,916,000
(Including Noncritical Overbank Covering Option)				92,964,000
TOTAL COST FOR ALTERNATIVE USING CONTAINMENT AREA AS DISPOSAL SITE				88,855,000

[1] See Table III-20, part (a) for itemized within-basin diversion costs.
[2] See Table III-11, part (a) for itemized TDMDA costs.
[3] See Table III-11, part (c) for itemized hydraulic dredging costs.
[4] See Table III-17, part (h) for itemized critical overbank covering costs.
[5] See Table III-11, part (f) for itemized permanent disposal costs.
[6] This dredging cost is adjusted for deleting 2 booster pumps and the shorter pumping distance required.

Table III-24. Cost Summary for Alternative F (As Detailed in Table III-23)

Disposal Option Implemented	Total Estimated Cost (Millions of Dollars)
Use TDMDA	
-excluding overbank covering option	86.92
-including overbank covering option	92.96
Use Within-Basin Diversion Containment Area for Disposal Area	88.86
Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):	
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 14.00
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63
-Obtain On-Site Borrow Material for Construction and Closure of Disposal Site Within the Containment Area (Suitability must be determined)	- 5.09

Table III-25. Estimated Annual Expenditures - Alternative F

Year After Start Time	Estimated Annual Expenditures (Millions of Dollars-1989) Without Noncritical Overbank Mitigation
1	3.9
2	3.9
3	5.9
4	8.3
5	8.2
6	20.2
7	12.0
8	5.5
9	3.5
10	11.3
11-14	0.6
15-40	0.1
Average Annual Expenditure, 1980 Dollars (assuming an interest rate of 7.125% and a project life of 50 years):	6.50

10.0 CULTURAL RESOURCES IMPACTS

10.1 INTRODUCTION

Five alternative techniques are under consideration for containment or isolation of DDTR containments in Huntsville Spring Branch (HSB). These engineering alternatives can be simplified with respect to cultural resources. Archaeological sites by their nature occupy specific geographic areas, and the method whereby they are disturbed be it by dredge or dragline, does not matter. What does matter is the fact of the disruption. In considering the alternatives four geographic areas under consideration can be evaluated separately. The alternatives can then be evaluated according to the geographic areas that will be altered. The four geographic areas are:

1) Contaminated Area (Areas A-C, Figure III-26)

Included in this area are the channel beds of Huntsville Spring Branch below Patton Road and Indian Creek to the Tennessee River, including access roads which will be constructed along the south and east banks of Indian Creek and HSB.

2) Dredged Material Disposal Sites (Areas D and E, Figure III-26)

The primary dredge material disposal site (TDMDA) is located on the Arsenal northeast of the junction of Redstone Road and Patton Road. The alternate disposal site (Alt TDMDA) is located just east of the Arsenal and south of Redstone Road.

3) Out-of-Basin Diversion Corridor (Area F, Figure III-26)

The channel will be located along the Redstone Arsenal boundary diverting the flow of McDonald Creek and Huntsville Spring Branch to the Tennessee River.

4) Within Basin Diversion Channel and Containment Dike (Figure III-27)

This consists of a bypass channel around the area of maximum contamination. It will divert the flow of HSB from a point northeast of Wheeler Lake and channel it south and west of the contaminated zone. In order to prevent contaminated waters from flowing into the bypass channel during periods of flooding, a containment dike will be constructed along the north side of the channel.

10.2 IMPACTS BY AREA

In the following paragraphs, we shall consider the potential for cultural resources being located in each of the proposed impact areas, and will then attempt to evaluate the alternatives in terms of their probable effect on archaeological sites.

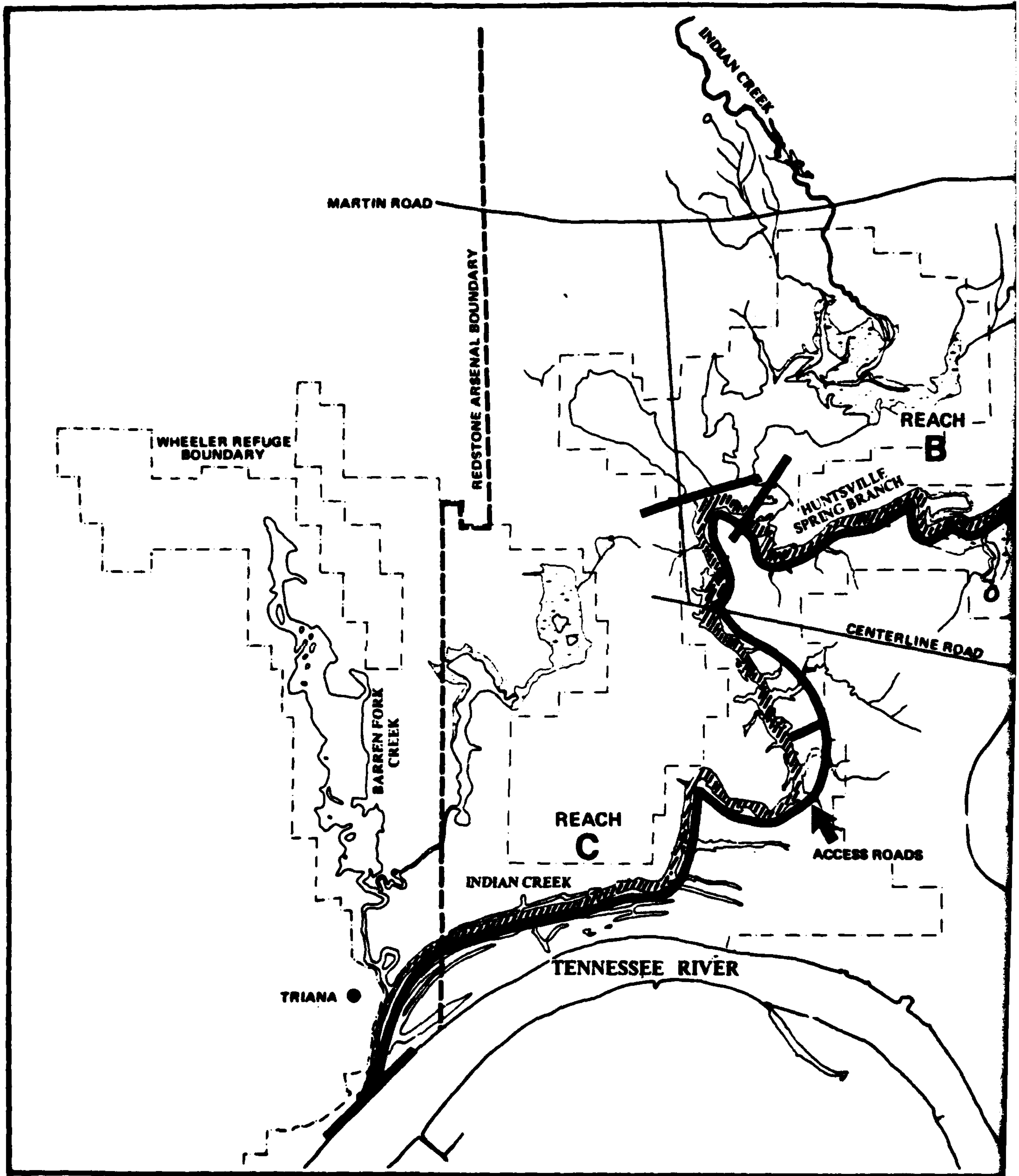
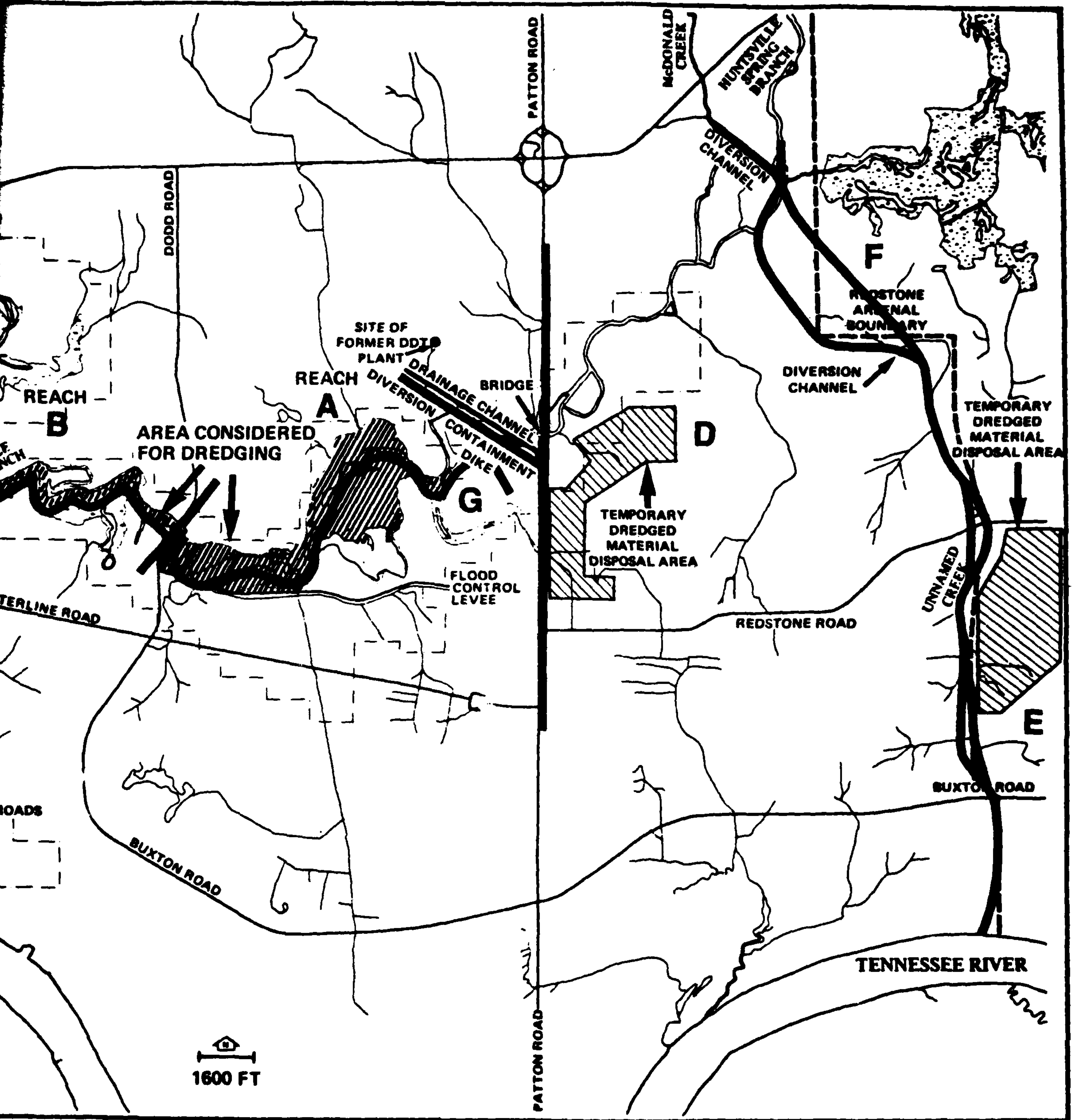


FIGURE III-26. Dredging Areas and Access Road, Primary and Secondary Disposal Sites, Out-of-Basin Diversion Channel, and Containment Dike.

SOURCE: WATER AND AIR RESEARCH, INC., 1980



Sites,

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Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters, Wheeler Reservoir, Alabama

12

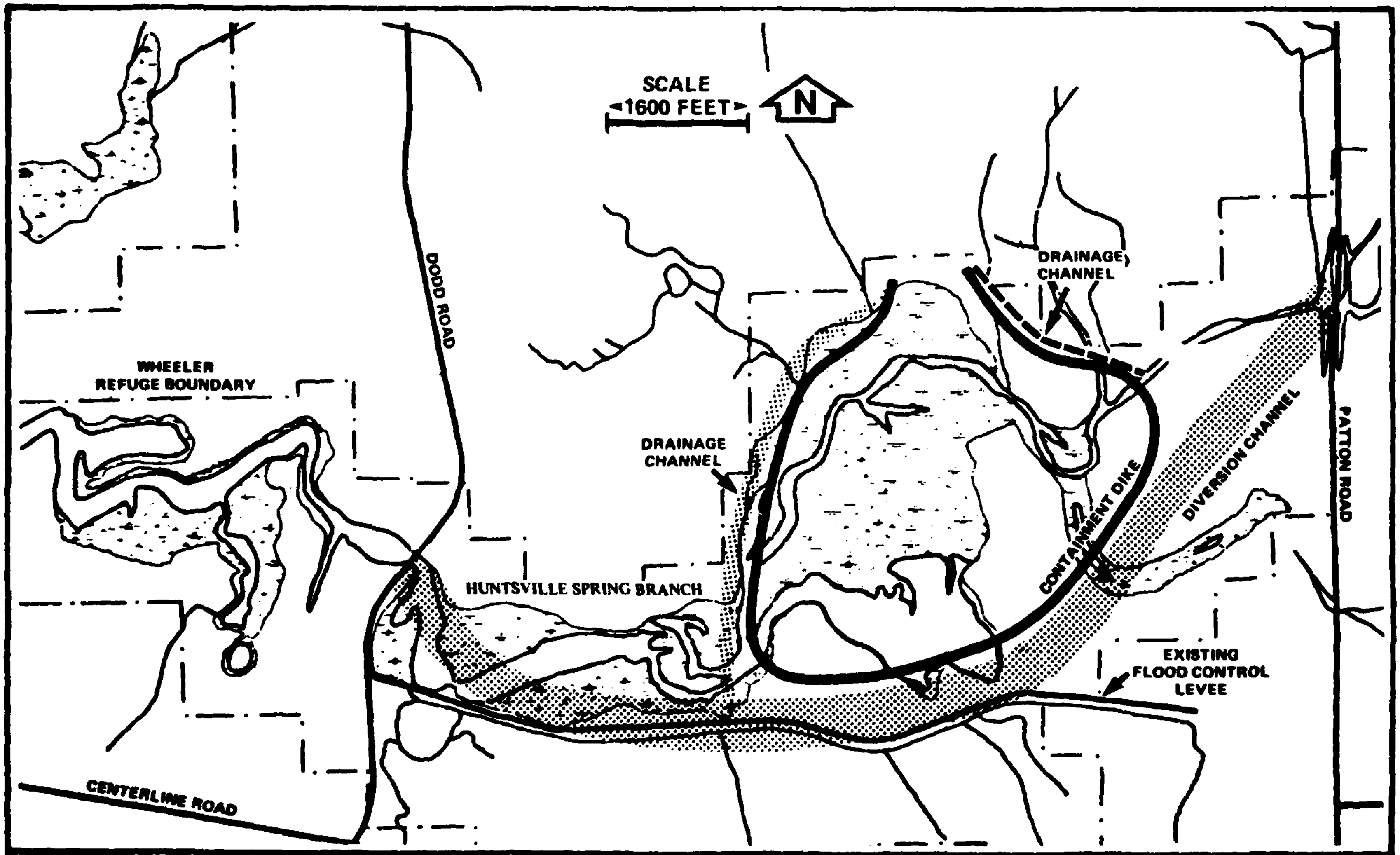

FIGURE III-27. Within Basin Diversion and Containment

SOURCE: WATER AND AIR RESEARCH, INC., 1980

U.S. ARMY CORPS OF ENGINEERS,
MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of
Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters
Wheeler Reservoir, Alabama

The archaelogical impacted area by its nature is somewhat larger than the physical impacted area due to the following:

1) Minor realignments are unforeseen during the planning stages;
2) Temporary staging areas are arbitrary in placement;
3) New access roads create an archaeological hazard providing easy access for collectors;
4) Previously recorded sites are often poorly recorded.

These aspects require the intensive survey to be somewhat broad to insure site coverage.

10.2.1 Contaminated Area (Areas A-C, Figure III-26)

Although no known archaeological sites lie directly within the impact zone, nine sites are presently recorded within 600 feet of proposed access roads and dredge areas (Figure III-26, Areas A-C). These sites include 1Ma96, 107, 118, 119, 120, 121, 122, 127, and 134. Six of the nine sites are prehistoric, two are historic house sites, and one is of undetermined affiliation. Even though none of these sites lies directly in the impact zone, all are very close to the dredge areas. Extreme caution would have to be exercised in order to avoid damaging these resources.

In addition to the nine presently known sites, it is likely that other undiscovered prehistoric and historic sites are located within this impact zone. As determined in the Predictive Model, proximity to water is one of the most reliable indicators of prehistoric site location. The majority of limited activity and base camp sites are located at distances of 600 feet or less from perennial streams, lakes, or swamps. The Wheeler Basin is characterized by an extremely intensive prehistoric occupation and any elevated knoll, ridge or terrace marked by well-drained silty loam soils within a short distance of water is likely to yield evidence of prehistoric occupation. Since this alternative for DDT mitigation will affect an enormous linear distance of shoreline, it follows that the potential for impacting unreported prehistoric sites is substantial. This potential is made even more dramatic by the extensive zones of suitable soils lining the waterways. It is likely that dozens of yet undiscovered sites would be impacted.

The lower HSB, and Indian Creek system is somewhat difficult to evaluate on the basis of our study. Although the reconnaissance survey included the upper reaches of HSB, none of the project corridor touched upon the portions of streams near their juncture with the Tennessee River. Therefore, we are not certain whether the Tennessee River settlement zone is similar through the Arsenal or whether, around Indian Creek, the Tennessee River settlement system extends further to the north. The issue is crucial in terms of evaluating the potential occurrence of mound and village sites.

Nevertheless, the potential along the shore for additional, undiscovered sites dating to the Paleo-Indian, Archaic, and Woodland periods is extremely high. In view of the large area affected, there is a 99 percent probability that unknown limited activity sites of one, two, or three periods will be impacted. Also, there is a 99 percent chance that new base camp sites of the Archaic and Woodland periods will be encountered.

In addition to the high probability for sites being located along the shore, it is likely that the dredging will disturb sites inundated by the waters of the Wheeler Reservoir. The archaeological survey of the Wheeler Basin conducted in the 1930s (Webb 1939) focused exclusively on sites located on the Tennessee River. No survey was undertaken along the tributary streams such as Indian Creek or HSB. After the dam was completed, the waters backing up in the Wheeler Reservoir flooded substantial portions of alluvial bottomland, and doubtless inundated unreported archaeological sites situated on low knolls. Sites in the Reservoir that were flooded in this manner may well remain intact, and efforts must be made to locate them prior to dredging.

In addition to prehistoric sites, the proposed dredging will quite possibly impact unreported historic sites. At present, only two historic house sites are known in the vicinity of the dredging area. These sites are 1Ma119 and 1Ma122. However, the map of Rural Delivery Routes of Madison County prepared in 1934 indicates not two, but at least five, historic houses located in close proximity to the impact area. If this map is accurate, several additional historic sites may be affected by this alternative.

10.2.2 Dredge Material Disposal Sites (Areas D and E, Figure III-26)

Currently two locations are under consideration as disposal sites (Figures III-26, Areas D and E). The primary dredged material disposal site is located on the Arsenal northeast of the junction of Redstone Road and Patton Road. Only one archaeological site has been reported from this area, 1Ma127. However, there is a strong possibility that additional sites are located at the disposal site. The area encompasses an expanse of elevated terrain on the margin of HSB and also bordering a swamp. Such a situation was a highly favored site location. Also, a rank 1 stream drains the uplands in this area and joins HSB northeast of the disposal site. Again, elevated terrain adjacent to a feeder stream was a common location for sites, both during the Archaic and Woodland periods.

The alternate dredged material disposal site is located just east of the Arsenal and south of Redstone Road (Figure III-26, Area E). Three sites are known to exist within the area encompassed by the alternate disposal site. These sites include 1Ma216, 217, and 218, all prehistoric lithic scatters. During our reconnaissance survey, the northern half of the alternate dredged material disposal site was examined and only the three sites noted above were found. The southern half of the disposal site has not been surveyed, however; and it is highly probable that additional unreported sites occur in the area. In particular, a large zone of Etowah, Decatur/Cumberland, and Linside soils located near the margin of a former lake will almost surely be found to contain archaeological sites.

10.2.3 <u>Out-of-Basin Diversion Corridor</u> (Area F, Figure III-26)

This requires the construction of a diversion channel to divert the flow of HSB and McDonald Creek away from the contaminated area (Figure III-26, Area F). This channel will intersect HSB and McDonald Creek at some point above the contaminated area and will divert them into the Tennessee River.

Ten archaeological sites fall directly within the impact zone. These include sites 1Ma33/50, 133, 140, 141, 157, 158, 159, 162, 209, and 218. An additional four sites lie in close proximity to the corridor, and any of them might be affected by construction. These sites include 1Ma152, 156, 210, and 217.

Two sets of alternate alignments have been suggested. In the northern portion of the route, the diversion canal would intersect HSB at one of two locations. The easternmost alternative would impact site 1Ma209, while the western alternative would impact site 1Ma162. These are the only two sites known to occur along these alternate sections.

To the south, two alternate routes have been suggested for bypassing Gate 3 at the Arsenal. The easternmost alternative would pass very close to site 1Ma218, while the westernmost route would pass rather close to site 1Ma152.

Sites likely to be impacted which appear to be of National Register significance include 1Ma33/50, 133, 140, 141, 156, 162, 209, and 210.

The proposed route passes through both the Upland and the Tennessee River Settlement Zones. Consequently, this route has the maximum potential for impacting every type of site known in the region. Also, it is probable that additional, undiscovered sites lie within the corridor. This is especially true of areas adjacent to the Boundary Canal where zones of Etowah silt loam or silty clay to the Boundary Canal where zones of Etowah silt loam or silty clay loam, Decatur/Cumberland silty clay loam, Captina and Capshaw loams, Ooltewah silty loam, Linside silty clay loam, or Allen fine sandy loam occur near the water. In the northern portion of the corridor, additional limited activity sites and possibly base camp sites may occur. It is, however, unlikely that additional mound or mound and village sites lie along this corridor within the Tennessee River Settlement Zone.

More known archaeological sites occur within this proposed corridor than along any of the other alternate alignments. However, more archaeological survey work has been completed in this area, and it is a reasonable assumption that the greater number of sites is a direct consequence of the intensity of the survey. Additional investigations along other alignments would doubtless even the numbers.

In conjunction with the out-of-basin diversion route there will be flood control levees (Figure III-26, Area G) which will prevent storm flows from utilizing the original, contaminated stream bed. This proposed area encompasses two known archaeological sites, 1Ma127 and 134. Construction of the diversion dike and the elevation of Patton Road will affect a sizeable area in the vicinity of HSB, it is quite possible that additional, undiscovered archaeological sites will be impacted. There is a high probability for both limited activity sites and Archaic or Woodland base camps in the construction zone.

10.2.4 Within-Basin Diversion Channel and Containment Dike (Figure III-27)

Only one presently known archaeological site lies in the zone of potential impact (Figure III-27). This site is 1Ma134, a small lithic scatter. Although site 1Ma134 is the only site located directly within the proposed construction zone, six sites in close proximity to the channel or containment dike. These sites include 1Ma107, 118, 119, 120, 121, and 127.

The within-basin diversion aspect would impact a significantly smaller area than the out-of-basin diversion. Accordingly, the potential for damage to archaeological sites is reduced. Also, this plan would not impact sites in the Tennessee River Settlement Zone, thus reducing the probability of encountering large mound or mound and village sites of the Woodland and Mississippian periods.

Most of the sites presently known in this corridor consist of: 1) limited activity sites, and 2) historic house sites located on ridge crests or lower ridge slopes along the northwest shore of HSB. However, numerous zones of Etowah silt loam or silty clay loam, Captina and Capshaw silt loams, and Ooltewah silt loam occur near the south shore of HSB . These locales are highly probable locations for prehistoric sites, particularly Archaic and Woodland limited activity sites, and possibly base camp sites. Other likely locations for prehistoric sites are elevated knolls of Etowah and Captina-Capshaw soils in the vicinity of an old oxbow on the eastern margin of the impact area.

The proceeding geographic areas can be associated with the five engineering alternatives. As displayed in Table III-26, Column 1, geographic areas listed in Column 2 with site information in Column 3456.

10.3 MITIGATION BY AREA

Based on the results of our investigations, the significance of each site was evaluated in terms of criteria for eligibility for listing in the National Register of Historic Places. In making our evaluations, we relied upon these and other criteria listed in the guidelines published in the Advisory Council's Procedures for the Protection of Historic and Cultural Properties (36CFR 800.10). Although the specific details vary for each site, the evaluations are of two general types: either a site is deemed significant, and, therefore, eligible for listing in the Register, or it is not.

If a site has been subjected to testing and a background research, and is considered not to be eligible for the Register, then no additional archaeological work is warranted. On the other hand, if a site appears significant in terms of the guidelines noted above, further work or mitigation is in order.

In specific terms, the recommendations fall into four categories, two in which no additional action is suggested, and two in which mitigative measures are deemed appropriate. No additional work is recommended at:

(1) recent historic sites;

(2) light lithic scatters without integrity, and mitigative measures are appropriate at:

(3) sites deemed eligible for the Register because of _in situ_ cultural deposits; and

(4) sites with heavy artifact densities, where weather prevented completion of all of our testing procedures.

1. Historic sites that are fifty years of age or less are not eligible for inclusion in the National Register. These sites consist of standing structures of recent date, or artifact scatters of modern debris. Even if some of these structures were actually constructed before 1929 , they constitute a small element of a very widespread rural settlement pattern. Similar structures and sites are to be found over a large portion of northern Alabama, and it would be extremely difficult to argue that the sites are of significance in terms of being unique, or offering the possibility of advancing scientific knowledge.

2. Light scatters of very low artifact density are found in profusion in the Tennessee River Valley. Although such sites formed part of a more complex settlement system, and deserve thorough study, present archaeological techniques for dealing with low-density, shallow sites are poorly developed. Such sites are most commonly found in plowed fields, where discovery is enhanced by the disturbance, but while aiding discovery, the cultivation also destroys site integrity. Deep deposits, such as pits or postmolds, may survive below the plowzone at these sites, and our testing procedures were designed to locate such undisturbed deposits. But, at sites where testing failed to reveal evidence of subsurface features, the only remaining suitable and cost-effective data recovery technique is surface collection. Controlled surface collections were not a part of our work plan, but, at small sites, the systematic collection intervals along the radial transects provide an adequate sample of site contents. In such cases, we do not feel that additional investigations would be productive, given present archaeological techniques.

3. Sites considered eligible for listing in the National Register of Historic Places require protection. Prehistoric sites, at which intact deposits are found offer an excellent opportunity to advance the knowledge of prehistoric cultural development in the Tennessee River Valley. Also, each site must be sufficiently unique, within the project corridor, that it would not be possible to group them, and recommend a single sample for listing in the Register.

4. At a number of sites, our investigations failed to show evidence of intact deposits. In this group, one of several factors leads us to recommend additional work. At several of the larger sites, the radial transect collections served to define site boundaries, but resulted in a controlled collection from only a very small percentage of the site area. At such sites, particularly those with an artifact density sufficient to suggest an occupation of greater duration than a single flaking incident, we feel that a controlled surface collection is warranted. Such collections would produce a representative sample of artifacts for dating purposes, and could also provide information allowing the delineation of discreet activity loci and/or the horizontal separation of temporal components. Perhaps, more importantly, extremely wet conditions prohibited stripping of the plowzone at several sites in this category. At such sites, our one-meter by one-meter test pits and limited augering simply did not expose an adequate area to confidently rule out the possibility of subsurface features . In these cases, we must suggest that a portion of the plowzone be stripped at the sites, in order to confirm the presence or absence of intact deposits which might make the site eligible for inclusion in the National Register.

10.3.1 Contaminated Area (Areas A-C, Figure III-26)

Dredging of contaminated materials from this area is potentially the most significant engineering aspect of the entire project. Dredging will involve direct impact to an extremely large number of high probability locations along the shore of the streams. In addition to the potential for encountering a host of unreported sites along the shoreline, there is the problem of sites inundated by waters of the Wheeler Reservoir. We have no way to accurately predict how many sites located in the alluvial bottomlands of Indian Creek and HSB are now covered by the Reservoir's waters. However, we do know that sites occur in profusion on very slight elevations along all of the streams in our study corridor. The elevations are so slight that many would have been submerged in the Reservoir. Thus, the dredging will not only impact a large number of high probability locations, but it also would affect a large zone in which site potential cannot be predicted.

As road and dredging corridors are agreed upon, an intensive field survey will be required to locate sites both previously recorded and new sites. Sites that will be impacted (there are nine recorded to date) will require intensive excavations to determine their eligibility for inclusions in the National Register Category 3 in the above discussion. The amount of dredging activities will be a direct factor in the area requiring survey or mitigation. A 50% reduction in the dredged area will produce a similar reduction in the level of cultural resource impact and the need for survey mitigation. The most difficult aspect within this area will be location of significant sites inundated by the Wheeler Reservoir. This will require an inovative sampling procedure to locate these now underwater sites.

10.3.2 Dredged Material Disposal Sites, (Areas D & E, Figure III-26)

The primary disposal site location Area D has not been subjected to an intensive archaeological survey. At present one site is reported for the area and there is a strong possibility of additional sites within the proposed area. The one reported site 1MA127 will require evaluation, as will all sites recorded in the intensive survey.

The alternative disposal site Area E has been surveyed in the northern section as part of the reconnaissance level survey. Three sites were located, all prehisotric lithic scatters. None is eligible for listing on the National Register of Historic Places, Category 3, and no additional work will be necessary in Category 4. The southern section will require an intensive survey. All located sites will require National Register eligibility determination.

10.3.3 Out-of-Basin Diversion Channel and Dikes, (Areas F & G, Figure III-26)

Area F falls within the area delimited for the reconnaisance level survey. This survey was designed to produce a predictive model. As a result the entire area was not subjected to an intensive level of investigation, and will require additional work to fill these gaps. At present there are eight sites which appear to be of National Register significance, Category 3 and 4. Additionally, sites located during the intensive survey will require National Register evaluation. The amount of mitigation required for this are is high for two reasons:
1) intensity of previous survey work and 2) the high level of cultural occupation in the impact area.

Area G includes flood control levees that have not been subjected to intensive archaeological survey, which will have to be completed. The sites located during the survey and the two previously recorded sites will require excavation to determine their National Register significance.

10.3.4 Within-Basin Diversion Channel and Containment Dike (Figure III-27)

This area, like HSB Area A which it shares has not been subjected to an intensive level survey. The area includes seven known sites that will also be impacted by Area A. Six of these sites are periphery or of an undetermined exact location and will have to be relocated and evaluated for National Register eligibility. The seventh site falls in the direct construction area and will require evaluation.

10.4 IMPACTS AND MITIGATION FOR EACH ALTERNATIVE

Based on the proceeding evaluation a matrix Table III-26 has been constructed correlating engineering alternatives with geographic areas, documented sites, National Register eligible sites, potential for site location and total number of sites that will be impacted. First it can be noted that HSB Reach A-B, and Indian Creek Reach C will all be impacted in all the engineering alternatives. Use of either of the two out-of-basin disposal sites will impact relatively small areas but still with a high probability for site location. Out-of-basin diversion (G-F) in degree of impact approaches that of dredging. Out-of-basin diversion occurs in both alternatives C and D. As a result these two alternatives, from a cultural resouce standpoint are the most damaging. Alternative E and F which include within-basin diversion are the least damaging, particularly when Alternative F which includes containment of contaminated materials within-basin. The within-basin diversion will overlap some of the areas requiring survey in Area A. Finally, it must be noted that none of the areas associated with their particular alternatives have been completely surveyed. The proceeding information is all derived from the predictive site model conducted in the area of the proposed diversion channel.

[redacted]

11.1 INTRODUCTION

The various alternatives can each be considered a group of tasks, or actions. Each of the tasks is usually a component of more than one alternative. To prevent the reiteration of identical impacts from alternative to alternative, the predicted impacts are discussed herein on a task by task basis. The total series of impacts for each alternative will then be briefly outlined, summarized, and compared.

11.2 DREDGING AND DISPOSAL

Dredging--The impacts of dredging and disposal can be characterized as being associated with (a) road construction, (b) mechanical removal of sediments and snag habitats, and (c) water quality degradation.

Total roadway to be constructed amounts to about 63,300 linear feet, or 66.7 acres. Almost 40 percent of this acreage is occupied by aquatic or wetland habitats; specifically open water, buttonbush swamp, bottomland hardwood swamp, and floodplain hardwood forest. These are among the most valuable of the site's habitats to wildlife, by providing fruit and mast for autumn and winter foods. Wildlife species which may be directly affected by this loss are turkey, deer, opossum, raccoon, red and gray fox, squirrels, and other rodents. Many of these are game species.

Approximately one-half of the total "edge" habitat along Huntsville Spring Branch and Indian Creek between Patton Road and the Tennessee River will be severely altered by construction of the road. Virtually all existing vegetation will be removed to allow working room for the dredge. During dredging operations, "pioneer" plant species will colonize the denuded stream bank, in probably lesser densities than the

Table III-26. Cultural Resource Matrix

Alternatives	Effected Geographic Areas	Documented Sites Impacted Due To Construction	Sites With Documented Eligibility For National Register	Site Concentration As Per The Predictive Model	Sites Impacted From Ancillary Construction Activities and Increased Public Access
A. Natural Restoration	None	None	None		
B. Dredging	Figure III- 26 Huntsville Spring Branch Indian Creek Reach A-C	None	None	High	1-MA-96, -107, -118, -119, -120, -121, -122, -127, -134
With Primary Disposal Site	TDMDA Area D	1-MA-127	None	High	
Or Secondary Disposal Site	TDMDA Area E	1-MA-216, -217, -218	None	High	
C. Out-of-Basin Diversion and Removal of Contaminated Sediments	Figure III-26 Diversion and Containment Dike Area G Diversion Canal Area F	1-MA-33/50, -140, -141, -157, -158, -159, -162, -209, -218, -133	1-MA-33/50, -133, -140, -141, -156, -162, -209, -210	High	1-MA-152, -156, -210, -212, -217, -229
Includes Alt. B - Dredging	Huntsville Spring Branch Indian Creek Reach A-C	None	None	High	1-MA-96, -107, -118, -119, -120, -121, -122, -127, -134
With Primary Disposal Site	TDMDA Area D	1-MA-127	None	High	
Or Secondary Disposal Site	TDMDA Area E	1-MA-216, -217, -218	None	High	

Table III-26. Cultural Resource Matrix (Continued, page 2)

Alternatives	Effected Geographic Areas	Documented Sites Impacted Due To Construction	Sites With Documented Eligibility For National Register	Site Concentration As Per The Predictive Model	Sites Impacted From Ancillary Construction Activities and Increased Public Access
D. Out-of-Basin Diversion and Containment of Contaminated Sediments	Figure III-26 Diversion Canal Area F Diversion and Containment Dike Area G	1-MA-33/50, -140, -141, -157, -158, -159, -162, -209, -218	1-MA-33/50, -162, -133, -140, -141, -156, -209, -210	High	1-MA-152, -156, -210, -212, -217, -229 1-MA-107, -118, -119, -120 -121, -127
Includes Alt. B - Dredging	Huntsville Spring Branch Indian Creek Reach A-C	None	None	High	1-MA-96, -122, -134
And Disposal	TDMDA Area D	1-MA-127	None	High	
Or Alternative Disposal	TDMDA Area E	1-MA-216, -217, -218	None	High	
E. Within Basin Diversion	Figure III-27 Diversion Channel and Containment Dike	1-MA-134		High	1-MA-107, -118, -119, -120, -121, -122, -127,
And Dredging of Contaminated Sediments	Figure III- 26 Huntsville Spring Branch Indian Creek Reach B-C	None	None	High	1-MA-96, -121, -122, -134
With Primary Disposal	TDMDA Area D	1-MA-127	None	High	
Or Alternative	TDMDA Area E	1-MA-216, -217, -218	None	High	

Table III-26. Cultural Resource Matrix (Continued, page 3)

Alternatives	Effected Geographic Areas	Documented Sites Impacted Due To Construction	Sites With Documented Eligibility For National Register	Site Concentration As Per The Predictive Model	Sites Impacted From Ancillary Construction Activities and Increased Public Access
F. Within Basin Diversion and Containment of Contaminated Sediments	Figure III- 27 Diversion Channel and Containment Dike	1-MA-134	None	High	1-MA-107, -118, -119, -120, -121, -127
And Dredging of Contaminated Sediments	Figure III-26 Huntsville Spring Branch Indian Creek Reach B-C	None	None	High	1-MA-96,-122, -134

original native vegetation. This habitat will receive some (mostly nocturnal) wildlife use. If subsequently managed to allow natural vegetation to occupy the bank, its present wildlife values will return over time. If the bank is grassed and mowed, this will represent a long-term loss of valuable habitat and wildlife, since it is a habitat for both upland and wetland plant species and it receives more insolation than the floor of the adjacent forests, and productivity and density of the edge habitat's shrub and herb layers is greater than in the forests. It is therefore useful to wetland and upland wildlife as a travel corridor, as resting cover, and as nesting and feeding habitat. Another point of concern is that removal of much of the vegetation and placement of a gravel roadway alongside of the stream will increase erosion along the stream channel due to a reduction of soil holding capacity. This could lead to increased DDT exposure and transport from contamination along this bank if DDT-contaminated areas in the adjacent channel, bank or overbank are missed.

Mechanical removal of 259 acres of sediments and snags associated with DDTR removal will result in the loss of aufwuchs communities, macroinvertebrate populations, fish and wildlife habitat, and perhaps some submerged vegetation. Aufwuchs communities, which consists of attached algae, bacteria, protozoa and fungi, organic detritus, silt, and clay, exist as a thin veneer which coats the light-receiving surfaces of submerged snags and sediments. Aufwuchs communities can have high productivities, higher than phytoplankton or macrophyte communities. They may not be so important in the highly-turbid stream system of this study, but since they were not sampled this cannot be stated with certainty. Aufwuchs communities also provide suitable habitat for a variety of macroinvertebrates, and are grazed by certain amphibian larvae and fish. These communities can be expected to become reestablished on the benthic substrate following dredging activities, but snag removal represents a long-term loss of substrate for plant productivity. Macroinvertebrate populations also exist on snags and in the bottom substrate. Benthic macroinvertebrates exist in moderate to low densities within the affected streams. Snag-dwelling macroinvertebrates were not quantified in this survey. Macroinvertebrates provide food sources for fish and other wildlife species. The loss of snags from the stream system will have a long-term, detrimental effect on snag-dwelling macroinvertebrates. Benthic macroinvertebrates, however, should recolonize within a year or two (Hirsch, et al., 1978). Snags are among the most valuable of stream habitats to fish and wildlife, by providing food (aufwuchs and macroinvertebrates), cover, and respite from stream currents. Unless uncontaminated snags are replaced subsequent to dredging of contaminants, this will represent a significant long-term loss to the Huntsville Spring Branch and Indian Creek stream system.

The removal of contaminated organisms will result in the removal of some DDTR from the system; however, as pointed out in Appendix II, Section 3.3, the DDTR removed via organisms will be very small in relation to the total quantity in the system.

Fish will be affected more after the dredging is completed than while it is in operation. During clearing and dredging of the channel, fish will probably migrate downstream to avoid the sediment plumes created by clearing debris and dredging, and to avoid the disturbance and noise of the operations. Once these operations are completed, the fish will migrate back and may be affected in several ways. For several years there will probably be reduced food available in the dredged areas. Available food may have residual DDTR levels due to contaminated sediments not completely removed by dredging. There will also be a marked reduction in habitats for juvenile fish since the productive shallow areas in and along the edges of the dredged portions of HSB and IC will have been dredged to a depth of at least 2 feet.

The effect on aquatic plants of dredging in HSB and/or IC would be very nominal since duckweed is the only vascular plant found to any extent. Duckweed has been shown to very rapidly adsorb DDT from surface films and also from the water (Meeks, 1968). Removal of contaminated sediments will reduce the burden of pesticide in this plant species. This is important since it is a source of food for Sora Rail and several species of ducks which are found in the area, most notably the Wood Ducks.

Dredging will be required at least in the approximately 25 acres of critical overbank area within Reach A in addition to dredging of the HSB channel. This acreage is entirely in wetland habitats; specifically buttonbush swamp, floodplain hardwood forest, and bottomland hardwood swamp. These are habitats important to terrestrial and wetland wildlife species. However, as much as 60 percent of the DDTR in the HSB-IC system may be located in this relatively small area.

Water quality will be degraded to some extent by turbidity and by suspension of DDTR. The turbidity plume is not expected to be of large size. The majority of the plume will move downstream and settle to the channel bottom. This short-term increase in downstream DDTR contamination will be subsequently removed as the dredge progresses downstream. See Sections 3.2.3 and 3.4.7 for additional information on turbidity generation by dredging.

In close proximity to the dredge, the plume will shade benthic macroinvertebrate and benthic aufwuchs communities, thus reducing productivity. Phytoplankton will be affected less than zooplankton and much less than benthic organisms by suspended DDTR, as shown by Hurlbert (1975), since the DDTR will remain suspended for a relatively short period of time before it settles to the bottom again. However, the DDT in solution could affect the phytoplankton since they can concentrate it over 1,000 times the water concentration (Hurlbert, 1975). As noted in Section 5.6 of Appendix I, this may have an effect on growth morphology and photosynthesis. Due to the shorter generation time of phytoplankton, algal blooms could occur if the suspended DDT reduces the zooplankton levels (Hurlbert, 1975). In general, any effect on the plankton should only be temporary since recolonization will continually take place from upstream of the dredging operations.

Some DDTR-contaminated material may be left along the dredged channel. This material will affect benthic organisms recolonizing the bottom until covered with uncontaminated sediments. This effect should be less than that presently occurring.

If the entire overbank area within Reach A is dredged, the environmental impact would be more extensive. Removal of all trees and plants from this area would result in a large loss of wildlife habitat. Revegetation and recovery would be slow due to removal of three feet of topsoil. There may also be a significant increase in suspended solids in Huntsville Spring Branch due to erosion in the area until such time that the overbank could be stabilized.

Dredging of contaminated sediments will require that the water level in Wheeler Reservoir be lowered more rapidly than is presently done, and that the water level be maintained a foot lower during the following summer if necessary, to facilitate dredging contaminated sediments from Indian Creek and Huntsville Spring Branch. Within the Tennessee River the reservoir's banks are relatively steep, so that lowering the level one foot should reduce the surface area relatively little. Also, the biota present is already adapted to changing water levels. Therefore, the impacts of these water level manipulations should have little adverse effects on Tennessee River biota. These water level manipulations will affect the backwater areas within the Wheeler National Wildlife Refuge (WNWR) to a greater extent. Since these backwaters are shallower, larger areas will become exposed in the autumn and winter than would normally. These "mudflats" become quickly vegetated with rushes and other graminoids, and are the main attraction to overwintering ducks and geese. Said water level lowering may therefore actually benefit these waterfowl (Atkeson, T., WNWR Manager, personal communication). Fisheries production in the shallow backwaters should be little-affected by dropping the water level sooner and more quickly. Maintaining the water level a foot lower the following spring and summer should also cause little harm to fish populations, since there should be sufficient backwater shallows for spawning to occur (Hooper, G., WNWR fisheries biologist, personal communication, 1980). Caution must be taken not to raise the water level in the spring to 556 feet msl and then to lower it back to 555 feet msl. This could result in stranding of spawning fish and nests, which would be detrimental to fish populations. Also, for protection of bass fisheries productivity, the drawdown should be delayed until mid-June, since bedding fish could be trapped, and nests destroyed, by falling water levels.

Bathymetric data (W. Sewell, TVA, personal communication) indicates that the 1-foot temporary drop will reduce the reservoir surface area by about 2,190 acres from a total of 61,190 acres, a loss of 3.6 percent. The amount of fish spawning and nursery acreage was not determinable at this time, so an accurate estimate of the loss or gain in habitat was not possible. However, if it is assumed that the primary habitat is six feet or less, the bathymetric data indicates there would be a loss of 380 acres of water less than six feet deep. This represents a temporary loss of 2.3 percent. This loss is considered to be insignificant if it occurs for no more than two years (G. Hooper and C. Lawson, Wheeler National Wildlife Refuge fisheries biologists, personal communication).

Two options are being considered for disposal of the contaminated dredged material. These are (1) the channel of Huntsville Spring Branch between Miles 2.4 to 5.7, which could be employed in Alternative F; and (2) the

Temporary Dredged Material Disposal Area, which could be employed in Alternatives B, C, D, E, and F.

Huntsville Spring Branch Channel Miles 2.4 to 5.7--This option would cause no additional adverse effects, since the stream channel to be filled would be altered anyway by containment activities as described in Section 11.4. This option would result in the elimination of the Temporary Dredged Material Disposal Area, thus reducing the total acreage potentially affected by Alternative F by 187 acres.

Temporary Dredged Material Disposal Area--Construction of the temporary dredged material disposal area (TDMDA) will result in a total habitat loss of about 187 acres. Only 0.6 acres of this is in wetland habitat, specifically, bottomland hardwood swamp. About half of the acreage is in mixed pine and deciduous hardwood forest. Most of the remainder is in deciduous hardwood forest and planted pine forest. A small amount of grassed area will be lost. If the size of the currently planned snag portion of the containment area is to be enlarged, it will occupy more grassed area. The affected upland forests are contiguous with the extensive wetland forests to the north, making them valuable as wildlife habitat. This represents a long-term loss.

Use of the TDMDA will temporarily expose wildlife to an additional source of DDTR contamination. The greatest period of risk to wildlife will be during filling and dewatering of the sediments. Although large animals will be restricted by the security fence, small animals, burrowing animals, and birds will be able to gain access. These exposures to wildlife are unquantifiable at present but are considered to be less important than the present exposures within the overbank area for several reasons. First, although the DDTR will be more exposed in the TDMDA than in the present system, that exposure will occur for a lesser period of time (about 5 years) than that which would occur if the DDTR is left in place. Second, the TDMDA occupies a smaller acreage than that occupied by the presently contaminated sediments (about 37 percent). Third, a system of less maturity, and therefore lower organism density, will occur in the TDMDA compared to the HSB floodplain system, resulting in less DDTR being accumulated in wildlife populations.

Sora Rails and ducks will eat the duckweed which will probably become established in the ponds during the first year, either from the dredged material itself or from aquatic birds landing on the water. Since several species of algae can tolerate relatively high concentrations of DDT, phytoplankton and algal blooms could occur during dredging as zooplankton and higher herbivores would not survive the high DDT levels (Hurlbert, 1975). Persistent ponding of water in the disposal cells can be minimized by frequent decanting.

Since DDT has a possible half-life of up to 30 years (Appendix I, Section 3.4) and presumably large concentrations in a dump area could have even longer half-lives (Duttweiler, 1970), it is important that the impermeable cap and grass cover be established as soon as possible after sediment dewatering to reduce the risk of DDTR exposure to wildlife.

This would also prevent the exposed, dried sediment and DDTR-laden dust particles from being blown about by high winds.

11.3 OUT-OF-BASIN DIVERSION OF HUNTSVILLE SPRING BRANCH

Huntsville Spring Branch and Indian Creek--Routing of Huntsville Spring Branch out of its current channel and into Unnamed Creek will result in lower flow within Indian Creek. Reduction of its base flow is expected to be about 61 percent of the present total. This alteration may cause the benthic substrate to become more silty; however, the bottom is now a silty mud, so any change will probably be insignificant to the benthic biota. It also will not change ordinary water levels in Indian Creek since they are controlled by Wheeler Reservoir. The detrital load in Indian Creek downstream of the confluence with HSB will be reduced an undetermined amount; however, the drainage basin of Indian Creek should be able to provide sufficient detrital input to sustain whatever detrital food chains currently exist in the Creek. The fishes of Indian Creek within the project area are adapted to its reservoir environment. Since the physical conditions within Indian Creek are not expected to change significantly by the out-of-basin diversion of HSB, the fauna of Indian Creek is also not expected to change significantly.

Current flow will cease in the affected portion of HSB with out-of-basin diversion. This is expected to cause a shift in macroinvertebrate populations from those preferring running water (lotic) to those preferring standing water (lentic). This might have a significant effect on molluscs. However, current flow has already been changed drastically by the Wheeler Reservoir, and HSB is polluted with DDT and excess nutrients. Benthic analysis revealed that, among the molluscs, only fingernail clams (*Sphaerium* sp.) and one species of snail (*Physa* sp.) occurred in the sediments. The artifical substrate samplers, which mimic snag habitat, were entirely devoid of molluscs. Therefore, the endangered and threatened mollusc species listed in Appendix II, Section 2.2 probably do not occur in the affected portion of Huntsville Spring Branch.

Unnamed Creek--Construction of the out-of-basin diversion channel along the route of Unnamed Creek will result in the destruction or alteration of 3.6 acres of aquatic habitat, 21.9 acres of wetland hardwood swamp, and 267 acres of upland habitat. Most of this is already in an environmentally degraded condition. The creek itself is nutrient-laden and supports macroinvertebrate populations of high density and low diversity (see Appendix II, Section 2.1.4). The forests are in an early stage of succession, without large, overmature trees, and are dominated generally by pioneer and understory species such as willow oak, loblolly pine, sweet gum, and blue-beech (see Appendix II, Section 2.1.4). Much of the corridor (20 percent) is in lawn grasses. Seventeen percent of the corridor is in agriculture.

Routing of HSB waters into the out-of-basin diversion channel will create a habitat dominated largely by those nutrient-pollution-tolerant species currently in HSB and Unnamed Creek. Benthic organisms would include chironomids (*Chironomus* spp. and other genera), tubificid oligochaetes (*Limnodrilus* spp. and *Branchiura sowerbyi*), and the exotic Asiatic clam

(Corbicula fluminea). Snag-dwelling organisms will not be present since there are no provisions for artificial introduction of snags. Total invertebrate productivity may be greater in the diversion channel than in the present Huntsville Spring Branch since there will be lower DDTR levels. Phytoplankton and aufwuchs unit area productivity should be about the same as that currently expressed in Huntsville Spring Branch. Fish and wildlife usage of the channel may be lower than in HSB due to a lower diversity of habitats, but this may be mitigated by the lower DDTR levels.

Muddy Cave (ALMD 1095), at 580 feet Msl, is about one half-mile east of the proposed out-of-basin alternative. It is a known habitat of the troglobitic southern cavefish, Typhlychthes subterraneus. Current water level in the cave is estimated to be 576 feet msl. This is above the 100 year flood elevation of the Tennessee River (575 feet msl), thus no adverse effects on this cave are anticipated.

Excavation of the out-of-basin diversion channel is expected to contact bedrock in at least two areas. This may provide some degree of communication between water in the channel and the underlying aquifer. Since water in the channel is expected to be somewhat degraded by high nutrient and suspended solids levels, the potential exists for some contamination of groundwater. This effect is believed to be minimal, as the aquifer appears to be discharging to the Tennessee River in this area (Geological Survey of Alabama, 1975).

Routing HSB down a relatively straight channel should result in somewhat higher pollution loads to TR. The meandering stream that is bypassed provides more overbank or floodplain area for deposition of solids loads and more biota for nutrient removal. The new channel will allow urban runoff loads from Huntsville to enter the Tennessee River with less natural purification.

The bottomland hardwood swamp habitat affected by the out-of-basin diversion occurs within the HSB floodplain and in two adjacent tributary systems. The wetlands of the portion of the tributaries within the diversion channel corridor are composed of relatively small trees in dense stands. They are heavily dominated by sweetgum (Liquidamber styraciflua), red maple (Acer rubrum), and green ash (Fraxinus pennsylvanicus). Buttonbush (Cephalanthus occidentalis) and muscadine (Vitis rotundifolia) are also common. The wetlands of the Huntsville Spring Branch floodplain within the diversion channel corridor are more mature, and are dominated by water tupelo (Nyssa aquatica) and green ash. Red maple and American elm (Ulmus americana) are common, buttonbush and swamp rose (Rosa palustris) occur frequently, and poison ivy (Rhus toxicodendron) is abundant.

11.4 WITHIN-BASIN DIVERSION OF HUNTSVILLE SPRING BRANCH

Within-basin diversion of HSB involves construction of a containment area and a diversion channel. Containment area work includes (a) construction of a containment dike, (b) construction of one drainage channel each on the northeast and western sides of the containment dike, (c) establishment of a pump, sump, and settling basin to remove water from the containment area and (d) dredging or covering of either (1) the HSB channel from Patton Road to Dodd Road and 25 acres of critical overbank or (2) the HSB channel and the entire overbank area within the containment area.

One effect of diversion channel construction will be water quality degradation associated with shortening of a meandering stream and replacement with a relatively straight channel. Relative to straight channels, meandering streams provide more overbank (floodplain) area for deposition of alluvium, and more biota for nutrient removal. The excess alluvium can be expected to cause more siltation in HSB below Dodd Road and in Indian Creek. Nutrients will also be shunted downstream; however, since nutrients are not limiting in this sytem this effect will probably have an insignificant impact. The channel will provide a habitat for benthic organisms (aufwuchs and invertebrates) probably for the same pioneer species already inhabiting HSB; but total populations will be lower since total benthic habitat will be reduced.

The second effect of diversion channel construction will be the loss of approximately 88.4 acres of aquatic and wetland habitat. Affected habitats include open water, buttonbush swamp, bottomland hardwood swamp, floodplain hardwood swamp, deciduous hardwood forest and mixed pine and deciduous hardwood forest. It will cross about 18 to 20 ecotonal, or edge habitats, since it passes through the edge of a floodplain containing many of plant associations.

Habitat alterations associated with development of the containment area will directly affect about 294 acres of wetland and aquatic habitat. This includes open water, buttonbush shrub swamp, bottomland hardwood swamp, floodplain hardwood forest, and a portion of recently clear-cut floodplain forest. These habitats will be lost altogether if the overbank within the containment area is dredged. If the overbank area remains undredged, it will gradually become drier as water is pumped out, and the continuum of aquatic and wetland habitats are expected to shift in species composition as described in Section 11.5.

Construction of the dewatering pump, sump, and settling basin will cover approximately 9 acres that are currently occupied by open water, floodplain hardwood forest, and buttonbush shrub swamp. If the entire containment basin is dredged, however, the dewatering area will result in no additional loss of resources other than the commitment of land space.

11.5 CONTAINMENT WITH OUT-OF-BASIN DIVERSION

Environmental Impacts--The impacts of this alternative are separated into those associated with containment and with out-of-basin diversion. The latter have been discussed in Section 11.3. The containment alternative involves the construction of a dike and a small drainage channel, and either of two filling options: (1) fill the HSB channel and 25 acres of critical overbank with two to three feet of clay and soil, or (2) fill the HSB channel and the entire floodplain overbank area within Reach A with two to three feet of clay and soil (290 acres).

The dike and drainage channel will displace about 11.3 acres of aquatic and wetland habitats, and 27.1 acres of uplands. The western dike and canal will run along the edge of the floodplain, disturbing a minimal amount of aquatic and wetland habitat. However, it will also serve as a partial barrier to wildlife attempting to move back and forth between the uplands and lowlands. This effect is not altogether detrimental to wildlife, since the lowlands removed from their range is a contaminated one, and the slope of the dike will be 3:1.

Excluding HSB from Reach A (Patton Road to Dodd Road) by constructing the western containment dike will result in lowered water levels within the reach. Lowering will be most pronounced in areas adjacent to the channel. The vegetation will respond by shifting to species preferring drier situations. There are five wetland and aquatic plant communities within the floodplain of Reach A, existing along a continuum from relatively dry to wet. These are: the natural levee association, the floodplain association, the bottomland hardwoods association, the buttonbush community, and the open water areas. The levee association may see introduced a number of upland species, such as loblolly pine, redbud, red cedar, and smooth sumac. The floodplain association should tend to shift from maple-ash dominants to one occupied by a wider variety of mesic species, such as oaks, (swamp chestnut, willow, water and cherrybark), elms (American and winged), hackberry, black cherry, dogwood and redbud. The bottomland hardwood association occurs in depressions within the floodplain, and should remain relatively wet. However, without periodic flooding from HSB overflows, water levels should be generally lower relative to present conditions. While the wetland species (green ash, water tupelo and red maple) should continue to predominate, other species could also invade. These may include sweetgum, black willow and blue beech. The buttonbush association occurs where the water is too deep to prevent the establishment of bottomland trees. With lower water levels, several species should be able to colonize the shallower portions. These include water tupelo, green ash, and red maple. The open water areas will be reduced in extent. Since HSB floodwaters will cease, the levels of suspended clays and organic detritus may be lowered sufficiently to allow the growth of submerged aquatic plants in the open water areas. In general, lowered water levels should increase aquatic plant diversity in each of the affected plant associations, and may also increase aquatic plant density.

Terrestrial and avian wildlife would be benefited by this change, specifically Wood Ducks, Turkey, raccoon, opossum, deer, and squirrels. Aquatic organisms would also benefit by removal of DDTR, and by an increase in aquatic and wetland plant foods. These would include otter, muskrat, wading birds, game fish, and invertebrates. Lowering of water levels within the containment area will create two shallow lakes; one in the existing "loop" section at HSB Mile 5.3, the other in the large ponded area near HSB Mile 4.5. Several smaller areas would also remain ponded. Creation of shallow lakes has the potential to be of high value to wildlife. After a few years of high plankton production, the ponded areas could become vegetated with submerged and emergent macrophytes, providing productive aquatic habitat.

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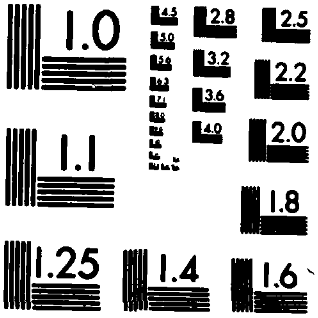
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If the non-critical overbank is not covered, the current effects of DDTR in this system can be expected to continue. As noted by Dimond (1969) and Peterson, et al. (1971), the DDTR will not leach downward or very rapidly become degraded by soil microorganisms (Clore, et al., 1961; Nash and Woolson, 1967). Also, only trace amounts are normally absorbed by vegetation (Yule, et al., 1972). Hence, current impacts on soil-dwelling organisms may continue for some years to come.

The situation would be vastly different if both the channel and the overbank were filled. All vegetation would be removed, including stumps, in an area totaling about 506 acres of aquatic and wetland habitat. The wetlands within this area are the most contaminated portions of the site. Removal of vegetation and filling with two or three feet of clean soil would have some value as a site of research in primary plant succession, but years would be required before the site obtained a level of plant and wildlife productivity and diversity approaching the surrounding environment.

11.6 CONTAINMENT WITH WITHIN-BASIN DIVERSION

Environmental Impacts--Tasks involved with this containment alternative are (a) re-routing HSB through a within-basin diversion channel, and (b) one of three fill options: (1) filling the HSB channel and critical overbank in the containment area to a depth of two to three feet; (2) filling the channel and the entire overbank in the containment area to depths of three and two feet, respectively; and (3) filling the containment area with dredged spoil from Reaches B, C, and the lower portion of A, and then covering with clay and topsoil (this option is discussed in Section 11.4). The impacts of re-routing HSB through the within-basin diversion channel have been discussed in Section 11.4. The impacts of filling the Huntsville Spring Branch channel and the overbank area are discussed in Section 11.5.

Of further impact would be the damage done to the upland area in "borrowing" clean fill for the above works. This site and its areal extent are currently unspecified.

11.7 ALTERNATIVE A: NATURAL RESTORATION

Alternative A involves allowing the system to be naturally restored. The major impact would be the continuing contaminaion of the environment by DDTR. More information on this alternative can be found in Section 9.1 of this Appendix.

11.8 ALTERNATIVE B: DREDGING AND DISPOSAL

Alternative B is comprised of the dredging of contaminated sediments and their disposal in an upland disposal site. Dredging options are to (1) dredge the contaminated portions of Huntsville Spring Branch and Indian Creek and the 290 acre overbank area, and (2) dredge the above plus most of the remaining wetlands between Dodd and Patton Roads. Dredging would require construction of an access road along the edge of the two steams. Disposal would occur in a temporary upland disposal site within the drainage basin. The major items of impact are listed below.

Habitat acreage alterations are listed in Table III-27 by aquatic, wetland and upland types. The impacts are described in more detail in Section 11.2.

Major items of impact:

Access road construction (See Section 11.2)
-Commitment of 67 acres of habitat
-Streamside vegetation altered for about 10 miles

Dredging of contaminated sediments (See Section 11.2)
-Removal of submerged snags
-Disruption of 10.3 miles of benthic habitat
-Suspension of contaminated sediments
-Disruption of 290 acres of wetlands

Disposal of contaminated sediments (See Section 11.2)
-Disruption of 187 acres of mostly uplands
-Commitment of 187 acres for underground storage

11.9 ALTERNATIVE C: OUT-OF-BASIN DIVERSION AND REMOVAL OF CONTAMINATED SEDIMENTS

Alternative C involves (1) constructing an out-of-basin diversion channel for Huntsville Spring Branch that would replace Unnamed Creek, and (2) the dredging and disposal of the contaminated sediments in Huntsville Spring Branch, Indian Creek, and the 25-acre critical overbank area. The major items of impact are listed below, and the acreages of habitat alterations by habitat type are in Table III-28.

Major areas of impact:

Construction of out-of-basin diversion channel (see Section 11.3)
-Alteration of 293 acres of habitat
-Replacement of small-stream biological communities with larger-stream biological communities
-Reduction in Indian Creek's base flow by 39 percent

Dredging and disposal of contaminated sediments (see Section 11.2)
-Commitment of 67 acres of habitat for access road construction
-Commitment of 187 acres for underground storage of contaminated sediments, and disruption of 187 acres of mostly forested habitat over the stored sediments
-Streamside vegetation altered for about 10 miles
-Removal of submerged snags for 10.3 stream miles
-Disruption of 10.3 miles of benthic habitat
-Suspension of contaminated sediments
-Disruption of 290 acres of wetlands by dredging the critical overbank area.

Table III-27. Habitat Alterations Associated With Alternative B: Dredging and Disposal

Tasks	Acreage Altered Aquatic	 Wetland	 Upland
Contruct TDMDA		0.6	186.4
Dredge Overbank		290	
Dredge HSB and IC Channels	259		
Construct Access Road	3.4	22.1	41.2
TOTALS	262.4	312.7	227.6
SUM OF TOTALS = 802.7			

Table III-28. Habitat Alterations Associated With Alternative C: Out-of-Basin Diversion and Removal of Contaminated Sediments

Tasks	Acreage Altered		
	Aquatic	Wetland	Upland
Construct Out-of-Basin Diversion Channel and Diversion Dikes	3.6	21.9	267.4
Construct TDMDA		0.6	186.4
Dredge Overbank		290.	
Dredge HSB and IC Channels	259		
Construct Access Road	3.4	22.1	41.2
Additional Habitat Altered by Disruption of Hydroperiod	47	349.4	
TOTALS	313.	684.	495.
SUM OF TOTALS = 1,492			

11.10 ALTERNATIVE D: OUT-OF-BASIN DIVERSION AND CONTAINMENT OF SEDIMENTS

Alternative D is comprised of (1) constructing an out-of-basin diversion channel for Huntsville Spring Branch that would replace Unnamed Creek, and (2) containment of contaminated sediments within a constructed containment area, and (3) dredging of contaminated sediments from Huntsville Spring Branch and Indian Creek downstream of HSBM 2.4, and disposal of the sediments in the containment area. The major items of impact are listed below, and the acreages of habitat alterations are listed in Table III-29.

Major items of impact:

Construction of the out-of-basin diversion channel (see Section 11.3)
-Alteration of 293 acres of habitat
-Replacement of small-stream biological communities with larger-stream biological communities
-Reduction in Indian Creek's base flow by 39 percent

Containment of sediments (see Section 11.5)
-Commitment of about 31.5 acres of habitat for containment dikes and their associated small drainage channels
-Conversion of 290 acres of forested overbank wetlands to grassed uplands by filling with clean soil
-Disruption of an unknown acreage of unknown habitat for acquisition of clean fill for covering contaminated sediments in the containment area
-Loss of about 3.0 miles of stream bottom

Dredging of contaminated sediments (see Section 11.2)
-Commitment of 47 acres of habitat for access road construction
-Disruption of 7.8 miles (211 acres) of stream habitat
-Suspension of contaminated sediments
-Streamside vegetation altered for about 7.7 miles
-Removal of submerged snags for about 7.7 miles of stream bottom
-Disruption of about 7.7 miles of benthic habitat
-Suspension of contaminated sediments

11.11 ALTERNATIVE E: WITHIN-BASIN DIVERSION AND REMOVAL OF CONTAMINATED SEDIMENTS

Alternative E involves (1) the construction of a within-basin diversion channel through the Huntsville Spring Branch Floodplain, (2) dredging of the contaminated sediments from Huntsville Spring Branch's channel and overbank, and Indian Creek's channel, and (3) disposal of contaminated sediments in the Temporary Dredged Material Disposal Area. The major items of impact are listed below, and the acreages of habitat alterations are listed in Table III-30.

Major items of impact:

Construction of the within-basin diversion channel (see Section 11.4)
-Commitment of 503 acres to the diversion channel and dikes
-Replacement of about 4.5 miles of natural stream channel with an artificial channel.

Table III-29. Habitat Alterations Associated With Alternative D: Out-of-Basin Diversion and Containment of Contaminated Sediments

Tasks	Acreage Altered		
	Aquatic	Wetland	Upland
Construct Out-of-Basin Diversion Channel and Diversion Dikes and Construct Western Containment Dike	4.1	25.8	294.5
Cover Critical Overbank and Contaminated HSB Channel	47.	290.	
Construct TDMDA		0.6	184.4
Dredge HSB and IC Below HSBM 2.4	211.		
Construct Access Road Below HSBM 2.4	1.3	5.5	39.8
Additional Habitat Altered by Disruption of Hydroperiod	49.9	379.2	
TOTALS SUM OF TOTALS = 1,535	313.3	701.1	520.7

Table III-30. Habitat Alterations Associated With Alternative E: Within-Basin Diversion and Removal of Contaminated Sediments

Tasks	Acreage Altered Aquatic	 Wetland	 Upland
Construct Within-Basin Diversion Channel	15.0	73.4	44.7
Construct Diversion/Containment Dike (includes habitat alteration from disrupted hydroperiod)	60.6	233.3	76.0
Construct TDMDA		0.6	186.4
Dredge Overbank		290.	
Dredge HSB and IC Channels	259		
Construct Access Roads	3.4	22.1	41.2
TOTALS	338.0	619.4	348.3
SUM OF TOTALS = 1,305			

Dredging of contaminated sediments (see Section 11.2)
-Commitment of 67 acres of habitat for access road construction
-Commitment of 187 acres for underground storage of contaminated sediments, and disruption of 187 acres of habitat over the stored sediments
-Streamside vegetation altered for about 11.8 miles
-Removal of submerged snags for about 10.3 miles of stream bottom
-Disruption of about 10.3 miles of benthic habitat
-Suspension of sediments

11.12 ALTERNATIVE F: WITHIN-BASIN DIVERSION AND CONTAINMENT OF CONTAMINATED SEDIMENTS

Alternative F consists of (1) construction of a within-basin diversion channel, (2) containment of the contaminated sediments between HSBM 4.0 to HSBM 5.4, and (3) dredging the stream channel from HSBM 4.0 to ICM 0.0. The major items of impact are listed below, and the acreages of habitat alterations are listed in Table III-31.

Major items of impact:

Construction of within-basin diversion channel (see Section 11.4)
-Commitment of 503 acres of wetlands to the diversion channel and dikes
-Replacement of about 3.6 miles of natural stream channel with an artificial channel

Containment of contaminated sediments (see Section 11.6)
-Commitment of 290 acres of forested wetlands to grassed uplands
-Disruption of an unknown acreage of unknown habitat for acquisition of clean fill for covering contaminated sediments in the containment area

Dredging of contaminated sediments (see Section 11.2)
-Commitment of 59 acres of habitat for access road construction
-Disruption of 7.8 miles (211 acres) of stream habitat
-Suspension of contaminated sediments.

11.13 SUMMARY OF ENVIRONMENTAL IMPACTS OF THE ALTERNATIVES

Table III-32 summarizes the total acreages of aquatic, wetland, and upland habitats that would be disrupted for each of the six mitigation alternatives. Only one, the natural restoration option (Alternative A) will result in no habitat disruption, although the DDTR will continue to contaminate the environment. The out-of-basin diversion alternatives (C and D) appear to be the most environmentally damaging, since they would cause the greatest losses of aquatic and wetland habitats, the disruption of the greatest acreages, and the disruption of a large area (293 acres, in the out-of-basin diversion channel) that is presently unaffected by DDTR contamination. The within-basin diversion alternatives (E and F) would also result in significant acreages disrupted, although to a somewhat lesser degree than with the out-of-basin alternatives. The within-basin alternatives have the added attraction of not requiring the disruption of as much additional lands as would be needed for the out-of-basin diversion channel. Dredging and disposal appears to be the most environmentally attractive alternative. Dredging and disposal would remove the majority of the contaminated

Table III-31. Habitat Alterations Associated With Alternative F: Within-Basin Diversion and Containment of Contaminated Sediments

Tasks	Acreage Altered		
	Aquatic	Wetland	Upland
Construct Within-Basin Diversion Channel	15.0	73.4	44.7
Construct Diversion/Containment Dike (includes habitat alteration from disrupted hydroperiod)	60.6	233.3	76.0
Cover Critical Overbank		290.	
Cover Contained Channel	18.8		
Construct TDMDA		0.6	186.4
Dredge HSB and IC Below HSBM 4.0	240.0		
Construct Access Road Below HSBM 4.0	3.4	14.5	41.2
TOTALS SUM OF TOTALS = 1,298	337.8	611.8	348.3

Table III-32. Habitat Disruptions, in Acres, Expected from the Various Alternatives

Alternative	Acreage Disrupted			
	Aquatic	Wetland	Upland	Total
A: Natural Restoration	0	0	0	0
B: Dredging and Disposal	262	313[1]	228	803[1]
C: Out-of-Basin Diversion and Removal of Contaminated Sediments	313	684	495	1492
D: Out-of-Basin Diversion and Containment of Contaminated Sediments	313	701	521	1535
E: Within-Basin Diversion and Removal of Contaminated Sediments	338	619	348	1305
F: Within-Basin Diversion and Containment of Contaminated Sediments	338	612	348[2]	1298[2]

[1] These values would be reduced by 290 acres if only the channels are dredged (25 acres for the critical overbank, and 265 acres for the remaining overbank between HSBM 5.4 and 2.4).

[2] If the contaminated sediments downstream of HSBM 4.0 are disposed of in the channel within the within-basin containment area, then the Temporary Dredged Material Disposal Area would be unnecessary. This would reduce the total area disrupted by 187 acres, all but 0.6 acres (which is bottomland hardwood swamp) of which is uplands.

sediments, would result in the least amounts of aquatic, wetland, and upland habitats being disrupted. Another positive factor for the dredging and disposal alternative is that it results in a final aquatic environment which is probably the most compatible with the existing system.

12.0 PREDICTED EFFECTIVENESS OF MITIGATION ALTERNATIVES

There are several measures by which the effectiveness of a mitigation alternative can be estimated. These include the following:

1) Percent or mass of contamination contained in-place
2) Percent or mass of contamination removed and disposed of
3) Residual contamination left in the system and the potential for its mitigation by natural processes
4) Degree of short-term transport of DDTR downstream during implementation
5) The time required for DDTR levels in biota (particularly fish) to reach acceptably low levels.

The distinction is made between items 1) and 2) because there is an inherent difference in effectiveness between the two. Covering contaminated sediments in place can be assumed to be near 100 percent effective, provided proper long-term maintenance is implemented. Removing and disposing of contaminated sediments is subject to the following shortcomings which preclude its being 100 percent effective:

- Some degree of residual contamination will inevitably be left behind

- Short-term transport of DDTR to the TR will occur to an undetermined extent during dredging

- The potential for leakage or spillage during removal operations.

The degree to which these occur can be minimized by careful monitoring and control of the dredging operation. However, since they will inevitably occur to some extent, dredging and removal can be assumed somewhat less effective than in-place containment.

The effectiveness of any of the alternatives is effected by residual contamination which can result from (1) areas of contamination where no direct mitigation is attempted and (2) contamination remaining due to inefficiency in the mitigation technique applied. Obviously if a decision is made not to dredge the lower reaches of IC, the contamination left in this area will reduce the effectiveness of the alternative.

Item 4 pertains strictly to dredging. The degree to which downstream DDTR transport occurs depends on the alternative selected as well as turbidity control at the dredge head. A within-basin diversion will eliminate DDTR transport from the highly contaminated area within the containment dike, but will afford no protection outside the dike. The out-of-basin diversion can eliminate DDTR transport from areas upstream of Dodd Road as well as greatly reduce it below Dodd Road and in IC.

A comparison of effectiveness of alterntiaves (excluding any consideration of biota contamination) is given in Table III-33.

Finally, a key factor is the effectiveness of an alternative in reducing DDTR levels in fish to below the 5 ppm FDA guideline. Unfortunately, this is probably the most difficult measure of effectiveness to predict with accuracy. On the one hand one can state that removal or isolation of a high percentage of the DDTR in the HSB-IC system can, in the long term, only help the situation. Yet because of the high potential for significant fish contamination from even low residual levels of DDTR, one cannot easily predict how quickly positive results can be realized following a clean-up effort.

Several factors should be considered in attempting to judge how long it might take for DDTR levels in fish to be reduced to below 5 ppm. These include current contamination levels, method of contamination, degradation of DDTR by natural processes, effectiveness of DDTR removal, and rate at which fish can excrete or break down DDTR. In Appendix II, Section 5.3, these factors are considered in some depth. Channel catfish in Wheeler Reservoir downstream of IC appear to have DDTR concentrations on the order of 10 ppm due to very low level contamination of either or both sediment and water. Near IC DDTR levels in channel catfish are higher which may be due to higher localized sediment or water DDTR concentrations and/or to migration of fish in and out of IC. Nevertheless, it appears that for channel catfish bioconcentration of DDTR produces fish concentrations in excess of 5 ppm from extremely low environmental concentrations. Hence, it is not reasonable to expect channel catfish DDTR levels to drop below 5 ppm until environmental DDTR levels are reduced below what currently exists in the TR. Presently this level is below what might reasonably be expected to initially remain in IC and HSB after a mitigation alternative was completed. Further, these levels of DDTR in the TR water and sediment would still be present even if a mitigation alternative were completed. Following the completion of any of the alternatives except natural restoration, it is assumed that the flow of DDTR to the TR would be significantly reduced. With little or no "fresh" DDTR entering the river, it could be expected that existing concentrations would go down.

Unfortunately, no data exists regarding natural degradation rates for DDTR under conditions similar to those found in IC and TR. Data for breakdown rates in soils show figures ranging from less than that one year to greater than 30 years depending on a number of conditions (see Appendix I, Table I-5). Under the assumption that some mitigation action had essentially eliminated the movement of DDTR from IC to the TR and that natural breakdown in an aquatic environment might roughly parallel breakdown in the soil, significant reductions in DDTR might occur in roughly 1-30 years.

Since the uptake and reduction of DDTR in fish has been shown to occur in significantly shorter time spans than appear to be required for natural degradation of DDTR, it is assumed that the fish are at or near equilibrium with respect to DDTR in the environment (Macek and Korn, 1970; Macek <u>et al</u>., 1970; Jarvinen <u>et al</u>., 1976). Consequently, one

Table III-33. Predicted Effectiveness of Mitigation Alternatives

Alternative	Estimated % DDTR			Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
	Removed	Contained In-Place	Total		
A	0	0	0	100%	None
B	99.3	0	99.3	0.7% not isolated plus residual contamination left in all dredging areas	Potential exists during dredging of all areas
C	99.3	0	99.3	0.7% not isolated plus residual contamination left in all dredging areas. All residual contamination subject to low flow and increased sedimentation	Potential reduced or eliminated in Reach A, greatly reduced in Reach B, and reduced in Reach C.
D	4.4	94.9	99.3	0.7% not isolated plus residual contamination left in Reaches B and C. All residual contamination subject to low flow and increased sedimentation.	Potential eliminated in Reach A, greatly reduced in Reach B, and reduced in Reach C.
E	99.3	0	99.3	0.7% not isolated plus residual contamination left in all dredging areas. Residual contamination within diversion dike isolated from HSB flow.	Potential eliminated within containment dike; potential exists during dredging of all other areas.
F	8.3	91.0	99.3	0.7% not isolated plus residual contamination downstream from HSB Mile 3.9. Ponded area within diversion dike isolated from HSB flow.	Potential eliminated within containment dike; potential exists during dredging of all other areas.

Table III-33. Predicted Effectiveness of Mitigation Alternatives (Continued, Page 2)

Alternative	Estimated % DDTR			Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
	Removed	Contained In-Place	Total		
F[3]	8.3	91.4	99.7[4]	0.3% not isolated plus residual contamination downstream from HSB Mile 3.9.	Potential eliminated within containment dike; potential exists during dredging of all other areas.

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[1] Estimates for action alternatives assume mitigation of contamination, in the noncritical overbank.

[2] *Percentage of estimated total, 838 tons.*

[3] Using diversion containment area for disposal of dredged material.

[4] Ponded area within containment filled and covered, isolating an additional 0.4%.

would expect DDTR levels in fish to closely parallel reductions of DDTR in the environment.

If the assumptions and conditions noted above are valid, it might take from a relatively few to 30 or more years for DDTR levels in channel catfish in the TR to drop below the 5 ppm guideline following completion of one of the action alternatives. Further, since any of the action alternatives will leave at least some residual amounts of DDTR in IC above what currently exists in the TR, the channel catfish in IC can be expected to remain contaminated for even longer periods of time.

No difference between the action alternatives can be detailed regarding how quickly DDTR levels in channel catfish in IC and HSB can be reduced.

The natural restoration alternative is predicted to be ineffective in controlling DDTR contamination of the HSB-IC-TR system. A more complete explanation can be found in Section 9.1 of this Appendix.

REFERENCES

Barnard, W.D. 1978. Prediction and Control of Dredged Material Dispersion Around and Open-Water Pipeline Disposal Operations. Technical Report DS-78-13. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 24-35.

Bartos, M.J., Jr. 1977. Containment Area Management to Promote Natural Dewatering of Fine-Grained Dredged Material. Technical Report D-77-19:65-84. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 44-45.

Battelle Memorial Institute. 1978. The Feasibility of Mitigating Kepone Contamination in the James River Basin. Appendix A to the EPA Kepone. Mitigation Project Report.

Black, Crow, and Eidsness, Inc. 1976. Huntsville Area Wastewater Facilities Plan (201 Facilities Plan). Prepared by Kenneth D. Byrd, Inc. in association with BC and E, Inc. Grant No. C-010307-01. pp. 5-24, 12-4.

Brye, B.A. 1980. Personal Communication. Tennessee Valley Authority, Chattanooga, TN.

Burks, S.A., and R.M. Engler. 1978. Water Quality Impacts of Aquatic Dredged Material Disposal (Laboratory Investigations). Technical Report DS-78-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 20-21.

Byerly, D.W.. 1973. Report of Investigation. ORNL Salt Mine Repository. TVA Sub-contract 3740. pp. 2-4.

Chen, K.Y., B. Eichenberger, J.L. Mang, and R.E. Hoeppel. 1978. Confined Disposal Area Effluent and Leachate Control (Laboratory and Field Investigations). Technical Report DS-78-7. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 58-59.

Chipley, A.S. 1980. Personal Communication. State of Alabama, Solid Waste Division.

Choi, W. and K.Y. Chen. 1976. Associations of Chlorinated Hydrocarbons With Fine Particles and Humic Substances in Nearshore Surficial Sediments. Environmental Science and Technology. Vol. 10, No. 8: pp. 782-786.

Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill Book Company. New York, NY. PP. 2165-268.

Clore, W.J., W.E. Westlake, K.C. Walker and V. Boswell. 1961. Wash. State Univ. Agr. Exp. Sta. Bull. 627.

Dall, B.. 1980. Personal Communication. Redstone Arsenal Support Activity. To District Engineer, U.S. Army Engineer District, Mobile, AL.

Dawson, G.W. and J.L. Goodier. 1977. Evaluation of Alternatives For Removal/Destruction of PCB-Contaminated Sediments in Waukegan Harbor. Contract No. 68-03-02552 (T2010) Battelle, Pacific Northwest Laboratories, Richland, WA. pp. 80-86.

Dimond, J.B. 1969. DDT in Maine Forests - A Report to the 104th Maine Legislature. 13 pp.

Dimond, J.B., A.S. Getchell and J.A. Blease. 1971. Accumulation and Persistence of DDT in a Lotic Ecosystem. Jour. Fisheries Res. Bd. Canada, 28:1877-1882.

Duttweiler, D.W. 1970. Personal Communication. Unpublished letter to John C. Bryson, Director, Delaware Water and Air Resources Commission. Director, Southeast Water Lab, Athens, GA, FWPCA.

Duvall, D.S. and W.A. Rubey. 1976. Laboratory Evaluation of High-Temperature Destruction of Kepone and Related Pesticides. EPA-600/2-76-299. Report prepared for the U.S. Environmental Protection Agency.

Environmental Protection Service. Montreal, Quebec. 1978. Burning Waste Chlorinated Hydrocarbons in a Cement Kiln. Contract No. 68-01-2966. Report prepared for the U.S. Environmental Protection Agency,

Ferguson, T.L., F.J. Bergman, G.R. Cooper, R.T. Li, and F.I. Honea. 1975. Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides. Report to U.S. Environmental Protection Agency. EPA 600-2/75-041:78.

Forster, T. 1980. Personal Communication. State of Alabama Water Improvement Commission, Alabama.

General Electric Company. 1977. Research on Removal or Treatment of PCB in Liquid or Sediments Dredged From the Hudson River. Semi-annual Progress Report, July-December to New York State Department of Environmental Conservation. pp. 1-16.

Geological Survey of Alabama. 1975. Environmental Geology and Hydrology of Huntsville and Madison County, Alabama. Atlas Series 8:59.

Haliburton, T.A. 1978. Guidelines for Dewatering/Densifying Confined Dredged Material. Technical Report DS-78-11. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MD.

Harris, C.R. 1970. Persistance and Behavior of Soil Insecticides. In: Pesticides in the Soil, p. 58. Michigan State University, East Lansing, MI. p. 58

Hirsch, N.D., L.H.D. Salvo and R. Peddicord. 1978. Effects of Dredging and Disposal on Aquatic Organisms. USACOE, Dredged Material Research Program, Technical Report DS-78-5.

Hoover, R. 1980. Personal Communication. Pipe Systems Inc. Atlanta, GA.

Huang, J. and C. Liao. 1970. Adsorption of Pesticides by Clay Minerals. Journal of the Sanitary Engineering Division, Proc. ASCE. Vol. 96, No. SA 5:1057-1078.

Hulbert, S.H. 1975. Secondary Effects of Pesticides on Aquatic Ecosystems. Residue Reviews 57:81-148.

Jarvinen, A.W., M.J. Hoffman, and T.W. Thorslund. 1976. Toxicity of DDT Food and Water Exposure to Fathead Minnows. U.S. Environmental Research Laboratory. EPA-600/3-76-114. Duluth, MN

Jenson, R. 1980. Personal Communication. TJK Inc., North Hollywood, CA.

Johnson, R.E. 1976. DDT Metabolism in Microbial Systems. Residue Reviews. Vol. 61.

Johnson, S.J., R.W. Cunny, E.B. Perry, and L. Devay. 1977. State-of-the-Art Applicability of Conventional Densification Techniques to Increase Disposal Area Storage Capacity. Technical Report D-77-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Kearney, P.C., E.A. Woolson, J.R. Plimmer, and A.R. Isensee. 1969. Decontamination of Pesticides in soils. Residue Reviews. Vol. 29.

Krizek, R.J., B.J. Gallagher, and G.M. Karadi. 1976. Water Quality Effects of a Dredging Disposal Area. Journal of the Environmental Engineering Division, Proc. ASCE. [EE2, No. 12040]: 389-409.

Krizek, R.J., G.M. Karadi, and P.L. Hummel. 1973. Engineering Characteristics of Polluted Dredgings. EPA Grants 15070-GK and R-800948. Technical Report No. 1. Northwestern University, Evanston, IL.

Lacasse, S.E., T.W. Lambe, and W.A. Marr. 1977. Sizing of Containment Areas for Dredged Material. Technical Report D-77-21:23-109. U.S. Army Engineer Waterways Experimental Station, Vicksburg, MS.

Lee, G.F., M.D. Piwoni, J.M. Lopez, G.M. Mariana, J.S. Richardson, D.H. Homer, and F. Saleh. 1975. Research Study for the Development of Dredged Material Disposal Criteria. Contract Report D-75-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 218-220.

Macek, K.J., and S. Korn. 1970. Significance of the Food Chain in DDT Accumulation by Fish. J. Fish. Res. Board Can. 27:1496-1498.

Macek, K.J., C.R. Rodgers, D.L. Stalling, and S. Korn. 1970. The Uptake, Distribution, and Elimination of Dietary ^{14}C-DDT and ^{14}C-dieldrin in Rainbow Trout. Trans. Amer. Fish. Soc. 99:689-240.

Mang, J.L., J.C.S. Lu, R.J. Lofy, and R.P. Stearns. 1978. A study of Leachate From Dredged Material in Upland Areas and/or in Productive Uses. Technical Report D-78-30. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 47-259.

McCall, P.J., R.L. Swann, D.A. Laskowski, S.A. Vrona, S.M. Unger, and H.J. Dishburger. 1979. Prediction of Chemical Mobility in Soil From Sorption Coefficients. Agricultural Products Department, Dow Chemical Co., Midland, MI. pp. 1-12.

Meeks, R.L. 1968. The Accumulation of ^{36}Cl Ring-labeled DDT in a Freshwater Marsh. Journ. Wildlife Mgmt. 32(2):376-398.

Munnecke, D.M. 1979. Chemical, Physical, and Biological Methods for the Disposal and Detoxification of Pesticides. Residue Reviews. Vol. 70.

Nash, R.R. and E.A. Woolson. 1967. Persistence of chlorinated Hydrocarbon Insecticides in Soils. Science 157:924.

Nash, R.R. and E.A. Woolson. 1967. Persistence of Chlorinated Hydrocarbon Insecticides in Soils. Science 157:924.

Palermo, M.R. 1977. An Evaluation of Progressive Trenching as a Technique for Dewatering Fine-Grained Dredged Material. Miscellaneous Paper D-77-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M.R. 1980. Personal Communication. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Peterson, J.R., R.S. Adams, Jr. and L.K. Cuthomp. 1971. Soil Properties Influencing DDT Bioactivity. Soil Sci. Soc. Amer. Proc., 35:72-78.

Redstone Arsenal. 1979. Boring Logs of Observation Wells RS040 to RS071, Drilled by Testing, Inc. Report dated December 27, 1979.

Sanders, S. 1980. Personal Communication. Motorola Positioning Determining Systems, Scottsdale, AZ.

Searles, D. 1980. Personal Communication. Waterless Dredging Co., Mattoon, IL.

Shih, C.C., R.F. Tobias, J.F. Clausen, and R.J. Johnson. 1975. Thermal Degradation of Military Standard Pesticide Formulations. Contract No. DADA 17-73-C-3172. Report prepared for the U.S. Army Medical Research and Development Command, Washington, DC.

Stribling, J. 1980. Personal Communication. Ellicott Machine Corp. Baltimore, MD.

Swann, R.L., P.J. McCall, D.A. Laskowski, and H.J. Dishburger. 1979. Estimation of Soil Sorption Constants of Organic Chemicals by HPLC. Agricultural Products Department, Dow Chemical Company, Midland, MI. pp. 1-12.

Tennessee Valley Authority. 1977a. Low-Level Radioactive Waste Disposal. Mine Interment Alternative. Phases I and II.

Tennessee Valley Authority. 1977b. Low-Level Radioactive Wastes Disposal (LLRWD). Shallow Land Burial. Phases I and II Report. Site Evaluation.

U.S. Army Corps of Engineers; Mobile District. 1960. Boring Logs and Soil Profiles for Martin Road Extension, Redstone Arsenal, AL, Mobile, AL.

U.S. Army Corps of Engineers; Norfolk District. 1978. Remedial Conventional Measures for Capturing, Stabilizing, or Removing Kepone in Bailey Bay, Bailey Creek, Gravelly Run, and the James River, Virginia. Appendix B of the EPA Kepone Mitigation Feasibility Project Report: A120-A147, Norfolk, VA.

U.S. Army. 1977. Installation Assessment of Redstone Arsenal, Alabama. Record Evaluation Report No. 118. I22-I24. Chemical Demilitarization and Installation Restoration. Aberdeen Proving Ground, Maryland.

U.S. Army. 1980. Boring Logs of Monitoring Wells RS068, RS069, and RS070 Installed by Testing, Inc., Redstone Arsenal, AL.

U.S. Department of Agriculture. Soil Conservation Service. 1958. Soil Survey of Madison County, Alabama. Series 1947, No. 3. pp. 13-67.

U.S. Environmental Protection Agency. 1978. Proposed Hazardous Waste Regulations Under the Resource Conservation and Recovery Act. 43 FR 58946. Federal Register. Vol. 9, No. 34 (Dec. 18, 1978): 1583-1584.

U.S. Environmental Protection Agency. 1974. Regulations for Acceptance and Recommended Procedures for Disposal and Storage of Pesticides and Pesticide Containers. 40 CFR Part 165. Federal Register. Vol. 39, No. 3 (May 1, 1974):15238.

U.S. Soil Conservation Service. 1973. Rainfall Frequency Atlas of Alabama, Florida, Georgia, and South Carolina for Durations From 30 Minutes to 24 Hours and Return Periods From 1 to 100 Years.

Yule, W.N., M.J. Hildebrand, G.G. Smith and R.S. Fox. 1972. DDT in Forest Trees and Lumber. Bull. Environ. Contamination and Toxicology, 8(1):19-25.

Yu, K.Y. and K.Y. Chen. 1978. Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas. Technical Report D-78-43. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. pp. 49-50.