KALAMAZOO RIVER REMEDIAL ACTION PLAN

SECOND DRAFT

Michigan Department of Natural Resources

December, 1987

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1.0 EXECUTIVE SUMMARY

The lower Kalamazoo River has been targeted as an Area of Concern due to contamination of fish with polychlorinated biphenyls (PCBs). The Area of Concern includes the Kalamazoo River from Calkins Dam to Lake Michigan, the area of the river which is open to fish migration from Lake Michigan. As a result of the PCB contamination, a fish consumption advisory has been issued by the Michigan Department of Public Health. The PCB contamination and fish consumption advisory has been identified as the impaired use in the Area of Concern.

The specific goals of the Remedial Action Plan are to 1) as a minimum, reduce fish PCB concentration to levels which will eliminate the need for a fish consumption advisory, and 2) as a long term goal, reduce human exposure of PCBs to acceptable levels. These goals specifically translate to 1) fish tissue PCB levels less than 2.0 mg/kg and 2) water column PCB concentrations of 0.012 ng/1, respectively.

Concentrations of PCBs in fish vary depending upon the species, but generally the most contaminated fish is the carp, with an average total PCB concentration of 3.46 mg/kg in 1986. Ongoing fish sampling and analyses has found no significant decline in fish PCB concentrations with time, thereby indicating the need for further remedial actions.

Water PCB concentrations in the Area of Concern are generally in the range of 40-80 ng/1 (parts per trillion). Sediment total PCB concentrations are usually less than 1.0 mg/kg (part per million).

The total PCB load to Lake Michigan from the Kalamazoo River has been estimated to be 217 pounds per year. The Kalamazoo River loading accounts for about 13% of the total load and 30% of the tributary/point source load to Lake Michigan.

The principle source of PCB contamination has been identified as the contaminated sediments in the Kalamazoo River and Portage Creek upstream of the Area of Concern. The mass of PCB contained in these sediments has been estimated to be over 230,000 pounds. These sediments continue to erode, resuspend or dissolve PCBs into the water column and be transported downstream.

Since PCBs were identified as a problem in 1971, several actions have been taken to improve conditions (Table ES-1). The direct discharge of PCBs has been substantially reduced due to the PCB ban, originally under Michigan law and now nationwide under the Toxic Substances Control Act. The direct discharge of PCBs is not authorized in any of the NPDES permits for the Kalamazoo River. A specific requirement to reduce the discharge of PCBs is included in the City of Kalamazoo's and Otsego's NPDES permits. Both cities have submitted a long term PCB reduction plan to the Michigan Department of Natural Resources as fulfillment of this requirement.

To address the remaining problem of sediment PCB contamination affecting about 80 miles of the Kalamazoo River, the Michigan Department

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of Natural Resources performed a feasibility study of remedial alternatives. This study included developing a mathematical model of the Kalamazoo River and Portage Creek relative to PCB contamination, collecting data as necessary for model simulations, screening of remedial technologies and an evaluation of each remedial action alternative. Numerous remedial actions were considered in this study. The relative effects of each remedial action were evaluated using a mathematical model, which simulated long term changes in PCB levels in the sediment, water column and fish of the river system. Based on this evaluation, the following recommendations were made:

- Some remedial action should be taken at Portage Creek/Bryant Mill Ponds. Such an action would have the greatest effect in reducing human exposure to PCBs and would decrease PCB levels in fish throughout the downstream reaches.
- Better management of the Allegan City Dam impoundment is needed. The practice of drawing the dam down should be discontinued since an uncontrolled release of PCBs to Lake Allegan and downstream reaches results.
- The removal of remnant dam structures and isolating the contaminated sediments at the Plainwell, Otsego and Trowbridge Dams is also recommended. If properly implemented, this action would result in a lowering of the river channel, which would have beneficial environmental effects since the exposed contaminated sediments above the river banks would be further isolated from the river.

All other actions on the Kalamazoo River were considered less cost effective due to the high costs of implementation and/or conditional due to uncertainties in the predictions. Dredging may be a preferred option at Allegan City Dam and possibly Lake Allegan. However, since this type of remedial action is very costly, further studies are recommended to evaluate this option.

Several steps have been taken by the State of Michigan to implement these recommendations. The State has identified Allied Paper Incorporated as a potentially responsible party for the PCB contamination of Portage Creek/Bryant Mill Pond. The State gave notice on August 29, 1986, of its intent to file a civil action against SCM Corporation (owner of Allied Paper), Allied Paper Incorporated, and other property owners along Bryant Mill Pond. A complaint has been filed by the State of Michigan in United States District Court pursuant to the Comprehensive Environmental Response, Compensation and Liability Act, the Resource Conservation and Recovery Act, the Federal Water Pollution Control Act, and the Toxic Substances Control Act. The State seeks injunctive relief to abate and remedy the release of hazardous substances into the environment, declaratory relief, damages, civil penalties, cost of litigation, reimbursement of state response costs and all appropriate relief.

The Michigan Department of Natural Resources (MDNR) has removed the superstructures of the Plainwell, Otsego and Trowbridge Dams. This is the first step toward total removal of these dams and contaminated sediments. Funds have been secured ($2.9 million) under State Act 307 to

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TABLE ES-1

Kalamazoo River PCB Actions

Date	Action
1971	PCB problem identified in the Kalamazoo River and Portage Creek
1972	Follow-up studies on Portage Creek
1974	NPDES discharge permit system initiated
1976	Basinwide study on the Kalamazoo River, TSCA enacted (PCB ban)
1977	Fish consumption advisory issued for Kalamazoo River
1978	Fish contaminant monitoring
1981	Fish contaminant, water, sediment monitoring
1983	Fish contaminant, water, sediment monitoring Kalamazoo River designated as "Area of Concern" by the International Joint Commission
1984	Kalamazoo River listed on initial State Act 307 list, Feasibility Study begun
1986	Feasibility Study completed
1987	Superstructure removed on DNR dams; Trowbridge, Plainwell, Otsego cleanup design begun; lawsuit filed on Portage Creek/Bryant Mill Pond cleanup; followup studies on impounded areas/sludge disposal areas
1988	Trowbridge, Plainwell, Otsego cleanups to begin; ? Feasibility Study for the Kalamazoo River in the Battle Creek area begins; Remedial actions begin at the Willow Boulevard site
1989	Plainwell, Otsego, Trowbridge cleanups completed Feasibility Study for Battle Creek area completed

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isolate contaminated sediments in the Plainwell, Otsego and Trowbridge impoundment from the Kalamazoo River. These projects are now in the design phase. The projected timetable for project completion is 1989.

2 In recognition of the uncontrolled release of PCBs upon drawdown, the MDNR has refused to issue the necessary permit for the drawdown of Allegan City Dam.

Follow up studies are also underway. Fish were collected for PCB analyses at six locations in 1987. Additional water and sediment sampling is also scheduled for 1987-88. Studies are also planned in 1987-88 to refine the estimates of sediment burial rates in Lake Allegan, Allegan City and Otsego City impoundments and to evaluate the partition coefficients between sediment, water and suspended solids with special emphasis on the clayey fiber materials.

The MDNR undertook additional sampling in 1987 to identify sludge disposal areas which may contain PCBs. The seven sites selected were, from upstream to downstream, the former Rex Mill site, Georgia Pacific (three sites), the former Allied Paper King Mill site, James River (Parchment), and Plainwell Paper. Initial results indicate substantial PCB contamination in the Willow Site (Georgia Pacific). Remedial Actions have been taken to restrict access and stop erosion into the Kalamazoo River at this site. Once detailed sampling is completed by Georgia Pacific, remedial actions will be reviewed and implemented.

The Allied Paper/Portage Creek/Kalamazoo River site has been proposed for listing on the National Priorities List under CERCLA (Superfund).

In addition to these activities on the Kalamazoo River between the city of Kalamazoo and Lake Michigan, an additional study of possible PCB contamination has been initiated for the Kalamazoo River between Battle Creek and Kalamazoo. The fish PCB levels upstream of Kalamazoo indicate some PCB contamination. The 1987 fish consumption advisory was revised to reflect this. The additional study will determine the level and any sources of PCB contamination and remedial options available.

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2.0 INTRODUCTION

2.1 BACKGROUND

The lower Kalamazoo River has been targeted as an Area of Concern (AOC) by the International Joint Commission (IJC), and the State of Michigan. The Kalamazoo River AOC is located in Allegan County in the southwest portion of Michigan's Lower Peninsula (Figure 1). The AOC will concentrate on the Kalamazoo River upstream from Lake Michigan as far as fish can migrate. Presently, this is Calkins Dam which forms Lake Allegan. This dam is about 26 miles upstream of Lake Michigan. The major problem affecting this AOC is water, sediment and fish contaminated with polychlorinated biphenyls (PCBs). PCB contamination in the AOC is thought to originate from upstream sources.

As a result of improvements to the Kalamazoo River basin wastewater treatment facilities, water quality in the AOC has improved greatly in terms of conventional contaminants. However, PCB contamination continues to be a problem to fish and biota. Fish consumption advisories in the AOC reflect this. Until the problems with PCB contamination are addressed, these impaired uses will continue. The purpose of this remedial investigation is to address the impaired uses and PCB contamination.

2.1.1 Great Lakes Water Quality Management

REWRITE

The Great Lakes Water Quality Board (GLWQB) was created as part of the Great Lakes Water Quality Agreement of 1978, signed by Canada and the United States. The Board is responsible for reporting water quality research activities and the environmental quality of the Great Lakes to the IJC. In order to track and measure the progress, in terms of environmental health, of the 42 identified Areas of Concern, the GLWQB adopted a system of six categories. These categories represent a logical sequence for problem solving and resolution; they identify the status of the information base, programs which are underway to fill the information gaps, and the status of remedial efforts. According to the Board, a site can be deleted as an AOC when evidence is presented verifying that the full complement of uses has been restored. The six categories are:

Category	Explanation
1	Causative factors are unknown and there is no investigative program to identify causes.
2	Causative factors are unknown and an investigative program is underway to identify causes.
3	Causative factors are known, but Remedial Action Plan is not developed and remedial measures are not fully implemented.
4	Causative factors are known and Remedial Action Plan developed, but remedial measures are not fully implemented.

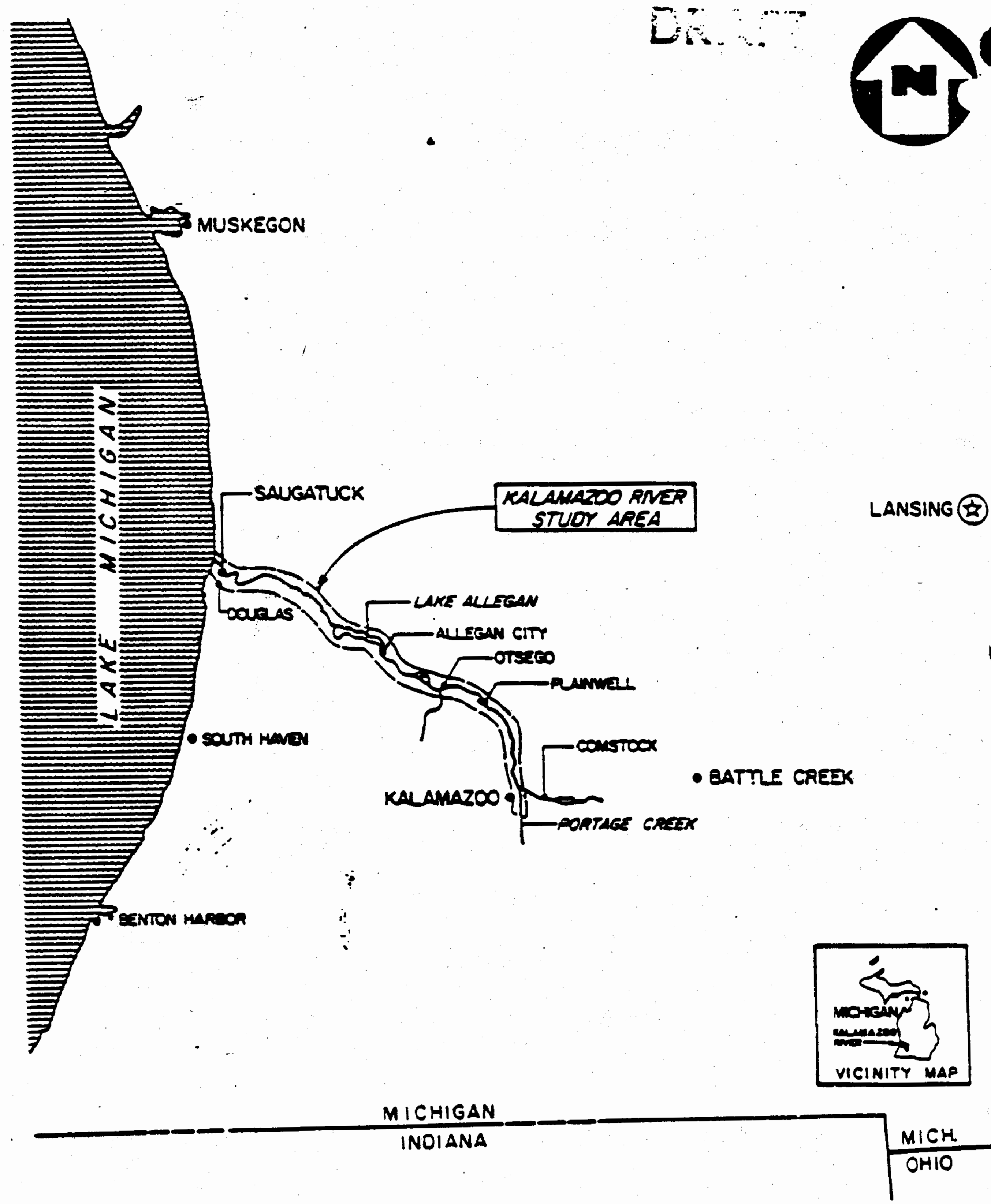

Figure 1.
GENERAL LOCATION MAP
KALAMAZOO RIVER PCB STUDY
SCALE: 1" = 15.2 MILES

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5	Causative factors are known, Remedial Action Plan is developed, and all remedial measures identified in the Plan have been implemented.
6	Confirmation that uses have been restored and deletion as an Area of Concern.

The Kalamazoo River is currently a Category 3 Area of Concern. Once the Remedial Action Plan has been completed, it is anticipated that this area will be moved to Category 4.

2.2 PURPOSE

The purpose of the Remedial Action Plan process is to provide a system-wide approach to environmental management that will ultimately lead to the successful rehabilitation of the Great Lakes. This approach requires an integration of available data on the environmental conditions, socioeconomic influences, and political/institutional frameworks. The purpose of this plan is to focus the data gathering and data synthesis to resolve the immediate problems which impair the AOC designated uses. Recommendations for restoring the impaired use and maintaining other designated uses are based on currently available data.

2.3 INTENDED USE

This Remedial Action Plan is intended as a technical management document providing a platform for future analyses and decision making. It is not a detailed review and synthesis of all data and/or information on the Area of Concern. Every attempt has been made to identify the major documents that relate to the critical environmental issues affecting the Kalamazoo River Area of Concern. Remedial action planning is an iterative process, and suggestion and additions are welcome.

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3.0 ENVIRONMENTAL SETTING

This chapter of the Remedial Action Plan defines the Area of Concern and provides background information on:

- Natural features and hydrologic conditions
- Land uses
- Water uses
- Water quality criteria and use designations

Each Remedial Action Plan concentrates on a specific Area of concern identified by the International Joint Commission. The physical boundaries are defined after consideration of sources, effects on the Great Lakes and extent of pollution from Great Lakes tributaries to the adjacent near shore zone. For this Remedial Action Plan, the Area of Concern was defined as the Kalamazoo River from Calkins Dam (Lake Allegan) downstream to Lake Michigan. This area will be referred to as the effect area. The source area includes a much larger portion of the river, upstream to the City of Kalamazoo including Portage Creek, a tributary in Kalamazoo. The effect area and expanded source areas are shown in Figure 1.

3.1 LOCATION

3.1.1. General

The Kalamazoo River is located in the southwest portion of Michigan's lower peninsula. The river drains about 2,020 square miles from 10 counties (Allegan, Barry, Calhoun, Eaton, Hillsdale, Jackson, Kalamazoo, Ottawa, Van Buren). The basin is about 162 miles long and varies in width from 11 to 29 miles. The North and South branches originate within a few miles of each other. The North Branch heads in Farewell and Pine Hills lakes in southern Jackson County while the South Branch rises in marshy areas south of Moscow in northeastern Hillsdale County. The two branches join at Albion, forming the mainstream which then flows northwesterly for approximately 123 miles before entering Kalamazoo Lake and eventually Lake Michigan near the towns of Douglas and Saugatuck. The river flows generally west-northwest through Marshall, Battle Creek, Augusta, Galesburg, Comstock, Kalamazoo, Parchment, Plainwell, Otsego, Allegan, and Saugatuck before discharging to Lake Michigan. Significant tributaries of the Kalamazoo River include Rice Creek, Battle Creek, Wabascon Creek, Portage Creek, Gun River, Swan Creek, and Rabbit River. Major municipalities on the river are Kalamazoo (population 80,000) and Battle Creek (population 36,000).

The Kalamazoo River basin is contained entirely within the South Michigan/Indiana Till Plains Ecoregion, as defined by Omernak (1987). Ecoregions are defined using a combination of factors including land use, land surface form, potential natural vegetation and soils. The characteristics of the South Michigan/Indiana Till Plain Ecoregion include irregular plains; potential natural vegetation of oak, hickory, beech and maple; land use of cropland with pasture, woodland and forest; and soils of gray-brown podzolic.

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3.1.2 The Area of Concern

The Kalamazoo River system contains approximately 542 linear miles of streams. Although the mainstream is roughly 123 miles long, only the 26-mile stretch between the Calkins Bridge Dam and Lake Michigan is considered in the Area of Concern at this time. The drainage area in the study area is estimated at 460 square miles (294,400 acres). One hundred and thirty-five miles of tributaries are included in this area. The major tributary to the Kalamazoo River in this area is the Rabbit River. Smaller tributaries include Swan Creek, Sand Creek, Bear Creek, and Mann Creek.

This area is located entirely within the County of Allegan. The major municipalities in this area include Saugatuck (population 1,100) and Douglas (population 950) located near the mouth of the Kalamazoo River. This area is the primary area which affects and interacts with Lake Michigan. This area is also primarily dependent on upstream water quality conditions for determining its water quality.

3.2 NATURAL FEATURES

3.2.1 Drainage Basin

The table below is a partial list of streams within the Kalamazoo River system. Lengths are shown in miles. (Many small streams and drains are not included.)

Stream		Stream	
Kalamazoo River (mainstream)	123.0	Spring Brook	6.0
North Branch Kalamazoo River	28.0	Gun River	13.0
South Branch Kalamazoo River	43.0	Miner Creek	7.0
Rice Creek (North and South Branches)	29.5	School Section Creek	3.0
		Schnable Brook	4.0
Wilder Creek	10.5	*Swan Creek	16.5
Seven Mile Creek	4.0	*Bear Creek	6.5
Wabascon Creek	16.0	*Sand Creek	3.5
Battle Creek River	46.0	*Mann Creek	6.0
Wanadoga Creek	12.0	*Rabbit River	46.5
Indian Creek	9.0	*Little Rabbit	14.0
Big Creek	6.0	*Red Run Drain	7.0
Augusta Creek	15.0	*Black Creek	15.0
Portage Creek (includes West Branch)	18.5	*Miller Creek	7.0
		*Miller Creek	3.5
Pine Creek	6.0	*Silver Creek	2.0
Baseline Creek	4.0	*Green Lake Creek	7.0
Sand Creek	4.0		
		TOTAL	542.0 miles

*Tributaries draining into the mainstream within the Area of Concern.

Approximately 2,450 lakes and ponds totaling 37,500 acres are scattered throughout the watershed. These lakes range in size from Gun

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Lake at 2,611 acres to numerous small ponds. There are 52 lakes or impoundments of 100 acres or more in size:

County	Number of Lakes 100+ Acres	Total Surface Acres
Allegan	17	5,510
Barry	11	5,560
Kent	0	0
Calhoun	12	2,360
Eaton	1	130
Hillsdale	0	0
Jackson	2	340
Kalamazoo	9	3,880
Ottawa	0	0
Van Buren	0	0
WATERSHED	52	17,780

The mainstream is dammed in nine locations and the majority of these dams were constructed for generating electric power. The State of Michigan, Department of Natural Resources acquired three dams in the 1960's in the Plainwell-Otsego area to be used for waterfowl hunting habitat. These areas were also to be managed for food production. Vandalism and high maintenance costs have forced the Department to draw these down to a low-sill head. There are three dams on tributary streams in the Area of Concern. One located on Swan Creek has become the base for a popular campground. A second dam on lower Swan Creek creates a diversion to maintain goose habitat in the Swan Creek Marsh. The third is Hamilton Mill Pond on the Rabbit River. Also, there is a control dam at the outlet for Palmer Bayou at the M-89 Bridge.

The North Branch of the Kalamazoo River above Concord is a small, clear water stream that varies in size from ten feet wide by four inches deep below Farewell Lake to 35 feet wide by one foot deep above the Concord impoundment. The bottom type, in general, through this stretch of stream is sand with some areas of gravel.

The South Branch of the Kalamazoo river from Homer to Albion is a larger river averaging 40 feet wide by 18 inches deep in the upper areas to 70 feet wide by two feet deep in the lower areas. There are a few flat areas in marsh situations where the river may widen up to 100 feet and the water is quite shallow (eight inches or less). Bottom types are mostly sands and gravel with some rubble and boulders in the riffle areas. The two branches join at Albion.

More than half the length of the mainstream between Albion and Ceresco is impounded or heavily developed in the cities of Albion and Marshall. The mainstream of the Kalamazoo River from Ceresco to the southwestern edge of Battle Creek is fairly scenic. A number of islands are present in the stream which adds to its attractiveness. The river is about 30 to 100 feet wide and averages 1-2 feet deep. Moderate current moves the canoeist or boater at a good speed in wide, flat areas. Although the bottom has many areas of gravel and aquatic weeds (curly

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leaf pondweed), the river through Battle Creek and down to Augusta is almost entirely within the urban developed areas of the city.

The river from Augusta to Galesburg has no development except in the villages. The river is wide and deep, averaging 110 feet wide and four feet deep. Low stream banks are well vegetated with soft maple, willow and ash. Oak is dominant in areas of high ground. Below Galesburg, the river flows into Morrow Pond. Below this pond, the river flows through the urbanized areas of Kalamazoo. The river gradient increases to 2.6 feet per mile between Plainwell and Allegan. This natural feature of the river was instrumental in bringing about the construction of five dams between the latter two cities.

The mainstream throughout the Area of Concern is free-flowing and varies from 50 to 150 feet in width, but generally is 100 feet wide by four to six feet deep. Some portions of the river reach 18 feet in depth. The bottom type is mostly sand in this area. Most of the river banks are low, two to six feet in height, with extensive flood plains along the main channel. In the mid to lower reaches of the river, the main channel splits into smaller channels creating a number of islands. It is also in these mid to lower areas where adjacent flood plains have been turned into extensive waterfowl marshes. During normal summer flows, the water is relatively clear. The river becomes very turbid below the Rabbit River after heavy rains, a result of suspended silt.

The Rabbit River is the major tributary of the Kalamazoo in the Area of Concern. Originating in the northeast corner of Allegan County, the stream flows through extensive agricultural areas. Although this stream contains some areas of gravel and rubble, the major bottom type is sand, silt and clay. The Rabbit River is a sizeable stream by the time it reaches Hamilton, with widths of about 50 to 60 feet. Average depth in this area is about four to five feet.

The other tributaries in the Area of Concern are Swan, Bear, Mann and Sand creeks. These are all small clear water streams containing significant spring seepage. Sand Creek is classed as top quality trout water, while the others are classed second quality trout water. Stream size varies from 10 to 15 feet in width by six to ten inches deep on Mann and Sand creeks, to 30 feet in width by 6 to 18 inches deep on Swan Creek. Although most of these streams are mainly sand bottomed, they do contain some areas of gravel. The exception is Bear Creek which contains a bottom of gravel, rubble and sand in its lower reaches. These streams are well vegetated along their banks and the smaller streams in particular have dense growths of tag alder in certain areas.

3.2.2 Topography

The surface topography of the watershed was determined by the last continental glacial period, the Wisconsinan. A wide variety of glacial or glacial-related deposits make up the surface area. These include ground moraines of variably textured materials, terminal moraines, coarse-textured outwash, alluvial ponded areas, and other types of deposits. The glacial materials extend to a depth of several hundred feet in the western portions of the watershed and generally are 50 feet or less in depth east of Battle Creek.

The entire region has generally rolling topography with prairie, swamp and hilly sections alternating at frequent intervals. Numerous small lakes and spring hollows are scattered throughout the region holding ponded water part or all of the time. Many of the small lakes located within the region have no surface outlets and feed main streams only through groundwater flow and seepage.

The North Branch of the Kalamazoo River originates in Farewell and Pine Hills lakes, Jackson County, at an elevation of 1,042 feet above sea level, while the South Branch rises in marshy areas in Hillsdale County at an elevation of 1,120 feet above sea level. The two branches join at Albion and drop to an elevation of 580 feet above sea level at Lake Michigan.

The Kalamazoo River has a relatively slow to moderate stream gradient dropping 540 feet in elevation from its headwaters on the South Branch to Lake Michigan. Although there are areas where the gradient is greater, the average drop in elevation over the 166 miles of mainstream and South Branch is just over three feet per mile.

Within the Area of Concern, the low areas along the Kalamazoo River are for the most part old glacial drainageways. These valley plains are generally not more than a mile or two wide and are traversed by streams. The streams in places have cut a lower plain a few feet deep which is floored with recent flood plain alluvium. The plains are nearly flat but are intersected in places by inflowing streams from the adjacent highlands. Although dry in places, most of these extensive flats have a high water table, large areas of muck soil and swampy land bordering the river channel. In addition to the large areas of muck soils, these areas contain wet sandy loams and loams of medium fertility.

3.2.3 Hydrology

The following chart summarizes available U.S. Geological Survey (USGS) flow data in cubic peet per second (cfs) for the Kalamazoo River including the Area of Concern:

USGS Gaging Station	Period of Record	Average Discharge (CFS)	Extremes for Period of Record (CFS) Maximum	Minimum
Battle Creek	1937-85	664	7,290 4/7/47	50 9/22/39
Comstock	1933-79, 1985	853	6,910 4/8/47	119 5/29/58
**Fennville	1929-1985	1,430	17,500 4/11/47	50* 8/19/76

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*Caused by shutting off flow at Calkins (Lake Allegan) Dam.
**Within the Area of Concern.

The Kalamazoo River discharge flow to Lake Michigan has been monitored by the USGS at Fennville since April, 1929. This gaging station is located 20.5 miles upstream of the mouth. The average discharge for the 55 years of record is 1,430 CFS.

The mean monthly Kalamazoo River flows to Lake Michigan have been estimated by the Michigan DNR to be:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
(CFS)	1620	1740	2370	2490	1990	1500	1200	1030	1030	1180	1500	1620

3.2.4 Climate

Climate varies from modified marine (Great Lakes influence) in the Area of Concern to continental in the eastern portions of the watershed. Average annual precipitation is about 32 inches, and snowfall exceeds 40 inches annually. In the Area of Concern, annual snowfall approaches 100 inches. The average July temperature is 72 degrees and average January temperature is about 24 degrees. Average January temperature is slightly warmer near Lake Michigan, being about 26 degrees. The annual mean temperature for the area is about 49 degrees. The average growing season ranges from about 153 days at the eastern end of the watershed to about 184 days along Lake Michigan.

3.2.5 Soils, Runoff, Erosion

The soils are diversified with gravel, clay and sand alternating in relatively small areas, with sandy loams predominating. Due to the numerous small lakes and marshy tracts scattered throughout the region and the commonly porous soils which increases the infiltration, the runoff peaks are not severe and the streams have relatively high sustained base flows.

Soils are as varied as the glacial materials in which they are developed. They range from clay and silt to sand and organic materials. About 25 percent of the soils have clay loam or clay textures. These soils, such as the Miami, Marlette and Blount soils, are found principally in Eaton County and to a lesser extent in Allegan and Van Buren counties. Forty percent of the soils are sandy loams and loams of intermediate texture. These soils, which include the Hillsdale, Kalamazoo and Boyer, are found primarily in Calhoun, Allegan, Barry and Kalamazoo counties.

Soils with loamy sand and sandy textures, which include the Oakville Spinks and Rubicon soils, are found on approximately 30 percent of the land. These sandy soils are largely in the western part of the basin. The remaining five percent of the soils are organic and are distributed throughout the basin, usually in river bottoms.

Upland areas adjacent to the rivers are flat to gently undulating glacial outwash plains. The predominant soils in these plains and the

Area of Concern are the dry sandy soils which are usually acid and low in fertility. An exception to these dry sandy soils are the areas along the Rabbit River which contain the more fertile sandy loams, loams and silt loam soils.

3.2.6 Vegetation

As a result of the action of the Wisconsinan glacier, the region is topographically diverse, possessing hills, valleys, plains, ponds, lakes and a variety of soil types that provide excellent habitat for a vast number of plants. In addition, the influence of nearby Lake Michigan somewhat moderates the climate of this region so that a number of plant species thrive or survive that otherwise might not do so.

Six major types of native plant communities are recognized in the watershed and are listed below. While each of these is considered as a distinct community, many ecotones, or gradual transition zones, exist between these communities. Some of the dominant species have a fairly wide tolerance of habitats and, therefore, may be prevalent in more than one habitat. All of these species are considered abundant where they occur.

Community	Characteristics
Dry Southern Hardwood Forest	Forests of dry upland sites with bur oak, black oak, or white oak dominating.
Moist Southern Hardwood Forest	Forests that occur in moist soils and are dominated by beech and sugar maple.
Wet Lowland Forest	Forests characterized by willow or cottonwood, or silver maple or ash.
Grassland-Savanna Complex	Includes the combination of prairies, sedge meadows and savannas. Characterized as treeless or with scattered trees and dominated by grasses or sedges either wet or dry.
Marshes and Emergent Aquatic Communities	Treeless areas in which the water table is above the soil surface during most of the growing season.
Submerged Aquatic Communities	Dominant plant species are below or on the water surface. These communities are essentially lakes and ponds.

Broad floodplains are characteristic of the lower Kalamazoo River. The floodplains along the rivers and streams in the Area of Concern are generally covered with lowland forest or are in marshy wetlands. Woody vegetation consists of varying mixtures of willow, cottonwood, silver maple and ash. Sycamores are scattered singly or in clumps along the entire lowland area. Where conditions are right, a few black walnut occur, which have grown to large sizes. The marsh areas contain various amounts of sedges, rushes, cattail, smartweed and aquatic species such as pondweeds and waterlilies.

There are three identified sites within the Area of Concern which contain one or more rare plant species. These sites ares listed below:

Ely, Little Tom & Crooked Lake Area	Allegan County Clyde Township	Bog plants, coastal plains species
Fennville Bog	Allegan County Manlius Township	Native orchids, other bog species
Prairie Areas	Allegan County Valley Township	Sandy prairie species

3.3 LAND USES

Distribution of land in the Kalamazoo River watershed by major use shows cropland and pasture account for the greatest share, 57.0 percent. Forest land is the second most important land use, utilizing 21.0 percent of available lands. The remaining 22.0 percent is composed of wetlands (three percent), water (two percent), urban areas (eight percent), and other (nine percent). Agricultural enterprises within the watershed vary from general farming to production of specialty crops, such as grapes, apples and blueberries. Those areas in the eastern half of the watershed produce the major share of row crops and small grains, while the western counties produce the greatest share of fruits and vegetables.

Land use within the Area of Concern varies only slightly from the watershed figures. Sixty percent of the land is in cropland and pasture and 27 percent is in forest land. Most of the lands classed as other and portions of the agricultural lands classed as idle are used as recreational lands. The upland areas and the adjacent wetlands and water areas are used for camping, hunting, wildlife production, fishing and boating.

3.3.1 Ownership

The Kalamazoo River watershed contains roughly 1,292,800 acres of land. Of this total, 1,245,550 acres (96%) are in private ownership. The remaining 48,250 acres are in public ownership as follows: Allegan State Game Area—44,290 acres, Fort Custer Recreation Area—2,960 acres, and Yankee Springs Recreation Area—1,000 acres. (Note: The Yankee Springs Recreation Area contains 5,000 acres of state land, however, only

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an estimated 1,000 acres is within the Kalamazoo River watershed.) Ownership along the mainstream of the Kalamazoo River and those tributaries in the Area of Concern is summarized as follows:

	LINEAR MILES			FRONTAGE		
Stream	Public	Private	Total	Public	Private	Total
Kalamazoo Mainstream	11	11	22	22	24	44
Rabbit River	0	17	17	0	34	34
Mann Creek	0	2	2	0	4	4
Bear Creek	3.5	1.5	5	7	3	10
Sand Creek	1.5	.5	2	3	1	4
Tributary Totals	5	21	26	10	42	52
OVERALL TOTALS	16	32	48	32	64	96

In addition, 26 county, township or municipal parks within the watershed provide additional camping (250 sites) and day-use facilities for recreationists.

3.3.2 Private Recreation Facilities

Private sources provide a wide range of recreational activities and uses within the ten counties making up the Kalamazoo River watershed. There are 55 private campgrounds which provide roughly 5,000 campsites. These sites range from the rustic tent campers to modern trailer or recreation vehicle sites. In addition, many of the camps provide swimming, boating and picnicking. With the Area of Concern, 12 private campgrounds provide 877 campsites.

Other recreational activities provided by private sources include golf courses, archery ranges, horseback riding, boat and canoe rentals, marinas, charter boats for Great Lakes fishing and fishing ponds and lakes.

3.3.3 Public Recreation Facilities

Public recreation facilities are limited within the Kalamazoo River watershed. Fort Custer Recreation Area, Allegan State Game Area and Yankee Springs Recreation Area offer a wide variety of recreation opportunities. Only Allegan Game Area and Yankee Springs provide camping. Six camp areas provide 540 campsites, while one organization camp provides for another 50 persons. Within a short drive of the Area of Concern, two state parks (Van Buren and Holland), provide an additional 545 campsites and a variety of day-use facilities.

3.3.4 Wildlife Observation and Hunting

The wildlife resources of the Kalamazoo River Basin are as varied as the habitat through which the river flows. From the rich farmlands of Calhoun and Kalamazoo counties to the oak-pine sand barrens of Allegan County, the make-up of the local fauna changes rather dramatically.

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Throughout the river basin, the forest species of fox, squirrel, cottontail rabbit and whitetailed deer can be found, while species such as the ring-necked pheasant, bobwhite quail and wild turkey require more specific habitat requirements.

Both resident and migratory species are important to the Kalamazoo River valley. Important resident species of game animals include the white-tailed deer, cottontail rabbit, fox squirrel, grey squirrel, raccoon, ring-necked pheasant, ruffed grouse, bobwhite quail and wild turkey. Furbearing mammals common to the river valley are the mink, muskrat, red fox, skunk, opossum, weasels and woodchuck. Less common mammals are the gray fox, badger and beaver. Many small mammal species also occur including the red squirrel, northern flying squirrel, chipmunk, ground squirrel, plus several species of voles, mice and bats. The list of songbirds and raptors number in the hundreds. Migratory species present range from the often seen and studied Canada goose to the seldom seen prothonatory warbler. Individual Canada geese can be found 12 months of the year in various areas of the valley. Several hundred other species of both migratory songbirds and waterfowl also occur.

Important species of waterfowl which commonly take up summer residence in the Kalamazoo valley include mallard duck, black duck, wood duck, Canada goose, blue-winged teal, and American coot. Other species common usually only during spring and fall migration, include the blue goose, whistling swan, redhead duck, canvasback, goldeneye, American merganser, bufflehead, lesser scaup, American gallinule, Wilson's snipe, baldpate, pintail, gadwall and green-winged teal.

The American woodcock is an important migratory forest species. Nongame species seldom receive attention from the general public because they are not hunted and often are inconspicuous. However, they make up the larger portion of the wildlife resource and their involvement in the physical well-being of the total environment is no less important than that of game species. Species densities of most nongame mammals and birds, amphibians and reptiles are relatively unknown.

Limited information is available on population estimates of endangered, rare or threatened species (with the exception of the sandhill crane). The only endangered amphibian or reptile in the basin is the Kirtland's water snake. An endangered species is one in danger of extinction through all or a significant part of its range. Some birds and mammals species that formerly occurred in the region have long since been extirpated locally.

There are 13 threatened species known to occur in the Kalamazoo River valley, including the copper bellied water snake, the barn owl, the Cooper's hawk and the pine vole. A threatened species is one likely to become endangered within the foreseeable future.

There are 49 known rare or scarce species in the basin, including the badger, coyote, river otter, sandhill crane, upland sandpiper, the great blue heron, the prothonotary warbler and the pileated woodpecker. Rare or scarce species are not known to be endangered or threatened but are uncommon and deserve continued monitoring of their status.

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The State of Michigan is an important landowner in the lower Kalamazoo River valley with over 48,000 acres in Kalamazoo and Allegan counties. Ownership includes approximately 23 miles of Kalamazoo River frontage. Management of the lands adjacent to the river are very dependent upon the river as a source of water and wildlife habitat. A great deal of furtrapping and waterfowl hunting occur on the Kalamazoo River and its adjacent marshes. Three specially managed waterfowl management units are in existence downstream from the Calkins Dam—the Koopman, Swan Creek and Ottawa marshes. These three units provide thousands of hunter days of recreation each fall as hunters seek out Canada geese, mallards, wood ducks and other waterfowl. Development and improvement projects planned for these three units will create additional quality habitat for waterfowl and waterfowl hunting. Possible future marsh management techniques which include diking, water control, diversions and ditching will provide many more acres of quality wetland habitat.

Four species of birds seldom seen in southern Michigan which are listed as endangered or rare are the American bald eagle, golden eagle, osprey and pileated woodpecker. Individuals of each of these species are usually spotted in or near the Ottawa marsh during the year.

The lands of the Allegan State Game Area which straddle the Kalamazoo River form the nucleus of the home range for a flock of wild turkeys. The river and its tributaries are an important part of habitat needed for the continuance of this flock of 300 to 400 birds. A limited spring hunting season for approximately 300 hunters has produced 25 to 30 turkeys for successful hunters each year from 1975 through 1979.

3.3.5 Historic and Archaeological Sites

Historic and archaeological resources in the Kalamazoo River watershed are numerous. There are 105 numbered or marked historic sites in the watershed area (Table 1). Of these, about half are registered as local sites and half as state sites. Twenty-one of these sites are also listed on one of the National Registers. All of the sites receive some protection under Michigan law.

Archaeological sites are scattered throughout the watershed (Table 2) and probably represent only a small percentage of the actual sites which exist.

The Lower Kalamazoo valley in Allegan County is one of the areas in the state best known to archaeologists. Professional archaeologists have surveyed about one third of the region between the Calkins Dam in Valley Township and the mouth of the river. Thus far, 83 archaeological sites have been recorded on the bluffs and terraces along this stretch of the Kalamazoo.

Few of the 83 reported sites have been investigated in enough detail to determine their time period or function, or whether enough scientific information has been preserved to qualify them for listing on the National Register of Historic Places.

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TABLE 1. RECOGNIZED HISTORIC SITES

County	Homes	Gov't and Business	Education -Schools	Church	Other	Total
Allegan	2	1	-	4	3	10
Barry	-	-	-	-	3	3
Calhoun	12	9	5	4	12	42
Eaton	2	2	1	1	1	7
Hillsdale	1	-	-	-	-	1
Jackson	-	-	1	-	-	1
Kalamazoo	3	5	6	-	12	26
Ottawa	-	-	1	5	4	10
Van Buren	-	3	1	1	1	5
BASIN	20	20	15	14	36	105

TABLE 2. IDENTIFIED ARCHAEOLOGICAL SITES IN THE WATERSHED

County	Number
Van Burean	0
Allegan	98
Ottawa	0
Kent	0
Barry	7
Kalamazoo	34
Calhoun	18
Eaton	12
Jackson	1
Hillsdale	6
BASIN	176

Artifacts representing all cultural periods known in southwestern Michigan have been found along the lower Kalamazoo River. These periods include:

Paleo-Indian (10000-8000 BC): Hunters of Pleistocene game such as mastodon and musk oxen entered Michigan as the Ice Age glaciers retreated. They left behind small campsites and butchering stations, identified by the presence of distinctive fluted lance points.

Archaic (8000-1000 BC): Human adaptations changed with the long transition from Pleistocene to modern climatic conditions, lake shore and drainage patterns, and vegetation. Hunting and gathering peoples developed annual cycles of camp location and group size to take advantage of a variety of natural resources, each in season. The spearthrower ground stone axes and woodworking tools, and copper tools came into use, and burial practices became more elaborate. This period is subdivided into the Early Archaic (8000-6000 BC), Middle Archaic (6000-3000 BC), and Late Archaic (3000-1000 BC).

Woodland (1000 BC-AD 1500): Ceramics, the bow and arrow, and horticulture were major innovations of the Woodland period. During the Early (1000-200 BC) and Middle (200 BC-AD 700) Woodland periods, burial ritual became increasingly complex, and burial mounds were often built. Horticulture did not become a major factor until the Late Woodland (AD 700-1500), when small, semi-permanent summer villages were built, sometimes protected by circular earthworks supporting stockades.

Upper Mississippian (AD 1500-1700): People with strong cultural ties to those in Indiana and Illinois lived in southwestern Michigan during late prehistoric times. They were probably the ancestors of the Potawatomi and Miami. They lived in large stockaded villages in the summer, and moved inland as a group to hunt in the winter. They depended more heavily on crops than did the Woodland peoples, tended to live in larger settlements, and made distinctive, well made artifacts.

Historic (AD 1700-present): The increasing dominance of European culture, first through trade, and then by white settlement characterizes this period. The Potawatomi and Ottawa both hunted in Allegan County in the winter, and some of the Ottawa stayed year round. Trading posts were built, and by the 1830's white settlement was underway. The area was ceded to the U.S. in the Treaty of Chicago, 1821. Mills were built, and towns grew up around them.

3.3.6 Waste Disposal

Twelve sites in the Area of Concern have been identified under Michigan's Public Act 307 (Michigan Environmental Response Act). These sites are listed in Table 3. None of these sites have been identified as containing PCBs.

Table 3. Proposed Priority List for Sites of Environmental Contamination

SAS Score	County and Date Screened	Common Site Name* and Location Code and Township	Source of Contamination	Point of Release	Pollutant	Resource Affected
0857	Allegan 08-11-87	Village of Douglas 03-03N-16W-16	Plating Polishing	Lagoon	Chromium TCE, PCB Lead Chloroform	Groundwater Municipal Well
0746	Allegan 09-02-87	Sunrise LF 03-03N-11W-08DB Wayland	Landfill	Barrels Landfill	Trichloro- ethane, Pentachloro- phenol, Acetone	Groundwater Soil
0283	Allegan 10-02-84	Michigan Fruit Canners 03-02N-15W-04AC Clyde	Landfill	Landfill	Phenols	Groundwater
	Allegan 09-25-84	Grocery Store East Saugatuck 03-04N-15W-32DD Fillmore	Gas station	Underground tank	Benzene Toluene Xylene	Groundwater
	Allegan 09-15-86	Fleming Oil Marathon Station 03-03N-16W-21CB Saugatuck	Gas station	Underground tank	Gasoline	Groundwater Soil
	Allegan 08-12-85	Goodale Facility Wayland 03-03N-11Q-17BC Wayland	Oil storage	Underground tank	Ethylbenzene Tetrachloro- ethene	Groundwater Wetland
	Allegan 08-12-85	Johnsons Amoco Service Douglas 03-03N-16W-16CB Saugatuck	Gas station	Underground tank	Benzene Toluene Xylene Ethylbenzene	Surface water Groundwater

Table 3 Continued

SAS Score	County and Date Screened	Common Site Name* and Location Code and Township	Source of Contamination	Point of Release	Pollutant	Resource Affected
	Allegan 09-25-84	LaGrange Lab Processors, Inc. 03-02N-15W-20AD Clyde	Laboratory	Surface discharge	Chloroform Methylene-Chloride	Groundwater Soil
	Allegan 10-01-85	Milliec Industrial Painting 03-04N-15W-06CC Fillmore	Paint products	Barrel	Dichloro-ethane Trichloro-ethane Ethylbenzene	Soil
	Allegan 09-23-86	Wolverine Power 03-04N-13W-15CB Salem	Gas Elec. utility	Underground tank	Diesel fuel	Groundwater Soil
	Allegan 09-25-84	MDOT Fennville 03-02N-15W-03AA Clyde	Salt storage	Dry well	Salt Chloride	Groundwater Residential Well
	Allegan 08-02-85	Pilgrim Farms Pickle Plant 03-04N-14W-25AAD Overisel	Food processing	Lagoon	Chlorides	Wetland Flora Fauna

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3.4 WATER USES

3.4.1 Accessibility

The Kalamazoo River system lies within easy access of the population centers of Holland, Grand Rapids, Lansing and Jackson, while Albion, Marshall, Battle Creek and Kalamazoo lie within the watershed boundaries. Highway access to the river system and Area of Concern is good. The watershed is crossed in a north-south direction by I-196 at the western edge, U.S. 131 in the western third, I-69 in the eastern third, and U.S. 127 just east of the headwater areas. I-94 crosses over two-thirds of the watershed in an east-west direction. In addition to the major highways, there are many paved state and county roads crossing the watershed.

In reference to the Area of Concern, U.S. 131 crosses the watershed in a north-south direction east of the area, while U.S. 31 crosses the river at the western end near Saugatuck. M-89 crosses the area east to west, south of the river, and M-40 cuts diagonally along the northern portion of the watershed crossing the Rabbit River at Hamilton.

3.4.2 Fishing

The Kalamazoo River system is conducive to a warmwater fishery, although a number of tributaries are cool enough to support a quality trout fishery. Warmwater species generally include northern pike, large and small mouth bass, walleye, panfish, carp and suckers. Coldwater species include brown and rainbow trout.

An anadromous salmonid fish stocking program was initiated on the lower Kalamazoo River in 1969. The stream has received plants of chinook and coho salmon, steelhead and domestic rainbow trout, and brown trout. The salmon fishery in the fall and the steelhead fishery throughout the winter and early spring are productive. Also, brown trout are taken during the fall and winter at the Calkins Dam and in the lower river areas. Presently, the anadromous salmonids from Lake Michigan can migrate upstream to the Calkins Dam. No fish ladders have been installed for passage further upstream. The Department of Natural Resources has developed a fisheries management plan for the Kalamazoo River which calls for salmonid passage upstream to Battle Creek.

The major gamefish in the Rabbit River are pike, smallmouth bass and rock bass. Also, the annual spring run of white suckers is heavily fished. In addition to these resident fish, the Rabbit River has been stocked with steelhead and domestic rainbow trout since 1972. These fish have provided a very good winter and spring fishery, particularly at the Hamilton Dam. Also, there have been significant stray runs of salmon in the streams during th[illegible] years. Some of the anadromous fish ascending the Rabbit River have passed over the Hamilton Dam, since steelhead and salmon have been observed in the very upper end of the mainstream east of Wayland.

The upstream portions of the Rabbit River, primarily in Wayland Township, are managed for brown trout. A chemical treatment project was conducted on this segment of the stream in 1971. Brown trout survival and growth was excellent after the project and a good trout fishery has developed.

Below 109th Avenue, Swan Creek is designated a second quality cold water stream. Brown trout have been stocked in Swan Creek since at least the early 1930's. Rainbow trout were also stocked until the mid 1960's. The stream has a history of providing a good brown trout fishery throughout the years. Since the stream's bottom is comprised almost entirely of sand, natural reproduction of trout is minimal. During the early 1970's, an extensive habitat development program was completed on the portions of the stream in state ownership. Two hundred and sixteen log fish cover structures were installed in the stream. Also, gravel and stone spawning areas were installed in eight locations.

Northern pike, largemouth bass, bluegills and other panfish are available in the Swan Creek Impoundment. This small impoundment and the creek immediately downstream receive considerable fishing pressure, since the popular Pine Point Campground is adjacent to the pond. Anadromous trout and salmon ascend Swan Creek in the fall and spring, and provide a fishery. The upstream end of these anadromous fish runs is the Swan Creek Impoundment.

Three small tributary streams to the lower Kalamazoo River (Mann, Bear and Sand creeks) are also classed as top or second quality cold water. Mann and Sand creeks are primarily brook trout streams and Bear contains predominantly brown trout. All of these streams support natural reproduction of trout. In addition to natural reproduction, Bear Creek also receives annual supplementary plants of brown and brook trout.

Anadromous trout and salmon spawn successfully in these streams. Coho salmon, brown trout, brook trout and rainbow trout reproduction have been documented in Sand and Bear creeks. Although Mann Creek has not been surveyed to document natural reproduction, brook trout reproduction obviously occurs and rainbow, chinook and coho reproduction is likely.

Bear Creek is the most heavily fished of the three streams. Since much of the stream is in the Allegan State Game Area, access is not a problem. Also, the stocking program is attractive to trout anglers. Sand Creek does not receive heavy angling pressure because of its small size. Mann Creek receives only moderate fishing pressure primarily because of its very brushy banks which make fishing difficult.

3.4.3 Wildlife

Wildlife in the Kalamazoo River basin have been discussed extensively in Section 3.3.4. In addition to that discussion, an additional animal, turtles, are commonly found and trapped in the basin. In 1986, several hundred turtles were removed from the Swan Creek Highbanks Wildlife Refuge. No permit is required to trap turtles in Michigan.

Turtles have caused extensive damage to certain animals. A 1986 program to reintroduce the trumpeter swan into the Allegan State Game Area was essentially negated due to suspected egg predation by turtles.

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Trumpeter swan eggs were switched with mute swan eggs in this effort to reintroduce the trumperter swan.

3.4.4 Water Supply

There are no potable water intakes in the surface waters of the Kalamazoo River basin. The main source of potable water is groundwater.

There are water intakes for industrial and agricultural applications. No industrial water intakes are located in the Area of Concern. Agricultural water use is not regulated in Michigan, therefore, there is no quantitative estimate of agricultural water use for the Area of Concern.

3.4.5 Canoeing and Boating

The North Branch of the Kalamazoo River is generally small and not considered canoeable water. Much of the South Branch, from the vicinity of Mosherville downstream, is canoeable and except for the urban areas is quite attractive for canoeing. The river becomes quite large below Battle Creek and will accommodate small fishing boats.

Below Calkins Dam, the mainstream is wide and deep and has a moderate current. These factors coupled with very little development makes it an enjoyable stretch of river to canoe or boat. There are six boat launching facilities on the Kalamazoo River in the Area of Concern operated by the Michigan Department of Natural Resources (Hacklander, New Richmond, Allegan Dam, M-89 Bridge, Main Ottawa landing, Howard Shultz Park). There are four additional boat launching facilities in the Allegan State Game Area. In the Saugatuck/Douglas area, there are numerous marinas which serve the boats using Lake Michigan.

Most of the tributaries entering the mainstream in the Area of Concern are not considered canoeable. The Rabbit, however, is smaller but similar in character to the Kalamazoo River and provides an enjoyable experience for canoeists who don't mind an occasional carry over a log jamb.

3.4.6 Waste Disposal

There are 91 permitted surface water discharges in the Kalamazoo River basin. Of these, only 10 discharges are located in the Area of Concern. Seven of these are located in the Rabbit River basin. The remaining 3 are located in the Saugatuck/Douglas area. These discharges are the Kalamazoo Lake Water and Sanitary Authority, Rich Products Corporation, and Culligan Soft Water Service.

3.4.7 Standards, Guidelines, Applicable Beneficial Uses

The State of Michigan has adopted Water Quality Standards which establish water quality requirements applicable to the Great Lakes, the connecting waters and all other surface waters of the state. These standards are Part 4 of the Water Resources Commission rules, established under State Act No. 245 of the Public Acts of 1929, as amended. These

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standards require that water quality in the mainstream sections of the Kalamazoo River be protected for the following uses: agriculture, industrial water supply, navigation, public water supply (at the point of intake), warmwater fish, other indigenous aquatic life, and wildlife, and total body contact. The same conditions apply on the tributary streams except for those streams classified for cold water fish, which received additional protection.

To protect these uses, control of PCBs in NPDES discharges is regulated pursuant to Rule 57(2) of the Water Quality Standards. Under this rule and associated guidelines, the water quality based level for PCBs was determined to be 0.012 ng/l (parts per trillion) as of January 27, 1987. In developing this water quality based level, consideration was given to aquatic life, terrestrial life, human life and cancer risk protection. For PCBs, the water quality based level is based on the cancer risk value.

The Kalamazoo River in the Area of Concern has been designated a Wild-Scenic River by the Michigan Natural Resources Commission under the Natural Rivers Act (Act 231 of the Public Acts of 1970). A Natural River Plan was adopted by the Commission in June, 1981. This plan provides for the protection of the river's natural qualities and guides its future use. The Natural River Plan is included as Appendix A.

The Michigan Department of Public Health issues fish consumption advisories for Michigan water. For PCB, the "action level" used by MDPH is 2 mg/kg in the edible portion of fish.

The International Joint Commission has identified a specific goal in the 1978 Great Lakes Water Quality Agreement for PCBs in whole fish as not more than 0.1 mg/kg.

The U.S. Food and Drug Administration has set various standards which govern the sale of food items. For PCBs, the applicable standards include those for fish (2 mg/kg), poultry and red meat (3 mg/kg on a fat basis), and eggs (0.3 mg/kg).

4.0 DEFINITION OF PROBLEM

4.1 IMPAIRED USES AND SPECIFIC CONCERNS

The objective of this Remedial Action Plan is to restore the impaired use of the Kalamazoo River. Therefore, it is critical to identify the impairment that is or has occurred. The International Joint Commission identified the Kalamazoo River as an Area of Concern because of the presence of toxic organics, contaminated sediments, and a fish consumption advisory (GLWQB, 1985). The description further discusses the PCB contamination of sediments and fish. Given this identification of an impaired use and the fact that the Michigan DNR is unaware of other impaired uses in the Kalamazoo River downstream of Calkins Dam, the objective of this Remedial Action Plan is to address the PCB contamination of water, sediments and biota.

The Michigan Department of Public Health (MDPH) has issued a fish consumption advisory for the Kalamazoo River. For the Kalamazoo River from Morrow Pond Dam (which is upstream of the City of Kalamazoo) to Lake Michigan, people are advised not to eat carp, suckers, catfish, and largemouth bass. People are advised to eat no more than one meal per week of all other species. Nursing mothers, pregnant women, women who expect to bear children, and children under age 15 are advised not to eat any fish from the Kalamazoo River because of the uncertainty of effect on the unborn, newborn or young child. This advisory includes the Area of Concern.

The fish consumption advisory includes additional contiguous areas. The same advisory applies to Portage Creek from Monarch Millpond dam to its confluence with the Kalamazoo River in Kalamazoo. For the Kalamazoo River upstream of Morrow Pond dam to the City of Battle Creek, people are advised not to eat carp.

In addition to the advisory on Kalamazoo River fish, certain advisories apply to migratory fish in Lake Michigan which also apply to the Area of Concern when these fish migrate up the Kalamazoo River. People are advised not to consume lake trout and brown trout over 23 inches long and chinook salmon over 32 inches long. People are advised to eat no more than one meal per week of lake trout 20-23 inches long, coho salmon over 26 inches long, chinook salmon 21-32 inches long and brown trout up to 23 inches long. Nursing mothers, pregnant women, women who expect to bear children, and children under age 15 are advised not to eat any of the fish listed because of the uncertainty of effects on the newborn or young child.

All of the advisories on the Kalamazoo River are based on PCB contamination of fish. This will be the major focus of this Remedial Action Plan.

The specific goals for the Remedial Action Plan are to 1) as a minimum, reduce PCB concentrations in fish to levels which will eliminate the need for a fish consumption advisory, and 2) reduce human exposure of PCBs to acceptable levels. These goals specifically translate to 1) fish

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tissue PCB levels less than 2.0 mg/kg to eliminate the fish consumption advisory, and 2) a water column PCB concentration of 0.012 ng/l to reduce PCBs to acceptable levels. The fish tissue levels of 2.0 mg/kg is based on the MDPH "action level" as described in Section 3.4.7. The water column concentration of 0.012 ng/l is based on the Michigan Water Quality Standards, as described in Section 3.4.7. This value is theoretically determined to be applicable to point source discharges; however, it is highly likely that the same value would be determined for ambient waters since the scientific information used to develop this value would not change. This value considers effects on aquatic, terrestrial and human life. The most stringent value (the cancer risk value in this case), is based on human exposure to PCBs, primarily through fish consumption. This value should protect all other biota.

4.2 MAJOR POLLUTANTS OF CONCERN

The only identified pollutant of concern in the Area of Concern is PCB. This section will discuss the PCB contamination of water, sediment and biota in the Area of Concern.

4.2.1 Water

Water column concentrations of PCBs have been reported for the Kalamazoo River Area of Concern since 1971 (Table 4). Mean concentrations near the river mouth have been in the range of 40-73 ng/l (parts per trillion). For 1971-72, the mean concentration reported was 65 ng/l (MDNR, 1972). Marti (1984) found a mean concentration of 40 ng/l in 1980-81. Horvath (1984) found a mean concentration of 73 ng/l for 1982. In 1985-86 the mean concentration near Saugatuck was 63 ng/l.

Concentrations decline as the river flows from Calkins Dam to Lake Michigan. In 1985-86, the mean concentration at Calkins Dam was 115 ng/l, versus a mean of 63 ng/l at Saugatuck. Based on this data, there appears to be a net input of PCBs into the Area of Concern. Using the 1985-86 data, the yearly net input of PCBs is in the range of 100 pounds per year.

The majority of PCBs found in the water column were Aroclor 1242. Marti (1984) reported a mean of 61% Aroclor 1242. All of the detectable values found by Horvath (1984) were Aroclor 1242. In 1985-86, 79% of the reported concentrations were Aroclor 1242. The data from 1971-72 were only analyzed for Aroclor 1254.

Marti (1984) estimated that in 1980-81 78% of the PCBs were associated with particulates. However, Horvath (1984) concluded that no strong relationship existed in 1982 between PCBs and suspended solids or total organic carbon.

Total mass loading of PCBs from the Kalamazoo River to Lake Michigan have been estimated for three different data sets (Table 5). Marti (1984), using 1980-81 data, estimated the yearly PCB load to Lake Michigan to be 57-220 pounds using a parabolic relationship between flow and PCB concentration. Horvath (1984) used 1982 data with Beale's stratified ratio estimator (Beale, 1962) to determine a yearly mean load

TABLE 4. WATER COLUMN CONCENTRATIONS OF PCBS FROM THE AREA OF CONCERN DRAFT

LOCATION	DATE	TOTAL PCB (NG/L)	AROCLOR 1242 (NG/L)	AROCLOR 1248 (NG/L)	AROCLOR 1254 (NG/L)	AROCLOR 1260 (NG/L)	SOURCE
CALKINS DAM 100 YDS DOWNSTREAM	13-May-86	174	160	NOT	19	<10	MDNR
	29-Jul-85	101	76	REPORTED	15	<10	MDNR
	22-Jul-85	140	110		30	<10	MDNR
	10-Jul-85	55	43		12	<10	MDNR
	24-Jun-85	127	100		27	<10	MDNR
	17-Jun-85	149	120		29	<10	MDNR
	10-Jun-85	131	96		25	<10	MDNR
	29-May-85	152	130		22	<10	MDNR
	20-May-85	63	50		13	<10	MDNR
	06-May-85	114	88		26	<10	MDNR
	29-Apr-85	79	61		18	<10	MDNR
	18-Apr-85	106	81		25	<10	MDNR
NEW RICHMOND	29-Jul-82	75	75	NOT	<30	<30	HORVATH,1984
	04-Jun-82	<30	<30	REPORTED	<30	<30	HORVATH,1984
	15-Apr-82	79	79		<30	<30	HORVATH,1984
M-89	08-Jul-83	53	44	NR	9	<5	MDNR
US 31	13-May-86	103	91	NOT	13	<10	MDNR
	22-Jul-85	60	40	REPORTED	20	<10	MDNR
	17-Jun-85	58	47		11	<10	MDNR
	20-May-85	49	33		16	<10	MDNR
	18-Apr-85	44	33		11	<10	MDNR
	29-Jul-82	53	53		<30	<30	HORVATH,1984
	04-Jun-82	115	115		<30	<30	HORVATH,1984
	15-Apr-82	121	121		<30	<30	HORVATH,1984
CHANNEL TO LAKE MICHIGAN	29-Jul-82	33	33	NOT	<30	<30	HORVATH,1984
	04-Jun-82	<30	<30	REPORTED	<30	<30	HORVATH,1984
	15-Apr-82	98	98		<30	<30	HORVATH,1984
RIVERMOUTH	15-May-81	90	75	*	9	6	MARTI,1984
	10-Apr-81	57	24	*	27	6	MARTI,1984
	16-Feb-81	13	1	5	1	6	MARTI,1984
	10-Dec-80	14	4	1	5	4	MARTI,1984
	06-Nov-80	70	0	30	27	13	MARTI,1984
	24-Aug-30	17	4	7	2	4	MARTI,1984
	07-Aug-30	20	17	*	1	2	MARTI,1984
	1971-72	65 (MEAN)	NR	NR	65	NR	MDNR,1973

*COMBINED WITH 1242
NR=NOT REPORTED

IMATED PCB LOAD FROM THE KALAMAZOO RIVER
LAKE MICHIGAN

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CE	LBS/YEAR
(1984)	57-220 (90% CONFIDENCE INTERVAL)
CH(1984)	271 103-438 (95% CONFIDENCE INTERVAL)
987)	242 169-314 (66% CONFIDENCE INTERVAL)
LOAD=	217

CHIGAN

CB LOAD 1672 (SWACKHAMMER + ARMSTRONG, 1986)
(EXCLUDES GREEN BAY)

MAZOO RIVER = 13% OF TOTAL LOAD

Y/
E LOAD 726 (SWACKHAMMER + ARMSTRONG, 1986)

IAZOO RIVER = 30% OF TRIB/PT SOURCE LOAD of 271 pounds. The third estimate was made using the 1985-86 MDNR data assuming mean flow and concentration. This produced an estimated yearly load of 242 pounds. The average of these three estimates is 217 pounds per year.

Excluding Green Bay, the Lake Michigan yearly PCB load from all sources was estimated to be 1,672 pounds per year (Swackhammer and Armstrong, 1986). Atmospheric deposition accounted for slightly over half (946 lbs/yr) of the total load, with tributaries/point sources accounting for the remaining load (726 lbs/yr). Using these estimates, the Kalamazoo River PCB loading to Lake Michigan accounts for about 13% of the total load and 30% of the tributary/point source load to Lake Michigan. This is consistent with the measured tributary loadings by Marti (1984), where the Kalamazoo River accounted for 13-31% of the total non-Green Bay tributary load to Lake Michigan.

4.2.2 Sediment

Sediment PCB concentrations for the Area of Concern have been measured in 1982 and 1985 (Table 6). These data show concentrations of PCBs ranging from 0.03 to 1.74 mg/kg. These concentrations are considerably lower than those reported in the Kalamazoo River (Lake Allegan) immediately upstream of the Area of Concern, where PCB concentrations in the sediments average 15 mg/kg.

4.2.3 Fish

Analyses for PCBs in fish in the Area of Concern have been conducted since 1971. All fish analysis has been conducted on standard edible portions of fish. Fish PCB concentrations have been determined in 1971, 1976, 1978, 1981, 1983, 1985 and 1986. These data are summarized in Table 7 by species.

There are several limitations in the fish PCB data which must be considered when interpreting or using the fish data:

- Other factors being equal, PCB concentration in fish will vary by species. For example, PCB contamination is expected to be greater in the bottom-feeding carp than in bass.

- PCB contamination in fish is a function of the age, size, weight, and percent body fat of the fish. Larger and older fish likely accumulate greater concentrations of PCBs.

- Laboratory analytical techniques used to quantify PCBs in fish have changed significantly since the early 1970's. Results are now computed differently, the standard for interpretation of results has changed, and the extraction method has changed. Also, the same laboratory has not analyzed all the fish samples. The fish collected in 1971, 1976, 1978 and 1985 were analyzed by MDNR lab. The 1981 fish were analyzed by the Environmental Research Group, a contract laboratory located in Ann Arbor. The 1983 fish were analyzed by the U.S. Fish and Wildlife Service. The 1986 fish were analyzed by the Michigan Department of Public Health laboratory.

TABLE 6

KALAMAZOO RIVER SEDIMENT DATA

ALLEGAN DAM TO SAUGATUCK: REACH 10
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
L1	0.04	1982	Horvath, 1984	North side of channel
L2	0.10	1982	Horvath, 1984	Mid-channel near F&W service dock
L3	1.74	1982	Horvath, 1984	Deepest part of Kalamazoo Lake
L4	0.10	1982	Horvath, 1984	Downstream of U.S. 131 Bridge
L5	0.08	1982	Horvath, 1984	Midstream, downstream of Tyler Bayou
L6	0.10	1982	Horvath, 1984	Midstream in large wetland
L7	0.04	1982	Horvath, 1984	Midstream in large wetland
L8	0.07	1982	Horvath, 1984	Midstream, downstream of Indian Cut
L9	0.12	1982	Horvath, 1984	At side of channel, downstream of gun club
L10	0.10	1982	Horvath, 1984	Inside of bend out of main channel in a deposition zone
L11	0.03	1982	Horvath, 1984	Inside of first bend downstream of old R.R. bridge at New Richmond
L12	0.46	1985	Unpublished MDNR June 1985	20.3 km below dam; depositional area; top 2cm
L13	1.40	1985	Unpublished MDNR, June 1985	17.6 km below dam; north shore
L14	0.30	1985	Unpublished MDNR June 1985	14.8 km below dam; downstream end of island
L15	0.10	1985	Unpublished MDNR June 1985	12.8 km below dam, north shore
L17	0.06	1985	Unpublished MDNR June 1985	8.1 km below dam; backwater area at bayou
L18	0.73	1985	Unpublished MDNR, June 1985	7.4 km below dam; 30' from river before confluence
L19	0.35	1985	Unpublished MDNR, January 1985	6.5 km downstream of dam; Allegan Game Area, 60 mile north of M-89
L19	0.14	1985	Unpublished MDNR, January 1985	8.7 km downstream of Allegan Dam; 0.4 km north of M-89
L20	0.13	1985	Unpublished MDNR, June 1985	6.15 km below dam; backwater area

TABLE 6
KALAMAZOO RIVER SEDIMENT DATA
PAGE TWO

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
L20	0.05	1985	Unpublished MDNR, June 1985	6.0 km below dam; west shore
L21	0.18	1985	Unpublished MDNR, June 1985	4.75 km below dam, on inside of bend
L22	0.06	1985	Unpublished MDNR, June 1985	4.3 km below dam, east shore
L23	0.25	1985	Unpublished MDNR, June 1985	4.0 km below dam, east of Swan Creek Marsh, upland ~26' from river
L24	0.15	1985	Unpublished MDNR, January 1985	2.2 km downstream of dam; Koopman Marsh, west side of river, near river
L24	0.20	1985	Unpublished MDNR, January 1985	2.2 km downstream of dam; Koopman Marsh, west side, 100 miles from river
L24	1.11	1985	Unpublished MDNR, January 1985	2.1 km downstream of dam, Koopman Marsh, 60 miles from river
L25	0.47	1985	Unpublished MDNR, June 1985	2.0 km downstream of dam; on inside of bend
L26	0.04	1985	Unpublished MDNR, June 1985	1.7 km downstream of dam; north shroe
L27	0.10	1985	Unpublished MDNR, June 1985	0.8 km downstream of Allegan Dam; north shore
L28	0.13	1985	Unpublished MDNR, January 1985	0.6 km downstream of dam; Koopman Marsh; east side by public launch

ALLEGAN DAM TO SAUGATUCK: REACH 10
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
L12	0.62 (4-6")	1985	Unpublished MDNR, June 1985	20.3 km below dam, depositional area, 10-15 cm deep
L16	0.38 (0-2")	1985	Unpublished MDNR, June 1985	10.9 km below dam, depositional area, surface 5 cm
L16	0.24 (4-6")	1985	Unpublished MDNR, June 1985	10.9 km below dam, depositional area, 10-15 cm deep

FISH PCB DATA FROM THE AREA OF CONCERN

=IGHT lbs)	AGE (yr)	SEX	AROCLOR 1242 (MG/KG)	AROCLOR 1254 (MG/KG)	AROCLOR 1260 (MG/KG)	TOTAL PCB (MG/KG)	FAT (%)
SPECIES: CARP							
			30.6	14.8		45.4	2.1
			26	12	<1.00	36	
	5-6		27	10	<0.60	37	12.7
			48	15	<5.00	63	23.4
			175	55	1	231	10
.3	3	M				8.4	
.4	3	F				5.2	
.2		F				3.4	
.0		M				16	
.7		M				9.1	
.0	2	F				7.9	
.4	3	M				5	
.9	2	M				2.9	
.1	3	F				4.5	
.8	3	M				8	
.9	3	F				2	
.3	3					6.6	
4		F				1.16	1.3
6		F				25.7	13
7		M				13.8	7.7
4		F				2.63	3.1
7		F				1.14	3.9
4		M				10.3	7
6		M				4.91	2.4
1		M				1.39	1.8
5		M				24.2	16
5		M				1.03	1.4
1		F				7.15	4
]						8.50	5.6
	3	F	1.6	2	0.29	3.89	6.9
	2	M	0.87	1.1	0.17	2.14	6.9
	2	M	0.42	1.1	0.16	1.68	3.4
	2	M	0.32	2.4	0.4	3.12	3.4
	2	M	<0.13	0.2	<0.13	0.2	1.3
	3	M	0.57	3.6	0.57	4.74	5.4
	2	M	0.63	1.4	0.17	2.2	4.7
	3	F	0.52	2.2	0.36	3.08	3.3
	2	M	1.1	1.6	0.25	2.95	5.1

TABLE 7 - SUMMARY OF FISH PCB DATA FROM THE AREA OF CONCERN

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (yr)	SEX	AROCLOR 1242 (MG/KG)	AROCLOR 1254 (MG/KG)	AROCLOR 1260 (MG/KG)	TOTAL PCB (MG/KG)	FAT (%)
	17	2.3	2	M	0.26	0.52	0.08	0.86	2.7
	20	3.8	2	M	1.1	2.3	0.34	3.74	3.3
	19	3.7	2	F	1.8	2.6	0.38	4.78	12.7
	19	3.4	2	M	1.1	3.6	0.56	5.26	10.1
	18	2.8	3	M	0.44	1.7	0.28	2.42	4.8
	19	3.0	3	M	0.36	2.3	0.4	3.06	3.9
	19	3.4	2	M	0.165	0.97	0.18	1.315	0.95
	19	3.5	3	M	0.8	4.5	0.68	5.98	11.5
	18	3.6	3	F	1.6	2.5	0.33	4.43	7.2
	20	4.1	3	F	0.64	5.3	0.88	6.82	7.4
	20	4.1	3	M	0.42	7.4	1.3	9.12	5.8
MEAN=	19	3.3	2					3.59	5.5
July 1986	17	4.0	2	F	0.29	0.22		0.51	0.6
	20	4.2	3	M	3.35	2.12		5.47	3.6
	19	3.7	3	F	4.43	2.73		7.16	5.8
	20	4.6	3	F	1.28	0.76		2.04	4.8
	20	4.2	3	M	2.43	1.06		3.49	8.3
	20	4.2	2	F	2.45	1.64		4.09	4.8
	20	4.1	2	M	0.90	0.39		1.29	5.3
	18	3.5	2	F	2.26	1.76		4.02	4.2
	18	2.9	2	M	2.30	1.12		3.42	6.9
	17	2.8	2-3	M	0.54	0.25		0.79	3.1
	19	3.1	2-3	M	1.77	0.87		2.64	4.3
	20	4.0	2-3	M	5.07	3.92		8.99	6.0
	18	2.9	2	M	1.35	0.60		1.95	7.4
	20	4.2	3	M	2.49	1.43		3.92	10.0
	21	4.6	3	M	3.60	2.36		5.96	6.0
	20	4.3	3	M	1.04	1.04		2.08	2.4
	20	4.2	3	F	0.68	0.38		1.06	1.7
	18	3.0	2	F	3.18	1.46		4.64	7.0
	20	4.2	2	M	5.25	3.14		8.39	9.9
MEAN=	19	ERR	2					3.78	5.4

SPECIES: BASS

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (yr)	SEX	AROCLOR 1242 (MG/KG)	AROCLOR 1254 (MG/KG)	AROCLOR 1260 (MG/KG)	TOTAL PCB (MG/KG)	FAT (%)
July 1976	16				23	10	1.1	34.1	2
Sept 1981	18	3.8	5	M				15	
	12	1.0	2	M				1.5	
	12	1.0	3	M				1.6	
	12	0.9	2	F				4.4	
	9	0.5	3	M				1.4	

TABLE 7 - SUMMARY OF FISH PCB DATA FROM THE AREA OF CONCERN

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (yr)	SEX	AROCLOR 1242 (MG/KG)	AROCLOR 1254 (MG/KG)	AROCLOR 1260 (MG/KG)	TOTAL PCB (MG/KG)	FAT (%)
	13	1.4	2	M				3.9	
	7	0.2	1	F				1	
	10	0.6	2	M				0.7	
MEAN=	12	1.2	3					3.7	
July 1985	13	1.1	3	M	0.99	1.7	0.28	2.97	1.7
	13	1.1	3	M	<0.13	0.53	<0.13	0.53	0.8
	14	1.6	4	F	0.18	0.74	0.16	1.08	0.7
	16	2.0	3	M	0.245	1.55	0.26	2.055	1
	12	0.8	2	M	<0.13	0.4	0.08	0.48	0.3
	16	2.2	4	M	0.3	1	0.19	1.49	0.8
	14	1.7	3	M	<0.13	1.2	0.24	1.44	0.8
	14	1.5	3	M	0.22	0.62	0.17	1.01	0.5
	13	1.1	3	F	<0.13	0.42	0.12	0.54	0.5
	12	0.6	2	F	0.23	1.2	0.28	1.71	0.9
MEAN=	14	1.4	3					1.33	0.8
			SPECIES:ROCK BASS						
July 1971	5				6.8	3.26		10.1	0.3
			SPECIES:NORTHERN PIKE						
July 1971	18				5.8	2.9		8.7	0.7
Aug 1976	19				3.5	1.2	<0.20	4.7	0.7
May 1978	25				3.4	1.5	<0.60	4.9	1.4
	20				2.6	0.9	<0.60	3.5	0.3
	31				7.5	2.6	0.8	10.9	0.7
	18				3.1	1	<0.5	4.1	0.21
Sept 1981	15	0.6	1	M				0.9	
	17	1.0	1	F				0.6	
MEAN =	16	0.8						0.75	
			SPECIES:TIGER MUSKIE						
Aug 1976	37				1.8	0.6	<0.20	2.4	0.4
			SPECIES:WHITE SUCKER						
JuLY 1971					30.7	14.8		45.5	0.7
May 1978	20				3.5	2.9	<0.60	6.4	0.9
	18				2.4	3.3	0.6	5.3	1.2

TABLE 7 - SUMMARY OF FISH PCB DATA FROM THE AREA OF CONCERN

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (yr)	SEX	AROCLOR 1242 (MG/KG)	AROCLOR 1254 (MG/KG)	AROCLOR 1260 (MG/KG)	TOTAL PCB (MG/KG)	FAT (%)
			SPECIES:BULLHEAD						
July 1971	7		.		15.5	7.7		23.2	0.8
			SPECIES:BOWFIN						
Sept 1981	23	4.1	4	M				2.25	

- The samples taken in the 1970's were primarily "screening" samples to determine if a contamination problem existed. The fish collected tended to be the largest fish found and, thus, to represent worst-case conditions. In contrast, the fish samples taken in 1981 and 1983 were intended to represent the entire population of the targeted species. The variance within these samples made statistical analysis difficult. Therefore, the 1985 and 1986 fish collections targeted a specific size range for carp and for bass in an effort to reduce sample variance, standardize exposure period, and to allow for more meaningful trend analysis.

Carp have been the most analyzed fish. Due to their prevalence throughout the Kalamazoo River, carp have been used as trend indicators. PCB concentrations in carp have averaged greater than 2 mg/kg at all locations in the Area of Concern during the period of analysis (1971-1986).

Largemouth bass collected in the Area of Concern averaged 1.33 mg/kg in 1985, somewhat lower than the average (3.69 mg/kg) found in 1981.

Northern pike have been sampled in 1971, 1976, 1978 and 1986 with 1-2 fish analyzed per year. Concentrations of PCBs in northern pike have ranged from 0.6 (1981) to 10.9 (1978).

All other species were analyzed on only one or two occasions. These species include rock bass, tiger muskie, white sucker, bullhead and bowfin.

Based on these results, the MDPH issued a fish consumption advisory which included the Area of Concern. The advisory recommends no consumption of carp, suckers, catfish and largemouth bass. No more than one meal per week is recommended for all other species. Nursing mothers, pregnant women, women who expect to bear children and children under age 15 are advised not to eat fish from the Area of Concern.

4.2.4 Statistical Analysis

In an effort to better define the trend in PCB concentrations in fish, the 1981-1986 carp data and 1981-1985 bass data was examined for trends using statistical analysis. The statistical method used was the Kruskal-Wallis non-parametric test (Kruskal and Wallis, 1952) as described in Conover (1980).

In the Feasibility Study (NUS, 1986), the statistical analyses were performed on age restricted carp in an effort to standardize exposure and other factors. However, in 1986, the MDNR collected a large number (81) of carp from Lake Allegan for PCB analysis (Creal, 1987). The purpose in this collection was to define the relationships between fish size, age, fat content and PCB concentrations. Strong linear relationships were found between length and age, length and weight ($R^2 = 0.96$), and fat and PCB ($R^2 = 0.80$). No relationship was found between size and PCB or size and fat. Therefore, it was concluded that the entire data base should be used for statistical analysis.

TABLE 8. PCB LEVELS IN WATERFOWL COLLECTED FROM THE KALAMAZOO RIVER, AUGUST, 1985

LOCATION	SPECIES	MATURITY	PCB AS 1260 (MG/KG)
MORROW POND	MERGANSER	ADULT	28.00
OTSEGO CITY IMPOUNDMENT	MALLARD	ADULT	4.80
	MALLARD	IMMATURE	2.00
	BLUEWINGED TEAL	IMMATURE	<0.25
TROWBRIDGE IMPOUNDMENT	MALLARD	IMMATURE	1.90
	MALLARD	IMMATURE	0.73
ALLEGAN STATE GAME AREA	WOOD DUCK	IMMATURE	1.50
	CANADA GOOSE	IMMATURE	<0.25
SAUGATUCK	MALLARD	IMMATURE	0.78
	MALLARD	IMMATURE	<0.25
	MALLARD	IMMATURE	<0.25
	MALLARD	IMMATURE	0.60
	MALLARD	IMMATURE	1.70
	MALLARD	IMMATURE	0.55
	MALLARD	IMMATURE	1.90
	MALLARD	IMMATURE	1.04
	MALLARD	ADULT	0.98
	WOOD DUCK	ADULT	<0.25

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Based on these results, the entire Saugatuck carp data base for the years 1981, 1983, 1985 and 1986 and the Saugatuck bass data base for the years 1981 and 1985 was analyzed using the Kruskal-Wallis non-parametric test. This analysis again found that no significant ($p = 0.05$) difference between years at this location for either species.

This indicates that there was no change in PCB concentrations in fish at Saugatuck during the 1981-86 time period.

4.2.5 Waterfowl

Waterfowl have been sampled in the Area of Concern in 1985 and 1986 by the United States Fish and Wildlife Service. In 1985, eight immature mallards, one adult mallard and one adult wood duck were analyzed for PCB. The birds were plucked, eviscerated and feet removed prior to analyses. PCB concentrations ranged from 0.25 to 1.9 mg/kg (Table 8). Converting these values to a fat basis, PCB values ranged from 2.7 to 700 ppm. All of the immature ducks collected exceeded the FDA action level of 3 ppm PCB on a fat basis.

In 1986, mute swan eggs were collected as part of the effort to reintroduce the trumpeter swan. The eggs were from the Allegan State Game Area in the vicinity of the Kalamazoo River. Fourteen eggs were anlyzed for PCBs. Concentrations ranged from 0.1 to 1.6 mg/kg with a mean concentration of 0.4 mg/kg (Table 9). This mean concentration is greater than the FDA action level for eggs (0.3 mg/kg).

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TABLE 9. RESULTS OF PCB ANALYSES OF MUTE SWAN EGGS COLLECTED FROM THE ALLEGAN STATE GAME AREA, 1986

	WEIGHT (GMS)	MOISTURE (%)	LIPID (%)	PCB (MG/KG WET)
	261.5	69.12	15.1	1.6
	266.3	67.32	15.1	0.5
	263.2	68.40	15.8	0.3
	268.8	68.41	14.5	0.4
	217.3	68.75	12.8	0.2
	255.7	66.28	16.6	0.6
	236.3	70.60	13.1	0.1
	260.4	67.80	14.1	0.2
	262.2	70.17	13.5	0.1
	254.2	70.45	15.4	0.2
	257.9	67.93	14.1	0.3
	265.2	68.65	15.0	0.2
	266.2	67.69	17.3	0.2
	284.3	68.12	14.5	0.2
MEAN=	259.96	68.55	14.8	0.4
STD DEV=	13.85	1.18	1.2	0.4

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5.0 SOURCES OF PCBs

The sources of PCBs to the Area of Concern will be defined as internal or external sources. Internal sources will consist of direct and indirect discharges within the Area of Concern. External sources consists of direct and indirect sources upstream of the Area of Concern.

5.1 INTERNAL SOURCES

There are no known direct discharges of PCBs to the Kalamazoo River in the Area of Concern. Indirect discharges of PCBs in the Area of Concern may result from the sediment. However, the PCB concentrations in the sediments are low, generally less than 1.0 mg/kg. The water data indicate that the Area of Concern has a net input of PCB from external sources. Therefore, internal sources will not be considered further as a source of PCB to the Area of Concern.

5.2 EXTERNAL SOURCES

External sources of PCBs include atmospheric deposition, point source discharges, nonpoint source, and in-place pollutants (sediment contamination). In the Kalamazoo River upstream of Calkins Dam to Kalamazoo, sediment PCB concentrations are generally in the 10-30 mg/kg range in depositional areas. At Portage Creek (Bryant Mill Pond) in Kalamazoo, sediment PCB concentrations are generally in the 100-300 mg/kg. As water passes over these sediments, PCBs may enter the water column in the dissolved form or adsorbed onto suspended sediment. The presence of upstream contaminated sediments is the major source of PCBs to the Area of Concern.

The amount of PCB mass in the sediment was estimated at 228,000 pounds in 1983 (Creal, 1983a). This estimate encompassed five major depositional areas only (Lake Allegan, Plainwell, Trowbridge and Otsego impoundments, and Bryant Mill Pond). The sediment contamination in the Allegan City and Otsego City impoundments was not included.

Nine major point source discharges were sampled for PCBs in these discharges in August-September, 1985. All nine discharges contained PCBs (Table 10). However, one discharge (James River, Kalamazoo) obtained its source water from the Kalamazoo River, which may have been the source of PCBs. Detectable concentrations of PCBs in the other eight discharges ranged from 16 to 178 ng/l. Converting these concentrations to a load based on mean annual discharge flow, the estimated PCB loading in pounds per year from all eight discharges is 3 pounds per year. These discharges are regulated by the NPDES permit system, currently administered by the State of Michigan. NPDES permits are issued for up to five years, and must be renewed upon expiration. The Kalamazoo River basin NPDES permits are scheduled for a basin review and reissuance in 1991. Two of these discharges, Kalamazoo and Otsego, have specific language in their NPDES permits requiring long term compliance with a value of 0.012 ng/l through a PCB reduction plan.

Table 10

Point Source Discharge Sampling Results for PCB, Kalamazoo area, August - September, 1985

Discharge	Date	Total PCB (ng/l)	Suspended Solids (mg/l)	Source H_2O
Allied Paper	8/ 7/85	<20 (INT)	-	
	9/ 6/85	69	38	Portage Creek
James River (Kalamazoo)	8/ 7/85	80	-	
	9/ 6/85	15	19	Kalamazoo River
Kalamazoo WWTP	8/ 7/85	<60 (INT)	-	
	9/ 6/85	13	<4	-
James River Parchment	8/ 7/85	30 (INT)	-	Kalamazoo River or Wells
	9/ 6/85	14	16	
Plainwell Paper	8/28/85	<10	24	Wells
	9/ 6/85	39	6	
Plainwell WWTP	8/ 7/85	17 (INT)	-	
	9/ 6/85	31	17	-
Otsego WWTP	8/ 7/85	178	-	-
	9/ 6/85	167	44	
Mead, Otsego	8/ 7/85	39 (L.R.)	-	Wells
	9/ 6/85	56	37	
Mensha, Otsego (Process H_2O)	8/ 7/85	16 (L.R.)	-	Otsego City or Wells
	9/ 6/85	20	460	

INT = Interference
L.R. = Low Recovery Probable

6.0 FEASIBILITY STUDY

To address the external sources of PCBs and to determine appropriate remedial actions, the Michigan DNR conducted a Feasibility Study of the Kalamazoo River PCB problem (NUS, 1986). The objective of this Feasibility Study was to determine cost-effective, technically feasible, and environmentally sound alternatives to minimize the further release of PCB-contaminated sediments, to reduce human exposure to PCBs, and at a minimum to reduce the PCB concentrations in fish in the Kalamazoo River and Portage Creek to less than 2.0 mg/kg (ppm). The following section is based primarily on this Feasibility Study, with some change due to more data.

The relative environmental effectiveness of the proposed alternatives was evaluated through the use of a mathematically-based water quality model. The use of the model to predict long-term changes in the PCB levels in fish provided a convenient measure of the relative effectiveness of alternative actions due to the basic remedial program goal of lowering PCB levels in fish to less than 2 ppm. However, data base limitations and model simplification must be considered when using the model results in a decision framework.

6.1 RIVER DESCRIPTION

The study area for this investigation consisted of approximately 80 miles of the Kalamazoo River, between the City of Kalamazoo, and the City of Saugatuck, where the river flows into Lake Michigan; and approximately 3 miles of a major tributary, Portage Creek, between Alcott Street and the confluence of Portage Creek and the Kalamazoo River in the City of Kalamazoo (Figure 2). This study area was selected because the majority of water, sediment and fish PCB contamination exists in this area. This stretch of the Kalamazoo River is characterized by a series of six dams. Three dams are currently impounded, and three are permanently drawn down. Some sections of river are erosional zones, whereas others are depositional zones. Extensive areas are contiguous with wetlands.

For purposes of the study, the river was divided into 10 sections, called reaches (Figure 2). The reaches are numbered 1 through 10, from upstream to downstream. Each reach has certain distinguishing features and characteristics, which are pointed out in the following discussion.

There are two areas that are not included in any of the 10 reaches but were still considered in the study. One area is Morrow Pond, located on the Kalamazoo River, approximately 4.25 miles upstream of the Portage Creek confluence. Samples taken from Morrow Pond are upstream of the study area and will be considered background data, to be used as a baseline for comparing levels of contamination downstream.

The other noteworthy area is located immediately upstream of Reach 1. Reach 1 begins at Bryant Dam (Alcott Street) on Portage Creek. Upstream of Bryant Dam is Bryant Mill Pond, a small, dewatered mill pond that is filled with contaminated sediment. The pond has been drawn down since 1976, and dewatered sediments are exposed on the banks of the

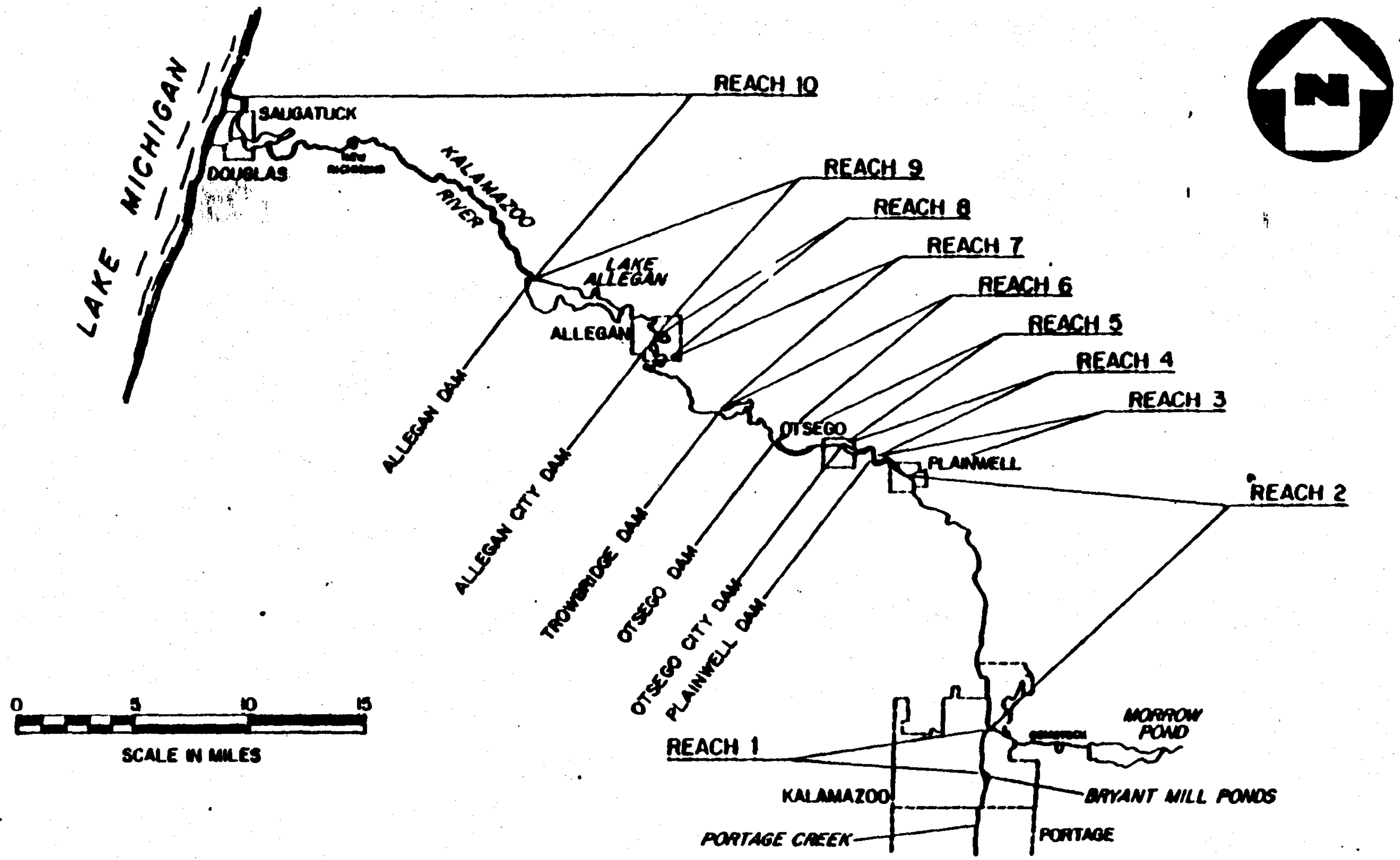

Figure 2.

KALAMAZOO RIVER REACHES AND MAJOR FEATURES

KALAMAZOO RIVER PCB STUDY

creek. Available data indicate that much of the continuing contamination of the Kalamazoo River originates from these mill ponds.

Reach 1 extends from Bryant Dam downstream to the confluence of Portage Creek and the Kalamazoo River. This reach runs through the City of Kalamazoo. Sediment samples taken from this reach indicate relatively high levels of contamination.

Reach 2 extends from the Portage Creek confluence to Main Street in the City of Plainwell. This is an erosional zone, meaning that upstream sediment would not be expected to deposit in this reach. Sediment sampling in this reach has indicated relatively low levels of contamination. However, because of discharges from the Kalamazoo wastewater treatment plant, the aquatic life in this reach is environmentally stressed.

Reach 3 extends from Main Street in Plainwell Dam. Basically, this reach is the former Plainwell Dam impoundment. While the dam was impounded, large quantities of contaminated sediment were deposited behind the dam. This dam was acquired by the MDNR in 1966 and was drawn down in the early 1970's. The historically deposited sediments were consequently exposed. The river has cut a channel down through the contaminated sediments, which are now above the water line. The dewatered sediments are revegetated, but flooding periodically submerges the sediments. The river banks are also being eroded and are sloughing off into the river, a process which releases additional PCBs. This same situation also exists at the Otsego Dam (Reach 5) and the Trowbridge Dam (Reach 6).

Reach 4 extends from the Plainwell Dam to the Otsego City Dam (also referred to as the Menasha Dam). This impoundment is heavily silted in and is characterized by swampy, marshy conditions. This reach is probably a depositional area during low flow and an erosional zone during periods of high flow.

Reach 5 extends from the Otsego City Dam to the Otsego Dam. The lower half of this reach is the former Otsego Dam impoundment. The situation at this dam is the same as described at the Plainwell Dam (Reach 3).

Reach 6 extends from the Otsego Dam to the Trowbridge Dam, and represents the former Trowbridge impoundment. The conditions are essentially the same as those at the former Plainwell and Otsego impoundments.

Reach 7 extends from the Trowbridge Dam to the Allegan city limit. This is a short, erosional reach upstream of the Allegan City Dam impoundment. No contaminated sediments would be expected to deposit in the reach.

Reach 8 is basically the Allegan City Dam impoundment. Large quantities of contaminated sediment have been deposited in this impoundment and will continue to be deposited. Analysis of core samples taken in this impoundment indicates that the contamination extends to depths of 7-8 feet in the sediment.

Reach 9 extends from the Allegan City Dam to the Allegan Dam. Allegan Dam impounds Lake Allegan, the largest lake on the Kalamazoo River. The sediments in Lake Allegan are contaminated, but not as highly as those in Allegan City Dam. However, Lake Allegan has a large carp population, which continuously mixes and resuspends the sediment. Lake Allegan receives sediment that is too fine to be deposited in the Allegan City Dam impoundment or sediment that washes downstream when Allegan City Dam is periodically drawn down.

Reach 10 extends from the Allegan Dam to the river's mouth near the City of Saugatuck at Lake Michigan. This area is a wetland, characterized by marshy conditions. Although the sediments show very low levels of PCB contamination, the PCB levels are relatively high in the fish in this area.

6.2 SUMMARY OF PCB DATA

Several studies have been conducted from 1971 to 1985 by the Michigan Department of Natural Resources (MDNR) to assess the extent of PCB contamination in the Kalamazoo River from Kalamazoo to Lake Michigan. A summary of data compiled from these studies for sediments, water, and fish is presented in this chapter. A detailed listing of all samples can be found in Appendix B. Summary tables, which show annual averages for PCB concentrations, can be found in the text. In this chapter, data is presented in units of parts per million (ppm), unless otherwise specified.

6.2.1 PCBs in Sediments

For purposes of data representation, the study area was divided into the 10 reaches described in Section 6.1. The 10 reaches, upstream to downstream are:

- Portage Creek: Bryant Dam to Confluence with Kalamazoo River - Reach 1
- Kalamazoo River: Portage Creek confluence to Main Street, Plainwell - Reach 2
- Kalamazoo River: Main Street, Plainwell to Plainwell Dam - Reach 3
- Kalamazoo River: Plainwell Dam to Otsego City Dam - Reach 4
- Kalamazoo River: Otsego City Dam to Otsego Dam - Reach 5
- Kalamazoo River: Otsego Dam to Trowbridge Dam - Reach 6
- Kalamazoo River: Trowbridge Dam to City Line of Allegan - Reach 7
- Kalamazoo River: City Line of Allegan to Allegan City Dam - Reach 8
- Kalamazoo River: Lake Allegan - Reach 9
- Kalamazoo River: Allegan Dam to Saugatuck - Reach 10

The area of Bryant Mill Ponds in Portage Creek was also included.

The sediment data, both surface and core samples, are presented by reach in Appendix B. This data was used to obtain annual average PCB concentrations for the reaches from 1971 to 1985 (Tables 11, 12).

In Reaches 3, 5, and 6 (i.e., the draw down dams), the river channel has eroded down through the PCB-contaminated sediments that now lie

TABLE 11

**AVERAGE PCB CONCENTRATIONS (ppm)
FOUND IN SURFACE SAMPLES (0-1')**

Year	Bryant Mill Ponds	#1 Portage Creek	#2 Portage Creek Confluence to Main Street Plainwell	#3 Main Street Plainwell to Plainwell Dam	#4 Plainwell Dam to Ostego City Dam	#5 Ostego City Dam to Ostego Dam
1971	116.0 (2)					
1972	131.9 (5)	117.6 (1)				
1976		36.8 (3)	9.0 (5)	5.1 (2)		66.6 (1)
1982		85.0 (1)	36.2 (4)	8.8 (2)		27.0 (1)
1983	191.4 (9)	12.6 (4)		19.9 (5)		
1984	226.8 (4)		13.0 (1)			
1985	183.0 (6)				16.5 (2)	
1986	189.6 (15)					

TABLE 11 (Con't)
AVERAGE PCB CONCENTRATIONS (ppm)
FOUND IN SURFACE SAMPLES (0-11)
PAGE TWO

Year	#6 Ostego Dam to Trowbridge Dam	#7 Trowbridge Dam to City Line of Allegan	#8 City Line of Allegan to Allegan City Dam	#9 Lake Allegan	Allegan Dam to Saugatuck
1971					
1972					
1976		0.0 (1)	24.7 (1)	10.8 (3)	
1982					0.23 (11)
1983	28.9 (7)			16.6 (5)	
1984					
1985			5.0 (2)		0.32 (21)

Note: Number in () indicates the number of samples analyzed.
Note: For Bryant Mill Oibdsm Reacg #3, Reach #5 and Reach #6, only river bank samples were used for averages.

TABLE 12

AVERAGE PCB CONCENTRATIONS (ppm) FOUND IN CORE SAMPLES

Depth Interval	Year	Bryant Mill Ponds	#1 Portage Creek	#2 Portage Creek Confluence to Main Street, Plainwell	#3 Main Street, Plainwell to Plainwell Dam	#4 Plainwell Dam to Otsego City Dam	#5 Otsego City Dam to Otsego Dam
0-2'	1972	29.7 (12)					
0-2'	1983	51.1 (5)			25.30 (5)		10.80 (10)
0-2'	1984				0.40 (8)		0.08 (1)
2'-4'					0.25 (5)		0.18 (2)
4'-6'					0.15 (3)		0.11 (2)
6'-8'					0.22 (2)		0.20 (1)
>8'					0.14 (2)		
0-2'	1985				13.00 (2)	43.6 (2)	
2'-4'					1.25 (2)	5.1 (2)	
4'-6'					1.15 (2)	0.9 (1)	
6'-8'					1.01 (2)		

TABLE 12 (con't)
AVERAGE PCB CONCENTRATIONS (ppm)
FOUND IN CORE SAMPLES
PAGE TWO

Depth Interval	Year	#6 Otsego Dam to Trowbridge Dam	#7 Trowbridge Dam to City Line of Allegan	#8 City Line of Allegan to Allegan City Dam	#9 Lake Allegan	#10 Allegan Dam to Saugatuck
	1972					
0-2'	1983	24.0 (5)			25.9 (5)	
0-2'	1984	23.1 (3)				
2'-4'		9.5 (4)				
4'-6'		0.8 (4)				
6'-8'		0.6 (4)				
>8'		0.3 (4)				
0-2'	1985	1.8 (2)		28.2 (4)		0.4 (2)
2'-4'		3.5 (2)		25.0 (4)		
4'-6'		2.6 (2)		51.9 (2)		
6'-8'		1.2 (2)		15.8 (2)		
>8'		0.9 (3)				

Note: Number in ( ) indicates the number of samples analyzed.
The (0-2') interval only includes samples that were deeper than 4".

exposed above the river banks. The sediments within the confines of the channel would thus be expected to exhibit much lower PCB concentrations than the exposed sediments, and would not be representative of the reach conditions that are most important to the development and evaluation of remedial actions for the corresponding Plainwell, Otsego, and Trowbridge Dam impoundments. Any instream sediment samples were thus ignored in the computation of the average PCB concentrations given in Tables 11 and 12. For consistency, a similar correction was made to the Bryant Mill Ponds data, even though relatively high concentrations were found even in instream sediment samples in this case.

6.2.2 Overall Discussion of Sediment Data

The following discussion is based on the average PCB values found in Tables 11 and 12, which are derived from the data presented in the tables in Appendix B. A few basic conclusions can be drawn about the levels of PCB contamination for the entire Kalamazoo River study area as a whole, but more trends can be seen by looking at each of the individual reaches of the river.

Generally, the highest concentrations of PCBs in sediments have been found, as would be expected, in the Bryant Mill Ponds and the Portage Creek area (Reach 1). These two sections have shown a substantial number of samples with PCB concentrations above the EPA "action level" of 50 ppm. An estimated 50 percent of the Bryant Mill Ponds data exceeded this level, while 38 percent of the sediment data from Portage Creek exceeded 50 ppm.

Approximately 6 percent of the entire sediment data base of 244 samples exceeded 50 ppm. A summary presenting the percent of sediment data base exceeding 50 ppm for each area can be found in Table 13.

The following paragraphs provide a discussion of the sediment data for each reach of the river.

Bryant Mill Ponds

The sediment data base for this area contained the highest PCB concentrations of the entire study area. Four surface samples taken at Lower Bryant Mill Pond had PCB levels well over 500 ppm, some of this data being as recent as 1986. The overall average of PCBs found in surface samples for all the years combined was greater than 175 ppm.

Most of the core samples taken throughout this area had somewhat lower concentrations than the surface sediments, but they were still substantially high. A core taken in Lower Bryant Pond in November 1983 had a PCB concentration of 212 ppm at a depth between 16 to 18 inches. No cores were taken deeper than 2 feet, unlike in some of the other reaches; thus the depth of contaminants is difficult to determine. The average PCB concentration of the cores for 1972 was 29.7 ppm, based on 12 samples, and the 1983 average was 51.1 ppm, based on 5 cores. These findings, along with the results from the surface sediment samples, suggest that the Bryant Mill Pond area has been and still is highly contaminated with PCBs relative to the other sections of the study area.

TABLE 13

SEDIMENT SAMPLES EXCEEDING ACTION LEVELS OF 50 ppm

	Bryant Mill Ponds	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5	Reach #6	Reach #7	Reach #8	Reach #9	Reach #10	Total
Number of Samples 50 ppm	26	3	2	1	1	1	3	0	1	0	0	38
Total Number of Samples	52	8	11	43	7	18	42	1	15	13	34	244
Percent 50 ppm	50%	38%	18%	2%	14%	5%	7%	0%	6%	0%	0%	16%

Reach 1: Portage Creek
Reach 2: Portage Creek confluence to Main Street, Plainwell
Reach 3: Main Street, Plainwell to Plainwell Dam
Reach 4: Plainwell Dam to Otsego City Dam
Reach 5: Otsego City Dam to Otsego Dam
Reach 6: Otsego Dam to Trowbridge Dam
Reach 7: Trowbridge Dam to City Line of Allegan
Reach 8: City Line of Allegan to Allegan City Dam
Reach 9: Lake Allegan
Reach 10: Allegan Dam to Saugatuck

Portage Creek - Reach 1

This reach is directly downstream of Bryant Mill Ponds; therefore, it was expected to be relatively highly contaminated due to the contamination from Bryant Mill Ponds. Based only upon the average annual PCB values found in the surface samples, the results tend to show a decline in concentration throughout the years 1972 to 1983. However, the data based is so small that trend analysis is not meaningful.

Based upon the exact locations of the samples, the conclusion is not the same. Most of the earlier samples (1972 and 1976) were taken toward Bryant Mill Ponds (upstream) and resulted in rather high levels of PCBs. The samples taken in 1983 reported lower concentrations, but were taken in locations downstream toward the confluence of Portage Creek and the Kalamazoo River.

Portage Creek Confluence to Main Street, Plainwell - Reach 2

Surface sediment samples for Reach 2 had an average PCB concentration of 9.0 in 1976, 36.2 in 1982, and 13.0 in 1984. No general trends can be detected from the annual averages; however, based on the upstream-downstream location of each of the samples, some spatial distribution trends seem to be apparent. All of the concentrations in the 1976 data were less than 15 ppm. The PCBs were distributed throughout the entire reach. A change occurred in the 1982 and 1984 data. No longer were the PCBs evenly distributed, but instead they seemed to be concentrated upstream near Michigan Avenue. A concentration of 57 ppm was reported at Michigan Avenue in the 1982 results. Downstream values at D-Avenue and Commerce Street were as low as 1.6 and 1.0 ppm.

Main Street, Plainwell to Plainwell Dam - Reach 3

The surface samples taken along Reach 3 (behind the Plainwell Dam) appeared to show a slight increase of contamination from 1976 to 1983. The concentration of PCBs in 1976 averaged 5.1 ppm, 8.8 ppm in 1982 and to 19.9 ppm in 1983. In general, the concentrations of PCBs found in this area are relatively low. The highest concentrations in surface samples were found close to Plainwell Dam. In 1983, samples located 50 feet and 0.15 miles upstream of the dam had concentrations of 25.6 ppm and 55.9 ppm, respectively. This latter sample was the only one found over the action level for this reach.

Core samples were taken in 1983, 1984, and 1985. The averages for the core samples suggest that most of the contamination lies in the upper 2 feet of the dry sediments. Many of the samples taken below 2 feet showed little contamination, most times in the range of 1 ppm or less. The cores that did reveal higher levels of contamination were located within 1 mile of the dam.

Plainwell Dam to Otsego City Dam - Reach 4

The data base for this reach is very limited. Only two surface samples and one core sample were available for this reach. The two surface samples, one taken 0.4 miles upstream of the dam and the other upstream, had an average concentration of 16.5 ppm. The core with many of the other core samples throughout the study area, that the majority of the PCB contamination is located within 2 feet of the sediment. At a depth of 12 inches, the sample level of 57.0 ppm, which decreased to 5.9 ppm at 3 feet. Since area that has been an active depositional zone, one would : a large quantity of contaminated sediment has been deposited. ent sampling is required in this area to fully assess the contamination.

Dam to Otsego Dam - Reach 5

wo surface sediment samples were taken in this reach, both r M-89. The 1976 data point recorded a PCB level of 66.1 ppm, 982 sample found about 27.0 ppm.

amples have been taken throughout most of the reach. The ns found in the core samples were generally low. Based on e data, the PCBs tended to increase in concentration upstream m, toward the dam. The PCB levels for the 1984 in-stream were less than 0.3 ppm for the entire depth of the 7-foot findings, along with the results from the surface samples, the contamination in this reach is limited to the top 2 feet ediment above the river channel.

Trowbridge Dam - Reach 6

ace samples available for this reach indicate that even as the area had relatively high levels of PCB concentrations. mples taken upstream of the dam had PCB levels over 60 ppm. les taken in 1983, 1984, and 1985 indicate that the majority ere within the uppermost 2 or 3 feet of exposed sediment r channel. Out of a total of 42 samples taken from this of the samples were above the action level of 50 ppm.

to Allegan City Line - Reach 7

e was taken in this reach at Bridge Street, and no PCBs ve the detection limit. The results of sample analysis sumption that this reach is free of PCB-contaminated e the reach is an erosional zone.

ne to Allegan City Dam - Reach 8

ace samples have been taken in this reach. A sample from Route 40-89 had a PCB concentration of 24.67 ppm. In taken close to the same location only had 3.61 ppm.

amples for this reach indicate that PCB concentrations n in the deeper sediments. Relatively high levels of PCBs were found throughout the core depths. One sample located upstream of the dam contained levels of 47.3 ppm at 0-2 t 5 feet; and 29.3 ppm at 7 feet. These levels are high other areas of the river.

Even though only one sample exceeded the 50 ppm level, four of the other samples are very close to the level and ranging from 45.5 to 47.3 ppm. These findings suggest that Reach 8 may be an area of particular concern.

Lake Allegan - Reach 9

Surface sediment samples from Lake Allegan were collected in 1976 and 1983. The 1976 data near Allegan Dam averaged 10.8 ppm. The 1983 data showed that throughout the lake, the PCB levels in surface sediments (0-4") averaged about 16 ppm.

Overall, the PCB levels showed an increasing trend going upstream from the dam toward Route 40-89. Near Route 40-89 the lake widens and the river velocity decreases. Sediments are likely to start depositing near this area. Therefore, the increase in PCB concentrations upstream to Route 40-89 is understandable. Upstream of Route 40-89, the river channel narrows, the velocity increases, and the PCB concentrations in the sediment decrease.

The core samples for this reach, taken in 1983, were composed of three transects and three other cores. On an average, the PCB values were approximately 15 ppm. Even though none of the data collected in this area exceeded the action limit of 50 ppm, the levels found in many of the core intervals are high enough to be of particular concern.

Allegan Dam to Saugatuck - Reach 10

Thirty-four surface sediment samples were collected throughout this reach in 1982 and 1985. These data suggest that the Lower Kalamazoo River sediments are relatively free of PCBs. The 11 surface samples from 1982 averaged 0.23 ppm, and the 1985 data averaged 0.32 ppm (21 samples). The highest level recorded was 1.74 ppm at a location in the deepest part of Kalamazoo Lake. The two core samples (4-6 inches) averaged 0.43 ppm.

Background: Morrow Pond and Monarch Mill Ponds

Morrow Pond and Monarch Mill Ponds serve as background data. Morrow Pond is located on the Kalamazoo River upstream of the confluence of Portage Creek. Reported PCB concentrations were below detection levels in 1986 (less than 1.8-3.4 ppm). Monarch Mill Ponds, located on Portage Creek upstream of Cork Street, had PCB values of 0.71, 0.40, and 0.35 ppm in 1984, and less than 1.8 and 2.3 ppm in 1986.

This background data helps to put the extent of PCB contamination into perspective relative to the other reaches of the Kalamazoo River involved in the study.

6.2.3 Results and Conclusions from Previous Studies: PCBs in Sediments

The following conclusions were taken from various reports that have been written over years. The conclusions are those of the original authors, and have been included to provide a more complete overall picture of the PCB problem in the Kalamazoo River.

- "PCB Survey of the Kalamazoo River and Portage Creek in the Vicinity of the City of Kalamazoo," (Lauer, 1973).

  -- Bottom sediments in the upper and lower Bryant Mill Ponds appear to act as a significant reservoir of PCBs for the Portage Creek system. A layer of highly contaminated sediment probably exists throughout the ponds.

  -- At the time of the drawdown of Bryant Mill Ponds, the sites downstream of Alcott Street appeared to have the highest levels of PCBs in the water. This increase in concentration was probably due to contaminated sediments releasing PCBs into the water.

  -- The effect of Portage Creek's PCB discharge to the Kalamazoo River could have been somewhat masked by the proximity of the Kalamazoo Wastewater Treatment Plant discharge, an additional historical source of PCBs. However, the discharge concentrations of PCBs from Portage Creek were considered significant.

- "Sediment Samples from Proposed Otsego Hydroelectric Reservoir," (USFWS, 1983).

  -- Generally, samples showed heavy contamination by Aroclor 1248 (PCB). The levels ranged from a low of 0.79 ppm to a high of 28.0 ppm. Deeper sediments were also heavily contaminated with PCBs.

  -- Exposure to the PCBs by aquatic biota can be expected if the sediments are reimpounded.

- "A Survey of PCBs in the Kalamazoo River and Portage Creek Sediments, Kalamazoo to Lake Allegan," (Creal, 1983a).

  -- PCB-contaminated sediments were found at all four sampling locations: instream sediment concentrations averaged 37 ppm in Lower Bryant Mill Pond; 25.6 ppm in the Plainwell impoundment; 10.8 ppm in the Trowbridge reach; and 15.7 ppm in Lake Allegan.

  -- In the Lower Bryant Mill Pond, Plainwell, and Trowbridge areas, the exposed shoreline sediments had average PCB concentrations of 135.0, 22.6, and 26.0, respectively.

  -- The exposed sediments in the above three areas appeared loosely consolidated and easily erodible.

  -- PCB contamination of apparently recent stream bank deposits in Portage Creek indicated the continued downstream transport of PCBs.

  -- The estimated mass of PCBs in the four areas, plus the Otsego Dam impoundment, was 227,910 pounds. More than half of this mass (132,000 pounds) was contained in the exposed sediments in the Lower Bryant Mill Pond, Plainwell, Otsego, and Trowbridge impoundments. The greatest in-stream mass of PCBs was found in Lake Allegan, approximately 75,000 pounds.

- "PCBs in Fish, Sediments and Water of the Lower Kalamazoo River and Nearby Lake Michigan," (Horvath, 1984).

  -- PCBs found in significant concentrations in the Lower Kalamazoo River ecosystem. Fish flesh exceeded the FDA "action level" of 5 ppm [since lowered to 2 ppm]. Sediment concentrations were low but widespread throughout the study area.

  -- Indications that sufficient sediment contamination exists to maintain high PCB concentrations in river fish for the foreseeable future.

  -- A direct PCB effect on Lake Michigan sediments was not obvious.

  -- PCBs in Kalamazoo River sediments are more closely associated with fine sediments than with coarse sediments, and of the fines, are more closely associated with clays than silts.

  -- The time required for the Kalamazoo River to be free of contamination, or before the fish consumption advisory can be lifted, cannot be estimated until the mechanisms of PCB transport and ultimate fate are understood for this river system.

6.2.4 PCBs in the Water Column

Water column data, collected from various studies, is summarized in Table 14. Samples taken in the Kalamazoo River at River Street in Comstock, and in Portage Creek at Cork Street are considered background data points.

The greatest concentration was found in Portage Creek at Bryant Dam. The concentrations found in Portage Creek downstream of Bryant Pond were greatly elevated over background levels. In the Kalamazoo River above Allegan Dam, concentrations generally increased from upstream to downstream. The greatest concentrations were found in Reaches 8 and 9 (from the Allegan City Dam impoundment to Lake Allegan). Below Allegan Dam, concentrations dropped to lower levels. In general, concentrations in the Kalamazoo River were also elevated above background levels but remained less than values found in Portage Creek downstream of Bryant Pond.

6.2.5 PCBs in Fish

Carp and Bass Data

Since one objective of this study is to develop cost-effective remedial actions to lower the PCB concentration in the fish to a level less than 2 ppm, it is important to examine and understand the available fish data. The study identified two species of fish (carp and bass), which were considered representative of the overall fish community. The carp was chosen because it is easily available throughout the study area

TABLE 14

SUMMARY TABLE
PCB CONCENTRATIONS IN WATER
(parts per trillion (ppt))

Sample Location		Average PCB Concentration (ppt)	Year	Reference
Portage Creek				
Cork Street	Upstream of Bryant Mill Ponds (background)	10	1985-7	MDNR
Alcott Street	Reach 1 at Bryant Dam	143	1985-7	MDNR
Kalamazoo River				
River Street	Below Morrow Dam in Comstock (background)	10	1985-7	MDNR
10th Street	Reach 3 above Plainwell Dam	84	1985-7	MDNR
Plainwell Dam	Reach 4 below Plainwell Dam	68	1985-6	MDNR
Farmer Street	Reach 5 below Otsego City Dam	60	1985	MDNR
Otsego Dam	Reach 6 below Otsego Dam	76	1985	MDNR
26th Street	Reach 7 below Trowbridge Dam	86	1985	MDNR
Williams Road	Reach 8 above Allegan City Dam	100	1985	MDNR
Route M-118	Reach 9 below Allegan City Dam	105	1985-6	MDNR
Allegan Dam	Reach 10 below Allegan Dam	116	1985-6	MDNR
New Richmond	Reach 10 town of New Richmond	61	1982	Horvath, 1984
U.S. 31 Bridge	Reach 10 town of Douglas	96	1982	Horvath, 1984
Old U.S. 131 bridge	Reach 10 town of Douglas	63	1985-6	MDNR
Saugatuck	Reach 10 river mouth	54	1982	Horvath, 1984
Saugatuck	Reach 10 river mouth	40	1980	Marti, 1984

and because it represents bottom-feeding fish, which are likely to be in contact with contaminated sediments. The bass represents predator species and is a target species in the MDNR plan to rebuild the game fishery in the study area.

The available data for these two species was compiled for five locations in the study area and for one location upstream of the study area (Morrow Pond) where the fish consumption advisory does not apply, except for carp. The five locations, upstream to downstream, are:

- Portage Creek/Bryant Mill Pond
- Mosel Avenue, Kalamazoo
- Downstream of Plainwell Dam
- Lake Allegan
- Saugatuck

The five study areas and Morrow Pond are all isolated by at least one physical barrier (a dam) that prevents upstream movement of the fish. These areas were chosen because data is available over a period of many years.

All data for carp and bass is presented by area in Appendix B. This data was used to obtain average PCB concentrations for each area, which are summarized by year in Tables 15 and 16.

Based on available data, the average levels of PCBs found in fish appear to have decreased from 1971 to 1986. However, this trend must be considered with several important qualifications. The following are some limitations in the data, which should be considered when interpreting or using the fish data.

- Other factors being equal, PCB concentration in fish will vary by species. For example, PCB contamination is expected to be greater in the bottom-feeding carp than in bass.

- PCB contamination in fish is a function of the age, size, weight, and percent body fat of the fish. Larger and older fish may accumulate greater concentrations of PCBs.

- Some areas of the river have highly stressed environment owing to industrial or water treatment plant discharges. Highly stressed environments can affect the overall health of the fish, the size and fat content of the fish, and thus possibly the PCB concentration in the fish flesh. For example, when the environment is highly stressed (as it is at Bryant Mill Ponds and Mosel Avenue), the fish will tend to be relatively small and will have relatively low fat content. Therefore, since PCBs accumulate in the fat, the PCB concentration in those fish may be less than expected. On the other hand, in a favorable environment (such as Morrow Pond or Saugatuck), the environmental conditions promote optimum fish growth. Therefore, the fish grow relatively large, have relatively high fat content, and may have higher PCB concentrations than expected.

TABLE 15

SUMMARY OF AVERAGE PCB CONCENTRATIONS FOR CARP IN THE KALAMAZOO RIVER STUDY AREA

Year	Morrow Pond	Portage Creek (Bryant Pond)	Mosel Avenue	Downstream Plainwell Dam	Lake Allegan	Saugatuck
1971	5.07 (1)	---	164.50 (1)	20.53 (2)	7.32 (1)	45.40 (1)
1976	2.10 (1)	---	8.00 (1)	13.35 (2)	7.40 (1)	36.00 (1)
1978	---	---	---	---		110 (3)
1981	1.71 (9)	---	2.33 (18)	3.22 (6)	7.97 (20)	6.58 (11)
1983	---	---	3.50 (11)	5.50 (11)	2.80 (3)	8.50 (11)
1985	2.56 (20)	3.06 (10)	4.98 (19)	5.27 (20)	4.41 (19)	3.59 (20)
1986	3.46 (20)	3.96 (21)	4.68 (20)	4.13 (21)	4.27 (81)	3.78 (19)

Note: Number in parentheses represents number of fish sampled.
Note: All PCB concentrations are in mg/kg (ppm).

TABLE 16

SUMMARY OF AVERAGE PCB CONCENTRATIONS FOR
BASS IN THE KALAMAZOO RIVER STUDY AREA

Year	Morrow Pond	Portage Creek (Bryant Pond)	Mosel Avenue	Downstream Plainwell Dam	Lake Allegan	Saugatuck
1976	0.20 (1)	---	---	---	2.40 (1)	34.10 (1)
1981	0.34 (23)	---	0.95 (3)	0.47 (1)	1.09 (9)	3.69 (9)
1985	1.28 (7)	---	1.69 (2)	3.28 (1)	2.79 (10)	1.33 (10)

Note: Number in parentheses represents number of fish sampled.
Note: All PCB concentrations are in mg/kg (ppm).

ıke Allegan, the carp population is stressed because of overpop-
.on. There is a competition for a limited food supply, and the
:h of the fish is stunted. Therefore, PCB concentrations may be
· than expected.

atory analytical techniques used to quantify PCBs in fish have
ed significantly since the early 1970's. Results are now
ted differently, the standard for interpretation of results has
ed, and the extraction method has changed. Also, the same
atory has not analyzed all the fish samples.

amples taken in the 1970's were primarily "screening" samples
termine if a contamination problem existed. The fish collected
i to be the largest fish found and, thus, to represent
-case conditions. In contrast, the fish samples taken in 1981
983 were intended to represent the entire population of the
:ed species. The variance within these samples made statisti-
ıalysis difficult. Therefore, the 1985 and 1986 fish collec-
targeted a specific size range for carp and bass in an effort
..-e sample variance, to standardize the exposure period, and
ow for more meaningful trend analysis.

effort to better define the trend in PCB concentrations in
vailable carp and bass data was examined statistically The
analysis method used was a non-parametric one-way analysis by
(Kruskal-Wallis 1952) as described by Conover (1980). All
analyses were performed using a level of significance of

Feasibility Study (NUS, 1986), the statistical analyses were
ı age (size) restricted carp in an effort to standardize
i other facors. However, in 1986 the MDNR collected a large
of carp from Lake Allegan for PCB analysis (Creal, 1987). No
› was found between age (size) and PCB. Therefore, it was
ıat the entire data base, where suitable, should be used for
analysis.

.table carp data base consisted of 1981, 1983, 1985, and 1986
l Avenue, Plainwell Dam, Lake Allegan and Saugatuck, 1981,
6 data at Morrow Pond, and 1985 and 1986 data on Portage

s data base consisted of 1981 and 1985 data at Morrow Pond,
and Saugatuck. The complete data bases are listed by
Appendix B.

› PCB data base was examined for temporal trends. No
:hange with time was found at the Morrow Pond, Plainwell,
. Saugatuck or Portage Creek locations. However, the carp at
exhibited significant increase with time. This is presented
:derlined years not significantly different and yearly
:oncentration in parentheses.

1981	1983	1986	1985
(2.33)	(3.50)	(4.68)	(4.98)

The bass PCB data base was also examined for temporal trends. No significant change with time was found at the Lake Allegan or Saugatuck locations. However, the bass at Morrow Pond exhibited a significant increase in PCB concentrations between 1981 and 1985.

Based on these temporal trends, it may be concluded that PCB concentrations in fish are not declining, and , at selected locations, are exhibiting a statistically significant increase in PCB concentrations.

The carp PCB data based was also examined for spatial trends. No significant differences by location were found for the 1983 and 1986 data sets. However, significant differences by location were found for the 1981 and 1985 data sets. These results are presented below with underlined locations not significantly different and location average PCB concentration in parentheses:

1981	MP (1.71)	MO (2.33)	PD (3.22)	SAUG (6.58)	LA (7.97)	
1985	MP (2.56)	PCK (3.06)	SAUG (3.59)	LA (4.41)	MO (4.98	PD (5.27)

Where MP = Morrow Ponds, MO = Mosel Avenue, PD = Plainwell, LA = Lake Allegan, SAUG = Saugatuck, and PCK = Portage Creek. Taken as a group, these data indicate some general spatial trends. First, the Morrow Pond carp PCB concentrations are consistently lower than the other four Kalamazoo River locations. As a corollary, the four Kalamazoo River stations (MO,PD,LA,SAUG) do not exhibit any spatial differentiation in PCB concentrations. This trend is especially evident in the recent years (1983-86).

The bass PCB data were also examined for spatial trends. Both the 1981 and 1985 data exhibited significant differences by location. These results are presented below with underlined locations not significantly different and location average PCB concentration in parentheses:

1981	MP (0.34)	LA (1.09)	SAUG (3.69)
1985	MP (1.28)	SAUG (1.33)	LA (2.79)

Based on these results, a general conclusion may be made that Morrow Pond bass are consistently, significantly lower in PCB concentrations than Lake Allegan bass, even though the Morrow Pond bass concentrations have increased significantly over the 1981-85 period as previously discussed. In general, this conclusion agrees with the carp spatial orientation in that Morrow Pond fish PCB concentrations were lower than the other downstream Kalamazoo River locations.

Based upon the PCB data base results, selected fat data sets were analyzed for trends. The Saugatuck and Mosel Avenue locations were analyzed for temporal trends in carp fat concentrations. No significant difference with time was found at Saugatuck, consistent with the PCB results. However, the Mosel Avenue location exhibited significant differences between years. These results are presented below with underlined years not significantly different and fat concentrations in parenthesis:

Mosel Ave	1985	1981	1983	1986
	(1.97)	(2.06)	(2.3)	(4.1)

The fat results at Mosel Avenue are not consistent with the PCB results. The 1985 PCB levels were significantly greater than all years but 1986, yet the fat level for 1985 was significantly lower than 1986. However, the Mosel Avenue station has been environmentally stressed by the poor water quality. In addition, fish may migrate into and out of this condition. These factors may be causing a bias in these results and thereby disrupting the usual relationship between PCB and fat levels.

The fat data set was also examined for spatial trends. For carp, significant differences by location were found for all years tested (1983, 1985, 1986). These results are presented below with underlined locations not significantly different and fat concentrations in parentheses:

1983	LA	MO	PD	SAUG		
	(0.80)	(2.30)	(2.80)	(5.60)		
1985	PCK	LA	MP	MO	PD	SAUG
	(0.6)	(1.58)	(1.62)	(1.92)	(2.30)	(5.54)
1986	PCK	LA	MP	PD	MO	SAUG
	(1.1)	(1.3)	(2.4)	(2.8)	(4.1)	(5.1)

These results indicate some general trends. First, carp in different sections of the river were exhibiting different levels of fat. The carp at Saugatuck were consistently significantly fatter than most other locations. This was suspected based on visual observations during collections as Saugatuck carp were distinctly larger than at other locations. Second, Portage Creek and, to a lesser extent, Lake Allegan carp have significantly less fat than the other locations. This result was also suspected based on visual observations. Third, the spatial trends with fat do not necessarily follow the PCB concentration trend. This is likely due to varying environmental exposure to PCBs.

- Based on these analyses, the following conclusions were made:

- There is no significant overall decline in PCB concentrations in the Kalamazoo River fish advisory area in recent years (1981-1986) and, at selected locations, fish are exhibiting a statistically significant increase in PCB concentrations.

- In general, Morrow Pond fish PCB concentrations were lower than the other downstream Kalamazoo River locations.

- Spatial trends with fat levels were evident. Saugatuck carp were significantly fatter than other locations, while Portage Creek and, to a lesser extent, Lake Allegan carp has less fat.

- Spatial trends with PCB concentration did not necessarily follow trends in fat levels. This is likely due to varying environmental exposure to PCBs.

6.2.6 Results and Conclusions from Previous Studies: PCBs in Fish

The following conclusions were taken from various reports that have been written over the years. The conclusions are those of the original authors and have been included to provide a more complete overall picture of the PCB problem in the Kalamazoo River.

- "Evaluation of the Aquatic Environment of the Kalamazoo River Watershed," (May 1972) MDNR.

  - Concentrations ranged from 0.01 to 109.9 ppm in the edible portions of fish tissue.

  - Significant increases in PCBs occurred downstream from the Battle Creek Wastewater Treatment Plant. An even greater increase was noted in the fish immediately downstream from the City of Kalamazoo, and concentrations remained high throughout the remainder of the stations sampled.

  - The data suggest that a very significant PCB contamination problem exists in the Kalamazoo River Basin and that the probable sources are within the cities of Battle Creek and Kalamazoo.

- "Contaminants in Kalamazoo River Fish" (MDNR, 1981).

  - Survey of fish from Morrow Pond to the mouth of the Kalamazoo River found that the average PCB concentration for 169 fish analyzed was 2.8 ppm.

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- — Seventeen percent of the fish had concentrations greater than 5 ppm, the then current FDA "action level"; thirty-seven percent were greater than 2 ppm, the recently imposed FDA "action level".
- — PCB concentrations in fish declined substantially, based on the comparison of 1981 data with data from 1971, 1976, and 1978.
- — Data showed that fish from Morrow Pond were relatively PCB-free. Portage Creek, D-Avenue, Plainwell, and New Richmond fish had slightly higher concentrations. Allegan, Douglas, and Saugatuck samples had the highest concentrations.

• "PCBs in Fish, Sediments, and Water of the Lower Kalamazoo River and Nearby Lake Michigan," Data from September 1981 study, by Horvath (1984).

- — It is probable that, even though no point sources exist, PCBs are still entering the river. Specifically, a now defunct deinking and recycling mill on Portage Creek is probably an active nonpoint source from land runoff and lagoon leachate.
- — The known history and distribution of PCBs in the river suggest that PCBs in the lower river have arrived, and continue to arrive, as a result of translocation from upstream.
- — The PCB concentrations found in fish were reasonable compared to those found in water and sediments. If water and sediment concentrations remain stable, fish concentrations will also remain stable.
- — A direct PCB effect on Lake Michigan fish was not evident.

• "PCB and Mercury Concentrations in Carp from the Lower Kalamazoo River" (Creal, 1983b).

- — PCB concentrations in carp averaged 3.15 ppm at Mosel Avenue in Kalamazoo, 5.5 ppm at Plainwell Dam, 2.8 ppm in Lake Allegan, and 8.5 ppm at Saugatuck.
- — The PCB concentrations in carp ranged from 0.88 ppm at Plainwell Dam to 25.7 ppm at Saugatuck.
- — Generally, the PCB concentrations in carp did not exhibit a noticeable change between 1981 and 1983.

6.2.7 Summary and Conclusions

The following is a summary of conclusions regarding PCB concentrations in the various media. Only general conclusions have been drawn from the sampling data because of the limited number of samples, the expected variability in the river system, and other complicating factors.

Sediment

- At Bryant Mill Ponds, both surface and core samples indicated high levels of contamination. Core samples showed contamination down to at least 2 feet. This is by far the most highly contaminated area of the river within the limits of this study.

- Portage Creek (Reach 1) has shown moderate levels of contamination, a fact which is likely due to contaminated sediment from Bryant Mill Pond being deposited in the downstream reach.

- Although Reach 2 is considered an erosional zone and is expected to be relatively free of contamination, moderate levels of PCBs have been found in the upper portions of the reach. This is possibly because of lateral variations in the flow field caused by the confluence of the Kalamazoo River and Portage Creek.

- At the Plainwell Dam (Reach 3), contamination appears to be restricted to the sediment beds above the river channel, and at relatively low concentrations. Core samples indicate that contamination is restricted to the top 1 or 2 feet of sediments. There appears to be very little in-stream contamination.

- At Otsego City Dam (Reach 4), contamination has been detected; however, there is not enough data to draw reliable conclusions.

- At Otsego Dam (Reach 5), surface and core samples have shown moderate levels of contamination down to a depth of 20". Contamination was detected mainly in the sediment above the river channel.

- At Trowbridge Dam (Reach 6), surface and core samples have shown moderate levels of contamination down to a depth of approximately 2 feet. Contamination appears to be restricted to the sediment beds above the river channel. Little in-stream contamination was detected.

- Reach 7 is an erosional zone and is not expected to show any contamination. No detectable level of PCBs was found in a single sample from this reach.

- Although surface samples generally exhibit relatively low PCB concentrations, core samples at Allegan City Dam (Reach 8) have indicated moderately high levels of contamination as deep as 1½ feet.

- Moderate levels of contamination have been detected in both surface and core samples from Lake Allegan (Reach 9). PCB concentrations increase with distance from the dam. This reflects the typical sediment deposition pattern of a large lake.

- A large number of sediment samples were taken in Reach 10, and all had levels PCB below 2 ppm. Therefore, it is reasonable to assume that the sediments below Allegan Dam have not been significantly affected by the PCB contamination problem. One possible explanation is that any fine suspended sediment that does not settle out in Lake Allegan would also likely stay in solution below the dam.

Water

- The entire river system from Bryant Mill Ponds to Lake Michigan exhibits PCB concentrations in water that are significantly elevated above background.

- The highest levels are found in Portage Creek, in and immediately downstream of Bryant Mill Pond.

- Downstream of the confluence of Portage Creek with the Kalamazoo River, PCB concentrations in water decrease due to dilution effects.

- From Plainwell Dam downstream, PCB concentrations steadily increase up to Allegan Dam, presumably resulting from increased contact with contaminated sediments.

- Downstream from Allegan Dam, PCB concentrations in water decrease.

Fish

- There is no significant overall decline in PCB concentrations in the Kalamazoo River fish advisory area in recent years (1981-86), and, at selected locations, fish are exhibiting a statistically significant increase in PCB concentrations.

- In general, Morrow Pond fish PCB concentrations were lower than the other downstream Kalamazoo River locations.

- Spatial trends with fat levels were evident. Saugatuck carp were significantly fatter than other locations, while Portage Creek and, to a lesser extent, Lake Allegan carp had less fat.

6.3 DEVELOPMENT OF THE PCB MODEL FOR THE KALAMAZOO RIVER

A steady-state, one-dimensional PCB distribution model was developed to simulate the PCB concentrations in the Kalamazoo River. The objective of this modeling study was to evaluate the long-term effectiveness of alternative remedial actions by predicting the PCB distribution in different reaches of the river with and without the action. Major environmental processes and factors affecting the transport of PCBs in the river, and the PCB exchange between water and sediment could be computed based on the principle of mass conservation.

Since the objective of this modeling study was to evaluate the long-term effects of different proposed remedial actions, in addition to the no-action alternative, the application of the governing equations was approximated by a steady-state solution. That is, the time-dependent terms representing the transient response of the concentrations of PCBs and suspended solids to environmental factors were neglected. In addition, the transport of bed sediment was not included in this model because the contribution of the bed materials to PCB transport was not considered significant enough to justify the additional complication of the model. The movement of bed sediment is relatively slow, when the bed

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material is cohesive, and the impoundments still existing in the river system constitute natural barriers to the continuous movement of bed material. As a result, the exchange of PCB between water and sediment, and the movement of PCBs and PCB-contaminated suspended solids within the water column, are the major mechanisms affecting the downstream movement of PCBs in this river system.

The available data base representing the average conditions of channel geometry, river flow, and PCB concentrations in water and sediment was split into two subgroups, which were then used to calibrate and verify the model. The purpose of this section is to present the basic concept and theory of the model, the calibration and verification of the model, and the results of sensitivity analyses of the model parameters. The model is then used to assess the response of PCBs in the river system under various proposed remedial actions. Finally, the simulated steady-state PCB concentrations in the water are used to determine the consequent PCB concentrations in the fish, through the use of a bioconcentration factor.

6.3.1 Development of the Model

The model developed in this feasibility study was selected by considering the goal of the modeling study, the restrictions in the data base, and the limitation of available time and budget. The model was developed originally by NUS, reviewed by the MDNR, and then presented for public review as part of the Kalamazoo River PCB Feasibility Study. The model is primarily used to compare the relative effectiveness of remedial actions. The accuracy of predicted PCB concentrations in water, sediments, and fish must be interpreted within the framework of data base limitations and model simplification. The model is a steady-state model, which means it cannot provide the change in the simulated results with time. Thus, the developed model was only used to simulate the long-term, steady-state concentrations of PCBs in water and sediment, as well as the concentration of suspended solids in the water column for the individual reaches as a result of the application of selected remedial actions.

6.3.2 Processes Affecting PCB Distribution

PCBs are hydrophobic and, therefore, have a strong affinity for particulate materials such as sediments and suspended solids. PCBs are also environmentally stable, owing to their refractory character and low vapor pressure. Thus, their losses through biodegradation and volatilization are relatively slow. The long-term equilibrium PCB concentrations between water and sediments can be predicted by considering all the major processes affecting the existence of sources and sinks of PCBs in the river system and considering the partitioning of PCBs between water and sediments.

The one-dimensional river system under study was spatially segmented into control volume elements, or river reaches, along its length. Within each reach two distinct physical layers were included. The water level is located directly above the sediment layer. The major sources of PCBs for the water layer included the following:

- Inflow of PCBs from the upstream reach
- Deposition of PCBs from the atmosphere
- Point sources of PCBs, including water discharges or sediment influx
- PCB benthic releases caused by turbulence or bioactivity
- Suspension of PCB-contaminated sediments
- Erosion of PCB-contaminated clayey materials at the bottom of the river
- PCB diffusion between water and sediment layers

The major processes for the loss of PCBs from the water layer included:

- Outflow of PCBs from the reach
- Settling of PCB-contaminated particles
- PCB biodegradation
- PCB volatilization

The sediment layer within each reach was only treated as a source or sink of PCBs. The transport of bed materials was not included in this model. Therefore, the input of PCBs into the sediment layer could occur as a result of the following processes:

- Settling of the PCB-contaminated particles from the water column
- Point sources of PCB-contaminated sediments

The loss of PCBs from the sediment layer could occur because of:

- PCB benthic releases
- PCB diffusion between water and sediment
- Suspension of PCB-contaminated sediment
- PCB biodegradation
- Sediment loss by permanent bed burial (i.e. burial of the active sediment layer)
- Erosion of PCB-contaminated clayey materials at the river bed.

PCB-contaminated solids in the water layer can directly affect the total PCB concentration in the water column and the amount of PCB that can be settled to the sediment layer. Therefore, suspended solids were also included in the model as a dependent model variable in addition to PCB concentration in water and sediment. Suspended solids were assumed to be completely entrained with the average velocity of water and were thus modeled like a water-soluble constituent. However, the concentration of suspended solids in the water layer could be affected by parameters such as particle settling velocity, sediment suspension velocity, and the clayey material erosion rate of the river bed. A schematic diagram describing the model structure and all the processes mentioned above is depicted in Figure 3.

6.3.3 Governing Equations

Based on the principle of mass conservation (i.e., mass balance) and including all the processes delineated above, the one-dimensional transport of PCBs may be described by the following equations:

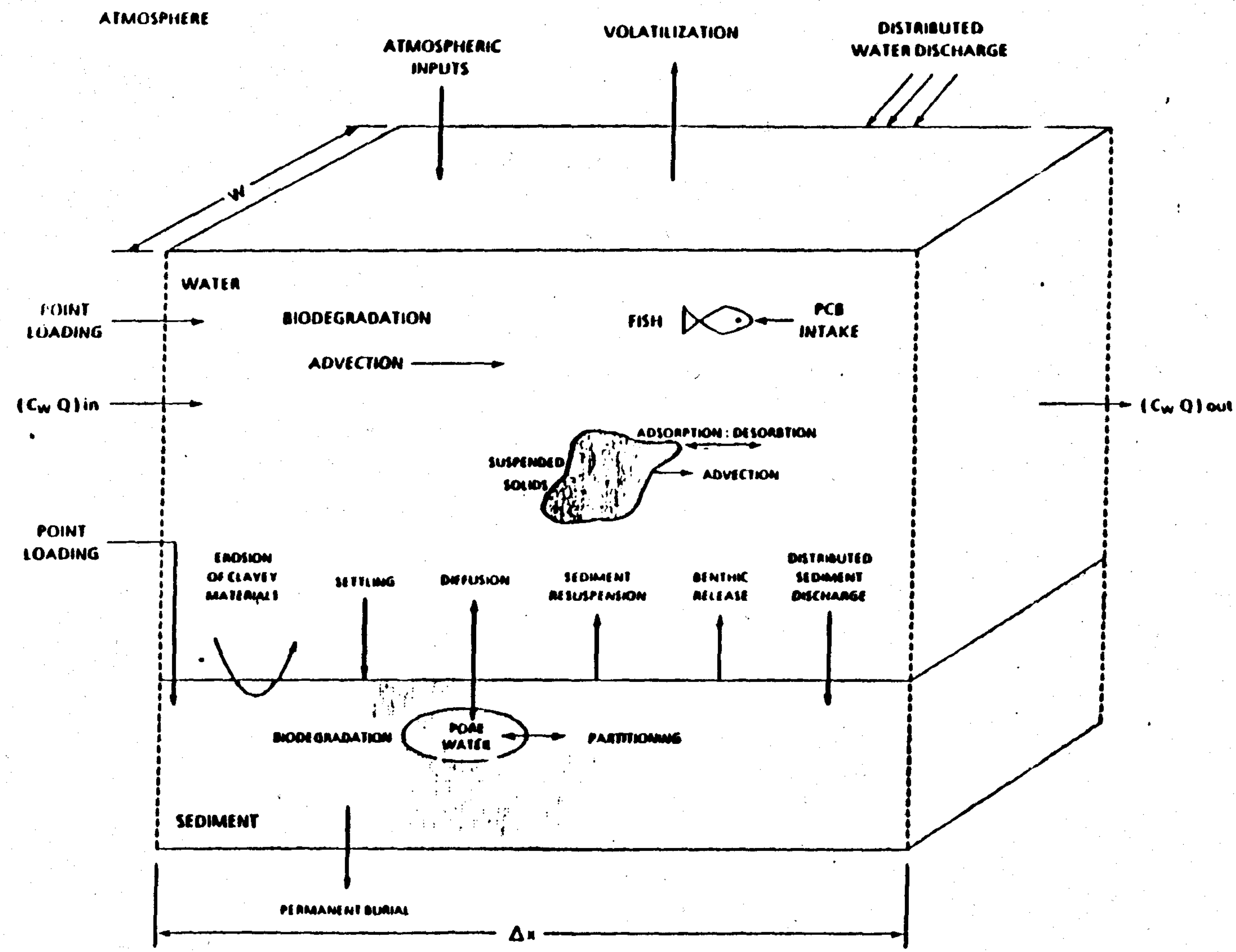

Figure 3.
SCHEMATIC DIAGRAM OF MODEL
KALAMAZOO RIVER PCB STUDY

$$\frac{d(Cw)(A)}{dt} = -\frac{d(Cw)(Q)}{dx} - (Qx)(Cw) + (Ra)(W) + (Rb)(Wp)$$

$$+ (Rr)(fps)(p)(1-P)(Cs)(Wp)(1-fcs)$$
$$+ (D)(Wp)[(Cs)(1-P)(p)(fds) - (Cw)(fdw)]$$
$$+ (E)(Cs)(Wp)(fps)(fcs) + (Os)(Cp/L)$$

$$+ (Qsd,p)-(Cps)(fdw/L)$$
$$- (S)(1-o)(fpw)(Cw)(W) - (K)(Cw)(fdw)(A)$$
$$- (Kr)(Rar)(Cw)(fdw)(A) \quad (1)$$

$$\frac{d[Cs.p.(1-P).Asd]}{dt} = (S)(1-o)(fpw)(Cw)(W) + (Qsd)(p)(Cps)(fpw/L)$$

$$- (D)(Wp)[(Cs)(1-P)(p)(fds) - (Cw)(fdw)]$$
$$- (Rr)(fps)(p)(1-P)(Cs)(Wp)(1-fcs)$$
$$- (Rb)(Wp) - (K)(p)(1-P)(fds)(Cs)(Asd)$$
$$- (B)(Cs)(fps)(p)(1-P)(Wp) - (Cs)(Qsd,x)(p)$$
$$- (E)(Cs)(Wp)(fps)(fcs) \quad (2)$$

$$\frac{d(Css.A)}{dt} = -\frac{d(Css)(Q)}{dx} - (Qx)(Css) - S(1-o)(Css)(W)$$

$$+ Rr(p)(1-P)(Wp)(1-fcs)$$
$$+ E(Wp)(fcs) \quad (3)$$

$$fdw = \frac{1}{1 + Css[kps(1-fcw)+Kpc(fcw)](10^{-6})} \quad (4)$$

$$fds = \frac{1}{1 + (1-P)p[kps(1-fcs) + Kpc(fcs)](10^{-6})} \quad (5)$$

$$fpw = 1-fdw \quad (6)$$

$$fps = 1-fds \quad (7)$$

$$E = E_k \left(\frac{T}{Tc} - 1\right) \quad (8)$$

$$T = 1.271.10^{11}.\ (A/Wp).S_1 \quad (9)$$

$$o = 1-0.0108(d_{50})/(d_{50}-1.62.10^{-6})K_v[(\frac{T}{1000})^{1/2} v_c] \quad (10)$$

$$v_c = [5.08(10^6)((p/10^6)-1)d_{50}]^{1/2} \quad (11)$$

where

Cw	=	PCB concentration in water	(g/m^3)
Cs	=	PCB concentration in sediment	(mg/kg)
Css	=	concentration of suspended solids in water	(mg/1)
Cp	=	PCB concentration in water from a point source	(g/m^3)

Cps	= PCB concentration in sediment from a point source	(mg/kg)
Q	= river flow rate	(m^3/min)
Qs	= water discharge from a point source	(m^3/min)
Qsd,p	= sediment discharge from a point source	(g/min)
A	= cross-sectional area of the reach	(m^2)
X	= longitudinal distance along the river	(m)
t	= time	(min)
W	= average width of the reach	(m)
Wp	= wetted perimeter of the reach	(m)
L	= length of the reach	(m)
Asd	= cross-sectional area of the active sediment layer within the reach	(m^2)
B	= sediment burial rate (related to loss in depth of the active sediment layer by permanent burial)	(m/min)
P	= porosity of the active sediment layer	(m^3/m^3)
	= sediment density	(g/m^3)
S	= average settling velocity of suspended solids	(m/min)
D	= benthic diffusion velocity of PCB	(m/min)
Ra	= atmospheric PCB fallout rate	(g/m^2/min)
Rb	= PCB benthic release rate (related to loss in depth of the active sediment layer by sediment resuspension)	(g/m^2/min)
Rr	= sediment suspension velocity	(m/min)
K	= PCB first-order biodegradation rate at 20°C	(min^{-1})
Kr	= oxygen reaeration rate	(min^{-1})
Rar	= reaeration coefficient ratio of PCB	(unitless)
fcs	= fraction of clayey materials in the sediment layer	(unitless)
fcw	= fraction of clayey materials in the water layer	(unitless)
kps	= PCB partition coefficient for sand	$\frac{(m^3 \text{ water})}{10^3 \text{ g sed}}$
kpc	= PCB partition coefficient for clayey materials	$\frac{(m^3 \text{ water})}{10^3 \text{ g sed}}$
d_{50}	= mean particle size of the suspended solids	(m)
K^v	= kinematic viscosity of water	(m^2/hr)
V_c	= critical shear velocity of suspended solids	(m/hr)
o	= probability of resuspension of suspended solids	(unitless)
fds	= fraction of dissolved PCB in sediment	(unitless)
fps	= fraction of adsorbed PCB in sediment	(unitless)
fdw	= fraction of dissolved PCB in water	(unitless)
fpw	= fraction of adsorbed PCB in water	(unitless)
Qx	= distributed water discharge along the reach	(m^3/min-m)
Qsd,x	= distributed sediment discharge along the reach	(m^3 sed/min-m)
E	= erosion rate of the cohesive bed materials	(g/m^2/min)
E_k	= erosion rate constant of the cohesive bed materials	(g/m^2/min)
T	= shear stress of the flows	($kg/m/hr^2$)
T c	= critical shear stress of the cohesive bed materials	($kg/m/hr^2$)
S	= bed slope	(fraction)

Dependent variables Cw, Cs, and Css contained in Eq (1) through (3) are functions of time and distance. Descriptions of the terms included in the governing equations are given in Table 17.

TABLE 17

DESCRIPTION OF TERMS IN GOVERNING EQUATIONS

Term	Description
(1) $\frac{\partial(Cw \cdot A)}{\partial t}$ and $\frac{\partial[Cs \cdot \rho \cdot (1-P) \cdot Asd]}{\partial t}$	Time-dependant change of mass of PCB per ~~unit length of~~ river in the water layer and sediment layer, respectively.
(2) $\frac{\partial Cw}{\partial x} \cdot Q$	Change of PCB concentration with distance due to advection
~~(3) Cr-Cw~~	~~Dilution of PCB by distributed discharge of water along the river~~
(4) $Ra \cdot W$	Atmospheric fallout of PCB
(5) $Rb \cdot Wp$	Benthic PCB releases due to disturbance of bottom sediment
(6) $Rr \cdot fps \cdot \rho \cdot (1-P) \cdot Cs \cdot Wp \cdot (1-fcs)$	PCB increase due to resuspension of contaminated sediment
(7) $D \cdot Wp \cdot [Cs \cdot (1-P) \cdot \rho \cdot fds - Cw \cdot fdw]$	PCB increase/decrease due to PCB diffusion between water column and pore water within sediment layer
(8) $E \cdot Cs \cdot Wp \cdot fps \cdot fcs$	PCB increase due to erosion of clayey materials
(9) $Qs \cdot Cp/L$	PCB increase due to point source discharge of contaminated water
(10) $Qsd,p \cdot Cps \cdot fdw/L$ and $Qsd,p \cdot Cps \cdot fpw/L$	PCB increase due to point loading of contaminated sediment
(11) $S \cdot (1-\phi) \cdot fpw \cdot Cw \cdot W$	PCB decrease due to settling of contaminated suspended solids

previously. Although PCB and suspended solids concentrations can be expected to vary within each segmented reach, only space-averaged concentrations are computed to represent the average concentrations within each reach.

6.3.4 Model Input

The inputs to the model can be generally divided into two major categories based on their sources. Data such as channel geometry, river flows, water temperatures, sediment characteristics, initial PCB concentrations in water and sediment, and the magnitude of PCB loadings into each of the ten reaches were obtained from historical records and the results of field sampling and measurements conducted for this study. The other category of input data is that associated with the coefficients or parameters of the formulas or relationships used to describe the PCB-related processes in the river system. These values were determined either through model calibration or through the review of pertinent literature.

Data from the first category, which represents the average condition of each reach under different flow rates, are listed in Appendix D. Values for the following parameters, which are from the second category, were determined through model calibration:

(a) Benthic diffusion velocity of PCBs (D)
(b) PCB benthic release rate (Rb)
(c) Sediment suspension velocity (Rr)
(d) Average settling velocity of suspended solids (S)
(e) Erosion rate constant of the cohesive bed materials (E_k)
(f) Critical shear stress of the cohesive bed materials (Tc)

Benthic diffusion velocity is affected by the relative PCB concentrations in water and sediment and the surface condition of their interface. PCB benthic release rate is primarily affected by the activity of aquatic organisms and the turbulence of the flow. Sediment suspension velocity depends on the size of the sediment particles, flow conditions, and the shear forces at the bottom of the channel. Average settling velocity of the suspended solids depends on the flow regime and the size of the particles. The erosion rate constant and the critical shear stress of the cohesive bed materials are functions of clay content, organic matter content, cation exchange capacity of the clay, sodium adsorption ratio, water quality, and other physicochemical characteristics of the cohesive materials. The above description indicates that parameters (D) and (Rb) are directly related to the concentration of PCBs in the water, while parameters Rr, S, E_k, and Tc are directly associated with the concentration of suspended solids which, in turn, influences the PCB concentrations in water and the distribution of PCBs between water and suspended solids.

Acceptable values for Rr, S, E_k, and Tc were developed by sequentially modifying the values and comparing the measured and simulated concentration of suspended solids in the water column of each reach until satisfactory agreement between the measured and calculated values were obtained. Values for D and Rb were then estimated in the same manner by comparing the measured and calculated PCB concentrations in the water and sediment for each individual reach. The calibrated values of these parameters for each reach are shown in Table 18.

The sediment burial rate (decrease in depth of the active sediment layer) was estimated based on the PCB core profiles sampled from the river. Their values were found in the range of 1.4×10^{-7} to 4.0×10^{-7} m/min in the Kalamazoo River system. Volume fractions of sediment in the sediment layer were also obtained from the field sampling results. Their associated range was from 0.33 to 0.65 m^3 sed/m^3. Atmospheric PCB fallout rate was determined by using the atmospheric PCB flux to Lake Michigan presented by Doskey and Andren (1981). The calculated value was 2.2×10^{-10} g/m^2-min. An average PCB fallout rate of 1.5×10^{-10} g/m^2-min was also reported by Nelson et al. (1972) for North America. A method proposed by Smith et al. (1979, 1980) was used to estimate the volatilization of PCBs from the surface of the river. They indicated that the PCB volatilization rate constant can be represented by the product of the oxygen reaeration rate and the reaeration coefficient ratio for PCBs. The oxygen reaeration rate constant for the Kalamazoo River was determined by using the relationship presented by Bennett and Rathbun (1972). The calculated value of the oxygen reaeration rate for the Kalamazoo River was 9.8×10^{-4} min^{-1}. The value of the reaeration coefficient ratio for PCB was calculated to be 0.33. This value was determined based on the chlorine content of each PCB isomer and the percentage of the isomers sampled in the Kalamazoo River by Marti (1984). The resultant PCB volatilization rate constant is 3.3×10^{-4} min^{-1}. In equation (10), the probability of resuspension of suspended solids is a function of the kinematic viscosity of water and the mean particle size of the suspended solids. Values of 0.005 m^2/hr and 4×10^{-6} meters were selected to represent the average kinematic viscosity and mean particle size, respectively.

Biodegradation of PCBs is greatly dependent on the chlorine content of chlorine number of the isomers, location of the chlorine substitution on the rings, species and concentration of microorganisms involved, and the total organic carbon content of the environment. Griffin and Chian (1980) investigated the biodegradation of water soluble PCBs by soil microorganisms. Their results indicated that the biodegradation rates for PCB isomers with a chlorine number greater than three were relatively low, sometimes unmeasureable. Field sampling results reported by Marti (1984) indicated that most PCB isomers in the Kalamazoo River have chlorine numbers greater than three. Therefore, the PCB first-order biodegradation rate was set to zero in this study. Use of the zero value to represent the biodegradation of PCBs in the river system is further justified because the biodegradation rate of PCBs is also concentration dependent, and the concentrations of PCBs and microorganisms in the Kalamazoo River system are generally low compared with laboratory conditions.

The sorption of PCBs on sediment materials has been studied by many investigators, such as Steen, et al. (1978); Karickhoff et al. (1979); O'Connor and Connolly (1980); and Marti (1984). Field sampling results reported by Marti (1984) indicated that a representative partition coefficient for total PCBs in the Kalamazoo River is 2.8×10^5, which is

TABLE 18

CALIBRATED VALUES OF MODEL PARAMETERS FOR EACH REACH

Parameters	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
(a) (m/min)	1.2×10^{-6}	2.0×10^{-6}	3.0×10^{-6}	3.2×10^{-6}	6.0×10^{-6}	2.8×10^{-6}	3.6×10^{-6}	1.0×10^{-6}	2.0×10^{-6}	6.0×10^{-6}
(b) (g/m^2-min)	1.0×10^{-10}	1.0×10^{-10}	1.7×10^{-8}	4.0×10^{-8}	4.8×10^{-8}	2.1×10^{-8}	0.7×10^{-7}	0	2.2×10^{-8}	0
(c) (m/min)	0.45×10^{-8}	0.4×10^{-10}	3.16×10^{-8}	0.39×10^{-10}	4.2×10^{-8}	2.3×10^{-8}	5.4×10^{-10}	6.5×10^{-9}	6.3×10^{-9}	0.55×10^{-10}
(d) (m/min)	2.7×10^{-5}	2.4×10^{-4}	1.6×10^{-5}	4.8×10^{-5}	3.1×10^{-5}	2.1×10^{-5}	1.2×10^{-3}	1.6×10^{-5}	1.3×10^{-5}	4.7×10^{4}
(e) (g/m^2-min)	5.0×10^{-5}	4.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	4.5×10^{-5}	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-4}
(f) (Kg/m-hr2)	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}	2.8×10^{7}

the largest value in comparison with the other published data. The range of published PCB partition coefficients was 3.4×10^3 to 2.8×10^5. The low value was adopted to represent the partition coefficient of sand, and the high value was used for clayey materials in this study.

The point sediment loading rate within each reach was evaluated based on the measured concentration of suspended solids and the river discharge, as well as the estimated sediment area to total drainage area ratio. The estimated increases of suspended solids were determined by using the measured monthly average suspended solids concentration and the average flow for the reaches were calculated from the average monthly values. The net annual increase in the mass of suspended solids within each reach was then determined by subtracting the upstream inflow of suspended solids from the total mass contained in the reach of interest.

Sediment area to total drainage area ratios were estimated by using the USGS quadrangle maps of the Kalamazoo River. The net annual increases of suspended solids were then multiplied by the estimated sediment area to total drainage area ratio, resulting in the estimated point sediment loading rate within the reaches. The average PCB concentration for the point sediment loading was determined from the surface sediment data. Values of the parameters associated with this estimation methodology are listed in Table 19.

The complete set of data resulting from historical records, field measurements, the literature review, and model calibration, along with a listing of input variables for the program, is presented in Appendix D. The simulated results under the input data presented are considered to represent the long-term distribution of PCBs in the Kalamazoo River without imposing any remedial actions (i.e., under the no-action alternative). Simulation of the possible response of PCBs in this river system under the proposed remedial action alternatives was then achieved through the alteration of the appropriate model input to represent the type of action taken. The results of model simulation under the no-action alternative and the other remedial strategies are described in Section 6.5.

6.3.5 Model Calibration and Verification

The river system was segmented into ten reaches, in which the mean concentrations of PCBs are the primary concern. The river segmentation was based on considerations such as location of dams, point sources, river tributaries, existence of major sediment storage areas, and potential future remedial actions. Descriptions of the reaches were presented in Section 6.1.

Averaged data describing the mean channel geometry, flow conditions, and PCB concentrations was compiled for each reach. This set of data was split into two different subsets. Subset 1 contains the data for the months of January to June, and Subset 2 includes the data for July through December. Data from subset 1 was used to calibrate the model until the assumed values of the model parameters were within a reasonable range and the observed concentrations of PCBs and suspended solids in the

TABLE 19

ESTIMATION OF POINT SEDIMENT LOADINGS

Reach	3	4	5	6	8	9
Upstream inflow (cfs)	985	985	1,108	1,152	1,208	1,210
Flow within the reach (cfs)	985	1,108	1,152	1,193	1,210	1,247
Upstream inflow suspended solids (mg/l)	7.2	9.2	9.5	11.8	11.0	14.3
Suspended solids within the reach (mg/l)	9.2	9.5	11.8	20.3	14.3	17.3
Ratio: Sediment Area to Total Drainage Area (%)	8.9	3.8	1.2	3.5	100*	100*
Point sediment loading (g/min)	298	95	63	628	6,720	7,248
Average PCB concentration (ppm)	5.3	8.0	16.8	1.8	18.5	11.5

* 100% sediment loading was assumed due to the strong sediment resuspension activity of carps.

water were satisfactorily reproduced by the model results. The parameters that were calibrated included:

- Benthic diffusion velocity of PCB (D)
- PCB benthic release rate (Rb)
- Sediment suspension velocity (decrease in depth of the active sediment layer)(Rr)
- Average settling velocity of suspended solids (S)
- Erosion rate constant of the cohesive bed materials (E_k)
- Critical shear stress of the cohesive bed materials (T_c)

The model results from the final calibration run are compared to field observations in Table 20. As can be observed, an excellent fit was obtained.

The data of Subset 2 were then used to verify the performance of the model after it was calibrated. The comparison of the simulated and measured data resulting from model verification is listed in Table 21. Again, an excellent fit is obtained, particularly for PCBs in the water column that is of critical importance to the prediction of PCB concentrations in fish.

This model is a steady-state, water-quality-oriented model. In other words, it is only applicable to those alternatives that can change the strength of sources of PCBs or mass loading of PCBs rather than those that change the reaction kinetics or mechanism of the processes occurring in the river system. The model was calibrated based on the data base representing the current conditions; the reaction kinetics are not being modeled. In order to extend the model capability, this model would have to be either calibrated by the use of other data bases representing future environmental conditions, or modified to include more detailed representations of the mechanisms. When the current model is applied for the evaluation of alternatives, the values of the six calibrated model parameters will be held constant.

The data set that was used to calibrate and verify the model represents the existing average condition of the river environment. It does not represent the situation that will occur after an extended period of time, which is the basis of steady-state, long-term simulation. The PCB concentration in the sediments is expected to decrease with time as long as the PCB inflow sources have been terminated. In other words, the existing PCB concentration in the sediment does not represent the ultimate steady-state condition for the Kalamazoo River. When the model was being calibrated, the governing equation used to describe the PCB exchange between water and sediment should not have been a steady-state equation. The existing exchange processes are not under steady-state, and the existing PCB concentrations in the water and sediment do not represent the long-term, steady-state condition. Therefore, a semi-steady-state version of the model was developed in which the river flow and upstream PCB sources were assumed to be steady and not to vary with time, whereas the PCB exchange processes between water and sediment were assumed to be time dependent. The extent of the exchange processes occurring between water and sediment was related to the travel time of the flow through each reach. Calibration of a model in this manner can

TABLE 20

CALIBRATED MODEL OUTPUT AND SAMPLED DATA
KALAMAZOO RIVER

Reach Number	Data* Source	Suspended Solids (PPM)	Total PCB in Water (PPB)	PCB in Sediment (PPM)
1	S	15.0	0.136	20
	M	14.6	0.134	20
2	S	8.3	0.062	0.1
	M	8.0	0.084	0.1
3	S	8.3	0.058	0.5
	M	8.3	0.058	0.498
4	S	10.0	0.056	30
	M	10.1	0.056	30
5	S	13.7	0.060	0.3
	M	12.5	0.060	0.298
6	S	20.2	0.079	2.0
	M	21.1	0.079	1.98
7	S	16.0	0.091	0.1
	M	15.6	0.089	0.099
8	S	15.7	0.084	21
	M	10.0	0.137	21
9	S	17.2	0.121	10
	M	17.3	0.120	9.6
10	S	15.5	0.054	0.2
	M	13.8	0.057	0.195

*S = Data from MDNR Samples (January-June)
M = Model Results
PPM = Parts per million
PPB = Part per billion

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TABLE 21

COMPARISON OF SAMPLED AND SIMULATED RESULTS
(MODEL VERIFICATION)
KALAMAZOO RIVER

Reach Number	Data* Source	Suspended Solids (PPM)	Total PCB in Water (PPB)	PCB in Sediment (PPM)
1	S	15.0	0.128	20
	M	14.6	0.127	20
2	S	6.0	0.100	0.1
	M	7.6	0.074	0.1
3	S	10.0	0.068	0.5
	M	7.8	0.050	0.5
4	S	9.0	0.091	30
	M	10.2	0.057	30
5	S	10.0	0.073	0.3
	M	15.1	0.070	0.298
6	S	20.3	0.084	2.0
	M	25.6	0.094	1.99
7	S	6.0	0.101	0.1
	M	14.7	0.097	0.099
8	S	12.9	0.107	21
	M	7.8	0.170	21
9	S	17.3	0.136	10
	M	19.1	0.123	9.25
10	S	12.0	0.058	0.2
	M	14.9	0.053	0.193

*S = Data from MDNR Samples (July-December)
M = Model Results

result in parameter values that more accurately represent the magnitude of PCB exchange between water and sediment under current field conditions. The results of the model verification shown on Table 22 demonstrate that the calibrated model does simulate the existing condition in a well-behaved manner.

In order to prove that the current situation does not represent a true steady-state condition, the complete steady-state version of the model was subsequently run using the following data as inputs: current PCB inflow at the headwater, the existing PCB concentration in the sediment, and the model parameter values determined from the model calibration. The simulated long-term, steady-state results are shown in Table 22. The results indicate that the steady-state PCB concentration in the sediment will be close to the "clean" level. However, the PCB concentrations in the water, even though lower than the current level, will not be complete eliminated because of the constant PCB influent at the headwaters. The developed model is a steady-state model; thus, the use of the model to predict the time needed to approach this steady-state level is impossible.

6.3.6 Sensitivity Analysis of Model Parameters

The PCB transport model developed in this study is a processes controlled model. That is, the PCB concentrations in the water and sediment are predominantly affected by several, relatively independent physical processes in the river system. This can be seen from the constituent terms in the governing equations of this model. There are a number of processes involving the use of reaction rate constants or specified process parameters. Values of these parameters or constants are not readily available either from laboratory or field measurements, or from published literature. In addition, several parameters, such as PCB benthic release rate and benthic diffusion velocity, are highly site specific. Appropriate values of these parameters or constants are determined through model calibration based on the measured data. In order to verify the values determined for the model parameters, a second independent set of data is usually applied to verify or validate the performance of the calibrated model. The procedures of model calibration and verification, and their associated results can be found in Section 6.3.5. The objectives of sensitivity analysis are to evaluate the magnitude of the impact caused by an alteration of various model parameter values and to determine the accuracy needed for the input data of the model. The percent error in the model output that would be caused by inaccuracies in the calibrated model parameters can thus be evaluated through a sensitivity analysis.

A sensitivity analysis, involving a series of model runs, was performed to evaluate the effect of parameter changes on simulation results. Based on the experience obtained from the initial calibration of this model and the understanding of the theory underlying the model, the following model parameters or inputs were selected for sensitivity analysis:

- Settling velocity of suspended solids (S)

TABLE 22

TRUE STEADY-STATE PCB CONCENTRATIONS
UNDER THE GIVEN CURRENT CONDITIONS
KALAMAZOO RIVER

Reach Number	Data* Source	Suspended Solids (PPM)	Total PCB in Water (PPB)	PCB in Sediment (PPM)
1	C	15.0	0.136	20
	P	14.6	0.129	0.008
2	C	8.3	0.062	0.1
	P	8.0	0.080	0.063
3	C	8.3	0.058	0.5
	P	8.3	0.049	0.0
4	C	10.0	0.056	30
	P	10.1	0.038	0.0
5	C	13.7	0.060	0.3
	P	12.5	0.027	0.0
6	C	20.2	0.079	2.0
	P	21.1	0.022	0.0
7	C	16.0	0.091	0.1
	P	15.6	0.013	0.0
8	C	15.7	0.084	21
	P	10.0	0.046	0.55
9	C	17.2	0.121	10
	P	17.3	0.029	0.0
10	C	15.5	0.054	0.2
	P	13.8	0.0008	0.004

*C = Current condition
P = Predicted steady-state results under current condition of PCB sources

- PCB benthic release rate (Rb)
- Sediment suspension velocity (Rr)
- Benthic diffusion velocity of PCB (D)
- Sediment burial velocity (B)
- Critical shear stress for the cohesive bed materials (Tc)
- Erosion rate constant of the cohesive bed materials (E_k)
- Sediment density (p)
- Mean particle size of the suspended solids (D_{50})

The measured/calibrated values of these parameters served as the baseline for this analysis. Several model runs were performed for each parameter with values greater than, and less than, the calibrated value. As one parameter was changed, all others were kept constant. A change in simulation results obtained from a change in the parameter value indicated the sensitivity of the model to the specific parameter. The results of this analysis are shown in Figures 4 through 12. The figures demonstrate the effects of parameter changes on the loading rates of PCBs and suspended solids in the water, and the total mass of PCBs contained in the active sediment layer. The sensitivity results are displayed in terms of percent parameter change versus the resulting percent change in loading rate of PCB and suspended solids in the water, and total mass of PCBs in the sediment. The slopes of the curves indicate the relative sensitivity of the parameter; i.e., the steeper the slope, the more sensitive the corresponding parameters.

Through this sensitivity analysis, parameters such as settling velocity of suspended solids, sediment suspension velocity, and benthic release rate were found to have a direct effect on the PCB loading in the water. However, even a 100 percent increase or decrease in those parameters was found to cause less than a few percent change in the PCB loading in the water (with the exception of a 20 percent change associated with settling velocity). The relative insensitivity of PCB concentration in water to the assumed values of model parameters is important, since water concentration is used in estimating the resultant levels of PCBs in fish.

Parameters such as sediment burial rate, settling velocity of suspended solids, benthic diffusion velocity of PCBs, benthic release rate of PCBs, critical shear stress for the cohesive bed materials, and sediment suspension velocity have significant impact on the total mass of PCBs in the active sediment layer. Parameters such as density of sediment, sediment suspension velocity, critical shear stress and erosion rate constant for the cohesive bed materials, and the settling velocity of suspended solids have a great effect on the loading of suspended solids in the water. Effects from the mean particle size of suspended solids are relatively small compared with the aforementioned parameters.

A sensitivity analysis was also conducted to determine the error or uncertainty of the simulated PCB concentrations for the Kalamazoo River with respect to assumed river conditions. Model inputs including the values of model parameters/coefficients, headwater discharge, and sources of PCB loadings were altered within reasonable limits so that the associated range of uncertainty of the simulated PCB concentrations could be assessed. The model inputs contained in this analysis were:

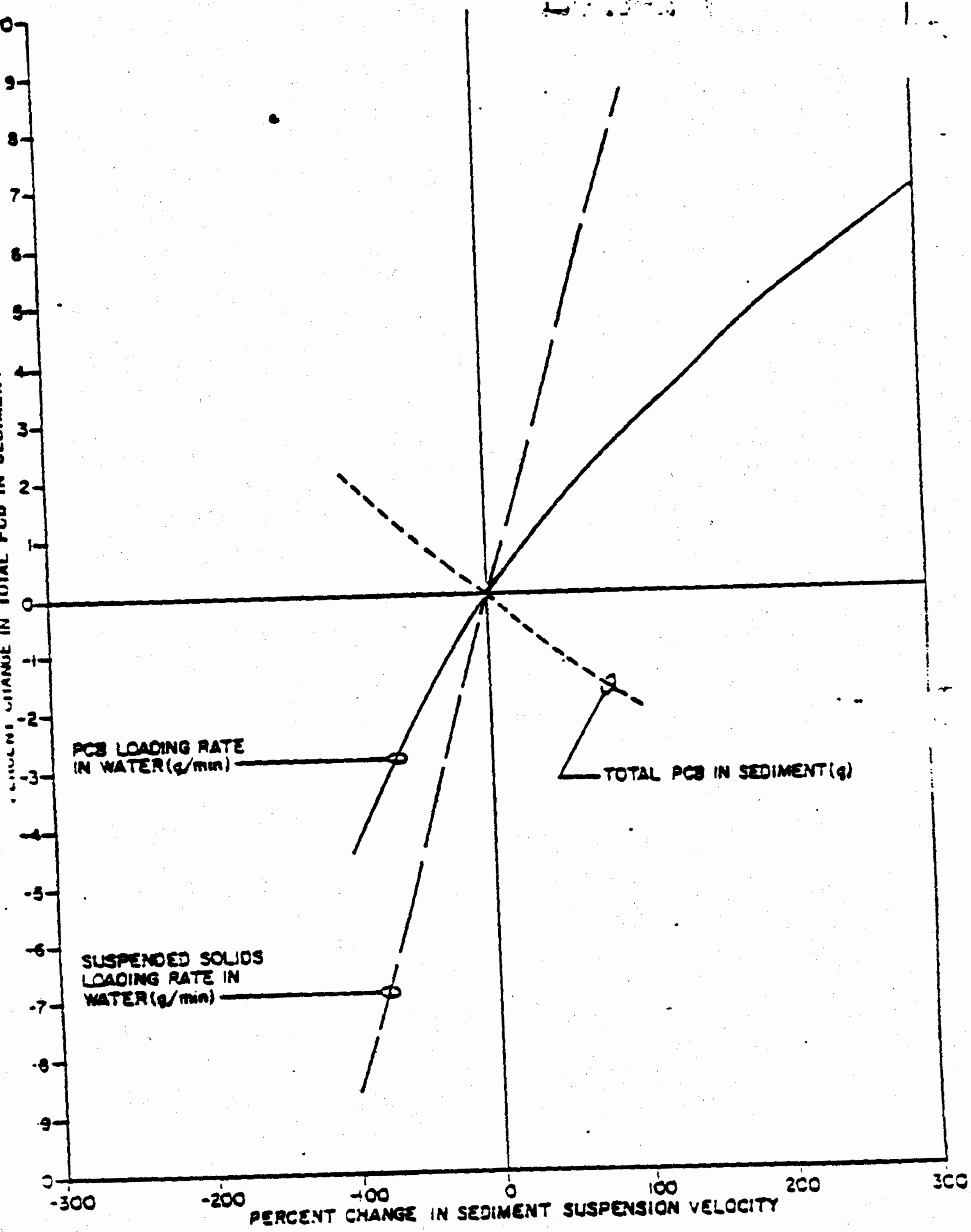

Figure 4
SENSITIVITY ANALYSIS
IENT SUSPENSION VELOCITY
)O RIVER PCBs, KALAMAZOO, MI

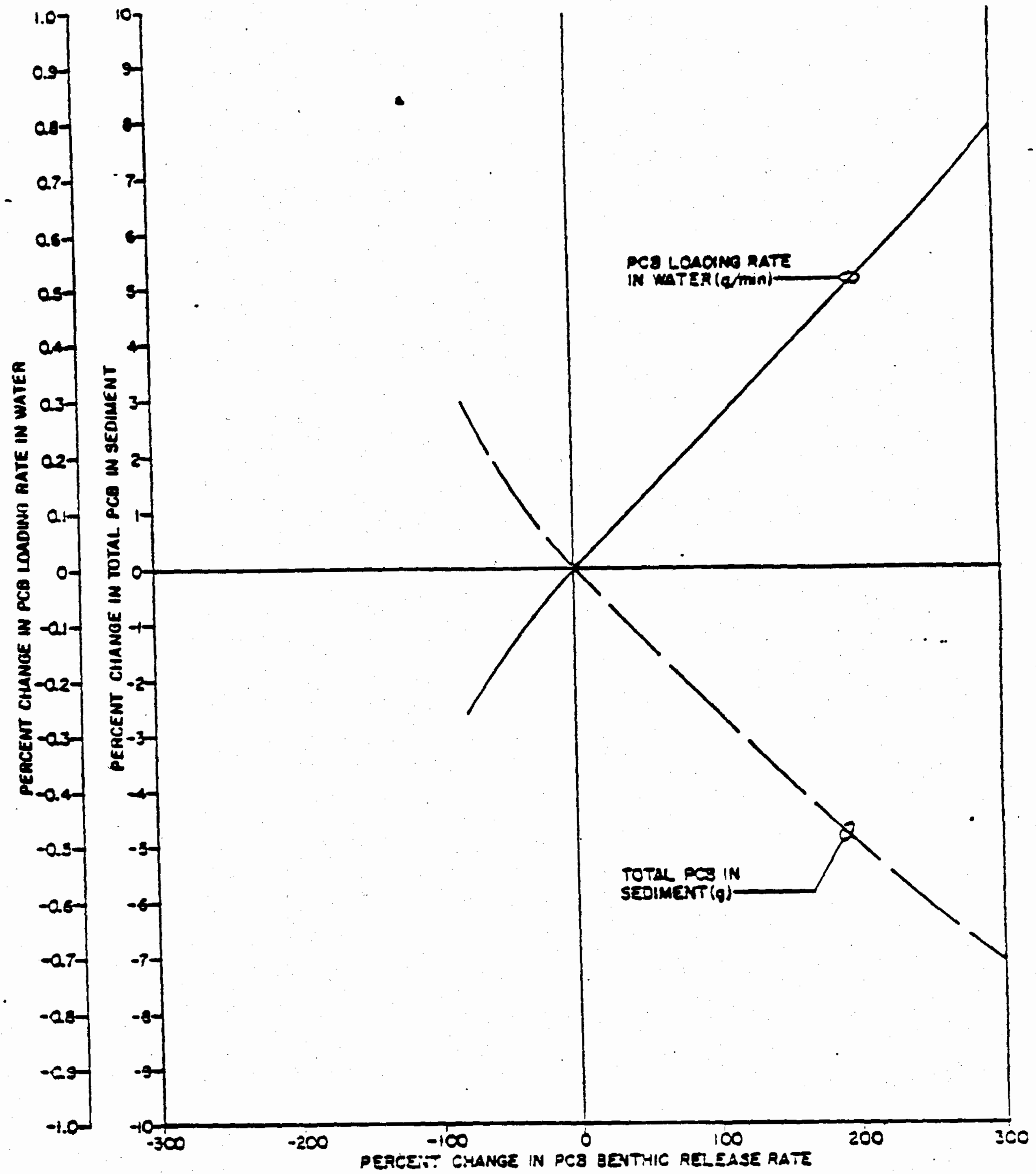

Figure 5

SENSITIVITY ANALYSIS

PCB BENTHIC RELEASE RATE

KALAMAZOO RIVER PCBs, KALAMAZOO, MI

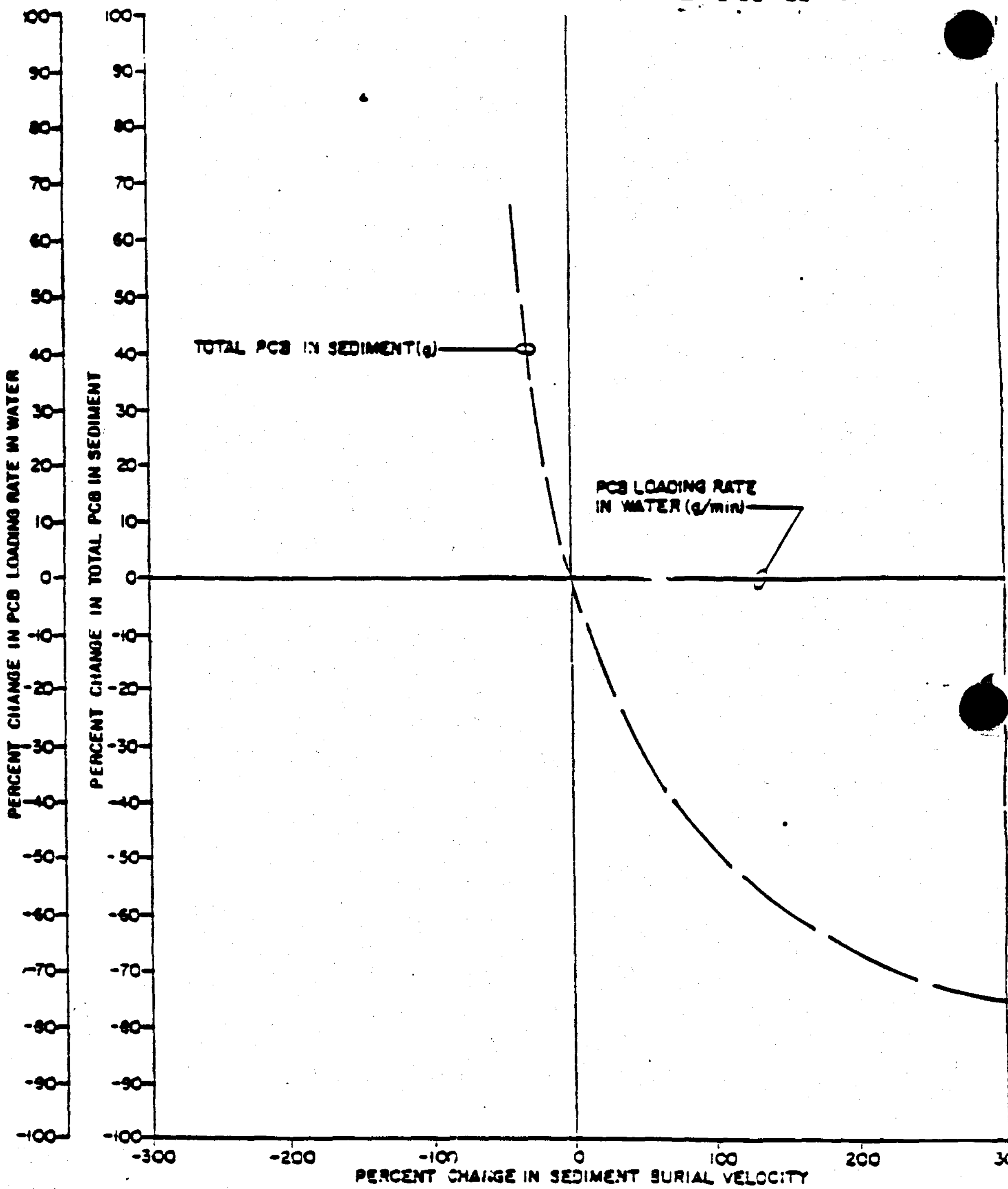

Figure 6

<u>SENSITIVITY ANALYSIS</u>

<u>SEDIMENT BURIAL VELOCITY</u>

<u>KALAMAZOO RIVER PCBs, KALAMAZOO, MI</u>

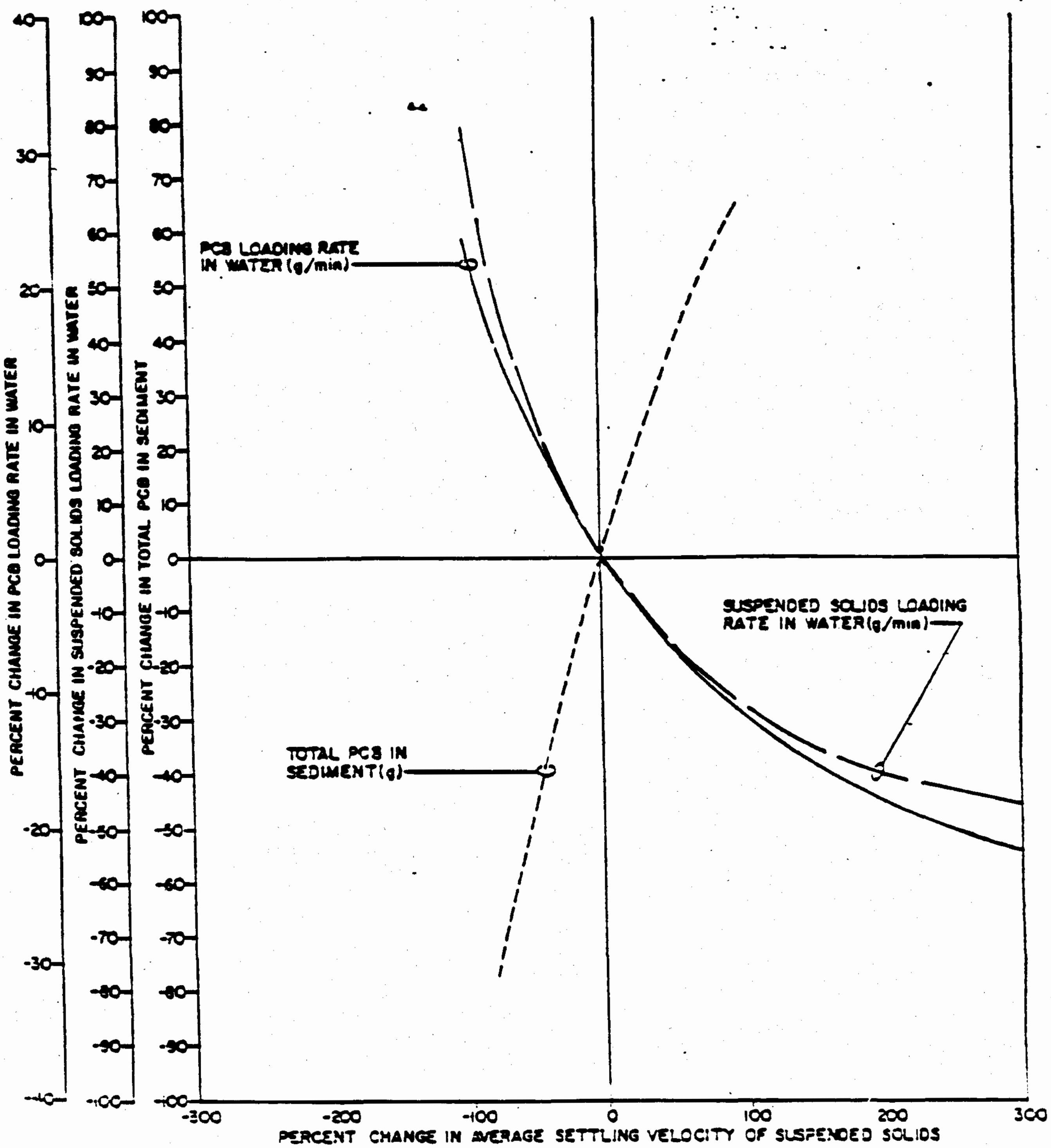

Figure 7

SENSITIVITY ANALYSIS

SETTLING VELOCITY OF SUSPENDED SOLIDS

KALAMAZOO RIVER PCBs, KALAMAZOO, MI

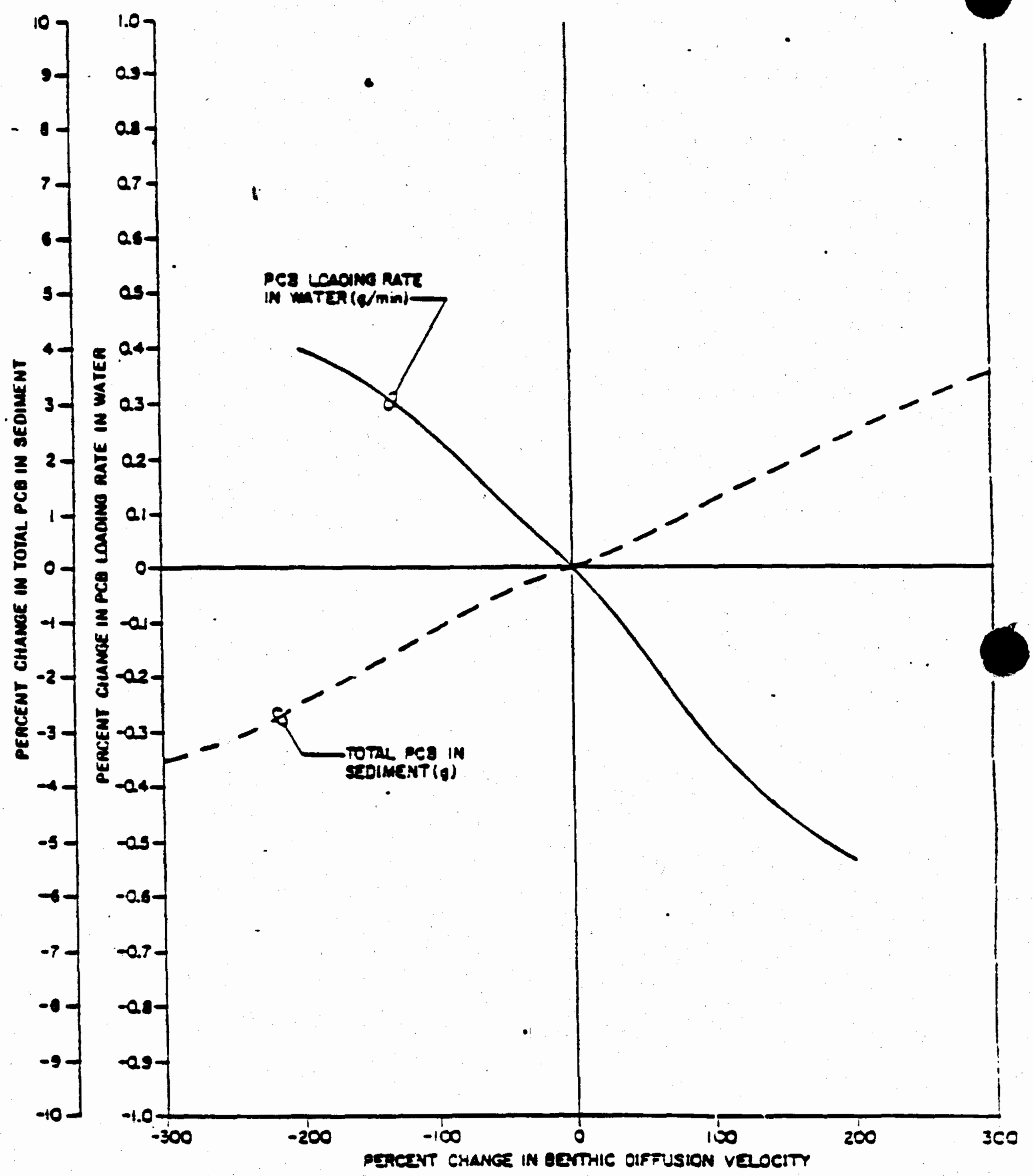

Figure 8
SENSITIVITY ANALYSIS
BENTHIC DIFFUSION VELOCITY
KALAMAZOO RIVER PCBs, KALAMAZOO, MI

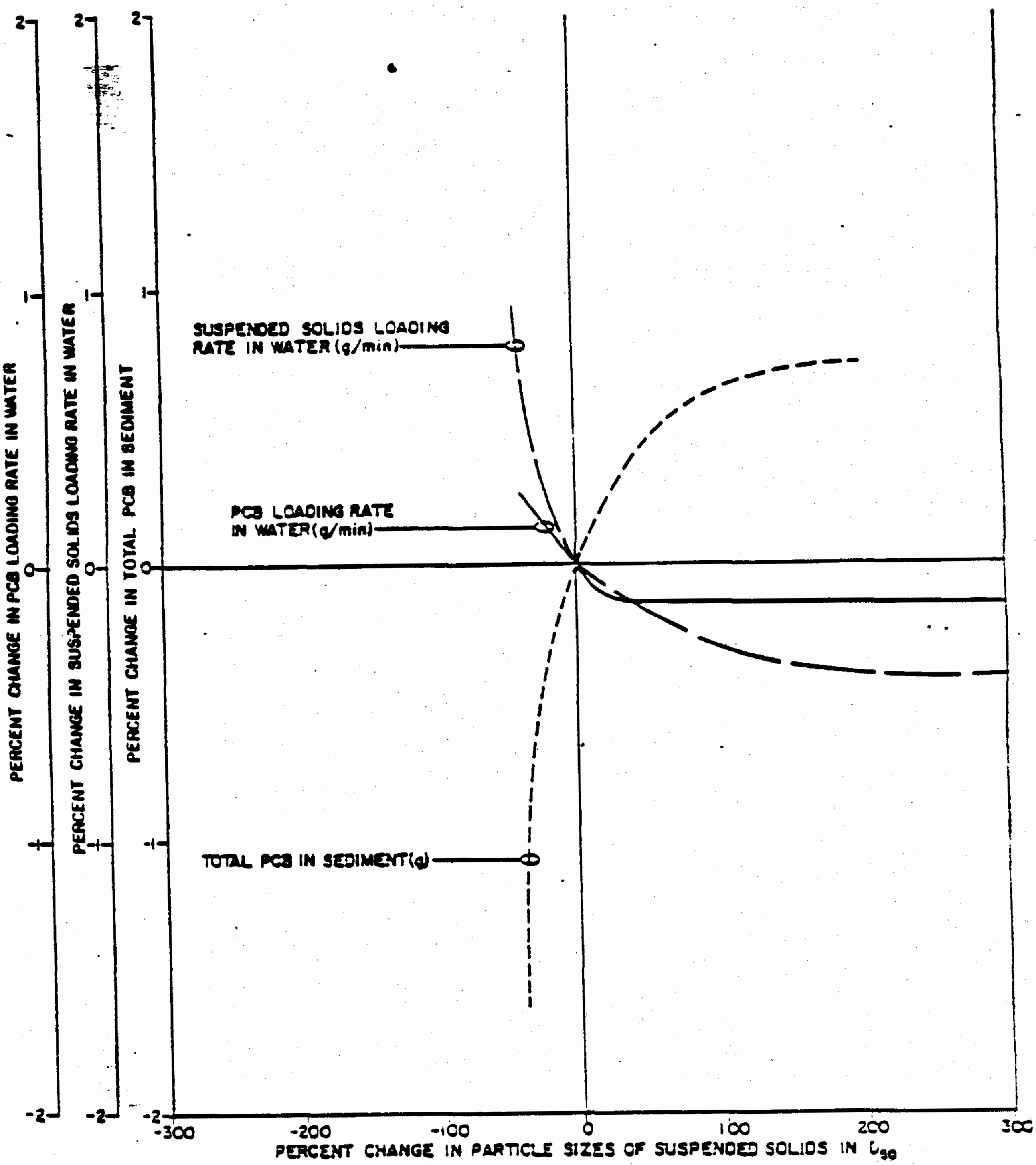

Figure 9

SENSITIVITY ANALYSIS

PARTICLE SIZES OF SUSPENDED SOLIDS IN D_{50}

KALAMAZOO RIVER PCBs, KALAMAZOO, MI

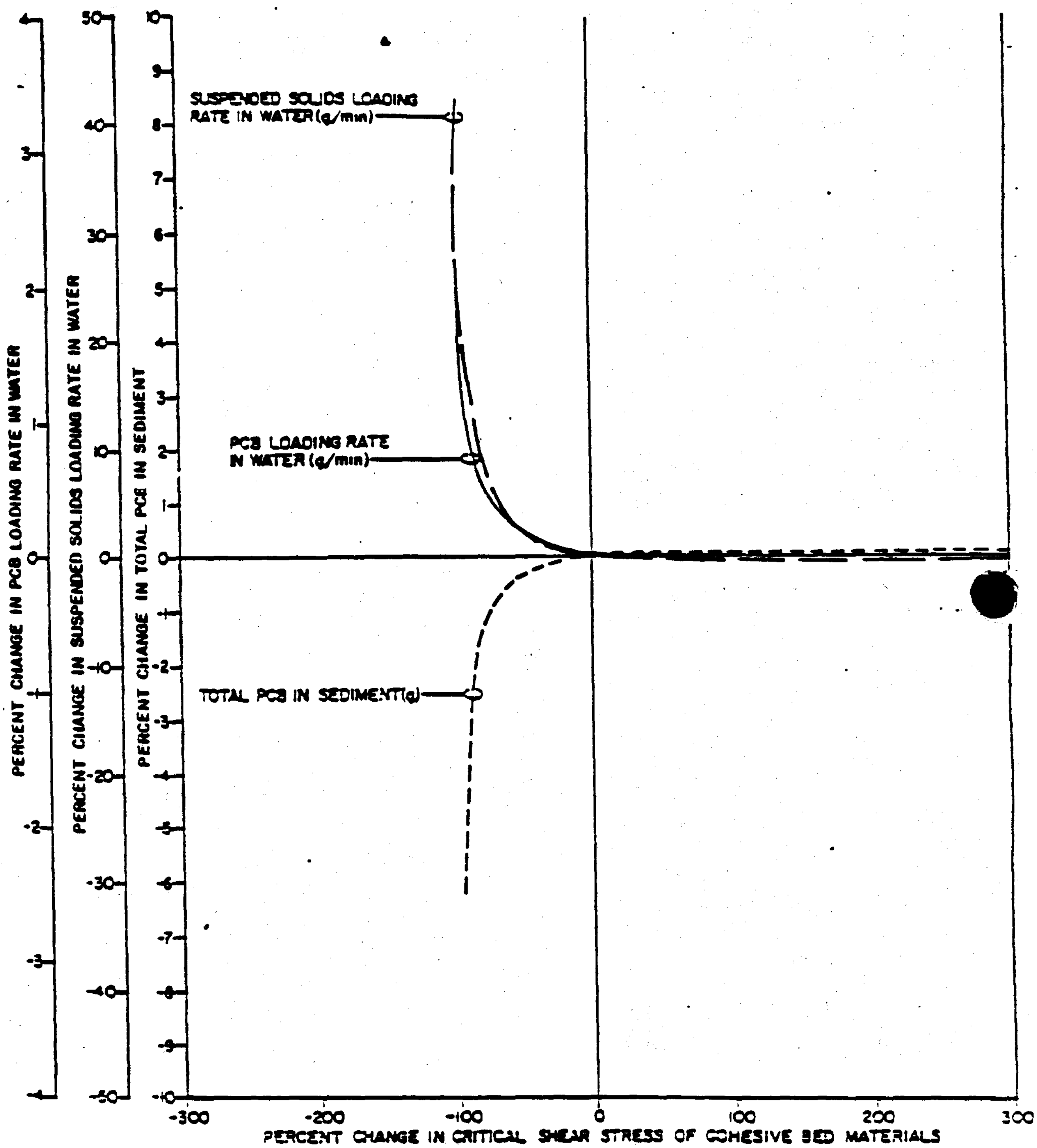

Figure 10
SENSITIVITY ANALYSIS
CRITICAL SHEAR STRESS OF
COHESIVE BED MATERIALS
KALAMAZOO RIVER PCBs, KALAMAZOO, MI

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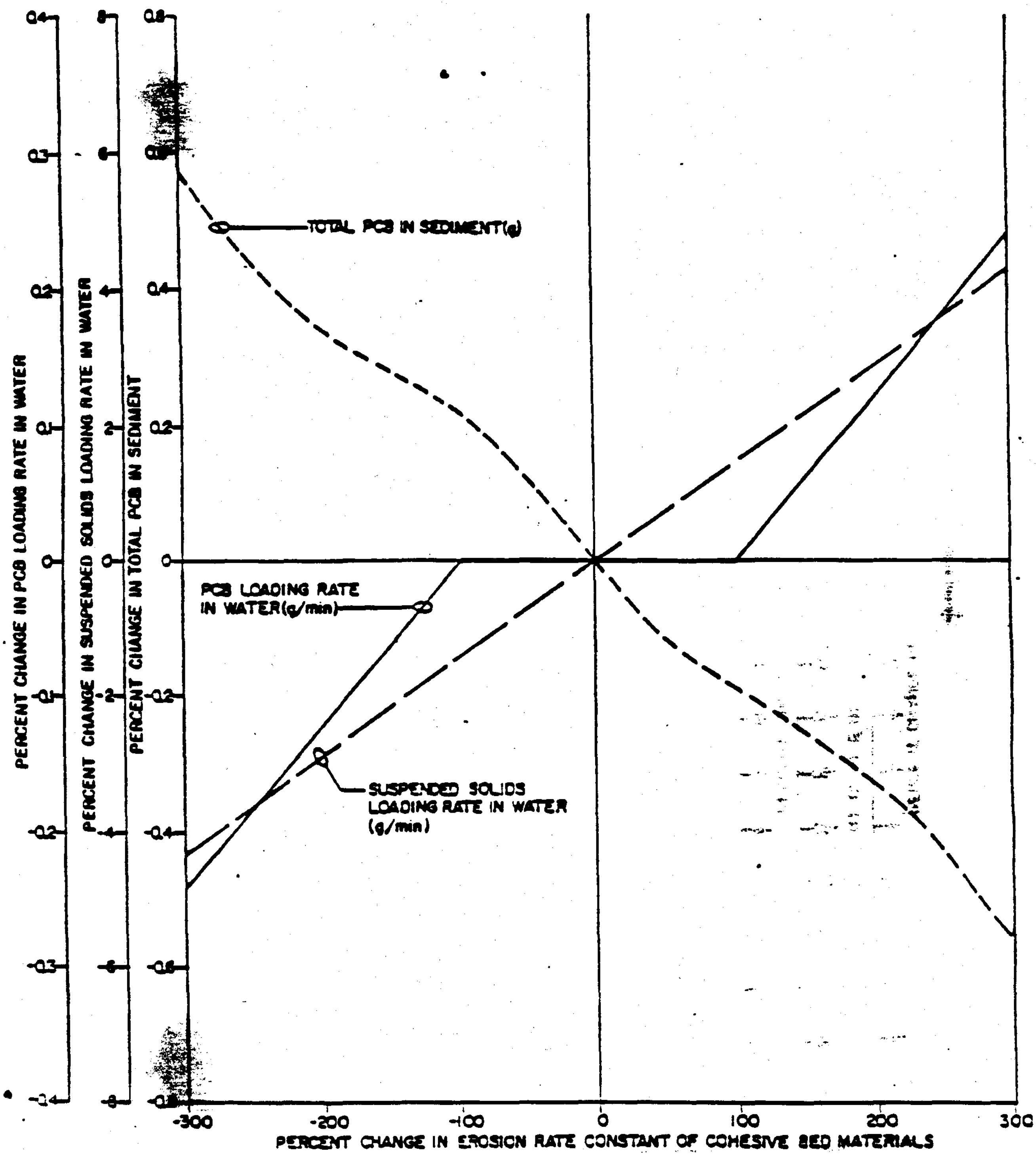

Figure 11

SENSITIVITY ANALYSIS
EROSION RATE CONSTANT OF
COHESIVE BED MATERIALS
KALAMAZOO RIVER PCBs, KALAMAZOO, MI

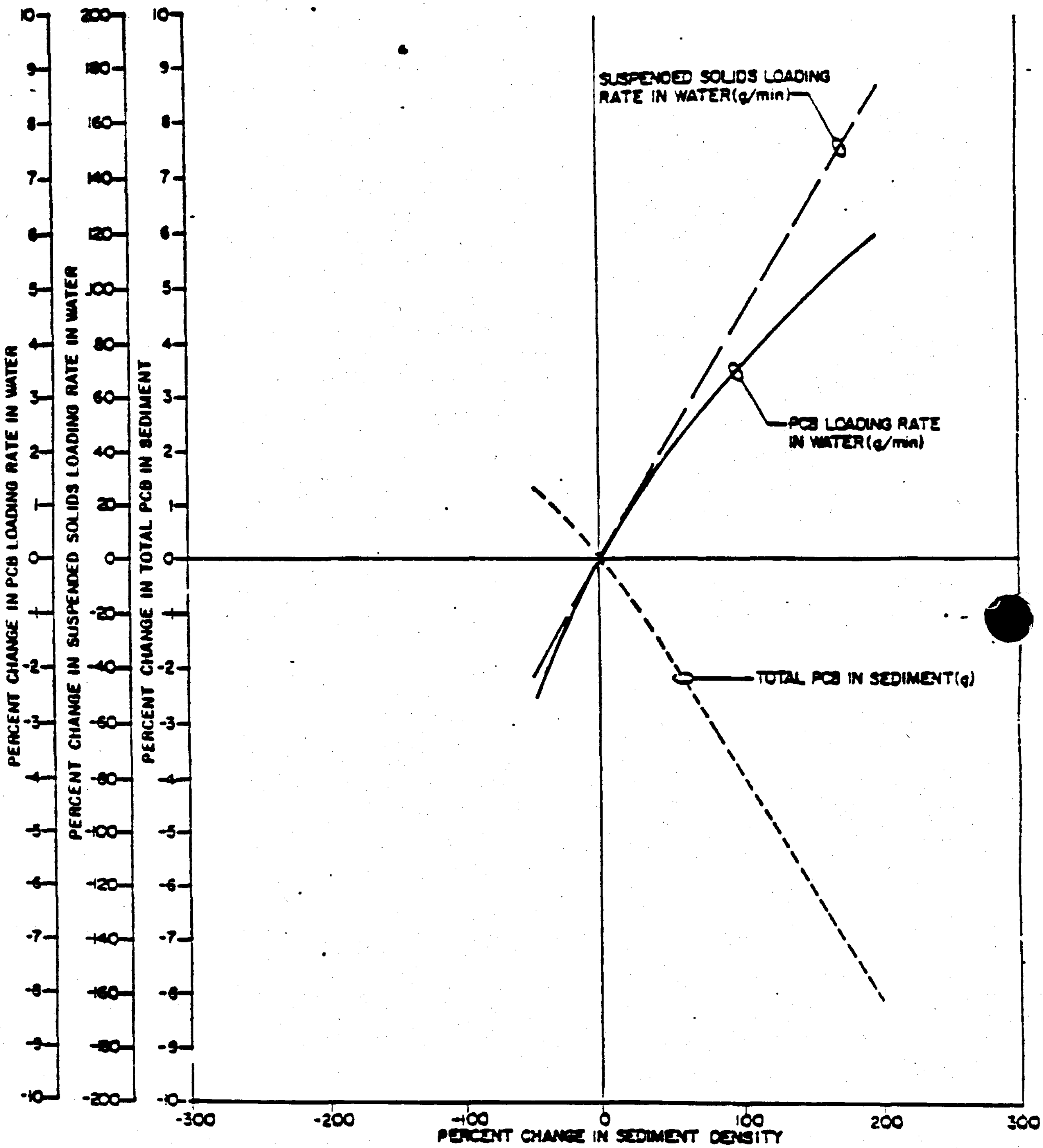

Figure 12.
SENSITIVITY ANALYSIS
SEDIMENT DENSITY
KALAMAZOO RIVER PCBs, KALAMAZOO, MI

- Upstream boundary PCB loading
- Dissolved PCB point discharge
- Upstream flow
- Upstream boundary suspended solids loading
- PCB contaminated point sediment discharge
- Sediment burial rate
- Sediment suspension velocity
- Benthic diffusion velocity
- Solids settling velocity
- PCB benthic release rate
- PCB first-order biodegradation rate
- PCB partition coefficients
- Erosion rate constant of the cohesive clayey materials
- Critical shear stress of the cohesive clayey materials

Consideration was given to the reasonable ranges for these inputs in the field situation. The first-order biodegradation rate constant was altered from the calibrated 0 min^{-1} to 1^{-6} min^{-1} for this sensitivity analysis. Dissolved and sediment PCB loadings were varied from -100% to +100%. The remaining model input parameters shown above were changed from -50% to +50%. The simulated long-term, steady-state PCB concentrations based on the calibrated/measured input were used as the baseline condition. The magnitude of errors (i.e., the uncertainty range) of the simulated PCB concentrations owing to the above changes in model inputs is presented in Figures 13 and 14.

Results of this analysis indicate that PCB loadings have a large impact on PCB concentrations in the Kalamazoo River, with the upstream PCB loading showing the most direct and significant effects; that is, large errors in the estimation of the strength of PCB sources would induce high uncertainty in the simulation results. Therefore, the identification of PCB sources and the determination of source strength should be emphasized during any future study.

The sediment burial rate, sediment suspension velocity, suspended solids settling velocity, and PCB partition coefficients are the model inputs that appear to have a smaller, yet measurable, impact on the simulated results. Sediment burial rates used in this modeling study were estimated based on the PCB core profiles sampled from the river. Additional core profiles should be able to improve the accuracy of this input data. Although partition coefficients used in this study were obtained from literature review, the high-range and low-range values were individually selected to represent the partition of PCBs for clayey materials and sands. Their use was considered appropriate and reasonable. Values of the two velocity parameters were determined through model calibration. The validity of these values to represent the existing condition can be ascertained from the good agreement between the simulated and measured suspended solids concentrations in the river.

In general, the results of this sensitivity analysis indicate the relative importance of each parameter in the model. If the model is to be applied for accurate quantitative prediction, rather than for its current use in evaluating the relative effectiveness of remedial alterna-

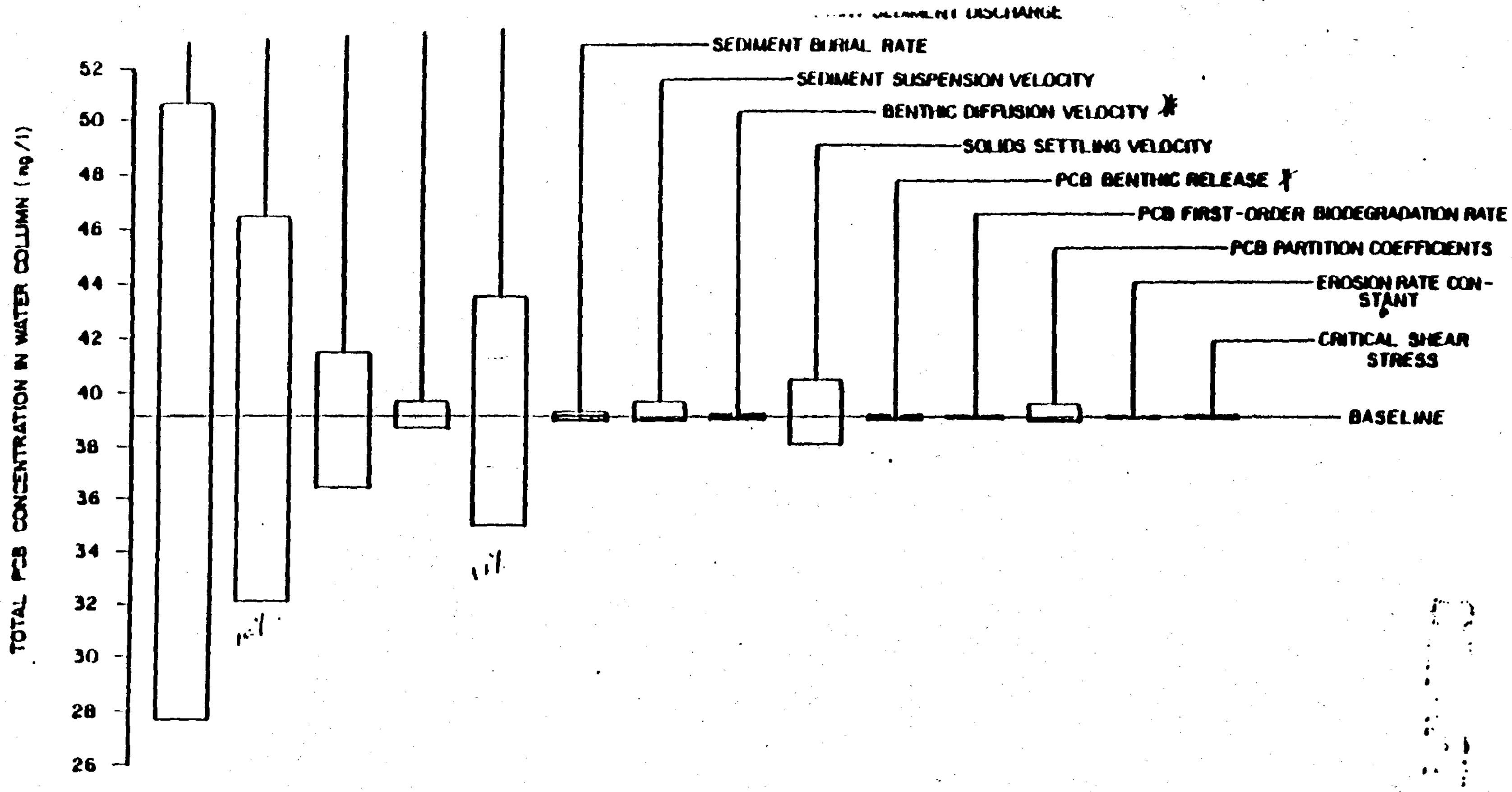

FIGURE 13
SENSITIVITY OF MODEL RESULTS TO VARIOUS INPUT PARAMETERS: WATER PCB CONCENTRATION KALAMAZOO RIVER STUDY AREA

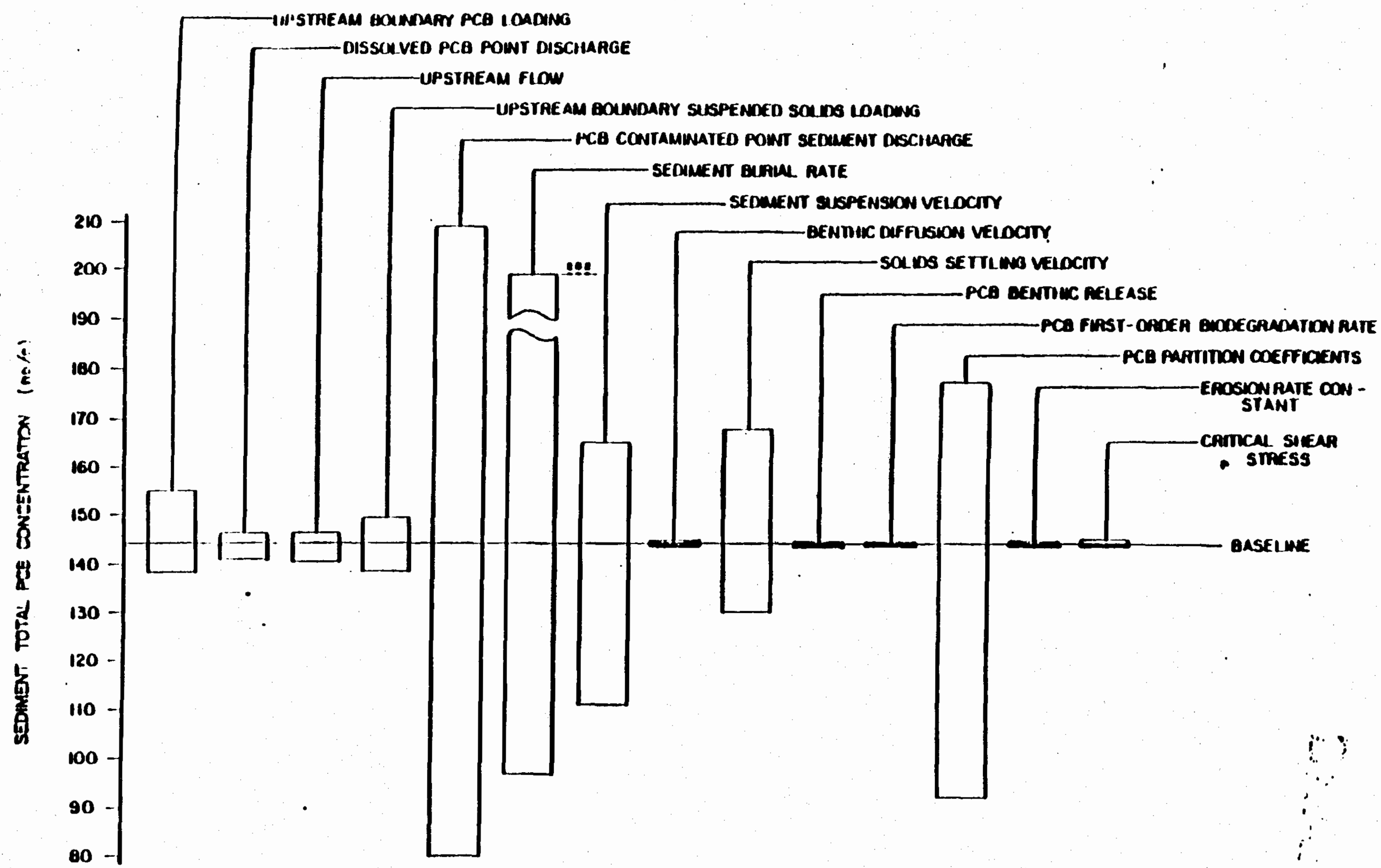

FIGURE 14
SENSITIVITY OF MODEL RESULTS TO VARIOUS INPUT PARAMETERS:
SEDIMENT PCB CONCENTRATION
KALAMAZOO RIVER STUDY AREA

tives, more investigative research or field data collection efforts will be necessary to refine the values of the highly sensitive parameters.

6.3.7 Methods of Determining PCB Concentration in Fish

The level of PCBs remaining in fish tissue results from PCB intake from external sources and the metabolic mechanisms of the fish. Direct PCB uptake from the water column and bioaccumulation through the food chain are considered to be the dominant sources of PCBs for fish. Therefore, the amount of PCB uptake by fish is dependent on PCB concentrations in the water column and in the prey organisms, and thus indirectly in the sediments. It also depends upon the feeding habits and metabolic activity of the fish. More specifically, the uptake of PCBs depends on the feeding rate of the fish, the transfer rate of PCBs across the gill surface, the species and weight/age of the fish, and the PCB concentrations in the water and food sources. The amount of PCBs retained in the fish tissue is affected by the assimilation efficiencies of the fish, the metabolic pathways, and the respective excretion rates for PCBs. This demonstrates the potential analytical complexity when one attempts to comprehensively model the PCB concentration in various fish species.

The application of the concept of partitioning and the development of food-chain models are the approaches most frequently used to determine PCB concentration in fish. PCB partitioning between water and fish is represented by the magnitude of a partition coefficient describing the relative distribution of PCBs between the fish and the water under equilibrium conditions. The concept of partitioning has long been used and was emphasized in the environmental modeling by Mackay and Paterson (1981, 1982). The partition coefficient empirically combines all of the effects resulting from numerous processes and factors, and indirectly accounts for the magnitude of mass flow and the resultant distribution of contaminant between the compartments in the system of interest. The drawback of this approach is that it does not include the detailed description of the processes in the system, and thus it is impossible to evaluate the relationships of the processes associated with a particular environmental compartment. In cases where the evaluation of the relative magnitude of the processes affecting the final contaminant distribution between the compartments of the system is imperative, the partitioning approach would not be recommended.

It is known that PCBs can be transferred into the top predators (i.e., the fish) through either PCB uptake directly from water or PCB accumulation through contaminated food sources. The relative importance of these two mechanisms varies depending on the environmental conditions and the relative location of the predators on the trophic levels. Neely et al. (1974), Neely (1979), and Kenaga (1980) reported that the maximum contaminant concentration in fish can be estimated without considering the accumulation by the food-chain process. Both the concept of the partition coefficient or the simple model of direct uptake from the water were suggested by these investigators. Similar conclusions were also published by Scura and Theilacher (1977).

The need to include an ecological food-chain concept to determine the contaminant concentration in the biomass has been investigated to different extents by the following authors: Gillett et al. (1974); Hill et al. (1968); Lassiter et al. (1976); Haefner and Gillett (1976); Norstrom et al. (1976); and Thomann (1981). According to the data analysis reported by Thomann and Connolly (1984), PCB concentration in the biomass increases as one proceeds up the food chain to the top predators. For example, lake trout PCB concentrations were found to be the highest of the top predators. These authors generally favor the use of food-chain modeling to determine the PCB concentration in fish rather than adopting the partition coefficient concept.

As indicated previously, the concept of partitioning is a simple and useful approach, especially when the ecosystem is assumed to be in an equilibrated, steady-state condition and the data availability is limited. Food-chain models usually provide a more detailed simulation of the PCB mass distribution within the trophic levels of the ecosystem; however, their use is highly dependent on the quality and availability of the measured data. The reason is that there are a number of model parameters, such as PCB uptake rate, excretion rate, feeding rate, and assimilation efficiency, that are highly site-, age-, and species-specific. The determination of appropriate values in order to provide adequate model accuracy relies on a great deal of sampled data. The decision to use a food-chain model is also dependent on the objective of the study. Thomann (1984) stated, "The issue of whether a simple calculation of uptake of a chemical directly from the water is sufficient, relates to the degree to which such a calculation would actually reproduce observed field data for important species such as the Lake Trout. If such a calculation does account for the observed data in the field, then there is no need for a model that includes a food chain component. If a simple partitioning calculation fails to reproduce the observed data, then the principal feature of the food chain must be included."

The partitioning coefficient concept was selected for this feasibility study for the following reasons:

- Thomann (1981) reported that the upper bound of the PCB partition coefficient determined from fish sampling in Lake Michigan is about one order of magnitude greater than that determined from laboratory studies in which fish accumulated PCBs directly from water only. Thomann's preference for food-chain models would, therefore, be easily justified. However, the partition coefficient determined from sample data in the Kalamazoo River is approximately identical with the value obtained from a flow-through aquarium study (Veith et al. 1979). This situation indicates that the simple partition coefficient calculation can be used to reproduce the Kalamazoo River field data without resorting to a food-chain model. In other words, the food-chain accumulation effect does not appear to be as significant in the Kalamazoo River as it is in other natural water bodies.

- [illegible] River was determined from field fish-sampling data. Therefore, the PCB concentration contained in the fish tissue inherently accounted for the accumulated PCBs resulting from the food chain in addition to that resulting from direct uptake from water. As long as this field partition coefficient is used, instead of laboratory-determined values, the effect of food-chain processes should be adequately accounted for.

- The physical-chemical model developed for this study is a steady-state model. Although the remedial actions may temporarily disrupt the current ecosystem in the river, a similar ecological environment will eventually develop under long-term, steady-state conditions. Therefore, the combined use of the simulated PCB concentrations in water under steady-state conditions, with the partition coefficient determined from the existing ecosystem, should satisfactorily simulate future PCB concentrations in the fish of the Kalamazoo River.

- The existing data from the Kalamazoo River are not sufficient to support the use of a steady-state food-chain model.

The partition coefficients for the Kalamazoo River were derived after comparison of the water PCB concentrations to the fish PCB concentrations at each location where comparable data existed (Table 23). There were six locations where this data was available - Morrow Pond, Portage Creek, Mosel Avenue, Plainwell Dam (downstream), Lake Allegan, and Saugatuck. All locations except Mosel Avenue had data for both 1985 and 1986.

Partition coefficients were calculated for each location. There was a large discrepancy in partition coefficients by location. The reason for this discrepancy may be due to differing environmental conditions at each location. Morrow Pond and Lake Allegan are impoundments, while the Portage Creek, Mosel Avenue and Plainwell Dam sites are riverine, with Saugatuck a mixture of riverine/lake with access to Lake Michigan. In addition to these differences, the fish at the Portage Creek, Mosel Avenue, Plainwell Dam and Lake Allegan locations are highly stressed due to poor environmental conditions. The biological communities at these locations are reflective of poor stream quality conditions.

The presence of body fat in the laboratory analysis appears reflective of these differing environmental conditions. As discussed in Section 6.2.5, carp in different sections of the river were exhibiting significantly different levels of fat. The carp at Saugatuck were consistently fatter and visually observed to be larger than the other fish collected. The carp at Portage Creek and Lake Allegan had less fat and were visually smaller than the other locations. These results are likely due to the different environmental conditions present - at Saugatuck, water quality was good, while at the Portage Creek and Lake Allegan locations, water quality was poor.

In 1986, the MDNR collected a large number (81) of carp from Lake Allegan for PCB analysis (Creal, 1987). The purpose of this collection was to define the relationships between fish size, age, fat content and PCB concentration. Strong linear relationships were found between length and weight ($R^2 = 0.96$), and fat and PCB ($R^2 = 0.80$). No relationship was found between size and PCB or size and fat at this location.

TABLE 23
ESTIMATED PARTITION COEFFICIENTS

LOCATION	YEAR	WATER PCB CONCENTRATION (PPM)	CARP PCB CONCENTRATION (PPM) (fat normalized)	BASS PCB CONCENTRATION (PPM) (fat normalized)	PARTITION COEFFICIENT CARP	PARTITION COEFFICIENT BASS
MORROW POND	1985	0.000020	2.56 (1.60)	1.28 (1.50)	128000	64000
	1986	0.000014	3.46 (1.44)	-	247143	-
PORTAGE CREEK	1985	0.000172	3.06 (5.1)	-	17790	-
	1986	0.000148	3.96 (3.2)	-	26757	-
MOSEL AVE.	1986	0.000042	4.68 (1.14)	-	111428	-
PLAINWELL DAM	1985	0.000055	5.27 (2.20)	-	95818	-
	1986	0.000068	4.13 (1.48)	-	60735	-
LAKE ALLEGAN	1985	0.000111	4.41 (2.76)	2.79 (3.07)	39730	25135
	1986	0.000116	4.27 (3.56)	-	36810	-
SAUGATUCK	1985	0.000053	3.59 (0.66)	1.33 (1.66)	67736	25094
	1986	0.000063	3.42 (0.62)	-	54286	-

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The relationship between PCB concentration and fat content is expected since PCBs are lipophillic. Fat content in the fish also appears to reflect and be responsive to differing environmental conditions in the study area. Therefore, a normalization of the PCB data on a unit fat basis was persued. For each location, the fish PCB concentration was divided by the fish fat concentration to obtain a "fat normalized fish PCB concentration". The result for each location was compared to the mean water concentration. When multiple years were available, a mean was determined for each location.

The resultant relationship is shown in Figure 15. A strong linear relationship ($R^2 = 0.80$) between water concentration and fat normalized fish PCB concentration was found. This indicates that water concentration can be used to predict fish PCB concentrations when environmental conditions are factored in by normalizing the fish PCB concentrations on a unit fat basis. Therefore, the relationship shown in Figure 15 (fat normalized fish PCB concentration (ppm) = 0.0277 water PCB concentration (ng/l) will be used to predict fish PCB concentrations and evaluate the relative effectiveness of various remedial actions. In order to convert back to absolute PCB values, the fat normalized PCB values were multiplied by the mean fat level found in the 1985-86 Morrow Pond fish. These values are considered representative of conditions after water quality is restored in the Kalamazoo River and Portage Creek. The fat values used for carp and bass were 2.01 and 0.83, respectively.

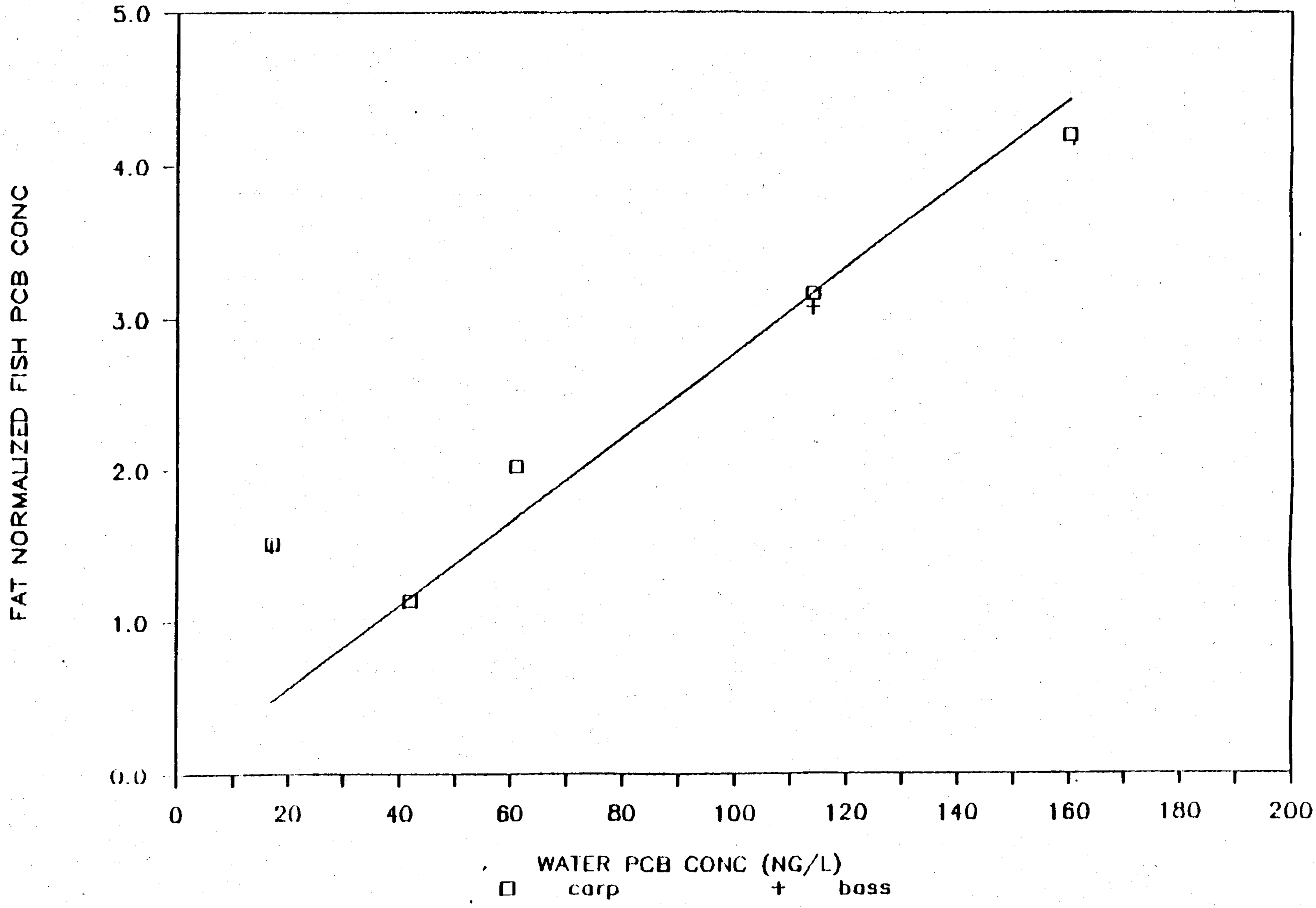
6.3.8 Summary of the Model Attributes

In order to study the transport of PCBs in the Kalamazoo River and to estimate the magnitude of PCB concentration in the fishes of the river under various remedial action alternatives, a mathematical modeling approach has been selected. Considering the availability and quality of the existing data base, and the objectives of this study, the Kalamazoo River was conceptually simplified into a one-dimensional system. The assumed river system was segmented into 10 reaches in which the river characteristics were assumed to be uniform and different remedial actions were to be potentially applied. A one-dimensional steady-state mathematical model was, therefore, developed and used to simulate this simplified river system for the evaluation of the long-term distribution of PCBs in water and fish after the application of remedial alternatives.

The PCB transport equation was developed to include both the major mechanisms affecting the movement of PCBs within the river and the other important processes associated with sources and sinks of PCBs in the river ecosystem. These mechanisms were combined into the governing equations for the conceptualized river system based on the principle of mass conservation. Advection is the only mechanism contained in the governing equation that influences the longitudinal transport of PCBs in water. The mechanism of dispersion was not included because of the assumption of uniform PCB concentration distribution and the relatively uniform river flow within each reach. The other processes affecting the sources and sinks of PCBs include atmospheric PCB influx, volatilization of PCBs, benthic release, settling of suspended solids, benthic diffusion, resuspension of contaminated bottom sediment, permanent burial

Figure 15. Kalamazoo River,1985-86

LINE OF BEST FIT:Y=0.0277X (R=0.89)



biodegradation of PCB, and point loadings of contaminated water and sediment.

These mechanisms were included based on the state-of-the-art and the current understanding concerning the transport and fate of PCBs in the river system. The river ecosystem was divided into two major compartments--the water column and the active sediment layer. Governing equations for each individual compartment were derived based on the assumptions and principles mentioned above to represent the transport and fate of PCBs within each reach of the river ecosystem. The model algorithms were established by incorporating the governing equations with the simplified spatial design of the river system. Governing equations for the PCB concentrations within each control volume were solved by a fourth-order Runge-Kutta method. Calculated concentrations were averaged for all control volumes located within each respective reach to determine the corresponding uniform PCB concentration within that reach.

The governing equations were simplified by neglecting the time differentiation terms before being incorporated into the model algorithms. As a result, the developed model can only simulate the steady-state equilibrated PCB distribution within the ecosystem of the river under long-term conditions. The consequent inability of the model to simulate the dynamic variation of PCB concentration with time is the most obvious disadvantage of this model. In addition, sediment transport associated with bed materials was not included in this modeling effort because the movement of bed materials is flow and time-dependent. The assumption of a stagnant sediment layer at the bottom of the river implies that the active sediment layer acts only as one of the sources/sinks for PCBs in the river system. The PCB concentration of the sediment layer is only a function of PCB diffusion and release rates between water and sediment, as well as the suspension and settling of sediment and suspended solids. The effect of horizontal sediment movement and the change of depth of the active sediment layer with flow were both neglected. This assumption is valid when the movement of bed material is slow and the flow is steady.

In general, modeling studies can serve several purposes, including the following:

(1) Serving as an analytical tool to predict future conditions if the existing system is left unaltered (i.e., the no-action scenario).

(2) Retracing or reproducing possible historical conditions.

(3) Providing a convenient, hands-on design tool.

(4) Comparing the relative effectiveness of management activities, or the possible responses due to modifications of the system of concern.

(5) Replacing the real physical system with a miniature or a computerized version, which can be conceptually manipulated.

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(6) Helping to understand the properties of the physical system and thus to identify critical data needs.

The model developed for this feasibility study was designed primarily to satisfy purposes (1) and (4). The model can also serve to partially satisfy purpose (6). It has been simplified to approximate the field conditions by the use of appropriately selected assumptions, as discussed in previous sections. If those assumptions are eventually found to be invalid for the existing or future conditions, the model concepts should be reexamined or updated. In addition, it is known that good field data is one of the important factors affecting the successful development and application of a model, especially for predictive purposes. Therefore, if more detailed design of the remedial alternatives is projected, the development of an unsteady-state model and/or further field investigations may be necessary.

6.3.9 Comparison with Other PCB Modeling Studies

Mathematical modeling has recently become a principal part of many studies involving PCB fate and transport in natural water systems. Examples include a feasibility study of the Saginaw and Pine Rivers (ECMPDR, 1983), the PCB-contaminated sediment cleanup project for the South Branch of the Shiawassee River (Rice et al., 1985), the feasibility study of the Hudson River (Lawler, Matusky, and Skelly, 1983), and the remedial investigation and feasibility study of New Bedford Harbor (NUS, ongoing). Different types of models have been selected among these studies primarily on the basis of study goals and the desired use of the information procured from the model. The purpose of this section is to compare the aforementioned modeling efforts with the model developed for this study.

The feasibility study of the Saginaw and Pine Rivers (ECMPDR, 1983; LTI, 1983) applied a time-dependent, completely-mixed box model. Simplified relationships or kinetics were used to individually represent the major physical and biological processes occurring in each box. The purpose of this model was to trace the change of PCB mass within each designated spatial box for various time frames. Although PCB mass was the only dependent variable used in this model and temporal variability was allowed, the model was only intended to provide a long-term simulation. That is, instantaneous responses resulting from a sudden stress or human activity on the box (e.g., a storm event) could not be simulated through this model. Therefore, the model was applied only to forecast the general trends of PCBs in the water and fish on a long-term basis. The approach is very similar to the one used in the Kalamazoo River study from the viewpoint of simplifying the state-of-the-art knowledge concerning the physical and biological processes controlling the PCB/water system. The model used for the Kalamazoo River includes the process of advection, which was neglected in the Saginaw River model. In addition, the model developed for the Kalamazoo River study was designed to compare the relative effectiveness of remedial alternatives under long-term conditions. The decision to retain time-dependent terms is an advantage of the Saginaw River model. However, the Kalamazoo River model was tailored to be more appropriate to demonstrate the relative, long-term effects of remedial alternatives in a spatially variable river system when compared to the Saginaw River model.

The model developed by Rice et al. (1985) for the Shiawassee River is a finite-difference, one-dimensional, dynamic model. Most physical and biological processes considered by the Kalamazoo River and Saginaw River models are included. The major characteristic of the Shiawasee River model is that it incorporates changes in both time and space. Only one spatial dimension was specified. In addition, both advection and dispersion of PCBs were included. The purpose of developing this type of model was to forecast the dynamic transport and distribution of PCBs in water and sediment. Therefore, a simple sediment transport mechanism is also contained in this model that was neglected in the Kalamazoo and Saginaw River models. Generally speaking, the Shiawassee River model is more realistic and capable than the Kalamazoo and Saginaw River models. However, it requires a larger data base than was available for the other studies. In addition, even though the Shiawassee River model is more flexible than the Kalamazoo and Saginaw River models, it is not appropriate for the long-term predictions important to the current study due to both the requirements of using a larger time increment and maintaining model stability.

The sediment transport model HEC-6, which contains the hydraulic submodel HEC-2 together with a simple PCB inventory model, was used to simulate the mass movement of PCBs in the Hudson River. HEC-2 uses kinematic routing to simulate the water surface profile. HEC-6 then uses the simulated water elevation and velocity profiles obtained from HEC-2 to simulate the scour and deposition of bed materials in the river. The PCB inventory submodel is a simplified mass conservation model compared to the Kalamazoo and Saginaw River models. Its usage is dependent on the hydrodynamic and sediment transport data input from HEC-6. Even though HEC-2 and HEC-6 are one-dimensional models that would be expected to be applicable to the flow conditions of the Hudson River, the lack of current understanding of the processes controlling the behavior of organic and fine materials in the sediment caused large errors in calculating the sediment loading at intermediate and low-flow conditions. The simulation of PCB loading for the Hudson River was consequently affected by the poor prediction of sediment dynamics under these conditions.

New Bedford Harbor, together with the adjacent Acushnet River Estuary, constitutes a very complicated hydrodynamic system. In order to understand the behavior of this system from the hydrodynamic and food-chain point of view, and to ultimately predict the spatial and temporal distribution of residual PCB body concentrations in the aquatic life after the implementation of selected remedial actions, the use of more complicated models was deemed to be necessary. A modified version of a dynamic, three-dimensional, finite-difference model, which can be used to simulate water and sediment transport in natural water bodies, and which considers the adsorption-desorption equilibrium of solute between water and sediment, was selected (Onishi and Trent, 1982). A modified version of a food chain model developed by Thomann (1981) was concurrently selected to satisfy the goals of the project. This combination of models is more capable and versatile than the simplified models mentioned above. It is expected that such models will better represent the field conditions and provide more definitive information on critical processes. Nevertheless, this approach needs a comparatively large amount of data to calibrate and validate the models, not to mention the required time, budget, and special expertise required. This study is still proceeding. Thus, no results are available to test the reliability of the detailed modeling approach.

6.4 REMEDIAL TECHNOLOGIES AND ALTERNATIVES

In this section, a two-phased process is used to determine potential remedial actions that may be implemented to address the PCB contamination in the Kalamazoo River.

In Section 6.4.1, the potential technologies are screened to assess their applicability to site conditions. Each technology is briefly described, and its advantages, disadvantages, and limitations are discussed. The goals of the technology screening are to select technologies that can provide effective methods to eliminate, contain, or minimize the spread of the PCB contamination and to eliminate obviously infeasible or inappropriate technologies.

In Section 6.4.2, a number of remedial alternatives for each major contaminated area of the river are developed, based on technologies that have passed the initial screening process. Each of the alternatives is described and evaluated with respect to its feasibility, time required for implementation, and general cost considerations.

In Section 6.4.3, an alternative summary table lists each alternative, approximate time required for implementation, and estimated cost of the alternative. Cost breakdowns for each alternative are provided in Appendix E.

The environmental effects of each alternative are evaluated through the uses of the mathematical model developed in Section 6.3. The model results are presented in Section 6.5. Final selection of remedial actions to address the PCB contamination in the Kalamazoo River will be based on the results of the model and the consequent cost-effectiveness of each alternative.

6.4.1 <u>Screening of Technologies</u>

The following technologies were considered potentially appropriate for remediation of the Kalamazoo River PCB problem. A description of each is provided in this section.

1. Channel Stabilization
2. Sediment Capping
3. Carbon Adsorption
4. Excavation
5. Sediment Dredging
6. Disposal Options (on site, off site, incineration)
7. Biological Degradation
8. Chemical Treatment (other than carbon adsorption)

6.4.2 Channel Stabilization

Stabilization of river sediments to minimize erosion and sloughing can be achieved by the installation of properly designed linings. Linings may be rigid, such as Portland cement or asphaltic concrete, or flexible, such as vegetation or rock riprap. Another type of lining that has been widely used in recent years is fabriform, which is formed by injecting mortar into porous synthetic fabric forms.

Flexible Linings (Vegetation or Riprap)

Flexible linings are generally less expensive to install than rigid linings and have self-healing qualities, which reduce maintenance costs. They also permit infiltration and exfiltration, have a natural appearance, especially after vegetation is established, and provide a filtering media for runoff contaminants. Vegetative and rock riprap liners provide less improvement in conveyance over natural conditions than rigid liners, and the resultant acceleration of flow velocity (and thus the increase in shearing force) is less than with rigid liners.

Flexible linings have the disadvantage of being limited in the depth of flow that they can accommodate without erosion occurring. As a result, the channel may provide a low capacity for a given cross-sectional areas when compared to a rigid lining. Also, the unavailability of rock or the inability to establish vegetation may preclude the use of flexible linings.

When vegetation is chosen as the permanent channel lining, it may be established by seeding or sodding. Sodding has been shown to be as effective as established grass in preventing erosion. Therefore, sodding provides the immediate protection of an established vegetative lining, provided the installation is properly performed and gaps do not exist between sod strips. Installation by seeding usually requires protection by one of a variety of temporary lining materials until the vegetation becomes established. Temporary lining materials include straw, or erosion mats made of paper yarn, fiberglass, or shredded wool.

When rock riprap is used, the need for an underlying filter material must be evaluated. A properly designed filter blanket should be used, as necessary, to prevent leaching of the underlying soil through the riprap. The filter material may be either a granular filter blanket or plastic filter cloth.

For purposes of safety, construction, maintenance, and erosion resistance, it is suggested that channel side slopes be kept as flat as possible. Ideally, side slopes should be 3:1 or flatter for erosion resistance. Therefore, areas that are being stabilized through the use of flexible linings should be regraded when necessary to achieve slopes of 3:1 or flatter.

Rigid Linings (Concrete or Asphalt)

When properly designed and constructed, rigid linings will prevent erosion in steep or difficult channels where other linings cannot be used. They may also be used in areas where the channel width is restricted, since steep sidewall slopes may be constructed. So long as the rigid lining is intact, the underlying soil is completely protected upon construction of the lining. Rigid linings are generally quite smooth; thus they provide a significant improvement in conveyance capacity, due to low hydraulic resistance, and produce a high-flow velocity.

However, rigid linings also have a number of inherent disadvantages. They are expensive to construct and maintain, have an unnatural appearance, prevent or reduce natural infiltration, and contribute to high velocities and scour at the downstream end of the lining unless roughness elements are added to slow the flow. Many rigid linings are destroyed due to flow undercutting the lining, channel headcutting, or unbalanced hydrostatic pressure behind the channel walls or floors.

Because of the inherent disadvantages associated with rigid linings, flexible linings of erosion-resistant vegetation and rock riprap should be used whenever feasible.

Fabriform

Introduced in the United States in the mid-1960's, fabriform linings have been widely used and accepted as an alternative erosion control system. They are relatively easy to install, and, depending on the local availability of other lining materials, can be more cost-effective than other types of linings.

Fabriform liners consist of a porous, synthetic, double-layered fabric into which concrete mortar has been injected and allowed to harden. The result is a high-strength concrete enveloped in synthetic fabric bubbles. The fabric has filter points in between the bubbles for relief of uplift pressure.

The fabriform combines some of the advantages of both flexible and rigid linings. Like flexible linings, fabriform allows infiltration and exfiltration, provides a filtering media for runoff contaminants, and has low maintenance costs. At the same time, fabriform provides the high strength of rigid liners and can be installed in steep or difficult channels where flexible liners cannot be placed.

Choice of a channel lining should be made on a site-specific basis. In some cases, fabriform can provide a cost-effective alternative to conventional liners.

6.4.3 Sediment Capping

For the exposed sediments along the Kalamazoo River, capping may be used to reduce surface water infiltration, to isolate and contain PCB sediments, to control erosion due to surface water runoff, and to prevent the PCBs from leaching from the sediments. The actual process of capping consists of covering the contaminated area with a layer or a system of layers of natural soils, modified soils, and/or synthetic membranes.

Sediment capping may be effective for the areas behind the three drawndown dams of Trowbridge, Otsego, and Plainwell where contaminated sediments on the river banks are exposed to erosion and sloughing. It may also prove useful in the area behind the Otsego City Dam, but large volumes of fill may be required to cover the marsh and low lying areas.

Potential capping materials may include the following:

- Clay
- Other natural soils
- Synthetic membranes
- Admixed materials
- Chemical sealants/stabilizers

Clay has been used extensively as a capping material, with positive and reliable results. A well graded, compacted clay will not only resist water infiltration, but will also act as a filter, absorbing small amounts of leachate contaminants that may percolate through it. However, clay is susceptible to erosion and cracking; therefore, an overlying top soil layer with vegetation is required for protection. Clay is also potentially susceptible to degradation when in contact with certain contaminants, but PCBs do not appear to present a problem of this nature.

A soil cap consisting of compacted natural soils other than clay can also be an effective means of covering the PCB sediments, reducing infiltration rates, and reducing offsite transport of these hazardous substances. Soil caps are similar to clay caps, but usually soil caps are more permeable. A soil cap would also require a vegetative cover for erosion protection.

Synthetic membranes have been used extensively as capping materials with positive results. Most synthetic membranes can resist water percolation, moisture, and chemicals. Disadvantages may exist with respect to specialized installation and covering procedures, durability, costs, burrowing animals, and extended exposure/deterioration. Like clays, synthetic membranes require careful grading, a protective top soil and vegetation cover, and routine maintenance.

Admixed materials such as Portland cement, bituminous concrete, soil cement, soil asphalt, and blown asphalt can be used to cover PCB-contaminated sediments. Typically, these admixed materials can provide a tight seal and a lower permeability. However, they usually are expensive and require special handling and application procedures. Most of these materials are susceptible to cracking due to weathering, frost heave, and settlement, and require frequent maintenance.

Chemical sealants and stabilizers such as cement, fly ash, lime, soluble salts, and freeze-point suppressants can be added to soils to form stronger and less permeable covers for PCB contaminated sediments. However, while these sediments and stabilizers produce a more rigid soil cover, they also increase the potential for the soils to crack.

Because of the inherent disadvantages of the admixed materials and the chemical sealants and stabilizers, they will not be considered further. For the purposes of this feasibility study, two types of caps will be evaluated: a soil cap and an impermeable cap.

- Soil Cap

  A soil cap would consist of 18 inches of a compacted natural soil, with an overlying 6-inch layer of topsoil to support vegetation. Vegetation can be established by either seeding or sodding as previously discussed.

  If properly designed, installed, and maintained, this type of cap will be effective in controlling erosion, containing the PCB sediments, and reducing surface water infiltration by 25-50 percent.

- Impermeable Cap

  The impermeable cap would consist of a layer of compacted clay and/or a synthetic membrane, a drainage layer of sand over the clay or membrane, and a soil cover with vegetation on top. If a synthetic membrane is used along, an underlying 6-inch layer of sand is required to relieve uplift pressure and to protect the membrane.

  If properly designed, installed, and maintained, this type of cap will be effective in controlling erosion, containing the PCB sediments, and reducing surface water infiltration by 90-100 percent.

  Proper design should provide for long-term minimization of surface water infiltration. This is generally accomplished through proper grading, installation of drainage swales, and other surface water diversion techniques. Also, the cap surface should be graded to minimize erosion of the soil cover.

  The effectiveness of the cap will depend on using proper construction techniques and high-quality construction materials. Installation of synthetic liners may be performed by qualified constructors to ensure proper placement and sealing procedures. Clay and soil must be properly compacted to achieve their specified permeability.

  Regular inspection and maintenance is required to prevent excessive erosion of the cover soil.

6.4.4 Carbon Adsorption

Activated carbon has been shown to adsorb PCBs, binding them to the carbon particle and rendering them immobile. Activated carbon may be used in various ways as an immobilizing agent. For example, activated carbon may be mixed with contaminated sediment to act as a direct immobilizing agent. However, the usefulness of this approach is limited because the carbon cannot be applied in situ. The carbon would have to be thoroughly mixed with the sediment in order to be effective. This requires that the sediment be excavated and mixed with carbon at a portable mixing station. This mixing technology would only be applicable to the dewatered sediments at the three drawndown dams, where the sediments are dry enough to be handled in a mixer. This application may be considered appropriate for use in conjection with onsite disposal.

Another potential application of carbon adsorption would be as an adsorbing agent in the bottom liner of an onsite disposal facility. If a layer of carbon could be incorporated into the landfill liner, it would adsorb solubilized PCBs and prevent them from percolating through the underlying soil.

6.4.5 Excavation

Excavation of PCB-contaminated sediment would be an effective source control measure, and, when used in conjunction with onsite or offsite disposal, would eliminate any long-term effects of the PCBs on the river. Excavation is a standard technology frequently used on waste disposal sites. If site conditions permit, excavation can be implemented using common construction equipment and procedures.

Excavation must be evaluated on a site-specific basis since site conditions can dictate the feasibility of excavation. In order to accurately determine the feasibility of excavation in a particular area, a site investigation would be required to determine areal and vertical extent of contamination, extent of excavation required, depth to water table, soil characteristics, subsurface soil conditions, and bearing capacity of the soil.

The areas where excavation may be considered feasible, and their respective estimated excavation volumes (based on a 3-ft excavation depth), are:

• Plainwell Dam	523,000 CY
• Otsego Dam	1,157,000 CY
• Trowbridge Dam	2,594,000 CY
• Bryant Mill Ponds	83,000 CY
• Otsego City Dam (upper reaches)	1,588,000 CY

These excavation volumes are gross estimates, since sufficient data is not available to accurately estimate the depth and areal extent of contamination. Excavation volumes may need to be revised based on the results of further site investigations. In addition, field screening during excavation activities will be required to provide the necessary data to define the extent of contamination and to determine when target cleanup levels have been achieved.

In general, relatively dry soil conditions are required for excavation. The dried sediments along the river banks of the three drawn down dams (Plainwell, Otsego, and Trowbridge) present no problem in this regard. However, the wet soil conditions at Bryant Mill Ponds and Otsego City Dam will make excavation more difficult. High-water-content soils generally have a low bearing capacity and will not support heavy construction equipment. Temporary stream diversion or dewatering may be required in some areas in order to facilitate the excavation.

One of the concerns associated with excavation is that large quantities of contaminated sediment may be released to the river and washed downstream. This situation can be controlled to some degree by using sediment controls such as sedimentation basins, silt fences, and straw bales. However, with large excavation projects in low-lying areas, it will be difficult to control all of the sediment, particularly during storm events.

6.4.6 Sediment Dredging

For subaqueous sediments, dredging of the contaminated sediments is the only feasible alternative available. The areas where dredging may be feasible and their respective estimated dredging depths and volumes are:

Area	Estimated Dredging Volume	Assumed Dredging Depth
Otsego City Dam (submerged areas)	159,000 CY	3 feet
Allegan City Dam	2,823,000 CY	7 feet
Lake Allegan	2,752,000 CY	1 foot

At the Otsego City Dam, only the submerged areas can be dredged using a hydraulic dredge. The silted in areas of the impoundment would best be removed by drawing the dam down to dewater the sediments, and then excavating with a dragline or backhoe.

Dredges may be classified as clamshell, bucket, dipper, and hydraulic, as described below:

Clamshell dredges are most appropriate where the material to be excavated is rock or hard material, or where the dredging operation is a considerable distance from the disposal area and hauling is required. With this type of dredge, production is very low and the unit cost of material excavated is very high. Clamshell dredges are not appropriate for the Kalamazoo River project.

Bucket dredges are used in shallow water and are especially adaptable to trenching under water. A bucket dredge is actually a chain conveyor with buckets attached that dump onto a conveyor belt. This type of operation resuspends large quantities of sediment and, for this reason, is not recommended for the Kalamazoo River.

Dipper dredges are comparable to land-based crawler shovels. They are mainly used for large, heavy rock excavation, and would not be considered appropriate for dredging river sediments.

Hydraulic dredges, available in many sizes, are the most widely used type of dredge. Hydraulic dredging is only feasible in areas where a floating vessel can operate. They remove soil and sediment by suction and pumping through a discharge pipe. Size is determined by the amount of material to be moved or production desired. The type of material to be excavated determines whether a cutter head will be required on the end of the suction line. A cutter head is used when material has to be loosened and cut up into small enough pieces to get into the suction line and flow through the pipes to discharge. For a free-flowing material, such as sand and gravel, no cutter head would be needed. The hydraulic dredge is recommended for dredging the Kalamazoo River sediments.

From an environmental point of view, one of the major concerns related to dredging is that any activity that disturbs and resuspends the sediments could accelerate the release of PCBs to the river environment. Therefore, only hydraulic dredges, which produce the minimal amount of sediment resuspension, will be considered. In addition to minimizing sediment dispersal, the selected dredge should have a high production rate since a large volume of sediment will likely be dredged.

In evaluating the feasibility of a dredging operation, all components of the dredging operation (dredging, spoil transportation, dewatering, disposal, or treatment) should be considered as a total integrated system. One of the major cost elements, and possibly a controlling factor in determining the overall feasibility of dredging, is the need to provide dredge spoil management and disposal facilities.

The three principle aspects of dredging are discussed in the following paragraphs: (1) selecting a dredge, (2) controlling turbidity, and (3) dredge spoil management.

Selecting a Dredge

General requirements to be considered in selecting a type of dredge for the Kalamazoo River include the following:

- The desire to minimize sediment resuspension and subsequent release of PCBs to the environment.
- The need to dredge in water ranging in depth from zero at the river banks to approximately 20 feet in Lake Allegan.
- The compatibility of the dredge equipment with the type of material to be dredged (predominantly silts, clays and sands in the Kalamazoo River).
- The desire to maximize slurry density in order to expedite solids dewatering and to reduce the amount of decant water which may require treatment.
- The desire for a high production rate, due to the large quantities of material to be dredged.
- The need for a land-based mobilization and operations station.

Added to these factors are the selection criteria imposed by local site conditions. Important selection criteria that will vary from site to site include the following:

- Maximum depth of the impoundment.

- Surface area of the impoundment.
- Physical nature of material being dredged - e.g., consolidated sludge or hard clay vs. loose sand and gravel.
- Total volume of material to be dredged.
- Distance over which material is to be pumped - proximity of spoil disposal site or treatment facilities.
- Terminal elevation of discharge pipeline - contributes to total head to be overcome by pumping; may require use of booster pumps.
- Type and amount of aquatic vegetation or overgrowth in the impoundment - tree stumps may require special excavation; special cutting attachments may be needed for heavy weed growth.
- Power source for dredge or pump systems; availability of electric current.
- Ease of access to impoundment.
- Maximum size and weight limits for overland transportation of equipment.

All these criteria must be considered before selection of a pumping system and dredge vessel of the appropriate size, efficiency, and overall capabilities can be made. It should be noted that the depth capability of a unit may be increased by lowering the water level of the impoundment.

Two optional techniques related to hydraulic dredging include centrifugal pumping systems and portable hydraulic pipeline dredges. Each may have potential application to some areas of the Kalamazoo River, and are described below.

Centrifugal Pumping Systems: Centrifugal pumping systems utilize specially designed centrifugal pumps that chop and cut heavy, viscous material as pump suction occurs. These submersible pumps are installed on floating, winch-driven platforms that can quickly and economically dredge small ponds or lagoons.

National Car Rental manufactures a small unit, the Mud Cat SP-810, that utilizes a submerged pump mounted directly behind a horizontal auger, which can handle sludges, or thick muddy sediments. The horizontal auger assembly can be tilted to a 45° angle to accommodate sloping sides of impoundments. The SP-810 can pump up to 1,000 gpm from depths up to 10 feet. This unit also has a detachable mud shield for greater suction efficiency and turbidity control. It is equipped with a depth gage to monitor cutting depth. Two people are required to operate this type of dredge, which is driven along a cable by a reversible winch, at average operating speeds of 8 to 1[illegible] feet per minute. This system is well suited for operation in shallow waters and small rivers where fine-grained sediment has to be dredged and turbidity is a problem. A slightly larger unit, the Mud Cat MC-915, removes sediment in a 9-foot wide swath, 18 inches deep, at depths as great as 15 feet and as shallow as 21 inches. This model discharges 1,500 gpm of slurry with 10 to 30 percent solids content. Depending on site-specific conditions, this model can remove up to 120 cubic yards of solids per hour. Vaughan-Maitlen Industries (VMI) manufactures a line of similar "mini-dredges" that can remove up to 133 cubic yards of material per hour, at depths as great as 20 feet. These types of dredges may be used in the Allegan City Dam impoundment and in the river channel in the Otsego City Dam impoundment.

These centrifugal pumping systems are relatively small, portable units and are ideal for small impoundment dredging where depths are less than 20 feet. For large impoundments that require greater operating depths, higher volume removal, higher pumping rates, and greater pumping distances, large (but still portable) dredge vessels are required.

Portable Hydraulic Pipeline Systems: For dredging in water greater than 20 feet deep, the standard cutterhead dredge is required. This type of dredge may be required for dredging some portions of Lake Allegan.

Cutterhead pipeline dredges are widely used in the United States; they are the basic tool of the private dredging industry. Cutterhead dredges loosen and pick up bottom material and water, and discharge the mixture through a float-supported spoil pipeline to offsite treatment or disposal areas. Portable cutterhead pipeline dredges are those small and light enough to be easily assembled and dismantled, and economically transported to inland dredging sites. They are generally from 25 to 60 feet in length, with pump discharge diameters from 6 to 20 inches. This type of dredge moves forward by pivoting about on two rear-mounted spuds (heavy vertical posts), which are alternately anchored and raised. The swing is controlled by winches pulling on cables anchored forward of the dredge. The rotating cutter on the end of the dredge ladder physically excavates material ranging from light silts to consolidated sediments or sludge, cutting a channel of variable width (depending on ladder length) as the dredge advances.

For deep surface impoundments containing only soft, unconsolidated bottom materials, a variation of the standard cutterhead dredge—the suction pipeline dredge—can be used to dredge the impoundment. Suction dredges are not equipped with cutterheads or they simply operate without cutterhead rotation; they merely suck the material and dilution water off the bottom and, like most dredges, discharge the mixture through a stern-mounted pipeline leading to a spoil disposal area. For most cutterhead dredges, if the disposal site is located more than one-half mile away over level terrain, booster pumps are required.

Ellicott Machine Corporation and the Dixie Dredge Corporation manufacture a diverse line of portable cutterhead dredges that can pump as much as 1,000 cubic yards per hour of solids (based on 10 to 20 percent solids by volume). Ellicott's "Dragon" series of portable dredges operate at digging depths from 17 to 33 feet.

There are several other dredges that may be applicable to surface impoundment work. Waterless Dredging Company is presently field-testing a newly developed system in which the cutter and a submerged centrifugal pump are enclosed within a half-cylindrical shroud. The cutting blades remove the material near the front of the cutterhead with minimal water pick-up. The system has a reported capability of pumping industrial sludges with solids contents of 30 to 50 percent by weight with little turbidity generated. A slurry with a high solids content is very advantageous because it saves time and expense in dewatering.

The Delta Dredge and Pump Corporation has also developed a small portable unit that has high solids capabilities. The system uses a submerged 12-inch pump coupled with two counter-rotating, low speed, reversible cutters.

Controlling Turbidity

Increased turbidity can be expected during any dredging operation; therefore, sediment dispersal and subsequent release of PCBs to the environmental will occur to some degree. Some techniques to control turbidity are discussed in the following paragraphs.

Sheet piling and double silt curtains are potentially applicable sediment dispersal control technologies. Sheet piling or silt curtains would serve as sediment traps for any construction-related sediment release during dredging operations.

Sheet piling can be used to prevent the hydraulic transport of bedload and near-bottom sediments or to impound water to promote the settling of suspended solids. However, sediment transport can still take place over the top of the piling under weir flow conditions. The suspended sediment in the upper water column may be effectively contained by silt curtains. However, since a silt curtain must be maintained at least 2 feet above the river bottom, contaminated sediments could pass beneath the curtain. Therefore, sheet piling and silt curtains used together, may provide an effective cutoff barrier to trap suspended sediments. When dredging an area behind a dam, silt curtains can be installed at the sluice gate or spillway to trap suspended sediments. The selection of sheet piling or silt curtains as sediment dispersal controls is dependent on the intended use within the framework of remedial action alternatives.

With most hydraulic dredging, it has been generally concluded that resettling of most sediments will take place in the immediate vicinity of the dredge. A silt curtain can provide a physical barrier to any fine-grained or organic materials that are resuspended. Fabrics have been developed that will control sediments in the 0.5 mm and smaller particle size range. The attachment of an absorbent material to the silt curtain would hinder the dispersal of any oily films that may be generated during dredging operations and other construction activities, which may be important since oils have a high affinity for PCBs.

In addition to standard downstream sediment controls such as silt curtains or sheet piling, there are certain procedures that all sediment dredging operations may follow to minimize streambed agitation and control turbidity. Where cutterhead dredges are being used, a reduction in the speed of the spiral cutter (in terms of revolutions per minute) will generally result in lower turbidity levels in the immediate vicinity of the cutter. Cutter speed reduction may adversely affect dredge production, however, particularly in hardened, irregular sediments.

Another consideration for turbidity reduction is the timing of dredging operations. Projects should be scheduled for periods of low flow and dry, calm weather whenever possible. Natural stream turbidity and current turbulence will be minimal at such times and will not contribute to dredge-generated turbidity. Timely dredging also allows for easy visual monitoring of any dredge-generated turbidity.

When preparing dredging contracts for contaminated sediments removal where turbidity control is essential, contract provisions should specify the use of special low-turbidity dredge vessels or auxiliary equipment and techniques designed to minimize turbidity generation. The bidder should be made to specify minimum sediment removal volumes and maximum allowable turbidity levels in the downstream environment to ensure an effective dredging operation.

Dredge Spoil Management

Contaminated dredge spoil management includes methods for dewatering, transporting, storing, or disposing of contaminated sediments after they have been dredged from the area of deposition.

Because of a large volume of dredge spoil to be managed, it would be cost-prohibitive to transport and dispose of the waste offsite. Also, since the hydraulically dredged spoil will require dewatering anyway, a spoil containment basin can serve both as a sedimentation (dewatering) basin and as a long-term disposal site. Cell construction may be necessary to implement this scenario.

Spoil containment basins can be formed by constructing perimeter berms or dikes around natural topographic depressions. Within the basin, sedimentation is the principal process that functions to remove suspended solids from the slurry stream. The surface area and depth of the containment facility, the detention time, the rate at which the dredge pumps into the basin, the solids content of the slurry, and the grain-size distribution of the dredged material are important factors in determining the rate of settling and the quantity of solids retained. The settling of the fine particles can be somewhat improved with the use of coagulants or polyelectrolytes.

Conventional spoil containment basins are constructed with sluices and overflows to release effluent to natural watercourses in which suspended solids concentrations are low enough to meet state or local water quality criteria. If the effluent does not meet requirements for PCB content, the effluent may discharge to a secondary containment basin for further treatment. A water treatment step may be required prior to discharge back into the river to satisfy all water quality regulations.

Although PCBs are not highly soluble in water, protection of groundwater from contamination by water draining from the dredge spoil may be a concern in the handling of this material. Dewatering and disposal facilities may be redesigned so as to prevent the infiltration of contaminated water into groundwater. This would involve the use of impermeable liners, underdrains, and/or collection systems.

The spoil containment facility can either be sized to serve as a final disposal area for all of the dredged material, or it may be designed as a temporary dewatering and transfer station. When the facility attains its maximum capacity, the contaminated spoil (if it has been sufficient dewatered), can be mechanically excavated and truck-loaded for transport to secured landfills or to a secondary containment basin for permanent storage.

6.4.7 Disposal Options (Onsite, Offsite, Incineration)

Quantities of contaminated sediments to be disposed for each area of the river were estimated, based on the area and assumed depth of contamination. Estimated volumes for each area are as follows:

Area	Assumed Depth	Estimated Sediment Volume for Disposal
Lake Allegan	1 foot	2,752,000 CY
Trowbridge Dam	3 feet	2,594,000 CY
Otsego Dam	3 feet	1,157,000 CY
Otsego City Dam	3 feet	1,747,000 CY
Plainwell Dam	3 feet	523,000 CY
Allegan City Dam	7 feet	2,823,000 CY
Bryant Mill Ponds	3 feet	83,000 CY

The estimated disposal volumes were based on a bulking factor of 1.0. This is, one cubic yard of disposal volume was assumed for each cubic yard of in situ sediment removed. Settling and consolidation tests will be required to test this assumption. If contaminated sediment is excavated or dredged from the river, it must be securely disposed in order to prevent future releases to the environment. Basically, there are three options for disposal of PCB contaminated sediment that have been dredged or excavated from the river.

- Offsite land disposal facility
- Onsite land disposal facility
- Incineration

The most cost-effective disposal option will depend on the quantity of material to be disposed, the PCB concentration of the material, and the applicable regulations regarding disposal of the material. The disposal of any material with a PCB concentration greater than 50 ppm is regulated under the Toxic Substances Control Act (TSCA), as specified in 40 CFR Part 761.60. Under TSCA, sediment containing PCB concentrations greater than 50 ppm must be disposed either by land disposal in a chemical waste landfill, or by incineration.

The first option, offsite land disposal, involves transporting the contaminated sediments by truck or rail to the nearest approved landfill that is permitted to accept the waste. The type of landfill that will be permitted to accept the waste will depend on the PCB concentration of the waste. Sediment with less than 50 ppm PCBs may be disposed in any landfill, provided the landfill will accept the waste. Some existing landfills may refuse the waste because they do not have the required capacity or they want to avoid potential liability problems. The following four landfills have been identified as potential disposal sites. All are approximately 300 miles roundtrip from Kalamazoo.

- Wayne Disposal - Belleville, Michigan
- Michigan Disposal - Belleville, Michigan
- Fondessy Landfill - Oregon, Ohio
- Adams Center Landfill - Fort Wayne, Indiana

If the PCB concentration in the sediment is greater than 50 ppm, it must be disposed by landfilling at an approved hazardous waste facility. The three closest existing hazardous waste facilities and their respective approximate roundtrip distances from Kalamazoo are:

• CECOS Landfill - Cincinnati, Ohio	600 miles
• CECOS Landfill - Niagara Falls, New York	800 miles
• SCA Landfill - Model City, New York	800 miles

Major costs for offsite disposal would include transporting of the waste and disposal fees. Sediment stabilization may also be required prior to shipment if the water content of the dredged materials exceeds the limit for a "liquid waste." For small quantities of waste, this disposal option is probably the least expensive.

The option of onsite disposal would involve construction of one or more new disposal areas at or near the site. Again, the type of disposal area required would depend on the PCB concentration of the contaminated sediment to be disposed. If the PCB concentration in the sediment is less than 50 ppm, the disposal area could be an area at a nearby site that could be diked off, filled with sediment, allowed to dewater naturally, and then capped. The use of activated carbon is recommended for adsorbing PCBs that may migrate into the underlying soil or groundwater. The disposal area should be located at a site where the bottom of the disposal facility is at least 10 feet above the high groundwater table, to prevent future groundwater problems.

If the PCB concentration is greater than 50 ppm, land disposal of this material is regulated under the Toxic Substances Control Act (TSCA), and a chemical waste land disposal facility would have to be constructed in compliance with the requirements of 40 CFR, Part 761.75. This type of facility requires an impermeable liner of clay or a synthetic membrane, leachate collection, and groundwater monitoring. The construction and operation of a chemical waste landfill is a complex undertaking. This option would only be cost-effective if a large quantity of waste exceeding the 50 ppm criterion was required to be disposed.

The third option, and almost certainly the most expensive, would be incineration. Incineration is a process that uses thermal oxidation to convert organic substances into a less bulky, inorganic material. This process will reduce the waste volume and will effectively destroy PCBs and any other organic contaminants found in the sediment. The use of a commercial offsite incineration facility is unlikely at this time. Potential facilities have only limited treatment capacities and presently have a large backlog of available capacity. Onsite incineration could be implemented by the use of either a mobile incinerator, or one or more newly-constructed incineration units built on site.

PCB incineration is regulated under the Toxic Substances Control Act (TSCA), and the incinerator must comply with the requirements specified in 40 CFR, Part 761.70. Basic requirements specified under TSCA include (1) air emissions regulations; (2) combustion efficiency of at least 99.9 percent; (3) measuring and monitoring requirements; and (4) various other operating procedures and requirements. The incinerator must be approved by the appropriate EPA Regional Administrator or the Assistant Administrator for pesticides and toxic substances.

For large volumes of waste, this is a very costly and time-consuming alternative. The incineration rate of even a large capacity incinerator is much less than the average rate of dredging or excavation. Several incinerators may be required, or material may have to be stored in a temporary facility. Construction, permitting, and operation of an incineration unit is very costly and time-consuming. Since current regulations do not require incineration of PCB contaminated sediments, it would be difficult to justify the expense of incineration, when more cost-effective alternatives are available. In addition, the levels of PCBs in the Kalamazoo River sediments are low relative to other PCB sites (e.g., New Bedford Harbor) for which incineration has been ruled out as a cost-effective alternative.

6.4.8 Biological Degradation

PCBs can be biodegraded by biological agents such as bacteria that use the PCBs as their sole source of carbon. However, only the lesser chlorinated biphenyls are degraded rapidly. Since most PCBs in the environment are a complex mixture of PCB isomers, this technology has not worked well in the past. Research is being conducted in an attempt to create microorganisms capable of degrading all PCBs. This technology works best under aerobic conditions. In a sediment matrix, corn cobs are sometimes used to add air space. Research has been conducted on providing bacteria with a supply of nutrients and sufficient air to maintain aerobic conditions and enhance degradation of PCBs.

This technology is still under development and has been approved for use in only a few EPA regions; however, this technology is advancing rapidly. One biodegradation process developed by DETOX Industries in Houston, Texas, is rapidly progressing toward full field application. It should be tracked as a potential PCB-destruction technology for selected areas in the event that the remedial action schedule is delayed. Potential uses of this technology would be in situ treatment of Portage Creek sediments, or treatment of dredge spoil.

6.4.9 Chemical Treatment

Three processes in commercial use (Goodyear, Acurex, and Sun-Ohio's PCBX) have been used to chemically dechlorinate PCBs. All three technologies involve the addition of alkalai metal organometallic reagents such as sodium naphthalide to dechlorinate the material. The residue from these processes can then be disposed as noncontaminated material.

These three processes have only been used to treat transformer oils and similar fluids, and are not readily applicable to sediments or soils. To treat soil, solvent extraction would be required to remove PCBs from the soil (soil washing), and the solvent would be treated using one of these processes.

Since the soil washing technology is still in the experimental stage, it will not be considered for the Kalamazoo River at this time.

6.4.10 Summary - Technology Screening

In this section of the report, eight categories of technologies were reviewed to assess their applicability to the Kalamazoo River Site conditions. Two of the technology categories (biological degradation and chemical treatment) were not considered appropriate at this time for the Kalamazoo River. The remaining six categories were judged to be potentially appropriate to the Kalamazoo River. They are the following:

1. Channel stabilization
    - flexible lining
        - vegetation
        - riprap
    - fabriform
2. Sediment Capping
    - soil cap
    - impermeable cap
3. Carbon Adsorption
    - mixing with sediments
    - liner for onsite disposal facility
4. Excavation
    - front-end loader
    - backhoe
    - dragline
5. Sediment Dredging
    - hydraulic dredging
    - dredge spoil management
    - Turbidity control
6. Disposal Options
    - less than 50 ppm
        - onsite land disposal facility
        - offsite land disposal facility
    - greater than 50 ppm
        - offsite chemical waste landfill
        - onsite chemical waste landfill
        - onsite incineration

Based on these technologies, remedial alternatives for each major contaminated area of the river are developed and evaluated in Section 6.4.10.

6.4.10 Screening of Alternatives by Area

Remedial actions will be directed toward mitigating the current source of PCBs to the river - the existing contaminated sediments. By looking at the erosional and depositional patterns of the river and analyzing the distribution of PCBs in the sediment samples, this study has identified seven areas of the river where contaminated sediments have accumulated over the years. Therefore, potential remedial action alternatives will be focused only on those seven areas.

In this section, the potential alternatives for remediation of the seven major contaminated areas of the river will be evaluated. To simplify the discussion, the seven areas will be placed into three categories, according to their respective site characteristics. All areas in each category have similar site characteristics that call for certain types of remedial action. The seven river areas are categorized as follows:

- Portage Creek/Bryant Mill Ponds
- Drawn Down Dams
  - Plainwell Dam
  - Otsego Dam
  - Trowbridge Dam
- Impounded Dams
  - Otsego City Dam
  - Allegan City Dam
  - Lake Allegan

Alternatives for each of the categories will be discussed according to the following criteria:

- Description - A general description of the various elements of the proposed remedial alternative including the intended purpose and function of the element, i.e., containment, diversion, removal, etc. Any special site conditions or waste characteristics that may affect the performance of the site remediation will be discussed.
- Feasibility - The implementability or constructability of the remedial alternative will be assessed. Site conditions that may affect the implementability of the alternative will be discussed.
- Time and Cost - A best estimate of the time required for implementation of the remedial alternative will be given. Implementation time includes the time required for site investigation, design, and implementation of the remedial alternative. Estimated construction time will be based on the most likely construction schedule, taking weather conditions and general construction problems into account.

Major capital costs and anticipated operating and maintenance (O&M) costs will be qualitatively discussed.

6.4.11 Portage Creek/Bryant Mill Ponds

The Bryant Mill Ponds are two small, dewatered mill ponds located on Portage Creek, a tributary of the Kalamazoo River. The ponds are filled with sediments, which are partially vegetated with naturally occurring vegetation. The ponds have been drawn down since 1976, and dried sediments are exposed on the banks of the creek. Portage Creek has eroded a channel through the sediments; however, contaminated sediments are still present in the creek bed. The exposed sediments are subject to erosion from storm runoff, and periodic inundation during high river flows. Current sources of PCBs result from erosion of the contaminated sediments, and movement of dissolved PCBs from the creek banks into the water column.

Available data indicate that the PCB concentrations in the sediments in this area are the highest of the entire study area. The depth of contaminated sediment is unknown. Core samples indicate that sediment at the 24-inch depth is highly contaminated, but no core samples were taken deeper than 24 inches. For purposes of evaluating remedial alternatives, the assumption has been made that the depth of contaminated sediment is 3 feet.

The areal extent of Bryant Mill Ponds is much smaller than any of the other dam areas. The area of even the smallest dam area, Plainwell, is seven times greater than the area of Bryant Mill Ponds. Since this area is relatively small and is a major source of PCB contamination, it is a prime candidate for some type of remedial action.

Remedial actions for Bryant Mill Pond are currently being pursued through litigation. The State of Michigan has filed a complaint in United States District Court. The State seeks injunctive relief to abate and remedy the release of PCBs into the environment. Because remedial actions for Bryant Mill Pond are being pursued through litigation, they will not be addressed in this document.

6.4.12 Drawn Down Dams

The available data for the Plainwell, Otsego, and Trowbridge Dams indicate that the sediments behind these dams are not highly contaminated relative to other areas of the river. Of the 103 samples taken in these three areas, only 3 samples exceeded 50 ppm PCBs. Core samples in these areas show very little, if any, contamination below two feet deep. A special analysis was performed on cores from Plainwell and Trowbridge areas to confirm that deeper sediments were not contaminated with organic compounds other than PCBs. No extraordinary levels of any of these compounds were detected. The results are presented in Appendix F.

The three dams were acquired by the Michigan Department of Natural Resources in 1966, and were drawn down in the early 1970s due to their deteriorated condition. Dried sediment is presently exposed along the river banks. The river has since cut a channel down through the contaminated sediments, which are now above the water level. Samples taken from the river bed in these three areas are relatively clean, a fact which indicates that the channel has eroded through the contaminated sediments and into non-contaminated material. The dried sediments are revegetated, but the river banks are being eroded and sloughing off into the river, releasing additional PCBs. Periodic inundation of the dried sediments may also release PCBs to the water column.

Dam removal is under progress at these three dams. If dam removal is implemented, the river channel would erode deeper into the sediment and re-establish itself at a lower elevation. This would be a beneficial effect, because the contaminated river banks sediments would be higher above the river level. Provided that proper precautions are taken, dam removal will have no adverse environmental effects on the river. Proper precautions include excavation of any contaminated sediment which may be carried into the river as a result of dam removal. This includes sediment directly behind the dam, and sediment along the river channel which would slough into the river as a result of the channel eroding deeper. Dam removal may be implemented alone, or in conjunction with any of the elevated alternatives. Dam removal will not be further evaluated.

The areas of the three impoundments, and their estimated contaminated sediment volumes (assuming 3 feet of contaminated sediment), are as follows:

	Former Flooded Area	Estimated Sediment Volume
Trowbridge Dam	536 acres	2,594,000 CY
Otsego Dam	239 acres	1,157,000 CY
Plainwell Dam	108 acres	523,000 CY

The following alternatives are being considered at the three drawn down dams:

- No action
- Channel lining and soil cap
- Channel lining and dredged area
- Channel lining and impermeable cap
- Excavation and disposal

For the three alternatives involving channel lining, the channel lining has been used for long-term stabilization of the river channel; however, the channel lining is optional. Costs for the no channel lining options are provided. If the no channel lining option is chosen, excavation would still be required to cut the channel side slopes back to a more stable 3:1 slope. Also, long term monitoring of the channel would be required to detect river meandering or bank erosion, which may require a maintenance program to avoid large quanities of contaminated sediment being added to the river. If meandering or bank erosion is detected, additional bank stabilization measures would then be implemented.

6.4.12.1 No Action

Description

If no action is taken, PCBs will continue to be gradually added to the river environment via erosion and sloughing of the river banks. The environmental impact of taking no action will be evaluated by the mathematical model.

6.4.12.2 Channel Lining and Soil Cap

Description

Under this alternative, a flexible lining, such as fabriform or riprap, will be used to stabilize the river channel and to prevent the river from future meandering. A soil cap will be used to protect the exposed sediments above the river banks against erosion.

For the river channel, a properly designed riprap lining with an underlying filter blanket of sand and filter fabric will be constructed. If riprap is not locally available, a fabriform channel may be constructed. The river banks in the areas behind the three drawdown dams are estimated to have 1:1 side slopes, due to the manner in which they were formed. These slopes are much too steep to construct a stable channel lining. Depending on the type of channel lining selected, the slopes will have to be cut back to approximately 3:1. Therefore, some dredging and/or excavation will be required to achieve the proper channel cross-section.

For the dried sediment beds, a soil cap, consisting of an 18-inch layer of soil and a 6-inch layer of vegetated topsoil, will be effective in controlling erosion. Seeding will be used to establish vegetation. Regrading may be required in order to improve the ability of the cap to provide proper drainage--to achieve positive drainage or to eliminate potential ponding.

Channel lining and soil capping, when properly designed, installed, and maintained, are expected to eliminate erosion and subsequent release of PCBs to the river environment at the three drawn down dams. However, some dissolved PCBs will still be carried into the water column from rainwater infiltrating through the contaminated sediments and into the river.

As a variation of this alternative, the channel may be lined as previously described; however, rather than placing a soil cap over the entire area, a layer of contaminated sediment approximately 3 feet deep and 25 feet wide would be removed along both river banks. Then a soil cap would be installed in place of the removed sediment. This would provide a "dredged area" between the river and the contaminated sediments. This "reduced" soil cap is assumed to provide the same environmental protection as the full soil cap, at less cost. However, this may create ponding problems behind the dredged area. A cost for the "reduced" soil cap (termed "dredged area") at the three drawndown dams will be provided.

Feasibility

This alternative is technically feasible and can be achieved using standard construction methods. Prior to design, a site investigation will be required to determine soil characteristics, subsurface soil conditions, and bearing capacity of the soil. Straw bales and/or silt fencing should be used during construction to minimize the quantity of contaminated sediment that washes downstream.

Time and Cost

These projects would be quite large in areal extent, would be completed in phases, and may take several years to complete. This alternative would be the least costly remedial action considered for the three drawndown dams in this feasibility study.

Maintenance costs are expected to be minimal, and would include annual or semi-annual inspections and periodic repairs, if necessary. Inspections following major storm events are also recommended. Repairs may include regarding and/or revegetating portions of the soil cap.

6.4.12.3 Channel Lining and Impermeable Cap

Description

This alternative is very similar to the previous one, in that flexible linings are used to reduce erosion of the dried sediment beds and in the channel. However, instead of using only a soil cover with vegetation, an impermeable cap is used to cover the exposed sediment beds.

The impermeable cap would consist of a layer of compacted clay and/or a synthetic membrane, a drainage layer of sand over the clay or membrane, then a soil cover with vegetation. If a synthetic membrane is used, a 6-inch sand layer under the membrane is recommended to relieve uplift pressure and to protect the membrane from puncture. Again, some regrading may be necessary to prepare the surface for placement of the cap. In the channel itself, a riprap liner or fabriform would be installed, as described in the last alternative.

Sediment capping and channel lining, when properly designed, installed, and maintained, are expected to eliminate erosion and subsequent release of PCBs to the environment. An impermeable sediment cap (as opposed to a soil sediment cap) will provide the added benefit of eliminating rainwater infiltration through the sediment and the subsequent leaching of PCBs. A soil cap is expected to eliminate 50 percent of rainwater infiltration, while the impermeable cap is expected to eliminate 100 percent.

Feasibility

This alternative is technically feasible and can be achieved using standard construction methods. However, the use of compacted clay in the multimedia cap may be difficult if the bearing capacity of the soil on the banks of the river is low. Also, a tremendous quantity of clay is required, which may not be available locally. In this case, a synthetic liner is recommended, with an underlying 6-inch blanket of sand to protect the liner and to provide a flow zone for the release of any excess water pressure.

- Time and Cost

These projects would be quite large in areal extent, would be completed in phases, and may take several years to complete.

This alternative would be slightly more expensive than the previous alternative because of the addition of the synthetic liner. Maintenance costs are expected to be minimal and would include annual or semi-annual inspections and periodic repairs, if necessary. Repairs may include regrading and/or revegetating portions of the impermeable cap.

6.4.12.4 Excavation and Onsite Disposal

Description

This alternative requires excavation of the dewatered, contaminated sediments on the river banks, and subsequent disposal. Since the PCB concentrations in the sediments behind the three drawn down dams are generally low (less than 50 ppm), the sediments would not be regulated under TSCA. Therefore, the TSCA requirement of disposal in a chemical waste landfill or disposal by incineration does not apply.

Given the low PCB concentrations in the sediments, offsite disposal or incineration would not be cost-effective disposal options. Some type of onsite containment facility appears to be the most appropriate disposal option for these sediments. The containment facility could be simply a diked off area near the dam that would be filled with the contaminated sediments and then capped with a soil cover.

A site investigation is required to determine the feasibility of excavation. If excavation is determined to be feasible, the bearing capacity of the soil and the haul distance required will dictate the type of equipment used to excavate the sediments. In general, the lower the bearing capacity of the soil, the more difficult the excavation.

If the bearing capacity is too low to support even a small haul truck, then a dragline, supported on a floating platform, must be used to move the material to firmer ground, where it could then be loaded into trucks with a front-end loader. The disadvantages of this method are that the excavating efficiency is low because of intermediate material handling time and because frequent setups are required. If the soil can support a front-end loader and if the material is to be hauled more than 500 feet, the most efficient method would be excavation with a front-end loader and direct loading into haul trucks, with no intermediate material handling.

If the material is going to be disposed of on site and does not need to be loaded into trucks, the best excavation equipment to use would be either dozers (haul distance 300) or scrapers (haul distance 300 to 500 feet). Scrapers are both excavating and hauling devices. The bottom loading pan removes a layer of soil and then transports it to a transfer station or disposal site. This method is very efficient; however, relatively dry soil conditions are required for proper operation.

A dozer is used to push the soil from one area to another. A dozer can only push material a distance of 300 to 500 feet with efficiency. Therefore, this excavation method is best suited to small areas, or long and narrow areas. If soil conditions cannot support a standard dozer, possibly a low ground-pressure dozer could be used. A low ground-pressure dozer has wider tracks and a longer undercarriage than a standard dozer. Their weight is distributed over a larger bearing surface, and they can be operated in areas where the normal dozer cannot.

Sediment controls such as sedimentation basins, silt fences, and straw bales may be required during excavation. However, with a large excavation in a low-lying area, it will be very difficult to control erosion, particularly during storm events. Large quantities of contaminated sediment may be released to the river and washed downstream. After excavation, the excavated area would be regraded and revegetated to reduce erosion.

Feasibility

The feasibility of total excavation cannot be assessed until more site data is obtained. In order to accurately determine the feasibility of excavation of these areas, an investigation would be required to determine the depth of contamination, the extent of excavation required, the depth to the water table, the soil characteristics, bearing capacity of the soil, and subsurface soil conditions for each area.

Preliminary analysis indicates that onsite disposal, if feasible, would be the best option for disposal in these areas. Although offsite disposal may be feasible, it would be less cost-effective and may not be practical, given the low PCB concentrations in the sediments. The feasibility of onsite disposal would depend on the availability of a suitable location for a disposal facility at each of the areas.

Time and Cost

There is insufficient site data at these three areas to estimate the time period required for excavation of the sediments. The rate of excavation is a function of the excavation method, which cannot be determined until site investigations are completed. However, these projects are quite extensive and could take several years to complete. The cost of the excavation alternatives would be much higher than the channel lining and sediment capping alternatives.

6.4.13 Impounded Dams

The three dams that are currently impounded in the lower Kalamazoo River are the Otsego City Dam (also called the Menasha Dam), the Allegan City Dam (also called Imperial Carving Dam), and the Calkins Dam (Lake Allegan).

There is not much sediment PCB data available for the Otsego City Dam. The highest concentrations found were 25.1 ppm in a surface sample and 57.0 ppm (at 12 inch depth) in a core sample.

Based on available data, the Allegan City Dam impoundment appears to be relatively highly contaminated. A deep core taken in this impoundment in 1985 indicated high concentrations of PCBs as deep as 7 feet.

Available data indicate that PCB concentrations in Lake Allegan are generally low. Eight surface samples ranged from 2.26 to 24.67 ppm. Five core samples, (4 to 16 inches in depth), ranged from 13.90 to 41.70 ppm. The highest PCB concentrations are found in the upper reaches of the lake, where much of the sediment deposition takes place.

The alternatives being considered for the impounded dams are:

- No Action
- Dredging and/or excavation, and upland disposal
- Channel dredging, channel lining, and soil cap (Otsego City Dam)
- Channel dredging, channel lining, and impermeable cap (Otsego City Dam)

The two latter options are being considered only for the Otsego City Dam. The Otsego City Dam impoundment is heavily silted in and is characterized by swampy conditions, particularly in the upper reaches. At this impoundment, hydraulic dredging would only be feasible in the channel, where a floating vessel can operate.

6.4.13.1 No Action

No action may possibly be a viable option for the impounded dams, particularly if upstream sources are remediated. If upstream sources of PCBs are remediated, eventually, only "clean" sediments will be carried downstream. Since the impounded dams are depositional areas, the contaminated sediments will then be covered up by "clean" sediments, and essentially isolated from the aquatic ecosystem. This alternative will be evaluated by the mathematical model.

6.4.13.2 Dredging and/or Excavation, and Upland Disposal

Description

Dredging is the technique used for removing subaqueous sediments. This is the only feasible alternative available for Lake Allegan. Hydraulic dredging was selected as the most appropriate dredging technique for the Kalamazoo River.

The channel of the Otsego City Dam impoundment may be dredged using a hydraulic dredge, but the silted-in sediment areas would best be removed by drawing the dam down to dewater the sediments, and then excavating with a dragline or backhoe. This technique may also be used in the Allegan City Dam impoundment.

A feasibility and cost study of the Allegan City Dam is required to determine whether dredging or excavation is the most cost-effective removal technique. For large volumes of material, the unit cost of mechanical excavation is greater than the unit cost for dredging. However, the cost for material handling will be less for mechanical excavation than for dredging, since the expense of spoil management and dewatering will be reduced.

Listed below are the areas where dredging or excavation may be feasible, along with their respective areas and estimated sediment removal volumes (based on an assumed depth of contamination) are as follows:

	Area	Estimated Sediment Volume	Assumed Depth
Allegan City Dam	250 acres	2,823,000 CY	7 feet
Lake Allegan	1,706 acres	2,752,000 CY	1 foot
Otsego City Dam	361 acres	1,747,000 CY	3 feet

Because of the large volumes of sediment to be disposed of, onsite disposal would be the most appropriate and cost-effective disposal option. Offsite disposal and incineration will be cost-prohibitive and will not be considered at this time. Also, available data indicate that the PCB concentrations are generally less than 50 ppm in these areas; therefore, there are no regulatory requirements that call for disposal in a chemical waste landfill.

Feasibility

The overall feasibility of dredging in each area and the most technically and economically effective strategy to manage the dredge spoil removed from each site will depend on the following factors:

- Volume of materials to be dredged.
- Physical characteristics of dredge spoil (water content, grain-size distribution).
- Proximity of available land area for construction of spoil containment/disposal facilities.
- Type and amount of aquatic vegetation; tree stumps may require special excavation, special cutting attachments for heavy weed growth.
- Terminal elevation and length of discharge pipeline; may necessitate use of booster pumps.
- Power source for dredge and pump system; availability of electric current.
- Ease of access to impoundment.

- Maximum size and weight limits for overland transportation.

Most potential problems can be overcome if enough money is spent. However, the limiting factor may be the availability of enough land in proximity to the site to accommodate spoil containment facilities.

With any dredging operation, sediment dispersal and increased turbidity can be expected, and subsequent release of PCBs to the environmental will occur to some degree.

Even if dredging is done carefully and systematically, not all of the PCBs will be removed. A carefully planned and executed dredging operation can be expected to remove 70 to 90 percent of the PCB-contaminated sediments.

The overall feasibility of excavating the dewatered sediments of the Otsego City or Allegan City Dams will be affected by the following factors.

- Volume of sediment to be excavated
- Physical characteristics of sediment, depth to water table
- Bearing capacity of soil, subsurface soil conditions
- Proximity of available land for containment/disposal facilities

Sediment controls, such as sedimentation basins, silt fences, or straw bales will be required during excavation to control erosion. However, with large excavation projects such as these, erosion will be difficult to control, and some release of PCBs to the environment can be expected.

If a dredging or excavation alternative is selected, an in-depth feasibility study should be conducted to determine the most cost-effective removal technique and to develop an effective spoil management strategy.

Time and Cost

A large hydraulic dredging operation such as dredging the Kalamazoo River impoundments will most likely be performed by a specialty contractor whose rates may be highly variable. The unit costs associated with representative hydraulic dredging techniques can be estimated at $3-$5 per cubic yard of material removed.

In addition to dredging costs, the other major cost will be that associated with dredge spoil management. These costs are highly variable from site to site, and unit costs are not readily determined. However, some general economic considerations are discussed here.

The land area required for construction of conventional spoil containment basins, for settling of both primary and secondary effluent, is an important cost consideration. Containment basins should be constructed as close as possible to the dredging operation. Where new land must be acquired for containment basin construction, local real estate values will determine initial capital requirements. In general, when fine-grained solids are removed by dredging, pipeline transport of a concentrated slurry using booster pumps is less costly than truck loading and transport of the same quantity of dry solids. Secondary dredging of containment basins to provide additional spoil storage volume, and coagulant addition to enhance settling, are effective methods of reducing required containment basin area and thereby decrease capital outlay required for a spoil management project. Also, the spoil volume can be reduced by (1) dredging slowly to decrease liquid entrainment, and (2) using a dredging system that is capable of pumping a high solids content stream.

The most cost-effective spoil management strategy will depend on many site-specific variables: the dredge pumping rate, suspended solids content of the dredge slurry, total quantity of solids to be handled, available land area, and proximity to dredging site.

The above considerations and associated problems demonstrate the enormous cost encountered when dealing with dredging large volumes of contaminated sediments, since large capital outlays are required to handle large volumes of waste material within a relatively short time. Also, if dredge spoil supernatant is contaminated and cannot be discharged back to the river, the onsite treatment of wastewater becomes an additional major cost.

6.4.13.3 Channel Dredging, Channel Lining, and Soil Cap (Otsego City Dam)

Description

Under this alternative, the entire length of the existing channel would be dredged to remove contaminated sediments and to prepare the channel for a riprap or fabriform lining. Dredge spoil would be contained behind dikes adjacent to the channel and allowed to dewater. A flexible channel lining, such as riprap or fabriform, would be used to stabilize the channel and to prevent future meandering of the river. A soil cap would then be placed over the entire sediment area to contain the contaminated sediments.

Channel dredging can be accomplished hydraulically using a mini-dredge, such as Mud Cat SP-310, or may possibly be excavated mechanically if the dam can be drawn down sufficiently. The dredge volume from the channel would be small enough that diked areas adjacent to the site could be used to contain the dredge spoil. The dredge spoil could be allowed to dewater naturally. The dewatering process could be greatly enhanced by drawing down the water level in the impoundment.

When the area is sufficiently dewatered, a soil cap, consisting of an 18-inch layer of soil and a 6-inch layer of topsoil, would be installed and vegetated. Sodding or seeding may be used to establish vegetation. The capped area may require some regrading and surface water diversion to prevent erosion and to promote drainage. Some extra backfilling may be required in the low-lying areas to eliminate ponding.

Channel dredging and lining, and soil capping, when properly designed, installed, and maintained, is expected to eliminate sediment erosion and subsequent release of PCBs to the river at Otsego City Dam. However, since the channel lining will permit infiltration and exfiltration, dissolved PCBs will still be carried to the river from the rainwater infiltration and groundwater movement through the contaminated sediments.

Feasibility

Installation of channel linings using riprap or fabrication is a common construction practice. The choice of the type of channel lining will be based on local availability and cost of riprap.

Channel dredging at Otsego City Dam is technically feasible using standard dredging techniques, provided a power source is available for the dredge and access to the impoundment is feasible.

In order to estimate the feasibility of dredge spoil dewatering and soil capping, a site investigation and conceptual design would be required.

The feasibility of using adjacent diked areas for containment and dewatering will depend on the dredge spoil volume, area available for containment and dewatering, and grain-size distribution and solids content of dredge material.

Placing a soil cap in this area is technically feasible using standard construction methods; however, site conditions may make this cost-prohibitive. Since the area is characterized by swampy conditions, dewatering may be required to reduce the swampy conditions in order to improve the bearing capacity of the soil and to facilitate placing the cap. Also, large volumes of backfill may be required in low-lying areas to eliminate ponding.

Time and Cost

This project would be quite large, would be completed in phases, and will take several years to complete.

6.4.13.4 Channel Dredging, Channel Lining, and Impermeable Cap (Otsego City Dam)

Description

This alternative is very similar to the previous alternative. However, instead of installing a soil cover with vegetation, an impermeable cap would be used to cover the sediments. The impermeable cap would consist of a layer of compacted clay and/or a synthetic membrane, a drainage layer of sand over the clay or membrane, then a soil cover with vegetation. If a synthetic membrane is used, a 6-inch sand layer under the membrane is recommended to relieve uplift pressure and to protect the membrane. Some extra backfilling may be required in the low-lying areas to eliminate ponding.

Channel dredging and lining, and an impermeable sediment cap, when properly designed, installed, and maintained, is expected to eliminate erosion at the Otsego City Dam.

The installation of an impermeable cap, rather than a soil cap, will provide the additional benefit of eliminating rainwater and surface water infiltration through the contaminated sediments. An impermeable cap is expected to eliminate nearly 100 percent of the infiltration, whereas a soil cap is expected to eliminate only 30 to 50 percent. However, since the channel lining will permit infiltration and exfiltration, dissolved PCBs may still be carried to the river due to groundwater movement through contaminated sediments.

Feasibility

The feasibility of dredging and channel lining is as discussed in the previous alternative.

In order to estimate the feasibility of installing an impermeable cap, a site investigation and conceptual design would be required. The use of compacted clay in the cap may be difficult because of the swampy conditions and the low bearing capacity of the soil in this area. A synthetic liner is recommended, with an underlying sand drainage layer to protect the liner and to provide a flow zone for the release of excess water pressure. Dewatering may be required in order to facilitate placing of the cap. Also, large quantities of backfill may be required to reduce the swampy condition.

Time and Cost

This project would be quite extensive and would take several years to complete.

This alternative would be slightly more expensive than the previous alternative because of the addition of the synthetic liner.

6.4.14 Alternative Summary

Table 24 presents a summary of the remedial alternatives, the approximate time required for implementation of the alternative, and the estimated cost of implementing the alternative. Cost breakdowns for each alternative are presented in Appendix E.

6.5 ASSESSMENT OF ALTERNATIVES

The effectiveness of each of the remedial action alternatives presented in Section 6.4 was evaluated through the use of a mathematical model. In this section, the results of that evaluation are presented, and the methodology [illegible] ...ive those results is discussed. In addition, the environmental effects of each alternative are discussed. For a discussion of the model theory and development, refer to Section 6.3.

TABLE 24

COST SUMMARY FOR ALTERNATIVES

	Alternative	Approximate Implementation Time	Estimated Capital Cost
A)	No Action for Entire River	---	---
B)	Portage Creek/Bryant Mill Ponds	---	---
	DRAWN DOWN DAMS		
C)	Channel Lining and soil Cap	3 yr	$ 59,603,000
	(no channel lining option)	(2 yr)	47,032,000
C1)	Dredged Area	1 yr	2.751,000
D)	Channel Lining and Impermeable Cap	3 yr	120,630,000
	(no channel lining option)	(2 yr)	108,146,000
E)	Excavation and Onsite Disposal	4 yr	108,116,000
	IMPOUNDED DAMS		
F)	Dredging and/or Excavation, and Upland Disposal	5 yr	110,045,000
G)	Channel Dredging, Channel Lining and Soil Cap (Otsego City Dam)	3 yr	23,945,000
H)	Channel Dredging, Channel Lining and Impermeable Cap (Otsego City Dam)	3 yr	51,387,000

The following remedial alternatives were selected for model evaluations:

A. No action for the entire river

B. Portage Creek/Bryant Mill Ponds: Assume remedial actions will eliminate Portage Creek as a source of PCBs.

Drawn Down Dams (Plainwell, Otsego, Trowbridge)
C. Channel lining and soil cap
C1. Buffer zone "Dredged Area"
D. Channel lining and impermeable cap
E. Excavation and disposal

Impounded Dams (Otsego City, Allegan City, Lake Allegan)
F. Dredging and/or Excavation
G. Channel dredging, channel lining, and soil cap (Otsego City Dam)
H. Channel dredging, channel lining, and impermeable cap (Otsego City Dam)

6.5.1 Summary of Remedial Alternatives

A. No Action for the Entire River

Under this alternative, the current sources of PCBs in the river will remain unchanged, and contaminants emanating from these areas will continue to affect the environmental quality of the river. The current conditions will continue to gradually change until the steady-state condition described by the model is reached.

B. Portage Creek

Under this alternative, Portage Creek will be eliminated as a source of PCBs.

C. Channel Lining and Soil Cap (Drawn Down Dams)

Under this alternative, the contaminated sediment will remain in place. A riprap or fabriform lining will be installed in the channel to minimize erosion, and a soil cap will be placed on the exposed sediments above the creek banks to minimize erosion. If properly implemented, these actions are expected to eliminate erosion and the subsequent release of PCBs to the environment via this route. However, since the channel lining will permit infiltration and exfiltration, dissolved PCBs will still be carried into the water column from rain infiltrating the soil cap and from groundwater movement through the contaminated sediments.

These actions would be implemented at the three drawn down dams. If properly implemented, these actions are expected to eliminate erosion and the subsequent release of PCBs to the environment.

However, dissolved PCBs will still be carried into the river from rainwater infiltrating through the sediments. In these three areas, the sediments are above the water table and thus are not affected by groundwater.

C1. Dredged Area (Drawn Down Dams)

Under this alternative, a layer of sediment approximately 3 feet deep and 25 feet wide would be removed along both banks. A soil cap would then be installed in place of the removed sediment. This measure would provide a buffer zone between the river and the contaminated sediments. The "reduced" soil cap is assumed to provide the same environmental protection as the full soil cap (Alternative C).

D. Channel Lining and Impermeable Cap (Drawn Down Dams)

This alternative is very similar to the previous one in that sediment capping and flexible linings will be used to minimize erosion in the channel and on the banks of the creek. However, instead of installing a soil cap on the creek banks, an impermeable cap would be installed. If properly implemented, these actions would be expected to eliminate erosion and the subsequent release of PCBs to the environment. However, groundwater movement through the contaminated sediments will continue to carry dissolved PCBs into the water column.

These actions would be implemented at the three drawn down dams. If properly implemented, these actions are expected to eliminate erosion at the three drawn down dams. An impermeable cap, as opposed to a soils cap, will provide the added benefit of eliminating rainwater infiltration and subsequent leaching of PCBs. Since the contaminated sediments lie above the water table in these three areas and are not affected by groundwater, the impermeable cap should effectively contain the contaminated sediments in these areas. Thus, these actions should entirely eliminate these areas as sources of PCBs.

E. Excavation and Disposal (Drawn Down Dams)

Under this alternative, the dewatered, contaminated sediments on the river banks would be excavated and properly disposed. Therefore, these areas would be eliminated as a source of PCBs.

F. Dredging and/or Excavation and Upland Disposal (Impounded Dams)

Under this alternative, the impounded areas behind the three existing dams would be either dredged or excavated to remove all of the contaminated sediment, with subsequent disposal. Although these three areas are depositional areas and are not considered to be significant PCB sources for downstream areas, they are considered contaminated and are affecting the local fish populations.

G. Channel Dredging, Channel Lining, and Soil Cap (Otsego City Dam)

Under this alternative, the entire length of the existing channel would be dredged to remove contaminated sediments and to prepare the channel for a riprap or fabriform lining. Dredge spoil would be contained behind dikes adjacent to the channel and allowed to dewater. A soil cap would then be placed over the entire sediment area to contain the contaminated sediment. These actions, when properly implemented, are expected to eliminate sediment erosion and subsequent release of PCBs to the river at the Otsego City Dam area. However, since the channel lining will permit infiltration and exfiltration, dissolved PCBs will still be carried to the river from rainwater infiltration and groundwater movement through the contaminated sediment.

H. Channel Dredging, Channel Lining, and Impermeable Cap (Otsego City Dam)

This alterative is very similar to the previous one; however, instead of placing a soil cap over the contaminated sediment, an impermeable cap would be installed. These actions are expected to eliminate erosion in this area. An impermeable cap, as opposed to a soil cap, will provide the added benefit of eliminating rainwater infiltration through the cap, and the subsequent leaching of PCBs. However, lateral groundwater movement through the contaminated sediments will continue to carry dissolved PCBs into the water column. The added benefit of the impermeable cap will depend on the percentage of contaminated sediment below the water table. If a large percentage of contaminated sediment is in the groundwater, then the impermeable cap will provide little added benefit.

6.5.2 Model Methodology

The successful application of a mathematical model to evaluate the effects of various remedial actions on PCB levels in the Kalamazoo River system depends on the degree to which the numerical formulation and model parameters reflect the anticipated river conditions after implementation of the alternative actions. For each remedial alternative, the appropriate model parameters that would be affected by the implementation of the alternative were identified. Appropriate values were then assumed for the identified model parameters based on the available site data, the technical literature, and professional judgment.

The model parameters coefficients that may be affected by the possible remedial actions are identified below:

a. Average width of the reach
b. Average depth of the reach
c. Wetted perimeter of the representative cross-section active cross-section area
d. Bed slope of the reach
e. PCB concentration in the sediment layer

f. PCB concentration at the most upstream location
g. Suspended solids concentration at the most upstream location
h. Discharge rate of each point PCB loading
i. Dissolved PCB concentration of the point loadings
j. Point sediment loading
k. PCB concentration of the point sediment loading
l. Benthic diffusion velocity
m. Sediment burial velocity
n. PCB benthic release rate
o. Sediment suspension velocity
p. Average settling velocity of the suspended solids
q. Volume fraction of sediment in the active layer

Parameters (a) through (d) would be varied if the remedial action involved a modification of the flow and channel geometry. Parameters (e) through (k) would be adjusted according to the estimated PCB inflows or concentrations after imposing the remedial alternative. Parameter (e) would be influenced by the completeness of dredging and excavation activities. Parameters (f) through (k) would be influenced by the effectiveness of source control activities such as total excavation, lining of the channel, or capping of the sediments. For example, installation of a soil cap was assumed to reduce the PCB concentration in the headwater and the point loading by 75 percent, whereas, installation of an impermeable cap was assumed to reduce these values by 95 percent.

Parameters (l) through (q) are dependent upon the modified flow regime, channel conditions, and the associated ecosystem in the river. Based on a review of the river conditions resulting from possible remedial actions and the subsequent response of the river system, it was concluded that the values of parameters (l) through (q) would remain essentially unchanged. Any small changes in magnitude of these parameters would be difficult to estimate without further studies that are beyond the scope of this work. Therefore, for purposes of this study, the assumption was made that the processes affecting PCB distribution in the river will be the same after the remedial action is implemented. Parameter (n), the benthic release rate, was assumed to be zero if the channel was completed dredged or excavated. In other words, the corresponding PCB source in the sediment layer was assumed to be zero under these conditions; otherwise, it was left unchanged.

Remedial Alternative D will be used as an example to demonstrate how the model parameters were adjusted to simulate the effects of the remedial alternatives. Under this alternative, the Kalamazoo River in the area of the drawn down dams is to be regraded, the channel lined, and the channel banks covered with an impermeable cap. In order to simulate the effects of this remedial alternative, the values of parameters (a) through (q) were examined and adjusted based on the aforementioned principles. Parameter values (a) through (d) were unchanged because the new channel geometry and river discharge were assumed to be identical with the existing conditions. PCB concentrations in the sediment layer (e) and the active cross-section area of the sediment layer, as well as PCB benthic release rate (n), were assumed to be zero because of the dredging and lining of the channel. The installation of the impermeable cap was assumed not to alter the magnitude of discharge. That is, the net discharge due to the inflow, overland flow, and subsurface flow was assumed to remain the same as the baseline condition. Moreover, the installation of the impermeable cap was assumed to reduce the PCB concentrations in the headwater and the point loadings by 95 percent. The residual 5 percent represents the condition in which the impermeable cap would not completely cut off the PCB contribution from both the upstream inflow and the subsurface flow from the surrounding area that is not capped. The rest of the model inputs remained identical to the baseline condition for this alternative.

The methodology used in Alternative D was similarly applied to adjust the appropriate model inputs for the other remedial alternatives. Modified values of the input parameters used to reflect the effect of each remedial alternative are listed in Table 25.

6.5.3 Model Results

For each alternative, the steady-state PCB concentrations in the water column for each reach were predicted by the model. The resulting PCB concentrations in the fish flesh for carp and bass in each reach were obtained by the equation: fish PCB concentration (ppm) = 0.0277 (water concentration (ng/l)) times 2.01 (carp) or 0.83 (bass). The use of the model to predict long-term changes in the PCB levels in fish provided a convenient measure of the relative effectiveness of alternative actions and general progress toward the minimum goal of lowering PCB levels in fish to less than 2 ppm. However, data base limitations and model simplification must be considered when using the model results in a quantitative fashion.

The numerical results of the model simulation of Alternatives A through H are presented in Table 26.

The model results are graphically presented in Figures 16, 17 and 18. In these figures, PCB concentrations in carp and bass are plotted by reach for each alternative. The predicted steady-state concentrations of PCBs in carp and bass under the no-action alternative are shown as Alternative A. The relative success of each remedial action alternative in reducing PCB concentrations in fish can be evaluated by comparing the plots for each alternative to those given for Alternative A. Also indicated is the minimum remedial action goal of 2 ppm. These figures show that no alternatives implemented alone will achieve the minimum goal of lowering the PCB concentrations in fish to less than 2 ppm in all reaches. However, alternative B, involving remedial actions in Portage Creek, will achieve the goal in all reaches except Reach 8 (Allegan City Impoundment).

6.5.4 Discussion of Results

No Action

Model results indicate that, even under the no-action alternative, PCB concentrations in Kalamazoo River fish will be reduced over the long term. The reduction in PCBs will occur through two principal mechanisms: sediment burial and sediment flushing. Sediment burial will occur in the

TABLE 25

MODEL INPUTS FOR THE REMEDIAL ALTERNATIVES

Alternative	Input Values
A	Same as baseline inputs
B	CS (1) = 0 RB (1) = 0 SI = 15 mg/l CI = 0 CP = 0
C	ASD (3) = 0 ASD (5) = 0 ASD (6) = 0 RB (3) = 0 RB (5) = 0 RB (6) = 0 CS (3) = 0 CS (5) = 0 CS (6) = 0 CS (6) = 0 QSDP (3,5,6) = 25% of the baseline value
D	ASD (3) = 0 ASD (5) = 0 ASD (6) = 0 RB (3) = 0 RB (5) = 0 RB (6) = 0 CS (3) = 0 CS (5) = 0 CS (6) = 0 QSDP (3,5,6) = 5% of the baseline value
E	RB (3) = 0 RB (5) = 0 RB (6) = 0 CS (3) = 0 CS (5) = 0 CS (6) = 0 QSDP (3,5,6) = 0
F	RB (4) = 0 RB (8) = 0 RB (9) = 0 CS (4) = 0 CS (8) = 0

TABLE 25 (con't)

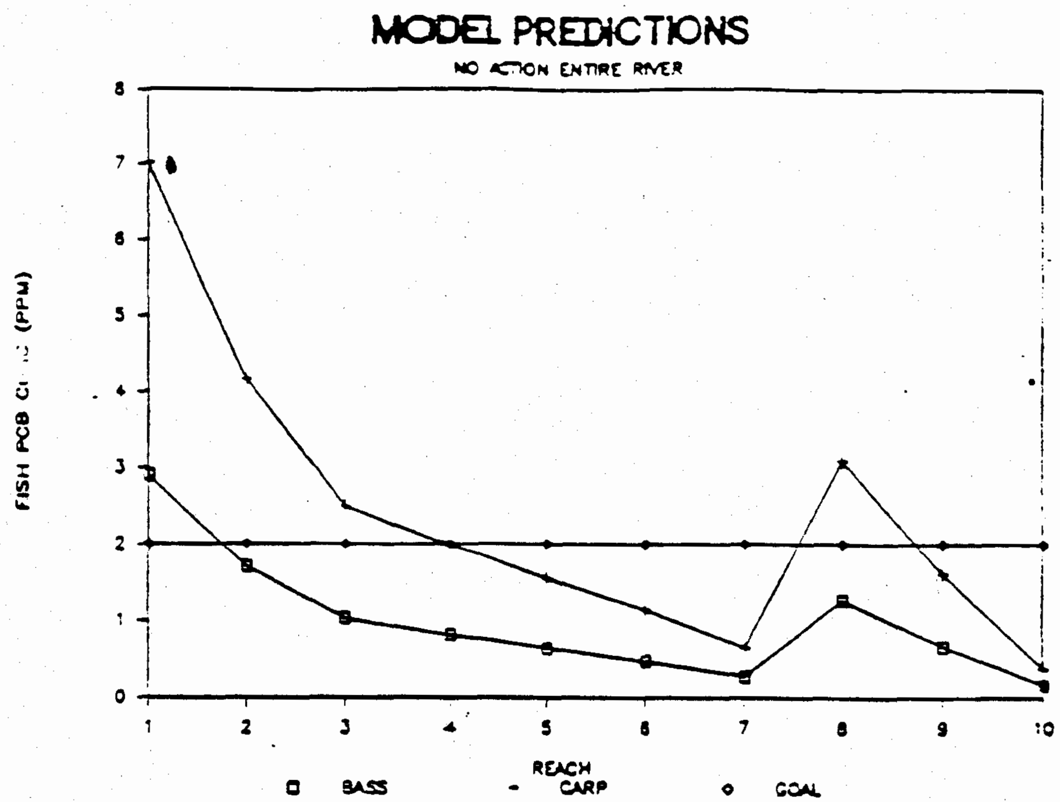
Alternative	Input Values
	CS (9) = 0 QSDP (4,8,9) = 0
G	ASD (4) = 0 RB (4) = 0 CS (4) = 0 QSDP (4) = 25% of the baseline value
H	ASD (4) = 0 RB (4) = 0 CS (4) = 0 QSDP (4) = 5% of the baseline value

TABLE 26. MODEL PREDICTIONS FOR WATER, CARP AND BASS

REACH	PRESENT 1985-87	ALTERNATIVE A	B	C	D	E	F	G	H
		WATER CONCENTRATION (NG/L)							
1	134	126.00	0.01	126.00	126.00	126.00	126.00	126.00	126.00
2	78	74.50	0.20	74.50	74.50	74.50	74.50	74.50	74.50
3	62	45.00	1.75	44.20	43.90	43.80	45.00	45.00	45.00
4	60	35.60	27.30	33.90	33.40	33.30	35.30	35.30	35.30
5	76	28.00	27.50	23.60	23.20	23.10	25.50	25.60	25.50
6	86	20.60	28.90	17.00	16.40	16.50	20.20	20.30	20.30
7	100	11.70	18.90	10.40	9.95	9.95	11.40	11.50	11.50
8	113	55.40	50.00	72.50	72.30	70.70	6.35	55.30	55.20
9	116	29.00	27.90	30.10	30.00	30.00	1.75	29.00	29.00
10	63	6.89	6.80	6.47	6.47	6.49	0.47	6.88	6.88
		CARP CONCENTRATION (PPM)							
1	7.46	7.02	0.00	7.02	7.02	7.02	7.02	7.02	7.02
2	4.33	4.15	0.01	4.15	4.15	4.15	4.15	4.15	4.15
3	3.46	2.51	0.10	2.46	2.44	2.44	2.51	2.51	2.51
4	3.34	1.98	1.52	1.89	1.84	1.85	1.97	1.97	1.97
5	4.22	1.56	1.53	1.31	1.29	1.29	1.42	1.43	1.42
6	4.80	1.15	1.61	0.95	0.91	0.92	1.12	1.13	1.13
7	5.57	0.65	1.05	0.58	0.54	0.55	0.63	0.64	0.64
8	6.29	3.08	2.78	4.04	[illegible]	3.94	0.35	3.08	3.07
9	6.46	1.61	1.55	1.68	1.58	1.67	0.10	1.61	1.61
10	3.51	0.38	0.38	0.36	0.34	0.36	0.03	0.38	0.38
		BASS CONCENTRATION (PPM)							
1	3.08	2.90	0.00	2.90	2.90	2.90	2.90	2.90	2.90
2	1.79	1.71	0.00	1.71	1.71	1.71	1.71	1.71	1.71
3	1.43	1.03	0.04	1.02	[illegible]	1.01	1.03	1.03	1.03
4	1.38	0.82	0.63	0.78	0.77	0.77	0.81	0.81	0.81
5	1.74	0.64	0.63	0.54	0.53	0.53	0.59	0.59	0.59
6	1.98	0.47	0.66	0.39	0.38	0.38	0.46	0.47	0.47
7	2.30	0.27	0.43	0.24	0.23	0.23	0.26	0.26	0.26
8	2.60	1.27	1.15	1.67	1.64	1.63	0.15	1.27	1.27
9	2.67	0.67	0.64	0.69	0.69	0.69	0.04	0.67	0.67
10	1.45	0.16	0.16	0.15	0.15	0.15	0.01	0.16	0.16

Figure 5

PORTAGE CREEK REMEDIAL ALTERNATIVES



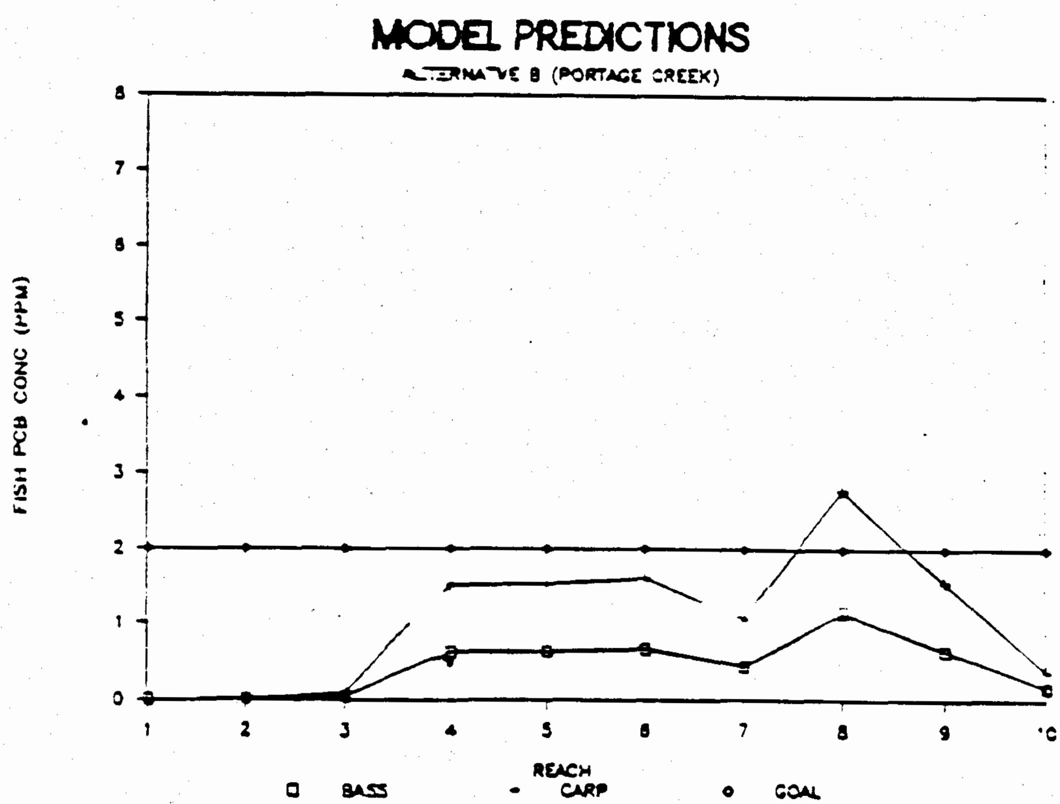
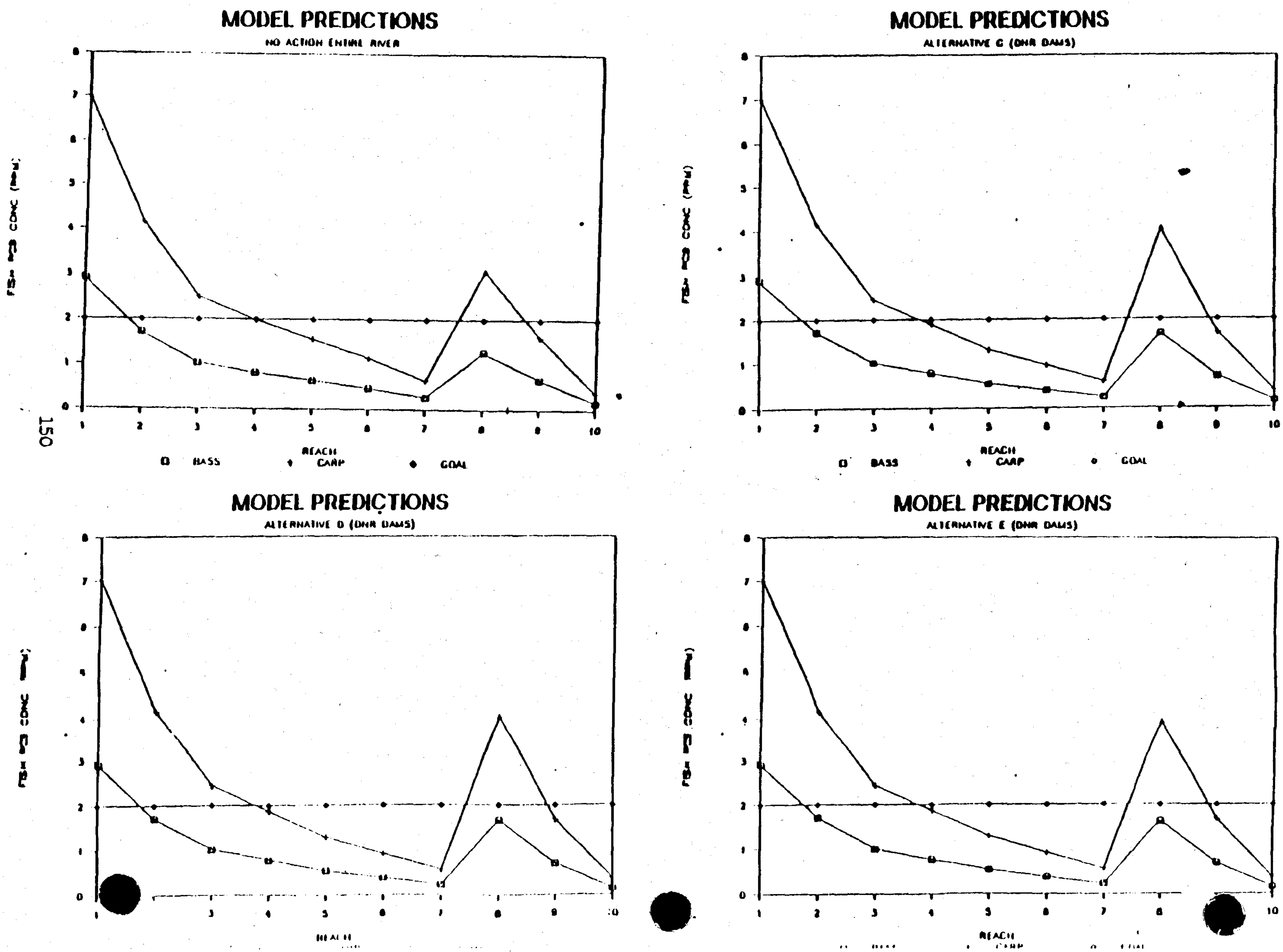


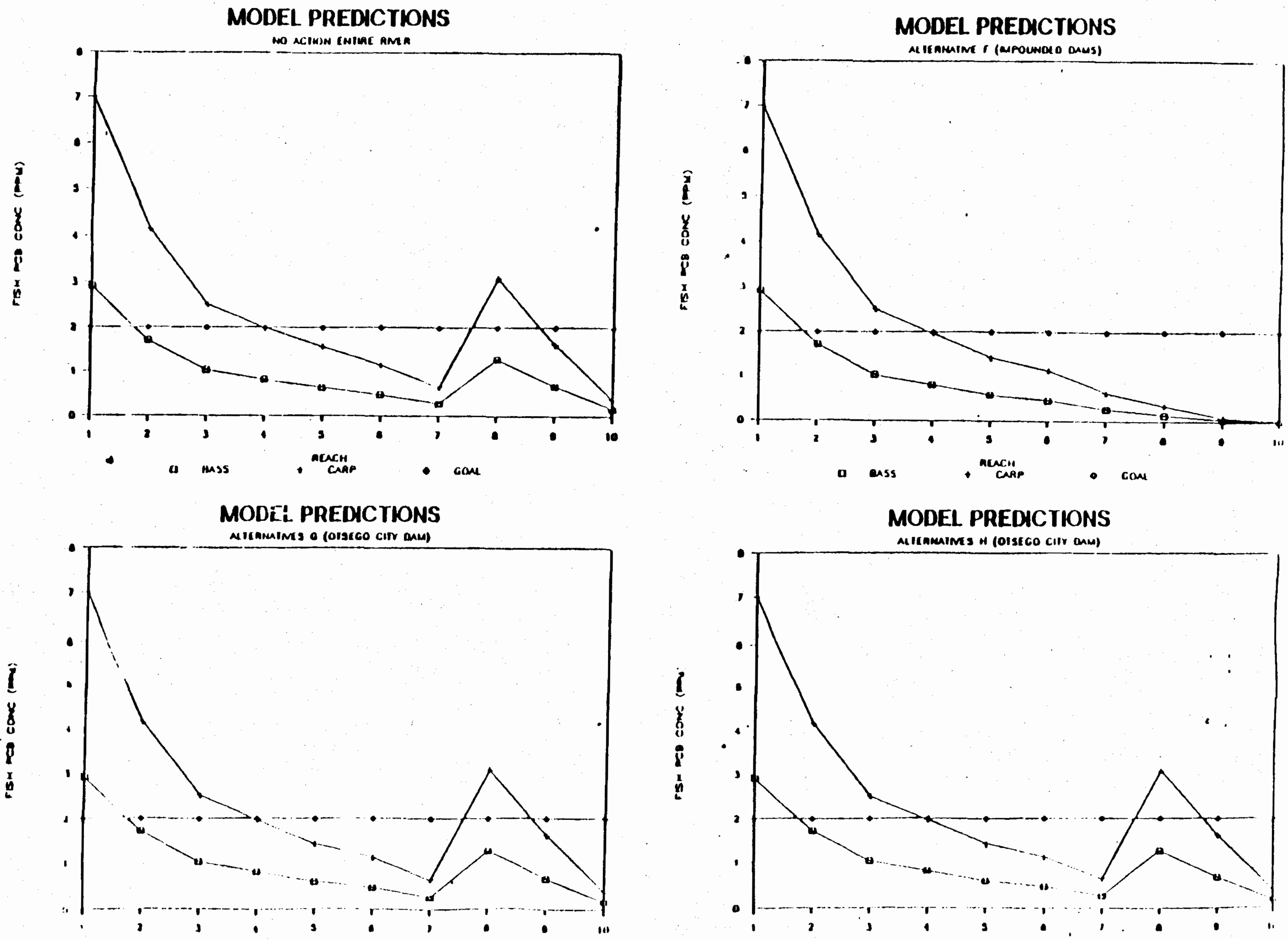
Figure 17

DRAWDOWN DAMS REMEDIAL ALTERNATIVES



ure 18

IMPOUNDED DAMS REMEDIAL ALTERNATIVES



impounded areas (the depositional areas). Through this process, contaminated sediment is isolated from the aquatic ecosystem by burial beneath clean sediments. A noteworthy shortcoming of this process is the potential reexposure of contaminated sediments if an extreme hydrologic event (e.g., a flood) erodes the overlying materials. Sediment flushing will occur in the erosional areas. This process removes PCBs from the in-stream sediments through resuspension, diffusion, and turbulence.

Currently, PCBs are being flushed from the Kalamazoo River into Lake Michigan at the rate of about 217 pounds per year. At this rate, it will take about 1000 years to flush the PCBs completely from the Kalamazoo River system. The State of Michigan views this long time frame, the continued PCB load to Lake Michigan and the continued fish PCB contamination as unacceptable. Therefore, the No Action alternative is not an acceptable solution to reduce human exposure to PCBs.

Portage Creek/Bryant Mill Ponds

A comparison of the results from all alternatives suggests that remedial actions applied at Portage Creek will have the most significant effect in reducing PCB concentrations in fish (Figure 16, Table 26). Portage Creek remedial actions are particularly effective in Reaches 1 through 7. The model results for Alternative B indicate in a general sense that the remediation of the Portage Creek/Bryant Mill Ponds area will achieve the minimum goal of lowering the PCB concentrations found in carp and bass to below 2 ppm in all reaches except Reach 8 (Allegan City impoundment).

Drawn Down Dams (Plainwell, Otsego, Trowbridge)

Alternatives C, D, and E involve remedial actions on Reaches 3, 5, and 6 and therefore have no effect on the first two reaches of the river. Therefore, the minimum goal of lowering the PCB levels in fish to less than 2 ppm will not likely be achieved in these upstream reaches. The results show that the middle reaches will be improved somewhat by these alternatives. In Reaches 8 and 9, these alternatives actually result in a slight increase in the PCB concentrations in the fish. The reason for this increase is that remedial actions taken at these dams result in lower concentrations of suspended solids. This, in turn, lowers the probability for dissolved PCBs from upstream reaches to attach to solid particles and settle out. Rather, the dissolved PCBs pass through to downstream Reaches 8 and 9 (Allegan City Dam and Lake Allegan).

Impounded Dams (Otsego City, Allegan City, Lake Allegan)

Alternative F (dredging the three impounded dams) has no effect on the PCB levels in fish in the upstream reaches (Reaches 1 through 3) and little effect in Reaches 4 through 7. However, a substantial reduction in PCB levels is observed in Reaches 8 through 10. Alternative F is the only alternative that has such an effect on the downstream reaches. This indicates that dredging Allegan City Dam (Reach 8) and possibly dredging Lake Allegan (Reach 9) would have substantial beneficial effects in the last three reaches.

The model results also indicate that Alternatives G and H (Otsego City Dam remedial actions) have virtually no effect on PCB levels in fish. The only significant decrease in PCB concentrations occurs in Reach 5 (Otsego City Dam to Otsego Dam).

6.5.5 Summary of Results

In summary, model results indicate that, even under the no-action alternative, PCB concentrations in the Kalamazoo River fish will be reduced over the long term; however, the continued PCB load to Lake Michigan and continued fish contamination make this alternative unacceptable.

A comparison of model results from Figure 16 indicates that remedial actions applied at Portage Creek will have the most significant overall effect in reducing PCB concentrations in fish, particularly in the upper reaches of the study area. Results indicate that remedial action in Portage Creek will have the most effect in reducing PCB concentrations in fish.

The model results for remedial actions involving the three drawn down dams (Alternatives C, D, and E) indicate that these alternatives have a beneficial effect on some of the other reaches.

Alternative F (dredging the three impounded areas) is the only alternative that has a substantial impact in the downstream reaches (Reaches 8 to 10). However, the model results indicate that remedial actions at Otsego City Dam (Alternatives G and H) have almost no effect in any of the reaches. Therefore, dredging Allegan City Dam (Reach 8) and possibly dredging Lake Allegan (Reach 9) would have to be considered if short-term improvements in Reaches 8-10 are of high priority in the decision process.

6.5.6 Recommendations

Based on results of the model and preliminary cost estimates for the alternatives, the following recommendations can be made:

- Some remedial action should be taken at Portage Creek/Bryant Mill Ponds. Such an action would have the greatest effect in reducing human exposure to PCBs, and would concomitantly decrease PCB levels in fish throughout downstream reaches.

- Better management of the Allegan City Dam impoundment is recommended. The practice of drawing the dam down should be discontinued since an uncontrolled release of PCBs to Lake Allegan and downstream reaches results.

- The removal of the remnant dam structures and isolating the contaminated sediments at the Plainwell, Otsego, and Trowbridge Dams is also recommended. If properly implemented, this action would result in lowering of the river channel, which would have beneficial environmental effects since the exposed contaminated sediments along the river banks would be further isolated from the river.

All other actions on the Kalamazoo River were considered less cost-effective due to the high costs of implementation and/or conditional due to uncertainties in the predictions. The following comments address these actions and uncertainties.

- Dredging may be a preferred option at Allegan City Dam and possible at Lake Allegan. However, since this type of remedial action is very costly, further studies are recommended to evaluate this option. If dredging is implemented at Allegan City Dam only, a reduction of the carp population in Lake Allegan is recommended to reduce sediment disturbance so that natural sediment burial processes can eventually cover and isolate the contaminated sediments of Lake Allegan.

Future studies on the Kalamazoo River should concentrate on the following:

- More comprehensive quantification of PCB levels in fish.
- Expanding the data base on PCB levels in the sediments within the Otsego City and Allegan City impoundments.
- Additional analyses of suspended solids concentration and corresponding PCB concentrations in the water column in order to quantify resuspension and to refine the value of the partition coefficient. Sampling under high flow conditions when the exposed sediments are temporarily inundated would be particularly valuable.
- Similar analyses of PCBs in sediments and the overlying water to better estimate the respective partition coefficient, with special emphasis on the clayey fiber material. Supporting laboratory studies would also be recommended.
- Additional efforts toward quantifying existing point sources of PCBs, including field sampling of shoreline sludge disposal ponds and treatment plant outfalls.
- Refined estimates of sediment burial rates within the Allegan City, Allegan, and Otsego City Dam impoundments using core profiles, including a related analysis of the depth of the active sediment layer.
- Additional sediment grain size analyses, with an attempt to isolate and quantify the amount of clayey fiber material present.
- Studies directed toward a quantification of sediment resuspension in Lake Allegan caused by biodisturbance (i.e., by carp stirring up the sediments).

7.0 REMEDIAL ACTIONS

7.1 COMPLETED ACTIONS

Since PCBs were identified as a problem in Michigan in 1971, several actions have been taken to improve conditions. The direct discharge of PCBs has been substantially reduced due to the PCB ban, originally under Michigan law and now nationwide under the Toxic Substances Control Act.

The direct discharge of PCBs is not authorized in any of the NPDES permits for the Kalamazoo River. A specific requirement to reduce the discharge of PCB is in the City of Kalamazoo's and Otsego's wastewater discharge NPDES permit.

In recognition of the uncontrolled release of PCBs upon drawdown, the MDNR since 1986 has refused to issue the necessary permit for the drawdown of the Allegan City Dam.

The MDNR has removed the superstructures of the Plainwell, Otsego and Trowbridge Dams. These dams were not active (i.e. there was no impounded water present). The removal process involved removing the structure above the impoundment sediments. This is the first step toward total removal of these dams and contaminated sediments, as recommended. Approximately $440,000 was allocated for this action, which was completed in 1987.

7.2 ACTIONS IN PROGRESS

The MDNR has listed the Kalamazoo River under State Act 307, the Michigan Environmental Response Act. Under this act, $1,562,000 was approved in 1987 for remedial action in Portage Creek/Kalamazoo River. These funds have been designated for use to isolate the contaminated sediments in the Trowbridge impoundment. The remedial action will consist of creating a "dredged area" of 25 feet between the river bank and the PCB contaminated sediments. The top of 2-3 feet of sediment will be removed (total about 100,000 cubic yards) and placed in an on-site dredged spoils sediment disposal facility. The area removed will be such that a 25 feet "dredged area" will exist between PCB contaminated sediments and the river bank edge after complete dam removal. A soil cap will be placed over a portion of the 25 feet buffer area and revegetated. The projected schedule calls for initiation of this project in early 1988 with completion in mid-1989.

The dredge spoils disposal facility will be located on DNR owned land. The disposal facility will be a diked area filled with dredged sediment, capped with a soil cap and seeded. A maintenance program will be designed to assure that river meanders do not elliminate the dredge area and that the disposal facility is entact.

As a final phase to the cleanup projects at the DNR owned dams, prior to complete dam removal, clean sediments will be dredged from the Kalamazoo River to control downstream sedimentation. An evaluation will be made of the feasibility of using these clean sediments as a soil cap to cover PCB contaminated sediments remaining in the impoundment beyond the 25 feet dredged area.

An additional $1.3 million in State Act 307 funds has been allocated in fiscal year 1988 to conduct the necessary engineering studies and remedial actions to control the PCB contamination behind the Plainwell and Otsego Dams. The remedial actions will be the same as that described for the Trowbridge impoundment. The projected timetable for these projects calls for initiation of the projects in 1988 with completion in 1989.

The State has identified Allied Paper Incorporated as a potentially responsible party for the PCB contamination of Portage Creek/Bryant Mill Pond. The State gave notice on August 29, 1986, of its intent to file a civil action against SCM Corporation (owner of Allied Paper), Allied Paper Incorporated, and other property owners along Bryant Mill Pond (Portage Creek). A complaint has been filed by the State of Michigan in United States District Court pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the Resource Conservation and Recovery Act, the Federal Water Pollution Control Act, and the Toxic Substance Control Act. The State seeks injunctive relief to abate and remedy the release of hazardous substances into the environment, declaratory relief, damages, civil penalties, cost of litigation, reimbursement of state response costs and all other appropriate relief.

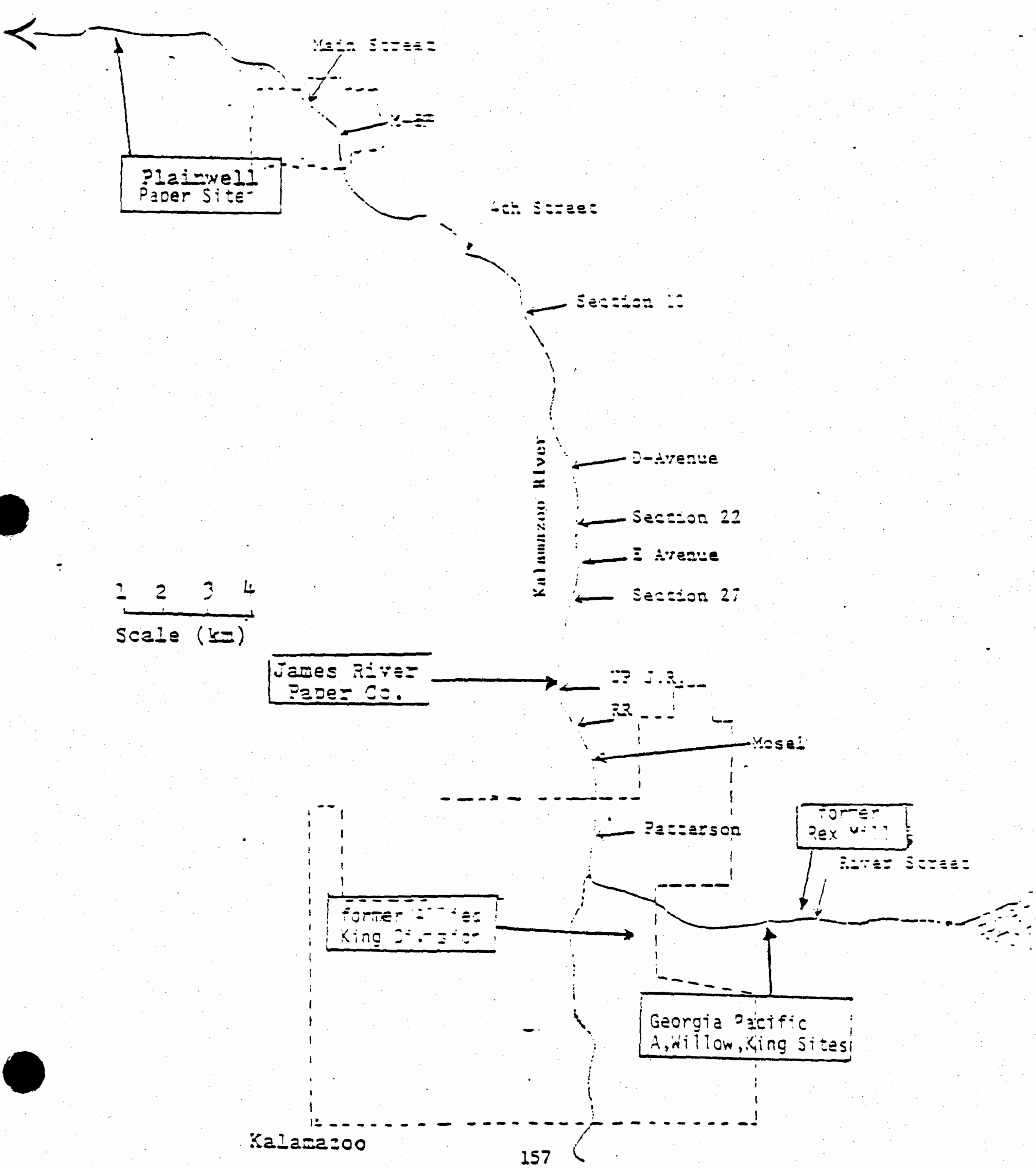
The Allied Paper/Portage Creek/Kalamazoo River site has been proposed for listing on the National Priority List under CERCLA (Superfund). Listing is expected by early 1988.

7.3 STUDIES

The MDNR has undertaken addition sampling in May/June 1987 to identify sludge disposal areas which may contain PCBs. Seven sites were identified in the Kalamazoo/Plainwell area for sampling. These sites were selected because a deinking process was used during paper making operations in the 1950-70 period and or due to close proximity to the Kalamazoo River. The seven sites selected were A Site (Georgia Pacific), Willow Site (Georgia Pacific), King Highway (Georgia Pacific), former Rex Mill sludge disposal area, former Allied King Mill treatment lagoons, Plainwell Paper sludge disposal area, and James River sludge disposal area. These sites are shown in Figure 19.

Results (Appendix G) indicate substantial PCB contamination in the Willow Site (Georgia Pacific). This nine acre site is located in Kalamazoo. The site was used for disposal of dewatered clarifier sludges generated by Georgia Pacific's Kalamazoo Paper Division. The site is contiguous with the Kalamazoo River and, judging from historical maps and photographs, was once a part of the river. A detailed sampling program has been conducted by Georgia Pacific Corporation to assess the horizontal and vertical extent of PCB contamination. Sediment PCB concentrations are about 100 mg/kg. Long term remedial actions are being reviewed with implementation scheduled for 1988.

Figure 19 Sludge Disposal Area Sampling, 1987.



The A Site (Georgia Pacific) and King Highway Site (Georgia Pacific) generally contained little if any PCBs. An exception was the dike walls and sediment outside the dike walls of the King Highway Site near King Street Storm sewer outlet. These areas are scheduled for further investigation.

Soil sampling results indicated PCB contamination at the Plainwell Paper and James River (Parchment) sludge disposal areas. Follow-up sampling is underway to determine the extent and magnitude of contamination and necessary remedial actions at these facilities.

Soil sampling results also indicated the presence of PCBs at the former Allied Paper King Mill site. The PCB levels found were relatively low. An evaluation is underway to determine if this site is connected to the Kalamazoo River.

Essentially no PCBs were found in the sampling at the former Rex Mill site.

Followup collections and analyses of fish is underway. In March, 1987, one hundred and seven (107) gamefish were collected from the Area of Concern for PCB analyses. The gamefish collected, with the number to be analyzed in parentheses, were northern pike (10), largemouth bass (10), channel catfish (10), flathead catfish (3), white suckers (10), black crappie (10), rockbass (10), walleye (10), steelhead (10), sheepshead (2), yellow perch (10), bluegill (10) and brown trout (4). In addition to these fish, carp were collected for PCB analyses in July, 1987 at six locations (Saugatuck, Lake Allegan, Plainwell, Bryant Mill Pond, Morrow Pond, Ceresco Impoundment). Bass were collected at three locations (Lake Allegan, Morrow Pond, Ceresco Impoundment). Ten fish of each species will analyzed for each location. The results of these analyses are expected in early 1988.

Water sampling and analysis is continuing on a monthly basis. The objectives of the water sampling are to document conditions in and around Portage Creek, identify a possible source of PCBs between Kalamazoo and Plainwell, and sample under high water conditions.

Additional sediment PCB sampling and analyses is planned for 1987-88. This sampling will be to expand the available data base for the Otsego City and Allegan City impoundments.

Studies in Lake Allegan, Allegan City and Otsego City Dam impoundments are also planned in 1987-88 to refine the estimates of sediment burial rates and to evaluate the partition coefficients between sediment, water and suspended solids with special emphasis on the clayey fiber materials.

In addition to these studies on the Kalamazoo River from the city of Kalamazoo downstream to Lake Michigan, an additional study of possible PCB contamination has been initiated for the Kalamazoo River between Battle Creek and Kalamazoo. The fish PCB levels upstream of Kalamazoo indicate some PCB contamination in carp. The 1987 fish consumption advisory was revised to reflect this. The additional study will determine the level and any sources of PCB contamination and remedial options available.

8.0 PUBLIC PARTICIPATION

8.1 PUBLIC MEETINGS

Several public meetings have been held regarding the issues surrounding the Kalamazoo River PCB problem. Public meetings were held prior to and upon completion of the Remedial Investigation/Feasibility Study. Two meetings were held in January, 1985 to initiate the study. One meeting was held in Allegan (January 8, 1985), the other in Kalamazoo (January 10, 1985). Upon completion of the study, public meetings were held in Plainwell and Allegon in April, [illegible] to present the results and open the public comment period.

A public meeting was held in May, [illegible] regarding the MDNR proposal to remove the Plainwell, Otsego and Trowbridge Dams to their respective sills. The meeting was specifically related to the Act 346 Dredge and Fill permits issued to this project.

To initiate this Remedial Action Plan, a public meeting was held in Kalamazoo in December, 1986. A summary of this meeting is provided in Appendix H.

8.2 BASIN STRATEGY COMMITTEE

A Kalamazoo River Basin Strategy Committee has been formed to develop mechanisms to implement the Kalamazoo River Remedial Action Plan, coordinate the Remedial Action Plan, Fisheries Management Plan and access development along the Kalamazoo River and provide local input into these plans. This committee was funded with a $[illegible] grant from the State of Michigan to the City of Kalamazoo. The committee members include the U.S. Environmental Protection Agency, MDNR, local units of government, environmental groups, industrial and labor representatives and interested citizens. The first committee meeting was held in July, 1987 with the second meeting in November, 1987. Two additional committee meetings will be devoted to reviewing the draft Remedial Action Plan.

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APPENDIX A

NATURAL RIVER PLAN

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A. Goal

To preserve, protect and enhance the Kalamazoo River environment in a natural state for the use and enjoyment of present and future generations.

B. Objectives

1. Maintain and enhance the water quality of the Kalamazoo River and its tributaries consistent with the wild-scenic classification of the river and adhere to the concept of nondegradation of water quality.

2. Maintain the existing free-flowing conditions and seek to stabilize or improve the water flow characteristics for the purpose of preserving the natural environment.

3. To prohibit or limit those developments and activities which may damage or destroy the Kalamazoo River's fish, wildlife, boating, scenic, aesthetic, flood plain, ecologic, historic-archaeological, and recreational values and uses.

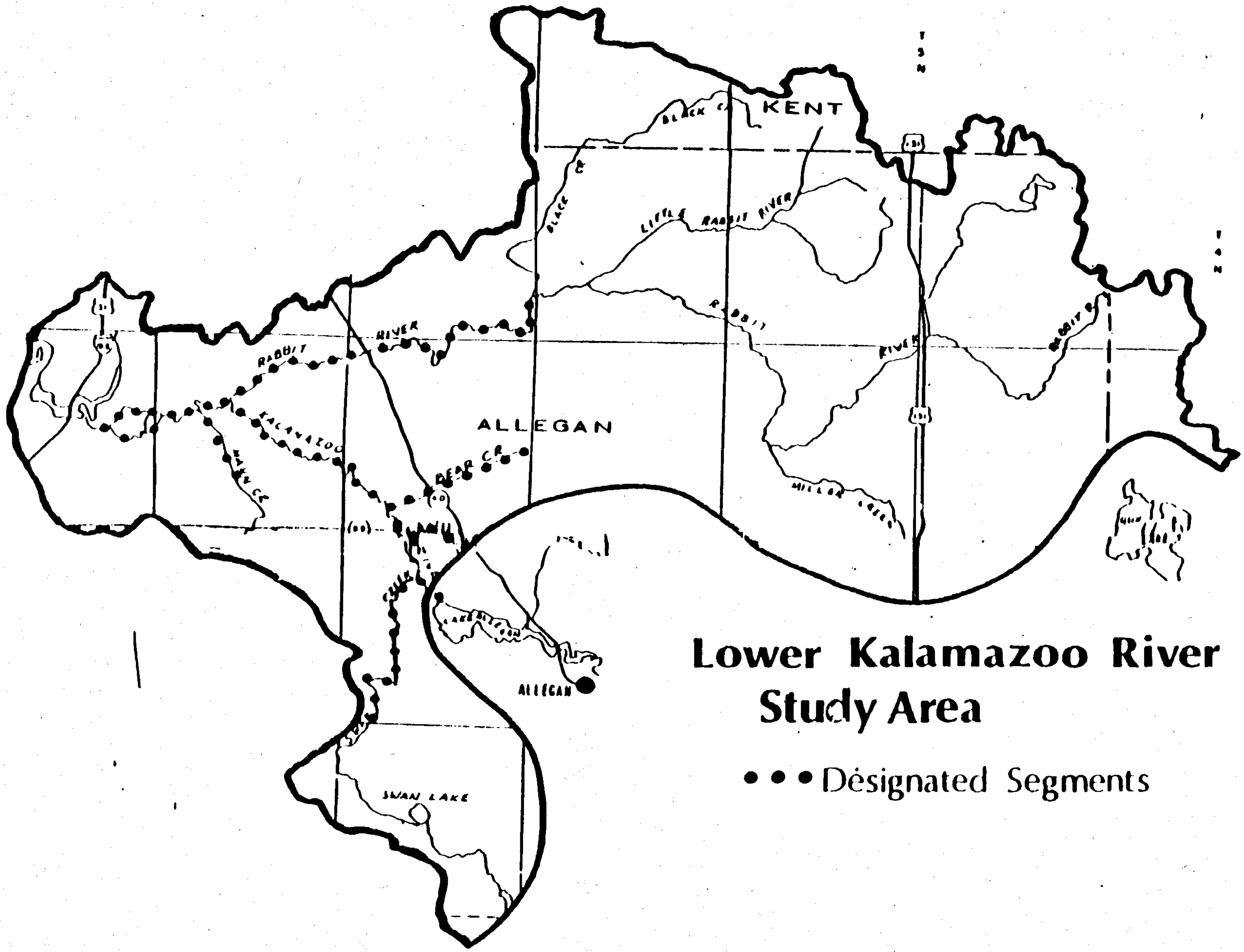
4. To ensure that the development and activities which do occur shall be done in an orderly manner, shall insure the protection of the river's natural values and qualities, and shall protect the river's outstanding scenic and aesthetic qualities.

5. To ensure that recreational uses which do occur, are done in an orderly manner consistent with the natural environment and aesthetic qualities of the stream, and that a quality recreation experience is maintained.

C. Designated Portions

It is recommended that the following portions of the Kalamazoo River within Allegan County be designated as a wild-scenic river under the authority of Act 231, P.A. 1970:

Mainstream: From Calkins Bridge Dam at Lake Allegan (Valley Township) downstream to the border between flood zones A2 and A3 in Saugatuck Township (approximately 1/2 mile downstream of the Hacklander public access site) as identified on the 1980 Flood Insurance Rate Map by the Federal Insurance Administration, including all channels of the mainstream (approximately 22 miles).



Lower Kalamazoo River Study Area

• • • Designated Segments

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Tributaries (approximately 33.0 miles)

1. Rabbit River from Overisel Township, east section line (Section 25) at 36th Street, downstream to the Kalamazoo River (17.0 miles).

2. Bear Creek from Heath Township, east section line (Section 24) at 36th Street, downstream to the Kalamazoo River (5.0 miles).

3. Sand Creek from the M-89 bridge, north section line (Section 3), Valley Township, downstream to the Kalamazoo River (2.0 miles).

4. Swan Creek from Valley Township, south section line (Section 32) at 112th Avenue, downstream to the Kalamazoo River (7.0 miles).

5. Mann Creek from the road crossing at 128th Avenue (south section line of Section 21, Manlius Township), downstream to the Kalamazoo River (2.0 miles).

D. Natural River District

The Kalamazoo River Natural River District includes an area 300 feet wide on each side of and parallel to all channels of the designated mainstream and the designated tributaries. This district establishes a definable area within which local zoning may guide future development and use. ESTABLISHMENT OF THIS DISTRICT IN NO WAY IMPLIES A "TAKING" OF THESE LANDS BY THE STATE OR OPENING THEM UP TO PUBLIC USE. PRIVATE LANDS REMAIN PRIVATE AND ARE SUBJECT TO ALL RIGHTS OF PRIVATE OWNERSHIP.

E. Land Management - Private Lands - Zoning Guidelines

1. Residential Housing: Unplatted lots and new subdivisions in the Natural River District shall be of sufficient size to accommodate the building setbacks as set forth in Section E.3, and shall have a minimum riverfront lot width of 150 feet.

   Lots or properties of record which are nonconforming at the time of the effective date of these regulations because of lack of size to accommodate the setback from the water's edge shall be allowed to be built upon and variances shall be allowed for the required setback upon such reasonable terms as set forth by the zoning administrator or the zoning review board.

   Upon approval by the Department of Natural Resources of an ordinance, a local community may allow the administrator of their zoning ordinance to determine the location of proposed structures on substandard lots of record, provided that structures be so placed so as to best meet the objectives of the Natural River Act.

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One single family dwelling will be permitted on each lot or parcel within the Natural River District subject to the building setbacks as set forth in Section E.3. A single family dwelling is defined as a detached building or structure designed for or occupied exclusively by one (1) family and containing housekeeping facilities.

2. Industrial and Commercial Structures and Uses:

   a. New industrial uses and buildings and expansion of existing uses and buildings will not be permitted within 300 feet of the designated portions of the Kalamazoo River and tributaries, except as allowed in approved local zoning ordinances or state administrative rules.

   b. Commercial uses and buildings; such as gas stations, motels, restaurants, retail stores, etc., will not be permitted within 300 feet of the designated river and tributaries. However, certain commercial uses requiring special exception permits may be compatible with maintaining the natural aspects of the river. Those uses permitted under the special exception procedure shall be strictly controlled. Controls such as location, parking, drainage, setback, natural vegetation strip, signs, hours of operation of the proposed use, shall be included in the special exception procedure. Those uses which may be compatible with natural river designation include:

      i. Commercial crop farms or forest plantations that are landward of the native vegetation strip.

      ii. Campgrounds that are constructed, maintained and operated in accordance with State Health Department regulations (Act 17, P.A. 1970). Includes tent, travel trailer, camper and motor home uses, buildings, cement pads, hookups, etc. in conformance with established setbacks.

      iii. Sales, rental and service of recreational watercraft, provided principle structures are in conformance with established setbacks.

      iv. Small home operated businesses such as photography studio, beauty shop, home repair, insurance, or other businesses which do not alter the residential nature of the property and are in conformance with established setbacks.

      v. Small rental cabins with light housekeeping, but not motels, which are in conformance with setback requirements.

3. Building Setbacks: On the designated portions of the Kalamazoo River system, the building setback for new structures and appurtenances along the mainstream and tributaries shall be at least 200 feet from the river's edge.[1] However, the setback may be decreased three feet for every foot of vertical bank height above the ordinary high water mark until a minimum setback of 75 feet from the river's edge is reached. Further, no building shall take place on land that is subject to flooding.[2]

4. Docks: Riparian owners have the right of reasonable access to the river. Therefore, construction of docks is a permitted use. Permanent docks must be constructed in accordance with the rules of Act 346, P.A. 1972. The use of "natural" materials is encouraged.

5. On-Site Sanitation Systems: All habitations within the Natural River District shall be provided with sanitary waste disposal facilities conforming in type to those required by health specifications of the State of Michigan and the county or district health department having legal jurisdiction. The facilities provided may be for either waterborne waste disposal by the septic tank-absorption tile field method or for nonwaterborne disposal by the use of a health department approved or other state approved sanitary system.

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[1] River's edge is defined as the ordinary high water mark and means "the line between upland and bottomland which persists through successive changes in water levels, below which the presence and action of the water is so common or recurrent that the character of the land is marked distinctly from the upland and is apparent in the soil itself, the configuration of the surface of the soil and the vegetation. Where water returns to its natural level as the result of the permanent removal or abandonment of a dam, it means the natural ordinary high water mark. (This is the definition used for administration of the Inland Lakes and Streams Act, Act 346, P.A. 1972.)

[2] Land that is subject to flooding means that area of land adjoining the designated portions of river and tributaries which:

a. Will be inundated by a flood which has a one percent chance of occurring or being exceeded in any given year (intermediate regional flood), as determined by detailed hydraulic studies which are acceptable to the Michigan Water Resources Commission; or

b. In the absence of such detailed floodplain studies, have a history of flooding or are delineated by approximate methods such as USGS flood prone area maps or HUD's special flood hazard boundary maps.

Minimum standards for new septic systems along designated portions of the Kalamazoo River shall be as follows:

a. The setback for septic tanks and absorption fields shall be a minimum of 100 feet from the ordinary high water mark. Further, Allegan County Health Department requirements state that septic systems must be setback a minimum of 25 feet from the edge of a bluff along a river or stream. However, depending on soil type and soil profile, height, slope and condition of the bank at the site, Health Department officials may increase the setback up to 100 feet from the edge of a bluff. This is done to prevent possible leaching or seepage of contaminants from a waste system from flowing directly down the bank to the stream.

b. The bottom of the absorption field shall be at least four feet above the known high ground water table.

c. No absorption field shall be closer than 50 feet from any permanent surface or subsurface drainage system. (This will not include basement footing drains.)

d. Variances from these standards may be allowed by the district health department where existing lots of record cannot conform because of their size.

6. Signs: Only those signs necessary for: identification, direction, resource information, regulation of use, and related to permitted uses, shall be placed along the designated river and tributaries. Within the Natural River District, signs for the sale of products or services shall be prohibited. Signs on private lands within the Natural River District must be in conformance with the following standards:

a. Not larger than one square foot in area posted no more than one per 100 feet or one sign posted at upstream and downstream corner of lot. However, one temporary real estate "for sale" sign per parcel of land not to exceed four square feet in area shall be allowed outside of the natural vegetation strip (as described in Section E.10).

b. Not attached to any tree or shrub.

c. Not illuminated.

7. Agriculture: Existing agricultural practices will be permitted within the natural vegetation strip. Grazing will be permitted within the natural vegetation strip unless the Bureau of Environmental Protection of the Department of Natural Resources determines that it contributes to stream degradation (Act 245, P.A. 1929). In those cases, livestock will be fenced out to

protect the river banks. Cattle crossings and watering areas shall be constructed according to accepted methods, after the landowner has consulted with the local Soil Conservation District, Soil Conservation Service, County Extension Service, and/or Department of Natural Resources.

Water withdrawal for irrigation will continue to be permitted in accordance with the rights of other riparians and the public values associated with the Kalamazoo River system.

New agricultural uses and practices including commercial tree farms shall be allowed in the Natual River District provided they are landward of the natural vegetation strip.

8. Disposal of Solid Wastes: No unsightly or offensive material, including, but not limited to: trash, refuse, junk cars, junk appliances or garbage, shall be dumped or stored within the Natural River District or as provided by Act 87, P.A. 1965.

   No dumps or sanitary landfills shall be permitted within 300 feet of the designated portions of the Kalamazoo River or its tributaries.

9. Land Alteration: Land alteration for building such as grading, dredging and filling of the land surface within 300 feet of the river's edge is permitted, unless the high ground water table is within six feet of the land surface or on lands subject to flooding. (This does not apply to septic system drain fields which must be four feet above the known high ground water table.) Dredging or filling for the construction of fish or wildlife ponds outside of the natural vegetation strip is permitted. All activities must meet provisions of Michigan's Inland Lakes and Streams Act, Act 346, P.A. 1972, the Soil Erosion and Sedimentation Control Act, Act 347, P.A. 1972, and the Wetlands Protection Act, Act 203, P.A. 1979.

10. Natural Vegetation Strip on Adjacent Shorelines: Trees, shrubs, and other vegetation native to the area shall be maintained and enhanced on each side of the river and tributaries to retain the river's natural values. Maintenance of the natural vegetation strip is required to help in stabilizing the riverbanks, minimize erosion, provide shading which will help maintain cool water temperatures, help protect water quality by absorbing nutrients from surface water runoff, provide screening of man-made elements, protect fisheries and wildlife habitat, and maintain the aesthetic quality of the river. The zoning administrator shall notify each applicant for a building permit of the purpose of the natural vegetation strip and of the provisions of this section.

a. Vegetation Strip

Private Land - On privately owned land, a fifty (50) foot deep minimum restricted cutting strip shall apply on each side of the mainstream and on all designated tributaries. The following provisions shall apply within the natural vegetation strip:

i. Dead, diseased, unsafe or fallen trees, shrubs and noxious plants, including poison ivy, poison sumac and poison oak, and other plants regarded as a common nuisance in Section 2, Public Act 359 of 1941, as amended, may be removed.

ii. Trees and shrubs may be pruned for a filtered view[1] of the river.

iii. Trees and shrubs may be selectively removed for harvest of merchantable timber, public utility facilities, to achieve a filtered view of the river from the principal structure, and for reasonable private access to the river upon approval of the local zoning administrator.

(a) If the zoning administrator feels it is necessary he should direct the property owner to consult with the Department of Natural Resources Forester in Plainwell to establish an acceptable selective cutting plan for the area.

iv. Clear cutting is not allowed.

11. Minerals: New development, exploration or production of oil, gas, salt brine, sand and gravel, or other minerals except groundwater are not permitted within 300 feet of the designated river or tributaries (Section 10, Natural River Act).

F. Land Management - State and Other Public Lands

1. Structures Related to Recreation: On public land, no new structures associated with a campground, picnic area, rest area, access site or any other publicly provided facilities, except

[1]"Filtered view" means the maintenance or establishment of woody vegetation of sufficient density to screen developments from the river, to provide for streambank stabilization and erosion control, to serve as an aid to infiltration of surface runoff, and to provide cover to shade the water. The vegetation need not be so dense as to completely block the river view. It means no clear cutting.

a. Signs posted by public agencies must be kept to a minimum, no larger than ten square feet in area, and placed so as to best meet the objectives of the Natural River Act.

b. The Department of Natural Resources should initiate a signing program at major access sites along the mainstream emphasizing litter control and respect for private property. Signs should be placed along the mainstream, particularly at bridge crossings and all other strategic locations indicating present location and float time to rest areas and access sites.

(Note: Signs by public agencies may need to be larger or within the 300-foot Natural River District to provide for public safety, such as warning of impending dangers in the river, or for an interpretive or historic sign.)

4. Minerals: New development, exploration or production of oil, gas, salt brine, sand and gravel, or other minerals except groundwater is not permitted within 300 feet of the designated river or tributaries (Section 10, Natural River Act). On new leases on state land, Natural Resources Commission policy prohibits drilling for gas or oil within 1/4 mile of any principal stream.

E. State Program Management

1. Stream Alteration: To protect the natural character of the river and the natural flow of its waters, no damming, dredging, filling or channelization of the stream will be permitted in those portions of the Kalamazoo River or tributaries designated under the Natural River Act unless approved by the Department of Natural Resources under authority of Michigan's Inland Lakes and Streams Act, Act 346, P.A. 1972.

Natural materials should be used to construct streambank stabilization projects to control erosion, or to enhance fisheries habitat. These structures should be camouflaged and the local Conservation Officer, District Fish Biologist, or Soil Conservation Service representative contacted to provide technical advice for such projects. All work done below the ordinary high water mark requires a permit under the authority of the Inland Lakes and Streams Act, Act 346, P.A. 1972.

Permission must be obtained from the property owner when removing fallen trees and log jams from the river. If extensive removal of log material from the bottom during these operations is anticipated, advice and permission should be sought from the District Fish Biologist.

those necessary to protect the riverbank, will be permitted within 200 feet of the designated mainstream or tributaries. Such structures shall be designed and constructed in such a manner as to further the purposes of the Natural River Act.

2. Natural Vegetation Strip on Adjacent Shorelines: Trees, shrubs and other vegetation native to the area shall be maintained and enhanced on each side of the river and tributaries to retain the river's natural values. Maintenance of the natural vegetation strip is necessary to help in stabilizing the riverbanks, minimize erosion, provide shading which will help maintain cool water temperatures, help protect water quality by absorbing nutrients from surface water runoff, provide screening of man-made elements, protect fisheries and wildlife habitat, and maintain the aesthetic quality of the river.

   a. Vegetation Strip

      Public Land - On all publicly owned land, a one hundred and fifty (150) foot deep minimum restricted cutting strip shall apply on each side of the mainstream and on all designated tributaries. The following provisions will apply within the natural vegetation strip:

      i. Dead, diseased, unsafe or fallen trees, shrubs and noxious plants, including poison ivy, poison sumac, and poison oak, and other plants regarded as a common nuisance in Section 2, Public Act 359 of 1941, as amended, may be removed.

      ii. Trees and shrubs may be pruned for a filtered view of the river.

      iii. Trees and shrubs may be selectively removed for harvest of merchantable timber to maintain and establish public utility facilities, and for reasonable access to the river.

      iv. Clear cutting within 150 feet generally is not permitted but may be allowed if it meets the policy of cutting within water influence zones on state forest land. Limited clear cutting of certain species for fish and wildlife habitat improvement may be allowed upon approval of such plans by the affected divisions of the Department of Natural Resources (Section 15, Act 231, P.A. 1970).

3. Signs: Only those signs necessary for identification, direction, resource information and regulation of use shall be placed along the designated river and tributaries.

2. Soil Erosion and Sediment Control Measures: Michigan's Soil Erosion and Sedimentation Control Act, Act 347, P.A. 1972. All earth changing activities, other than normal landscaping or maintenance, undertaken within 500 feet of a lake or stream must be conducted in accordance with the requirements of Act 347 of the Public Acts of 1972, its administrative rules and those procedures established by the local enforcing agency. Development along the river involving earth moving shall provide for water disposal and/or protection of the soil surface during and after construction.

Practical combinations of the following will provide effective erosion control when skillfully used in planning and construction:

a. The development plan should be fitted to the soils and topography so as to create the least erosion potential. Local offices of the Soil Conservation Service can provide detailed information on the soil characteristics of a given site and on the suitability of such soils for various uses.

b. Wherever feasible during construction, natural vegetation shall be retained and protected. Where adequate vegetation does not exist, temporary or permanent vegetation shall be established where possible.

c. Where it is necessary to remove vegetation for construction, limit the exposed area to the smallest practical size at any one time.

d. Limit the duration of exposure of soils to the shortest practical time.

e. Critical areas exposed during construction should be protected with temporary vegetation and/or mulching.

f. Permanent vegetation and improvements, such as roads, storm sewers and other features of development capable of carrying storm runoff in a safe manner, shall be installed as early as possible.

g. Provisions should be made to accommodate the increased runoff caused by changed soil and surface conditions during and after construction.

h. Sediment basins to remove suspended soil particles from runoff water from land undergoing development should be constructed and maintained where erosive conditions indicate their need to prevent sediment damage to the river.

i. Diversions, grassed waterways, grade stabilization structures, and similar mechanical measures required by the site shall be installed as early in the development as possible.

3. Utilities: New gas or oil pipelines, or electric transmission lines shall not be permitted in the Natural River District or to cross the designated river and tributaries without prior written consent of the Department of Natural Resources. Plans for these transmission lines which include crossing the river district or the river and designated tributaries shall be done in accordance with the rules entitled Utilities and Publicly Provided Facilities in Natural River Areas (Section 15 of Act 231).

New distribution lines within the designated portions of the river or housing setback zone shall be placed underground, unless overhead lines are less disruptive to the environment. Plans for distribution lines which are to be placed under the river shall be approved by the Department of Natural Resources and all construction shall meet the requirements under the Soil Erosion and Sedimentation Control Act, Act 347, P.A. 1972 and the Inland Lakes and Streams Act, Act 346, P.A. 1972. Local service lines to private dwellings shall originate from the landward side of the dwelling insofar as practical.

Management of trees, shrubs and other vegetation for maintenance of utility rights-of-way shall be done manually in the natural vegetation strip. However, hand application of herbicides to stumps of selectively cut trees may be allowed in the natural vegetation strip where it is the objective to establish and maintain a low growing shrub community in this zone. The Department may authorize application of selected pesticides to control insect or disease infestations.

No new dams will be allowed across the designated portions of the Kalamazoo River system. Permits for reactivation or relicensing of the Calkins Dam and/or the Hamilton Dam shall include a requirement that minimum flows be maintained which will ensure protection of the water quality, and fish, wildlife, wetlands, ecologic, recreational and aesthetic values of the designated portions.

4. Recreation:

a. Fishing, Hunting and Trapping: Fishing, hunting and trapping will be permitted in the Natural River District in accord with current state and local laws and regulations.

IT IS EMPHASIZED THAT NATURAL RIVER DESIGNATION, OR ESTABLISHMENT OF A ZONING DISTRICT ALONG THE RIVER, DOES NOT OPEN PRIVATE LANDS TO THE PUBLIC.

Fisheries and wildlife management will be done in conformance with the character of the area and objectives of the natural river designation. A definite fish management plan has not been developed for the lower Kalamazoo River system. However, emphasis will be placed on maintaining and enhancing the quality of the fisheries through stocking, rehabilitation and other necessary management practices. As long as PCB concentrations in fish in this area remain at a dangerous level, every effort should be made to keep the public advised of the situation.

Wildlife management plans call for development and improvement projects to enhance the three existing marsh management areas. In addition, adjacent uplands will be managed to maintain existing wildlife species.

b. Boating and Canoeing: Boating and canoeing are permitted. Local units of government (township or county) are encouraged to limit the use of motorized watercraft by limiting size of motor or no wake speeds in areas where problems of bank erosion, property damage or personal safety exist. Such controls should be done in accordance with the Marine Safety Section of the Law Enforcement Division.

c. Litter: In view of the special status of the Kalamazoo River and its unique beauty and character, the Department of Natural Resources shall encourage and cooperate with private interests as well as other public agencies that have programs for river clean-up.

5. Public Access Sites and Rest Areas: The Advisory Group feels that existing public access is adequate and recommends no new public access sites be provided along the lower Kalamazoo River. However, one new rest stop with no public vehicular access, may be desirable in the future. If such a facility is needed in the future, it should be established in the vicinity of the following areas:

   a. NW¼ of Section 30, T3N, R14W, on the north side of the river.

   b. SE¼ of SE¼ of Section 3[illegible], T3N, R14W, on the south side of the river.

   Any additional public access must be walk-in only with parking facilities at least maintaining established setbacks. These should be located only where there is sufficient adjacent public lands so as to minimize trespass and user conflicts on privately owned lands.

These recommendations should meet present and foreseeable future needs for access. Should use expand or an unexpected need for access arise, it may be necessary to restudy the adequacy of public access and rest areas.

6. Motorized Vehicles: Operation of all motorized vehicles except normal farm and lawn machinery, other than on designated public roads or access roads to permitted uses, will be prohibited within the Natural River District. Use of ORV's on publicly owned lands contiguous to the Natural River District shall be in conformance with guidelines and regulations of the agency administering such lands, and state and federal noise level standards shall be strictly enforced. (Muffler requirement of MVC - Section 708, Act 300, P.A. 1949, etc.)

7. Historic and Archaeological Sites: It is recommended that responsible groups, individuals and the History Division, Michigan Department of State, should continue to identify and evaluate historic and archaeological sites. For those sites that qualify, work should continue toward inclusion of these sites on the State and National Registers of Historic Places, and/or Historic Sites and Historic American Buildings.

8. Water Quality Management: Designated stretches of the Kalamazoo River and its tributaries will be governed by the "nondegradation" rule of the Water Resources Commission's water quality standards. Baseline water quality shall be determined, both chemically and biologically, at the time of designation. A program for water quality monitoring shall be established by the Bureau of Environmental Protection to ensure that continued efforts are being made to maintain or enhance water quality. Of particular concern is the monitoring of PCB levels in fish tissue.

   Upstream municipal and industrial discharges to the Kalamazoo River system should be closely controlled to insure protection to the water quality and natural values of the designated portions.

H. Administration

1. Land Use Guidelines: Under Act 231, zoning by local governmental units shall be the preferred means of protecting the Kalamazoo River and its designated tributaries as a natural river.

   a. Zoning shall be applied within the 300-foot Natural River District on both the designated mainstream and tributaries. Upon adoption of a local zoning ordinance, certified copies of maps and/or documents describing the Natural River District shall be filed with the local tax assessing officer and the County Equalization Department.

In establishing true cash value of property within the Natural River District, the assessing officer shall take cognizance of the effect of use limits established by the ordinance (Section 12, Act 231, P.A. 1970).

2. Utilities and Publicly Provided Facilities in Designated Natural River Areas: As provided in Section 15 of Act 231, P.A. 1970, administrative rules have been adopted by the state which provide that: Plans for construction, enlargement, and site or route location of all utility pipelines and transmission lines, roads and road rights-of-way, publicly provided recreation facilities, access sites, and public water management projects within a natural river area shall be approved by the Department. An application for the approval of such plans shall be submitted by the applicant, in writing, to the Department of Natural Resources, Division of Land Resource Programs.

3. Appeals: Under certain circumstances, strict adherence to this plan may create unreasonable hardships for the frontage owner. Such cases may be appealed to the appropriate state or local board for a variance. Applications for a variance shall be based on a site plan. The County Health Department, Soil Conservation Service, appropriate staff and field personnel of the Department of Natural Resources, and other experts should be consulted to recommend to the appeals board a course of action which will have the least degrading impact on the character of the natural river. Final determination of the variance shall be made by the appropriate board.

4. Nonconforming Uses: As stated in Section 13 of the Natural River Act, Act 231, P.A. 1970, "the lawful use of any building or structure, and of any land or premise as existing and lawful at the time of enactment of a zoning ordinance or rule or an amendment thereof, may be continued although such use does not conform with the provisions of the ordinance, rule or amendment. The ordinance or rule shall provide for the completion, restoration, extension or substitution of nonconforming uses upon such reasonable terms as may be set forth in the zoning ordinance or rule."

5. Zoning Regulations in Unusual Circumstances: The regulations proposed in this report are not intended to be applied in disregard of the requirement of Section 9 of the Natural River Act of 1970 that zoning regulations "take cognizance of the characteristics of the land and water concerned, surrounding development and existing uses." Where specific circumstances can be proven to warrant a variance, other or different regulations, either more or less restrictive, should be adopted.

6. Land Acquisition: The state may purchase or trade lands with owner consent on the designated river and tributaries to maintain or improve the river and its environment. Efforts should be made by the appropriate public agency to purchase key parcels for canoe rest areas, walk-in fishermen access, or to protect sensitive environmental areas. Some landowners in the Natural River District may be interested in offering scenic or other easements or inserting restrictions in their deeds which serve to protect the river environment and which coincide with their property interests. The opportunity to obtain such easements or restrictions should be pursued by interested public agencies.

7. State Resources: Overall responsibility for implementing and coordinating the natural river plan is assigned to the Region III Office of the Department of Natural Resources. The Natural Rivers Unit and the Department of Natural Resources Natural Rivers Advisory Group will act in an advisory capacity. Enforcement of water quality standards and water use regulations will be the responsibility of the Environmental Enforcement Division and other divisions of the Department of Natural Resources. Other laws and programs reinforcing natural rivers management objectives should be utilized to the extent necessary to protect the river in implementing the management plan for the river and tributaries (see Appendix C).

I. Recommendations - Encouragements

1. Private Landowners: Although not required by this plan, property owners are encouraged to consider the following recommendations which will help protect and enhance private lands, and offer additional protection to the river and adjacent environment.

   a. Building Design - Property owners along the streams are encouraged to use natural materials and natural unobtrusive colors in the construction of new or remodeling of existing buildings. Upon request to the Department of Natural Resources, individual property owners may receive technical advice on location and design of structures and management of their lands. Such requests and the Department's response should be channeled through the local zoning administrator.

   b. Building Screening - Property owners of new or existing buildings visible from the river are encouraged to screen them with native vegetation. The Department of Natural Resources Area Forester and Soil Conservation Service will advise on planting stock, etc. on request. When available at state nurseries, recommended planting materials will be supplied to property owners at cost.

c. Building Setbacks on Bluffs - Property owners are encouraged to maintain a reasonable setback from the edge of a bluff. Bluffs are sensitive areas subject to erosion. Where construction occurs too close to the edge of a bluff, damage to the structure and severe bank sloughing may occur. The following are suggested distances for these setbacks:

i) New buildings and appurtenances should be setback at least 50 feet from top of the bluff[1] on the cutting edge[2] of a stream.

ii) New buildings and appurtenances should be setback at least 25 feet from the top of a bluff on the noncutting edge of the stream.

d. Erosion Control - Planting of perennial native species in the natural vegetation strip is encouraged, especially where exposed soil and steep slopes exist. The Department of Natural Resources or Soil Conservation Service may be consulted for selection of plant species best suited for erosion control and/or screening of existing developments. When available at state nurseries, the recommended planting materials will be supplied to property owners at cost.

2. Local Units of Government: The management of areas beyond the natural river zone is extremely important since land use and water resources are closely related. What happens on the lands beyond the Natural River District but within the drainage area of the river, affects the river. Local units of government adjacent to the district, through their powers to influence the location, timing and nature of development, can have a positive effect on water resources.

It is recomemnded that local governmental units zone areas adjacent to the Natural River District to maintain the integrity of the Kalamazoo River and designated tributaries as a wild-scenic river:

a. By limiting residential development to low density, single family structures or medium density cluster developments. Medium density cluster developments are recommended because it is more cost effective to provide services and control.

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[1] "Bluff" means the top of a steep bank rising sharply from the water's edge.

[2] "Cutting edge of a stream" means the edge of a river or stream where water velocity is such that it may cause soil or stream bank erosion.

b. By providing districts where industry which may produce noise, smoke, fumes, odors, etc., will not affect the natural characteristics of the river area.

c. By providing districts for commerce where heavy traffic, parking, automobile exhaust and noise will not create environmental intrusions.

Further, it is recommended that local units of government incorporate water resouce protection and/or management measures into their plans, programs and decisions involving land use. Such measures are of particular importance when dealing with lands in the stream corridor as defined below.

A stream corridor essentially consists of lands contiguous to the stream, the alteration or development of which could potentially cause negative impacts on the stream and its environment. It is a composite of:

a. Soil types with severe limitations for development.
b. Vegetation along creek banks.
c. Wetlands.
d. Slopes.
e. Flood profiles when known.

Sensitive areas involving one or more of the above factors may occur within the drainage area of the river but outside of the Natural River District itself. Modification or development within such areas may adversely affect water resource benefits within the district or create problems requiring costly public investment to rectify.

It is recommended that local units of government consider such measures as regulating changes in surface water runoff from specific locations through use of the site plan review process, and protecting sensitive areas outside the Natural River District through use of conditional use permit procedures.

On private lands adjacent to and within 1/4 mile of the Natural River District, it is recommended that the local Soil Conservation Districts, local soil erosion and sedimentation control agencies, Cooperative Extension Service and the Department of Natural Resources cooperate with landowners to ensure that timber harvest, agricultural practices, housing, road building, or other land use activities are compatible with the wild-scenic designation of the river and with maintaining the water quality of the river.

Further, local governmental units are urged to adopt building setbacks, vegetation management and septic system controls for other streams under their jurisdiction not within the natural river designation.

APPENDIX B

Water, Sediment and Fish PCB Results

REACH	LOCATION	DATE	TOTAL PCB (NG/L)	AROCLOR 1242 (NG/L)	AROCLOR 1254 (NG/L)	AROCLOR 1260 (NG/L)
	PORTAGE CREEK					
BACKGROUND	CORK STREET	18-Apr-85	<10	<10	<10	<10
		29-Apr-85	<10	<10	<10	<10
		06-May-85	<10	<10	<10	<10
		29-May-85	<10	<10	<10	<10
		10-Jun-85	<10	<10	<10	<10
		17-Jun-85	<10	<10	<10	<10
		24-Jun-85	<10	<10	<10	<10
		10-Jul-85	<10	<10	<10	<10
		22-Jul-85	<10	<10	<10	<10
		29-Jul-85	<10	<10	<10	<10
		06-Sep-85	<10	<10	<10	<10
		24-Sep-85	<10	<10	<10	<10
		15-Oct-85	<10	<10	<10	<10
		14-Nov-85	<10	<10	<10	<10
		17-Dec-85	<10	<10	<10	<10
		22-Jan-86	<10	<10	<10	<10
		19-Feb-86	<10	<10	<10	<10
		20-Mar-86	<10	<10	<10	<10
		24-Apr-86	<10	<10	<10	<10
		13-May-86	<10	<10	<10	<10
		24-Jun-86	<10	<10	<10	<10
		01-Oct-86	<10	<10	<10	<10
		13-Nov-86	<10	<10	<10	<10
		10-Dec-86	<10	<10	<10	<10
		24-Mar-87	17	17	<10	<10
1	ALCOTT ST	18-Apr-85	86	70	16	<10
		29-Apr-85	145	130	15	<10
		06-May-85	283	250	33	<10
		20-May-85	262	230	32	<10
		29-May-85	129	110	19	<10
		10-Jun-85	255	230	25	<10
		17-Jun-85	161	140	21	<10
		24-Jun-85	114	95	19	<10
		10-Jul-85	111	97	14	<10
		22-Jul-85	110	90	20	<10
		29-Jul-85	335	300	35	<10
		28-Aug-85	153	130	23	<10
		06-Sep-85	116	90	26	<10
		24-Sep-85	88	76	12	<10
		15-Oct-85	155	130	25	<10
		14-Nov-85	74	74	<10	<10
		17-Dec-85	61	49	12	<10
		22-Jan-86	120	92	28	<10
		19-Feb-86	71	57	14	<10
		20-Mar-86	81	69	12	<10
		24-Apr-86	75	58	17	<10
		13-May-86	192	180	12	<10
		24-Jun-86	222	205	<10	17
		01-Oct-86	32	32	<10	<10

WATER PCB DATA FROM THE KALAMAZOO RIVER

REACH	LOCATION	DATE	TOTAL PCB (NG/L)	AROCLOR 1242 (NG/L)	AROCLOR 1254 (NG/L)	AROCLOR 1260 (NG/L)
		13-Nov-86	34	34	<10	<10
		10-Dec-86	89	89	<10	<10
		24-Mar-87	68	54	14	<10
	DAVIS CREEK					
BACKGROUND	COMSTOCK AVE	19-Feb-86	<10	<10	<10	<10
		20-Mar-86	<10	<10	<10	<10
		24-Apr-86	<10	<10	<10	<10
		21-Apr-87	<10	<10	<10	<10
	KALAMAZOO RIVER					
BACKGROUND	35TH ST	13-May-86	<10	<10	<10	<10
BACKGROUND	RIVER ROAD	18-Apr-85	24	12	12	<10
		20-May-85	13	<10	13	<10
		17-Jun-85	14	<10	14	<10
		22-Jul-85	30	20	10	<10
		24-Sep-85	13	<10	13	<10
		15-Oct-85	26	14	12	<10
		14-Nov-85	11	11	<10	<10
		17-Dec-85	<10	<10	<10	<10
		22-Jan-86	<10	<10	<10	<10
		19-Feb-86	138	120	18	<10
		20-Mar-86	<10	<10	<10	<10
		24-Apr-86	<10	<10	<10	<10
		13-May-86	14	<10	14	<10
		24-Jun-86	<10	<10	<10	<10
		01-Oct-86	<10	<10	<10	<10
		13-Nov-86	<10	<10	<10	<10
		10-Dec-86	<10	<10	<10	<10
		23-Feb-87	<10	<10	<10	<10
		24-Mar-87	<10	<10	<10	<10
BACKGROUND	KING HGHWY	22-Jan-86	<10	<10	<10	<10
		19-Feb-86	<10	<10	<10	<10
		20-Mar-86	<10	<10	<10	<10
		24-Apr-86	<10	<10	<10	<10
		13-Nov-86	<10	<10	<10	<10
BACKGROUND	MICHIGAN AVE	24-Sep-85	41	24	17	<10
		15-Oct-85	33	19	14	<10
		17-Dec-85	<10	<10	<10	<10
		22-Jan-86	14	<10	14	<10
		19-Feb-86	<10	<10	<10	<10
		20-Mar-86	<10	<10	<10	<10
		24-Apr-86	39	<10	39	<10
		01-Oct-86	<10	<10	<10	<10
		13-Nov-86	<10	<10	<10	<10
		10-Dec-86	<10	<10	<10	<10

WATER PCB DATA FROM THE KALAMAZOO RIVER

REACH	LOCATION	DATE	TOTAL PCB (NG/L)	AROCLOR 1242 (NG/L)	AROCLOR 1254 (NG/L)	AROCLOR 1260 (NG/L)
		23-Feb-87	<10	<10	<10	<10
2	PATERSON AVE	24-Sep-85	40	26	17	<10
		15-Oct-85	42	24	14	<10
		19-Feb-86	19	19	<10	<10
		20-Mar-86	<10	<10	<10	<10
		24-Apr-86	<10	<10	<10	<10
		13-May-86	15	<10	15	<10
		24-Jun-86	37	37	<10	<10
		01-Oct-86	<10	<10	<10	<10
		13-Nov-86	11	11	<10	<10
		10-Dec-86	<10	<10	<10	<10
		23-Feb-87	10	10	<10	<10
2	MOSEL AVE	24-Jun-86	44	44	<10	<10
		01-Oct-86	<10	<10	<10	<10
		10-Dec-86	13	13	<10	<10
		23-Feb-87	30	30	<10	<10
		24-Mar-87	41	27	14	<10
		20-May-87	23	<10	23	<10
2	D AVE	10-Dec-86	14	14	<10	<10
		23-Feb-87	<10	<10	<10	<10
		24-Mar-87	27	27	<10	<10
		20-May-87	30	<10	30	<10
3	10TH ST	18-Apr-85	48	32	16	<10
		20-May-85	62	39	23	<10
		17-Jun-85	48	36	12	<10
		22-Jul-85	110	70	40	<10
		13-May-86	153	130	19	<10
		10-Dec-86	12	12	<10	<10
		23-Feb-87	50	25	<10	25
		24-Mar-87	42	42	<10	<10
		20-May-87	97	61	36	<10
4	PLAINWELL DAM	18-Apr-85	31	20	11	<10
		20-May-85	62	44	18	<10
		17-Jun-85	57	38	14	<10
		22-Jul-85	70	50	20	<10
		13-May-86	91	76	15	<10
5	FARMER ST	18-Apr-85	47	31	16	<10
		20-May-85	58	39	19	<10
		17-Jun-85	46	36	10	<10
		22-Jul-85	90	60	30	<10
6	OTSEGO DAM	18-Apr-85	122	93	29	<10
		20-May-85	49	32	17	<10
		17-Jun-85	52	40	12	<10
		22-Jul-85	80	55	25	<10

WATER PCB DATA FROM THE KALAMAZOO RIVER

REACH	LOCATION	DATE	TOTAL PCB (NG/L)	AROCLOR 1242 (NG/L)	AROCLOR 1254 (NG/L)	AROCLOR 1260 (NG/L)
7	26TH ST	18-Apr-85	126	96	30	<10
		20-May-85	100	72	28	<10
		17-Jun-85	43	26	17	<10
		24-Jun-85	62	44	18	<10
		22-Jul-85	100	70	30	<10
8	WILLIAMS RD	18-Apr-85	119	91	28	<10
		20-May-85	99	70	29	<10
		17-Jun-85	71	58	13	<10
		22-Jul-85	110	80	30	<10
9	M-118	18-Apr-85	104	80	24	<10
		29-Apr-85	101	77	24	<10
		06-May-85	108	77	31	<10
		20-May-85	87	64	23	<10
		29-May-85	93	67	26	<10
		10-Jun-85	130	95	25	<10
		17-Jun-85	63	50	13	<10
		24-Jun-85	193	140	53	<10
		10-Jul-85	57	42	15	<10
		22-Jul-85	170	130	40	<10
		29-Jul-85	101	75	26	<10
		13-May-86	149	130	19	<10

PORTAGE CREEK SEDIMENT RESULTS, 1983-86

DISTANCE FROM BRYANT DAM (FT)	LOCATION	DISTANCE FROM STREAMBANK (FT)	PCB CONC(PPM)	DATE
	BRYANT MILL POND RESULTS			
LOWER BRYANT				
150	INSTREAM		145.0	06-Aug-86
	INSTREAM		24.3	06-Aug-86
	INSTREAM		36.4	15-Oct-85
	INSTREAM		105.0	22-Jul-83
	EASTBANK	0	328.0	06-Aug-86
		5	33.9	06-Aug-86
		55	444.0	06-Aug-86
	WESTBANK	0	980.0	06-Aug-86
		0	36.9	22-Jul-83
		5	10.7	06-Aug-86
		55	171.0	06-Aug-86
		95	322.0	06-Aug-86
160	EASTBANK	20	582.0	02-Nov-83
	WESTBANK	20	97.0	02-Nov-83
200	EASTBANK	0	530.0	15-Oct-85
		20	333.0	02-Nov-83
	WESTBANK	0	510.0	15-Oct-85
600	INSTREAM		3.2	22-Jul-83
	EASTBANK	30	27.5	02-Nov-83
	WESTBANK	0	344.0	22-Jul-83
900	INSTREAM		3.3	22-Jul-83
	EASTBANK	0	36.8	10-Dec-86
		(0-2") 5	<0.91	10-Dec-86
		(0-2") 55	33.2	10-Dec-86
		(6-8") 55	161	10-Dec-86
	WESTBANK	0	23.0	22-Jul-83
		0	18.2	10-Dec-86
		(0-2") 5	2.6	10-Dec-86
		(0-3") 60	23.0	10-Dec-86
		(3-5") 60	19.7	10-Dec-86
1050	EASTBANK	20	8.1	02-Nov-83
CONSTRICTION=1200				
UPPER BRYANT				
1400	INSTREAM		85.0	15-Oct-85
BEGINNING OF POND=1900				

DISTANCES ESTIMATED FROM USGS 7.5` TOPOGRAPHICAL MAP 08-Sep-87

PORTAGE CREEK SEDIMENT RESULTS, 1983-86

DISTANCE FROM BRYANT DAM (FT)	LOCATION	DISTANCE FROM STREAMBANK (FT)	PCB CONC(PPM)	DATE
2100	INSTREAM		56.9	03-Apr-84
			0.2	03-Apr-84
	WESTBANK	5	5.9	03-Apr-84
2600	EASTBANK	0	2.3	03-Apr-84
	WESTBANK	0	0.9	03-Apr-84
3000	WESTBANK	0	54.1	15-Oct-85
		0	<1.4	15-Oct-85
3400	WESTBANK	5	4.1	15-Oct-85
3600	WESTBANK	0	<1.3	15-Oct-85
3800	WESTBANK	0	898.0	03-Apr-84
SEEP ONE = 3900	WESTBANK	10	69.0	15-Oct-85
SEEP TWO = 4200	WESTBANK	0	<1.1	15-Oct-85

ALLIED 002=4900

CORK ST = 5300

MONARCH DAM=6300

MONARCH MILL POND RESULTS

50	(FROM MONARCH DAM)	<1.8	06-Aug-86
100		<2.3	06-Aug-86
		0.7	03-Apr-84
300		0.4	03-Apr-84
600		0.4	03-Apr-84

BRYANT MILL PONDS
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
B1	107.6 (0-2.5")	1972	Lauer, 1972	Northeast side, lower pond, 10" core
	70.8 (2.5-5")			
	61.0 (5-7.5")			
	65.8 (7.5-10")			
B1	88.0 (0-3.5")	1972	Lauer, 1972	Northwest side, lower pond, 14" core
	5.1 (3.5-7")			
	5.0 (7-10.5")			
	8.8 (10.5-14")			
B1	8.6 (0-2.5")	1972	Lauer, 1972	Southwest side, lower pond, 14" core
	28.3 (2.5-5")			
	6.4 (5-8")			
	76.8 (8-11")			
	13.4 (11-14")			
B1	8.1 (0-6")	1983	Unpublished MDNR, November 2, 1983	50 mile downstream of upper basin constriction, east side; brown color
	1.4 (8")			1" sand layer
	212.0 (16-18")			Gray sediment
	32.8 (24")			Gray sediment
B1	27.5 (0-2")	1983	Unpublished MDNR, November 2, 1983	200 mile upstream of Bryant Dam, 10 meters east of river, high ground; brown-gray
	1.2 (16")			Light gray
B2	368.7 (0-2")	1972	Lauer, 1972	West side, upper Bryant Mill Pond, 14" core
	10.0 (6-8")			
	0.6 (12-16")			

* Represents instream samples

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TABLE A-2

KALAMAZOO RIVER SEDIMENT DATA

PORTAGE CREEK: REACH 1
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
PC4	117.81	1972	Lauer, 1972	Lake Street
PC1	0.50	1976	Unpublished, MDNR August, 1976	Michigan Avenue
PC3	65.58	1976	Unpublished, MDNR August, 1976	Vine Street
PC3	54.50	1976	Wuycheck, 1976	Vine street
PC1	85.00	1982	MDNR, November 1982	Michigan Avenue
PC1	16.00	1983	MDNR, November 1983	Michigan Avenue; instream, silty, slight oils
PC1	14.60	1983	MDNR, November 1983	Michigan Avenue; stream banks, silt, resembles paper waste deposits
PC2	10.00	1983	MDNR, November 1983	Portage Road; instream, sandy silt, slight oils
PC2	11.00	1983	MDNR, November 1983	Portage Road; stream bank, loosely consolidated brown silt

TABLE A-3

KALAMAZOO RIVER SEDIMENT DATA

PORTAGE CREEK CONFLUENCE TO MAIN STREET, PLAINWELL: REACH 2
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
K1	6.28	1976	Unpublished, MDNR, August 9-10, 1976	Fourth Street
K2	10.30	1976	Unpublished, MDNR August 9-10, 1976	D Avenue
K3	8.17	1976	Unpublished, MDNR, August 9-10, 1976	R.R. trestle (Parchment)
K5	12.34	1976	Unpublished MDNR, August 9-10, 1976	Gull Street
K6	7.73	1976	Unpublished MDNR, August 9-10, 1976	Michigan Avenue (Portage Creek Confluence)
K2	1.60	1982	MDNR, November 1982	D Avenue
K3	1.00	1982	MDNR, November 1982	Commerce Street & R.R. crossing
K4	57.00	1982	MDNR, November 1982	Patterson Avenue
K4	13.00	1984	Creal, 1984	Patterson Avenue

TABLE A-4

KALAMAZOO RIVER SEDIMENT DATA

MAIN STREET, PLAINWELL TO PLAINWELL DAM: REACH 3
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
P8	7.81	1976	Unpublished MDNR, August 1976	Route 131, Plainwell
P10	2.58	1976	Unpublished MDNR, August 1976	R.R. trestle, Plainwell
P8	3.60	1982	MDNR, November 1982	Route 131 Bridge
P10	14.00	1982	MDNR, November 1982	R.R. crossing
*P1	26.80	1983	MDNR, November 1983	60' upstream of dam, south side, active depositional area, 18" grab sample in river
P6	16.60	1983	MDNR, November 1983	0.3 miles upstream of dam, north side, grab near present river level; top 1/4"
P6	24.50	1983	MDNR, November 1983	0.3 miles upstream of dam, north side, grab near present river level; sample without top 1/4"

MAIN STREET, PLAINWELL TO PLAINWELL DAM: REACH 3
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
P2	3.01 (0-4") 28.95 (8-10")	1983	MDNR, November 1983	100' upstream of dam, north side of river, 10" core; 2' above river level
P6	65.90 (0-4") 29.20 (8-12")	1983	MDNR, November 1983	0.15 miles upstream of dam, north side of river, 12" core; 4' below present river level
P5	37.40 (0-10")	1983	MDNR, November 1983	0.3 miles upstream of dam, north side of river, 10" core; 2' above river level; composite
P7	25.00 (0-10")	1983	MDNR, November 1983	0.75 miles upstream of dam, south side, 10" core; 2' above water level; composite

TABLE A-4
KALAMAZOO RIVER SEDIMENT DATA
PAGE TWO

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
P9	0.60 (0-4") 0.20 (6-10")	1983	MDNR, November 1983	1 mile upstream of dam, upstream of 131 Bridge, south side of river, 10" core; 2' above water level
*P1	0.81 (12") 0.64 (2') 0.18 (3') 0.21 (4') 0.21 (5') 0.08 (6') 0.08 (7') 0.37 (8') 0.08 (9') 0.21 (10')	1984	Unpublished MDNR, June 1984	3 meters upstream of dam; overlying water depth -- 0.3 meters
*P3	0.34 (12") 0.04 (2') 0.81 (3')	1984	Unpublished MDNR, June 1984	0.1 km upstream of dam on first bend, 3 meters from shore, overlying water depth -- 1.0 meter
*P5	0.18 (12") 0.13 (2') 0.17 (3') 0.17 (4-6')	1984	Unpublished MDNR, June 1984	0.4 km upstream of dam, 36' from left bank (north); overlying water depth -- 1.6 meters
*P8	0.08 (12") 0.08 (2') 0.08 (3')	1984	Unpublished MDNR, June 1984	0.5 km upstream of dam, on right bank(south); overlying water depth -- 1.6 meters

TABLE A-4
KALAMAZOO RIVER SEDIMENT DATA
PAGE THREE

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
P4	13.20 (12")	1986	Unpublished MDNR, August 1, 1986	
	14.60 (2')			
	1.30 (3')			
	1.20 (4')			
	1.10 (5')			
	1.20 (6')			
	1.20 (7')			
	0.83 (8')			

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* Represents instream samples

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TABLE A 5

KALAMAZOO RIVER SEDIMENT DATA

PLAINWELL DAM TO OTSEGO CITY DAM: REACH 4
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
M2	7.86	1985	Unpublished MDNR, January 1985	0.8 km upstream of dam, south side of river; east of Platt and Court Streets
M3	25.10	1985	Unpublished MDNR, January 1985	2.3 km upstream of dam, north side of river; 100 meters east of R.R. and 106 Street

PLAINWELL DAM TO OTSEGO CITY DAM: REACH 4
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
M1	57.00 (12") 30.30 (2") 5.80 (3") 4.24 (4") 0.81 (5")	1985	Unpublished MDNR, May 28, 1985	0.1 km upstream of dam; instream sample

TABLE A-6

KALAMAZOO RIVER SEDIMENT DATA

OTSEGO CITY DAM TO OTSEGO DAM: REACH 5
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
08	66.60	1976	Unpublished MDNR, August 1976	M-89 Otsego
08	27.00	1982	MDNR, 1982	M-89; down from 131 Bridge

OTSEGO CITY DAM TO OTSEGO DAM: REACH 5
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
02	11.00 (20")	1983	USFWS, May 20, 1983	
03	26.00 (20")	1983	USFWS, May 20, 1983	
03	28.00 (20")	1983	USFWS, May 20, 1983	
04	1.10 (0-6")	1983	USFWS, May 20, 1983	
04	17.00 (20")	1983	USFWS, May 20, 1983	
06	8.40 (20")	1983	USFWS, May 20, 1983	
05	6.60 (20")	1983	USFWS, May 20, 1983	
06	0.79 (20")	1983	USFWS, May 20, 1983	
07	8.30 (0-6")	1983	USFWS, May 20, 1983	
07	5.00 (20")	1983	USFWS, May 20, 1983	
*01	0.08 (12")	1984	Unpublished MDNR	0.1 km upstream of dam in existing river channel
	0.08 (3")			
	0.29 (4")			
	0.17 (5")			
	0.08 (6")			
	0.20 (7")			

* Represents instream samples

TABLE A-7

KALAMAZOO RIVER SEDIMENT DATA

OTSEGO DAM TO TROWBRIDGE DAM: REACH 8
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
T3	64.8	1983	Unpublished MDNR, June 1983	Grab sample at present water level
T3	81.0	1983	Unpublished MDNR, June 1983	Grab sample at present water level
T7	23.8	1983	Unpublished MDNR, June 1983	Grab sample 4' above water level

OTSEGO DAM TO TROWBRIDGE DAM: REACH 8
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
*T1	8.4 (0-2") 13.3 (17-18")	1983	MDNR, November 1983	South side of river channel, 150' upstream of dam; active depositional zone, 18" Eckman, 3' below river level
T4	16.7 (0-4") 50.8 (14-18")	1983	MDNR, November 1983	Upstream portion of downstream basin, 1.4 miles upstream; 18" core at river level
T4	3.8 (0-4") 7.4 (11-15")	1983	MDNR, November 1983	Upstream portion of downstream basin, 1.4 miles upstream; 15" core; 3' above water level
T5	44.2 (0-15")	1983	MDNR, November 1983	Channel between reservoir basins, 2.2 miles upstream of dam; 15" composited core
T6	3.8 (0-4") 8.8 (6-10")	1983	MDNR, November 1983	Middle portion of upstream reservoir basin; 10" core; 1' above river level; 2.5 miles upstream of dam

TABLE [illegible]-7
KALAMAZOO RIVER SEDIMENT DATA
PAGE TWO

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
T2	3.81 (12")	1984	Unpublished MDNR, August 1984	0.2 km upstream of dam on streambank next to existing channel; water level at 4'
	2.04 (3')			
	1.00 (4')			
	1.10 (5')			
	0.88 (6')			
	1.18 (7')			
	0.64 (8')			
T4	1.88 (12")	1984	Unpublished MDNR, August 1984	2.4 km upstream of dam on streambank next to existing channel; water level at 4'
	84.00 (2')			
	30.00 (3')			
	4.80 (4')			
	1.18 (5')			
	0.13 (6')			
	0.13 (7')			
	0.48 (8')			
	0.68 (9')			
	0.28 (10')			
	0.12 (11')			
	0.26 (12')			
T4	0.70 (12")	1985	Unpublished MDNR, August 1985	Upstream portion of downstream basin, 1.4 miles upstream of dam
	2.80 (2')			
	3.80 (3')			
	3.00 (4')			
	4.10 (5')			
	1.10 (6')			
	1.40 (7')			
	1.10 (8')			
	0.06 (9')			
	0.06 (10')			
	0.02 (11')			

* Represents instream samples

TABLE A-8

KALAMAZOO RIVER SEDIMENT DATA

CITY LINE OF ALLEGAN TO ALLEGAN CITY DAM: REACH 8
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
AC2	24.87	1976	Unpublished MDNR, August 8-10, 1976	Route 40-89
AC3	3.81	1985	Unpublished MDNR, January 1985	0.7 km upstream of dam, south of M-89, west side of river
AC4	6.47	1985	Unpublished MDNR, January 1985	1.4 km upstream of dam, east side in bay

CITY LINE OF ALLEGAN TO ALLEGAN CITY DAM: REACH 8
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
AC1	47.30 (0-2') 38.30 (3') 48.80 (4') 67.40 (5') 46.60 (6') 28.30 (7') 2.23 (8')	1985	Unpublished MDNR, May 28, 1985	0.4 km upstream of dam on east shore
AC2	4.88 (0-6")	1985	Unpublished MDNR, May 1985	0.6 km upstream of dam, composite of 6 samples taken of top 15 cm from east/west transect across river
AC2	45.60 (12") 16.20 (24") 13.90 (3') 0.95 (4')	1985	Unpublished MDNR, May 1985	0.8 km upstream of dam on west shore

TABLE A-8

KALAMAZOO RIVER SEDIMENT DATA

LAKE ALLEGAN: REACH 8
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
A1	5.58	1976	Unpublished MDNR, August 9-10, 1976	Lake Allegan; near dam
A1	2.26	1976	Unpublished MDNR, August 9-10, 1976	Route 89 (Lake Allegan)
A6	24.67	1976	Unpublished MDNR, August 9-10, 1976	Route 40-89 (Lake Allegan)

LAKE ALLEGAN: REACH 8
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
A_t2	13.90 (12-16")	1983	MDNR, November 1983	0.8 miles upstream of dam, 16" cores; transect
A3	11.00 (0-4")	1983	MDNR, November 1983	1.25 miles upstream of dam, in bay, 10" core
A_t4	14.10 (0-4") 26.20 (12-16")	1983	MDNR, November 1983	2 miles upstream of dam, 16" cores
A6	24.40 (0-4") 41.70 (4-8")	1983	MDNR, November 1983	2.1 miles upstream of dam, in bay; 8" core
A7	17.80 (0-4") 28.30 (8-12")	1983	MDNR, November 1983	Directly west of fairgrounds; about 4.75 miles upstream of dam, 12" core
A_t8	16.80 (0-4") 20.20 (8-12")	1983	MDNR, November 1983	Directly north of fairgrounds; about 5 miles upstream of dam, 12" cores

Note: Subscript t indicates samples were composites taken from transects.

TABLE A-10

KALAMAZOO RIVER SEDIMENT DATA

ALLEGAN DAM TO SAUGATUCK: REACH 10
SURFACE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
L1	0.04	1982	Horvath, 1984	North side of channel
L2	0.10	1982	Horvath, 1984	Mid channel near F&W service dock
L3	1.74	1982	Horvath, 1984	Deepest part of Kalamazoo Lake
L4	0.10	1982	Horvath, 1984	Downstream of U.S. 131 Bridge
L5	0.08	1982	Horvath, 1984	Midstream, downstream of Tyler Bayou
L6	0.10	1982	Horvath, 1984	Midstream in large wetland
L7	0.04	1982	Horvath, 1984	Midstream in large wetland
L8	0.07	1982	Horvath, 1984	Midstream, downstream of Indian Cut
L9	0.12	1982	Horvath, 1984	At side of channel, downstream of gun club
L10	0.10	1982	Horvath, 1984	Inside of bend out of main channel in a deposition zone
L11	0.03	1982	Horvath, 1984	Inside of first bend downstream of old R.R. bridge at New Richmond
L12	0.46	1985	Unpublished MDNR June 1985	20.3 km below dam; depositional area; top 2cm
L13	1.40	1985	Unpublished MDNR, June 1985	17.6 km below dam; north shore
L14	0.30	1985	Unpublished MDNR June 1985	14.8 km below dam; downstream end of island
L16	0.10	1985	Unpublished MDNR June 1985	12.8 km below dam, north shore
L17	0.08	1985	Unpublished MDNR June 1985	8.1 km below dam; backwater area at bayou
L18	0.73	1985	Unpublished MDNR, June 1985	7.4 km below dam; 30' from river before confluence
L19	0.36	1985	Unpublished MDNR, January 1985	6.5 km downstream of dam; Allegan Game Area, 50 mile north of M-89
L19	0.14	1985	Unpublished MDNR, January 1985	6.7 km downstream of Allegan Dam; 0.4 km north of M-89
L20	0.13	1985	Unpublished MDNR, June 1985	6.15 km below dam; backwater area

TABLE A 10
KALAMAZOO RIVER SEDIMENT DATA
PAGE TWO

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
120	0.05	1985	Unpublished MDNR, June 1985	5.0 km below dam; west shore
121	0.18	1985	Unpublished MDNR, June 1985	4.75 km below dam, on inside of bend
122	0.08	1985	Unpublished MDNR, June 1985	4.3 km below dam, east shore
123	0.25	1985	Unpublished MDNR, June 1985	4.0 km below dam, east of Swan Creek Marsh, upland ~26' from river
124	0.15	1985	Unpublished MDNR, January 1985	2.2 km downstream of dam; Koopman Marsh, west side of river, near river
124	0.20	1985	Unpublished MDNR, January 1985	2.2 km downstream of dam; Koopman Marsh, west side, 100 miles from river
124	1.11	1985	Unpublished MDNR, January 1985	2.1 km downstream of dam, Koopman Marsh, 60 miles from river
125	0.47	1985	Unpublished MDNR, June 1985	2.0 km downstream of dam; on inside of bend
126	0.04	1985	Unpublishd MDNR, June 1985	1.7 km downstream of dam; north shroe
127	0.10	1985	Unpublished MDNR, June 1985	0.8 km downstream of Allegan Dam; north shore
128	0.13	1985	Unpublished MDNR, January 1985	0.6 km downstream of dam; Koopman Marsh; east side by public launch

ALLEGAN DAM TO SAUGATUCK: REACH 10
CORE SAMPLES

Sample Number	PCB Concentration (ppm)	Year	Reference	Comments
112	0.62 (4-6")	1985	Unpublished MDNR, June 1985	20.3 km below dam, depositional area, 10-15 cm deep
116	0.36 (0-2")	1985	Unpublished MDNR, June 1985	10.9 km below dam, depositional area, surface 5 cm
116	0.24 (4-6")	1985	Unpublished MDNR, June 1985	10.9 km below dam, depositional area, 10-15 cm deep

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DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
			MORROW POND						
			SPECIES: CARP						
July 1971								5.07	1.49
Aug 1976	20		5		<0.20	1.80	0.20	2.10	0.40
Sept 1981	25	8.0		F	0.20	2.40	<0.10	2.60	1.50
	26	9.1		M	0.85	1.60	<0.10	2.45	3.80
	25	7.3		F	<0.10	<0.10	<0.10	<0.10	0.98
	24	7.8		F	<0.10	1.10	<0.10	1.10	2.00
	21	4.4		F	<0.10	0.29	<0.10	0.29	3.50
	19	3.6		F	<0.10	<0.10	<0.10	<0.10	0.45
	21	4.4		F	<0.10	<0.10	<0.10	<0.10	0.36
	20	4.4		F	3.20	4.90	<0.10	8.10	3.45
	25	6.8		F	<0.10	0.56	<0.10	0.56	0.20
MEAN=	23	6.4						1.71	1.80
July 1985	19	3.0	3	M	<0.13	2.30	0.79	3.09	2.70
	18	2.6	4	F	<0.13	1.80	0.37	2.17	1.20
	18	2.5	3	F	<0.13	5.50	0.40	5.90	1.20
	17	2.4	2	M	<0.13	1.80	0.42	2.22	2.80
	20	3.3	4	M	<0.13	1.60	0.64	2.24	1.20
	19	3.1	3	F	<0.13	2.05	0.67	2.72	1.35
	19	3.7	3	M	<0.13	1.80	0.48	2.28	1.50
	19	3.3	3	F	<0.13	1.90	0.64	2.54	1.30
	18	2.7	3	M	<0.13	0.28	0.11	0.39	0.10
	19	3.0	3	F	<0.13	0.52	0.22	0.74	0.70
	19	2.1	3	F	<0.13	2.60	0.89	3.49	1.30
	19	3.5	3	M	<0.13	7.30	1.60	8.90	5.60
	18	2.7	3	M	<0.13	2.40	0.89	3.29	1.40
	17	2.6	3	M	<0.13	2.20	0.63	2.83	2.10
	20	3.7	4	F	<0.13	0.56	0.31	0.87	0.80
	20	3.8	3	F	<0.13	2.10	<0.13	2.10	2.50
	18	2.5	3	M	<0.13	0.55	<0.13	0.55	0.80
	20	3.4	4	M	<0.13	0.65	<0.13	0.65	0.85
	20	3.8	4	M	<0.13	2.20	<0.13	2.20	1.60
	19	3.1	3	F	<0.13	2.10	<0.13	2.10	1.30
MEAN=	19	3.0	3					2.56	1.62
July 1986	19	2.9	3	M		7.25		7.25	7.9
	19	3.3	3-4	M		2.25		2.25	2.1
	18	2.9	3	F		0.60		0.60	1.1
	18	2.5	3	M		1.23		1.23	1.1
	19	3.4	4	F		2.10		2.10	2.3
	19	3.5	3	F		0.64		0.64	1.1
	18	2.9	3	M		1.27		1.27	0.9
	17	2.5	3	F		1.03		1.03	1.1

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	18	2.8	3	M		6.16		6.16	2.1
	18	3.2	3	M		5.72		5.72	5.1
	19	3.3	3	F		2.02		2.02	2.2
	17	2.4	2	F		0.89		0.89	0.8
	19	2.8	3	F		1.31		1.31	1.0
	19	3.3	3	F		6.15		6.15	5.9
	19	3.3	3	M		9.65		9.65	7.5
	19	3.1	3	M		2.42		2.42	1.1
	18	2.5	3	M		1.59		1.59	0.5
	18	3.0	3	F		2.51		2.51	1.6
	20	3.9	3-4	F		1.81		1.81	1.7
	20	4.1	3-4	F		12.69		12.69	1.5
MEAN=	18	3.1	2					3.46	2.4

SPECIES:BASS

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
June 1976			3		<0.20	<0.20	<0.20	< 0.20	0.70
Sept 1981	13	1.1		F	0.09	0.08	<0.10	0.17	0.21
	14	1.2		F	<0.10	<0.10	<0.10	< 0.10	0.16
	9	0.4		F	<0.10	<0.10	<0.10	< 0.10	0.18
	8	0.3			<0.10	0.51	<0.10	0.51	0.59
	7	0.2			<0.10	0.15	<0.10	0.15	0.23
	14	1.5		M	<0.10	1.80	<0.10	1.80	1.40
	14	1.4		F	0.24	0.55	<0.10	0.79	0.38
	13	1.3		F	<0.10	0.14	<0.10	0.14	0.28
	12	0.8		F	<0.10	<0.10	<0.10	< 0.10	0.14
	11	0.7		F	<0.10	0.29	<0.10	0.29	0.25
	11	0.7		F	<0.10	<0.10	<0.10	< 0.10	0.09
	11	0.6		F	<0.10	<0.10	<0.10	< 0.10	0.10
	10	0.6		F	<0.10	0.17	<0.10	0.17	0.19
	10	0.6		F	<0.10	0.15	<0.10	0.15	0.15
	10	0.5		M	<0.10	<0.10	<0.10	< 0.10	0.42
	9	0.4		M	<0.10	<0.10	<0.10	< 0.10	0.11
	9	0.3			<0.10	0.39	<0.10	0.39	0.30
	8	0.3			<0.10	<0.10	<0.10	< 0.10	0.21
	8	0.3			<0.10	0.90	<0.10	0.90	0.98
	8	0.3			<0.10	0.54	<0.10	0.54	0.48
	8	0.2			<0.10	0.61	<0.10	0.61	0.64
	17	3.5			<0.10	0.22	<0.10	0.22	0.16
	12	1.4			<0.10	0.25	<0.10	0.25	1.02
MEAN=	11	0.8						0.34	0.38
July 1985	14	1.2	4	M		1.60	0.35	1.95	2.00
	12	0.7	3	M		1.30	0.24	1.54	1.10
	12	0.7	3	M		0.95	0.21	1.16	0.30
	13	1.0	4	M		1.10	0.34	1.44	0.80
	9	0.3	2	M		0.66	0.13	0.79	0.50
	10	0.4	3	M		0.99	0.21	1.20	0.40

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB MG/KG)	FAT (%)
	10	0.4	3	M		0.85		0.85	0.70
MEAN=	11	0.7	3					1.28	0.83
			SPECIES: NORTHERN PIKE						
July 1971	30					17.60		17.60	1.25
Aug 1976					<0.20	3.10	0.60	3.70	0.50
Sept 1981	17.00	1.10		M	<0.10	<0.10	<0.10	<0.10	0.09
			SPECIES:WHITE SUCKER						
July 1971						5.50		5.50	0.38
Aug 1976					<0.20	1.80	0.20	2.00	1.10
			RIVER STREET						
			SPECIES:CARP						
July 1971						8.87		8.87	2.56
			SPECIES:BASS						
Aug 1976					<0.20	1.20	<0.20	1.20	0.90
					<0.20	0.40	<0.20	0.40	0.50
			SPECIES:WHITE SUCKER						
July 1971						18.31		18.31	1.48
			SPECIES:ROCK BASS						
July 1971						2.26		2.26	0.51
			SPECIES:BULLHEAD						
July 1971						3.26		3.26	0.96
			MOSEL AVENUE						
			SPECIES: CARP						
July 1971					109.90	54.66		164.50	20.78
June 1976	21		4		3.30	4.20	0.50	8.00	2.60
Sept 1981	24	7.0		F	0.63	2.70	<0.10	3.33	0.72

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA, MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	17	3.3		M	0.74	1.80	<0.10	2.54	2.70
	17	2.8		M	1.80	1.70	<0.10	3.50	2.60
	17	3.2		M	1.50	2.30	<0.10	3.80	3.40
	18	4.1		F	1.30	2.20	<0.10	3.50	2.90
	18	2.8		M	0.52	1.00	<0.10	1.52	1.40
	16	2.8		M	0.75	1.10	<0.10	1.85	1.60
	16	2.5		M	0.55	0.76	<0.10	1.31	1.30
	15	2.0		M	0.28	0.18	<0.10	0.46	0.53
	16	2.5		F	0.97	1.40	<0.10	2.37	3.60
	16	2.1		M	0.26	0.22	<0.10	0.48	0.34
	17	3.0		F	0.54	0.69	<0.10	1.23	1.20
	17	2.8		F	0.42	0.84	<0.10	1.26	2.50
	19	3.6		F	0.36	0.53	<0.10	0.89	1.90
	19	4.3		F	1.90	3.70	<0.10	5.60	6.40
	18	2.6		F	<0.10	0.33	<0.10	0.33	0.10
	16	2.3		F	<0.10	0.33	<0.10	0.33	0.78
	27	12.8		F	1.30	6.40	<0.10	7.70	3.03
MEAN=	18	3.8						2.33	2.06
July 1983	19	5.1		F				3.24	2.20
	18	4.7		F				3.06	2.40
	18	3.4		M				6.53	4.00
	17	2.7		F				1.57	1.00
	15	2.1		M				1.46	0.64
	18	4.3		F				6.04	4.30
	20	5.8		F				4.30	2.50
	17	3.4		F				0.98	1.40
	19	5.4		F				3.84	4.30
	20	4.7						1.90	2.20
	21	5.8		F				1.78	0.59
MEAN=	18	4.3						3.50	2.30
July 1985	18	3.1	3	M	0.56	3.50	1.10	5.16	1.25
	17	3.0	3	M	<0.13	2.70	0.60	3.30	0.50
	19	4.5	3	F	1.40	4.20	0.82	6.42	3.55
	18	3.7	3	F	0.86	2.70	0.55	4.11	1.90
	18	3.0	3	M	<0.13	3.60	0.87	4.47	1.20
	17	2.7	3	F	0.56	4.60	0.95	6.11	1.00
	19	3.7	3	M	0.68	3.55	0.71	4.94	4.10
	19	3.2	3	M	0.88	4.00	0.73	5.61	3.35
	20	4.4	4	F	2.40	6.40	1.40	10.20	4.85
	18	3.0	3	M	1.20	4.90	1.10	7.20	1.35
	19	3.8	3	F	0.71	2.20	0.65	3.56	1.50
	19	3.5	3	M	0.62	3.20	0.73	4.55	0.25
	18	3.8	3	M	4.00	5.20	1.60	10.80	9.45
	17	2.2	3	M	<0.13	1.00	0.42	1.42	0.20
	18	3.5	3	M	0.71	1.60	0.43	2.74	0.70
	19	3.7	3	M	0.20	2.20	0.42	2.82	0.20
	17	2.5	3	M	0.74	1.70	0.47	2.91	1.05
	18	3.1	3	M	0.52	3.60	0.96	5.08	0.80

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	18	4.0	3	M	0.37	2.40	0.53	3.30	[illegible].30
MEAN=	18	3.4	3					4.98	[illegible].57
July 1986	19	6.1	3			2.25		2.25	[illegible].30
	18	3.1	2	F	1.45		0.84	2.29	[illegible].70
	17	2.2	2	M		1.58		1.58	[illegible].20
	19	3.9	3	F	6.83		2.33	9.16	5.70
	20	5.3	3	F	2.63		0.75	3.38	[illegible].60
	18	4.3	2	F	3.12		1.40	4.52	[illegible].50
	19	4.0	2		1.40	1.33		2.73	[illegible].70
	17	3.4	2		2.81	2.22		5.03	5.20
	18	4.1	2	F	0.73	0.75		1.48	[illegible].30
	20	5.9	3	F	1.92	1.65		3.57	[illegible].10
	20	4.4	3	M	4.72	2.92		7.64	7.40
	17	3.1	2	M	2.97	2.70		5.67	6.10
	19	4.4	3	F	1.25	1.22		2.47	[illegible].80
	17	4.0	2	F	1.06	1.60		2.66	[illegible].20
	20	4.4	3	M	2.47	1.73		4.20	6.10
	18	3.8	2	F	3.16	2.50		5.66	5.10
	19	4.4	2	F	6.19	4.90		11.09	11.90
	18	4.2	2	F	6.32	4.70		11.02	8.00
	20	5.1	3	F	2.92	1.69		4.61	[illegible].90
	18	3.1	2	F	1.16	1.48		2.64	[illegible].30
MEAN=	18	4.2	2					4.68	4.1
			SPECIES: BASS						
Sept 1981	9	0.4		F	0.83	1.30	<0.10	2.13	[illegible].40
	15	2.0		F	<0.10	0.37	<0.10	0.37	[illegible].72
	10	0.5		F	<0.10	0.35	<0.10	0.35	[illegible].62
MEAN=	10	0.8						0.95	[illegible].91
July 1985	17	1.8	4	M	<0.13	1.25	0.25	1.50	[illegible].13
	10	0.6	3	M	<0.13	1.50	0.39	1.89	[illegible].21
MEAN=	13	1.2	4					1.69	[illegible].17
			SPECIES:BLUEGILL						
Sept 1981	7	0.4			0.43	0.48	<0.10	0.91	4.10
	7	0.3		F	<0.10	0.46	<0.10	0.46	[illegible].40
	8	0.4		M	0.50	0.65	<0.10	1.15	[illegible].20
	7	0.3		F	<0.10	0.93	<0.10	0.93	[illegible].20
	7	0.3		M	<0.10	0.65	<0.10	0.65	[illegible].10
	7	0.3		F	0.59	0.52	<0.10	1.11	[illegible].80
	7	0.3		F	0.34	0.90	<0.10	1.24	[illegible].90
MEAN=	7	0.3						0.92	[illegible].96

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

:E	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
			SPECIES:BLACK CRAPPIE						
Sept 1981	8	0.4		M	0.43	2.60	<0.10	3.03	6.20
			SPECIES:ROCK BASS						
Sept 1981	7	0.3		M	0.38	1.10	<0.10	1.48	1.30
			SPEICES:WHITE SUCKER						
July 1971					38.42	18.47		56.89	1.89
			PLAINWELL DAM						
			SPECIES: CARP						
Julu 1971	11				12.52	6.23		18.75	1.70
					14.94	7.37		22.31	1.94
June 1976	21		5		<0.20	12.00	0.90	12.90	6.60
					11.00	2.80	<0.20	13.80	5.90
Sept 1981	17	3.0			0.49	1.90	<0.10	2.39	0.48
	8	0.3			1.30	<0.10	<0.10	1.30	0.81
	8	0.3		F	0.49	0.34	<0.10	0.83	0.49
	18	3.1		F	3.80	0.93	<0.10	4.73	2.25
	23	8.8		F	6.50	2.70	<0.10	9.20	1.90
	8	0.4			0.60	0.30	<0.10	0.90	0.74
MEAN=	14	2.7						3.22	1.11
July 1983	21	4.7		M				3.60	1.20
	21	3.8		M				0.92	0.06
	18	3.2		M				3.71	1.70
	22	5.6		M				3.47	1.00
	18	3.0		M				4.13	2.30
	17	2.5		M				3.08	1.50
	18	3.2		M				5.21	2.60
	20	3.6		M				7.59	3.30
	22	5.6		M				0.88	1.20
	24	8.0		M				11.70	8.60
	17	3.8		M				15.90	6.80
MEAN=	20	4.3						5.50	2.30
..ly 1985	16	2.1	2	F	1.20	1.70	0.27	3.17	3.00
	19	3.1	3	M	<0.13	1.20	0.37	1.57	0.30
	19	2.7	3	M	1.20	4.20	0.60	6.00	2.80
	16	3.0	4	M	0.85	2.30	0.55	3.70	1.45

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	19	3.6	3	F	2.50	4.30	0.80	7.60	2.20
	19	3.[illegible]	3	M	0.96	2.20	0.41	3.57	1.50
	16	3.[illegible]	3	M	0.54	1.50	0.31	2.35	1.40
	16	2.5	3	M	<0.13	1.30	0.34	1.64	0.40
	17	2.5	3	M	0.48	8.10	1.40	9.98	4.30
	18	2.5	3	M	<0.13	2.50	0.69	3.19	0.40
	17	2.7	3	M	1.00	2.10	0.48	3.58	2.50
	19	3.4	4	F	2.00	2.50	0.38	4.88	4.40
	19	3.3		M	0.89	4.90	0.76	6.55	2.60
	19	3.5		M	2.30	5.90	1.00	9.20	5.60
	18	3.5		F	2.40	5.60	0.81	8.81	3.50
	17	2.5		M	0.23	2.30	0.70	3.23	1.20
	18	2.9		F	0.90	2.85	0.56	4.31	1.95
	19	3.3		M	1.00	9.60	1.90	12.50	6.40
	19	3.4		M	0.93	2.80	0.44	4.17	1.80
	18	3.[illegible]		F	0.43	4.20	0.81	5.44	0.10
MEAN=	18	3.[illegible]	3					5.27	2.39
July 1986	18	2.5	2	M			4.10	4.10	0.3
	18	3.[illegible]	2	F	3.16	2.20		5.36	3.5
	19	2.9	2-3		0.51		0.83	1.34	0.8
	19	3.[illegible]	2-3	M	0.98	1.54		2.52	1.1
	18	3.[illegible]	3	M	0.30	0.20		0.50	3.0
	19	4.[illegible]	3	M	2.00	1.76		3.76	2.4
	18	3.[illegible]	2	M			3.32	3.32	0.4
	18	3.[illegible]	2	M	5.07	2.97		8.04	5.2
	21	4.8	3	M	3.55	2.78		6.33	3.7
	20	4.[illegible]	3	M	2.97	1.96		4.93	2.2
	18	4.[illegible]	3	F	3.12	1.77		4.89	3.2
	19	3.5	3	M	0.94	2.74		3.68	1.0
	21	5.6	3	M	2.55	6.91		9.46	6.3
	19	4.[illegible]	3	F	4.88	2.26		7.14	6.3
	17	3.[illegible]	2	F	1.16	0.77		1.93	1.7
	17	2.7	2	M	0.83	1.66		2.49	1.4
	16	2.[illegible]	2	M	0.77	0.35		1.12	1.6
	19	3.4	2-3	M	1.33	0.98		2.31	1.9
	18	3.[illegible]	2-3	M	3.38	2.74		6.12	5.7
	18	3.[illegible]	2	M	0.69	0.64		1.33	1.1
	21	4.6	3	M	3.73	2.25		5.98	5.2
MEAN=	19	3.5	2					4.13	2.8

SPECIES: BASS

Sept 1981	10	0.5		F	0.47	<0.10	<0.10	0.47	0.14
July 1985	11	0.5	3	F	0.36	2.50	0.42	3.28	1.20

SPECIES: NORTHERN PIKE

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
Sept 1981	25	3.4		M	0.29	<0.10	<0.10	0.29	1.14
	25	3.9		M	0.36	<0.10	<0.10	0.36	1.19
	26	3.5		M	0.37	<0.10	<0.10	0.37	1.14
	23	2.5		M	0.59	0.37	<0.10	0.96	1.25
MEAN =	25	3.3						0.50	1.18
			SPECIES:BLUEGILL						
Sept 1981	7	0.4			0.85	0.43	<0.10	1.28	1.40
	7	0.3		F	0.68	<0.10	<0.10	0.68	0.75
MEAN =	7	0.4						0.98	1.08
			SPECIES: PUMPKINSEED						
Sept 1981	7	0.2		M	0.96	1.20	<0.10	2.16	0.66
			SPECIES: BLACK CRAPPIE						
Sept 1981	11	0.8			1.10	0.18	<0.10	1.28	0.46
	8	0.4			0.61	<0.10	<0.10	0.61	0.51
MEAN =	9.5	0.6						0.95	0.49
			SPECIES: BROWN BULLHEAD						
Sept 1981	9	0.5		F	0.14	0.16	<0.10	0.30	0.65
	8	0.4			0.52	0.14	<0.10	0.66	0.22
	9	0.4			0.40	<0.10	<0.10	0.40	0.11
MEAN =	9	0.4						0.45	0.33
			SPECIES: YELLOW BULLHEAD						
July 1971					4.48	2.22		6.70	0.76
Sept 1981	10	0.5			0.28	<0.10	<0.10	0.28	0.17
	11	0.8			0.44	<0.10	<0.10	0.44	0.38
MEAN =	11	0.7						0.36	0.28
			SPECIES:CHANNEL CATFISH						
Sept 1981	12	0.4			1.10	0.48		1.58	0.38
			SPECIES:WHITE SUCKER						
1971					14.25	7.00		21.25	1.42
Aug 1976					<0.20	3.30	1.00	4.30	1.00

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
					2.50	0.40	<0.20	2.90	1.00
			OTSEGO DAM						
			SPECIES:CARP						
July 1971					39.22	19.50		58.72	5.66
Aug 1976					8.10	3.20	0.50	11.80	1.20
			SPECIES:BASS						
Aug 1976					1.10	0.40	<0.20	1.50	0.80
			SPECIES:WHITE SUCKER						
July 1971					8.47	4.21		12.68	0.78
Aug 1976					3.00	1.00	<0.20	4.00	0.50
			TROWBRIDGE DAM						
			SPECIES:CARP						
July 1971					2.71	1.35		4.06	0.36
			SPECIES:WHITE SUCKER						
July 1971						12.14		12.14	0.45
			SPECIES:NORTHERN PIKE						
July 1971					5.54	2.68		8.22	0.44
			LAKE ALLEGAN						
			SPECIES: CARP						
July 1971					4.91	2.41		7.32	0.68
Aug 1976	18		4		5.80	1.60	<0.20	7.40	0.80
Sept 1981	15	1.8		F	1.10	3.20	<0.10	4.30	2.00
	24	7.7		M	0.97	11.00	<0.10	11.97	6.00
	14	1.7		M	0.34	0.94	<0.10	1.28	0.37
	14	2.1		M	0.61	2.40	<0.10	3.01	0.88
	14	1.7		M	12.00	4.60	<0.10	16.60	4.00
	16	2.6		F	33.00	14.00	<0.10	47.00	7.50
	14	1.8		M	1.60	3.50	<0.10	5.10	4.20
	17	2.9		F	0.33	0.98	<0.10	1.31	0.54
	16	2.7		F	1.60	3.50	<0.10	5.10	3.30
	16	2.4		M	1.00	2.70	<0.10	3.70	1.80

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

TE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	15	2.1		F	1.10	3.50	<0.10	4.60	1.90
	14	1.8		F	1.10	6.90	<0.10	8.00	3.00
	-14	1.9		M	7.00	2.90	<0.10	9.90	2.90
	25	8.4		M	2.50	3.20	<0.10	5.70	11.00
	25	19.8		F	<0.10	10.00	<0.10	10.00	19.00
	15	2.0		M	0.66	2.50	<0.10	3.16	1.20
	14	1.7		M	0.52	1.35	<0.10	1.87	0.74
	15	2.3		M	0.63	1.90	<0.10	2.53	1.60
	17	2.9		M	0.84	1.80	<0.10	2.64	1.50
	15	2.3		F	9.90	1.80	<0.10	11.70	5.00
MEAN=	17	3.6						7.97	3.92
July 1983	17	2.5		M				5.03	0.83
	17	2.3		F				1.60	1.10
	18	3.0		M				1.69	0.46
MEAN=	17	2.6						2.80	0.80
July 1985	16	2.2	2	F	0.41	1.50	<0.13	1.91	0.85
	16	2.3	2	F	0.90	2.20	<0.13	3.10	1.20
	15	1.7	3	M	0.72	2.30	0.47	3.49	0.45
	16	2.2	2	F	0.62	3.70	0.60	4.92	1.55
	15	1.9	2	F	3.00	5.90	0.99	9.89	3.00
	18	2.8	3	M	0.63	1.70	0.27	2.59	1.20
	16	1.9	2	M	1.80	11.00	1.20	14.00	3.65
	16	2.1	2	F	1.20	2.60	0.50	4.30	1.70
	16	1.9	2	M	1.30	2.40	0.43	4.13	1.60
	15	2.3	2	F	1.20	3.00	0.60	4.80	1.85
	15	1.8	2	M	0.85	2.10	0.49	3.44	2.70
	17	1.8	2	M	2.60	5.10	0.88	8.58	2.50
	17	2.2	2	M	1.30	4.80	0.66	6.76	2.35
	16	2.5	2	F	0.90	1.50	<0.13	2.40	0.85
	17	2.3	2	F	0.53	1.00	<0.13	1.53	0.70
	18	2.6	2	M	0.76	1.20	<0.13	1.96	1.05
	16	1.7	2	F	0.73	1.40	<0.13	2.13	1.00
	18	2.7	2	F	0.84	1.50	<0.13	2.34	0.90
	16	1.9		M	<0.13	1.60	<0.13	1.60	1.25
MEAN=	16	2.1	2					4.41	1.60
July 1986	12	0.9	1		0.53	0.58		1.11	0.60
	12	0.7	1			1.36		1.36	0.60
	20	3.7	3		9.32	5.02		13.34	2.50
	-		3		2.39	1.22		3.61	1.40
	13	1.1		F	1.41	1.03		2.44	1.10
	13	0.9		F	0.88	0.88		1.76	0.70
	13	0.7	1	F		0.17		0.17	0.50
	12	0.6	1	F	0.20	0.31		0.51	0.60
	13	0.9	1	F	0.69	0.62		1.31	0.80

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	12	0.7	1	F	2.45	1.85		4.30	1.40
	14	1.5	1	F		0.46		0.46	0.50
	13	1.1	1	F	1.70	1.23		2.93	1.10
	14	1.4	1	F	2.48	1.62		4.10	1.20
	12	0.7	1	F	0.20	0.27		0.47	0.70
	12	0.7	1	F	1.84	1.81		3.65	1.00
	15	1.9	2	F	3.12	1.96		5.08	1.80
	15	1.9	2	F	3.41	1.95		5.36	1.40
	15	1.8	2	F	5.73	2.97		8.70	1.90
	16	1.9	2	F	1.20	1.32		2.52	0.60
	17	2.4	2	F	0.33	0.27		0.60	0.40
	13	1.0	2	F	0.32	0.33		0.65	0.70
	15	1.5	2	F	3.46	2.16		5.62	1.30
	15	1.7	2	F	0.94	1.05		1.99	0.70
	14	1.3	2	F	6.88	3.99		10.87	2.70
	12	0.8	2	F	0.24	0.39		0.63	0.40
	16	1.9	2	F	4.28	2.62		6.90	1.50
	15	1.6	2	F	1.15	1.34		2.49	0.60
	18	3.1	2	F	6.92	3.46		10.38	3.60
	18	3.3	2	F	3.11	1.89		5.00	2.30
	15	2.0	2	F	0.62	0.53		1.15	1.20
	13	1.1	2	F	3.82	2.17		5.99	1.40
	17	2.6	2	F	3.14	1.71		4.85	1.70
	14	1.5	2	F	5.16	3.50		8.66	2.30
	16	2.2	2	F	2.59	1.63		4.22	1.00
	14	1.6	2	F	7.62	4.37		11.99	2.10
	12	0.7	2	F	1.40	0.89		2.29	0.90
	13	1.1	2	F	6.51	2.58		9.09	2.70
	17	2.3	2	F	1.95	1.22		3.17	1.20
	12	0.9	2	F	1.52	1.31		2.83	0.70
	19	3.1	3	F	0.45	0.60		1.05	0.40
	19	3.1	3	F	1.67	1.33		3.00	0.80
	20	3.4	3	F	0.48	0.38		0.86	0.40
	18	3.1	3	F	1.17	0.82		1.99	0.70
	18	3.0	3	F	0.70	0.65		1.35	0.60
	24	5.6	4	F		1.55		1.55	0.20
	22	5.0	4	F		2.32		2.32	0.40
	14	0.9	1	M	0.07	0.20		0.27	0.40
	13	0.8	1	M	1.85	1.56		3.41	1.50
	12	0.7	1	M	0.46	0.58		1.04	0.70
	13	1.1	1	M	1.37	1.38		2.75	1.30
	11	0.7	1	M	1.90	1.65		3.55	1.00
	14	1.3	1	M	1.76	1.48		3.24	0.80
	17	2.3	2	M	1.16	0.93		2.09	0.90
	17	2.3	2	M	2.76	1.66		4.42	1.30
	14	1.1	2	M	0.56	0.52		1.08	0.50
	17	2.8	2	M	4.04	2.28		6.32	2.30
	14	1.1	2	M	2.04	1.51		3.55	0.80
	16	1.9	2	M	0.25	0.50		0.75	0.40
	17	2.4	2	M	3.13	2.12		5.25	1.10
	16	1.8	2	M	8.25	4.81		13.06	2.20
	18	2.6	2	M	3.71	1.97		5.68	1.80

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

Y	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	16	2.2	2	M	1.23	0.92		2.15	0.70
	15	1.7	2	M	2.62	1.50		4.12	1.10
	13	0.9	2	M	0.60	0.45		1.05	0.80
	17	2.3	2	M	1.44	1.18		2.62	0.80
	18	2.8	2	M	4.68	2.95		7.63	1.50
	17	2.2	2	M	2.34	1.30		3.64	1.30
	13	1.0	2	M	6.05	2.48		8.53	2.80
	13	1.0	2	M	1.52	0.43		1.95	1.00
	17	2.1	2	M	4.44	3.03		7.47	1.30
	13	0.8	2	M		0.09		0.09	0.60
	17	2.1	2	M	3.87	2.98		6.85	1.40
	17	2.3	2	M	1.75	1.46		3.21	0.70
	17	2.5	2	M	9.01	3.87		12.88	2.60
	19	3.1	2	M	0.99	22.96		23.95	2.60
	16	1.9	2	M	0.95	0.82		1.77	0.60
	14	1.4	2	M	2.23	1.53		3.76	0.90
	14	1.0	2	M	7.64	4.99		12.63	2.40
	19	3.3	3	M	0.34	0.23		0.57	0.30
	20	4.0	3	M	1.98	1.11		3.09	0.90
	18	2.3	3	M	4.23	2.43		6.66	1.70
MEAN=	15	1.9	2					4.27	1.19

SPECIES: BASS

Aug 1976	10		3		1.70	0.70	<0.20	2.40	0.40
Sept 1981	9	0.4		F	0.61	<0.10	<0.10	0.61	0.18
	8	0.3		F	0.84	<0.10	<0.10	0.84	0.45
	7	0.2		F	0.48	<0.10	<0.10	0.48	0.22
	15	1.8		F	0.84	0.15	<0.10	0.99	0.35
	12	1.4			1.30	<0.10	<0.10	1.30	0.54
	9	0.9		F	0.79	<0.10	<0.10	0.79	0.42
	8	0.3		F	1.30	<0.10	<0.10	1.30	0.45
	8	0.3		F	2.20	<0.10	<0.10	2.20	0.66
	12	0.8		M	1.30	<0.10	<0.10	1.30	0.44
MEAN=	10	0.7						1.09	0.41
July 1985	15	1.7	2	M	0.49	1.85	<0.13	2.34	0.25
	12	0.8	2	M	0.43	1.60	<0.13	2.03	0.60
	12	0.8	2	M	<0.13	1.90	<0.13	1.90	0.75
	13	1.4	2	M	<0.13	1.60	<0.13	1.60	0.65
	11	0.7	2	M	0.90	2.40	<0.13	3.30	1.55
	12	0.8	2		1.60	4.30	0.64	6.54	2.65
	16	1.3	3	M	0.44	1.80	<0.13	2.24	1.00
	16	1.6	4	M	<0.13	3.90	0.96	4.86	0.20
	14	1.3	3	M	0.41	2.00	<0.13	2.41	0.75
	12	0.6	2	M	<0.13	0.67	<0.13	0.67	0.68
MEAN=	13	1.1	2					2.79	0.91

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
			SPECIES: NORTHERN PIKE						
July 1971	14				9.15	4.29		13.44	0.46
Aug 1976					1.60	0.50	<0.20	2.10	0.30
			SPECIES: WHITE SUCKER						
July 1971	9				9.37	4.40		13.77	0.50
Aug 1976					5.80	1.60	<0.20	7.40	0.50
			SPECIES: BULLHEAD						
July 1971	6				7.18	3.47		10.65	1.00
			SAUGATUCK						
			SPECIES: CARP						
July 1971					30.60	14.80		45.40	2.10
July 1976	19				26.00	12.00	<1.00	36.00	
May 1978	24		5-6		27.00	10.00	<0.60	37.00	12.70
	27				48.00	15.00	<5.00	63.00	23.40
					175.00	55.00	1.00	231.00	10.00
Sept 1981	20	4.3	3	M				8.40	
	20	4.4	3	F				5.20	
	22	5.2		F				3.40	
	22	5.0		M				16.00	
	21	4.7		M				9.10	
	21	4.0	2	F				7.90	
	19	3.4	3	M				5.00	
	20	3.9	2	M				2.90	
	20	4.1	3	F				4.50	
	20	3.8	3	M				8.00	
	20	3.9	3	F				2.00	
MEAN=	21	4.3	3					6.58	
July 1983	23	5.4		F				1.16	1.30
	24	6.6		F				25.70	13.00
	21	4.7		M				13.80	7.70
	18	3.4		F				2.63	3.10
	21	4.7		F				1.14	3.90
	19	3.4		M				10.30	7.00
	19	3.6		M				4.91	2.40

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

E	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	16	2.1		M				1.39	1.80
	19	3.6		M				24.20	16.00
	- 16	2.5		M				1.03	1.40
	20	4.1		F				7.15	4.00
MEAN=	20	4.0						8.50	5.60
July 1985	19	3.3	3	F	1.60	2.00	0.29	3.89	6.90
	18	2.8	2	M	0.87	1.10	0.17	2.14	6.90
	18	2.8	2	M	0.42	1.10	0.16	1.68	3.40
	18	2.8	2	M	0.32	2.40	0.40	3.12	3.40
	17	2.3	2	M	<0.13	0.20	<0.13	0.20	1.30
	19	3.6	3	M	0.57	3.60	0.57	4.74	5.40
	20	3.6	2	M	0.63	1.40	0.17	2.20	4.70
	20	3.6	3	F	0.52	2.20	0.36	3.08	3.30
	19	3.1	2	M	1.10	1.60	0.25	2.95	5.10
	17	2.3	2	M	0.26	0.52	0.08	0.86	2.70
	20	3.8	2	M	1.10	2.30	0.34	3.74	3.30
	19	3.7	2	F	1.80	2.60	0.38	4.78	12.70
	19	3.4	2	M	1.10	3.60	0.56	5.26	10.10
	18	2.8	3	M	0.44	1.70	0.28	2.42	4.80
	19	3.0	3	M	0.36	2.30	0.40	3.06	3.90
	19	3.4	2	M	0.17	0.97	0.18	1.32	0.95
	19	3.5	3	M	0.80	4.50	0.68	5.98	11.50
	18	3.6	3	F	1.60	2.50	0.33	4.43	7.20
	20	4.1	3	F	0.64	5.30	0.88	6.82	7.40
	20	4.1	3	M	0.42	7.40	1.30	9.12	5.80
MEAN=	19	3.3	2					3.59	5.54
July 1986	17	4.0	2	F	0.29	0.22		0.51	0.6
	20	4.2	3	M	3.35	2.12		5.47	3.6
	19	3.7	3	F	4.43	2.73		7.16	5.8
	20	4.6	3	F	1.28	0.76		2.04	4.8
	20	4.2	3	M	2.43	1.06		3.49	8.3
	20	4.2	2	F	2.45	1.64		4.09	4.8
	20	4.1	2	M	0.90	0.39		1.29	5.3
	18	3.3	2	F	2.26	1.76		4.02	4.2
	18	2.9	2	M	2.30	1.12		3.42	6.9
	17	2.8	2-3	M	0.54	0.25		0.79	3.1
	19	3.1	2-3	M	1.77	0.87		2.64	4.3
	20	4.0	2-3	M	5.07	3.92		8.99	6.0
	18	2.9	2	M	1.35	0.60		1.95	7.4
	20	4.2	3	M	2.49	1.43		3.92	10.0
	21	4.6	3	M	3.60	2.36		5.96	6.0
	20	4.3	3	M	1.04	1.04		2.08	2.4
	20	4.2	3	F	0.68	0.38		1.06	1.7
	18	3.0	2	F	3.18	1.46		4.64	7.0
	20	4.2	2	M	5.25	3.14		8.39	9.9

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA, MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
MEAN=	19	3.8	2					3.78	5.4
SPECIES: BASS									
July 1976	16				23.00	10.00	1.10	34.10	2.00
Sept 1981	18	3.8	5	M				15.00	
	12	1.0	2	M				1.50	
	12	1.0	3	M				1.60	
	12	0.9	2	F				4.40	
	9	0.5	3	M				1.40	
	13	1.4	2	M				3.90	
	7	0.2	1	F				1.00	
	10	0.6	2	M				0.70	
MEAN=	12	1.2	3					3.69	
July 1985	13	1.1	3	M	0.99	1.70	0.28	2.97	1.70
	13	1.1	3	M	<0.13	0.53	<0.13	0.53	0.80
	14	1.6	4	F	0.18	0.74	0.16	1.08	0.70
	16	2.0	3	M	0.25	1.55	0.26	2.06	1.00
	12	0.8	2	M	<0.13	0.40	0.08	0.48	0.30
	16	2.2	4	M	0.30	1.00	0.19	1.49	0.80
	14	1.7	3	M	<0.13	1.20	0.24	1.44	0.80
	14	1.5	3	M	0.22	0.62	0.17	1.01	0.50
	13	1.1	3	F	<0.13	0.42	0.12	0.54	0.50
	12	0.6	2	F	0.23	1.20	0.28	1.71	0.90
MEAN=	14	1.4	3					1.33	0.80
SPECIES: ROCK BASS									
July 1971	5				6.80	3.26		10.10	0.30
SPECIES: NORTHERN PIKE									
July 1971	18				5.80	2.90		8.70	0.70
Aug 1976	19				3.50	1.20	<0.20	4.70	0.70
May 1978	25				3.40	1.50	<0.60	4.90	1.40
	20				2.60	0.90	<0.60	3.50	0.30
	31				7.50	2.60	0.80	10.90	0.70
	18				3.10	1.00	<0.50	4.10	0.21
Sept 1981	15	0.6	1	M				0.90	
	17	1.0	1	F				0.60	
MEAN =	16	0.8	1					0.75	

E	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
			SPECIES:TIGER MUSKIE						
Aug 1976	37	-			1.80	0.60	<0.20	2.4[illegible]	0.40
			SPECIES:WHITE SUCKER						
JuLY 1971					30.70	14.80		45.50	0.70
May 1978	20				3.50	2.90	<0.60	6.4[illegible]	0.90
	18				2.40	3.30	0.60	5.3[illegible]	1.20
			SPECIES:BULLHEAD						
July 1971	7				15.50	7.70		23.2[illegible]	0.80
			SPECIES:BOWFIN						
Sept 1981	23	4.1	4	M				2.2[illegible]	
			PORTAGE CREEK						
			BRYANT POND						
			SPECIES: CARP						
July 1985	17	2.1	3	M	0.86	0.71	<0.13	1.5[illegible]	0.35
	18	2.8	3	M	2.40	0.87	<0.13	3.2[illegible]	0.80
	18	3.0	3	F	1.80	0.91	<0.13	2.7[illegible]	0.40
	17	2.2	3	F	1.90	0.64	<0.13	2.54	0.35
	18	3.0	3	M	2.20	1.10	<0.13	3.3[illegible]	0.65
	19	3.1	2	M	1.80	1.40	<0.13	3.2[illegible]	0.70
	19	3.2	3	F	1.30	0.40	<0.13	1.7[illegible]	0.60
	19	3.1	3	F	2.90	1.60	<0.13	4.5[illegible]	0.95
	17	2.1	2	F	3.20	0.88	<0.13	4.0[illegible]	0.55
	19	3.0	3	F	2.65	1.05	<0.13	3.7[illegible]	0.68
MEAN=	18	2.7	3					3.0[illegible]	0.60
JULY 1986	18	3.6	3	F	0.80		0.17	0.9[illegible]	0.60
	18	2.6	2	M	2.09		0.28	2.3[illegible]	0.70
	19	3.8	2	M	2.46		0.45	2.9[illegible]	1.50
	18	3.3	3	F	7.89		0.95	8.54	2.10
	20	4.0	3	M	1.46		0.29	1.7[illegible]	0.60
	17	2.9	3	M	2.56		0.56	3.1[illegible]	1.10
	17	2.5	2	F	1.60		0.37	1.9[illegible]	0.70
	18	2.9	2	M	1.83		0.39	2.2[illegible]	0.70
	21	4.4	3	M	1.08		0.24	1.3[illegible]	0.70
	16	2.0	2	F	2.18		0.39	2.5[illegible]	0.40
	17	2.7	2	F	0.69		0.12	0.8[illegible]	0.40
	19	3.6	3	M	5.00		0.75	5.7[illegible]	1.90
	17	2.6	2	M	24.70		2.67	27.3[illegible]	5.60
	19	3.0		M	2.20		0.42	2.6[illegible]	0.90

APPENDIX B - KALAMAZOO RIVER FISH PCB DATA,MORROW POND TO MOUTH

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
	17	2.5	2	F	0.77		0.17	0.94	1.70
	15	1.7	2	M	2.80		0.45	3.25	1.00
	19	3.9	3	F	1.61		0.30	1.91	0.80
	22	3.0	3	F	2.75		0.72	3.47	0.80
	20	4.6	3	M	1.80		0.26	2.06	1.10
	15	1.6	1-2	F	1.58		0.31	1.89	0.80
	23	6.0	3-4	M	4.53		0.62	5.15	1.30
MEAN=	18	3.2	2					3.96	1.21

VINE STREET

SPECIES: CARP

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
ept 1981	25	7.1		M	0.18	<0.10	<0.10	0.18	0.23
	15	1.9		F	0.79	<0.10	<0.10	0.79	0.38
	13	1.0			0.69	<0.10	<0.10	0.69	0.24
	12	1.0			1.00	<0.10	<0.10	1.00	0.31
	11	8.0			0.95	<0.10	<0.10	0.95	0.26
MEAN =	15	3.8						0.72	0.30

SPECIES: WHITE SUCKER

DATE	LENGTH (in)	WEIGHT (lbs)	AGE (YR)	SEX	AROCLOR 1242	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	FAT (%)
pt 1981	14	1.1		F	5.50	<0.10	<0.10	5.50	1.50
	11	0.6		M	2.90	<0.10	<0.10	2.90	0.56
	10	0.4		M	6.60	1.00	<0.10	7.60	1.40
	10	0.5		F	2.10	0.59	<0.10	2.69	0.63
	10	0.4		M	1.90	<0.10	<0.10	1.90	0.44
MEAN =	11	0.6						4.12	0.91

Appendix C

Measured Data for Reaches 1 - 10

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TABLE 3-2
MEASURED DATA FOR REACH 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Average Width (m)	6	6	6	6	6	6	6	6	6	6	6	6
Average Depth (m)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Average Wetted Perimeter (m)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Cross-section area of active sediment (m^2)	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Slope (%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Monthly Flow (cfs)	61	61	77	83	74	70	80	87	61	81	84	61
Monthly Water Temperature (°C)	6.7	6.0	9.6	13.6	16.9	21.2	22.2	21.0	18.3	13.0	9.0	7.0
Monthly Suspended Solid Concentration (mg/l)	16	16	16	16	16	16	16	16	16	16	16	16
PCB in Water (ng/kg)	120	120	85	200	100	110	130	130	130	130	130	120
PCB in Sediment (mg/Kg)	20	20	20	20	20	20	20	20	20	20	20	20

TABLE 3-3
MEASURED DATA FOR REACH 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	23000	23000	23000	23000	23000	23000	23000	23000	23000	23000	23000	23000
Average Width (m)	43.7	43.9	46.0	46.0	44.6	43.7	43.0	42.6	42.6	42.0	43.4	43.6
Average Depth (m)	1.15	1.10	1.42	1.42	1.26	1.15	1.07	1.02	1.01	1.06	1.12	1.14
Average Wetted Perimeter (m)	46.0	46.3	48.0	48.8	47.1	46.0	45.1	44.6	44.5	45.0	45.6	45.9
Cross-section area of active sediment (m^2)	4.60	4.63	4.88	4.88	4.71	4.60	4.51	4.46	4.45	4.50	4.56	4.59
Slope (%)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Monthly Flow (cfs)	940	1000	1630	1630	1190	940	700	600	650	770	800	930
Monthly Water Temperature (°C)	0.2	0.6	6.0	12.5	16.0	21.0	24.0	26.0	19.0	12.5	6.0	2.5
Monthly Suspended Solid Concentration (mg/l)	6	7	10	10	11	6	6	6	6	6	6	6
PCB in Water (ng/kg)	40	40	57	57	40	40	40	40	40	40	40	40
PCB in Sediment (mg/Kg)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

TABLE 3-4
MEASURED DATA FOR REACH 3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200
Average Width (m)	60.4	71.5	93.3	93.3	79.8	71.6	62.7	58.6	57.6	62.6	60.9	69.0
Average Depth (m)	0.96	1.06	1.68	1.68	1.42	0.96	0.68	0.46	0.40	0.63	1.34	1.43
Average Wetted Perimeter (m)	71.3	73.6	97.4	97.4	86.1	73.4	64.0	60.5	58.3	63.7	71.8	71.7
Cross-section area of active sediment (m^2)	7.13	7.36	9.74	9.74	9.61	7.34	6.40	6.96	6.03	6.37	7.18	7.17
Slope (%)	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
Monthly Flow (cfs)	940	1000	1530	1530	1190	940	700	600	650	770	C90	930
Monthly Water Temperature (°C)	0.2	0.6	6.0	12.5	16.0	21.0	24.0	25.0	19.0	12.5	6.8	2.6
Monthly Suspended Solid Concentration (mg/l)	10	10	5	5	10	10	10	10	10	10	10	10
PCB in Water (ng/kg)	87	87	82	82	60	87	87	87	87	87	87	87
PCB in Sediment (mg/Kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

TABLE 3-6
MEASURED DATA FOR REACH 4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Average Width (m)	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6
Average Depth (m)	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Average Wetted Perimeter (m)	85.1	85.1	85.1	85.1	85.1	85.1	85.1	85.1	85.1	85.1	85.1	85.1
Cross-section area of active sediment (m^2)	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
Slope (%)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Monthly Flow (cfs)	1120	1200	1630	1720	1300	1030	820	710	710	820	1030	1120
Monthly Water Temperature (°C)	0.2	0.4	6.0	12.5	18.0	21.0	24.0	25.0	19.0	12.5	6.5	2.5
Monthly Suspended Solid Concentration (mg/l)	9	9	11	12	10	9	9	9	9	9	9	9
PCB in Water (ng/kg)	46	48	54	55	57	46	46	46	46	46	46	44
PCB in Sediment (mg/Kg)	30	30	30	30	30	30	30	30	30	30	30	30

TABLE 3-6
MEASURED DATA FOR REACH 6

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	6242	6242	6242	6242	6242	6242	6242	6242	6242	6242	6242	6242
Average Width (m)	76	76	94	94	88	76	76	76	76	76	76	76
Average Depth (m)	1.2	1.2	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Average Wetted Perimeter (m)	77.4	77.4	97.0	97.0	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4
Cross-section Area of Active Sediment (m^2)	7.74	7.74	9.70	9.70	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74
Slope (%)	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
Monthly Flow (cfs)	1160	1260	1700	1700	1430	1070	860	740	740	850	1070	1160
Monthly Water Temperature (°C)	0.2	0.6	6.0	12.5	16.0	21.0	24.0	26.0	19.0	12.6	6.6	2.6
Monthly Suspended Solids Concentration (mg/l)	10	10	18	18	14	10	10	10	10	10	10	10
PCB in Water (ng/l)	52	51	67	76	40	52	52	52	52	52	52	52
PCB in Sediment (mg/Kg)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

TABLE 3-7
MEASURED DATA FOR REACH 6

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500
Average Width (m)	90	90	200	200	150	90	90	90	90	90	90	90
Average Depth (m)	1.2	1.2	1.6	1.6	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Average Wetted Perimeter (m)	100.4	100.4	203.0	203.0	152.6	100.4	100.4	100.4	100.4	100.4	100.4	100.4
Cross-section Area of Active Sediment (m^2)	10.0	10.0	20.3	20.3	15.3	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Slope (%)	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
Monthly Flow (cfs)	1200	1300	1750	1850	1400	1110	890	770	770	880	1110	1200
Monthly Water Temperature (°C)	0.2	0.6	6.0	12.5	18.0	21.0	24.0	25.0	19.0	12.6	6.6	2.5
Monthly Suspended Solids Concentration (mg/l)	21	22	19	18	20	21	20	20	20	20	21	21
PCB in Water (mg/l)	48	55	107	109	97	58	62	62	62	62	58	48
PCB in Sediment (mg/Kg)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

TABLE 3-8
MEASURED DATA FOR REACH 7

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	11760	11760	11760	11760	11760	11760	11760	11760	11760	11760	11760	11760
Average Width (m)	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2
Average Depth (m)	1.4	1.4	1.7	1.7	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Average Wetted Perimeter (m)	73.0	73.0	70.6	73.6	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0
Cross-section Area of Active Sediment (m^2)	7.3	7.3	7.4	7.4	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Slope (%)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Monthly Flow (cfs)	1220	1310	1760	1800	1500	1120	900	780	780	890	1120	1220
Monthly Water Temperature (°C)	0.2	0.6	6.0	12.8	16.0	21.0	24.0	26.0	19.0	12.6	6.5	2.6
Monthly Suspended Solids Concentration (mg/l)	6	9	26	26	26	6	6	6	6	6	6	6
PCB in Water (ng/l)	72	76	104	106	96	72	72	72	72	72	72	72
PCB in Sediment (mg/Kg)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

TABLE 3-9
MEASURED DATA FOR REACH 0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650
Average Width (m)	210	210	210	210	210	210	210	210	210	210	210	210
Average Depth (m)	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Average Wetted Perimeter (m)	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0	213.0
Cross section Area of Active Sediment (m^2)	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1
Slope (%)	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Monthly Flow (cfs)	1220	1315	1705	1805	1600	1125	900	700	700	890	1125	1220
Monthly Water Temperature (°C)	0.2	0.6	6.0	12.5	18.0	21.0	24.0	25.0	19.0	12.5	6.6	2.5
Monthly Suspended Solids Concentration (mg/l)	10	9	23	22	19	11	13	16	16	13	11	10
PCB in Water (ng/l)	65	68	103	102	88	80	115	130	130	116	82	67
PCB in Sediment (mg/Kg)	21	21	21	21	21	21	21	21	21	21	21	21

TABLE 3-10
MEASURED DATA FOR REACH 9

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	16829	16829	16829	16829	16829	16829	16829	16829	16829	16829	16829	16829
Average Width (m)	301	301	301	301	301	301	301	301	301	301	301	301
Average Depth (m)	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36
Average Wetted Perimeter (m)	307.7	307.7	307.7	307.7	307.7	307.7	307.7	307.7	307.7	307.7	307.7	307.7
Cross-section Area of Active Sediment (m^2)	116.3	116.3	116.3	116.3	116.3	116.3	116.3	116.3	116.3	116.3	116.3	116.3
Slope (%)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Monthly Flow (cfs)	1260	1360	1640	1930	1660	1160	930	800	660	920	1160	1260
Monthly Water Temperature (°C)	0.2	6.4	6.0	12.6	16.0	22.0	26.0	26.0	20.0	13.6	6.6	2.6
Monthly Suspended Solids Concentration (mg/l)	20	19	14	15	16	19	16	16	16	17	19	20
PCB in Water (ng/l)	146	142	87	81	120	142	134	132	132	133	142	146
PCB in Sediment (mg/Kg)	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7

TABLE 3-11
MEASURED DATA FOR REACH 10

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Length (m)	45122	45122	45122	45122	45122	45122	45122	45122	45122	45122	45122	45122
Average Width (m)	55	65	76	76	55	55	55	55	55	55	55	55
Average Depth (m)	2.6	2.6	3.0	3.0	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Average Wetted Perimeter (m)	60.2	60.2	81.0	81.0	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2
Cross-section Area of Active Sediment (m^2)	6.0	6.0	8.1	8.1	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Slope (%)	0.0378	0.0378	0.0378	0.0378	0.0378	0.0378	0.0378	0.0378	0.0378	0.0378	0.0376	0.0378
Monthly Flow (cfs)	1620	1740	2370	2490	1990	1500	1200	1030	1030	1180	1500	1620
Monthly Water Temperature (°C)	0.2	0.6	5.0	12.5	16.8	21.6	24.3	23.1	19.2	11.3	6.8	1.0
Monthly Suspended Solids Concentration (mg/l)	9	11	24	21	19	9	13	14	14	13	9	9
PCB in Water (ng/l)	58	57	49	48	63	58	58	58	58	58	68	58
PCB in Sediment (mg/Kg)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

APPENDIX D

INPUT VARIABLES FOR MODEL

TABLE D-1

LIST OF INPUT VARIABLES FOR THE PROGRAM

Variable	Description
DX	Spacial increment for solving the system differential equations (m)
NSIZE	Number of subdivision of DX to improve the accuracy of the solution
NM	Number of monthly flows used for simulation
NR	Number of reaches in the river
RL(I)	Length of reach I (m)
W(I,J)	Average width of reach I and month J (m)
D(I,J)	Average depth of reach I and month J (m)
WP(I,J)	Wetted perimeter of the representative cross-section for reach I and month J (m)
ASD(I)	Cross-section area of the active sediment layer (m^2)
SLOPE(I)	Bed slope of reach I (fraction)
D_{50}(I)	Mean particle size for the suspended solids of reach I (m)
PCW(I)	Fraction of clay in the suspended solids of reach I
PCS(I)	Fraction of clay in the sediment layer of reach I
DD(I)	Benthic diffusion velocity of PCB of reach I (m/min)
B(I)	Sediment burial velocity of reach I (m/min)
RB(I)	PCB benthic release rate of reach I (g/m^2/min)
RR(I)	Sediment suspension velocity of reach I (m/min)
S(I)	Average settling velocity of suspended solids for reach I (m/min)

TABLE D-1
LIST OF INPUT VARIABLE FOR THE PROGRAM
PAGE TWO

Variable	Description
SS(I)	Volume fraction of sediment in the active sediment layer of reach I (m^3 sed/m^3)
SI(J)	Concentration of suspended solids in the first reach of month J (g/m^3)
RAO	Sediment density (g/m^3)
VIS	Kinematic viscosity of water (m^2/hr)
RKO	PCB first-order biodegradation rate at 20°C (min^{-1})
RKR	Oxygen reaeration rate (min^{-1})
RA	Atmospheric PCB fallout rate (g/m^2/min)
RAR	Reaeration coefficient ratio for PCB (dimensionless)
THETA	Thermal factor for PCB biodegradation (dimensionless)
RKPS	PCB partition coefficient for sand (m^3 water/10^6 g solid)
RKPC	PCB partition coefficient for clayey materials (m^3 water/10^6 g solid)
TAOC	Critical shear stress of the cohesive bed materials (kg/m/hr^2)
ER(I)	Erosion rate constant of the cohesive bed materials of reach I (g/m^2/min)
CS(I,J)	Discharge of point PCB loading of reach I and month J (m^3/min)
QX(I,J)	Distributed water discharge along reach I and month J (m^3/min/m)
CSDX(I,J)	Distributed sediment discharge along reach I and month J (m^3 sed/min/m)

TABLE D-1
LIST OF INPUT VARIABLE FOR THE PROGRAM
PAGE THREE

Variable	Description
QSDP(I,J)	Point sadiument loading rate within reach I and month J (g_sed/min)
QW(J)	Average monthly flow of the headwater of month J (m^3/min)
WT(I,J)	Average monthly water temperature for reach I and month J (°C)
CI(J)	PCB concentration of the headwater of month J (g/m^3 or ppm)
CS(I)	PCB concentration in sediment of reach I (mg/kg sed)
CP(I,J)	Dissolved PCB concentration of the point loading within reach I and month J (g/m^3 or ppm)
CPS(I,J)	PCB concentration of the point sediment loading within reach I and month J (mg/kg sed)

TABLE D-1
LIST OF INPUT VARIABLE FOR THE PROGRAM
PAGE FOUR

Values of all the input available shown in Table B-1 were entered through Subroutine READIN of the computer program of this model. The input sequences are indicated in the following read statements.

```
READ (IN,*)   DX,NM,NR
READ (IN,*)   NSIZE

READ (IN,*)   (RL(I),I=1,NR)
READ (IN,*)   ((W(I,J),J=1,NM),I=1,NR)
READ (IN,*)   ((D(I,J),J=1,NM),I=1,NR)
READ (IN,*)   ((WP(I,J),J=1,NM),I=1,NR)
READ (IN,*)   (ASD(I),I=1,NR)
READ (IN,*)   (SLOPE(I),I=1,NR)
READ (IN,*)   (CSO(I),I=1,NR)
READ (IN,*)   (PCW(I),I=1,NR)
READ (IN,*)   (PCS(I),I=1,NR)

READ (IN,*)   (DO(I),I=1,NR)
READ (IN,*)   (B(I),I=1,NR)
READ (IN,*)   (RB(I),I=1,NR)
READ (IN,*)   (RR(I),I=1,NR)
READ (IN,*)   (ER(I),I=1,NR)
READ (IN,*)   (S(I),I=1,NR)
READ (IN,*)   (SS(I),I=1,NR)
READ (IN,*)   (SI(I),I=1,NR)
READ (IN,*)   RAO,VIS

READ (IN,*)   RKO,RKR,RA,RAR,THETA,RKPS,RKPC,TACC

READ (IN,*)   ((CS(I,J),J=1,NM),I=1,NR)
READ (IN,*)   ((CX(I,J),J=1,NM),I=1,NR)
READ (IN,*)   ((CSDX(I,J),J=1,NM),I=1,NR)
READ (IN,*)   ((CSDP(I,J),J=1,NM),I=1,NR)

READ (IN,*)   (QW(I),I=1,NM)

READ (IN,*)   ((WT(I,J),J=1,NM),I=1,NR)

READ (IN,*)   (CI(J),J=1,NM)
READ (IN,*)   (CS(I),I=1,NR)
READ (IN,*)   ((CP(I,J),J=1,NM),I=1,NR)
READ (IN,*)   ((CPS(I,J),J=1,NM),I=1,NR)
```

Calibrated input data for the No-Action alternative are also listed on the following pages.

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APPENDIX E

COST ESTIMATES

MALAMAINI RIVER
Plainwell Dam - Channel Lining / Soil Cap
(KAL-CF)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL LINING												
a. Rip Rap - 12"	46900	CY		8.00	4.98	4.97		375200	233562	233093	841855	
b. Gravel Bed - 6"	24250	CY		10.50	2.20	6.11		254625	53350	148168	456143	
c. Filter Fabric	147100	SY		1.20	.16			176520	23536		200056	
d. Excavation & Spread.	326000	CY			.39	1.77			127140	577020	704160	
2) SOIL CAP												
a. Regrading	62800	CY			.41	1.66			25748	104248	129996	
b. Soil Layer - 18"	188500	CY		1.50	1.80	4.90		282750	339300	923650	1545700	
c. Topsoil Layer - 6"	62800	CY		5.50	1.80	4.90		345400	113040	307720	766160	
d. Revegetation	3390	MSF		24.60	5.60	4.43		83394	18984	15066	117444	
e. Silt Fence	17600	LF		2.30	.27			40480	4752		45232	
							0	1558369	939412	2308964	4806745	
Burden @ 13% of Labor Cost									122124		122124	
Labor @ 15% of Labor Cost									140912		140912	
Material @ 5% of Material Cost								77918			77918	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	1636287	1202447	2308964	5147719	
Indirects @ 50% of Total Direct Labor Cost									601224		601224	
Profit @ 10% Total Direct Cost											514772	
											6263714	
Health & Safety Monitoring @ .06											375823	
Total Field Cost											6639537	
Contingency @ 20% of Total Field Cost											1327907	
Engineering @ 6% of Total Field Cost											398372	
TOTAL COST THIS PAGE											8365817	

KALAMAZOO RIVER
Plainwell Imp - Channel Excavation / Soil Cap
(KAL-EF11)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL												
a. Excavation & Spread.	326000	CY			.39	1.77			127140	577020	704160	
2) SOIL CAP												
a. Regrading	62800	CY			.41	1.66			25748	104248	129996	
b. Soil Layer - 18"	188500	CY		1.50	1.80	4.90		282750	339300	923650	1545700	
c. Topsoil Layer - 6"	62800	CY		5.50	1.80	4.90		345400	113040	307720	766160	
d. Revegetation	3390	MSF		24.60	5.60	4.45		83394	18984	15086	117464	
e. Silt Fence	17600	LF		2.30	.27			40480	4752		45232	
							0	752024	628964	1927724	3308712	
Burden @ 13% of Labor Cost								-	81765		81765	
Labor @ 15% of Labor Cost									94345		94345	
Material @ 5% of Material Cost								37601			37601	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	789625	805074	1927724	3522423	
Indirects @ 50% of Total Direct Labor Cost									402537		402537	
Profit @ 10% Total Direct Cost											352242	
											4277202	
Health & Safety Monitoring @ .06											256632	
Total Field Cost											4533834	
Contingency @ 20% of Total Field Cost											906767	
Engineering @ 6% of Total Field Cost											272030	
TOTAL CONST COST											5712631	

KALAMAZOO RIVER
Otsego Dam - Channel Lining / Soil Cap
(KAL-E0)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL LINING												
a. Rip Rap - 12"	61900	CY		8.00	4.98	4.97		495200	308262	307643	1111105	
b. Gravel Bed - 6"	32000	CY		10.50	2.20	6.11		336000	70400	195520	601920	
c. Filter Fabric	193800	SY		1.20	.16			232560	31008		263568	
d. Excavation & Spread.	429600	CY			.39	1.77			167544	760392	927936	
2) SOIL CAP												
a. Regrading	160800	CY			.41	1.66			65928	266928	332856	
b. Soil Layer - 18"	482300	CY		1.50	1.80	4.90		723450	868140	2363270	3954860	
c. Topsoil Layer - 6"	160800	CY		5.50	1.80	4.90		884400	289440	787920	1961760	
d. Revegetation	8680	MSF		24.60	5.60	4.45		213528	48608	38626	300762	
e. Silt Fence	23200	LF		2.30	.27			53360	6264		59624	
							0	2938498	1855594	4720299	9514391	
Burden @ 13% of Labor Cost									241227		241227	
Labor @ 15% of Labor Cost									278339		278339	
Material @ 5% of Material Cost								146925			146925	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	3085423	2375160	4720299	10180882	
Indirects @ 50% of Total Direct Labor Cost									1187580		1187580	
Profit @ 10% Total Direct Cost											1018088	
											12386551	
Health & Safety Monitoring @ .04											495462	
Total Field Cost											12882013	
Contingency @ 20% of Total Field Cost											2576403	
Engineering @ 5% of Total Field Cost											644101	
TOTAL COST THIS PAGE											16102516	

KALAMAZOO RIVER
Otsego Dam - Channel Excavation / Soil Cap
(KAL-601)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL												
a. Excavation & Spread.	429600	CY			.39	1.77			167544	760392	927936	
2) SOIL CAP												
a. Regrading	160800	CY			.41	1.66			65928	266928	332856	
b. Soil Layer - 18"	482300	CY		1.50	1.80	4.90		723450	868140	2363270	3954860	
c. Topsoil Layer - 6"	160800	CY		5.50	1.80	4.90		884400	289440	787920	1961760	
d. Revegetation	8680	MSF		24.60	5.60	4.45		213528	48608	38626	300762	
e. Silt Fence	23200	LF		2.30	.27			53360	6264		59624	
							0	1874738	1445924	4217136	7537798	
Burden @ 13% of Labor Cost									187970		187970	
Labor @ 15% of Labor Cost									216889		216889	
Material @ 5% of Material Cost								93737			93737	
*Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	1968475	1850783	4217136	8036394	
Indirects @ 50% of Total Direct Labor Cost									925391		925391	
Profit @ 10% Total Direct Cost											803639	
											9765424	
Health & Safety Monitoring @ .06											585925	
Total Field Cost											10351350	
Contingency @ 20% of Total Field Cost											2070270	
Engineering @ 5% of Total Field Cost											517567	
TOTAL COST THIS PAGE											12939187	

KALAMAZOO RIVER
Trowbridge Dam - Channel Lining / Soil Cap
(KAL-E1)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL LINING												
a. Rip Rap - 12"	123700	CY		8.00	4.98	4.97		989600	616026	614789	2220415	
b. Gravel Bed - 6"	63900	CY		10.50	2.20	6.11		670950	140580	390429	1201959	
c. Filter Fabric	387700	SY		1.20	.16			465240	62032		527272	
d. Excavation & Spread.	859300	CY			.39	1.77			335127	1520961	1856088	
2) SOIL CAP												
a. Regrading	368300	CY			.41	1.66			151003	611378	762381	
b. Soil Layer - 18"	1105000	CY		1.30	1.80	4.90		1437500	1989000	5414500	9041000	
c. Topsoil Layer - 6"	368300	CY		5.50	1.80	4.90		2025650	662940	1804670	4493260	
d. Revegetation	19890	MSF		24.60	5.60	4.45		489294	111384	88511	689189	
e. Silt Fence	44400	LF		2.36	.27			104720	12320		119240	
							0	6404954	4080620	10445238	20930812	
Burden @ 11% of Labor Cost									510481		510481	
Labor @ 15% of Labor Cost									612093		612093	
Material @ 5% of Material Cost								320248			320248	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	6725202	5223194	10445238	22393433	
Indirects @ 50% of Total Direct Labor Cost									2611597		2611597	
Profit @ 10% Total Direct Cost											2239343	
											27244593	
Health & Safety Monitoring @ .04											1089784	
Total Field Cost											28334377	
Contingency @ 20% of Total Field Cost											5666875	
Engineering @ 4% of Total Field Cost											1133375	
TOTAL COST THIS PAGE											35134627	

KALAMAZOO RIVER
Trowbridge Ave - Channel Excavation / Soil Cap
KAL-E11

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL												
a. Excavation & Spread.	859100	CY			.39	1.77			335137	1520961	1856098	
2) SOIL CAP												
a. Regrading	368300	CY			.41	1.66			151003	611378	762381	
b. Soil Layer - 18"	1105000	CY		1.50	1.80	4.90		1657500	1989000	5414500	9061000	
c. Topsoil Layer - 6"	368300	CY		5.50	1.80	4.90		2025650	662940	1804670	4493260	
d. Revegetation	19890	MSF		24.60	5.60	4.45		489294	111384	88511	689189	
e. Silt Fence	46400	LF		2.30	.27			106720	12528		119248	
							0	4279164	3261982	9440020	16981166	
Burden @ 13% of Labor Cost									424058		424058	
Labor @ 15% of Labor Cost									489297		489297	
Material @ 5% of Material Cost								213958			213958	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	4493122	4175337	9440020	18108479	
Indirects @ 50% of Total Direct Labor Cost									2087668		2087668	
Profit @ 10% Total Direct Cost											1810848	
											22006995	
Health & Safety Monitoring @ .04											880280	
Total Field Cost											22887275	
Contingency @ 20% of Total Field Cost											4577455	
Engineering @ 4% of Total Field Cost											915491	
TOTAL COST THIS PAGE											28380221	

TROWBRIDGE DAM
DREDGED AREA

ITEM	QTY	UNIT	UNIT COST MAT.	UNIT COST LABOR	UNIT COST EQUIP.	TOTAL COST MAT.	TOTAL COST LABOR	TOTAL COST EQUIP.	TOT. DIRECT COST
EXC + SPREAD	64400	CY		0.39	1.77		25116	113988	139104
BACKFILL 30"	53700	CY	1.5	1.8	4.9	80550	96660	263130	440340
TOPSOIL 6"	10700	CY	5.5	1.8	4.9	58850	19260	52430	130540
REVEGETATION	580	MSF	24.6	5.6	4.45	14268	3248	2581	20097
SILT FENCE	46400	LF	2.3	0.27		106720	12528		119248
						260388	156812	432129	849329

BURDEN @13% LABOR	20386
LABOR @15% LABOR	23522
MATERIAL @5% MATERIAL	13019
SUBCONTRACT @10% SUB	0
TOTAL DIRECT COST	906256
INDIRECTS @ 50% LABOR COST	78406
PROFIT @10% DIRECT COST	90626
	1075287
HEALTH$SAFETY MONITORING@0.08	86023
ENV MONITORING @0.04	430[illegible]
TOTAL FIELD COST	1204322
CONTINGENCY @20%	180648
ENGINEERING @ 6%	120432
TOTAL COST	1505402

OTSEGO DAM
DREDGED AREA

ITEM	QTY	UNIT	UNIT COST MAT.	UNIT COST LABOR	UNIT COST EQUIP.	TOTAL COST MAT.	TOTAL COST LABOR	TOTAL COST EQUIP.	TOTAL DIRECT COST
EXC + SPREAD	32200	CY		0.39	1.77		12558	56994	69552
BACKFILL 30"	26900	CY	1.5	1.8	4.9	40350	48420	131810	220580
TOPSOIL 6"	5300	CY	5.5	1.8	4.9	29150	9540	25970	64660
REVEGETATION	290	MSF	24.	5.6	4.45	7134	1624	1291	10049
SILT FENCE	23200	LF	2.3	0.27		53360	6264		59624
						129994	78406	216065	424465

BURDEN @13% LABOR	10193
LABOR @15% LABOR	11761
MATERIAL @5% MATERIAL	6500
SUBCONTRACT @10% SUB	0
TOTAL DIRECT COST	452918
INDIRECTS @ 50% LABOR COST	39203
PROFIT @10% DIRECT COST	45292
	537413
HEALTH$SAFETY MONITORING @0.08	42993
ENV MONITORING @0.04	21497
TOTAL FIELD COST	601902
CONTINGENCY @20%	90285
ENGINEERING @ 6%	60190
TOTAL COST	752378

PLAINWELL DAM
DREDGED AREA

ITEM	QTY	UNIT	UNIT COST MAT.	UNIT COST LABOR	UNIT COST EQUIP.	TOTAL COST MAT.	TOTAL COST LABOR	TOTAL COST EQU[illegible].	TOTA DIREC COST
EXC + SPREAD	24500	CY		0.39	1.77		9555	433[illegible]	52920
BACKFILL 30"	20400	CY	1.5	1.8	4.9	30600	36720	99[illegible]	157280
TOPSOIL 6"	4100	CY	5.5	1.8	4.9	22550	7380	20[illegible]	50020
REVEGETATION	220	MSF	24.6	5.6	4.45	5412	1232	[illegible]	7623
SILT FENCE	17600	LF	2.3	0.27		40480	4752		45232
						99042	59639	164[illegible]	323075

BURDEN @13% LABOR	7753
LABOR @15% LABOR	8946
MATERIAL @5% MATERIAL	4952
SUBCONTRACT @10% SUB	0
TOTAL DIRECT COST	344726
INDIRECTS @ 50% LABOR COST	29820
PROFIT @10% DIRECT COST	34473
	409018
HEALTH§SAFETY MONITORING @0.08	32721
ENV MONITORING @0.04	16361
TOTAL FIELD COST	45810[illegible]
CONTINGENCY @20%	91620
ENGINEERING @ 6%	27486
TOTAL COST	577206

KALAMAZOO RIVER
Plainwell Dam - Channel Lining / Impermeable Cap
(KAL-FF)

Item	Qty	Unit	Unit Cost: Sub.	Unit Cost: Mat.	Unit Cost: Labor	Unit Cost: Equip.	Total Cost: Sub.	Total Cost: Mat.	Total Cost: Labor	Total Cost: Equip.	Total Direct Cost	Comments
1) CHANNEL LINING												
a. Rip Rap - 12"	46900	CY		8.00	4.98	4.97		375200	233562	233093	841855	
b. Gravel Bed - 6"	24250	CY		10.50	2.20	6.11		254625	53350	148168	456143	
c. Filter Fabric	147100	SY		1.20	.16			176520	23536		200056	
d. Excavation & Spread.	326000	CY			.39	1.77			127140	577020	704160	
2) IMPERMEABLE CAP												
a. Regrading	62800	CY			.41	1.66			25748	104248	129996	
b. Sand Base - 6"	62800	CY		6.50	2.50	6.48		408200	157000	406944	972144	
c. Liner - 30 mil	3393000	SF		.30	.20			1017900	678600		1696500	
d. Sand Cover - 6"	62800	CY		6.50	2.50	6.48		408200	157000	406944	972144	
e. Soil Layer - 18"	188500	CY		1.50	1.80	4.90		282750	339300	923650	1545700	
f. Topsoil Layer - 6"	62800	CY		5.50	1.80	4.90		345400	113040	307720	766160	
g. Revegetation	3390	MSF		24.60	5.60	4.45		83394	18984	15086	117464	
h. Silt Fence	17600	LF		2.30	.27			40480	4752		45232	
							0	3392669	1932012	3122872	8447553	
Burden @ 13% of Labor Cost									251162		251162	
Labor @ 15% of Labor Cost									289802		289802	
Material @ 5% of Material Cost								169633			169633	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	3562302	2472975	3122872	9158150	
Indirects @ 50% of Total Direct Labor Cost									1236488		1236488	
Profit @ 10% Total Direct Cost											915815	
											11310453	
Health & Safety Monitoring @ .04											452418	
Total Field Cost											11762871	
Contingency @ 20% of Total Field Cost											2352574	
Engineering @ 5% of Total Field Cost											588144	
TOTAL COST THIS PAGE											14703588	

KALAMAZOO RIVER
Plainwell Dam - Channel Excavation / Impermeable Cap
(RAM FF1)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL												
a. Excavation & Spread.	326000	CY			.39	1.77			127140	577020	704160	
2) IMPERMEABLE CAP												
a. Regrading	62800	CY			.41	1.66			25748	104248	129996	
b. Sand Base - 6"	62800	CY		6.50	2.50	6.48		408200	157000	406944	972144	
c. Liner - 30 mil	3393000	SF		.30	.20			1017900	678600		1696500	
d. Sand Cover - 6"	62800	CY		6.50	2.50	6.48		408200	157000	406944	972144	
e. Soil Layer - 18"	188500	CY		1.50	1.80	4.90		282750	339300	923650	1545700	
f. Topsoil Layer - 6"	62800	CY		5.50	1.80	4.90		345400	113040	307720	766160	
g. Revegetation	3390	MSF		24.60	5.60	4.45		83394	18984	15086	117464	
h. Silt Fence	17600	LF		2.30	.27			40480	4752		45232	
							0	2586324	1621564	2741612	6949500	
Burden @ 13% of Labor Cost									210803		210803	
Labor @ 15% of Labor Cost									243235		243235	
Material @ 5% of Material Cost								129316			129316	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	2715640	2075602	2741612	7532854	
Indirects @ 50% of Total Direct Labor Cost									1037801		1037801	
Profit @ 10% Total Direct Cost											753285	
											9323940	
Health & Safety Monitoring @ .06											559436	
Total Field Cost											9883376	
Contingency @ 20% of Total Field Cost											1976675	
Engineering @ 5% of Total Field Cost											494169	
TOTAL COST THIS PAGE											12354220	

KALAMAZOO RIVER
Otsego Dam - Channel Lining / Impermeable Cap
(KAL-F0)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL LINING												
a. Rip Rap - 12"	61900	CY		8.00	4.98	4.97		495200	308262	307643	1111105	
b. Gravel Bed - 6"	32000	CY		10.50	2.20	6.11		336000	70400	195520	601920	
c. Filter Fabric	193800	SY		1.20	.16			232560	31008		263568	
d. Excavation & Spread.	429600	CY			.39	1.77			167544	760392	927936	
2) IMPERMEABLE CAP												
a. Regrading	160800	CY			.41	1.66			65928	266928	332856	
b. Sand Base - 6"	160800	CY		6.50	2.50	6.48		1045200	402000	1041984	2489184	
c. Liner - 30 mil	8681500	SF		.30	.20			2604450	1736300		4340750	
d. Sand Cover - 6"	160800	CY		6.50	2.50	6.48		1045200	402000	1041984	2489184	
e. Soil Layer - 18"	482300	CY		1.50	1.80	4.90		723450	868140	2363270	3954860	
f. Topsoil Layer - 6"	160800	CY		5.50	1.80	4.90		884400	289440	787920	1961760	
g. Revegetation	8680	MSF		24.60	5.60	4.45		213528	48608	38626	300762	
h. Silt Fence	23200	LF		2.30	.27			53360	6264		59624	
							0	7633348	4395894	6004267	18033509	
Burden @ 13% of Labor Cost									571466		571466	
Labor @ 15% of Labor Cost									659384		659384	
Material @ 5% of Material Cost								381667			381667	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	8015015	5626744	6004267	20446027	
Indirects @ 50% of Total Direct Labor Cost									2813372		2813372	
Profit @ 10% Total Direct Cost											2044603	
											25304002	
Health & Safety Monitoring @ .04											1012160	
Total Field Cost											26316162	
Contingency @ 20% of Total Field Cost											5263232	
Engineering @ 4% of Total Field Cost											1052646	
TOTAL COST THIS PAGE											32632040	

KALAMAZOO RIVER
Otsego Dam - Channel Excavation / Impermeable Cap
(KAL-FD1)

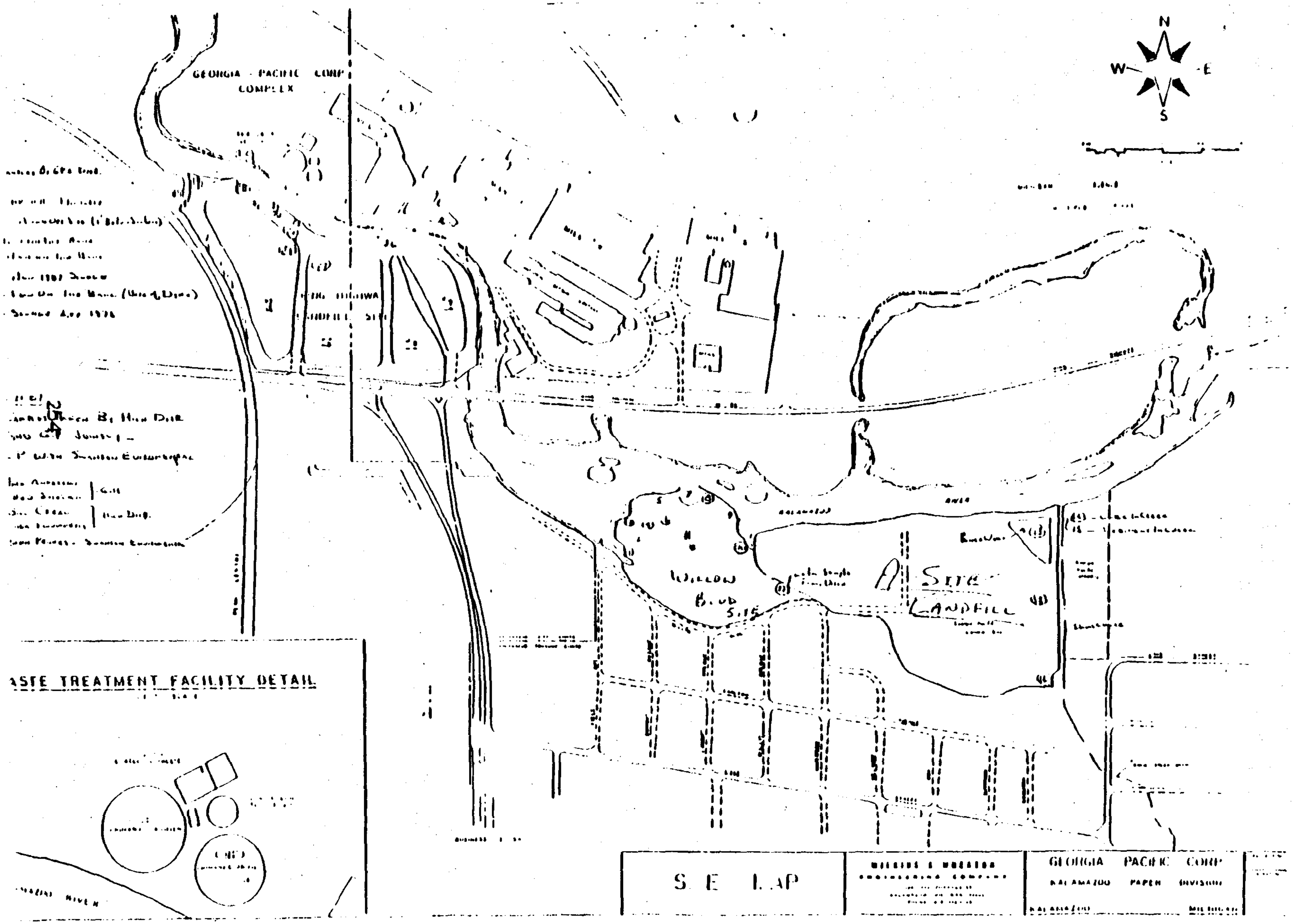
Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL												
a. Excavation & Spread.	429600	CY			.39	1.77			167544	760392	927936	
2) IMPERMEABLE CAP												
a. Regrading	160800	CY			.41	1.66			65928	266928	332856	
b. Sand Base - 6"	160800	CY		6.50	2.50	6.48		1045200	402000	1041984	2489184	
c. Liner 10 mil	8681500	SF		.30	.20			2604450	1736300		4340750	
d. Sand Cover 6"	160800	CY		6.50	2.50	6.48		1045200	402000	1041984	2489184	
e. Soil Layer - 18"	482300	CY		1.50	1.80	4.90		723450	868140	2363270	3954860	
f. Topsoil Layer - 6"	160800	CY		5.50	1.80	4.90		884400	289440	787920	1961760	
g. Revegetation	8680	MSF		24.60	5.60	4.45		213528	48608	38626	300762	
h. Silt Fence	23200	LF		2.30	.27			53360	6264		59624	
							0	6569588	3986224	6301104	16856916	
Burden @ 13% of Labor Cost									518209		518209	
Labor @ 15% of Labor Cost									597934		597934	
Material @ 5% of Material Cost								328479			328479	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	6898067	5102367	6301104	18301538	
Indirects @ 50% of Total Direct Labor Cost									2551183		2551183	
Profit @ 10% Total Direct Cost											1830154	
											22682875	
Health & Safety Monitoring @ .04											907315	
Total Field Cost											23590190	
Contingency @ 20% of Total Field Cost											4718038	
Engineering @ 4% of Total Field Cost											943608	
TOTAL COST THIS PAGE											29251836	

KALAMAZOO RIVER
Trowbridge dam - Channel Lining / Impermeable Cap
(KAL-F1)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL LINING												
a. Rip Rap - 12"	123700	CY		8.00	4.98	4.97		989600	616026	614789	2220415	
b. Gravel bed - 6"	63900	CY		10.50	2.20	6.11		670950	140580	390429	1201959	
c. Filter Fabric	387700	SY		1.20	.16			465240	62032		527272	
d. Excavation & Spread.	859300	CY			.39	1.77			335127	1520961	1856088	
2) IMPERMEABLE CAP												
a. Regrading	368300	CY			.41	1.66			151003	611378	762381	
b. Sand Base - 6"	368300	CY		6.50	2.50	6.48		2393950	920750	2386584	5701284	
c. Liner - 30 mil	19889500	SF		.30	.20			5966850	3977900		9944750	
d. Sand Cover - 6"	368300	CY		6.50	2.50	6.48		2393950	920750	2386584	5701284	
e. Soil Layer - 18"	1105000	CY		1.50	1.80	4.90		1657500	1989000	5414500	9061000	
f. Topsoil Layer - 6"	368300	CY		5.50	1.80	4.90		2025650	662940	1804670	4493260	
g. Revegetation	19890	MSF		24.60	5.60	4.45		489294	111384	88511	689189	
h. Silt Fence	46400	LF		2.30	.27			106720	12528		119248	
							0	17159704	9900020	15218406	42278130	
Burden @ 13% of Labor Cost									1287003		1287003	
Labor @ 15% of Labor Cost									1485003		1485003	
Material @ 5% of Material Cost								857985			857985	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	18017689	12672026	15218406	45908120	
Indirects @ 50% of Total Direct Labor Cost									6336013		6336013	
Profit @ 10% Total Direct Cost											4590812	
											56834945	
Health & Safety Monitoring @ .04											2273398	
Total Field Cost											59108343	
Contingency @ 20% of Total Field Cost											11821669	
Engineering @ 4% of Total Field Cost											2364334	
TOTAL COST THIS PAGE											73294345	

KALAMAZOO RIVER
Trowbridge dam - Channel Excavation / Impermeable Cap
(KAL-F11)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) CHANNEL												
a. Excavation & Spread.	859100	CY			.39	1.77			335127	1520961	1856088	
2) IMPERMEABLE CAP												
a. Regrading	368300	CY			.41	1.66			151003	611378	762381	
b. Sand Base - 6"	368300	CY		6.50	2.50	6.40		2393950	920750	2386584	5701284	
c. Liner - 30 mil	19889500	SF		.30	.20			5966850	3977900		9944750	
d. Sand Cover - 6"	368300	CY		6.50	2.50	6.40		2393950	920750	2386584	5701284	
e. Soil Layer - 18"	1105000	CY		1.50	1.80	4.90		1657500	1989000	5414500	9061000	
f. Topsoil Layer - 6"	368300	CY		5.50	1.80	4.90		2025650	662940	1804670	4493260	
g. Revegetation	19890	MSF		24.60	5.60	4.45		489294	111384	88511	689189	
h. Silt Fence	46400	LF		2.30	.27			106720	12528		119248	
							0	15033914	9081382	14213180	38328484	
Burden @ 13% of Labor Cost									1180580		1180580	
Labor @ 15% of Labor Cost									1362207		1362207	
Material @ 5% of Material Cost								751696			751696	
Subcontract @ 10% of Sub. Cost							0				0	
Total Direct Cost							0	15785610	11624169	14213180	41622966	
Indirects @ 50% of Total Direct Labor Cost									5812084		5812084	
Profit @ 10% Total Direct Cost											4162297	
											51597347	
Health & Safety Monitoring @ .04											2063894	
Total Field Cost											53661241	
Contingency @ 20% of Total Field Cost											10732248	
Engineering @ 4% of Total Field Cost											2146450	
TOTAL COST THIS PAGE											66539939	



N
W
E
S
GEORGIA - PACIFIC CORP
COMPLEX
WILLOW
BLVD
SITE
LANDFILL
ASTE TREATMENT FACILITY DETAIL
S. E. MAP
GEORGIA PACIFIC CORP
KALAMAZOO PAPER DIVISION

Sediment sampling results from the Kalamazoo River, Trowbridge and Plainwell impoundents, August 1, 1985.

Trowbridge impoundment

Depth ft	Total solids %	Phenols mg/kg	Mercury mg/kg	Acenaphthylene ug/kg	Anthracene ug/kg	Benz(a) anthracene ug/kg	Benzo(k) fluoranthene ug/kg	Benzo(a) pyrene ug/kg	Chrysene ug/kg	Fluoranthene ug/kg	Fluorene ug/kg	Phenanthrene ug/kg	Pyrene ug/kg	PCB mg/kg
1	73.2	1.4	int	<87	<87	110	M	<87	280	640	<87	450	690	<0.7
2	77.3	2.1	<0.3	<180	<180	310	M	<180	330	330	<180	330	220	2.9
3	60.8	5.7	0.8	<980	<980	<980	<980	<980	1200	1200	<980	<980	<980	3.9
4	70.2	4.4	0.8	<890	<890	<890	<890	<890	<890	<890	<890	<890	<890	3.0
5	59.4	4.5	1.3	<1100	<1100	1100	<1100	<1100	1500	<1100	<1100	<1100	<1100	4.1
6	46.8	2.6	1.7	<1400	<1400	<1400	<1400	<1400	3300	4000	<1400	<1400	<1400	<1.1
7	44.3	6.4	3.1	<1800	<1800	<1800	<1800	<1800	3100	4700	<1800	<1800	M	1.4
8	45.0	8.2	3.9	<1400	<1400	<1400	<1400	<1400	3600	4200	<1400	1500	M	<1.1
9	54.2	4.1	1.7	<1200	<1200	<1200	<1200	<1200	2100	1700	<1200	<1200	M	<0.96
10	49.2	2.5	4.1	<240	<240	<240	<240	<240	360	380	<240	260	M	<0.96
11	51.6	4.5	5.3	<230	<230	1000	<230	<230	360	230	<230	400	M	<0.92

Plainwell impoundment

Depth ft	Total solids %	Phenols mg/kg	Mercury mg/kg	Acenaphthylene ug/kg	Anthracene ug/kg	Benz(a) anthracene ug/kg	Benzo(k) fluoranthene ug/kg	Benzo(a) pyrene ug/kg	Chrysene ug/kg	Fluoranthene ug/kg	Fluorene ug/kg	Phenanthrene ug/kg	Pyrene ug/kg	PCB mg/kg
1	64.3	1.8	1.0	<290	<290	<290	<290	<290	800	M	<290	320	M	13.2
2	47.4	5.6	2.6	<1500	<1500	<1500	<1500	<1500	2100	<1500	<1500	<1500	5600	14.6
3	48.4	4.9	2.0	<1300	<1300	<1300	<1300	<1300	7000	6500	<1300	<1300	M	1.2
4	42.9	5.9	3.2	<1500	M	<1500	<1500	<1500	M	6000	<1500	2400	M	<1.2
5	43.3	2.1	3.2	2000	M	1000	<1400	<1400	M	6100	<1500	2300	M	<1.1
6	43.6	1.8	4.3	M	M	<1500	<1500	<1500	M	7100	<1500	2900	M	<1.2
7	45.3	1.6	4.6	M	M	<1500	<1500	<1500	M	8700	<1500	3000	M	<1.2
8	59.2	1.0	2.4	<1000	M	<1000	<1000	1100	M	5600	<1000	1200	M	0.93

M=presence of material verified but not quantified

All other scan [illegible] or 7 compounds not detected

APPENDIX G

Sludge Disposal Area Sampling Results
1987

SOIL SAMPLING RESULTS FROM JAMES RIVER (PARCHMENT) DISPOSAL AREA
MAY 19,1987

STATION	TOTAL SOLIDS (%)	TOTAL PCB (MG/KG)	ARSENIC (MG/KG)	MERCURY (MG/KG)	SELENIUM (MG/KG)
1	66.2	1.1 (1254)			
2	50.8	7.3 (1248)			
3	56.8	7.0 (1248)			
4	43.9	<1.2			
5	63.2	2.6 (1248	46	0.12	2.2
6	67.7	<0.75			
VACUUM FILTER SLUDGE	27.1	<1.9			

WATER SAMPLING RESULTS FROM JAMES RIVER (PARCHMENT) OUTFALL 006,
MAY 19,1987

TOTAL SUSPENDED SOLIDS (MG/L)	TOTAL PCB (NG/L)	AROCLOR 1242 (NG/L)	AROCLOR 1254 (NG/L)
11	110	50	60

James River
5-19-87

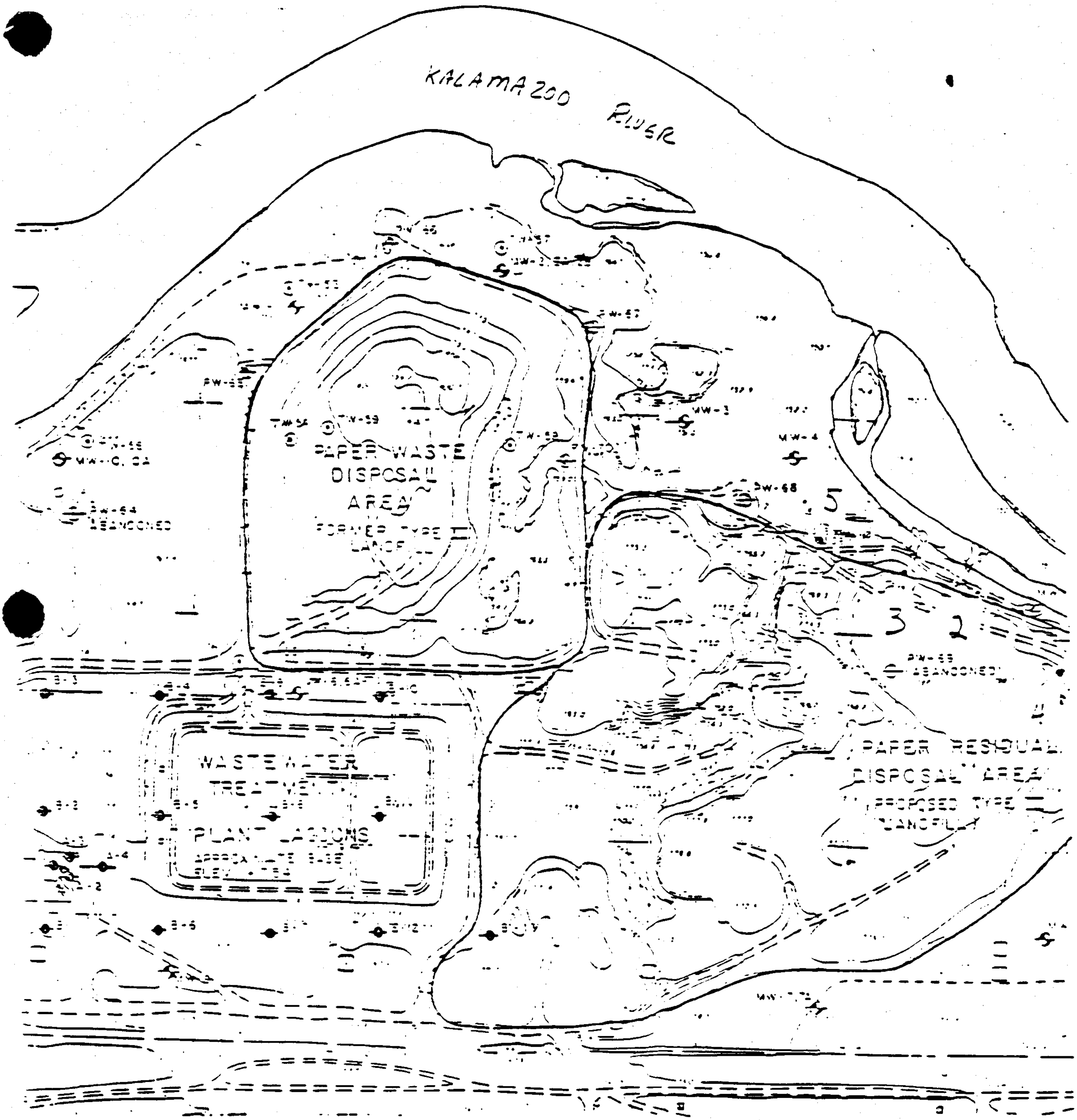


Table 1. Soil sampling results from the Plainwell Paper Company sludge disposal area, June 10, 1987.

Location	Total Solids (%)	Aroclor 1242 (mg/kg)	Aroclor 1248 (mg/kg)	Aroclor 1254 (mg/kg)	Total PCB (mg/kg)
Dike wall, northeast corner of landfill	78.0	< 0.65	30.0*	< 0.650	30.0
Dike wall, 100 feet south of sample 1	86.1	< 0.60	< 0.60	2.60	2.60
South property line, outside diked area	80.1	< 6.50	39.0	< 6.50	39.00
New sludge from Plainwell Paper	31.7	< 1.60	< 1.60	4.60	4.60

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* Estimated value. All other Scan 3 values were less than detectable.

Table 2. Soil sampling results from the former Allied Paper King Mill site and Rex Paper site, Kalamazoo. May 26, 1987.

Sample No.		Total Solids (%)	Aroclor 1248 (mg/kg)	Aroclor 1254 (mg/kg)	Total PCB (mg/kg)
KING MILL					
1	East of railroad tracks.	79.1	< 0.65	-	< 0.65
2	Old Lagoon, north of railroad tracks.	52.1	4.5	-	4.5
3	East of railroad tracks.	70.0	9.1	-	9.1
REX PAPER					
4	150 yards east of Sprinkle.	59.8	-	1.5	1.5
5	75 yards east of Sprinkle.	67.3	-	0.32	0.82
6	10 yards east of Sprinkle.	57.2	-	< 0.85	< 0.35
7	500 yards east of Sprinkle.	46.1	-	< 1.1	< 1.1
8	300 yards east of Sprinkle. 10 yards north of river.	59.7	-	< 0.85	< 0.35
9	300 yards east of Sprinkle, 10 yards north of river.	56.7	-	< 0.85	< 0.85

All other Scan 3 compounds were not detected.

APPENDIX H

OFFICE OF THE GREAT LAKES

PUBLIC MEETING SUMMARY

KALAMAZOO RIVER AREA OF CONCERN

Date and Time:	Tuesday, December 16, 1986 at 7 p.m.
Place:	Kalamazoo City Hall Commission Chambers Second Floor 241 West South Street Kalamazoo, Michigan
Chair:	Thomas D. Martin, Office of the Great Lakes
Chief Technical Presenter:	William Creal, Surface Water Quality Division
Other Department of Natural Resources Officials:	Karen Gottlieb, Office of the Great Lakes David Kenaga, Surface Water Quality Division Linda Koivuniemi , Surface Water Quality David Johnson, Fisheries Division Fred Morley, Surface Water Quality Division
Attendance:	56 members of the public

Problem Statement

The Kalamazoo River drains nearly 2,000 square miles of land from ten counties in southwestern Michigan. The river is a highly valued recreational resource supporting anadromous cold-water fishing including salmon, steelhead, and smallmouth bass, the Allegan State game area, along with scenic vistas and marshes and wetlands. From the 1950s to the early 70s, the water quality was very poor due to poor waste disposal practices, excessive heating of the water, and sedimentation behind the dams. Inadequate treatment of waste resulted in 1956 loadings to the river of the equivalent of raw sewage from a half a million people. Fish kills were so bad that in 1953 the river gained national recognition in a Life magazine photograph. Algae growths choked the river. Odors caused the people to keep their windows closed at night, and the river often was a milky white color. The excessive heat load from a power plant also resulted in fish kills. Sediments settled behind dams which buried the gravel bottom and changed it from a game fish to a rough fish habitat.

Remedial actions have included over $500 million being spent in the Kalamazoo River basin on wastewater treatment plants. This has dramatically improved the water quality including increased oxygen, reduced algae and odors, and improvement in water clarity. The closing of the Morrow Power Plant reduced the heat load on the river. The water quality, especially between Battle Creek and Kalamazoo and downstream of Lake Allegan now is generally good to excellent. With recent upgrading of the Kalamazoo Wastewater Treatment Plant, oxygen levels should continue to increase, nuisance algae growths reduce, and compliance with Michigan's Water Quality Standards is expected in the near future.

The major remaining problem is PCB-contaminated sediments which are associated with the sediments behind the dams and other specific locations along the water course. PCB is a human carcinogen and is transferred from the sediments to fish to people. Fish in the river exceed the 2 parts per million action level and 80 miles of the river--between Kalamazoo and Saugatuck at the mouth--are subject to a fish consumption health advisory restricting fish consumption. Several actions are being taken to address this issue. A feasibility study conducted by the Department of Natural Resources indicates that remedial efforts are needed in order to reduce the level in the fish below two parts per million. Based on the recommendations of this study, the Department is pursuing clean-up of Bryant Mill Pond and Portage Creek with legal actions underway involving a suspected responsible party. Annual draw-down of the Allegan City dam has been stopped because it causes downstream transport of PCBs. The state is pursuing the removal of DNR-owned dams in the Plainwell/Ostego area.

Further studies were conducted in 1986 and are planned for 1987. The DNR is recommending the Kalamazoo River for consideration as a Federal Superfund priority. Finally, a Basin Strategy Committee composed of state and local public officials, business, industry, labor, and environmental and conservation groups will participate in the development of the remedial action plan and address remaining issues such as PCB contamination, the dams, dissolved oxygen problems between Kalamazoo and Allegan, and fish management. The geographic area defined as the Area of Concern for the Kalamazoo River is from Calkens Dam to Lake Michigan. This is the portion of the River which is contiguous with Lake Michigan and where fish from Lake Michigan can migrate into the River.

Stated Public Concerns

Area of Concern

What criteria was used to determine which of Michigan's areas were the 14 worst ones?

Response: In the Areas of Concern, environmental quality is degraded and beneficial uses of the water or biota are adversely affected. These areas have been designated by the various jurisdictions based on determination of whether or not the Great Lakes Water Quality Agreement objectives or jurisdictional guidelines, criteria or standards for environmental quality are being exceeded.

Remedial Action Plan

The RAP should not slow down or stop the clean-up process. The RAP should have a comprehensive long-term approach.

Response: We agree.

What will the role and function of the Basin Strategy Committee be?

Response: The role of the Committee will be to develop mechanisms to implement the Kalamazoo Remedial Action Plan; coordinate the Remedial Action Plan, Fisheries Management Plan and access development along the Kalamazoo River; and provide local input into these plans.

How far will this year's $10,000 funding for the Basin Committee go?

Response: The money is intended to fund at least four committee meetings by October 1, 1987.

We want the public to get very involved in the Kalamazoo River such as the experience in the Grant Calumet River area. We suggest that more than the 3 or 4 meetings be held, that there be workshops to explain the process and turn public concern into action.

Response: We will consider this with the Basin Strategy Committee.

What percent of the PCB's go into the Great Lakes? Is it significant?

Response: We estimate that the Kalamazoo River loads about 200 pounds per year of PCB into Lake Michigan. The significance of this load is not known at this time. A PCB budget for Lake Michigan is being developed by the EPA. This budget will allow the Kalamazoo River load significance to be assessed.

Will the RAP look at dissolved oxygen and phosphorous problems in the area between Allegan and Kalamazoo?

Response: No. The RAP will address impaired uses in the Area of Concern, which has been defined as the Kalamazoo River as far upstream as Great Lakes fish can presently migrate, which is Calkins Dam.

Will the scope of the RAP include nonpoint source pollution from phosphorous and BOD?

Response: No. The impaired uses identified do not include problems associated with phosphorus or BOD.

Remedial Actions

Concern was raised about the actions recommended in the NUS study. Have detailed tests of sediments been done on the hotspots? What is the status of the reservoirs, aren't they filled up? This study didn't talk of disturbance by carp. Are carp increasing the loadings?

Response: Extensive testing for PCB's has occurred in areas where concentrations are highest, primarily Bryant Mill Pond (Portage Creek). Other areas have been less extensively sampled.

There are three impoundments between Kalamazoo and Saugatuck - Otsego City, Allegan City and Lake Allegan. Otsego City is considered to be relatively full of sediment. Allegan City and Lake Allegan impoundments are filled in to lesser degrees.

Carp disturbance of the sediment and its significance relative to PCB loadings is very difficult to quantify. We are aware that this occurs but at a loss as how to quantify it.

What is the estimated cost of dredging and disposal of the PCB contaminated sediments?

Response: The estimated costs for remedial action is available in the MDNR 1986 Kalamazoo River Feasibility Study. Depending on the site involved and action considered, costs range from about $500,000 to $400 million.

There may be different degrees of clean-up and we need to take a reasonable course. We don't have the money to do it all.

Response We agree.

What is our goal? The people living along the river may not want salmon. What if we do nothing, just kill the carp? How far are we from the 2.0 ppm action level for PCB's in the Kalamazoo River?

Response: Our goal is to reduce the risk to the fish-consuming public to acceptable levels. One part in this goal is to reduce fish PCB concentrations to less than 2 ppm. This will not be reached by just eliminating the carp.

We can't just look at getting fish down to 2 ppm.

Response: Our goal is to reduce the risk to the fish-consuming public to acceptable levels. The studies performed to date allow us to examine any fish tissue PCB concentrations.

Have you examined sealing the contaminated sediments in place?

Response: Yes. For some situations this may be a suitable alternative. However, there are concerns with the long-term maintenance requirements associated with this option.

On August 29, 1986 the DNR served a notice to sue Allied Paper. What is the DNR's intention regarding this suit?

Response: The DNR's intention is still to file a lawsuit if a settlement is not reached with Allied Paper.

The $1.5 million allocated to clean-up the Allied Paper site -- how and when will that money be spent?

Response: That money has been reallocated to other remedial actions on the Kalamazoo River.

Note: Concern was raised about the temporary injunction stopping the DNR from removing the dams down to the sill level. Because of the recent temporary injunction, the DNR could not comment on this question or any related questions at this point in time.

Why won't the removal of the DNR dams transport the toxic materials downstream?

Response: The present removal project is only to remove the dam superstructure. The dams are not active and there is no impounded water that will be released and no downstream movement of sediments. This project will not change the hydraulic characteristics of the river.

How much will it cost to remove the DNR-owned dams to the sill level?

Response: About $400,000.

<u>Fisheries</u>

While it has been mentioned that millions of dollars will result from an improved fishery after PCB levels are reduced, has any consideration been given to negative primary and secondary affects from job losses and other negative impacts?

Response: We do not anticipate any job losses from these activities.

Are steelhead being stocked in the River?

Response: Yes. Since 1973, between 5,000 and 25,000 fish have been stocked annually, except for 1977, 1979 and 1983. The Rabbit River has also received steelhead plantings during this time period.

In the river upstream of Allegan Dam, what exists now and what will be done - other than PCB's and the dam - in the future?

Response: Presently, the fishing is poor and dominated by carp. In the future, plans are being made to eliminate the present fishery and restock this river between Allegan and Kalamazoo. Emphasis will be placed on developing a resident bass and pike fishery in conjunction with an anadromous salmonid fishery.

If the Kalamazoo upstream of Allegan Dam is a warm water fishery, how can salmon survive?

Response: The critical period of the year for salmonids is when water temperatures rise above 68° F. Rivers that reach water temperatures above 68° F generally do not support salmonids. The salmon fishery planned for the Kalamazoo River is an anadromous fishery where the salmon reside in Lake Michigan until their spawning migration upstream in the Kalamazoo River. The spawning migration occurs in the fall, when river temperatures are cooler and pose no problem for the salmonids.

Is the temperature of the stream in that area all right?

Response: Yes. The river temperatures are meeting State Water Quality Standards.

How do you plan to eliminate the carp?

Response: The present plan is to apply a chemical (rotenone) which suffocates the fish.

Will the rotenone affect only the carp?

Response: No. Rotenone will eliminate virtually all fish and some invertebrates.

Will the public be notified when the rotenone is used and be able to comment on how the carp are killed and where they are buried?

Response: Yes. All such projects are presently reviewed by the Water Resources Commission, which holds public meetings monthly.

How will you dispose of the dead carp?

Response: The details of this project have yet to be worked out. But the most likely disposal method will be on-site burial.

Will the fish burial site be lined?

Response: The PCB concentration in fish presently is nominal relative to sediment concentration. We hope that when the project is conducted that the PCB concentration will be even lower and that a liner for the disposal site will not be necessary.

Is the dissolved oxygen problem caused by carp?

Response: The dissolved oxygen problem is very complex. However, the contribution to the problem by carp is insignificant.

Nonpoint Source Pollution

What is going to be done about municipal stormwater discharges and nonpoint source pollution?

Response: On a national level, permits are now being required for municipal stormwater discharges. For nonpoint source pollution, the state has developed the Clean Water Incentives Program.

We need more statewide management of nonpoint source pollution such as the Clean Water Incentives Program.

Response: We agree. The state is assessing statewide nonpoint source pollution problems and developing a management strategy.

How many agricultural acres drain into the Kalamazoo River?

Response: In the Kalamazoo River Basin, about 57 percent (737,000 acres) of the land is used for agricultural purposes.

The potential is high for nonpoint source pollution from pesticide use effecting the Kalamazoo River.

Response: The issue of nonpoint source pesticide pollution will be addressed in the statewide management strategy.

We are very concerned about the effects of the Road Commission on the Great Lakes. In Kalamazoo County, 100,000 gallons of 2-4-D herbicides were used in August and September. These were washed away because of heavy rains during that period of time. Also, the companies that do the spraying are paid by the gallon. This seems like a bad practice. Who do we contact about this program?

Response: The Department of Agriculture regulates the use of restricted use "pesticides."

Have pesticide studies been done for the Kalamazoo River?

Response: Periodic sampling has been conducted on the Kalamazoo River. No problems have been identified to date.

We want statewide monitoring for pesticides.

Response: This issue will be addressed in the statewide management plan.

General

We need to upgrade the water quality of Kalamazoo River and change our attitude toward the River. We need more parks and access sites.

Response: We agree.

What is the status of the application for the new cogeneration plant in Otsego? They will be using a lot of water.

Response: There has been no formal application for the project to date. Informal discussion has been held regarding the project.

There is a dissolved oxygen problem upstream of the Kalamazoo City wastewater treatment plant.

Response: The DNR is investigating this in cooperation with the City of Kalamazoo.

Under the new water quality standards, the DNR is responsible for a comprehensive plan for dissolved oxygen. When will the Department take initiative on this effort?

Response: The DNR is currently developing a strategy to conduct comprehensive planning for dissolved oxygen.

WATER SAMPLING RESULTS FROM GEORGIA PACIFIC, KALAMAZOO SLUDGE DISPOSAL AREAS, APRIL 21, 1987. RESULTS IN () REPRESENT GEORGIA PACIFIC LAB RESULTS.

STATION NUMBER	LOCATION	AROCLOR 1248	TOTAL PCB (NG/L)	TOTAL SUSPENDED SOLIDS (MG/L)
13	A SITE (STANDING WATER)	150 (<1000)	150 (<1000)	68
14	LEACHATE	<20 (<1000)	<20 (<1000)	9
17	DAVIS CREEK	<20 (<1000)	<20 (<1000)	14

KALAMAZOO RIVER
Otsego City Dam - Dredging and Excavation - Upland Disposal
(KAL 10C)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) DREDGING CHANNEL AREA	159000	CY	5.65				898350				898350	
a. Mob. & Demob.		LS	15000.00				15000				15000	
2) CONTAMINATED SEDIMENT EXCAVATION	1300000	CY			.39	1.77			419320	2010740	3430080	
3) HAULING CONTAM. SED.	1588000	CY			.42	1.24			666960	1949120	2616080	
4) CONTAINMENT AREA												
a. Excavation	501000	CY			.39	1.77			195390	886770	1082160	
b. Dike	65000	CY			.80	1.38			52000	89700	141700	
c. Backfill	434000	CY			.31	.74			134540	321160	455700	
d. Topsoil 6"	128000	CY		5.50	1.80	4.90		704000	230400	627200	1561600	
e. Revegetation	3600	MHF		41.60	2.90	2.97		149760	10440	10708	170908	
5) SILT FENCE	19200	LF		2.30	.27			44160	5184		49344	
6) EXCAVATED AREA BACKFILL												
a. Backfill	1456000	CY		1.50	1.80	4.90		2184000	2620800	7134400	11939200	
b. Topsoil Layer - 6"	291000	CY		5.50	1.80	4.90		1600500	523800	1425900	3550200	
c. Revegetation	15700	MHF		24.40	5.60	4.45		384320	87920	69865	544005	
							913350	5088420	5175574	15375700	26553324	
Burden @ 11% of Labor Cost									672025		672025	
Labor @ 15% of Labor Cost									776336		776336	
Material @ 5% of Material Cost								254421			254421	
Subcontract @ 10% of Sub. Cost							91335				91335	
Total Direct Cost							1004685	5342841	6623935	15375700	30348254	
Indirects @ 50% of Total Direct Labor Cost									3312367		3312367	
Profit @ 10% Total Direct Cost											3034825	
											36695446	
Health & Safety Monitoring @ .04											1379818	
Total Field Cost											38075261	
Contingency @ 20% of Total Field Cost											7615052	
Engineering @ 4% of Total Field Cost											1523010	
TOTAL COST THIS CASE											[illegible]	

KALAMAZOO RIVER
Otsego City Dam - Channel Dredging, Lining & Impermeable Cap
(KAL-3)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) DREDGING SEDIMENT AREA	159000	CY	5.65				898350				898350	
a. Mob. & Demob.		LS	15000.00				15000				15000	
2) CONTAINMENT AREA												
a. Excavation	69400	CY			.39	1.77			27066	122838	149904	
b. Dike	9200	CY			.80	1.38			7360	12696	20056	
c. Backfill	60200	CY			.31	.76			18662	45752	64414	
d. Topsoil - 6"	20500	CY		5.50	1.80	4.90		112750	36900	100450	250100	
e. Revegetation	1100	MSF		24.60	5.60	4.45		27060	6160	4895	38115	
3) CHANNEL LINING												
a. Rip Rap - 12"	51200	CY		8.00	4.98	[illegible]		409600	254976	234464	919040	
b. Gravel Bed - 6"	26500	CY		10.50	2.20	6.11		278250	58300	161915	498465	
c. Filter Fabric	160400	SY		1.20	.16			192480	25664		218144	
d. Excavation & Spread.	197000	CY			.39	1.77			76830	348690	425520	
4) IMPERMEABLE CAP												
a. Sand Base - 6"	265000	CY		6.50	2.50	6.48		1722500	662500	1717200	4102200	
b. Liner - 30 mil	14296000	SF		.30	.20			4288800	2859200		7148000	
c. Sand Cover - 6"	265000	CY		6.50	2.50	6.48		1722500	662500	1717200	4102200	
d. Soil Layer - 18"	794000	CY		1.50	1.80	4.90		1191000	1429200	3890600	6510800	
e. Topsoil Layer - 6"	265000	CY		5.50	1.80	4.90		1457500	477000	1298500	3233000	
f. Revegetation	14300	MSF		24.60	5.60	4.45		351780	80080	63635	495495	
g. Silt Fence	19200	LF		2.30	.27			44160	5184		49344	
h. Regrading	265000	CY			.41	1.66			108650	439900	548550	
							913350	11798380	6796232	10178735	29686697	
Burden @ 13% of Labor Cost									883510		883510	
Labor @ 15% of Labor Cost									1019435		1019435	
Material @ 5% of Material Cost								589919			589919	
Subcontract @ 10% of Sub. Cost							91335				91335	
Total Direct Cost							1004685	12388299	8699177	10178735	32270896	
Indirects @ 50% of Total Direct Labor Cost									4349588		4349588	
Profit @ 10% Total Direct Cost											3227090	
											39847574	
Health & Safety Monitoring @ .04											1593903	
Total Field Cost											41441477	
Contingency @ 20% of Total Field Cost											8288295	
Engineering @ 4% of Total Field Cost											1657659	
TOTAL COST THIS CASE											51387431	

KALAMAZOO RIVER
City of Allegan Dam - Dredging - Upland Disposal
(KAL-MA)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) DREDGING SEDIMENT AREA	2023000	CY	3.45				15949950				15949950	
a. Mob. & Demob.		LS	25000.00				25000				25000	
2) CONTAINMENT AREA												
a. Excavation	712000	CY			.39	1.77			277680	1260240	1537920	
b. Dike	98000	CY			.80	1.38			78400	135240	213640	
c. Backfill	614000	CY			.31	.76			190340	466640	656980	
d. Topsoil - 6"	182000	CY		5.50	1.80	4.90		1001000	327600	891800	2220400	
e. Revegetation	9800	MSF		24.60	5.60	4.45		241080	54880	43610	339570	
							15974950	1242080	928900	2797530	20943460	
Burden @ 13% of Labor Cost									120757		120757	
Labor @ 15% of Labor Cost									139335		139335	
Material @ 5% of Material Cost								62104			62104	
Subcontract @ 10% of Sub. Cost							1597495				1597495	
Total Direct Cost							17572445	1304184	1188992	2797530	22863151	
Indirects @ 50% of Total Direct Labor Cost									594496		594496	
Profit @ 10% Total Direct Cost											2286315	
											25743962	
Health & Safety Monitoring @ .04											1029758	
Total Field Cost											26773721	
Contingency @ 20% of Total Field Cost											5354744	
Engineering @ 4% of Total Field Cost											1070949	
TOTAL COST THIS PAGE											33199414	

KALAMAZOO RIVER
Otsego City Dam - Channel Dredging, Lining & Soil Cap
(KAL-1)

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) DREDGING SEDIMENT AREA	159000	CY	5.65				898350				898350	
a. Mob. & Demob.		LS	15000.00				15000				15000	
2) CONTAINMENT AREA												
a. Excavation	69400	CY			.39	1.77			27066	122838	149904	
b. Dike	9200	CY			.80	1.38			7360	12696	20056	
c. Backfill	60200	CY			.31	.76			18662	45752	64414	
d. Topsoil - 6"	20500	CY		5.50	1.80	4.90		112750	36900	100450	250100	
e. Revegetation	1100	MSF		24.60	5.60	4.45		27060	6160	4895	38115	
3) CHANNEL LINING												
a. Rip Rap - 12"	51200	CY		8.00	4.98	4.97		409600	254976	254464	919040	
b. Gravel Bed - 6"	26500	CY		10.50	2.20	6.11		278250	58300	161915	498465	
c. Filter Fabric	160400	SY		1.20	.16			192480	25664		218144	
d. Excavation & Spread.	197000	CY			.39	1.77			76830	348690	425520	
4) SOIL CAP												
a. Soil Layer - 18"	794000	CY		1.50	1.80	4.90		1191000	1429200	3890600	6510800	
b. Topsoil Layer - 6"	265000	CY		5.50	1.80	4.90		1457500	477000	1298500	3233000	
c. Revegetation	14300	MSF		24.60	5.60	4.45		351780	80080	63635	495495	
d. Silt Fence	19200	LF		2.30	.27			44160	5184		49344	
e. Regrading	265000	CY			.41	1.66			108650	439900	548550	
							913350	4864500	2612032	6744335	14334297	
Burden @ 13% of Labor Cost									339564		339564	
Labor @ 15% of Labor Cost									391805		391805	
Material @ 5% of Material Cost								203229			203229	
Subcontract @ 10% of Sub. Cost							91335				91335	
Total Direct Cost							1004685	4267809	3343401	6744335	15360230	
Indirects @ 50% of Total Direct Labor Cost									1671700		1671700	
Profit @ 10% Total Direct Cost											1536023	
											18567953	
Health & Safety Monitoring @ .04											742718	
Total Field Cost											19310672	
Contingency @ 20% of Total Field Cost											3862134	
Engineering @ 4% of Total Field Cost											772427	
TOTAL COST THIS PAGE											23945234	

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SEDIMENT SAMPLING RESULTS FROM GEORGIA PACIFIC, KALAMAZOO SLUDGE DISPOSAL AREAS, APRIL 21, 1987. RESULTS IN () REPRESENT GEORGIA PACIFIC LAB RESULTS.

STATION NUMBER	LOCATION	AROCLOR 1248	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	TOTAL SOLIDS(%)
1	WILLOW SITE (NEAR RIVER)	79 (80)		 (26)	79 (106)	62.3
2	WILLOW SITE (UPLAND)	(77)		(16)	(93)	
3	WILLOW SITE (NEAR RIVER)	81 (141)		 (26)	81 (167)	56.4
4	WILLOW SITE (UPLAND)	68 (113)		 (21)	68 (134)	70.4
5	WILLOW SITE (NEAR RIVER)	(90)		(8)	(98)	
6	WILLOW SITE (UPLAND)	80 (145)		<3.9 (13)	80 (158)	64.1
7	WILLOW SITE (NEAR RIVER)	(33)		(7)	(40)	
8	WILLOW SITE (NEAR RIVER)	43 (39)		 (9)	43 (48)	73.9
9	WILLOW SITE (NEAR RIVER)	(33)		(7)	(40)	
10	WILLOW SITE (NEAR RIVER)	45 (84)		 (17)	45 (101)	66.8
11	WILLOW SITE (UPLAND)	(112)		(21)	(133)	
12	A SITE (NEW SLUDGE)	<1 (<1)		<1 (<1)	<1 (<1)	49.6
16	A SITE (OLD SLUDGE)	 (1)	1.1	 (1)	1.1 (2)	60.9
18	KING STORM S (OLD PIPE)	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)	
19	KING SITE (NEAR RIVER)	57 (81)		 (18)	57 (99)	39.2
20	KING SITE (DIKE WALL)	57 (63)		 (11)	57 (74)	68.7
21	KING SITE	(<1)	(<1)	(<1)	(<1)	

SEDIMENT SAMPLING RESULTS FROM GEORGIA PACIFIC, KALAMAZOO SLUDGE DISPOSAL AREAS, APRIL 21, 1987. RESULTS IN () REPRESENT GEORGIA PACIFIC LAB RESULTS.

ATION NUMBER	LOCATION	AROCLOR 1248	AROCLOR 1254	AROCLOR 1260	TOTAL PCB (MG/KG)	TOTAL SOLIDS(%)
	(DIKE WALL)					
22	KING SITE (DIKE WALL)	51 (64)		 (13)	51 (77)	68.1
23	KING SITE (DIKE WALL)	(<1)	(<1)	(<1)	(<1)	
24	KING SITE (DIKE WALL)	0.96 (<1)	 (<1)	 (<1)	0.96 (<1	87.2
25	KING SITE (NEW SLUDGE)	<1.2 (<1)	<1.2 (<1)	<1.2 (<1)	<1.2 (<1)	40.9
26	KING SITE (DIKE WALL)	(<1)	(<1)	(<1)	(<1)	
27	KING SITE (OLD SLUDGE)	5.4 (2)	 (<1)	 (<1)	5.4 (2)	60.3