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DEPARTMENT OF THE ARMY

MOBILE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2288
MOBILE, ALABAMA 36628

JUL 3 1984

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May 4, 1984

REPLY TO
ATTENTION OF:
Environmental Quality Section

DACW01-79-C-0224
Revision Apr 84
for AD-A128023

TO ALL INTERESTED PARTIES:

In November of 1980 we sent you a copy of the Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters, Wheeler Reservoir, Alabama, prepared under contract by Water and Air Research, Inc. (W.A.R.) for the Mobile District.

In a detailed review of the report data in preparation for testimony in conjunction with a legal case, W.A.R. found that an error had been made in the calculation for the total number of tons of DDT in Huntsville Spring Branch (HSB) and Indian Creek (IC). According to Dr. James H. Sullivan, Project Manager for W.A.R., this error resulted from two causes: (1) a misinterpretation of the units for some of the data received from the Tennessee Valley Authority and (2) some wrong data being entered into the computer program that calculated the total DDT present. This error impacts all references to the total amount of DDT present at any particular location in the HSB-IC system. However, it has no impact on concentrations of DDT in sediments or on any of the impacts of DDT on fish or other species.

The main difference between the old and new figures is the total, 837 tons originally vs. 475 tons now. Another difference is that the new figures show that the majority of the DDT is in the channel, not the overbank. The relative amount of DDT in each stream reach has changed very slightly as follows:

Stream Reach	Old Data	New Data
Upstream of Dodd Rd. in HSB	95.9%	97.8%
Dodd Rd. to IC	3.1%	1.4%
Indian Creek	1.0%	0.8%

W.A.R. has considered the possible impact of these new figures on the clean-up alternatives proposed in 1980. Their conclusion is that there is no change. The most significant facts that led to the selection of these alternatives were: (1) that fish were highly contaminated in all parts of the HSB-IC system and even in the Tennessee River, (2) that a significant amount of the fish contamination appeared to be resulting in situ from very low sediment concentrations, and (3) that the concentrations of DDT in sediment in all parts of the HSB-IC system were well above that which would result in fish concentrations above 5 ppm. Hence, the alternatives that deal with clean-up of all contaminated parts of HSB-IC are still valid. This is not meant to imply that other alternatives could not be developed that might be appropriate, only that the error found in the original work does not impact the alternatives developed at that time.

In response to our request, W.A.R. prepared pages to be inserted in the report. These pages incorporate all changes resulting from correction of the sediment DDT calculation error as well as the errata sheets dated January 1981. The enclosed revision pages should replace all pages in the original document with corresponding page numbers.

We regret the error; however, we feel that it does not alter the basic conclusions of the 1980 report. If you have any questions about these revisions, please call Dr. Diane Findley at 205/694-3857 or FTS 537-3857.

Sincerely,

Willis E. Ruland
Chief, Environment and Resources
Branch

Enclosure

III. APPENDIX III: ALTERNATIVES FOR MITIGATION OF DDT CONTAMINATION IN HUNTSVILLE SPRING BRANCH AND INDIAN CREEK

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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; Hamaker, 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, 1970; 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 (Liechtenstein and Schulz, 1959; Liechtenstein 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. (1972)

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

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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.

Johnsen (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; Neudorf and Khan, 1975).

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.

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Table 1-6. 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, 1976

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*	4,426,600	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

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

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

Tab[illegible].0. Freshwater Fish Acute Values for DDT and [illegible]lites (Continued, Page 5)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (µg/l)	Adjusted LC50 (µg/l)	Reference
Goldfish, *Carassius auratus*	S	U	DDT	96	21	11.48	Macek and McAllister, 1970
Goldfish, *Carassius auratus*	S	U	DDT	96	76	41.55	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	27	14.76	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	32	17.49	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	180	98.41	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	40	21.87	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	35	19.13	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	21	11.48	Marking, 1966
Goldfish, *Carassius auratus*	S	U	DDT	96	36	19.68	Henderson, *et al.*, 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.*, 1977

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 Maki 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

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

Organism	Test Duration	Effect	Result (ug/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 californica*	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

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

Organism	Test Duration	Effect	Result (ug/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 Johnsen, 1969

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 (Stickel 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.

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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 noted 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 Prouty (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 ug/l to 0.3 ug/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).

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

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control levels of contaminants in human food and animal feed.

The action levels are established and revised according to criteria specified in Title 21, Code of Federal Regulations, Parts 109 and 509 and are revoked when a regulation establishing a tolerance for the same substance and use become effective.

Action levels and tolerances represent limits at or above which FDA will take legal action to remove adulterated products from the market. Where no established action level or tolerance exists, FDA may take legal action against the product at the minimal detectable level of the contaminant.

Action levels and tolerance are established based on the unavoidability of the poisonous or deleterious substance and do not represent permissible levels of contamination where it is avoidable.

The "Action Level" defined for DDTR in fish is 5.0 ppm. DDTR is defined as the sum of DDT, DDE, and DDD except "do not count any of the three found below 0.2 ppm" (FDA, 1978).

REFERENCES

The following references were not cited in the text but contain material that has some relevance to this appendix.

Hansen, et al., 1972; Janke and Fritsche, 1978; Lichtenstein, et al., 1977; Metcalf, et al., 1973; Metcalf, et al., 1975; Miles, et al., 1976; QueHee, et al., 1975; Somnunathan, 1973; Sundaram, 1974; Talekar, et al., 1977; Willis, et al., 1971; Wolfe, et al., 1977; Yadav, et al., 1976; Young, et al., 1971; and Yule, et al., 1972.

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. & 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. 1:181.

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. Prouty. 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 Cosmet. 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.

Desaiah, 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. Blease. 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. Peterle. 1971. Nature. 230:60.

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

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

Eksteat, 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.

Gaufin, 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. Dumas. 1972. Bull. Environ. Contam. Toxicol. 8:46.

Haegele, 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. Gotne, and M.O. Kindst. 1972. Nature 240:421.

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.

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

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.

REVISED APRIL 1984

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

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.

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-Calanorro. 1970. J. Agr. Food Chem. 18:520.

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

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

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

Macek, K.J. and H.O. 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.

Marking, L.L. 1966. "Evaluating p,p-DDT as a Reference Toxicant in Bioassays." An Investigation in Fish Control. U.S. Fish Wild. 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 (Unpublisned). "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, 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.

Moore, R.B. and D.A. Dorward. 1968. J. Phycol. 3 (Suppl.), p.7.

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

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

Ogilvie, D.M. and J.M. Anderson. 1965. J. Fish. Res. Board Am. 22:503.

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

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. Bousn. 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, L.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 .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. 1966. Trans. Am. Fish. Soc. 95:165.

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.

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.

Wilkes, 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.

Windholz, M., S. Budavari, L.Y. Stroumtsos, and M.N. Fertig. 1976. The Merck Index, 9th Ed., Merck & Co. Inc., Rahway, New Jersey.

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

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 (USAEHA, 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 (USAEHA, 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 ug/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 ug/l limit for discharge (USAEHA, 1969). Sometime later the same year the Federal Water

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1947 — DDT production begun by Calabama Chemical Corporation 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.

1948

1949

1950 — 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.

1951

1964 — Analysis of crows collected Patuxent Wildlife Researc DDT levels as high as 119 tissue and approximately 1 The DDT content of mamr 0.5 ppm in rabbit muscle opossum. The level in fat ra 348.5 ppm in these animals

1965 — DDT levels in waste ditch contained maximum of 2,409 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.

1966 — FWPCA showed mean levels of DDT in water below discharge from drainage ditch to be 5 micrograms per liter.

1967 — 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.

1968 — FWPCA shows HSB immediately below drainage ditch to have an average of 3.85 micrograms per liter DDT in water.

1969 — Federal Water Pollution Control Administration set standards for DDT in discharged wastewater at .020 micrograms per liter.

1970 — 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 295.

Olin installs carbon filter to reduce DDT levels in wastewater.

1971 — 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.

1972 — Plant demolished. Double-crested Cormorant absent from Wheeler Wildlife Refuge for past 9 years.

1973 — U.S. Army begins drinking w program at Redstone.

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

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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

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

9 — 1950 — 1951 — 1952 — 1953 — 1954 — 1955 — 1956

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.

DDT levels in waste ditch contained maximum of 2,409 ppm. TVA shows range in water t- ' i-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.

DDT in sediment at HSBM 4.7 estimated at 6500 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.

Wheeler Wildlife Refuge pe
97.5% reduction in the Dou
morant population. During a
from 1949 Cormorants annu
Refuge was reduced from 2C

5 — 1965 — 1964 — 1963 — 1962 — 1961 — 1960 — 1959

levels of DDT in
rom drainage ditch
ter.

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.

lant demolished. Double-crested Cormorant
bsent from Wheeler Wildlife Refuge for
ast 9 years.

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.

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

Abatement program suggested
tion of DDT from Redstone
Spring Branch. TVA data sl
TRM 275-292 contained abou
estimate that 4000 tons of DD
from HSBM 2.45 to 5.9. Duc
Wheeler Refuge showed DD
comparable to levels found
DDTR in waterfowl ranged fr.
ppm.

1972 — 1973 — 1974 — 1975 — 1976 — 1977 — 1978

Conservation re-
fish near Triana as
Decatur as high as
on Reservoir con-

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

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.

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DDT Manufacture at Redstone Arsenal

U. S. ARMY CORPS OF ENGINEERS, MOBILE I
Engineering and Environmental Study of DDT Contamination of
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...hieson Chemical Company pur... Alabama Chemical Co. and con... manufacture of DDT.

1954 1955 1956 1957

...ion con... ...ed north ...of heavy ...mmer of ...that the ...l macro... ...m pesti...

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.

1961 1960 1959 1958

...containing DDT on Redstone (area... ...re closed.

Abatemen 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.

1976 1977 1978 1979

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.

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.

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. Trichloroacetonitrile (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 extensive 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 (USCOE, 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, 1978c).

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 U.S. Army Environmental Hygiene Agency (USAEHA) 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	USCOE
9/65	HSBM 4.7	27.96	1.08	0.97	30.01	USCOE
9/65	HSBM 4.7	110.32	2.90	3.00	116.22	USCOE
9/65	HSBM 5.75	3.34	0.12	---	3.46	USCOE
9/65	ICM 4.6	1.3	0.53	2.51	4.34	USCOE
9/65	ICM 4.6	0.55	0.83	3.11	4.69	USCOE
9/65	ICM 4.6	0.52	0.24	1.06	1.82	USCOE
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; USCOE, 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	<1.0 ug/l (19 samples)				CDIR
1977	IC at Triana	---	---	---	9	USAEHA
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; USAEHA, 1978; CDIR, 1978a & b.

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	---	---	---	USAEHA
10/77	0	0.08	0.14	0.24	0.46	TVA
	0.91	1.2	---	---	---	USAEHA
	0.91	11.85	---	---	---	USAEHA
	0.91	28.90	---	---	---	USAEHA
	0.91	41.08	---	---	---	USAEHA
	0.91	40.48	---	---	---	USAEHA
	0.91	30.80	---	---	---	USAEHA
	0.91	41.47	---	---	---	USAEHA
	0.91	38.38	---	---	---	USAEHA
	0.91	33.89	---	---	---	USAEHA
	0.91	35.47	---	---	---	USAEHA
	0.91	33.23	---	---	---	USAEHA
	0.91	3.03	---	---	---	USAEHA
	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; USAEHA, 1977; TVA, 1977; CDIR, 1978(a) & (b); TVA, 1978(a); TVA, 1978(b).

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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	---	---	---	USAEHA
	1.0	32.66	---	---	---	USAEHA
	1.31	59.8	---	---	---	USAEHA
1977	1.7	1.48-33.6	---	---	---	TVA
12/77	2.0	1.39	---	---	---	USAEHA
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 ug/gm.

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

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

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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	---	---	---	USAEHA
	4.2	19.5	---	---	---	USAEHA
	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	---	---	---	USAEHA
	5.6	0.38	---	---	---	USAEHA
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

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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; USAEHA, 1977; TVA, 1978; TVA, 1978a; TVA, 1979b; 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 ug/gm were reported in 1978 (TVA, 1979b). In October 1977, concentrations up to 0.30 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 Sediments (Values in ug/gm)

Date	Mile Marker	Concentration in ug/gm				Data Source
		DDT	DDE	DDD	DDTR	
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	-	-	-	USAEHA
12/77	SE of Causeway	8.67	-	-	-	USAEHA
11/77	NW of Causeway	2.49	-	-	-	USAEHA
	NW of Causeway	2.30	-	-	-	USAEHA

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

Source: TVA, 1977; TVA, 1978(c); CDIR, 1978(a) & (b); USAEHA, 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-15. DDT Residues in Whole Fish Collected Between 1977-79 (FDA)

Species	Location	DDT	Concentration in ppm 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, 1979a.

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

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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.

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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	11.9
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, 1979b; CDC, 1979.

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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

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, 1979a

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

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

* nests locally

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Table II-26. Mammals Possibly Occurrina 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-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

[1]From Freeman, et al., 1979.
[2]USDI, 1979b.
[3]E=Endangered; T=Threatened; SSC=Species of Special Concern; NL=Not Listed.

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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

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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

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

[2]From USDI, 1979b.

[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, 1979b.

[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, 1979a). 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, 1979a). 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

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

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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 <u>DDTR DISTRIBUTION</u>

3.1 DDTR IN SEDIMENTS

3.1.1 <u>Indian Creek and Huntsville Spring Branch</u>

<u>Introduction</u>--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 475 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 465 tons or 97.8 percent of the total is contained within the sediments of Huntsville Spring Branch between Dodd and Patton Roads. Only 6.7 tons, or 1.4 percent of the total, is contained in Huntsville Spring Branch from Mile 0 to 2.4, and 3.7 tons, or 0.8 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

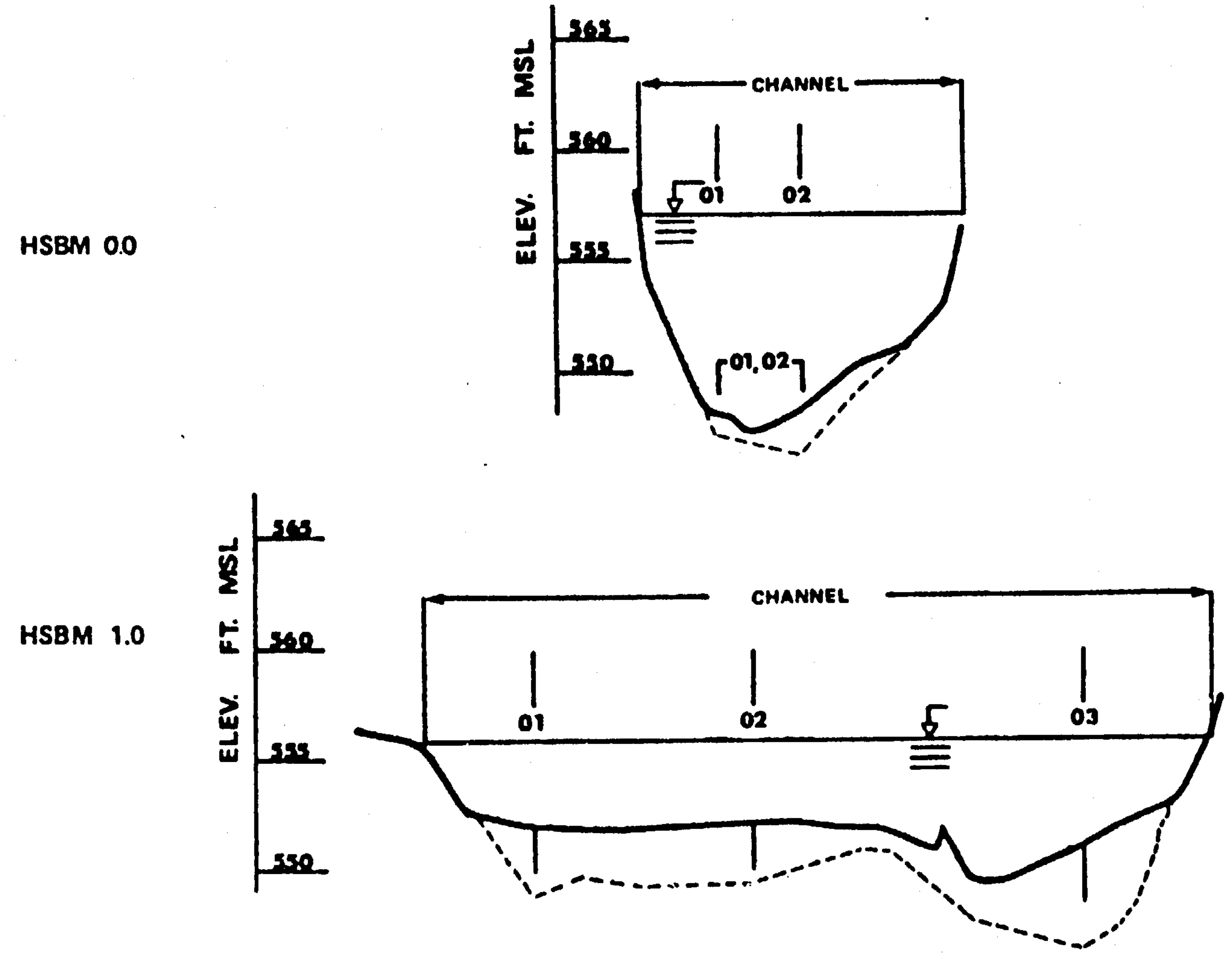

FIGURE II-4B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 0.0 and 1.0

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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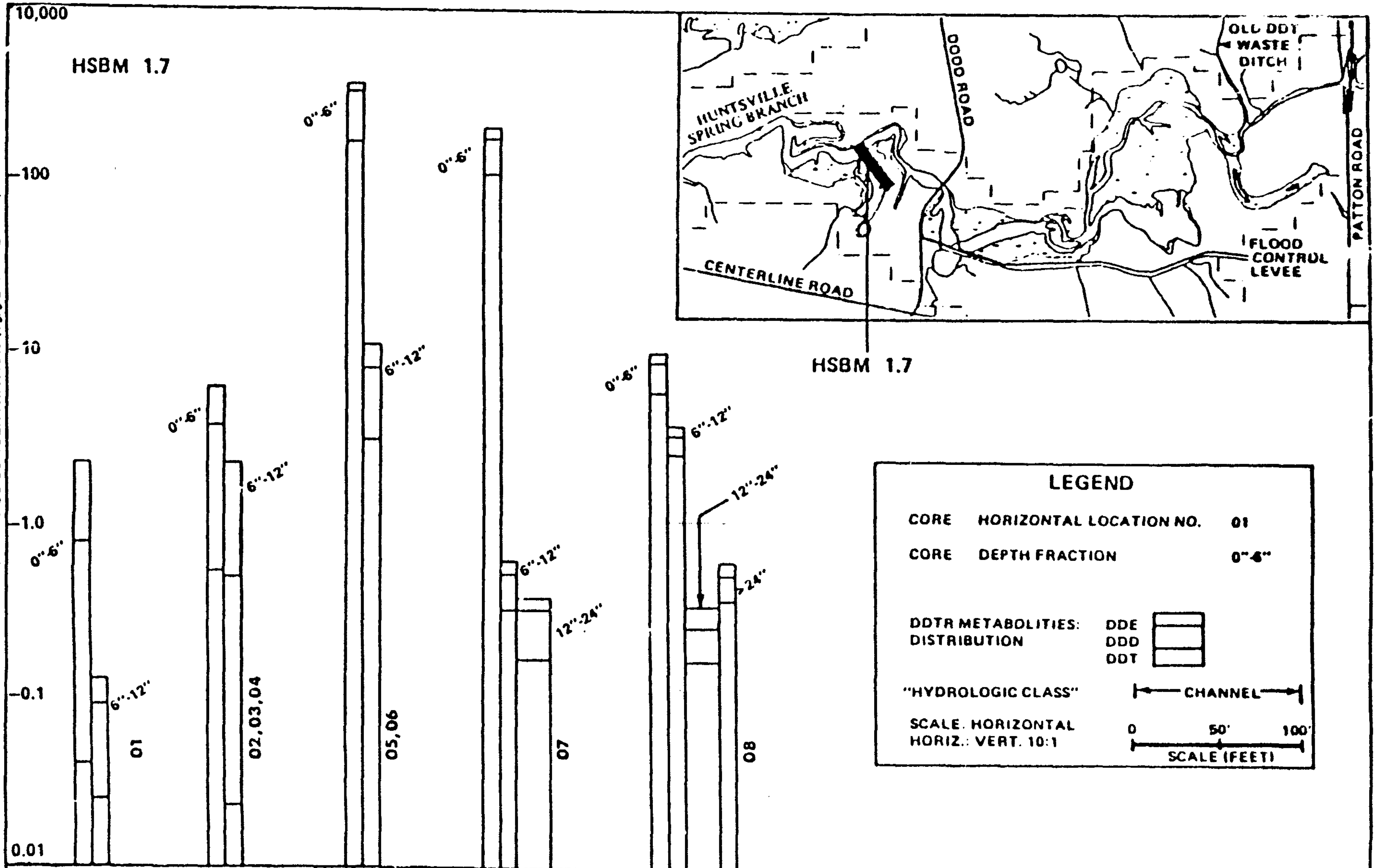

FIGURE II-5A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 1.7

SOURCE: WATER AND AIR RESEARCH, INC., 1980.

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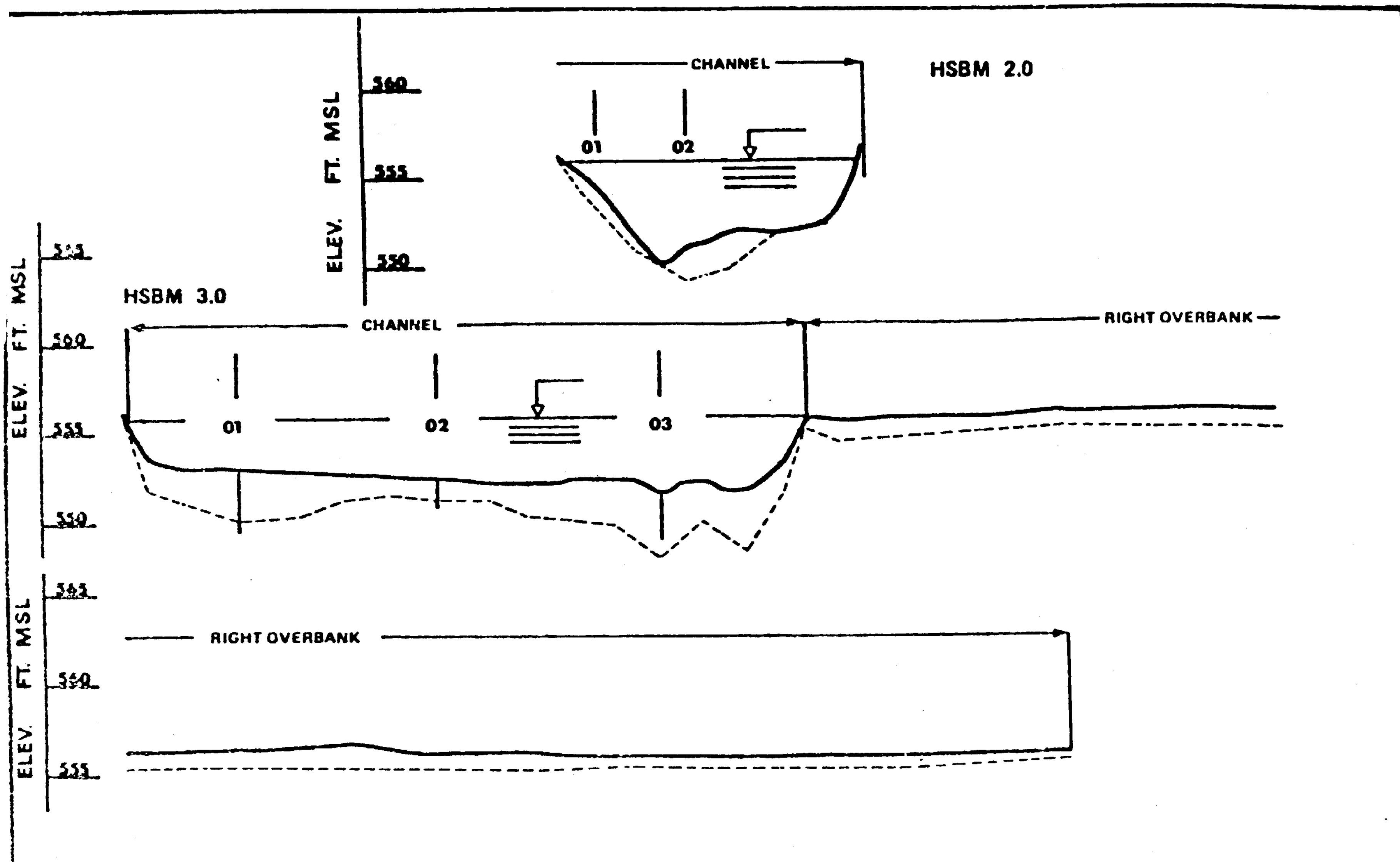

FIGURE II-6B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 2.0

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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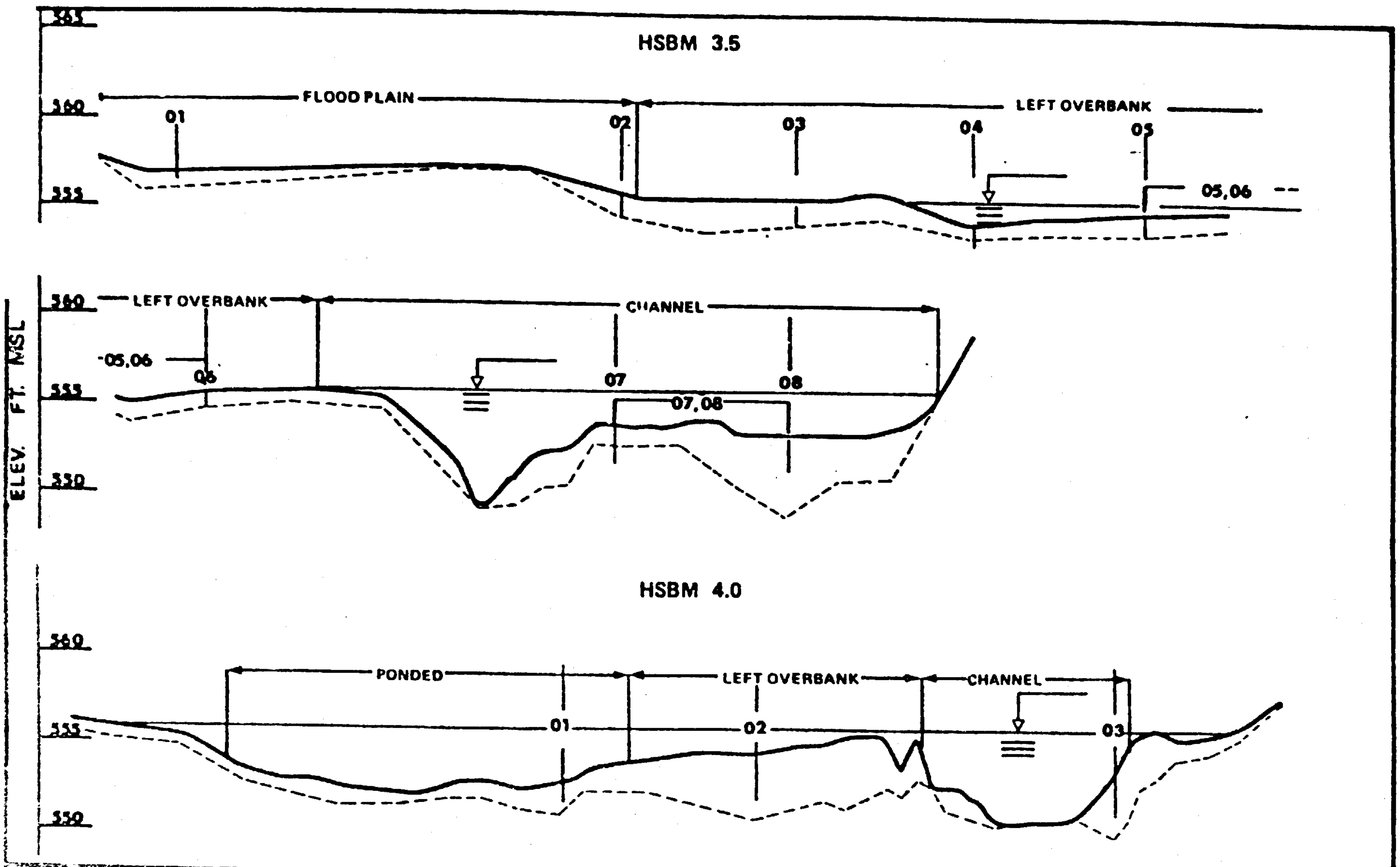

FIGURE II-7B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Miles 3.5 and 4.0

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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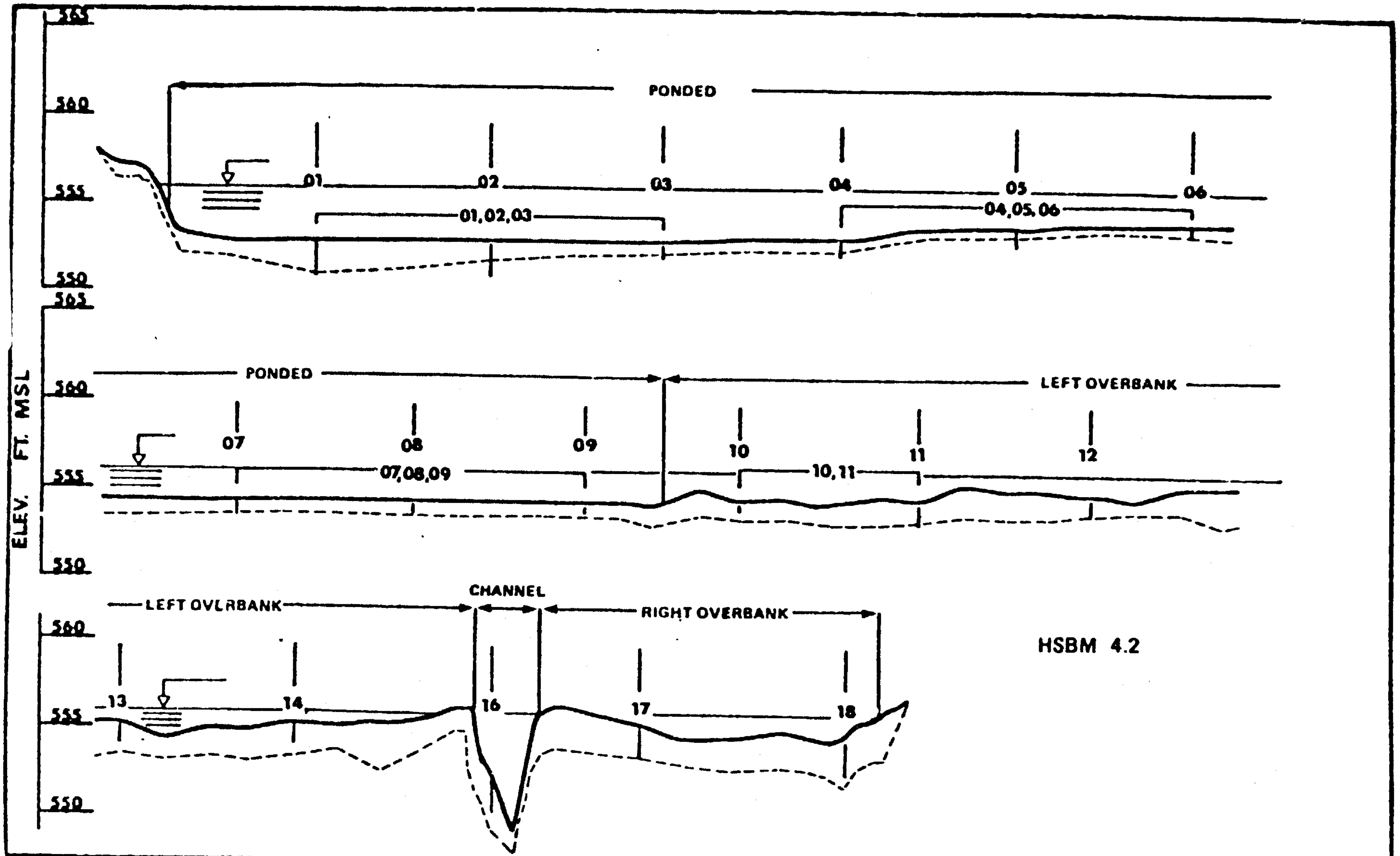

FIGURE II-8B. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 4.2

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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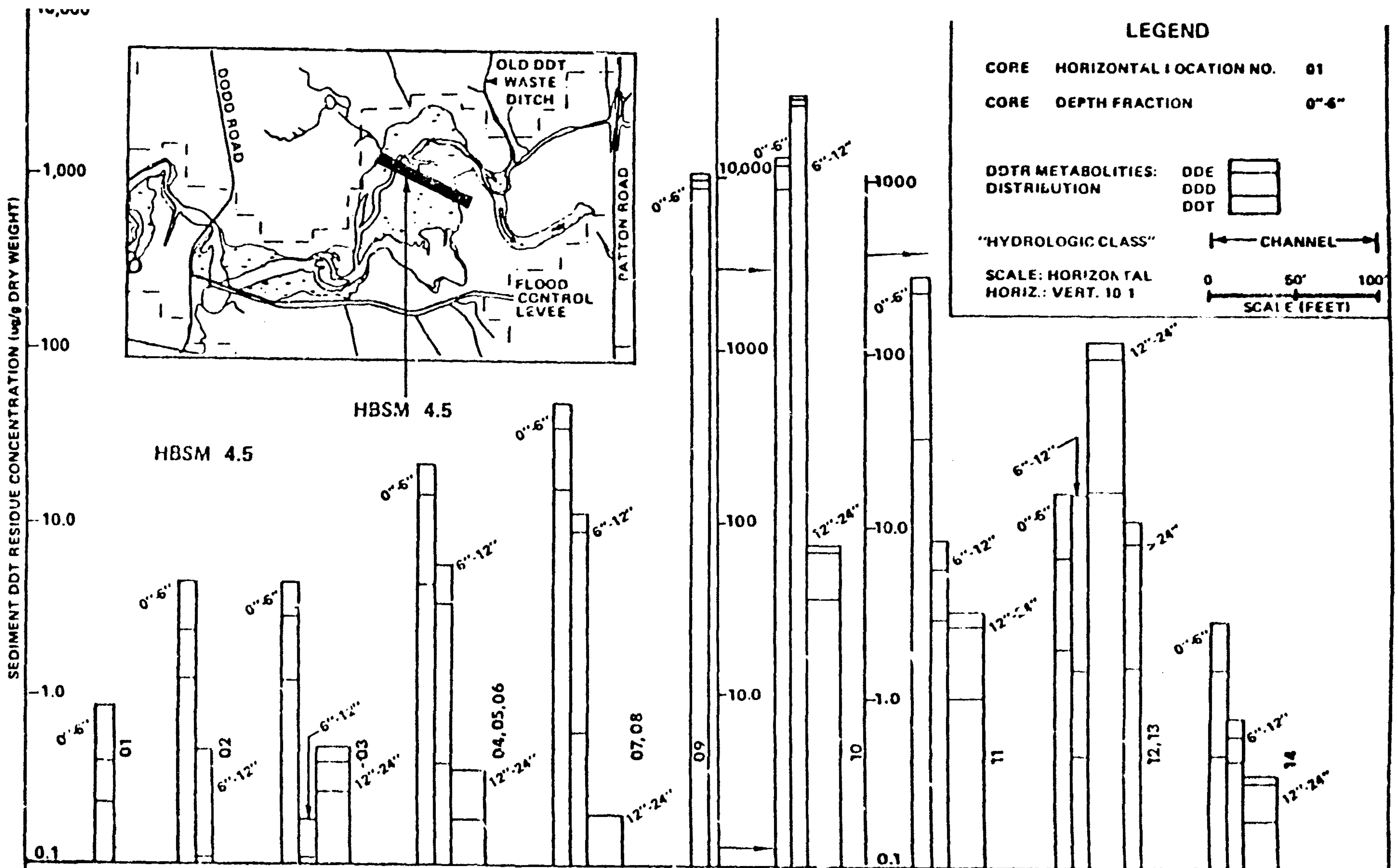

FIGURE II-9A. Horizontal and Vertical Distribution of Sediment DDT Residue Concentration in Huntsville Spring Branch - Mile 4.5

SOURCE: WATER AND AIR RESEARCH, INC., 1980.

U. S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT
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The total surface area assigned to each transect as well as surface areas in each of the above-mentioned hydrologic 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

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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:

$$\gamma_d = \frac{\gamma_s}{\left(\frac{W}{1-W}\right)\gamma_s + 1}$$

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):

$$c_c = (W\tau) - \Sigma\ c$$

where: c_c = calculated concentration
W = weight factor = number of cores in the composite
τ = 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-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 >47 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 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 0.001-0.5 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 are approximately 17 pounds per acre vs. 490 pounds per acre at the thalweg. Channel deposits in Indian Creek downstream of the confluence with Huntsville Spring Branch contain DDTR levels ranging from approximately 2.2 lb/acre at the confluence with the Tennessee River to over 0.5 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 0.002 to over 2 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 <2.3 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 <1 to 23 lb/acre. These levels are comparable to those found in Indian Creek downstream of Mile 3.0.

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 4-80 lb/acre, although at Miles 3.0 and 3.5 levels in excess of 200 lb/acre were observed. Nevertheless, all ponded areas sampled in the course of this study contained DDTR levels 2-3 orders of magnitude lower than those observed in the adjacent channel deposits. Although no off-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 57 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 475 tons of DDTR contained in the sediments of IC-HSB, 465 tons or over 97 percent is contained within the 2.7 mile stretch of HSB between Dodd Road and Patton Road. Of this total, 333 tons or 70 percent resides in the channel bottom deposits, 136 tons or 29 percent resides in the overbank sediments and the remaining 2.2 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 29 percent of the DDTR upstream of Dodd Road occurs in the overbank areas outside of the main channel, at least 131 tons or over 96 percent occurs within 200 feet of the channel. Furthermore, over 99 percent of the total DDTR in the overbank occurs upstream of Mile 3.5. Nearly 124 tons or 91 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 one million cubic yards.

Over 73 percent of the DDTR contaminating the surficial sediments of the IC-HSB system occurs within only 0.12 million cubic yards in the channel and near overbank areas of HSB between Miles 4.0 and 5.4. This volume of sediment constitutes only 3 percent of the total volume of DDTR contaminated sediment in the IC-HSB system. The next 20 percent of the

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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"	82.2	71.4	1.26	155
	6-12"	104	52.0	0.10	156
	12-24"	102	12.7	0.14	115
	>24"	39.1	0.21	NEGL	39.3
	Overall	327	136	1.50	465
HSBM 0-2.4	0-6"	4.25	0.22	0.15	4.62
	6-12"	1.65	0.06	NEGL	1.71
	12-24"	0.34	NEGL	NEGL	0.34
	>24"	0.03	NEGL	NEGL	0.03
	Overall	6.27	0.28	0.15	6.70
ICM 0-5.0	0-6"	1.40	0.14	0.57	2.11
	6-12"	0.69	NEGL	NEGL	0.69
	12-24"	0.85	NEGL	NEGL	0.85
	>24"	0.04	NEGL	NEGL	0.04
	Overall	2.98	0.14	0.14	3.69

NOTE: Includes estimated data.

NEGL = Negligible

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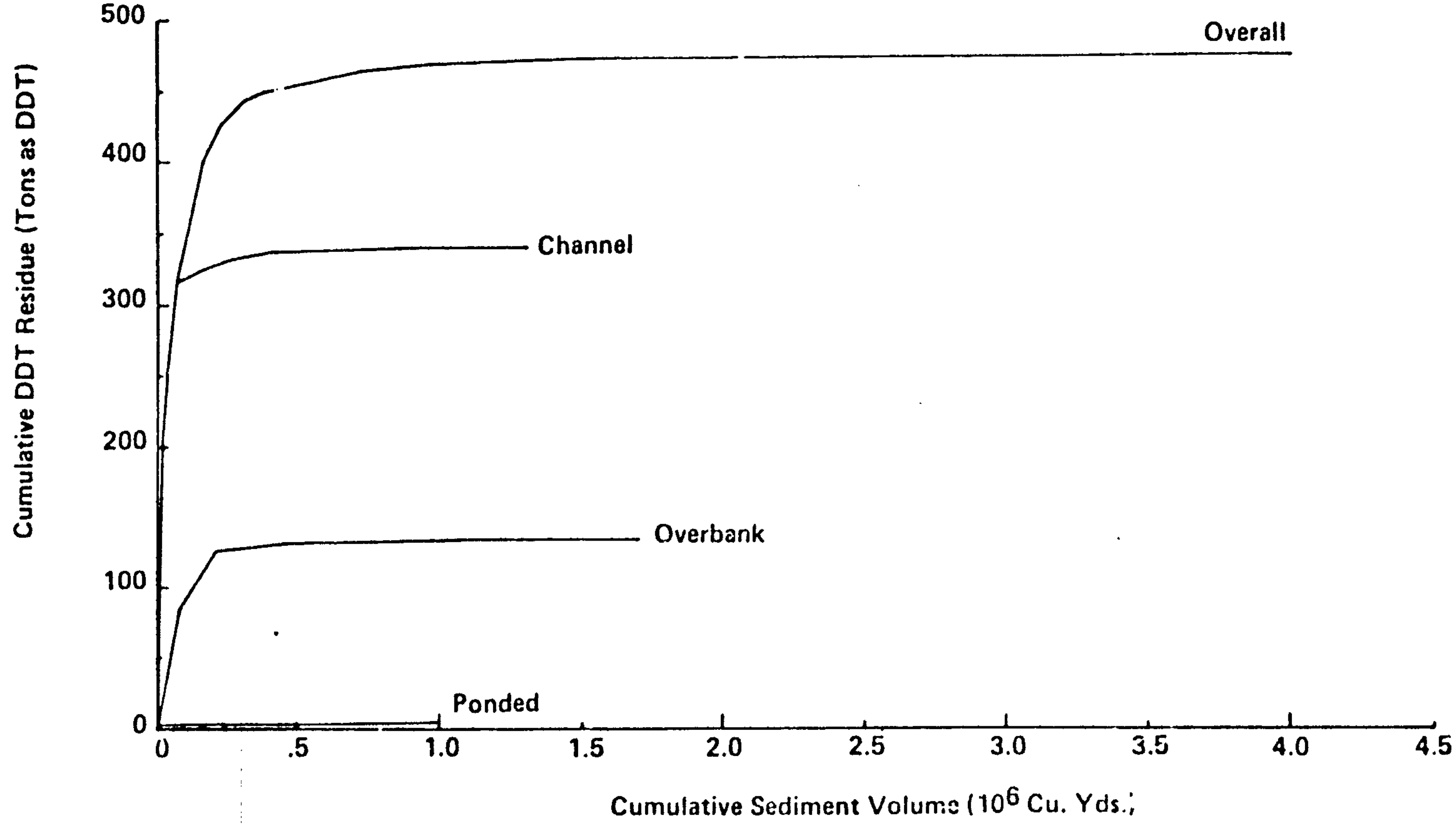

FIGURE II-17. Distribution of DDT Residue in the Contaminated Surface Sediments of Indian Creek and Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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DDT residue contaminates an additional 0.17 million cubic yards. Just under 99 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 0.75 percent of the DDTR contaminates a volume of sediment approximately equal to the volume contaminated by 99 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.

Nearly 67 percent of the total DDTR in the sediments of IC and HSB, or 318 tons, occurs as either the o,p- or p,p-isomer of DDT. The remaining 157 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 113 tons. Approximately 44 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 in 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

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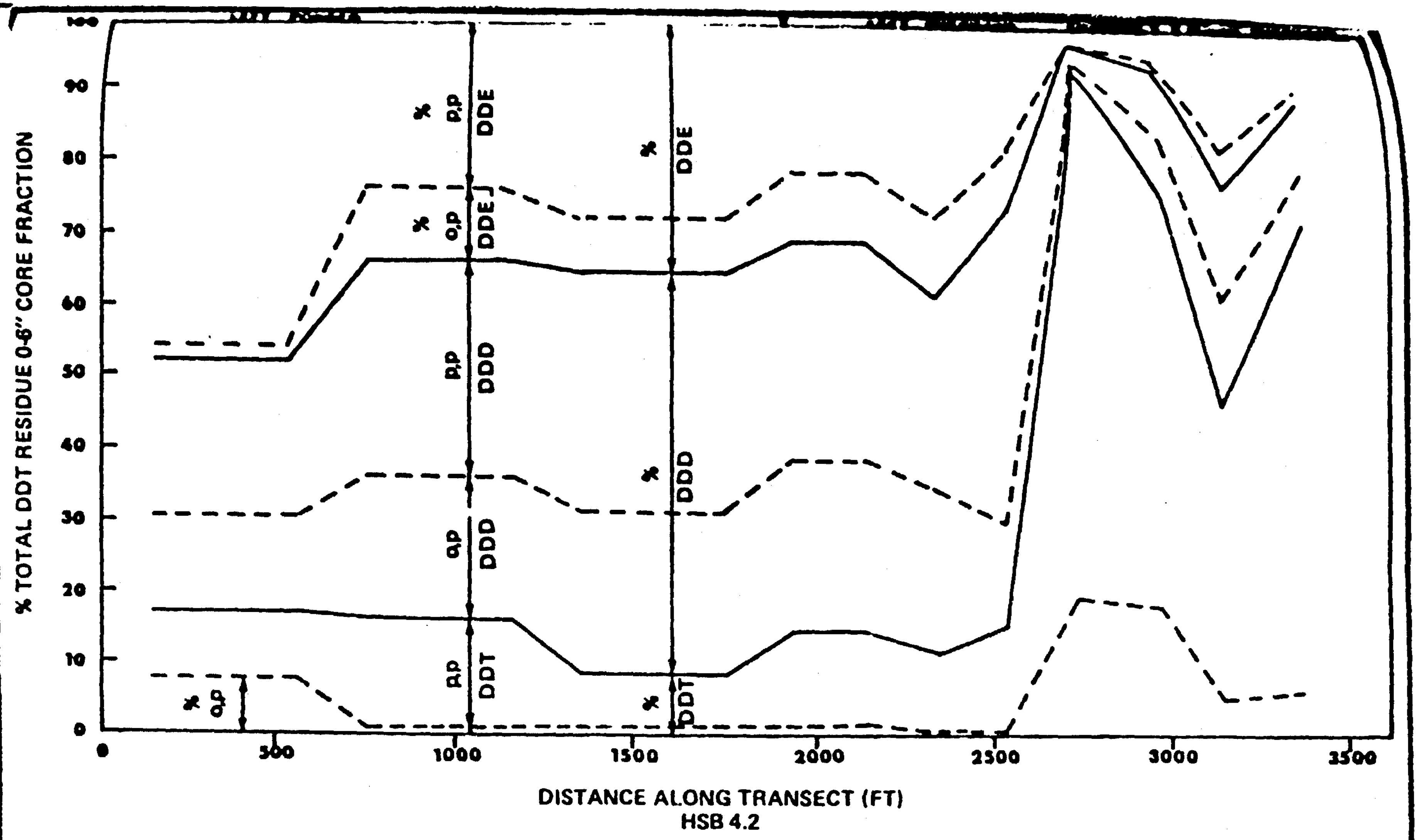

FIGURE 22. Relative Metabolite and Isomer Composition of the DDT Residue in the Surface 0-6" Sediments along the Sampling Transect at HSBM 4.2 (see Figure II-8)

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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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 moisture and volatile solids fractions, bottom area at high pool (i.e. elev. 556) measured DDTR values and the calculation procedure described in Section 3.1.1. The results are as follows:

	Total DDTR, lbs	
Wilson Reservoir	> 800	<1,780
Tennessee River 275-300	>2,790	<3,880
Paint Rock River	> 0.9	< 19
Limestone Creek	> 34	< 134
Spring Creek	> 45	< 81

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 17.8 ug/l as DDT was observed, of which over 80 percent was associated with suspended material >1u. 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.

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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	475	99.4
Sediments	TRM 275-300	1.4-1.9	0.29-0.40
Sediments	Wilson Res.	0.4-0.9	0.08-0.19
Sediments	Other TR Tribs.	0.04-0.12	0.008-0.025
Water	Wheeler Res.	<0.3-1	<0.063-0.21
Fish	Wheeler Res.	0.017-0.17	0.004-0.036
Macroinvertebrates	Wheeler Res.	0.007	0.001
Mammals	Wheeler Refuge	0.003	0.001
Birds	Wheeler Refuge	0.001	0.001
TOTAL		477-479	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 0.07 to 0.3 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 fiber 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

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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.

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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 flow component was contributed by flow originating outside of the IC-HSB drainage basin. The criteria employed in this classification was whether or not the stage in the TR at Whitesburg equalled or exceeded elevation 564 feet MSL, the elevation of the saddle of the sill separating the HSB drainage basin from the Unnamed Creek basin. 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 was treated in a manner 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 total 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 mi²		Station 4 HSBM 5.9 DA = 72.9 mi²		Station 3 HSBM 2.4 DA = 83.9 mi²		Station 2 ICM 4.6 DA = 153 mi²		Station 1 ICM 0.9 DA = 157 mi²	
	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 (mi²)
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

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>1u) 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 0.13 (0.07-0.27) 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 and 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>1u, 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

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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 relative DDE and DDT components of the suspended DDTR fraction are 6.5 and 1.3 times that of the corresponding dissolved/suspended DDTR fractions, respectively. 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

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 No. River Mile	Percent of Predicted Seasonal Total DDTR Loading: Winter (Nov-April) DDT	Winter DDD	Winter DDE	Summer (May-October) DDT	Summer DDD	Summer DDE	Annual DDT	Annual DDD	Annual DDE
Dissolved/Suspended DDTR Passing a Glass Fiber Filter (~1μ)									
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 (~1μ)									
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

load appears to be deficient in both the DDT 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 ug/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 ug/gm was noted with a reduction to 48.1 ug/gm at ICM 0.0. In the Tennessee River levels varied from 0.17 ug/gm to 4.6 ug/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.

Table II-50. 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

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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 (TVA, 1979b). July - Sept. data were collected as part of the current study (see Appendix V).

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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 31. 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:

Species	Distance from Release Point after 50 Days (miles) 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	8.6	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 et al., 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 study 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-52.

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	0.36	---	0.31	---
	N	1	---	1	---
Limestone	Mean	0.95	1.04	0.02	7.1
	N	2	4	1	3
Madison	Mean	3.43	4.84	---	6.09
	N	2	2	---	1
Jackson Marshall Morgan	Mean	0.52	---	0.33	0.44
	N	1	---	1	2
Green Sumter Choctaw	Mean	---	0.48	---	---
	N	---	2	---	---
Clarke Wilcox Washington	Mean	0.03	0.02	0.07	0.17
	N	1	1	1	2
Mobile Baldwin	Mean	---	0.06	---	0.19
	N	---	1	---	1
N. County Pool	Mean	0.81	0.127	0.69	---
	N	1	3	2	---
S. County Pool	Mean	0.08	---	0.7	---
	N	2	---	1	---
Controls[2]	Mean	0.07	---	---	---
	N	5	---	---	---

[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)

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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

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.

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.

Bender, E. 1979. Personal Communication.

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.

Bystrack, D. 1980. Personal Communication.

Center for Disease Control. 1979. Letter - Kreiss to Foster: DDT Levels in Fish.

Blank Pages

Chemical Demilitarization and Installation Restoration. 1978a. Sampling and Analysis Data Redstone Arsenal, AL.

Chemical Demilitarization and Installation Restoration. 1978b. DDT Contamination Data by Group Location.

Chemical Demilitarization and Installation Restoration. 1978c. Plan for DDT Migration Abatement, U.S. Army Missile Material Readiness Command, Redstone Arsenal, AL. 21 pp.

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.

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.

Geological Survey of Alabama. 1975. Environmental Geology and Hydrology, Huntsville and Madison Counties, Alabama. Atlas Series 8, 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 Wild.

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.

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. 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.

Thompson, E.G. 1980. Personal Communication.

U.S. Army Corps of Engineers (USCOE), Mobile District. 1966. Industrial Waste, Stream Pollution Survey, Redstone Arsenal, AL, Final Report.

U.S. Army Environmental Hygiene Agency (USAEHA). 1965. DDT Pollution at Redstone Arsenal.

U.S. Army Environmental Hygiene Agency (USAEHA). 1969. Report of Water Pollution Evaluation Visit. Project No. 24-009-69. Redstone Arsenal, AL. 24-28 February, 1969.

U.S. Army Environmental Hygiene Agency (USAEHA). 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 (USAEHA). 1978. Water Quality Engineering Special Study 24-0044-78. Evaluation of Environmental Degradation from Prior DDT Waste Disposal, Redstone Arsenal, AL.

U.S. Army Environmental Hygiene Agency (USAEHA). 1977. Drinking water Surveillance Program. Part of unidentified report.

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. 1964. 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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disposal sites. Similar studies by Chen et al. (1978) using laboratory columns indicated that levels of DDTR in final leachate were at concentrations less than 1 ppb. Parallel field studies at an inactive dredged material disposal site conducted by the same investigators showed non-detectable DDTR levels in the liquid phase of dredged materials and underlying soils, regardless of their organic content.

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 $R = \frac{\text{cm. moved by chemical}}{\text{cm. of water entering soil}}$

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k_d = sorption coefficient = $\frac{\text{ug chemical/g soil}}{\text{ug chemical/g water}}$,

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, K was determined to be 7.006 x 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 63u sieve. Volatile solids content of the sediment samples averaged 7.5 percent. The average in situ 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 63u 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 adsorptive 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.

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 5.4 (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 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 (tons)	Estimated % of Total[1] 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	327	69	100-30,000
		Critical Overbank[3]	364,500	364,500	131	28	100-15,000
		Noncritical Overbank[4]	879,500	879,500	5.15	1.1	5-40
		Ponded[5]	293,000	293,000	1.50	0.32	1-5
B	HSB Miles 2.4-0.0	Channel	408,000	408,000	6.27	1.3	10-400
		Overbank	313,000	313,000	0.28	0.06	2-7
		Ponded	231,000	231,000	0.15	0.03	1-5
C	IC Miles 0.0-5.4	Channel	615,000	615,000	2.98	0.63	10-30
		Overbank	50,000	50,000	0.14	0.03	0-1
		Ponded	614,000	614,000	0.57	0.01	0-1

1. "Total" refers to the total estimated DDTR contained in HSB and IC, 475 tons.
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 contain a significant fraction 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.

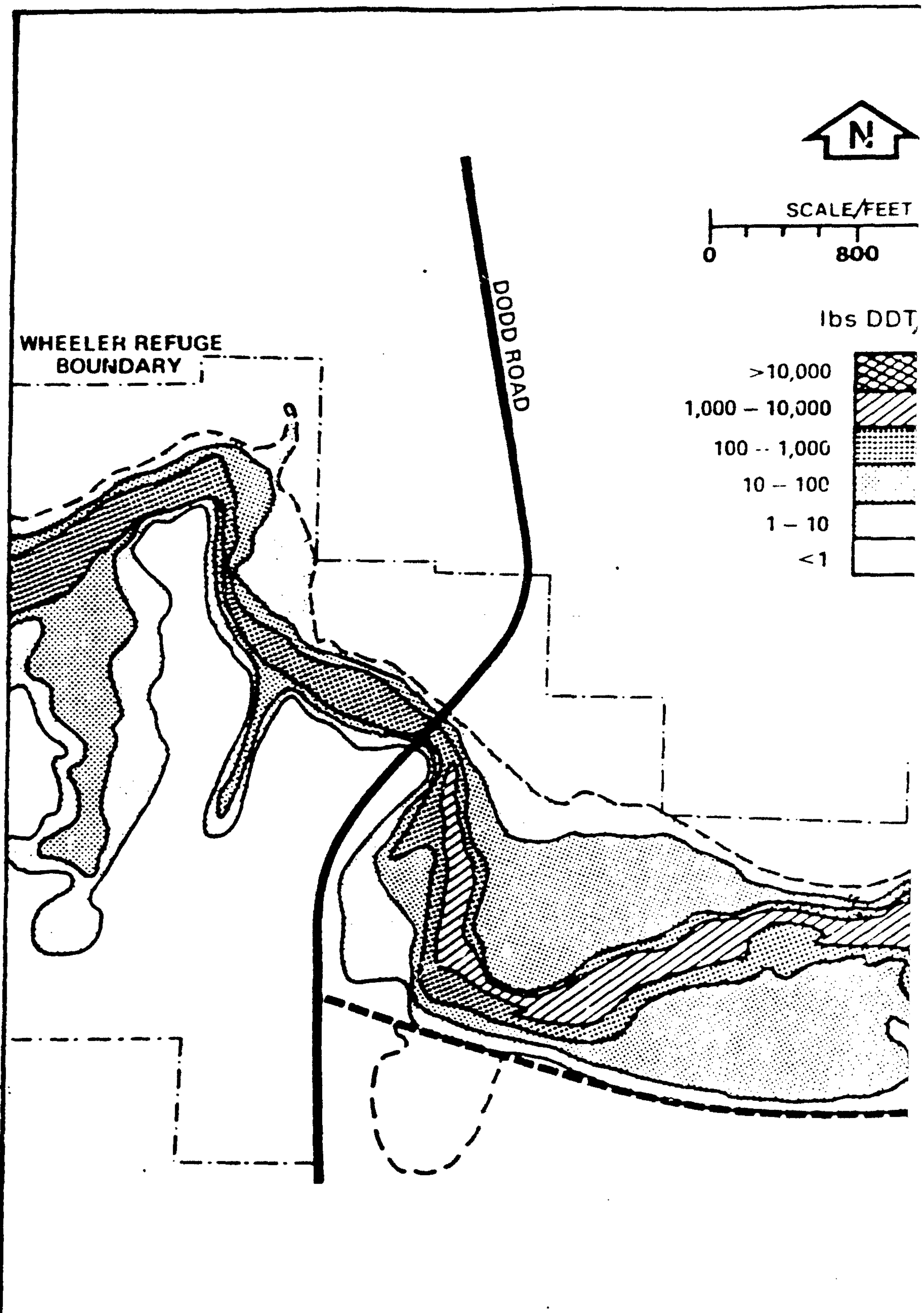
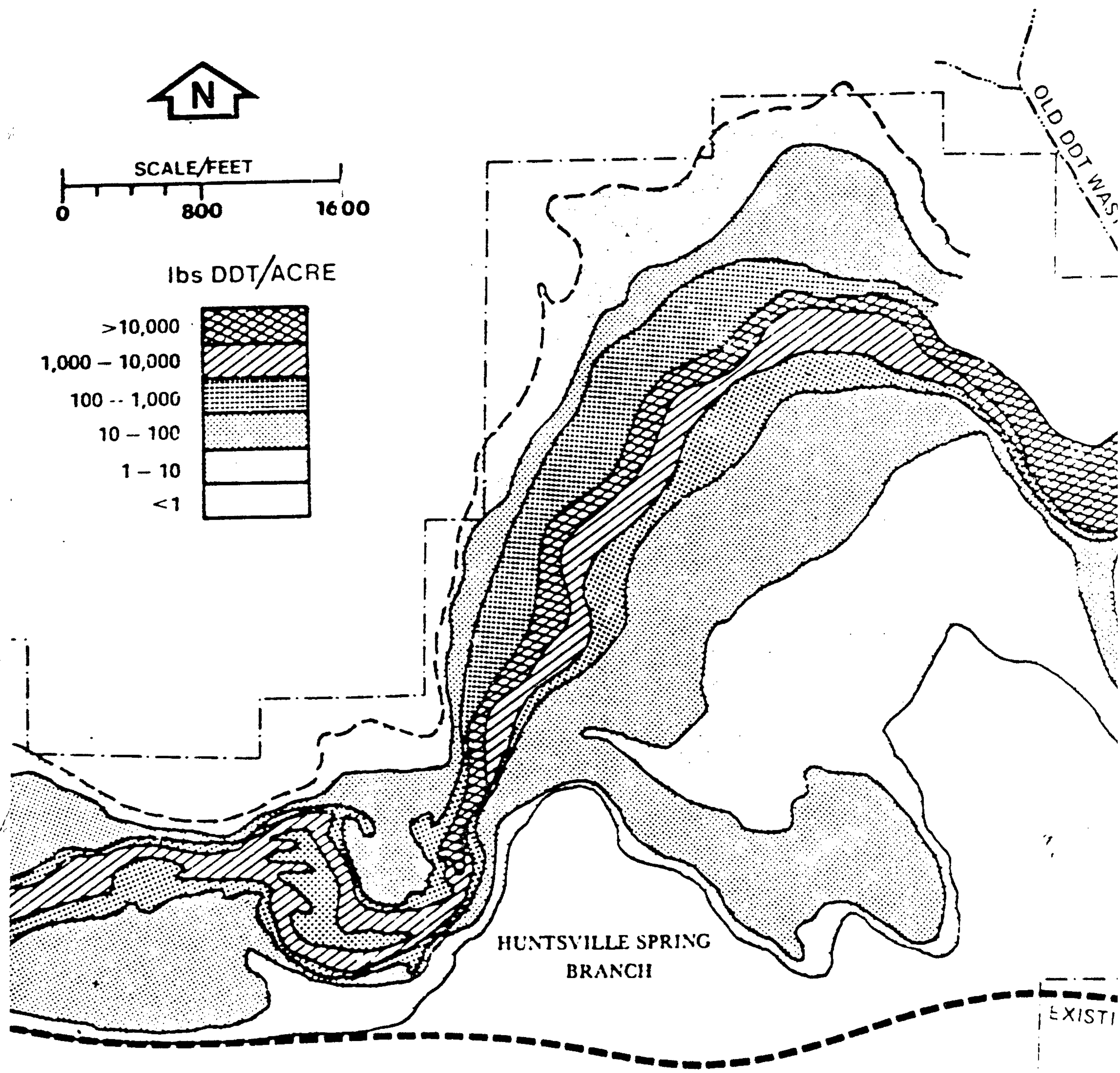


FIGURE III-2 Extent of DDTR Residue Contamination of Surface Sediments Huntsville Spring Branch Between Miles 1.5 and 5.6

SOURCE: WATER AND AIR RESEARCH, INC., 1980.



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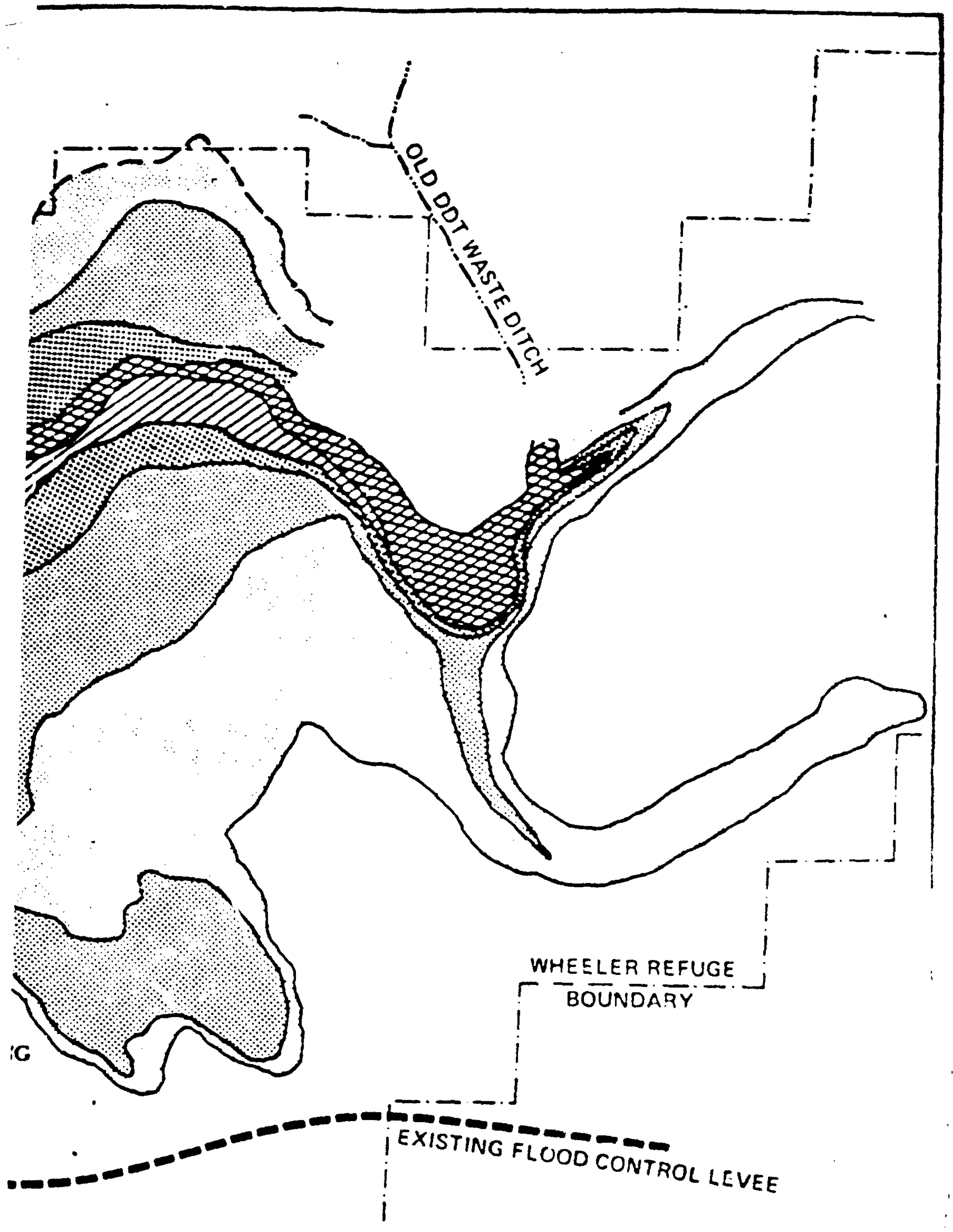

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that the critical overbank contains a significant fraction of the total DDTR in the HSB-IC system, therefore mitigation of contamination there is a primary concern. Contamination of the non-critical overbank of Reach A is typically 5-40 ppm DDTR, sufficient to warrant consideration of removing those sediments.

DDTR concentrations in overbank areas of 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 (TUMDA) designed to provide complete containment of the sediments and adequate treatment of the return water to HSB. The TUMDA 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 TUMDA 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	96.4
II	A,B	HSB Mile 5.6-0.0	636,000 - hydraulic 121,600 - dragline	97.7
III	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 121,600 - dragline	98.4
III plus Noncritical overbank	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 1,244,000 - dragline	99.4

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

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 Channel 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.

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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.

<u>Low-Turbidity Hydraulic Dredges--</u>

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.

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 be 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 less than 0.03 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 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

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 over-topped 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

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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

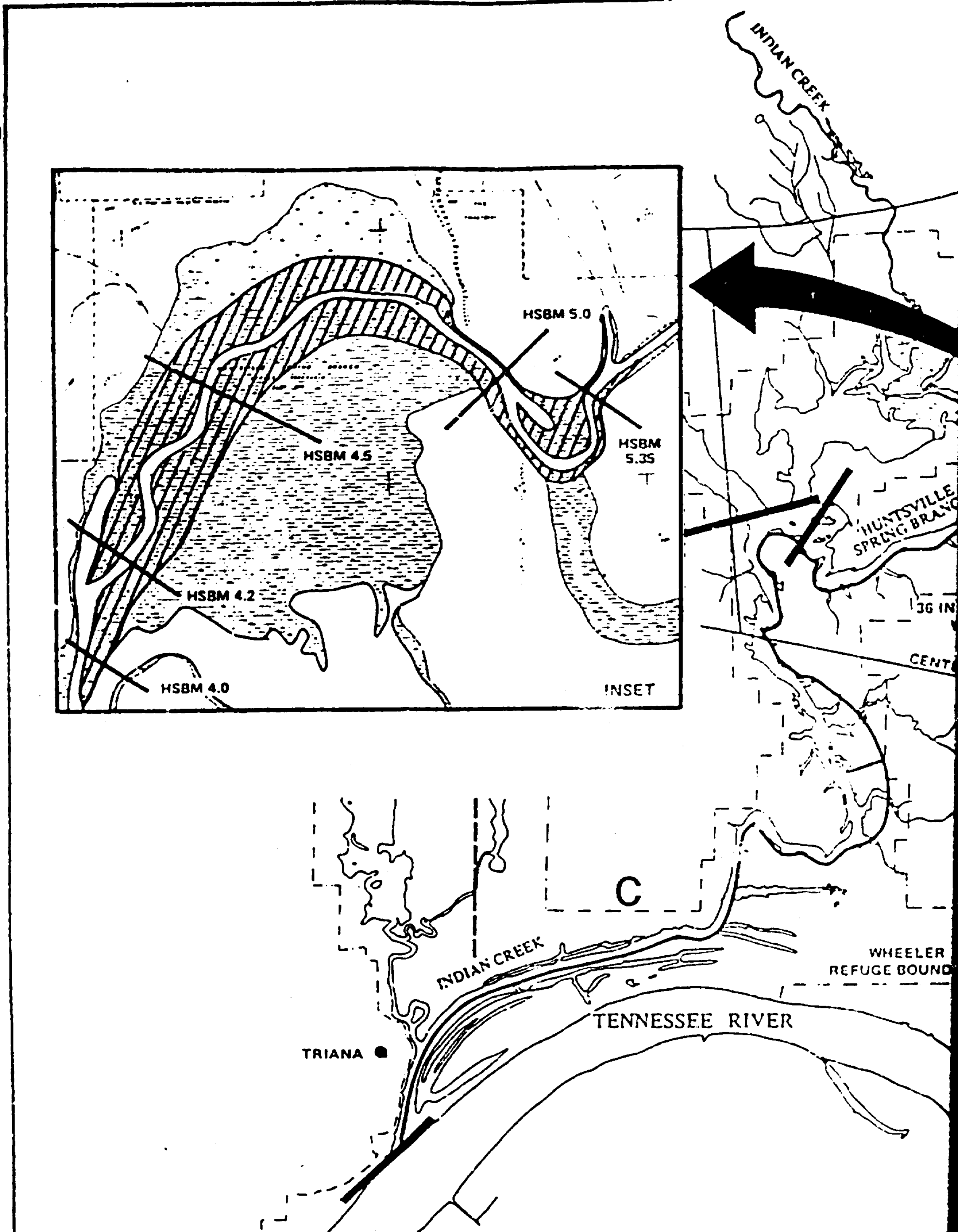

FIGURE III-7. Areal Plan for Hydraulic Dredging in Huntsville Spring Branch and Indian Creek

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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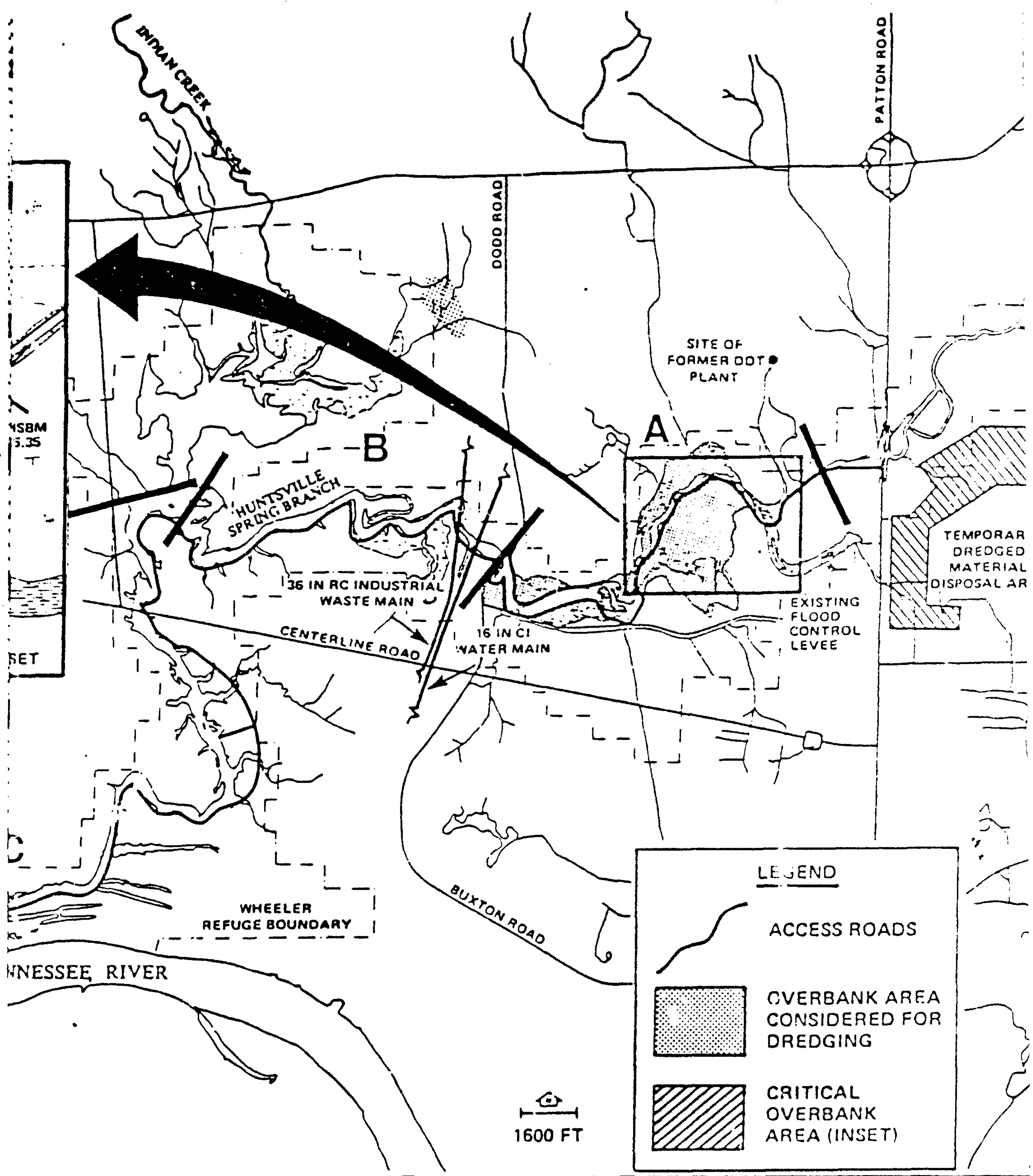

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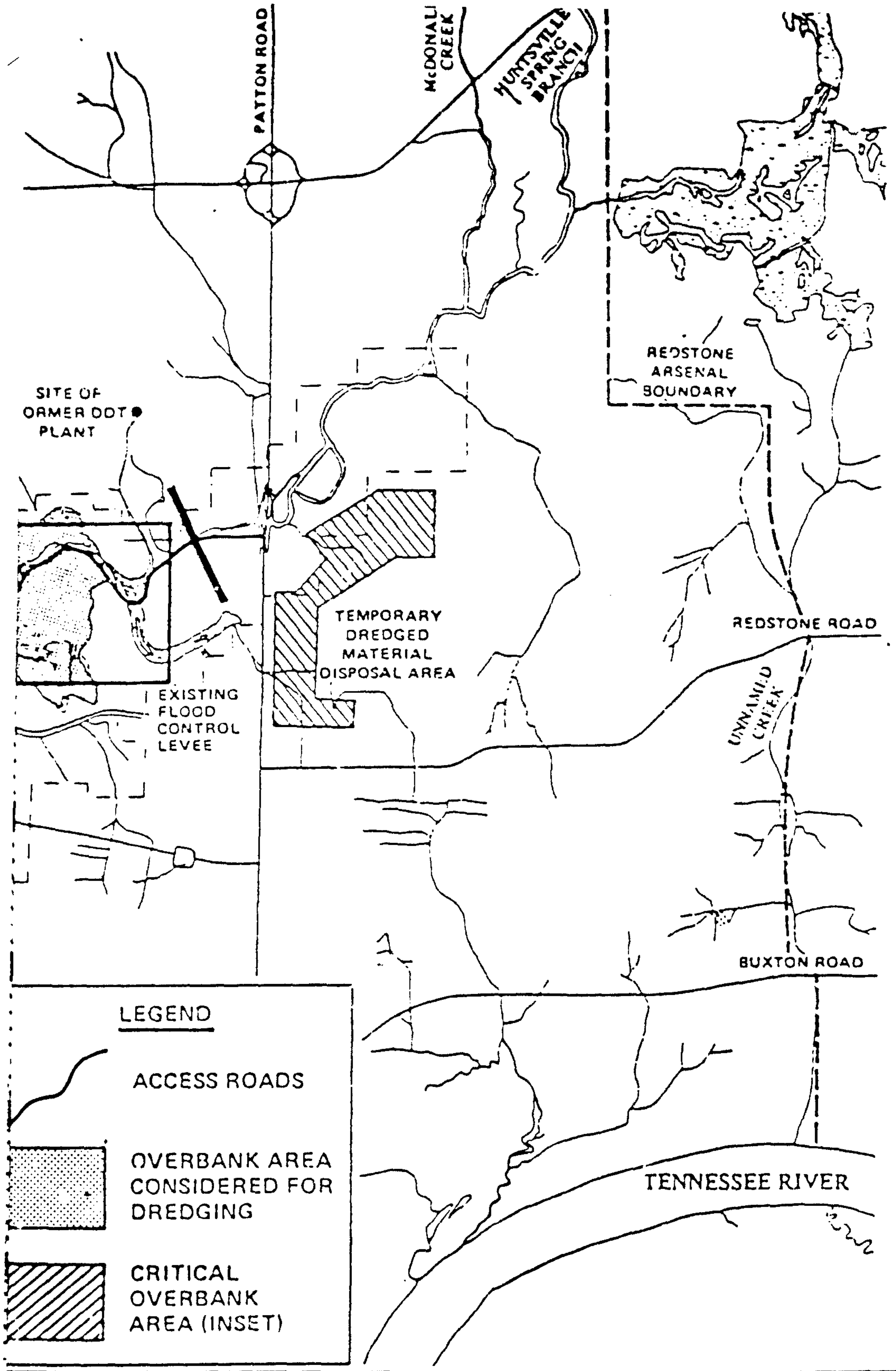

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flow in the discharge line (Stribling, 1980). Flow monitoring and control for all boosters could be performed at a single location with this type of system. The 14-inch Ellicott boosters upon which dredging costs are based have a discharge range of 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

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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 28 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 1.1 percent of the total DDTR in the HSB-IC system. In order to remove this 1.1 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 TOMDA (Figure III-5). Sediments from the critical overbank area will be 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 address 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

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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 significant 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 supplemental funding must be addressed as unavoidable adverse impacts in the Environmental Impact Statement.

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 11988 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 practicable 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 59 tons of DDTR left. At a 30-year half-life, 118 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 34 percent of the DDTR is in the top 6 inches of sediment and about 67 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 0.8 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

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

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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,
-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	75	2,500	188,000
-Access Road Construction	sq. yd.	20,000	5	100,000
-Dragline Dredging[7]	cu. yd.	364,500	5	1,823,000
-Hauling to TDMDA	cu. yd.	364,500	4	1,458,000
-Placement/Grading in TDMDA	cu. yd.	364,500	1	365,000
-Final Grading of Overbank	sq. yd.	364,500	1	365,000
-Seeding, Mulching, Fertilizing of Overbank	acre	75	1,300	98,000
SUBTOTAL				4,497,000
-20% Contingency				899,000
-15% Engineering Design, Supervision, and Administrative Costs				675,000
TOTAL CRITICAL OVERBANK REMOVAL COSTS				6,071,000

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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	182	2,500	455,000
-Access Road Construction	sq. yd.	85,000	5	425,000
-Dragline Dredging[7]	cu. yd.	879,500	5	4,398,000
-Hauling to TDMDA	cu. yd.	879,500	4	3,518,000
-Placement/Grading in TDMDA	cu. yd.	879,500	1	880,000
-Final Grading of Overbank	sq. yd.	879,500	1	880,000
-Seeding, Mulching, Fertilizing of Overbank	acre	182	1,300	236,000
SUBTOTAL				10,792,000
-20% Contingency				2,158,000
-15% Engineering Design, Supervision, and Administrative Costs				1,619,000
TOTAL				14,569,000
(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

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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)				72,026,000
(including noncritical overbank removal)				86,595,000

[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	30.91
II	A,B	42.53
III	A,B,C	72.03

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option	+ 14.57
-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

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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

Table III-13. Estimated Annual Expenditures - Alternative 6

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	9.4	8.1
4	25.5	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

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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

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

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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,[illegible]
-Relocate Power Lines	L.S.	---	---	20,[illegible]
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	1,026	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]				6,071.
(h) Hydraulic Dredging of HSB and IC Channel[5]				24,203,000

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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 TDMUA	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

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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				122,246,000
-With Dragline Option				127,395,

[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).

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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	122.25
Dragline Dredging between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	127.40

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option in Reach A	+ 14.57
-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.

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Table III-16. Estimated Annual Expenditures - Alternative C

Year After Start Time	Estimated Annual Expenditures (Millions of Dollars-1980) Without Noncritical Overbank Mitigation	With Noncritical Overbank Mitigation
1	5.2	6.0
2	5.2	6.0
3	13.8	12.0
4	19.8	17.6
5	38.1	38.1
6	13.1	13.9
7	9.7	16.3
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

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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	75	2,500	188,000
-Hauling Cover Material from Out-of-Basin Diversion	cu. yd.	243,300	4	973,000
-Placement and Compaction of Cover Material	cu. yd.	243,300	3.5	852,000
-Seeding, Mulching, Fertilizing Cover	acre	75	1,300	98,000
SUBTOTAL				2,211,000
-20% Contingency				442,000
-15% Engineering Design, Supervision, and Administrative Costs				332,000
TOTAL				2,985,000

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	182	2,500	455,000
-Hauling Cover Material From Out-of-Basin Diversion	cu. yd.	587,000	4	2,348,000
-Placement and Compaction of Cover Material	cu. yd.	587,000	3.5	2,055,000
-Seeding, Mulching, Fertilizing Cover	acre	182	1,300	237,000
SUBTOTAL				5,095,000
-20% Contingency				1,019,000
-15% Engineering Design, Supervision, and Administrative Costs				764,000
TOTAL				6,878,000
(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,
(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)				122,893,000
(Including Overbank Covering Option)				129,771,000

[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.

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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	122.89
Channel and Entire Overbank	129.77

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

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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	44.6	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 F 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,[illegible]
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]				6,071,000
(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,[illegible]
-20% Contingency				3,928,000
-15% Engineering Design, Supervision, and Administrative Costs				2,774,000

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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 TUMDA[7]				6,235,000
(h) Cultural Resources Activities	L.S.	---	---	1,170,000
Operation and Maintenance Costs				
(a) TUMDA 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				90,670,000
-With Dragline Option				91,431,000

[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 TUMDA 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	90.67
Dragline Dredging between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	91.43

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option in Reach A	+ 14.57
-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	31.0	26.6
6	11.1	12.5
7	8.3	10.2
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

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 8.1 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

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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 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 $1,170,000.

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.

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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]				2,985,000
(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

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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[illegible]
-Leachate Monitoring System	ft.	2,000	12	24,[illegible]
-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,[illegible]

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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)				88,316,000
(Including Noncritical Overbank Covering Option)				94,364,000
TOTAL COST FOR ALTERNATIVE USING CONTAINMENT AREA AS DISPOSAL SITE				88,355,000

[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.

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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	88.32
-including overbank covering option	94.36
Use Within-Basin Diversion Containment Area for Disposal Area	88.36

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

Start Time	Estimated Annual Expenditures Using Within-Basin Diversion Containment Area for Disposal (Millions of Dollars-1989)
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	11.0
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) <u>Contaminated Area</u> (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) <u>Dredged Material Disposal Sites</u> (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) <u>Out-of-Basin Diversion Corridor</u> (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) <u>Within Basin Diversion Channel and Containment Dike</u> (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.

a former lake will almost surely be found to contain archaeological sites.

10.2.3 Out-of-Basin Diversion Corridor (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 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.

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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 exist 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:

(1) sites deemed eligible for the Register because of in situ cultural deposits, and

(2) 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 <u>Contaminated Area</u> (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 HS3 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 preceding 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.

11.0 ENVIRONMENTAL IMPACTS OF THE ALTERNATIVES

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

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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	TOMDA Area D	1-MA-127	None	High	
Or Secondary Disposal Site	TOMDA 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	TOMDA Area D	1-MA-127	None	High	
Or Secondary Disposal Site	TOMDA 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 -122, -127
Includes Alt. B - Dredging	Huntsville Spring Branch Indian Creek Reach A-C	None	None	High	1-MA-96, -121, -134
And Disposal	TOMDA Area D	1-MA-127	None	High	
Or Alternative Disposal	TOMDA 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, -122, -127
And Dredging of Contaminated Sediments	Figure III- 26 Huntsville Spring Branch Indian Creek Reach B-C	None	None	High	1-MA-96, 0121, -134
With Primary Disposal	TOMDA Area D	1-MA-127	None	High	
Or Alternative	TOMDA 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, -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, -134

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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, 1980). 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, 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 (Seawell, 1980) 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 (Hooper, 1980; Lawson, 1980).

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

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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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 contamination 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.

A comparison of effectiveness of alternatives (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 et al., 1970; Jarvinen et al., 1976). Consequently, one

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Table III-33. Predicted Effectiveness of Mitigation Alternatives

Alternative[1]	Estimated % DDTR[2]			Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
	Removed	Contained In-Place	Total		
A	0	0	0	100%	None
B	99.4	0	99.4	0.6% not isolated plus residual contamination left in all dredging areas	Potential exists during dredging of all areas
C	99.4	0	99.4	0.6% 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	1.9	97.5	99.4	0.6% 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	99.4	0	99.4	0.6% 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	13.2	86.2	99.4	0.6% 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.

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Table III-33. Predicted Effectiveness of Mitigation Alternatives (Continued, Page 2)

Alternative[1]	Estimated % DDTR[2] Removed	Contained In-Place	Total	Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
F[3]	13.2	86.5	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.

1 Estimates for action alternatives assume mitigation of contamination, in the noncritical overbank.

2 Percentage of estimated total, 475 tons.

3 Using diversion containment area for disposal of dredged material.

4 Ponded area within containment filled and covered, isolating an additional 0.3%.

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

Atheson, T. October 31, 1980. Personal communication. Wheeler National Wildlife Refuge manager.

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.

Burrows, R.E. 1957. Special Scientific Report--Fisheries No. 24, U.S. Department of the Interior, Washington, D.C.

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.

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.

REVISED APRIL 1984

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.

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.

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, MO.

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

 REVISED APRIL 1984

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.

Hooper, J. October 31, 1980. Personal communication. Alabama Game and Fish Division.

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.

Hurlbert, 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

Jensen, R. 1980. Personal Communication. TJR Inc., North Hollywood, CA.

Johnsen, 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.

Lawson, C. October 31, 1980. Personal communication. Alabama Game and Fish Division.

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.

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. Cutkomp. 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.

Seawell, W. November 5, 1980. Personal Communication. Tennessee Valley Authority.

Shin, 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. 1979a. Low-Level Radioactive Waste Disposal. Mine Interment Alternative. Phases I and II.

Tennessee Valley Authority. 1979b. Low-Level Radioactive Wastes Disposal (LLRWD). Shallow Land Burial. Phases I and II Report. Site Evaluation.

U.S. Army Corps of Engineers; Mobile District. 1980. 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. Department of Agriculture, 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.

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.

Webb, William S. 1939. An Archaeological Survey of Wheeler Basin on the Tennessee River in Northern Alabama. Bureau of American Ethnolog, Bulletin 122. Washington, D.C.

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.