THE USE OF BIOTIC VALUE ALLOCATION IN THE ASSESSMENT OF HEATED DISCHARGES

by

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INTRODUCTION

Current management approaches to achieving waterbody integrity emphasize restriction of the discharge of pollutants based on best practicable control technology. At present levels of control, this management approach must allow for mixing zones, or areas contiguous to a discharge which are not in compliance with water quality objectives. Since water quality objectives indicate minimum acceptable conditions, by definition, mixing zones constitute a loss of value. Present procedures for regulating mixing zones address the individual discharger, and fail to consider the presence of other mixing zones or the overall capacity of the receiving waterbody.

In response to this problem, Carlos M. Fetterolf of the Great Lakes Fishery Commission and William A. Brungs of the National Water Quality Laboratory in Duluth, Minnesota have developed the concept of biotic value allocation. First presented in a draft version of the Interagency 316(a) Technical Guidance Manual (U.S. Environmental Protection Agency, 1975), the biotic value allocation methodology was designed to provide a more holistic framework for waterbody management based on the following principles: A waterbody or waterbody segment has an inherent biological value, defined by the ability of the system to accommodate the resource requirements of resident organisms; these necessary resources, or habitat attributes are not uniformly distributed; rather, they are geographically distributed in identifiable patterns. For instance, shallow areas having a particular bottom type necessary for the successful spawning of an important resident fish species may be bound only in specific littoral zones of a waterbody. Such zones are particularly valuable if they are limited in the system. By defining the location of important habitats and by accounting for their abundance within a waterbody, the amount of habitat impacted by effluent mixing zones can be determined.

Notably, the biotic value allocation concept is representative of recent trends toward incorporating habitat concepts into Federal resource management policies. Jahn (1978) reviews major Federal laws, policies, and guidelines which include requirements for the assessment of habitat. These include the following:

- Fish and Wildlife Coordination Act (16 U.S.C. 661-666c, 1934 as amended), which requires the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to assess effects of proposed Federally funded water and land development projects.
- The National Environmental Policy Act of 1969 (P.L. 91-190), which requires lead Federal agencies to assess probable environmental impacts of major Federally funded projects.
- Coastal Zone Management Act of 1972 (P.L. 92-583), which requires states to designate "areas of land and water of particular concern," such as important habitat zones and areas of high productivity. Further, it is required that states develop policies and procedures for the management of these critical coastal habitats.
- Water Pollution Control Act Amendments of 1972 (P.L. 92-500). Of particular concern to this research, Section 316(a) requires an identification of key habitat zones in the assessment of effects of thermal discharges.
- Marine Protection, Research and Sanctuaries Act of 1972 (P.L. 92-532), which charges the U.S. Environmental Protection Agency with identifying unacceptable adverse impacts on fish spawning and breeding areas which would result from ocean disposal of waste materials.

- Endangered Species Act of 1973 (P.L. 93-205), which requires identification of critical habitats necessary for the conservation of endangered and threatened species.

- Sikes Act of 1974 (P.L. 93-452), which requires a state cooperation in the management of wildlife habitat on Federal lands.

- Forest and Rangeland Renewable Resources Planning Act of 1974 (P.L. 93-378), which requires the U.S. Forest Service to inventory natural resources of the National Forest System and to develop comprehensive plans for their management.

- Fishery Conservation and Management Act of 1976 (P.L. 94-265), which requires development of habitat management plans, toward the protection of anadromous and continental shelf fisheries within the 200-mile fishery conservation zone of the United States.

- Federal Land Policy and Management Act of 1976 (P.L. 94-579), which directs that fish and wildlife habitat be inventoried for National Resource Lands and that multiple use and sustained yield management policies be developed.

State and local planning efforts have also demonstrated a striking shift toward an emphasis on natural resource values. Kusler (1978) reports that since 1964, states have adopted more than 90 critical area regulatory programs. These programs are oriented toward the classification of management zones, providing a basis for determining the suitability of areas for development. However, state and local agencies often lack sufficient monetary resources to develop an adequate information base. Thus, Federal programs for the classification and inventory of habitat are an important source of information for state and local agencies. To ensure that a habitat classification or evaluation system is usable at all management levels, Kusler suggests that the system demonstrate the following characteristics: (1) management orientation;

(2) procedure simplicity; (3) usable by relatively untrained personnel (with mapped classifications being identifiable with local area features); (4) large-scale mapping; (5) inclusion of raw data; and (6) emphasis on key issues and areas of information need.

STATEMENT OF PURPOSE

The purpose of this research is to further develop the concept of biotic value allocation, and to outline the potential for its use by natural resource managers with limited financial resources. This entailed the application of the concept in a case study involving the heated discharge of the Kanawha River Power Plant, near Charleston, West Virginia. The general plan of the study was to undertake the tasks necessary to determine the expected amount of biotic value which should be allocated to the heated discharge, and then to compare results based on allocation theory to results obtained based on field observations.

RESEARCH OBJECTIVES

As outlined by the U.S. Environmental Protection Agency (1975), biotic value allocation involves a series of individual procedures to be conducted in a systematic fashion. Research objectives were generally consonant with these procedural requirements. It is notable, however, that some elements of the biotic value allocation methodology have been subjected to severe criticism. A major problem area has been the suggested procedures for the assignment of numerical values to individual biotic zones. Consequently it was a special objective of this research to develop a reasonable procedure for biotic zone evaluation. Including this special problem, research objectives were:

- Determination of the distribution of selected habitat attributes within the study area, which involved the identification of parameters known to influence microhabitat distribution of fishes, and the mapping of their distribution within the study area.
- Identification of biotic zones within the study area, which involved the classification of microhabitat types based on the results of the aforementioned research phase.
- Evaluation of biotic zones, which involved the development of a new procedure for the assignment of representative numerical values to individual biotic zones.
- Allocation of biotic value to the heated discharge of the Kanawha River Power Plant, which involved the application of the results of the biotic zone evaluation procedure in a system of allocation equations, and in a measurement of the amount of biotic value actually represented within the thermal mixing zone.

STUDY AREA LOCATION

The study area comprised a six-mile (9.6 km) reach of the Kanawha River, located above Charleston, West Virginia (Figure 1). The upstream boundary is located approximately one rivermile (1.6 km) upstream from the Kanawha River Power Plant at Glasgow, West Virginia. The downstream boundary was located just below rivermile 74, along a water quality classification boundary that denotes worsening conditions downstream.

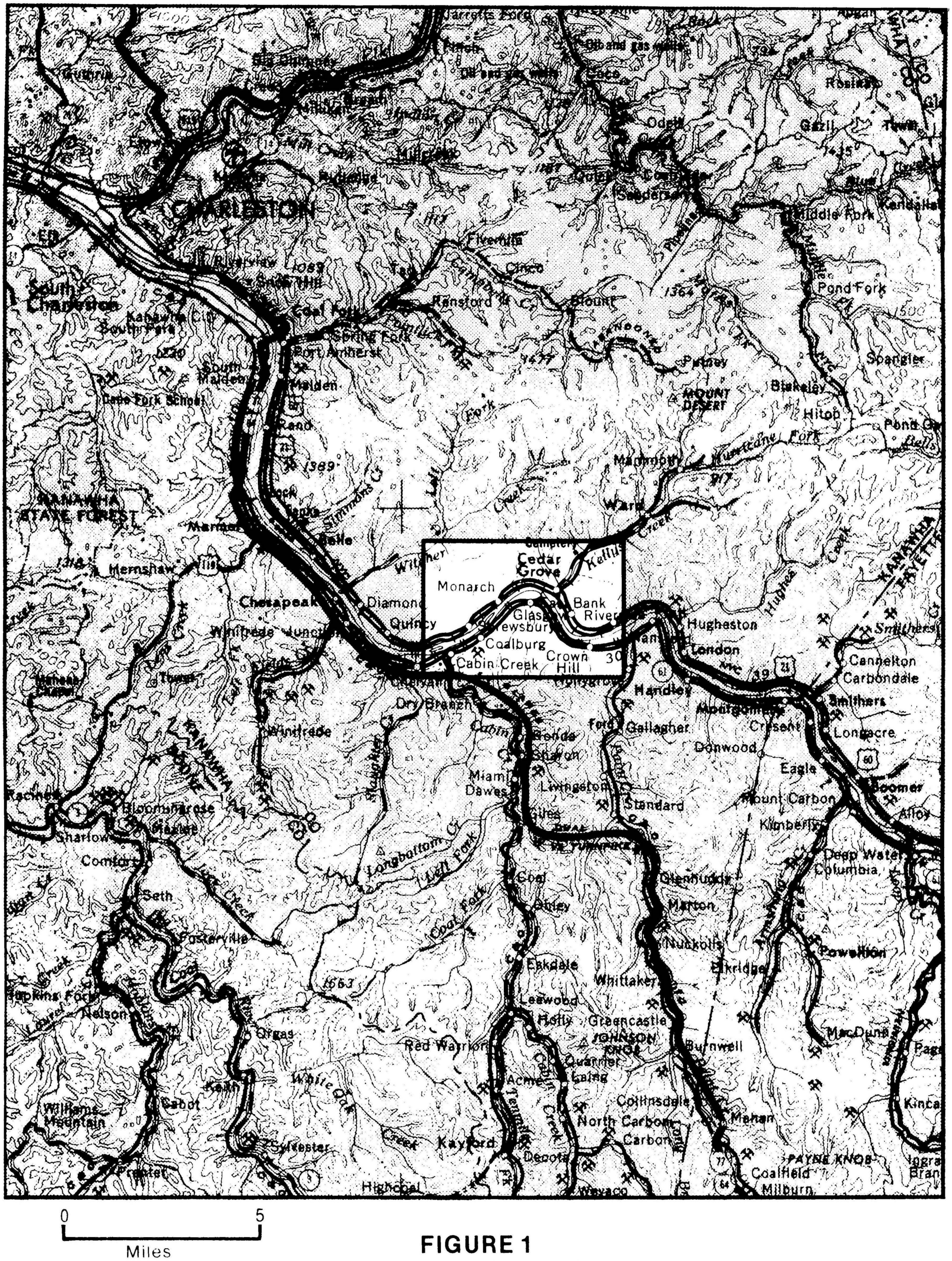


FIGURE 1
STUDY AREA LOCATION

BACKGROUND INFORMATION ON THE STUDY AREA

As the overall intent of the biotic value allocation concept is to serve as a more holistic framework for waterbody management, it is appropriate in this case study to provide an initial overview of the study area environment. As noted by Hynes (1970) and by Brown (1975), fish habitat includes the total range of physical, chemical and biological factors which describe a river system. In addition, habitat utilization is influenced by specific local disturbances, such as structures impeding water flow, shoreline developments, and wastewater mixing zones. Accordingly, the following descriptive information provides both a context for this research and specific data which was used in the evaluation of biotic zones. Areas addressed in this section are:

- The physical setting of the study area, including drainage basin characteristics, river morphometry, and flow regime.
- Water quality characteristics, including a description of major factors influencing local water chemistry.
- Biological characteristics, including baseline data on phytoplankton, zooplankton, benthic macroinvertebrates and fishes.

PHYSICAL SETTING

The Kanawha River System has its origins at Blowing Rock, North Carolina. From this area, the New River flows approximately 250 miles (400 km) through North Carolina and Virginia to its convergence with the Gauley River at Gauley Bridge, West Virginia (U.S. Corps of Engineers, 1975). This confluence creates the mainstem of the Kanawha River, which flows 96.5 miles (155 km) to its mouth on the Ohio River at Point Pleasant, West Virginia. The entire drainage system comprises 12,300 square miles (31,900 km^2), with approximately 69 percent of this area being located within the State of West Virginia (West Virignia Department of Natural Resources, 1975). Although the basin is located within several physiographic provinces, most of the Kanawha River, including the study area, occurs within the Cumberland-Allegheny Plateau Province (West Virginia Geologic and Economic Survey, 1968). This province is characterized by a sedimentary series of sandstones, limestones, and shales, interbedded with coal (Krebs and Teets, 1914). Within the western section of this province, Addair (1944) notes that the Kanawha River flows "gently past low hillocks," in contrast with upper reaches which appear like "mountain torrents." This view is reflected by the drainage regime of the Kanawha River, with a dendritic pattern predominating in the Cumberland-Allegheny Plateau Province, and a trellis pattern being typical of more mountainous areas within the basin.

Reports from the 1800's show that the Kanawha River was at one time a fast flowing, shallow, riffle and pool stream to a point about 33 miles (53 km) from its confluence with the Ohio River (U.S. Army Corps of Engineers, 1975). However, natural river conditions have been modified by the construction of three dams with high lift locks. Impoundment and channel maintenance to a point 90.0 miles (145 km) upstream from the mouth have transformed the river into a series of shallow pools interspersed with shoal areas. Estimated average depth ranges from less than ten feet (3.0 m) near Gauley Bridge, West Virginia, to 25 feet (7.6 m) at the mouth of the river (Elberfeld, personal communication, 1977). A 300-foot (91 m) wide channel is maintained at a minimum depth of nine feet (2.7 m) to ensure safe navigation.

Streamflow has been regulated since 1939 by Claytor Lake; and, additionally, by Bluestone Lake since 1949, and by Summersville Lake since 1965 (U.S. Geological Survey, 1977). The resulting average discharge at Kanawha Falls is reported to be 12,510 cfs (354.3 cms), with the period of record being 1877 to 1976. Downstream from this station, the West Virginia Department of Natural Resources (1975) identified 31 important tributaries of the Kanawha River, which together account for 30 percent of the drainage area of the entire Kanawha River basin. Two of these tributaries, Cabin Creek and Kellys Creek, enter the Kanawha River within the study area. Since flow data are lacking for these waterways, their contribution to the total discharge of the Kanawha mainstem cannot be determined. However, the overall importance of tributary flow is indicated by the contribution to mainstem flow of the Elk, Coal, and Pocatalico Rivers. Using 1976 data, these principal tributaries contribute a combined average discharge of 2,770 cfs (78.4 cms), representing about 18 percent of the average daily flow recorded at the mouth of the Kanawha (Table 1). In addition, the discharge of these tributaries accounts for about 55 percent of the difference between the average discharge at the mouth of the river and average discharge at rivermile 94.5.

WATER QUALITY

Water quality of the Kanawha River is periodically monitored by the West Virginia Department of Natural Resources, the Ohio River Valley Water Sanitation Commission (ORSANCO), and several Federal agencies. Data collection efforts have intensified since 1974, with 35 stations currently in operation within the Kanawha River basin (West Virginia Department of Natural Resources, 1977). Despite extensive participation, limitations of the sampling program have hindered recent efforts to formulate an areawide waste treatment management plan (West Virginia Region III Intergovernmental Council, 1977). Noting that data deficiencies exist, the following subsection

TABLE 1

1976 STREAMFLOW DATA FOR THE KANAWHA RIVER AND ITS PRINCIPAL TRIBUTARIES

STREAM	MILES ABOVE THE MOUTH OF THE MAINSTEM	RIVER FLOWS (1,000 cfs)											
		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Kanawha River	94.5												
Maximum Day		81.8	31.4	19.2	30.7	14.5	37.8	10.5	7.5	6.6	--	--	--
Monthly Average		22.1	18.4	11.2	8.8	6.2	11.6	6.4	3.6	3.3	--	--	--
Minimum Day		6.3	11.6	5.6	3.6	3.0	3.3	3.9	2.3	2.4	--	--	--
Elk River	57.8												
Maximum Day		15.5	5.3	9.6	3.8	4.7	0.8	7.5	0.8	3.1	--	--	--
Monthly Average		4.4	3.3	2.8	0.8	0.9	0.4	1.3	0.3	0.5	--	--	--
Minimum Day		1.0	1.7	0.6	0.2	0.2	0.1	0.2	0.1	0.1	--	--	--
Kanawha River	54.3												
Maximum Day		99.2	36.4	35.2	34.8	17.5	37.1	17.0	8.1	10.1	--	--	--
Monthly Average		28.0	22.5	15.5	10.1	7.2	11.8	7.6	4.0	4.0	--	--	--
Minimum Day		8.3	14.7	6.9	4.2	3.4	3.5	4.4	2.3	2.7	--	--	--
Coal River	45.4												
Maximum Day		6.6	3.8	7.4	3.5	1.5	0.3	0.2	0.4	1.4	--	--	--
Monthly Average		2.3	2.0	1.7	0.9	0.4	0.2	0.1	0.1	0.2	--	--	--
Minimum Day		0.9	1.1	5.8	0.3	0.2	0.1	<0.1	<0.1	<0.1	--	--	--
Pocatalico River	39.5												
Maximum Day		2.5	1.9	2.8	1.7	0.3	0.2	2.2	1.3	2.5	--	--	--
Monthly Average		0.7	0.4	0.4	0.2	0.1	<0.1	0.2	0.1	0.2	--	--	--
Minimum Day		0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--
Kanawha River	0.0												
Maximum Day*		111.0	43.9	60.3	40.6	26.4	39.8	22.0	11.4	13.7	130.4	33.6	53.6
Monthly Average*		34.2	27.7	19.8	13.0	8.6	13.9	10.2	4.9	5.0	35.6	14.7	19.7
Minimum Day*		11.6	18.8	10.3	3.6	3.8	4.2	6.0	3.0	2.8	5.5	8.3	9.2

*West Virginia Department of Natural Resources, 1977.

Source: U.S. Geological Survey, 1977.

presents a general description of water quality characteristics of the Kanawha River, with particular emphasis on the study area.

Historically, the Kanawha River has suffered from severe water quality problems since the early 1900's (Goldsborough and Clark, 1908). By 1946, river conditions in the vicinity of Charleston had deteriorated severely, marked by depleted oxygen levels, chemical and septic odors, and the loss of all but very coarse fish life (West Virginia Department of Natural Resources, 1975). Recent studies indicate that, although conditions have improved, violations of Federal and state water quality criteria commonly occur (West Virginia Department of Natural Resources, 1977).

The State of West Virginia segments the mainstem of the Kanawha River into two broad water quality zones (West Virginia Department of Natural Resources, 1975). The upstream segment (rivermile 96.5 to rivermile 74.0) is classified as "effluent limiting," indicating that quality standards will be met if available technology is applied to existing wastewater discharges: The downstream segment (rivermile 74.0 to rivermile 0.0) is classified as "water quality limiting," indicating that quality standards will not be met even with the application of best practical control technology for industrial discharges and secondary treatment for municipal discharges.

Attributed to the cumulative influences of the Charleston urban industrial area, progressive deterioration of water quality downstream from rivermile 74.0 is reflected in the concentrations of five major parameters from Glen Lyn, Virginia to Point Pleasant, West Virginia (Figures 2 and 3).

Calculations made from raw data supplied by the West Virginia Department of Natural Resources (1977) and the U.S. Geological Survey (1977) show that conductivity and concentrations of suspended solids are notably higher at Winfield Dam than at Chelyan (Table 2). Of those parameters which have been measured, several indicate violations of West Virginia standards and U.S. Environmental Protection Agency criteria for ammonia, fecal coliform bacteria, iron, lead, manganese, mercury, and phosphorus. Violations have also been documented or suspected for cadmium and dissolved oxygen (West Virginia Region III Intergovernmental Council, 1977). The West Virginia Department of Natural Resources (1975) reports that high organic levels and mine drainage characterize both Kellys and Cabin Creek, serving to intensify water quality problems within the study area.

Major point sources within the regional area include 36 industries, 18 municipalities, two power generation facilities and 36 coal preparation plants which discharge into the Kanawha River system (West Virginia Region III Intergovernmental Council, 1977). Although municipal discharges include more than 16 million gallons (6×10^7 l) of treated sewage wastewater and almost one million gallons (4×10^6 l) of untreated sewage per day, it is estimated that eight major industries

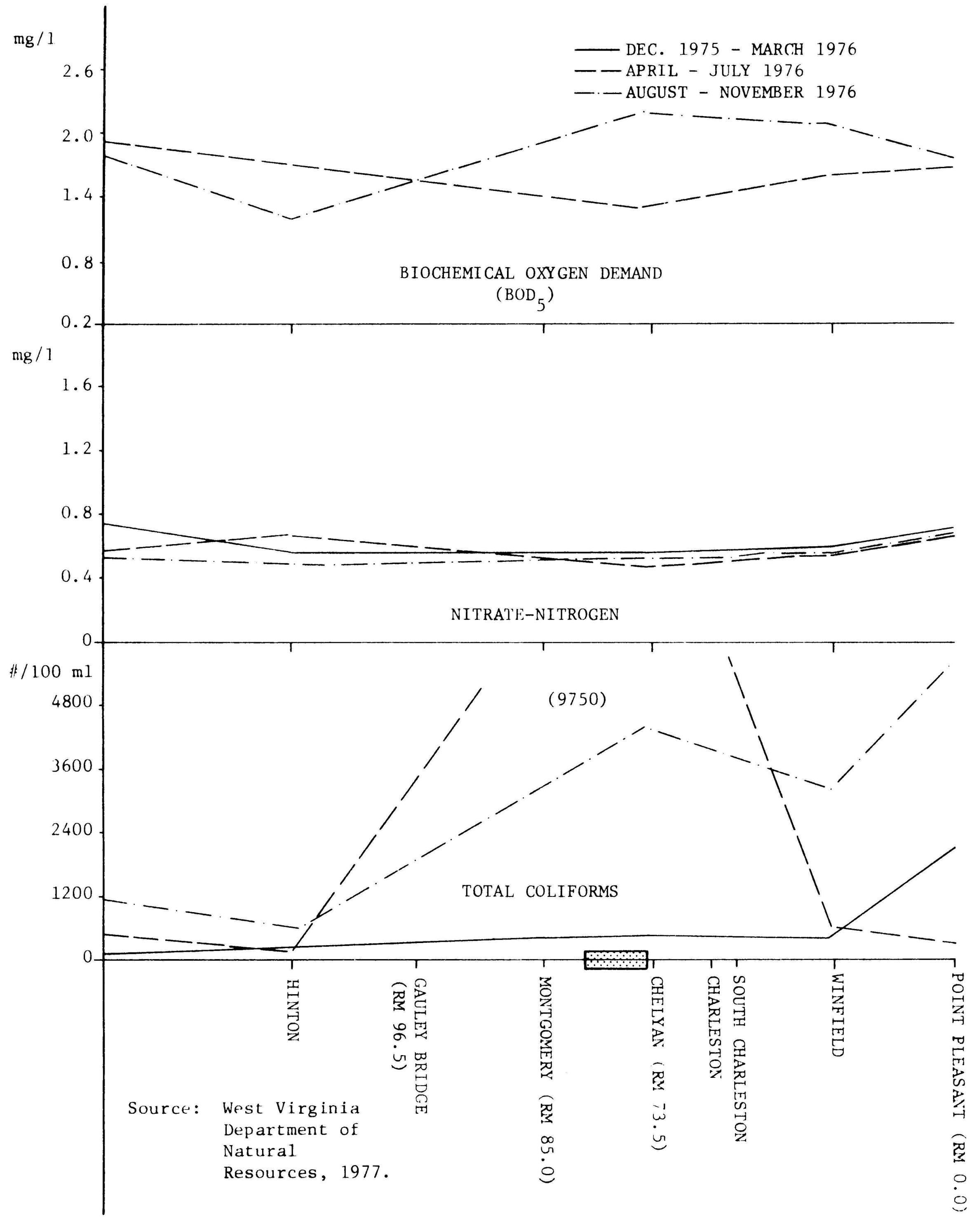


FIGURE 2

LEVELS OF BIOCHEMICAL OXYGEN DEMAND, NITROGEN, AND TOTAL COLIFORMS IN THE KANAWHA AND NEW RIVERS

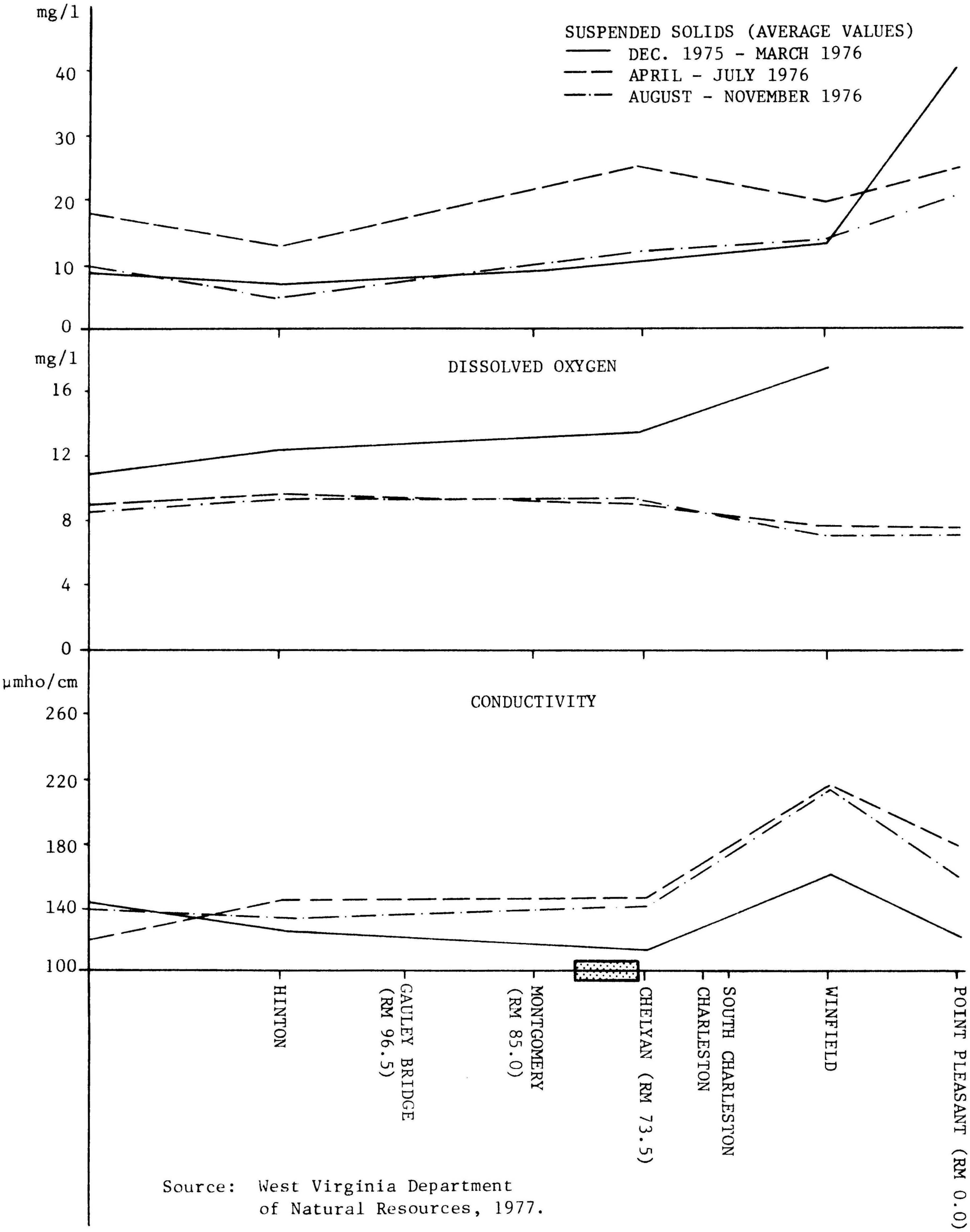


FIGURE 3

LEVELS OF SUSPENDED SOLIDS, DISSOLVED OXYGEN, AND CONDUCTIVITY
KANAWHA AND NEW RIVERS

TABLE 2

WATER QUALITY DATA
(mg/l Unless Otherwise Noted)

PARAMETER	KANAWHA RIVER AT CHELYAN[a]			KANAWHA RIVER AT WINFIELD DAM[b]			W.VA. STANDARD[c]	EPA CRITERION[d]
	AVE.	MAX.	MIN.	AVE.	MAX.	MIN.		
Total Alkalinity	36.67	51.00	30.00	-	-	-	-	20.00 minimum
Ammonia	0.17	0.45	0.05	-	-	-	-	0.02
Arsenic	0.00315	0.011	<0.002	0.001	0.002	0	0.01	0.05
Barium	<0.04	0.04	<0.04	-	-	-	0.5	1.00
Cadmium	0.0037	0.009	0.001	0.0012	0.004	0	0.01	0.01
Chloride	7.10	14.00	3.00	-	-	-	100.00	250.00
Chromium (hexavalent)	0.00265	0.004	<0.001	0.0075	0.01	0	0.05	0.05
Color Units	9.42	20.00	5.00	-	-	-	-	75.00
Conductivity (μmho)	136.70	208.00	112.00	224.00	426.00	109.00	-	-
Copper	0.0118	0.023	0.003	0.015	0.02	0.01	-	1.0
Cyanide	<0.001	0.001	<0.001	-	-	-	0.025	0.005
Dissolved Oxygen	10.00	14.30	7.40	8.70	14.80	3.70	5.00 minimum	5.00 minimum
Fecal Coliform Bacteria (MF/100ml)	415.00	1900.00	<100.00	33.00	1800.00	8.00	200.00	200.00
Iron	0.41	1.90	0.10	0.55	1.2	0.25	-	0.30
Lead	0.049	0.10	0.02	0.104	0.339	0.015	0.05	0.05
Manganese	0.085	0.12	0.064	0.097	0.14	0.07	-	0.05
Mercury	0.00028	0.00099	<0.0001	0.00162	<0.005	<0.0005	-	0.00005
Nickel	<0.015	<0.020	<0.010	-	-	-	-	.01 X 96 hr. LC_{50}
Nitrite and Nitrate	0.53	0.66	0.40	0.58	1.10	0.30	45.00	1.00
Total Organic Carbon	11.20	21.00	8.00	-	-	-	-	-
pH	7.15	7.80	6.40	7.00	8.40	6.30	6.0-8.5	6.5-9.0
Total Phosphorus	0.101	0.530	0.025	0.101	0.16	0.08	-	0.001
Selenium	0.00125	0.002	0.001	0.0005	0.001	0	0.01	0.01
Sulfates	19.60	34.00	14.00	-	-	-	-	250.00
Suspended Solids	14.30	63.00	4.00	33.20	138.00	8.00	-	10% reduction in compensation depth
Temperature (^{o}F)	56.20	77.00	35.00	60.80	81.50	35.60	Δ5 maximum	
Zinc	0.031	0.088	0.012	0.027	0.050	0.010		5.00

[a]West Virginia Department of Natural Resources, 1977.

[b]U.S. Geological Survey, 1977.

[c]West Virginia Department of Natural Resources, 1974.

[d]U.S. Environmental Protection Agency, 1976.

contribute 85 to 90 percent of the point source pollutant load to the river (West Virginia Region III Intergovernmental Council, 1977). All are chemical manufacturers, with most plants producing a variety of organic chemical substances. These manufacturers are located outside the study area, mainly occurring downstream.

In addition to the heated discharge of the Kanawha River Power Plant, point discharges within the study area include four municipal wastewater outfalls, with daily discharge rates ranging from 0.040 million gallons (1.5×10^5 l) to 0.128 million gallons (4.84×10^5 l) (Table 3). Locations of these wastewater discharges are shown on Figure 4.

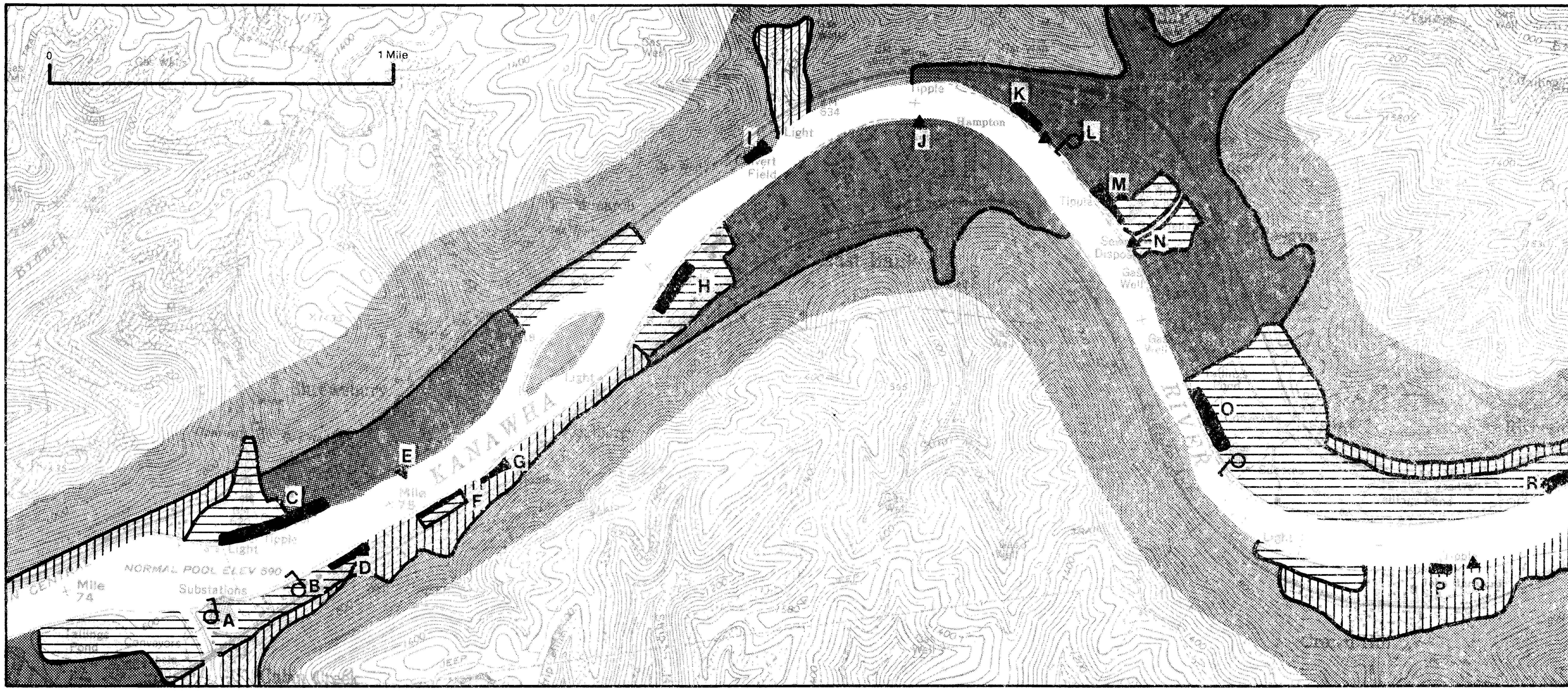
Although there is a paucity of data regarding non-point contaminant sources, the West Virginia Region III Intergovernmental Council (1978) concludes that surface water runoff and groundwater contamination constitute a significant source of contaminants entering the Kanawha River. Urban development accounts for six percent of the total land area of the four-county region which includes the study area (West Virginia Region III Intergovernmental Council, 1977). However, with almost 70 percent of the region having slopes of 25 percent or greater, most urban development is concentrated along the Kanawha River and its tributaries (Figure 4). Based on analysis of urban runoff in the vicinity of Charleston, the West Virginia Region III Intergovernmental Council (1977) estimates regional urbanized areas annually contribute 25 million pounds of suspended solids and associated contaminants to the Kanawha River.

TABLE 3

MUNICIPAL DISCHARGES WITHIN THE STUDY AREA

WASTE SOURCE	LOCATION (RM)	FLOW (MGD)	TYPE OF DISCHARGE
Community of Crown Hill[a]	79.3	0.040	Raw Sewage
Glasgow Sewage Treatment Plant[b]	77.9	0.22	Municipal Waste-water (primary treatment and chlorination)
Community of Cedar Grove[a]	77.4	0.128	Raw Sewage
East Bank Sewage Treatment Plant[b]	77.0	0.125	Municipal Waste-water (primary treatment and chlorination)
Community of Shrewsbury[a]	74.9	0.080	Raw Sewage

Source: [a]West Virginia Department of Natural Resources, 1975.
[b]West Virginia Region III Intergovernmental Council, 1977.



Key:

- Rural Residential
- Residential, Institutional, Recreational and Other
- Forested
- Industrial
- Intake
- Terminal Facilities
- ▲ Wastewater Discharge

A	Appalachian Power Co. (Industrial intake)
B	Cardox Corp. (Industrial intake)
C	Valley Camp Coal Co.
D	Union Coal Co. of California
E	Shrewsbury Sewage Discharge
F	E.M. Fredrick and Associates
G	Oak Development Co.
H	East Bank Dock Co.
I	Indiana and Michigan Electric Co.
J	Eastbank Sewage Treatment Plant
K	North American Coal Corp.
L	Town of Cedar Grove (Municipal intake and sewage discharge)
M	Kellys Creek and Northwestern R.R. Co.
N	Glasgow Sewage Treatment Plant
O	Appalachian Power Co. (Industrial intake, heated Discharge)
P	Riverton Coal Co.
Q	Crown Hill Sewage Discharge
R	Midwest Steel Corp.

Sources: Kanawha County Planning and Zoning Commission (1964, 1969), U.S. Army Corps of Engineers (1975, 1977), West Virginia, Department of Natural Resources (1975).

FIGURE 4
LAND AND WATER USE IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

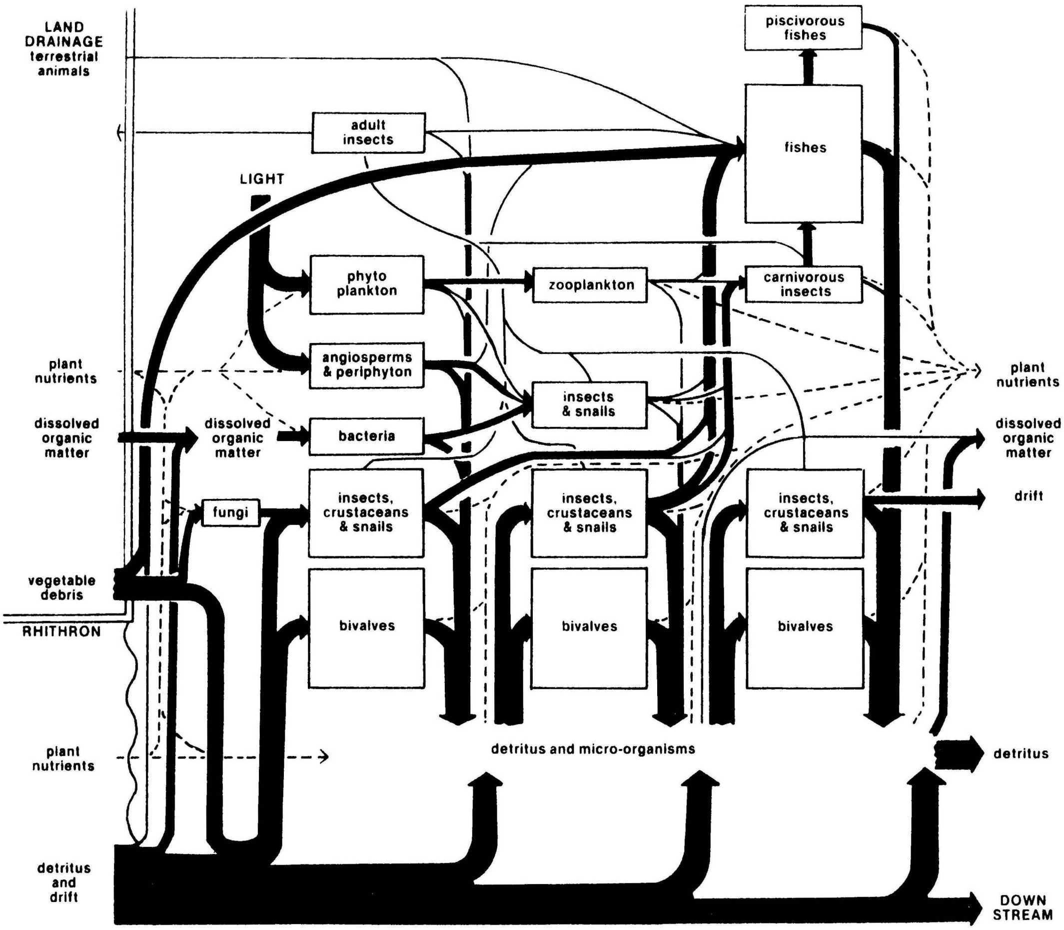
ECOLOGICAL OVERVIEW

Following the terminology of Hynes (1970), large rivers generally comprise three longitudinal ecological zones. The rhithron or upstream segment is characterized by high oxygen levels, fast and turbulent flow, and predominantly rocky substrate. In accordance with these characteristics, the resident community is characteristic of running water, generally cold stenothermic, with little or no true plankton component. Accordingly, allochthonous material such as leaf litter and nutrient-rich surface runoff would constitute the major source of energy input in these reaches (Odum, 1971; Hynes, 1970). The potamon, or downstream segment, is characterized by lower oxygen levels, slow and more laminar flow, and predominantly sandy to silty substrate (Hynes, 1970). In these reaches, the resident community is more typical of limnetic environments, generally eurythermic or warm stenothermic, often with a rich plankton component. The area of overlap between the thithron and potamon, which typically supports a rich community containing species from both ecological zones, can be considered a third zone.

Although longitudinal zonation is apparent on the Kanawha River, previously described physical modifications have resulted in the creation of artificial ecological boundaries. Reports from the 1800's indicate that under natural conditions the boundary between the rhithron and the potamon occurred less than 33 miles (53 km) upstream from the mouth of the Kanawha River (U.S. Army Corps of Engineers, 1975). However, the river has been modified to form a series of four navigational pools. Accordingly, the lower boundary of the rhithron zone has been adjusted to a point between rivermile 96.5 and rivermile 90.0, with downstream pools having more of the characteristics of the potamon.

In addition to physical modification, the Kanawha River has been subjected to a range of industrial and municipal discharges for more than 50 years. As previously noted, these discharges have resulted in severe water quality problems within the Kanawha River basin. In some reaches of the river, particularly downstream from the study area, high levels of contamination have had severe adverse effects on local ecology. Accordingly, faunal discontinuities within an ecological zone often occur as an artifact of local pollution (Hynes, 1970).

Extensive surveys of aquatic communities of the Kanawha River are lacking. However, sufficient baseline information exists to approximate the ecological relationships within the study area. In accordance with concepts presented by Hynes (1970), it is concluded that the main source of energy in the study area is fine detritus from upstream reaches (Figure 5). In addition, surface runoff and sewage outfalls within the study area contribute large amounts of nutrients and dissolved organic matter. These materials support a rich phytoplankton community, especially during summer months. Settling material provides food for the benthic macroinvertebrate community, which consists predominantly of oligochaetes, dipterans and molluscs. Due to



Source: Hynes, 1970

FIGURE 5
DIAGRAMMMATIC REPRESENTATION
OF TROPHIC RELATIONSHIPS
WITHIN THE STUDY AREA

the constant and rich supply of organic matter in the study area, a large proportion of resident fishes would tend to feed directly on allochthonous matter. Baseline data used in formulating this profile is summarized in the following sections on phytoplankton, zooplankton, benthic macroinvertebrates, and fishes.

Phytoplankton

The phytoplankton of the Kanawha River at Winfield Dam, located 41.5 miles (66.8 km) below the study area, was sampled monthly from November 1975 to September 1976 by the U.S. Geological Survey (1977). Dominant phytoplankers were diatoms, chlorophytes, and blue-green algae. Populations remained at low levels during the winter months, 190/ml during December, with the diatom *Nitzchia* sp. dominant. It is notable, however, that the February sampling showed that 43 percent of the phytoplankton count was comprised by the blue-green algae, *Oscillatoria* sp. During warmer months, total numbers of phytoplankton increased to 10,000/ml, with major increases occurring in populations of *Cyclotella* and *Melosira*.

The U.S. Army Corps of Engineers (1975) report that annual average phytoplankton counts at Winfield Dam are more than twice those found in the Ohio River, and about nine times greater than those reported for the Potomac River. Further, this report notes that elevated populations of green algae have resulted in severe taste and odor problems within the study area. Although no quantitative data are available for phytoplankton within the study area, it is notable that acid-tolerant forms such as *Euglena nutabilis*, *Cryptomonas erosa*, *Ulthrix zonata*, *Ochromonas*, and *Closteriopsis* occur in tributaries affected by mine drainage, such as Cabin Creek (U.S. Army Corps of Engineers, 1975). In addition, concentrations of the blue-green alga *Oscillatoria* were identified near the mouth of Kellys Creek during the conduct of field research for this study.

Zooplankton

Few studies of zooplankton have been carried out on the Kanawha River. The U.S. Army Corps of Engineers (1975) report that limited sampling indicates that copepods, cladocerans and rotifers are the major groups comprising the local zooplankton community. Prevalent genera include the copepods *Cyclops* and *Macrocyclops*, the cladocerans *Daphnia* and *Bosmina*, and the rotifers *Branchionus*, *Trichocera*, *Polyarthra*, *Keratella*, and *Synchaeta*.

Benthic Macroinvertebrates

Several studies of macrobenthos have been conducted on the Kanawha River, although sampling has been limited. A study conducted by the U.S. Department of the Interior (1967) found that degraded water quality conditions resulted in the elimination of benthic organisms below Blaines Island, located 16.5 miles (26.5 km) below the study area. Mason et al. (1971) also reported severe reduction of macroinvertebrates due to high contaminant levels. Benfield et al.

(1975) found that the area between London Locks and the confluence of the Gauley and New Rivers supported a relatively undisturbed benthic macroinvertebrate community. Between London Locks and a point upstream from the City of Charleston, some evidence of degradation was found, with populations being severely depressed further downstream. Approximately three miles (5 km) upstream from the study area, major components of the benthic community were oligochaetes, dipterans, and molluscs. Approximately 10 miles (16 km) downstream from the study area, the numbers of taxa, density, and diversity were above values for the upstream station. However, it was concluded that a comparative reduction in the variety and density of molluscs collected at the downstream station indicates a degree of environmental degradation. Results of this study are generally supported by an abbreviated survey undertaken by the U.S. Army Corps of Engineers (1975). Sampling stations for this research included an area near Kellys Creek. Worms and midges predominated at this station, with the Asiatic claim (*Corbicula manilensis*) and the pollution-intolerant burrowing mayfly (*Hexagenia* sp.) also being collected.

Fishes

Several studies on the fish of the Kanawha River system have been conducted. Addair (1944) noted that the earliest reported collection was conducted in the 1860's by E. D. Cope. Another early study was undertaken by Goldsborough and Clark (1908), who collected 20 species from the Greenbriar, New and Bluestone Rivers. These investigators concluded that the Kanawha River system had suffered a depletion of its fishery resources due to mining and timbering practices, and to the practice of killing fish with dynamite. Addair (1944) collected 36 species below Kanawha Falls, with low numbers and diversity found near Charleston being attributed to toxic discharges by local industries. Jenkins et al. (1971) reported that a total of 98 species occur below the falls.

Recent collections from the Kanawha River indicate that the most abundant fish species include Notropis atherinoides and N. stramineus, the sucker Moxostoma macrolepidotum, and the game fishes Ambloplites rupestris, Micropterus dolomieui, and M. punctulatus (Stauffer and Hocutt, 1977). Rotenone samples of London Locks in 1970 and 1976 produced a total of 16 and 27 species, respectively (Muth, personal communication, 1977). Such surveys, taken periodically, indicate that fish populations in the Kanawha River have improved in recent years, probably due to reductions in contaminant loading.

MATERIALS AND METHODS

The biotic value allocation methodology applied in this study involved the use of existing data to the extent possible. To supplement the literature, extensive study area reconnaissance and a limited sampling program were undertaken. The following chapter details materials and methods used in the conduct of field studies. Additionally, an overview of the biotic value allocation methodology is presented, outlining the concept as originally presented by Fetterolf (1975, 1976) and by the U.S. Environmental Protection Agency (1975), and detailing the modified procedure developed in this research.

FIELD STUDIES

A general program of study area reconnaissance was conducted from June 1977 through September 1977. A record was maintained of riparian land use and vegetation, and special shoreline modification features such as barge terminals, bulkheads, boat ramps, and rip-rap. Field notes were supplemented by photographs and by a record of the location of key features on working maps at a scale of 1:9600. In addition to this general reconnaissance, the following special studies were undertaken.

Bottom Type Survey

Between August and September 1977, a grab sample of sediment was collected at each of 16 stations, using either SCUBA equipment or a Ponar Dredge Sampler. Due to the extensive area requiring characterization, samples were taken or visual observations were made at approximated 1500 foot (460 m) intervals. Special effort was taken to characterize sediment in areas where a variation in substrate type was suspected, such as at creek mouths, in mudflat zones, and at Watsons Island. Sampling sites were identified on a study area base map during the sampling period. Ten samples were selected for detailed analysis, and were refrigerated until processed. The samples were processed using the Wentworth scale (Wentworth, 1922), as modified by Cummins (1962). Silts were obtained by settling. Organic content was determined for particle size classes less than 2 mm diameter by drying subsamples at $90^{o}C$ for 24 hours, and then ashing at $550^{o}C$ for two hours.

Aquatic Macrophyte Survey

Between June and August 1977, grab samples of aquatic macrophytes were taken while mapping the location of beds. A total of 41 samples was collected representing 18 sampling locations. These were preserved by drying using suitable presses and storing for seven days in a heated drying closet. Samples were identified using the following references: Beal (1977), Fassett (1969), and Prescott (1976).

BIOTIC VALUE ALLOCATION

The biotic value allocation methodology is a complex stepwise process, involving descriptive, synthetic and evaluative phases. As conceptually presented by Fetterolf (1975, 1976) and by the U.S. Environmental Protection Agency (1975), major components of the methodology were:

- Determination of general management objectives, with identification of biological and other uses to be protected.

- Selection of representative, important species, whose protection assures the protection of the ecosystem to support management objectives.

- Biological mapping to establish the biotic zones of representative, important species.

- Evaluation of biotic zones, using a numerical rating system.

- Identification of an appropriate level of protection, indicating the amount of biological value expendable for efficient mixing zones within the water body or water body segment.

- Allocation of biotic value to existing dischargers, and calculation of the reservoir available for future dischargers.

This list serves as the general foundation for the methodology applied in this research. It is noted, however, that the preliminary tasks of definition of broad management objectives and selection of representative, important species were undertaken as part of an earlier study by Dickson (1977). Consequently, these subjects are not addressed in this section.

Although the general scope of the methodology applied in this research is consonant with previously presented conceptual models, some major modifications have been introduced. Foremost is a redefinition of the term biotic zone. The conceptual models characterize the term biotic zone as an area of actual resource use by individual representative, important fish species (Fetterolf, 1975, 1976; U.S. Environmental Protection Agency, 1975). However, as shown in a subsequent section, a range of habitat types may be suitable for the conduct of critical activities, reflecting the dynamic use of space by fishes. Thus, the occurrence of a particular species within a specific area is more appropriately viewed as a probability function. Further, since the data necessary to calculate statistical probabilities are lacking, such predictions can only be based on educated judgment. Consequently, determination of the probable use of particular areas by representative, important species is presented as an integral part of the evaluation procedure. To provide for this more flexible approach, the term biotic zone is redefined as a microhabitat type, possessing a unique set of characteristics which may influence the distribution of species within a general aquatic habitat.

With the incorporation of these modifications, the methodology comprises three basic phases: identification of biotic zones; biotic zone evaluation; and allocation of biotic value to the heated discharge of the Kanawha River Power Plant.

The following section details procedures comprising each phase. Where field studies were involved and where extensive literature review was used in refining procedures, reference is made to an appropriate section of this report.

Identification of Biotic Zones

Habitat structure within the study area was described in three dimensions: depth, bottom type, and the presence or absence of aquatic macrophytes. Three depth categories and three bottom types were recognized as representative within the study area (see Distribution of Habitat Attributes Within the Study Area). A bathymetric survey conducted by Weston Geophysical Engineers, Inc. (1977) provided the data base for the mapping of bathymetric zones. Field surveys, conducted between June and September 1977, provided the data used in mapping the distribution of bottom types and aquatic macrophytes (see previous section on Field Studies). Using working maps drafted at a scale of 1:9600, the surface area of bathymetric and bottom type zones was calculated using a high resolution digitizing planimeter having a resolution capability of 0.010" (0.25 mm) (Numonics Corporation, 1976). Three measurements were taken of each area, with the average of these values being used in this study.

An overlay technique was used to synthesize biotic zones from the individual maps of habitat attributes. Six biotic zones were recognized within the study area: shallow areas with a boulder/cobble bottom; shallow areas with a pebble/gravel bottom; shallow areas with a sand/silt bottom; moderately deep areas; deep areas; and areas of aquatic macrophyte growth. Surface area calculations were based on previous measurements, with the exception of the aquatic macrophyte zone. In this case, a buffer area of 0.1 acre (0.04 ha) was subtracted from a surrounding zone and allocated to each of the 41 macrophyte bed units identified within the study area.

Evaluation of Biotic Zones

The evaluation of biotic zones was conducted as a two-part procedure during November 1978. The initial phase consisted of the evaluation of the suitability of biotic zones for use by representative, important species. Ten aquatic biologists, all members of the technical staff of The MITRE Corporation of McLean, Virginia, were provided with descriptive information on the six biotic zones, including areal measurements; and life history information for representative, important species. Additionally, population estimates were provided, to indicate resource demand levels. Using this information in conjunction with professional judgment, biologists selected those representative, important species that would be likely to use each of the six biotic zones according to five resource use categories: general requirements (living space), feeding, spawning, nursery, and migration. Thus, the assessment form comprised a 30-unit matrix.

The second phase consisted of transforming the results of the assessments into representative numerical values. The overall plan of this phase was to consolidate the ten evaluations onto a single matrix form for each species and then to interpret the information using a composite index system. The biotic value of each zone comprises the sum of composite index values for each resource use category or matrix unit within that zone for all eight representative, important species. Composite index values were calculated by species and represent the product of the two components discussed below.

The first term of the composite index is a confidence quotient, reflecting the level of agreement among biologists on a particular judgment. The confidence quotient was calculated for each matrix unit according to species. For example, where five of the ten biologists determined that gizzard shad (Dorosoma cepedianum) would be likely to use Biotic Zone 1 for feeding, the resulting confidence quotient is 0.5.

The second term of the composite index is an exclusivity quotient, reflecting the importance of individual zones to representative, important species, according to resource use category. The exclusivity quotient was calculated by dividing the number of times a given species was identified within a particular matrix unit by the total number of times that species was identified within that resource use category. These values were then represented as percentages. For instance, where five biologists determined that gizzard shad would be likely to use Biotic Zone 1 for feeding and gizzard shad are listed 26 times in the entire feeding category, the resulting exclusivity quotient is 0.192 or 19.2 percent.

Allocation of Biotic Value

This final procedural phase was conducted in strict accordance with the methodology outlined by the U.S. Environmental Protection

Agency (1975). As outlined in this procedure, the study area was divided into m biotic zones, with known areas (A_1, A_2, . . ., A_m) and correspondingly assigned relative biotic values (BV_1, BV_2, . . ., BV_m). In addition, n dischargers were identified within the river segment with relative flow rates of Q_1, Q_2, . . ., Q_n. The general plan of the procedure is to allocate biotic value to mixing zones using a series of equations involving the representation of management objectives with assigned numerical values. As shown in the following description of the procedure, where such representations were required, values recommended by the U.S. Environmental Protection Agency (1975) were used.

A. Assignment of a value representing a suitable level of protection (p): In accordance with recommendations by the U.S. Environmental Protection Agency (1975), a moderate level of 0.05 was set for p, indicating that up to 5 percent of the study area could be used for mixing zones.

B. Assignment of a value representing the fraction of biotic value alloted to present dischargers (θ): In accordance with suggested procedures, a reasonable value of 0.5 was set for θ. This value indicates that 50 percent of the total biological value which could be used for mixing zones could be allocated to existing dischargers, creating a reservoir of 50 percent for future dischargers.

C. Selection of a method for allocating mixing zone sizes: The suggested option allocates mixing zones proportionally according to a monotonic increasing function of the discharge volume.

In accordance with the aforementioned factors, the following equations were used in allocating biotic value:

1. The total biological value (TBV) of the study area was calculated by taking the sum of the biotic value (BV) for each biotic zone:

$$TBV = BV_1 + BV_2 + . . . + BV_m$$

2. The total amount of biotic value expendable for all mixing zones was calculated as:

$$p(TBV)$$

3. The amount of biotic value allocated to existing dischargers was calculated as:

$$\theta p(TBV)$$

4. Using the aforementioned allocation option, the amount of biological value allocated (BVA_k) to a discharger with a flow rate of Q_k was calculated as:

$$BV_k = \theta p(TBV) \frac{f(Q_k)}{\Sigma f(Q_k)}$$

where the subscript k denotes a specific discharger, and where

$$f(Q_k) = \frac{Q_k}{Q_k + \bar{Q}}$$

and,

$$\bar{Q} = (\sum_{k=1}^{n} Q_k)/n$$

The calculation of the actual amount of biotic value represented within the thermal mixing zone of the power plant discharge was based on a report on thermal conditions in the vicinity of the Kanawha River Power Plant (Marchman et al., 1976). Maps showing surface temperature contours on four days, representing seasonal variation, were synthesized to define the surface area of the mixing zone. The mixing zone was defined in accordance with state standards, which limit increases to $5^{o}F$ ($3^{o}C$) above ambient levels (West Virginia Department of Natural Resources, 1974). Additionally, areas where temperature was increased by $2^{o}F$ ($1^{o}C$) were defined to provide a worst case estimate of mixing zone extent. Using an overlay technique, biotic zones within the heated discharge were defined, with intersected areas being calculated using a digitizing planimeter (Numonics Corporation, 1976).

THE DISTRIBUTION OF SELECTED HABITAT ATTRIBUTES WITHIN THE STUDY AREA

Habitat selection was recognized by Lack (1949) as a behavioral adaptation indicating the advantage of detecting favorable environments, and is a concept which is well represented in the ecological literature (Allee et al. 1949; Krebs, 1972; Williams et al. 1978). Specific environmental attributes which act as stimuli in habitat selection by freshwater fishes have been addressed in several studies. Munther (1970) reported that current, bottom type, depth, temperature, and light intensity are major factors determining the movement and distribution of smallmouth bass (*Micropterus dolomieui*). A laboratory study by Baker (1971) showed that fourspine sticklebacks (*Apeltes quadracus*) showed a significant preference for areas planted with elodea, even when other types of vegetation were available. In another study, Winn (1958) found that microhabitat selection by darters is related to current and substrate. These studies and supporting anecdotal evidence (Trautman, 1957; Cross, 1967; Pflieger, 1975; Clay, 1975) indicate that depth, substrate, macrophytes, and current are of major importance in microhabitat selection by freshwater fishes.

Field reconnaissance showed that flow velocity ranges at least from 0.2 ft/sec (0.06 m/sec) at a depth of three feet (1 m) near East Bank to 0.9 feet/sec (0.27 m/sec) at a depth of three feet (1 m) near London Locks. However, current velocity is highly variable within the study area, and data which would indicate trends are lacking (Preston, personal communication, 1978). Accordingly, the profile presented in this section addresses three dimensions of fish habitat: depth, bottom types, and aquatic macrophytes. Material presented includes a general description of each habitat attribute and maps showing the distribution within the study area of three depth categories, three bottom types, and aquatic macrophytes. Special emphasis is given to the areal extent of mapped features, represented in acres and percent of total surface area. A brief summary of this material is presented at the end of the section.

DEPTH

A bathymetric survey of the study area indicated that riverbed elevations decrease sharply within 50 to 100 feet (15-30 m) of the shoreline, with a relatively flat bottomed mid-channel area ranging in width from 300 to 600 feet (91-183 m) and ranging in depth from 15 to 30 feet (4.6-9.1 m) (Weston Geophysical Engineers, Inc., 1977). As previously noted, the study area is located within the 90-mile segment of the Kanawha River which has been impounded to improve navigability (see Background Information). The U.S. Army Corps of Engineers (1975) indicate that due to the steep banks of the Kanawha River, elevation of the water level effectively eliminated much of the river's natural littoral zone. Further, channel maintenance operations control the expansion of shallow zones in areas of sediment acretion. Plybon (personal communication, 1977) reports that periodic dredging is conducted near the outflows of Cabin and Kellys Creeks.

Based on the results of the Weston survey, three depth categories were established: 0 to 10 feet (0-3.0 m) corresponds to shallow zones; 10 to 25 feet (3.0-7.6 m) to zones of moderate depth; and more than

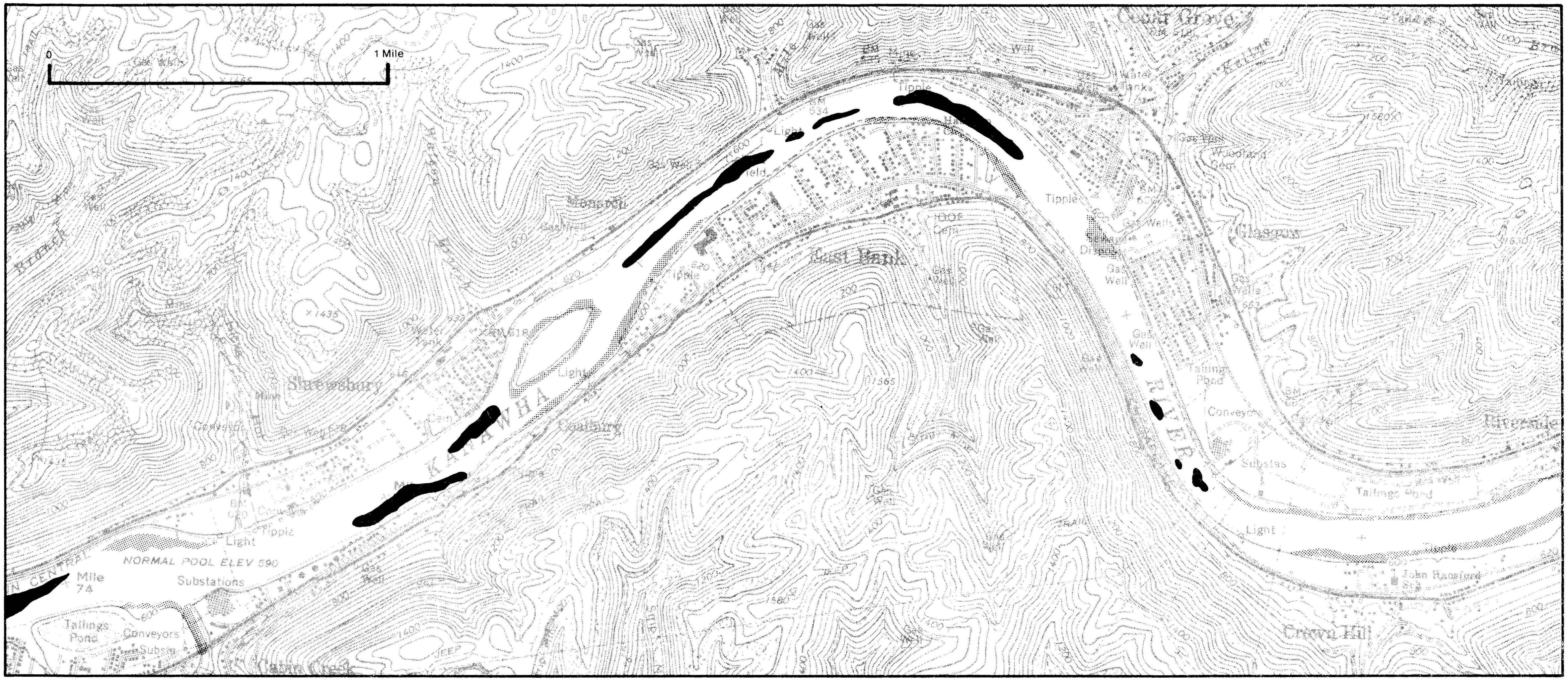
25 feet (7.6 m) to deep zones. Figure 6, depicting the distribution of these zones, confirms that shallow areas are particularly limited within the study area. Occurring primarily near the outflows of Cabin and Kellys Creeks, near East Bank, and upstream from the Kanawha River Power Plant, shallow zones comprise a total of 63.4 acres (25.7 ha), or 13 percent of the study area. Zones of moderate depth were found to predominate, accounting for 378.0 acres (153.0 ha), or 79 percent of the study area. Deep zones were found to comprise 38.6 acres (15.6 ha), or about eight percent of the total study area.

BOTTOM TYPES

The distribution of bottom types within the study area was characterized using several information sources. The results of a limited field sampling program served as the basis for substrate classification, with three generic bottom types being identified. This information was used in conjunction with visual inspection of sediments in unsampled areas and the results of past studies, to formulate a map of bottom type distribution. The following section details the results of substrate sample analyses, describes the classification of bottom types, and presents a bottom type map generated from the synthesis of available information.

Grain Size Analysis

The processing of sediment samples for grain size distribution showed that cobble and sand sized fractions were most common in the study area. As shown in Table 4, the cobble sized fraction accounted



Key:

Shallow (0-10 Feet)

Moderately Deep (10-25 Feet)

Deep (>25 Feet)

Approximate shoreline elevation is 590 feet.

Source: Weston Geophysical Engineers, Inc., 1977

FIGURE 6
BATHYMETRIC ZONES IN THE VICINITY
OF THE KANAWHA RIVER POWER PLANT

TABLE 4

SIZE CLASSIFICATION BY WEIGHT OF SUBSTRATE SAMPLES
COLLECTED FROM THE KANAWHA RIVER IN THE VICINITY
OF THE KANAWHA RIVER POWER PLANT

STATION	LOCATION	COLLECTION METHOD	BOULDERS PRESENT	COBBLE SIZED FRACTION (64-256 mm)		PEBBLE SIZED FRACTION (16-64 mm)		GRAVEL SIZED FRACTION (2-16 mm)		SAND SIZED FRACTION (.074-2 mm)		SILT SIZED FRACTION (.0039-.074 mm)		CLAY SIZED FRACTION (<.0039 mm)		TOTAL WEIGHT (g)
				Weight (g)	% of Total	Weight (g)	Total	Weight (g)	% of Total	Weight (g)	Total	Weight (g)	% of Total	Weight (g)	% of Total	
01	North Bank near London Locks	SCUBA grab	X	530.0	78.3	77.8	11.5	8.0	1.2	50.0	7.4	4.8	0.7	6.4	0.9	677.0
02	Mid-Channel near London Locks	SCUBA grab	X	1221.5	85.0	142.3	9.9	8.0	0.6	55.0	3.8	5.9	0.4	3.6	0.2	1436.3
03	Mid-Channel near London Locks	Ponar grab	-	34.7	45.2	10.0	13.0	3.5	4.6	26.5	34.5	2.0	2.6	*	-	76.7
04	South Bank near London Locks	Ponar grab	X	248.0	78.7	20.1	6.4	6.1	1.9	38.7	12.3	2.3	0.7	*	-	315.2
05	South Bank upstream from the Kanawha River Power Plant	SCUBA grab	X	716.0	90.5	2.5	0.3	0.1	<0.1	54.0	6.8	12.2	1.5	6.5	0.8	791.3
06	Mid-Channel upstream from the Kanawha River Power Plant	SCUBA grab	-	204.7	57.4	81.2	22.8	6.0	1.7	49.0	13.7	10.8	3.0	4.8	1.3	356.5
07	North Bank near the Kanawha River Power Plant	Ponar grab	-	0.0	0.0	53.7	10.7	7.3	1.4	320.3	63.8	120.9	24.1	*	-	502.2
08	Mid-Channel near the Kanawha River Power Plant	Ponar grab	-	101.5	37.1	82.5	30.2	15.4	5.6	50.9	18.6	23.0	8.4	*	-	273.3
09	South Bank downstream from the Kanawha River Power Plant	SCUBA grab	X	832.2	87.2	74.5	7.8	5.9	0.6	30.9	3.2	10.1	1.1	0.9	0.1	954.5
10	Mid-Channel downstream from the Kanawha River Power Plant	SCUBA grab	-	36.0	29.3	32.2	26.2	5.0	4.1	20.0	16.3	26.0	21.2	3.6	2.9	122.8
11	North Bank near Mile Branch	Ponar grab	-	153.9	62.0	46.9	18.9	3.9	1.6	26.3	10.6	17.1	6.9	*	-	248.1
12	Downstream from Watson's Island	Ponar grab	-	0.0	0.0	1.2	0.3	2.4	0.5	339.0	72.5	124.7	26.7	*	-	467.3
13	North Bank near mouth of Cabin Creek	SCUBA grab	-	0.0	0.0	0.0	0.0	1.0	0.1	443.8	66.9	195.5	29.5	22.8	3.4	663.1
14	Mid-Channel near mouth of Cabin Creek	SCUBA grab	-	0.0	0.0	11.2	2.7	2.9	0.7	307.5	73.3	87.0	20.7	10.7	2.5	419.3
15	Mid-Channel near Marmet Locks	Ponar grab	-	52.6	21.2	5.6	2.2	2.8	1.1	144.6	58.2	43.0	17.3	*	-	248.6
16	Mid-Channel near Marmet Locks	Ponar grab	-	0.0	0.0	10.1	6.4	6.2	3.9	84.2	53.7	56.2	35.9	*	-	156.7

Note: All samples were collected between August and September 1977. * denotes samples where the clay sized fraction was undetermined.

for more than 50 percent of seven samples, and the sand sized fraction accounted for more than 50 percent of six samples, with the remaining four samples being comprised by a more even distribution of particle sizes. The presence of boulders was noted at five upstream stations, although this component was not accounted for in calculations of percentage composition by weight.

Organic Content Analysis

The processing of selected subsamples showed that organic content ranged widely among samples and among grain size classes. As shown in Table 5, sample averages ranged from 2.56 percent to 32.09 percent. At stations 13 and 14, where sample averages were notably high, the gravel sized component was found to be especially rich in organic content. An abundance of coal particles observed in these samples is thought to account for high organic levels.

Bottom Type Classification

Graphic representation of the results of sediment analyses was used to identify trends in substrate composition. As shown in Figure 7, the following generic sediment types were identified within the study area: Type 1 corresponds to a boulder/cobble association; Type 2 to a cobble/pebble association; and Type 3 to a sand/silt association. The Type 1 classification was assigned to four sampling stations, the Type 2 classification to five stations, and the Type 3 classification to seven stations. Table 6, which shows ranges in

TABLE 5

ORGANIC CONTENT OF SUBSTRATE SAMPLES COLLECTED FROM THE KANAWHA RIVER IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

STATION	SIZE CLASS	A CONTAINER (CRUCIBLE OR PAN) WEIGHT (g)	B WEIGHT OF CONTAINER AND DRIED SEDIMENT SUBSAMPLE (g)	B-A WEIGHT OF SEDIMENT SUBSAMPLE (g)	C WEIGHT OF CONTAINER AND SUBSAMPLE AFTER ASHING AT 550°C (g)	B-C LOSS OF WEIGHT AFTER COMBUSTION (ESTIMATED ORGANIC CONTENT) (g)	(B-C):(B-A)X100 PERCENT ORGANIC CONTENT	AVE. OF SIZE CLASS VALUES SAMPLE AVERAGE PERCENT ORGANIC CONTENT
01	Gravel	1.4534	6.5974	5.1440	5.9950	0.6024	11.71	
	Sand	1.4237	7.6035	6.1798	7.4517	0.1518	2.46	
	Silt	1.4552	1.4813	0.0261	1.4773	0.0040	15.32	7.99
	Clay	11.2296	11.2862	0.0566	11.2848	0.0014	2.47	
02	Gravel	1.4433	7.8165	6.3732	6.9702	0.8463	13.28	
	Sand	1.4411	5.4259	3.9848	5.2825	0.1434	3.60	6.81
	Silt	1.4326	1.4617	0.0291	1.4588	0.0029	9.97	
	Clay	9.6100	9.6367	0.0267	9.6366	0.0001	0.38	
05	Gravel	1.4378	1.4813	0.0435	1.4802	0.0011	2.53	
	Sand	1.4400	4.6207	3.1807	4.5103	0.1104	3.47	
	Silt	1.4500	1.6150	0.1650	1.6150	0.0000	0.00	2.56
	Clay	9.6502	9.6713	0.0211	9.6704	0.0009	4.26	
06	Gravel	1.4254	5.9800	4.5546	5.6988	0.2812	6.17	
	Sand	1.4242	5.1700	3.7458	5.0062	0.1638	4.37	6.92
	Silt	1.4512	1.5969	0.1457	1.5787	0.0182	12.50	
	Clay	10.2466	10.2832	0.3660	10.2815	0.0017	4.64	
09	Gravel	1.4300	5.6735	4.2435	5.4269	0.2466	5.81	
	Sand	1.4502	6.9926	5.5424	6.7671	0.2255	4.07	6.65
	Silt	1.4566	1.5750	0.1184	1.5590	0.0160	13.51	
	Clay	10.8756	10.8943	0.0187	10.8937	0.0006	3.21	
10	Gravel	1.4464	5.1400	3.6936	4.8626	0.2774	7.51	
	Sand	1.4457	6.4367	4.9910	6.2082	0.2282	4.58	5.38
	Silt	1.4390	1.7947	0.3557	1.7470	0.0477	2.81	
	Clay	9.7746	9.7912	0.0166	9.7901	0.0011	6.63	
13	Gravel	1.4353	1.8945	0.4592	1.5991	0.2954	64.32	
	Sand	1.4505	5.8489	4.3984	5.5890	0.2599	5.91	22.18
	Silt	1.4421	2.0815	0.6394	2.0412	0.0403	6.30	
	Clay	9.7573	9.7811	0.0238	9.7782	0.0029	12.18	
14	Gravel	1.4500	6.6367	5.1867	3.5088	3.1279	60.31	
	Sand	1.4480	5.3800	3.9320	5.1108	0.2692	6.83	
	Silt	1.4272	2.5250	1.0978	1.9857	0.5393	49.13	32.09
	Clay	9.8685	9.8900	0.0215	9.8874	0.0026	12.09	

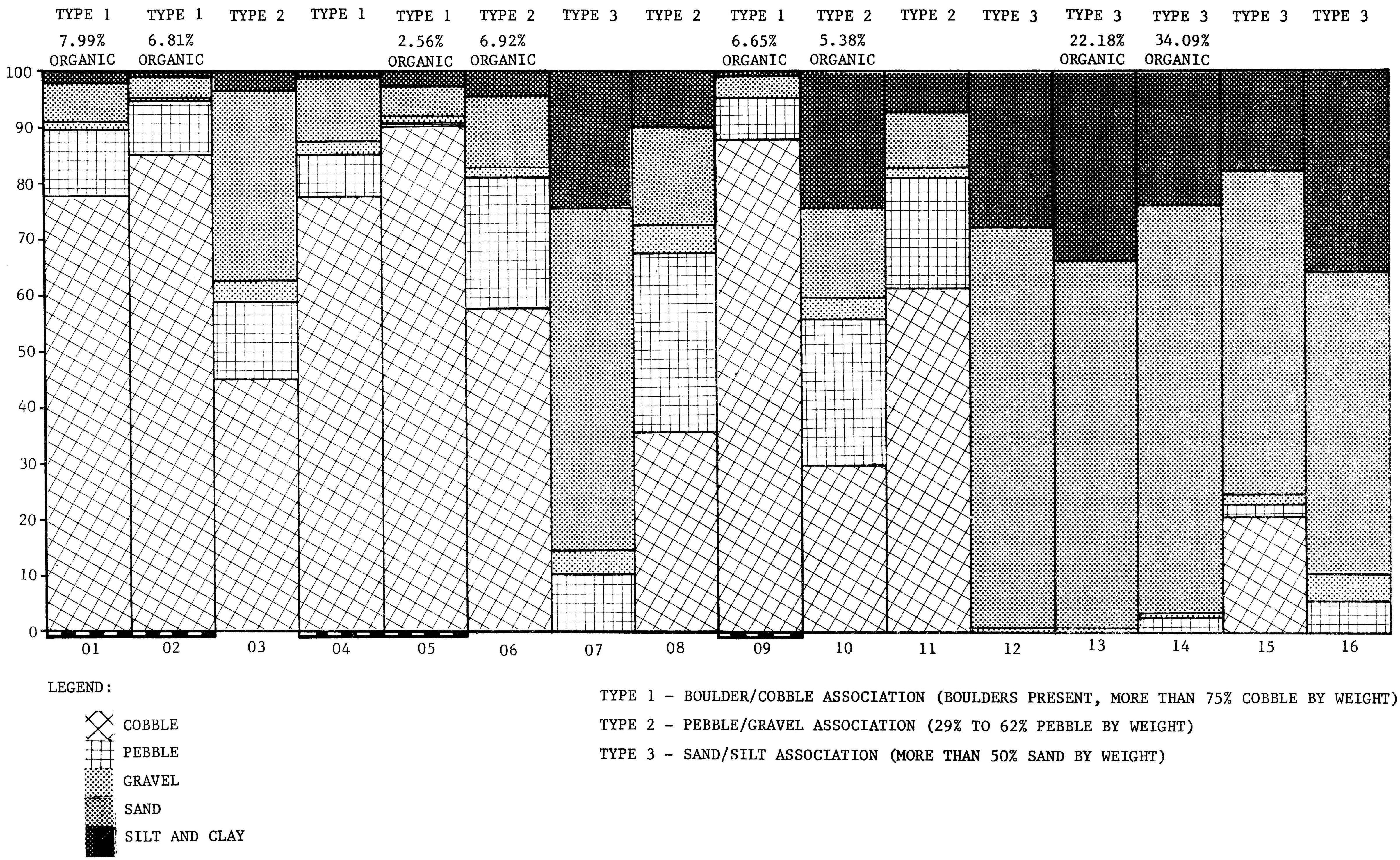


FIGURE 7

CLASSIFICATION OF BOTTOM TYPES ACCORDING TO SEDIMENT ANALYSES

TABLE 6

CLASSIFICATION OF BOTTOM TYPES ACCORDING TO TRENDS IN GRAIN SIZE COMPOSITION

Bottom Type	Ranges in Percent Composition		Aggregated Stations
1. Boulder/Cobble Association	Boulders:	present	01, 02, 04, 05, 09
	Cobble:	78.3-90.5	
	Pebble:	0.3-11.5	
	Gravel:	<0.1-1.9	
	Sand:	3.2-12.3	
	Silt:	0.4-1.5	
2. Pebble/Gravel Association	Boulders:	--	03, 06, 08, 10, 11
	Cobble:	29.3-62.0	
	Pebble:	13.0-30.2	
	Gravel:	1.6-5.6	
	Sand:	10.6-34.5	
	Silt:	2.6-21.2	
3. Sand/Silt Association	Boulders:	--	
	Cobble:	0.0-21.2	07, 12, 13, 14, 15, 16
	Pebble:	0.0-10.7	
	Gravel:	0.1-3.9	
	Sand:	53.7-73.3	
	Silt:	17.3-35.9	

grain size composition using this system of aggregation, indicates that bottom types are distinct from one another.

Distribution of Bottom Types

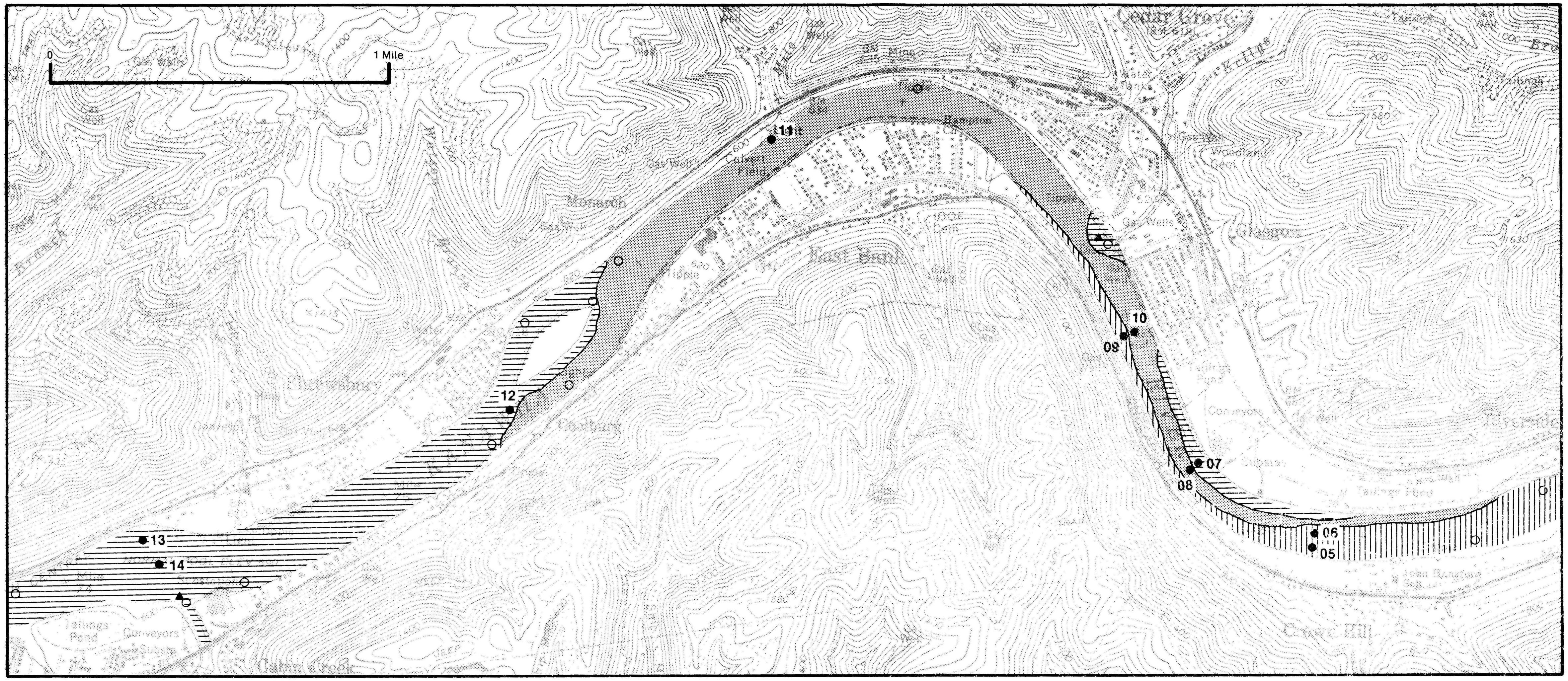
The aforementioned classification scheme served as the basis for the identification of bottom type distribution. Field observations were used to better identify zones of transition from one substrate type to another. A summary of these observations is presented in Table 7. In addition, a study conducted by the U.S. Army Corps of Engineers (1975) provided supportive data. This study indicates that substrate in the vicinity of the outflows of Cabin and Kellys Creeks consists of sand, silt, and coal particles underlain by a mixture of sand and gravel. Together, these points of reference were used to determine the general conformation of substrate zones shown in Figure 8. Overall this map indicates a transition from coarse substrate to finer particle sizes progressing downstream. Areas of exception include the occurrence of the Type 3 bottom association at the mouth of the Kanawha Power Plant and in the vicinity of the Kanawha River Power Plant. In total, areas identified as Type 1 comprise about 81 acres (32.8 ha), or 17 percent of the study area; areas identified as Type 2 comprise about 193 acres (78.1 ha), or about 40 percent; and areas identified as Type 3 comprise about 206 acres (83.4 ha), or about 43 percent.

TABLE 7

SUMMARY OF FIELD NOTES ON BOTTOM TYPES IN UNSAMPLED AREAS

Location	Description of Sediment
Near Riverside, West Bank	boulder, cobble, silt
Near Riverside, East Bank	boulder, cobble, silt
Mouth of Kellys Creek	sand, silt, coal particles, sewage
Upstream from Kellys Creek, West Bank	cobble, gravel, sand
Upstream from Watsons Island	gravel, sand
Upstream, tip of Watsons Island	sand, silt, detritus
Near Watsons Island, West Bank	sand, silt, mud
Near Watsons Island, East Bank	cobble, gravel, sand
Downstream from Watsons Island	gravel, sand, silt
Upstream from Cabin Creek	sand, silt
Mouth of Cabin Creek	sand, silt, coal particles
Downstream from Cabin Creek, West Bank	gravel, sand, silt

Field reconnaissance was conducted during August and September, 1977.



Key:

- Boulder/Cobble Association (Type 1)
- Pebble/Gravel Association (Type 2)
- Gravel/Sand/Silt Association (Type 3)

Source of Information:

- ● Processed Sample
- ○ Visual Inspection
- ▲ U.S. Army Corps of Engineers, 1975

FIGURE 8
DISTRIBUTION OF BOTTOM TYPES IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

AQUATIC MACROPHYTES

A survey of aquatic macrophytes within the study area resulted in the collection of ten species, six of which occur as emergents (Table 8). Based on a unit estimate of three square feet (0.3 m^2), a total of 41 beds of vegetation were identified. As shown in Figure 9, plant beds occur in all segments of the study area, although local distribution is typically clustered or clumped. Water willow (*Justicia americana*) was the predominant form, accounting for 66 percent of the plant bed units. A mudflat near the mouth of Cabin Creek supported a diverse macrophyte community, including three species which were not found elsewhere in the study area. Submerged beds of pondweed (*Potamogeton* spp.) were found only at one location, upstream from the Kanawha River Power Plant.

Overall, these findings indicate that aquatic macrophyte growth is limited within the study area, with levels of diversity and abundance being notably lower than those observed above rivermile 90. It is concluded that this situation is due primarily to the reduction of the littoral zone associated with navigational improvements (see section on depth).

TABLE 8

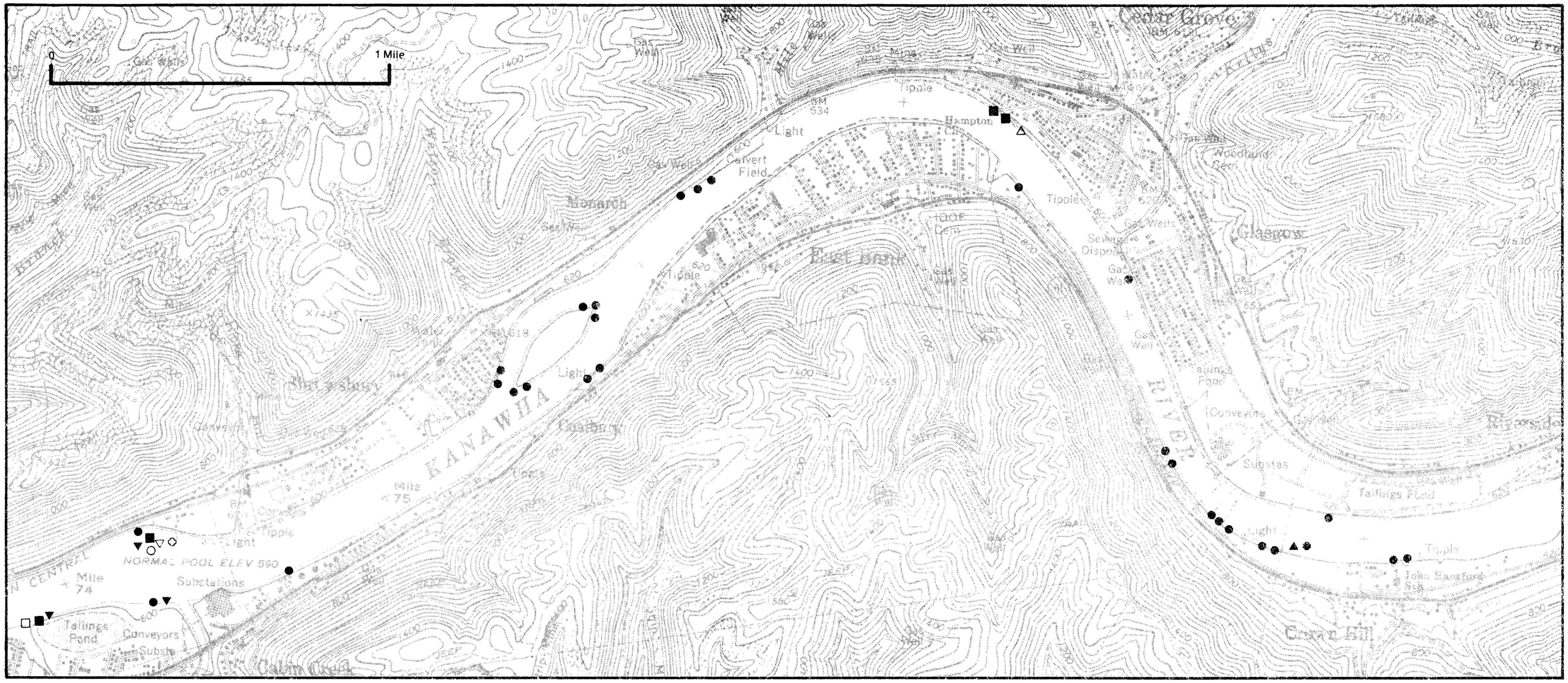
CHECKLIST OF AQUATIC MACROPHYTES COLLECTED IN THE KANAWHA RIVER, JUNE - AUGUST 1977

Emergent Species

Carex sp. (sedge)
Juncus acuminatus (rush)
Justicia americana (water willow)
Sagittaria latifolia (arrowhead)
Scirpus sp. (bulrush)
Typha latifolia (cattail)

Submerged Species

Elodea canadensis (Canada waterweed)
Najas sp. (naiad)
Potamogeton sp. (pondweed)
P. crispus (pondweed)



- ○ *Carex sp.*
- ▽ *Elodea sp.*
- ■ *Juncus sp.*
- ● *Justicia americana*
- ⭘ *Najas sp.*
- ▲ *Potamogeton crispus*
- ⬢ *Potamogeton sp.*
- □ *Sagittaria latifolia*
- △ *Scirpus sp.*
- ▼ *Typha latifolia*

Note: Each symbol represents about 3 square feet of growth.

FIGURE 9
DISTRIBUTION OF AQUATIC MACROPHYTES
IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

IDENTIFICATION OF BIOTIC ZONES

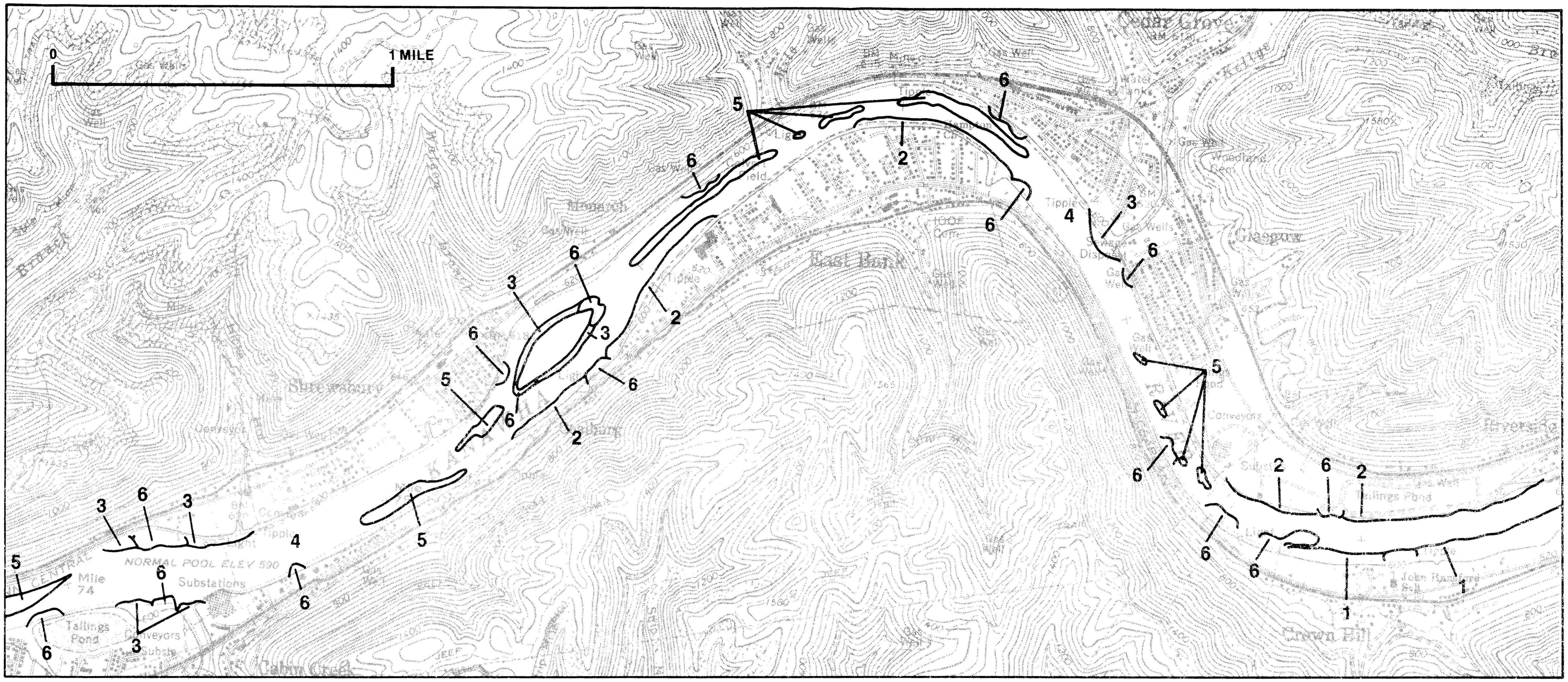
Habitat classification of biotic environments has been the subject of extensive study, especially in Europe. Reviews by Hynes (1970), Brown (1975) and Pennak (1978) show that the most widely acknowledged classification schemes are single-criterion systems, such as the saprobic system, and longitudinal zonation according to typical or dominant fish species. Pennak notes that such systems are generally inappropriate in the United States, where the characteristics of running waters are highly variable. In accordance with the special characteristics of U.S. waters, it is suggested that careful study of chironomid distribution may lead to a usable stream typology. Another alternative is a classification system based on variations in fish community structure. As developed by Fry and Pflieger (1978), this approach assumes that species which comprise the community can detect and respond to variations in environmental parameters with a degree of precision that cannot be duplicated by measuring the parameters themselves.

Biotic zonation, the system of habitat classification presented in this research, is more closely allied to previously developed multi-criteria schemes for classifying biotic habitats. A study conducted by Ricker (1934) classified Ontario streams according to flow, width, temperature, substrate, current, vegetation, hardness, and dominant bottom fauna and fishes. Pennak (1978) notes that a similar study has been developed for streams in Maryland. Toward characterizing streams at a national scale, Pennak (1971) suggested consideration of the following parameters: width, temporary or permanent flow, current velocity, substrate, temperature, turbidity, total dissolved inorganic matter, total dissolved organic matter, alkalinity, dissolved oxygen, rooted aquatics and streamside vegetation.

As described in a previous chapter on habitat attributes, major factors influencing microhabitat selection include depth, bottom type, and aquatic macrophytes. Accordingly, maps detailing the distribution of these parameters (Figures 6, 8, and 9) have been used in identification of biotic zones within the study area. Identification was accomplished by using these maps in an overlay fashion. As shown in Figure 10, the primary basis for classification is depth according to three established categories: shallow, moderately deep, and deep. Shallow areas are further categorized according to the three generic bottom types found within the study area: the boulder/cobble association, the cobble/pebble association, and the sand/silt association. A sixth category represents macrophyte zones. Descriptions of the six zones are presented in the following:

Shallow Areas with a Boulder/Cobble Bottom (Zone 1)

The Zone 1 classification applies to areas from 0 to 10 feet (0-3.0 m) deep having the most coarse of the three bottom types identified within the study area. This zone occurs in only one location, along the east bank near the upstream boundary of the study area (Figure 10). A bed of water willow (Zone 6) segments the area into two parcels, which together comprise 11.5 acres (4.6 ha), or 2.4 percent of the



1 Shallow zone with boulder / cobble bottom
2 Shallow zone with cobble / pebble bottom
3 Shallow zone with sand / silt bottom
4 Moderately deep zone
5 Deep zone
6 Aquatic macrophyte bed

FIGURE 10
LOCATION OF BIOTIC ZONES
IN THE VICINITY OF THE KANAWHA
RIVER POWER PLANT

study area. Adjacent areas include beds of submerged vegetation downstream (Zone 6) and a moderately deep area toward mid-channel (Zone 4). Study area reconnaissance showed that special features within the zone include a small barge terminal consisting of several steel pilings and a narrow rock jetty extending about 25 feet (8 m) into the river, which forms a quiet backwater area. The adjacent shoreline area comprises a narrow fringe of fine-grained material, supporting such riparian vegetation as river birch, sycamore, willow and hackberry. Several trees had fallen into the river and were partially or totally submerged.

Shallow Areas with a Pebble/Gravel Bottom (Zone 2)

The Zone 2 classification applies to areas from 0 to 10 feet (0-3.0 m) deep having a moderately coarse bottom type. This habitat type occurs in three locations: (a) along the west bank near the upstream boundary of the study area; (b) along the convex shoreline near the town of East Bank, and (c) along the east bank across from Watson's Island (Figure 10). Collectively, these areas comprise approximately 30.4 acres (12.3 ha), or 6.3 percent of the study area. Adjacent areas include interspersed beds of water willow (Zone 6) and moderately deep areas (Zone 4) with similar bottom characteristics. Field reconnaissance showed that each of the three Zone 2 areas is associated with its own special characteristics. The upstream segment (area a) is located adjacent to a barge terminal facility and is moderately vegetated with a steeply sloped bank separating the river from nearby tailings ponds and a steel storage area. Special features associated with the central segment (area b) include a bulkhead extending the width of four riverfront residential properties and a sandy point bar extending about 15 feet (5 m) into the river, with quiet pools on either side. The downstream segment (area c) is located adjacent to a coal barge facility and extends downstream along a particularly narrow reach of the barge channel.

Shallow Areas Within a Sand/Silt Bottom (Zone 3)

The Zone 3 classification applies to areas from 0 to 10 feet (0-3.0 m) deep having the most fine-grained of the three bottom types identified within the study area. This habitat type occurs in four locations: (a) at the mouth of Kellys Creek, (b) along the edge of Watsons Island, (c) along the west bank opposite from the mouth of Cabin Creek, and (d) at the mouth of Cabin Creek (Figure 10). Collectively, these areas account for approximately 19.7 acres (8.0 ha), or 4.1 percent of the study area. Adjacent habitat types include interspersed beds of aquatic vegetation (Zone 6) and moderately deep areas (Zone 4). Study area reconnaissance showed that each of the four Zone 3 areas is associated with its own special characteristics. The area furthest upstream (area a) is a sandbar produced by the outflow of Kellys Creek, with much of the area covered by less than two feet (0.6 m) of water. Downstream from this shallow zone, depth increases sharply, with a more gradual increase being noted upstream. Numerous concrete blocks have been placed along the shoreline upstream from the sandbar, leading to a public boat ramp about 25 feet away. Small bits of organic material, coal particles, and vigorous algae populations were observed in the vicinity of the sandbar. The area surrounding Watsons Island (area b) has a mud or mucky bottom, which is fairly unconsolidated. The island itself is heavily vegetated to its margins, especially by green ash (Fraxinus pennsylvanica). Trees and shrubs extend over much of the shallow zone, with root systems protruding through the banks. The area opposite the mouth of Cabin Creek (area c) consists of a firm mudflat, surrounding an area of aquatic vegetation (Zone 6). Depth throughout much of this quiet area was observed to be less than three feet (0.9 m).

Moderately Deep Areas (Zone 4)

The Zone 4 classification is applied to all areas from 10 to 25 feet (3.0-7.6 m) deep regardless of bottom type. This habitat type extends the length of the study area and is interrupted by areas of deeper water (Figure 10). The zone occupies approximately 378 acres (153 ha), or 78.7 percent of the study area. The main shipping channel, a 200-foot (61 m) wide swath heavily used by coal barges, occupies about 50 percent of this zone. Since barges may have up to a 9-foot (2.7 m) draft, periodic disturbance may extend the depth of the water column in some Zone 4 areas. Reconnaissance using SCUBA gear in areas deeper than 20 feet (6 m) indicated that physical disturbance in most Zone 4 areas is minimal, although engine sounds and water movement due to passing vessels were detected by divers at least 50 feet (15 m) from the main channel. Zone 4 areas are also heavily utilized by recreational boaters, who frequently travel outside the deeper main channel.

Deep Areas (Zone 5)

The Zone 5 classification is applied to all areas deeper than 25 feet (7.6 m), with the maximum depth reported as 30 feet (9 m) (Weston Geophysical Engineers, Inc., 1977). This habitat type occurs in 11 locations, distributed throughout the study area (Figure 10). Collectively, these areas account for approximately 38.6 acres (15.6 ha), or 8.0 percent of the study area. Only one deep zone was explored using SCUBA gear, due to heavy barge traffic. Limited observations indicate that the slope of the riverbed is fairly gradual in the vicinity of the deeper pools and that bottom characteristics are similar to those of surrounding areas.

Aquatic Macrophyte Beds (Zone 6)

The Zone 6 classification is applied to areas of aquatic macrophyte growth, regardless of bottom type. As shown on Figure 10, the 41 beds of aquatic macrophytes identified in a previous section have been consolidated into 17 Zone 6 areas. Based on an allocated value of 0.1 acres (0.04 ha) for each of the 41 beds, Zone 6 areas collectively occupy approximately 4.1 acres (1.7 ha), or 0.8 percent of the study area. Study area reconnaissance showed that with two exceptions macrophyte beds occur near the shoreline. During late May and early June, shoreline beds of water willow were limited to areas less than one foot (0.3 m) deep. However, by mid-August these beds had grown substantially, extending into areas three feet deep (0.9 m). The two exceptional cases of submerged vegetation, beds of pondweed located near rivermile 79 and a diverse community located opposite the mouth of Cabin Creek, were found in especially quiet areas located outside the main channel.

HABITAT REQUIREMENTS OF REPRESENTATIVE, IMPORTANT FISH SPECIES

An important aspect of the biotic value allocation procedure is consideration of the habitat preferences of the local aquatic community and the level of demand for those habitat types. Such information is required for the identification and evaluation of the biotic zones of particular fish species. Based on a previous study of the Kanawha River by Dickson (1977), representative, important species selected for detailed consideration include two nuisance species,* two forage species, and four game fishes:

Gizzard shad (*Dorosoma cepedianum*)
Carp (*Cyprinus carpio*)
Emerald shiner (*Notropis atherinoides*)
Spotfin shiner (*Notropis spilopterus*)
Channel catfish (*Ictalurus punctatus*)
Rock bass (*Ambloplites rupestris*)
Bluegill (*Lepomis macrochirus*)
Smallmouth bass (*Micropterus dolomieui*)

This chapter presents background information on the life history of these selected species, population estimates of species comprising the local fish community, and a review of recent fish sampling efforts within the study area. The contents of the chapter have been drawn from secondary sources, including studies conducted on a variety of river systems. Consequently, this information should not be viewed as an actual profile of the micro-distribution of representative, important species, but rather as supportive data for identifying and evaluating biotic zones.

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*Gizzard shad are at times considered an important forage fish, providing a short, efficient link in the food chain of some important game fishes (Pflieger, 1975).

LIFE HISTORY INFORMATION

A summary of selected life history information for representative, important species was compiled based on a review of the ecological literature. As shown in Table 9, most of these species utilize shallow areas for at least a portion of their life cycle, particularly for spawning and nursery activities. Some species, such as carp, channel catfish and bluegill are known to frequent deeper pools, especially during warmer months. Only the two minnow species, the emerald and spotfin shiners, exhibit a notable preference for middle water layers; although schools of gizzard shad probably occupy this stratum during seasonal migrations.

POPULATION ESTIMATES

A major objective of the biotic zone allocation concept is to ensure a resource supply which can adequately meet the needs of the aquatic community. Of special importance is the identification of habitat types which are particularly limited in supply. With regard to this problem, population estimates for resident fish species were viewed as an important indicator of resource demand. Standard population estimates for the Kanawha River are lacking (Muth, personal communication, 1978; Preston, personal communication, 1978). However, the West Virginia Department of Natural Resources collects limited fish population data from rotenone samples of the lock chamber at London Lock and Dam, located at rivermile 82.5. As shown in the following, these data have been used to extrapolate rough estimates of population sizes within the study area.

TABLE 9

LIFE HISTORY INFORMATION FOR REPRESENTATIVE, IMPORTANT FISH SPECIES OF THE KANAWHA RIVER IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

SPECIES	GENERAL HABITAT PREFERENCE	FEEDING HABITS	SPAWNING HABITAT	SPAWNING PERIOD	NURSERY REQUIREMENTS	MOVEMENT/ MIGRATORY BEHAVIOR
1. Dorosoma cepedianum Gizzard shad	Quiet waters, such as pools and back-waters of streams; nutrient rich, highly productive waters (20)	Feeds along bottom, on algae, small insect larvae (20, 22), and organic debris (5)	Demersal eggs are released in shallow protected waters, over various bottom types (20,22)	Early April-May (20), mid-March to mid-August (22)	Eggs hatch in 4-5 days, and young begin to feed about 5 days later; schools of young remain in shallows for at least 6 months (5)	Highly migratory, moving great distances in large schools (5,20,22)
2. Cyprinus carpio Carp	Deep pools, near piles of drift, logs or other sub-merged cover, and in shallow near-shore areas (20); often attracted to organic efflu-ent discharges (6)	Feeds in shallow water, along sub-strate and near plant beds, on detritus, phyto-plankton, zoo-plankton, and insects (4,5,7,21)	Eggs are broadcast in shallow water near plant beds, logs, rocks or rubble (7,20,27)	March-May (7) mid-April to early June (3), May to August (27)	Eggs hatch within 3-6 days (22), with no parental care given to young (20)	Considered a wanderer, but not truly migratory (5)
3. Notropis atherinoides Emerald shiner	Middle and upper layers of lakes, large streams and rivers (5); toler-ate a variety of bottom types, but prefers clean, sandy substratum (5,20)	Feeds in middle and upper water layers, on plank-ton and small insects (5,9,10)	Non-adhesive eggs are released near surface in open water over a sand or firm mud sub-stratum (12,20)	June-August (2,3, 19); May-August (22)	Eggs hatch in 24-36 hours; fry remain on the bottom for 4 more days, then congre-gate in schools at the surface (20)	A schooling species, staying offshore during summer months, and moving inshore in autumn (22); known to ascend to smaller streams (5)
4. Notropis spilopterus Spotfin shiner	Tolerates a variety of conditions, but prefers shallow areas in large rivers, adjacent to gently sloping, clean gravel bars (7)	Feeds at the sur-face, in middle water layers, and occasionally along the bottom of shal-low zones, on insects and seeds (18,24,26)	Eggs are deposited in crevices of sub-merged objects or in cavities in rocky substrate (11,17)	Mid-June to mid-August (11); early June to early August (28)	Eggs hatch in 5-6 days (11,20); no reports of a definitive nursery period have been found	Occurs in schools (20); no reports of migratory behavior or seasonal movements have been found

(4) Cherry and Guthrie, 1975; (5) Clay, 1975; (6) Cross, 1951; (7) Cross, 1967; (9) Forbes and Richardson, 1909; (10) Fuchs, 1967; (11) Gale and Gale, 1977; (12) Gray, 1942; (17) Mills et al., 1966; (18) Minckley, 1966; (19) Pflieger, 1965; (20) Pflieger, 1975; (21) Rehder, 1959; (22) Scott and Crossman, 1975; (24) Starrett, 1950; (25) Stevens, 1959; (26) Stone, 1940; (27) Swee and McCrimmon, 1966; (28) Trautman, 1957.

TABLE 9 (CONTINUED)

LIFE HISTORY INFORMATION FOR REPRESENTATIVE, IMPORTANT FISH SPECIES
OF THE KANAWHA RIVER IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

SPECIES	GENERAL HABITAT PREFERENCE	FEEDING HABITS	SPAWNING HABITAT	SPAWNING PERIOD	NURSERY REQUIREMENTS	MOVEMENT/ MIGRATORY BEHAVIOR
5. Ictalurus punctatus Channel catfish	Tolerates a wide variety of flow conditions and bottom types (16); adults found in pools, near log banks; young found in riffles and shallow pools	Feeds in lower water layers and along bottom in areas with strong current, and near plant beds, on fish, crustaceans, seeds, plant material and zooplankton (1,15, 20,25)	Eggs are deposited in crevices along stream banks and in secluded cavities in submerged piles of drift or logs (7,14)	Late May to early July (7); late May to late July (20)	Eggs hatch in about 7 days, with males guarding fry until they leave the nest about 7 days later (20)	Mainly sedentary, although marked downstream movements during fall are reported (22); evidence of long distance travel, especially downstream to return to home territory (5)
6. Ambloplites rupestris Rock bass	Shallow zones and nearshore pools, with rocky clean bottoms; near cover such as boulders, submerged logs and dense beds of Justicia (20,22)	Forages at night in shallow nearshore zones for insects, crustaceans, mollusks, and small fish (20,22)	Nests in shallows with variable substratum, although gravel bottoms are preferred (20)	Maximum 1 month season, occurring between early April and late June (20)	Eggs hatch in 3 to 4 days, with male remaining to guard fry for a short period (22)	Adults usually found in aggregations, often in association with other sunfishes such as smallmouth bass (22); no reports of true migratory behavior have been found
7. Lepomis macrochirus Bluegill	Deeper pools and backwaters of clear streams, and near aquatic plants or other cover (20)	Feeds in morning and at night in shallows, on insects, small fish, crayfish and snails (20); also zooplankton and plant material (22)	Nests in shallows with variable substratum, although gravel bottoms are preferred (20)	Late May to August (20)	Eggs hatch in 3-5 days (22), after which no parental care is given (20)	Gregarious, moving locally in aggregations of up to 30 individuals (20)
8. Micropterus dolomieui Smallmouth bass	Clear cool, moderately shallow zones, with rocky clean substrate, near aquatic vegetation (8), such as Justicia and rocky shoals below navigation dams (20)	Feeds in shallows and nearshore pools, on insects crustaceans and fish (5,8)	Nests in shallow, sheltered zones with minimal current, often near macrophyte beds; prefers sand, gravel or rocky bottom, but known to nest in soft substratum (13, 29)	May-July (2), April-May (7)	Eggs hatch in 2-3 days, with male guarding fry for up to 2 weeks, when they leave the nesting area (20); fry are found 2 to 7 inches from shoreline or submerged objects (23)	Usually movements are confined to a single pool, with home range extending as far as 0.5 mile (20); seasonal shifts such as movements to deep pools during summer are attributed to response to temperature gradient (22)

(1) Bailey and Harrison, 1948; (2) Breder and Rosen, 1966; (3) Carlander, 1969; (5) Clay, 1975; (7) Cross, 1967; (8) Emig, 1966; (13) Hubbs and Bailey, 1938; (14) Marzolf, 1957; (15) Mathur, 1970; (16) Miller, 1966; (20) Pflieger, 1975; (22) Scott and Crossman, 1973; (23) Smitherman and Ramsey, 1971; (25) Stevens, 1959; (29) Watson, 1955.

In accordance with the area-density approach suggested by Preston (personal communication, 1978), results of the 1976 survey of the London Lock chamber provide a ratio of numbers of individuals to surface area which is applied to the total surface area of the study area. Formally stated by Everhart et al. (1975), a population estimate based on the sampling of a subarea can be derived from the following formula:

$$\hat{N} = \frac{A}{a} \sum_{i=1}^{a} N_i$$

where $\hat{N}$ = the estimated population

A = the area occupied by the total population

a = the area sampled

N_i = the number of individuals counted in the sample area

Based on an estimated sampling efficiency of 75 percent (Muth, personal communication, 1978), a correction factor of 1.25 was employed with regard to lock chamber values.

Results of this procedure, shown on Table 10, must be viewed conservatively, as estimates are based upon limited data. For instance, several species which are known to be common within the study area, including the representative, important fish species M. dolomieui are not represented in the data base. Further, as noted by Everhart et al. (1975), the area-density method of estimating population size is most

TABLE 10

POPULATION ESTIMATES BASED ON A
1976 LONDON LOCK CHAMBER SURVEY

FAMILIES AND SPECIES	NUMBER OF INDIVIDUALS		
	Subarea Sample	Corrected Subarea Sample	Study Area Estimate
Clupeidae			
Dorosoma cepedianum*	8	10.00	3,200
Cyprinidae			
Cyprinus carpio*	2	2.50	800
Hybopsis aestivalis	7	8.75	2,800
Hybopsis amblops	21	26.25	8,400
Hybopsis dissimilis	3	3.75	1,200
Notropis atherinoides*	482	602.50	192,800
Notropis buchanani	33	41.25	13,200
Notropis hudsonius	1	1.25	400
Notropis rubellus	1	1.25	400
Notropis spilopterus*	2	2.50	800
Notropis stramineus	1	1.25	400
Notropis volucellus	106	132.50	42,400
Pimephales notatus	7	8.75	2,800
Pimephales vigilax	1	1.25	400
Catostomidae			
Ictiobus bubalus	1	1.25	400
Moxostoma anisurum	1	1.25	400
Moxostoma macrolepidotum	2	2.50	800
Ictaluridae			
Ictalurus punctatus*	45	56.25	18,000
Pylodictus olivaris	5	6.25	2,000
Percopsidae			
Percopsis omiscomaycus	11	13.75	4,400

*Denotes a representative, important species. Note that Micropterus dolomieui is not represented in the survey.

TABLE 10 (CONTINUED)

POPULATION ESTIMATES BASED ON A
1976 LONDON LOCK CHAMBER SURVEY

FAMILIES AND SPECIES	NUMBER OF INDIVIDUALS		
	Subarea Sample	Corrected Subarea Sample	Study Area Estimate
Centrarchidae			
Ambloplites rupestris*	1	1.25	400
Lepomis macrochirus*	1	1.25	400
Lepomis megalotis	2	2.50	800
Micropterus punctulatus	1	1.25	400
Pomoxis annularis	1	1.25	400
Percidae			
Percina caprodes	3	3.75	1,200
Sciaenidae			
Aplodinotus grunniens	84	105.00	33,600

Source: Muth, personal communication, 1978.

*Denotes a representative, important species. Note that Micropterus dolomieui is not represented in the survey.

meaningful when several locations are sampled. However, these rough population estimates provide meaningful indicators of relative abundance and are especially valuable in the evaluation of biotic zones.

RESULTS OF RECENT FIELD STUDIES

An additional line of evidence indicating habitat selection by representative, important species is provided by recent fish collections conducted within the study area. A study by Stauffer and Hocutt (1977) included collections at 14 stations located within the study area for this research. Results indicated that all eight representative, important species occur within shallow zones, with the minnows N. atherinoides and N. spilopterus being most abundant in the shallows near the mouths of Kellys and Cabin Creeks. While accompanying the West Virginia Department of Natural Resources on a 7 July 1978 field survey of the study area using electroshocker gear, it was observed that the most common representative, important species occurring within shallow zones were L. macrochirus and M. dolomieui.

The study by Stauffer and Hocutt (1977) also provides limited information on community composition and abundance when compared to the results of the previously discussed rotenone survey of the London Lock chamber. As shown in Table 11, Stauffer and Hocutt (1977) collected a total of 32 species, within the study area including 14 species which are not represented in the rotenone sample. A portion of this difference can be attributed to the collection by Stauffer and Hocutt of certain creek residents which would be more common in the

TABLE 11

COMPARISON OF NUMBERS OF FISH COLLECTED IN THE ROTENONE SURVEY OF LONDON LOCK CHAMBER AND THOSE COLLECTED WITHIN THE STUDY AREA BY TRAP NET, GILL NET, AND SEINE

SPECIES	Number Collected by Rotenone Survey	Percent of Total	Number Collected by Trap Net, Gill Net, and Seine[b]	Percent of Total
Ichthyomyzon bdellium	0	0.0	1	0.2
Lepisosteus osseus	0	0.0	4	0.9
Alosa chrysochloris	0	0.0	2	0.4
Dorosoma cepedianum*	8	1.0	7	1.5
Campostoma anomalum	0	0.0	12	2.6
Cyprinus carpio*	2	0.2	15	3.2
Hybopsis aestivalis	7	0.8	0	0.0
Hybopsis amblops	21	2.5	0	0.0
Hybopsis dissimilis	3	0.4	0	0.0
Notropis atherinoides*	482	57.9	309	66.6
Notropis buchanani	33	4.0	0	0.0
Notropis hudsonius	1	0.1	0	0.0
Notropis spilopterus*	2	0.2	5	1.1
Notropis stramineus	1	0.1	11	2.4
Notropis volucellus	106	12.7	0	0.0
Pimephales notatus	7	0.8	14	3.0
Pimephales vigilax	1	0.1	0	0.0
Carpiodes cyprinus	0	0.0	3	0.6
Hypentelium nigricans	0	0.0	6	1.3
Ictiobus bubalus	1	0.1	1	0.2
Moxostoma anisurum	1	0.1	4	0.9
Moxostoma carinatum	0	0.0	2	0.4
Moxostoma erythrurum	0	0.0	12	2.6
Moxostoma macrolepidotum	2	0.2	13	2.8
Ictalurus punctatus*	45	5.4	6	1.3

*Denotes a representative, important species.

TABLE 11 (CONTINUED)

COMPARISON OF NUMBERS OF FISH COLLECTED IN THE ROTENONE SURVEY OF LONDON LOCK CHAMBER AND THOSE COLLECTED WITHIN THE STUDY AREA BY TRAP NET, GILL NET, AND SEINE

SPECIES	Number Collected by Rotenone Survey	Percent of Total	Number Collected by Trap Net, Gill Net, and Seine[b]	Percent of Total
Pylodictus olivarus	5	0.6	4	0.9
Percopsis omiscomaycus	11	1.3	0	0.0
Morone chrysops	0	0.0	1	0.2
Ambloplites rupestris*	1	0.1	6	1.3
Lepomis macrochirus*	1	0.1	2	0.4
Lepomis megalotis	2	0.2	2	0.4
Micropterus dolomieui*	0	0.0	2	0.4
Micropterus punctulatus	1	0.1	8	1.7
Pomoxis annularis	1	0.1	2	0.4
Etheostoma caeruleum	0	0.0	2	0.4
Etheostoma nigrum	0	0.0	1	0.2
Percina caprodes	3	0.4	1	0.2
Stizostedion canadense	0	0.0	2	0.4
Stizostedion vitreum	0	0.0	1	0.2
Aplodinotus grunniens	84	10.1	3	0.6
TOTAL	832	99.6	464	99.7

Source: [a]Muth, personal communication, 1978.

[b]Stauffer and Hocutt, 1977.

*Denotes a representative, important species.

vicinity of creek outlets than in mid-channel zones. Examples include the stoneroller and the darters, *Etheostoma caeruleum* and *E. nigrum*. Of particular note is the similar percentage composition value for *N. atherinoides* in both collections. Based on habitat preference information shown in Table 9, it would be expected that the emerald shiner would be much more likely to be taken in the main channel environment of the lock chamber than in the shallow zones sampled by Stauffer and Hocutt (1977). However, results of their survey show that 76 percent of the emerald shiners collected were taken at the mouth of Kellys Creek with an additional 23 percent being taken at the mouth of Cabin Creek. As shown in a previous section presenting background information on the study area, both these tributaries are subject to sewage discharges. At the mouth of Kellys Creek, coal particles, evidence of a sewage outfall, and vigorous growths of algae along bank areas were noted. Thus, it is concluded that either the organic material itself or the abundance of algae resulting from local nutrient enrichment acts as an attractant for the emerald shiner. Consequently, schools of this fish species are drawn from their more typical main channel habitat to the rich feeding grounds provided near organic effluent discharges.

EVALUATION OF BIOTIC ZONES

This chapter represents the culmination of preceding chapters, with the identification of biotic zones and background information on representative, important species being synthesized according to a newly developed evaluation procedure. The objective was to obtain a set of numerical values representing the biological importance of specific habitat zones within the study area, to be used in testing the biotic value allocation equations presented by the U.S. Environmental Protection Agency (1975).

As detailed in the chapter on materials and methods, evaluation of biotic zones was conducted during November 1978 by ten aquatic biologists, all members of the environmental assessment staff of The MITRE Corporation of McLean, Virginia. Evaluation entailed two phases: First, biologists independently identified probable uses of study area zones by representative, important species according to five resource use categories; and second, these assessments were translated into representative numerical values. As shown in the reporting of detailed results, each numerical representation of biotic value is the product of a "confidence quotient," representing the level of agreement among biologists on a particular judgment, and an "exclusivity quotient," representing the degree to which a given biological activity is restricted to a single zone.

GENERALIZED RESULTS

The numerical representation of the total biotic value of the study area was found to be 2386.17, with an average unit value of 5.0 per acre. As shown in Table 12, the three shallow area classifications were considered most valuable, although the highest unit value was attributed to aquatic macrophyte beds due to the limited areal extent of this zone. Deep areas were considered to be of relatively low value, with the calculated unit value of this zone being below the average of 5.0. Biologists also determined that moderately deep zones were only about half as valuable as individual shallow zones, with the abundance of Zone 4 areas resulting in the lowest unit value of the six zones.

Overall it was determined that no single zone meets all resource requirements for any of the representative, important species. However, as reflected in the range of biotic values which were determined, some zones were found to be especially important in maintaining current fish populations. To illustrate the particular functional roles of each zone, the following section presents a detailed account of the results of the evaluation procedure.

DETAILED RESULTS

Zone 1 (Shallow Areas with a Boulder/Cobble Bottom)

The numerical representation of the total biotic value of this zone is 491.57 as shown on Table 13. Important resource use categories include spawning, feeding, and nursery activities, collectively

TABLE 12

BIOTIC VALUE SUMMARY FOR THE KANAWHA RIVER
IN THE VICINITY OF THE KANAWHA RIVER POWER PLANT

BIOTIC ZONE	TOTAL BIOTIC VALUE	ACREAGE	UNIT VALUE (per acre)
1. Shallow Areas with Boulder/Cobble Bottom	491.57	10.8	45.5
2. Shallow Areas with Pebble/Gravel Bottom	577.37	29.6	19.5
3. Shallow Areas with Sand/Silt Bottom	574.46	18.9	30.4
4. Moderately Deep Areas	214.08	378.0	0.6
5. Deep Areas	146.56	38.6	3.8
6. Aquatic Macrophyte Beds	382.13	4.1	93.2
TOTAL	2386.17	480.0	---

TABLE 13

RESULTS OF THE EVALUATION OF BIOTIC ZONE 1 BY TEN AQUATIC BIOLOGISTS
SHALLOW AREAS WITH BOULDER/COBBLE BOTTOM

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Dorosoma cepedianum Gizzard shad	General Requirements (resting)	3	0.3	11.1	3.33
	Feeding	5	0.5	19.2	9.60
	Spawning	6	0.6	20.0	12.00
	Nursery	8	0.8	25.8	20.64
	Migration/Seasonal Movement	6	0.6	15.0	9.00
Cyprinus carpio Carp	General Requirements (resting)	2	0.2	6.4	1.28
	Feeding	4	0.4	13.3	5.32
	Spawning	9	0.9	30.0	27.00
	Nursery	6	0.6	22.2	13.32
	Migration/Seasonal Movement	1	0.1	9.0	0.90
Notropis atherinoides Emerald shiner	General Requirements (resting)	2	0.2	9.5	1.90
	Feeding	3	0.3	11.1	3.33
	Spawning	1	0.1	5.8	0.58
	Nursery	4	0.4	17.4	6.96
	Migration/Seasonal Movement	4	0.4	22.2	8.88
Notropis spilopterus Spotfin shiner	General Requirements (resting)	5	0.5	22.7	11.35
	Feeding	8	0.8	26.7	21.36
	Spawning	9	0.9	50.0	45.00
	Nursery	7	0.7	33.3	23.31
	Migration/Seasonal Movement	0	0.0	0.0	0.00

TABLE 13 (CONTINUED)

RESULTS OF THE EVALUATION OF BIOTIC ZONE 1 BY TEN AQUATIC BIOLOGISTS
SHALLOW AREAS WITH BOULDER/COBBLE BOTTOM

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Ictalurus punctatus Channel catfish	General Requirements (resting)	4	0.4	11.8	4.72
	Feeding	5	0.5	14.7	7.35
	Spawning	8	0.8	36.4	29.12
	Nursery	7	0.7	26.9	18.83
	Migration/Seasonal Movement	1	0.1	9.1	0.91
Ambloplites rupestris Rock bass	General Requirements (resting)	10	1.0	31.2	31.20
	Feeding	9	0.9	30.0	27.00
	Spawning	5	0.5	20.8	10.40
	Nursery	6	0.6	24.0	14.40
	Migration/Seasonal Movement	1	0.1	16.7	1.67
Lepomis macrochirus Bluegill	General Requirements (resting)	2	0.2	7.1	1.42
	Feeding	7	0.7	21.9	15.33
	Spawning	4	0.4	16.0	6.40
	Nursery	5	0.5	18.5	9.25
	Migration/Seasonal Movement	1	0.1	11.1	1.11
Micropterus dolomieui Smallmouth bass	General Requirements (resting)	10	1.0	28.6	28.60
	Feeding	10	1.0	32.2	32.20
	Spawning	5	0.5	15.6	7.80
	Nursery	8	0.8	23.5	18.80
	Migration/Seasonal Movement	0	0.0	0.0	0.00
		TOTAL BIOTIC VALUE OF BIOTIC ZONE 1 = 491.57			

accounting for more than 75 percent of the zone's biotic value. Fish species judged to be particularly dependent upon these areas include the following: the spotfin shiner, with 50 percent of the identifications of suitable spawning habitat for this species being assigned to Zone 1; the smallmouth bass, with all ten evaluators agreeing that Zone 1 areas are being used by this species for resting and feeding; and the rock bass, with a consensus of opinion on the value of Zone 1 areas as general living space for this species and with nine out of ten evaluators identifying the zone as an important feeding area.

Zone 2 (Shallow Areas with a Pebble/Gravel Bottom)

The numerical representation of the total biotic value of this zone is 577.37, as shown on Table 14. Value is well distributed among resource use categories, with the exception of migration, which accounts for less than five percent of the total. Fish species found to be particularly dependent upon Zone 2 areas include the following: the rock bass, with a consensus of opinion on the importance of this habitat type for spawning and nursery activities; and the spotfin shiner, with a consensus of opinion on the value of Zone 2 areas as general living space for this species.

Zone 3 (Shallow Areas with a Sand/Silt Bottom)

The numerical representation of the total biotic value of this zone is 574.46, as shown on Table 15. Important resource use categories include spawning, nursery, and feeding activities, which collectively account for almost 80 percent of total value. Evaluators

TABLE 14

RESULTS OF THE EVALUATION OF BIOTIC ZONE 2 BY TEN AQUATIC BIOLOGISTS
SHALLOW AREAS WITH PEBBLE/GRAVEL BOTTOM

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Dorosoma cepedianum	General Requirements (resting)	4	0.4	14.8	5.92
Gizzard shad	Feeding	8	0.8	30.7	24.56
	Spawning	7	0.7	23.3	16.31
	Nursery	8	0.8	25.8	20.64
	Migration/Seasonal Movement	7	0.7	17.5	12.25
Cyprinus carpio	General Requirements (resting)	2	0.2	6.4	1.28
Carp	Feeding	6	0.6	20.0	12.00
	Spawning	5	0.5	16.7	8.35
	Nursery	4	0.4	14.8	5.92
	Migration/Seasonal Movement	1	0.1	9.0	0.90
Notropis atherinoides	General Requirements (resting)	4	0.4	19.0	7.60
Emerald shiner	Feeding	4	0.4	14.8	5.92
	Spawning	2	0.2	11.8	2.36
	Nursery	4	0.4	17.4	6.96
	Migration/Seasonal Movement	4	0.4	22.2	8.88
Notropis spilopterus	General Requirements (resting)	10	1.0	45.4	45.40
Spotfin shiner	Feeding	7	0.7	23.3	16.31
	Spawning	7	0.7	38.9	27.23
	Nursery	5	0.5	23.8	11.90
	Migration/Seasonal Movement	0	0.0	0.0	0.00

TABLE 14 (CONTINUED)

RESULTS OF THE EVALUATION OF BIOTIC ZONE 2 BY TEN AQUATIC BIOLOGISTS
SHALLOW AREAS WITH PEBBLE/GRAVEL BOTTOM

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Ictalurus punctatus Channel catfish	General Requirements (resting)	6	0.6	17.6	10.56
	Feeding	4	0.4	11.8	4.72
	Spawning	7	0.7	31.8	22.26
	Nursery	6	0.6	23.1	13.86
	Migration/Seasonal Movement	1	0.1	9.1	0.91
Ambloplites rupestris Rock bass	General Requirements (resting)	8	0.8	25.0	20.00
	Feeding	8	0.8	26.7	21.36
	Spawning	10	1.0	41.7	41.70
	Nursery	10	1.0	40.0	40.00
	Migration/Seasonal Movement	1	0.1	16.7	1.67
Lepomis macrochirus Bluegill	General Requirements (resting)	2	0.2	7.1	1.42
	Feeding	7	0.7	21.9	15.33
	Spawning	10	1.0	40.0	40.00
	Nursery	7	0.7	25.9	18.13
	Migration/Seasonal Movement	1	0.1	11.1	1.11
Micropterus dolomieui Smallmouth bass	General Requirements (resting)	9	0.9	25.7	23.13
	Feeding	9	0.9	29.0	26.10
	Spawning	8	0.8	25.0	20.00
	Nursery	7	0.7	20.6	14.42
	Migration/Seasonal Movement	0	0.0	0.0	0.00
		TOTAL BIOTIC VALUE OF BIOTIC ZONE 2 = 577.37			

TABLE 15

RESULTS OF THE EVALUATION OF BIOTIC ZONE 3 BY TEN AQUATIC BIOLOGISTS
SHALLOW AREAS WITH SAND/SILT BOTTOM

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
<u>Dorosoma cepedianum</u> Gizzard shad	General Requirements (resting)	7	0.7	25.9	18.13
	Feeding	9	0.9	34.6	31.14
	Spawning	10	1.0	33.3	33.30
	Nursery	9	0.9	29.0	26.10
	Migration/Seasonal Movement	8	0.8	20.0	16.00
<u>Cyprinus carpio</u> Carp	General Requirements (resting)	7	0.7	22.6	15.82
	Feeding	9	0.9	30.0	27.00
	Spawning	6	0.6	20.0	12.00
	Nursery	7	0.7	25.9	18.13
	Migration/Seasonal Movement	2	0.2	18.2	3.64
<u>Notropis atherinoides</u> Emerald shiner	General Requirements (resting)	7	0.7	33.3	23.30
	Feeding	5	0.5	18.5	9.25
	Spawning	6	0.6	35.3	21.18
	Nursery	7	0.7	30.4	21.28
	Migration/Seasonal Movement	4	0.4	22.2	8.88
<u>Notropis spilopterus</u> Spotfin shiner	General Requirements (resting)	6	0.6	27.3	16.38
	Feeding	7	0.7	23.3	16.31
	Spawning	2	0.2	11.1	2.22
	Nursery	4	0.4	19.0	7.60
	Migration/Seasonal Movement	0	0.0	0.0	0.00

TABLE 15 (CONTINUED)

RESULTS OF THE EVALUATION OF BIOTIC ZONE 3 BY TEN AQUATIC BIOLOGISTS
SHALLOW AREAS WITH SAND/SILT BOTTOM

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Ictalurus punctatus Channel catfish	General Requirements (resting)	5	0.5	14.7	7.35
	Feeding	3	0.3	8.8	2.64
	Spawning	6	0.6	27.3	16.38
	Nursery	7	0.7	26.9	18.83
	Migration/Seasonal Movement	2	0.2	18.2	3.64
Ambloplites rupestris Rock bass	General Requirements (resting)	3	0.3	9.4	2.82
	Feeding	7	0.7	23.3	16.31
	Spawning	7	0.7	29.2	20.44
	Nursery	7	0.7	28.0	19.60
	Migration/Seasonal Movement	1	0.1	16.7	1.67
Lepomis macrochirus Bluegill	General Requirements (resting)	4	0.4	14.3	5.72
	Feeding	7	0.7	21.9	15.33
	Spawning	8	0.8	32.0	25.60
	Nursery	8	0.8	29.6	23.68
	Migration/Seasonal Movement	1	0.1	11.1	0.11
Micropterus dolomieui Smallmouth bass	General Requirements (resting)	3	0.3	8.6	2.58
	Feeding	5	0.5	16.1	8.05
	Spawning	10	1.0	31.2	31.20
	Nursery	9	0.9	26.5	23.85
	Migration/Seasonal Movement	0	0.0	0.0	0.00
		TOTAL BIOTIC VALUE OF BIOTIC ZONE 3 = 574.46			

determined that Zone 3 areas are particularly important to the gizzard shad, providing the most suitable habitat for the spawning, feeding, and nursery activities of this species. Additionally, biologists identified this zone as an important spawning habitat for the smallmouth bass.

Zone 4 (Moderately Deep Areas)

The numerical representation of the total biotic value of this zone within the study area is 214.08, as shown on Table 16. Important resource use categories include resting, migration, and feeding, collectively accounting for almost 90 percent of the total value of this zone. Although results indicate that this zone is not of critical importance to representative, important species, such areas are identified as a favored habitat of the gizzard shad for resting and migration; of the emerald shiner for feeding; and of the channel catfish for feeding and seasonal movements.

Zone 5 (Deep Areas)

The numerical representation of the total biotic value of this zone is 146.56, as shown on Table 17. The most important resource use category for this zone is resting, accounting for almost 50 percent of total value. Although it was judged that most species do not frequent deeper areas, this biotic zone was identified as a favored resting habitat of the carp and of the smallmouth bass.

TABLE 16

RESULTS OF THE EVALUATION OF BIOTIC ZONE 4 BY TEN AQUATIC BIOLOGISTS
MODERATELY DEEP AREAS

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Dorosoma cepedianum Gizzard shad	General Requirements (resting)	8	0.8	29.6	23.68
	Feeding	1	0.1	3.8	0.38
	Spawning	1	0.1	3.3	0.33
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	10	1.0	25.0	25.00
Cyprinus carpio Carp	General Requirements (resting)	5	0.5	16.1	8.05
	Feeding	1	0.1	3.3	0.33
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	3	0.3	27.3	8.19
Notropis atherinoides Emerald shiner	General Requirements (resting)	5	0.5	23.8	11.90
	Feeding	8	0.8	29.6	23.68
	Spawning	5	0.5	29.4	14.70
	Nursery	4	0.4	17.4	6.96
	Migration/Seasonal Movement	4	0.4	22.2	8.88
Notropis spilopterus Spotfin shiner	General Requirements (resting)	1	0.1	4.5	0.45
	Feeding	4	0.4	13.3	5.32
	Spawning	0	0.0	0.0	0.00
	Nursery	1	0.1	4.8	0.48
	Migration/Seasonal Movement	0	0.0	0.0	0.00

TABLE 16 (CONTINUED)

RESULTS OF THE EVALUATION OF BIOTIC ZONE 4 BY TEN AQUATIC BIOLOGISTS
MODERATELY DEEP AREAS

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Ictalurus punctatus Channel catfish	General Requirements (resting)	8	0.8	23.5	18.80
	Feeding	8	0.8	23.5	18.80
	Spawning	1	0.1	4.5	0.45
	Nursery	2	0.2	7.7	1.54
	Migration/Seasonal Movement	4	0.4	36.4	14.56
Ambloplites rupestris Rock bass	General Requirements (resting)	3	0.3	9.4	2.82
	Feeding	0	0.0	0.0	0.00
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	1	0.1	16.7	1.67
Lepomis macrochirus Bluegill	General Requirements (resting)	5	0.5	17.8	8.90
	Feeding	1	0.1	3.1	0.31
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	2	0.2	22.2	4.44
Micropterus dolomieui Smallmouth bass	General Requirements (resting)	2	0.2	5.7	1.14
	Feeding	1	0.1	3.2	0.32
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	1	0.1	20.1	2.00
		TOTAL BIOTIC VALUE OF BIOTIC ZONE 4 =			214.08

TABLE 17

RESULTS OF THE EVALUATION OF BIOTIC ZONE 5 BY TEN AQUATIC BIOLOGISTS
DEEP AREAS

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Dorosoma cepedianum Gizzard shad	General Requirements (resting)	3	0.3	11.1	3.33
	Feeding	0	0.0	0.0	0.00
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	5	0.5	12.5	6.25
Cyprinus carpio Carp	General Requirements (resting)	9	0.9	29.0	26.10
	Feeding	1	0.1	3.3	0.33
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	2	0.2	18.2	3.64
Notropis atherinoides Emerald shiner	General Requirements (resting)	2	0.2	9.5	1.90
	Feeding	6	0.6	22.2	13.32
	Spawning	3	0.3	17.6	5.28
	Nursery	3	0.3	13.0	3.90
	Migration/Seasonal Movement	1	0.1	5.5	0.55
Notropis spilopterus Spotfin shiner	General Requirements (resting)	0	0.0	0.0	0.00
	Feeding	2	0.2	6.7	1.34
	Spawning	0	0.0	0.0	0.00
	Nursery	1	0.1	4.8	0.48
	Migration/Seasonal Movement	0	0.0	0.0	0.00

TABLE 17 (CONTINUED)

RESULTS OF THE EVALUATION OF BIOTIC ZONE 5 BY TEN SQUATIC BIOLOGISTS
DEEP AREAS

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Ictalurus punctatus Channel catfish	General Requirements (resting)	9	0.9	26.5	23.85
	Feeding	7	0.7	20.6	14.42
	Spawning	0	0.0	0.0	0.00
	Nursery	1	0.1	3.8	0.38
	Migration/Seasonal Movement	2	0.2	18.2	3.64
Ambloplites rupestris Rock bass	General Requirements (resting)	1	0.1	3.1	0.31
	Feeding	0	0.0	0.0	0.00
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	1	0.1	16.7	1.67
Lepomis macrochirus Bluegill	General Requirements (resting)	6	0.6	21.4	12.84
	Feeding	1	0.1	3.1	0.31
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	2	0.2	22.2	4.44
Micropterus dolomieui Smallmouth bass	General Requirements (resting)	1	0.1	2.8	0.28
	Feeding	0	0.0	0.0	0.00
	Spawning	0	0.0	0.0	0.00
	Nursery	0	0.0	0.0	0.00
	Migration/Seasonal Movement	3	0.3	60.0	18.00
		TOTAL BIOTIC VALUE OF BIOTIC ZONE 5 =			146.56

Zone 6 (Aquatic Macrophyte Beds)

The numerical representation of the total biotic value of this zone is 382.13, as shown on Table 18. All resource use categories are well represented in this calculation, with the exception of migration, which accounts for less than five percent of the total value. Species judged to be particularly dependent upon this zone include the following: carp, with a consensus of opinion on the value of Zone 6 areas as spawning and nursery sites for this species, and nine out of ten evaluators identifying the zone as an important feeding area; smallmouth bass, with all evaluators identifying this zone as a major resting and nursery habitat for this species, and nine out of ten biologists agreeing that the zone is used for spawning; bluegill, with nine out of ten evaluators identifying Zone 6 areas as an important resting and feeding habitat for this species.

TABLE 18

RESULTS OF THE EVALUATION OF BIOTIC ZONE 6 BY TEN AQUATIC BIOLOGISTS
AQUATIC MACROPHYTE BEDS

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Dorosoma cepedianum	General Requirements (resting)	2	0.2	7.4	1.49
Gizzard shad	Feeding	3	0.3	11.5	3.45
	Spawning	6	0.6	20.5	12.00
	Nursery	6	0.6	19.3	11.58
	Migration/Seasonal Movement	4	0.4	10.5	4.20
Cyprinus carpio	General Requirements (resting)	6	0.6	19.3	11.58
Carp	Feeding	9	0.9	30.0	27.00
	Spawning	10	1.0	33.3	33.30
	Nursery	10	1.0	37.0	37.00
	Migration/Seasonal Movement	2	0.2	18.2	3.64
Notropis atherinoides	General Requirements (resting)	1	0.1	4.8	0.48
Emerald shiner	Feeding	1	0.1	3.7	0.37
	Spawning	0	0.0	0.0	0.00
	Nursery	1	0.1	4.3	0.43
	Migration/Seasonal Movement	1	0.1	5.5	0.55
Notropis spilopterus	General Requirements (resting)	0	0.0	0.0	0.00
Spotfin shiner	Feeding	2	0.2	6.7	1.34
	Spawning	0	0.0	0.0	0.00
	Nursery	3	0.3	14.3	4.29
	Migration/Seasonal Movement	0	0.0	0.0	0.00

TABLE 18 (CONTINUED)

RESULTS OF THE EVALUATION OF BIOTIC ZONE 6 BY TEN AQUATIC BIOLOGISTS
AQUATIC MACROPHYTE BEDS

Species	Resource Use Category	Number of Biologists Identifying Zone as Suitable	Confidence Quotient	Exclusivity Quotient	Biotic Value
Ictalurus punctatus	General Requirements (resting)	2	0.2	5.9	1.18
Channel catfish	Feeding	7	0.7	20.6	14.42
	Spawning	0	0.0	0.0	0.00
	Nursery	3	0.3	11.5	3.45
	Migration/Seasonal Movement	1	0.1	9.1	0.91
Ambloplites rupestris	General Requirements (resting)	7	0.7	21.9	15.33
Rock bass	Feeding	6	0.6	20.0	12.00
	Spawning	2	0.2	8.3	1.66
	Nursery	2	0.2	8.0	1.60
	Migration/Seasonal Movement	1	0.1	16.7	1.67
Lepomis macrochirus	General Requirements (resting)	9	0.9	32.1	28.89
Bluegill	Feeding	9	0.9	28.1	25.29
	Spawning	3	0.3	12.0	3.60
	Nursery	7	0.7	25.9	18.13
	Migration/Seasonal Movement	2	0.2	22.2	4.44
Micropterus dolomieui	General Requirements (resting)	10	1.0	28.6	28.60
Smallmouth bass	Feeding	6	0.6	19.3	11.58
	Spawning	9	0.9	28.1	25.29
	Nursery	10	1.0	29.4	29.40
	Migration/Seasonal Movement	1	0.1	20.0	2.00
		TOTAL BIOTIC VALUE OF BIOTIC ZONE 6 = 382.13			

ALLOCATION OF BIOTIC VALUE
TO THE HEATED DISCHARGE
OF THE KANAWHA RIVER POWER PLANT

In this chapter, the results of the biotic zone evaluation procedure are applied in the assessment of the heated discharge of the Kanawha River Power Plant. This assessment comprised two phases: calculation of theoretical biotic allocation values according to three management scenarios and calculation of the actual amount of biotic value represented within the thermal mixing zone based on field surveys. In addition to providing a line of evidence for the assessment of a specific discharge, comparison of expected and observed values serves as a practical test of the biotic value allocation procedure.

RESULTS USING THE ALLOCATION PROCEDURE

In accordance with procedural requirements outlined in the chapter on materials and methods, all six effluent discharges identified within the study area by personnel of the West Virginia Department of Natural Resources (Casto, personal communication, 1978) were represented in the allocation equations. Equations were solved for three management options, representing a high level, a moderate level, and a low level of environmental protection. All options assumed that the full amount of biotic value alloted for mixing zones could be allocated to existing dischargers. Thus, no reserve was allocated to future dischargers.

As shown on Table 19, results according to varying levels of protection indicate a simple linear relationship. The moderate level of protection scenario allocates five times as much biotic value to mixing zones as the high level of protection case; and the low level of protection scenario permits usage of ten times as much biotic value as the high level of protection case, and twice as much as that allowed under the moderate level of protection plan.

The heated discharge of the Kanawha River Power Plant was found to have the highest flow rate of the six discharges identified within the study area. Using the recommended discharge dependent allocation option, the heated discharge was thus assigned more than 99 percent of the total mixing zone allotment in all three scenarios. Based on an average unit value of 5.0 (per acre), the high level of protection scenario indicates that the heated discharge should occupy no more than 4.7 acres (1.9 ha), the moderate level of protection scenario indicates no more than 23.6 acres (9.5 ha), and the low level of protection case indicates that no more than 47.2 acres (19.9 ha) should be utilized.

RESULTS BASED ON FIELD SURVEYS

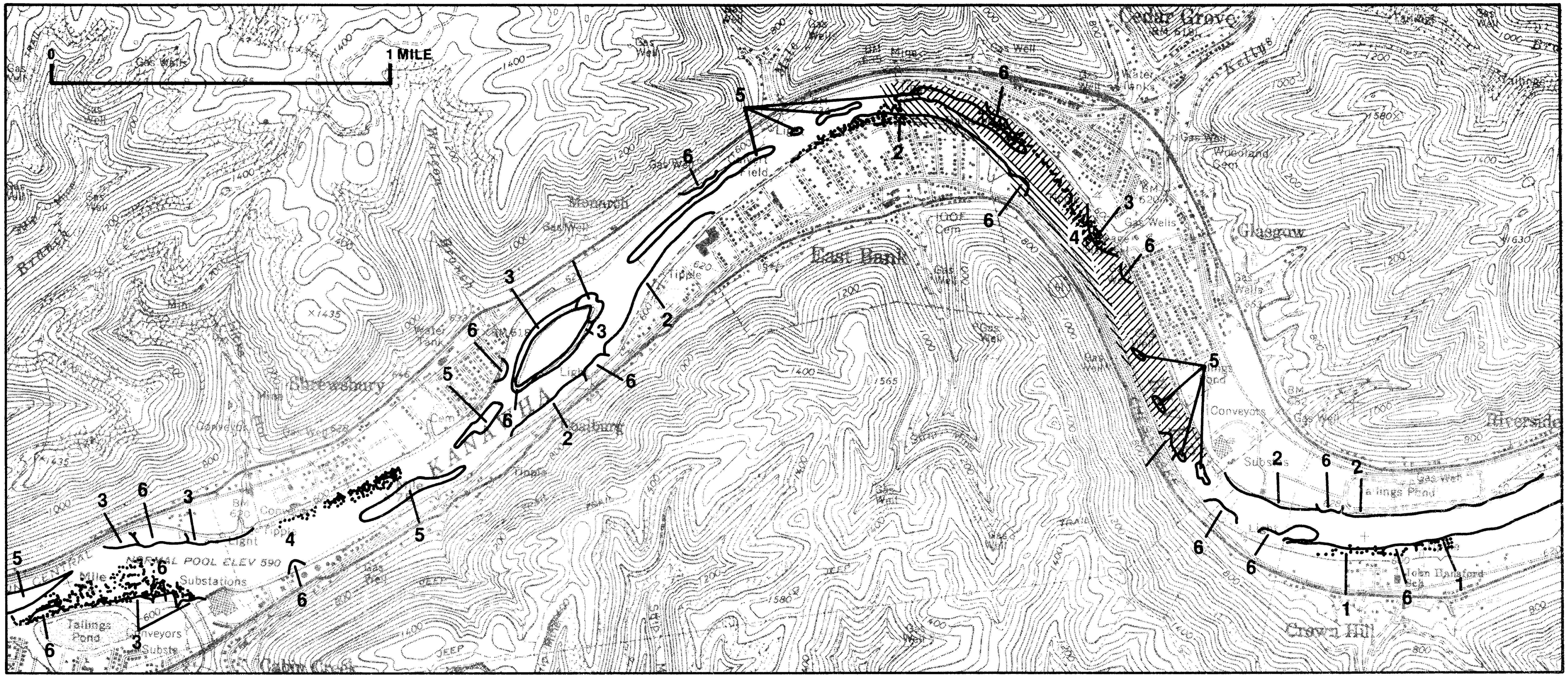
A report on surface temperature characteristics in the vicinity of the Kanawha River Power Plant by Marchman et al. (1976) was used in estimating the actual extent of the thermal mixing zone (see Materials and Methods). As illustrated on Figure 11, the mixing zone occupies approximately one-sixth of the study area and intersects several biotic zone classifications.

TABLE 19

RESULTS OF THE BIOTIC VALUE ALLOCATION PROCEDURE

SOURCE OF DISCHARGE	Flow (cfs) Q_k*	Allocation Function $f(Q_k)$	BIOTIC VALUE ALLOCATED TO MIXING ZONE (BVA_k), Where Θ=1.0		
			High Level of Protection $p = 0.01$	Moderate Level of Protection $p = 0.05$	Low Level of Protection $p = 0.1$
Community of Crown Hill (sewage)	0.06	0.0006	0.0165	0.0827	0.1643
Kanawha River Power Plant (cooling water)	646.20	0.8570	23.6300	118.1504	236.3009
Glasgow Sewage Treatment Plant	0.34	0.0031	0.0855	0.4274	0.8547
Community of Cedar Grove (sewage)	0.19	0.0018	0.0496	0.2481	0.4963
East Bank Sewage Treatment Plant	0.19	0.0018	0.0496	0.2481	0.4963
Community of Shrewsbury (sewage)	0.12	0.0011	0.0303	0.1516	0.3033
TOTALS	647.10	0.08654	23.8615	119.3083	238.6158

*Sources: West Virginia Department of Natural Resources, 1975, West Virginia Region III Intergovernmental Council, 1977, and Marchman et al., 1974.



Key:

- Maximum Extent of the Thermal Mixing Zone Associated with the Heated Discharge of the Kanawha River Power Plant
- Areas Where Surface Temperatures Have Been Elevated More Than 5°F. above Ambient Levels
- Other Mixing Zones within the Study Area

FIGURE 11
GRAPHIC REPRESENTATION OF THE RELATIONSHIP BETWEEN BIOTIC ZONES OF THE STUDY AREA AND THE HEATED DISCHARGE OF THE KANAWHA RIVER POWER PLANT

As shown on Table 20, the mixing zone, or area where temperatures more than $5^{o}F$ ($3^{o}C$) above ambient levels were reported, comprises 71.67 acres (29.00 ha). Four of the six biotic zone classifications are represented within the mixing zone, with the moderately deep classification accounting for 84 percent of the total area. The calculated total biotic value represented by the mixing zone is 202.74, with a 3.3 acre (1.3 ha) area of Zone 3 habitat accounting for about 50 percent of the total.

The maximum area affected by the heated discharge, representing areas where temperatures more than $2^{o}F$ ($1^{o}C$) above ambient levels were reported, was found to comprise 107.25 acres (43.40 ha). Five of the six biotic zones are represented with this area, with the moderately deep classification accounting for 81 percent of the total area. The calculated total biotic value represented by this area is 345.53, with Zones 2 and 3 collectively accounting for 60 percent of the total.

DISCUSSION

Calculation of the actual amount of biotic value within the thermal mixing zone appears to support the results of the biotic value allocation procedure. Comparison of the two sets of results indicates that the actual amount of biotic value allocated to the Kanawha River Power Plant represents a level of protection (p) of 0.086, which lies within the range designated as a moderate level of protection (0.02 to 0.09). According to the U.S. Environmental Protection Agency (1975), such a level would be appropriate for an aquatic system which is relatively "capable of withstanding insults." A review of the ecological

TABLE 20

CALCULATION OF BIOTIC VALUE REPRESENTED WITHIN THE HEATED DISCHARGE OF THE KANAWHA RIVER POWER PLANT BASED ON INFRARED IMAGERY SURFACE ISOTHERMS*

BIOTIC ZONE	Unit Value (per acre)	MIXING ZONE $\Delta t > 5^oF (3^oC)$		MAX. AREA AFFECTED $\Delta t > 2^oF (1^oC)$	
		Area (acres)	Biotic Value	Area (acres)	Biotic Value
1. Shallow Areas with Boulder/Cobble Bottom	45.5	0.00	0.00	0.00	0.00
2. Shallow Areas with Pebble/Gravel Bottom	19.5	0.00	0.00	5.43	105.88
3. Shallow Areas with Sand/Silt Bottom	30.4	3.30	100.32	3.30	100.32
4. Moderately Deep Areas	0.6	60.36	36.22	87.42	52.45
5. Deep Areas	3.8	7.61	28.92	10.60	40.28
6. Aquatic Macrophyte Beds	93.2	0.40	37.28	0.50	46.60
TOTALS	--	71.67	202.74	107.25	345.53

*Generalized surface isotherms were adapted from Marchman et al., 1976.

literature on the study area shows that the resident aquatic community is generally comprised by hardy or tolerant species (see Background Information on the Study Area). Accordingly, results of the allocation procedure would indicate that current levels of biotic value utilization are reasonable for this particular reach of the Kanawha River.

Although results of the biotic value allocation procedure appear reasonable, conclusions based on a comparison of results of the two allocation approaches are predicated on the accuracy of the definition of the actual thermal mixing zone. As noted in the section on materials and methods, this definition was based on limited data which may not be truly representative of actual field conditions. Additionally, the mixing zone was defined in accordance with the state standard which limits temperature increases to $5^{o}F$ ($3^{o}C$) above ambient levels (West Virginia Department of Natural Resources, 1974). Criteria set by the U.S. Environmental Protection Agency (1976) for upper limiting temperatures are based on potential effects on sensitive important species. Thus, the definition of the mixing zone according to Federal criteria may be dissimilar to the definition presented in this research.

CONCLUSIONS

This study was intended to further develop the concept of biotic value allocation and to evaluate its applicability in the assessment of heated discharges. These were accomplished in a case study of the heated discharge of the Kanawha River Power Plant near Charleston, West Virginia. In general, it is concluded that a methodology based on the biotic value allocation concept could be an effective and practical management tool. Most promising are potential applications in the areas of long-term monitoring and regulation of the cumulative impacts of multiple mixing zones. To detail the prospects for use of the concept, the four major procedural components of this study are discussed below.

1. Two tasks must be accomplished to map the distribution of habitat attributes: identification of the environmental parameters that influence habitat selection by representative, important species; and compilation of sufficient data to map the distribution of those parameters at a meaningful scale. In this case study, three depth categories, three bottom types, and the presence or absence of aquatic macrophytes were identified as important habitiat attributes for representative, important fish species. Available data, extensive site reconnaissance, and a limited field sampling program were sufficient for mapping the distribution of these attributes at a scale of 1:9600.

2. The identification of biotic zones, or microhabitat types, requires the development of a classification scheme that enables the synthesis of individual habitat attribute maps. In this research, a review of life history information for representative, important species led to a classification scheme based on six biotic zone categories. Synthesis of the individual habitat attribute maps according to these categories was easily accomplished using an overlay technique.

3. The evaluation of biotic zones is the most crucial and the most controversial element of the biotic value allocation concept. The resource manager must ensure that the evaluations represent an accurate assessment of the importance of each zone in meeting the resource requirements of representative, important species. A major problem encountered in this research was the failure of previously developed procedures to account for the dynamic use of space by fishes. Of particular concern were numerous cases where a species was known to use several habitat types for a given critical function. In response to this problem, a new evaluation procedure was developed as part of this research. This procedure involved individual assessment by ten aquatic biologists of the suitability of each zone for use by each species according to five resource use categories. These assessments were translated into numerical values representing a composite of the probabilities of the use of each zone and of the availability of suitable alternative habitats.

4. The allocation of biotic value to individual discharges must accurately reflect management objectives. In this case study, theoretical allocation values were calculated using a system of equations outlined by the U.S. Environmental Protection Agency (1975). Comparison of the results of this procedure with values obtained based on field studies strongly suggests that the allocation equations can be used effectively.

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THE USE OF BIOTIC VALUE ALLOCATION
IN THE ASSESSMENT OF HEATED DISCHARGES

by

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(ABSTRACT)

A recently developed waterbody management concept was refined and applied in the assessment of the heated discharge of Appalachian Power Company's Kanawha River fossil fuel plant near Charleston, West Virginia. Depth, bottom type, and aquatic macrophyte beds were identified as important habitat attributes for eight representative, important fish species. The distribution of three depth categories, three bottom types, and aquatic macrophytes was mapped for a six mile (9.6 km) reach of the Kanawha River. Using an overlay technique, six biotic zones, or microhabitat types, were identified. The importance of each zone in meeting habitat requirements of the selected species was assessed by ten aquatic biologists: Three shallow area classifications were considered most valuable, followed by aquatic macrophyte beds, moderately deep areas, and deep areas. Assessments were translated into representative numerical values using a procedure developed for this study. Values were applied in a system of equations for allocating biotic value to study area mixing zones according to discharge volume. The actual amount of biotic value represented within the $\Delta 5^{o}F(3^{o}C)$ isotherm produced by the heated discharge was

measured based on four surface imagery surveys. Comparison of calculated and observed values indicated that the allocation procedure provided a meaningful representation of the impacts of the heated discharge.