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ADEM
TECHNICAL REPORT

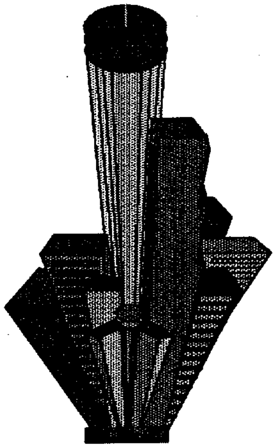
A SURVEY OF THE DOG RIVER WATERSHED
Second Year's Findings

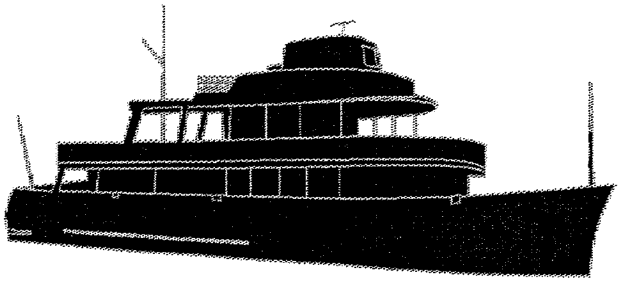
A Review of Ongoing Development in the Basin and an Assessment of the Effects of Urban Non-Point Sources on the Aquatic Resources of the Basin

COASTAL PROGRAM

November 1995

ALABAMA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
1751 CONG. W. L. DICKINSON DRIVE • MONTGOMERY, AL 36130





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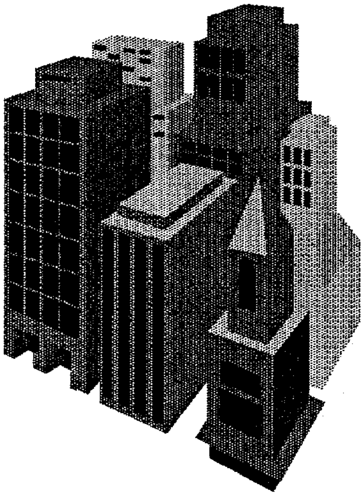

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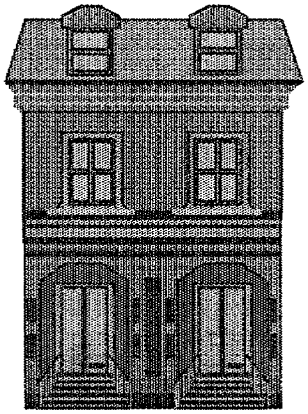

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DISCLAIMER

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Executive Summary

The Dog River Watershed, a basin located in an area with extensive commercial and residential development, was surveyed for an evaluation of the stresses of urban growth on the streams of the basin. Active construction sites were found to have a significant impact on water clarity and streambed siltation. Lack of effective erosion control at project sites was the single most responsible contributor to the degradation of stream habitat. Erosion and siltation furthermore appear to pose a potential threat to waterfront property and wetlands. Existing development and historical land-use practices also have left their mark on the aquatic fauna and stream bottom habitats of the basin. Analysis of sediment cores from streams of the watershed indicated a conspicuous enrichment of lead, zinc and other metals characteristic of urban runoff. Examination of the benthic infauna revealed low overall abundances, depressed community diversity and dominance by pollution tolerant species at some stations. Conditions considered by many biologists as emblematic of aquatic habitats affected by streambed siltation, organic enrichment and other aspects of urban runoff.

Introduction and Overview

The Dog River Watershed (Figure 1) has been studied since 1993 by the Alabama Department of Environmental Management's Coastal Program. The project was designed to assess the effects of land-use practices and development on the aquatic resources of the watershed. This was accomplished through determining the physical characteristics of the watershed (i.e., topography, soil types, etc.), reviewing past and present land-use practices, inspecting active construction sites, monitoring the effects of non-point sources on the basin's water and sediment quality, surveying the wetlands flora and examining the benthic infaunal community of the watershed.

In the first report, entitled *A Survey of the Dog River Watershed - An Overview of Land-Use Practices and the Affects of Development on the Natural Resources of the Basin* and published in May, 1994, the historical development and recent land-use practices of the Dog River Watershed (DRW) were reviewed and the impacts of such activities on the aquatic habitats and water quality of the basin were examined. The findings of the first report revealed that streambed siltation and impairment of water clarity (turbidity) from non-point sources in the watershed pose the most significant threat to aquatic life and water quality. Erosion and storm runoff from construction sites are the primary contributors to the siltation and turbidity problem. Secondary impacts include degradation of aesthetics due to trash and litter in the water, elevated nutrient concentrations in storm water runoff, loss of natural shoreline habitat due to bulkhead and fill developments and impairment of recreational uses of surface waters due to bacterial (fecal coliform) contamination.

In this second report, ongoing development and construction within the basin are more closely examined. The potential of these activities for promoting additional losses of stream habitats and contributing to water quality degradation effects are taken into account. Also discussed in this report are the results of a survey of the benthic infaunal communities and sediment chemistry of streams in the watershed.

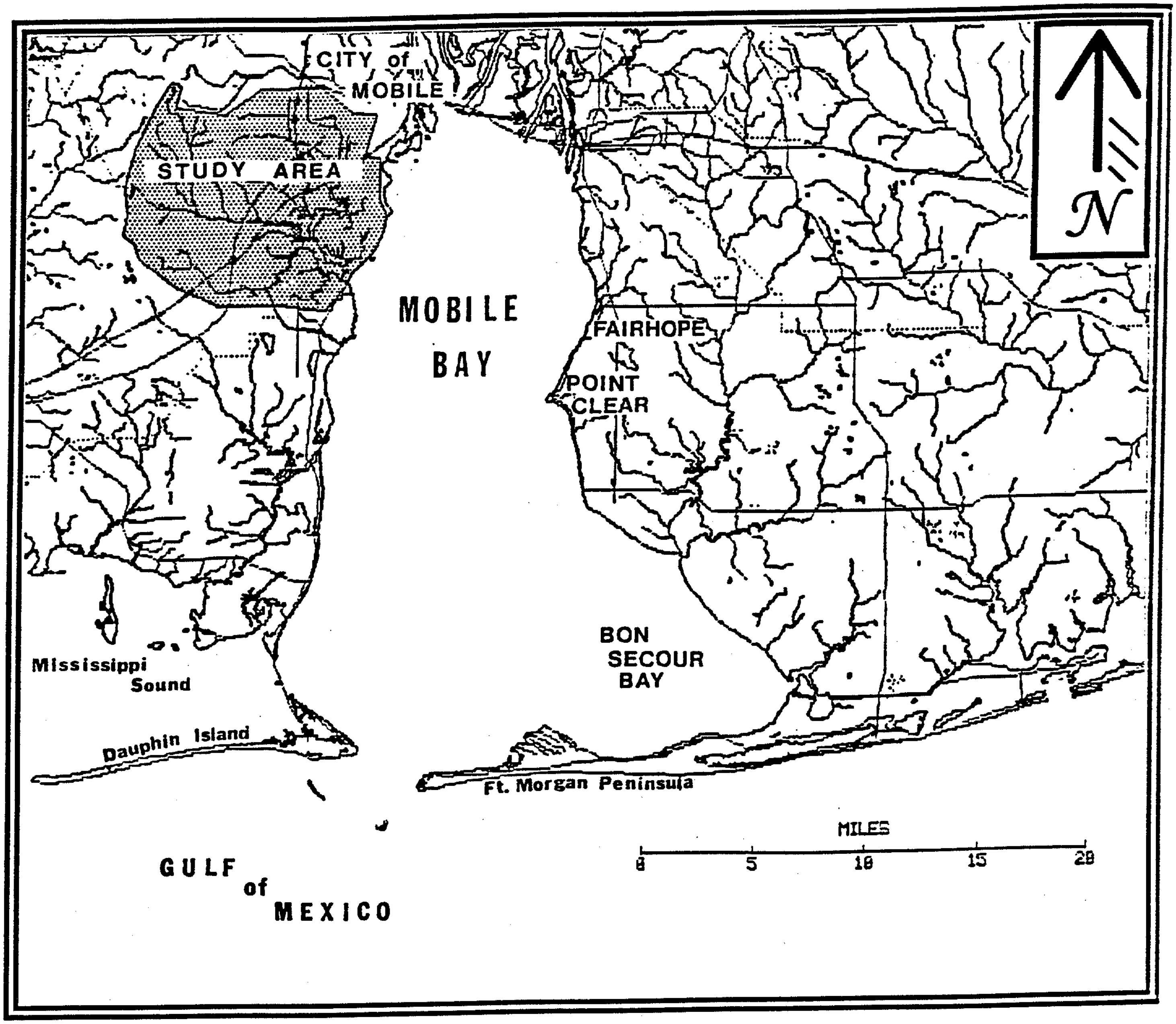

Figure 1

Coastal Alabama showing the Dog River Watershed

Ongoing Development and Impacts to the Watershed

Land Clearing, Stream Siltation and Water Clarity

The focus of the second year of the study was directed at the areas of the watershed experiencing the most active growth and development. The western and southern portions of the watershed continue to experience extensive real estate development in the form of light industrial parks, office buildings, retail businesses (shopping centers) and residential subdivisions.

As is typical with these activities, significant acreage is cleared during site preparation including the removal of all undergrowth and ground cover along stream banks. Uncontrolled, such practices subject large areas of cleared land to erosional processes. Erosion is a pervasive problem in actively developing areas of the DRW due to the erodible sandy-loam type soils, rolling topography and the intense rainstorms common to Mobile County. The result has been, and continues to be, that soil laden runoff from construction projects drains to nearby streams. Soil losses of 42 lbs/acre from a single storm-event have been measured at residential developments in Mobile County (South Alabama Regional Planning Commission, 1989). Annual loss rates of soil from construction sites may be as high as 50 tons per acre (US Fish and Wildlife Service, 1990).

During the watershed survey, all known construction projects of an area greater than five acres in the DRW were inspected by ADEM personnel. Construction sites of such size are now regulated under the NPDES General Permit Program which requires these activities to utilize various industry standard methods of erosion control, soil stabilization and detention of stormwater runoff. Methods proven effective in the control of runoff from cleared areas include sodding, seeding and mulching, applying soil binders or "tackifiers", silt fences and maintaining uncleared vegetated boundaries or greenbelts. The term Best Management Practices (BMP) has been applied to the devices and techniques employed for the control of erosion and runoff from construction sites and developed property.

Many of the sites inspected were found to have inadequate measures for control of erosional runoff and stream siltation. A common problem at sites where the contractor had attempted some means of BMP was improper installation of silt fences and hay bales. Silt fences often were set in place without burying the bottom edge flap allowing storm water to run underneath the silt fence. In more than one case, wash-outs formed under silt fences leaving the bottom of the fence suspended above the ground. Contractors also were somewhat negligent seeding, mulching and sodding the bare ground after clearing and grading operations. In a few cases the contractor properly installed these devices and initiated BMPs at the beginning of a project but failed to maintain such practices as the job progressed. In general the problem was that little if any detention of stormwater runoff nor effective stabilization of cleared ground was observed at construction sites.

Halls Mill Creek (Figure 2) appears to be the recipient of the majority of the sediment burden currently discharged to the DRW. Surveys of the Halls Mill Creek sub-basin show that siltation has significantly affected Halls Mill Creek for over half its length, from below the I-10 bridge to its uppermost reaches near the western boundary of the city limits. The numerous recently completed and ongoing construction projects in the Halls Mill Creek sub-basin have released a considerable quantity of soil to the system.

Currently, the most active development within the watershed is occurring near Milkhouse Creek and Second Creek, the main tributaries to Halls Mill Creek (Figure 2). These streams receive drainage from the land along Mobile County Road 31 (Schillinger Rd.) and Co. Rd. 37 (Cody Rd.), see Figure 3. A sizable amount of these projects involve clearing, grading and excavating along stream courses. At the time of the survey there were nine subdivisions undergoing development, ongoing road improvements including a new bridge across Milkhouse Creek and construction of an office complex. Inspections of construction sites by ADEM staff revealed that most of these projects were started without any attempts of controlling erosion. The few contractors initiating BMP measures at the beginning of a job neglected to maintain these devices and failed to expand coverage of stormwater control to keep up with the growth of the project. The result being a lack of control of erosion and runoff after just a few days of installation.

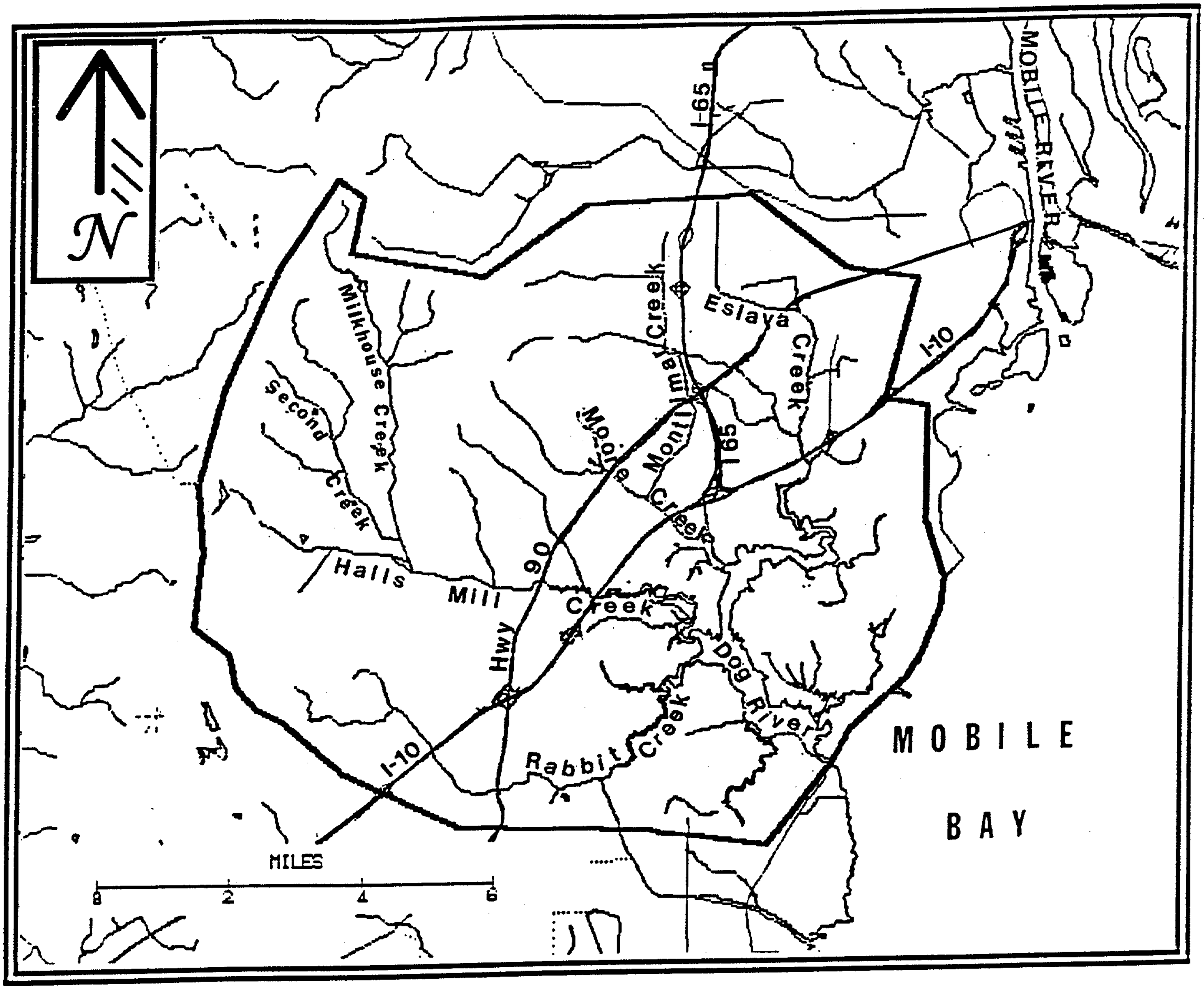

Figure 2

Dog River Watershed

Major Streams and Highways are Shown

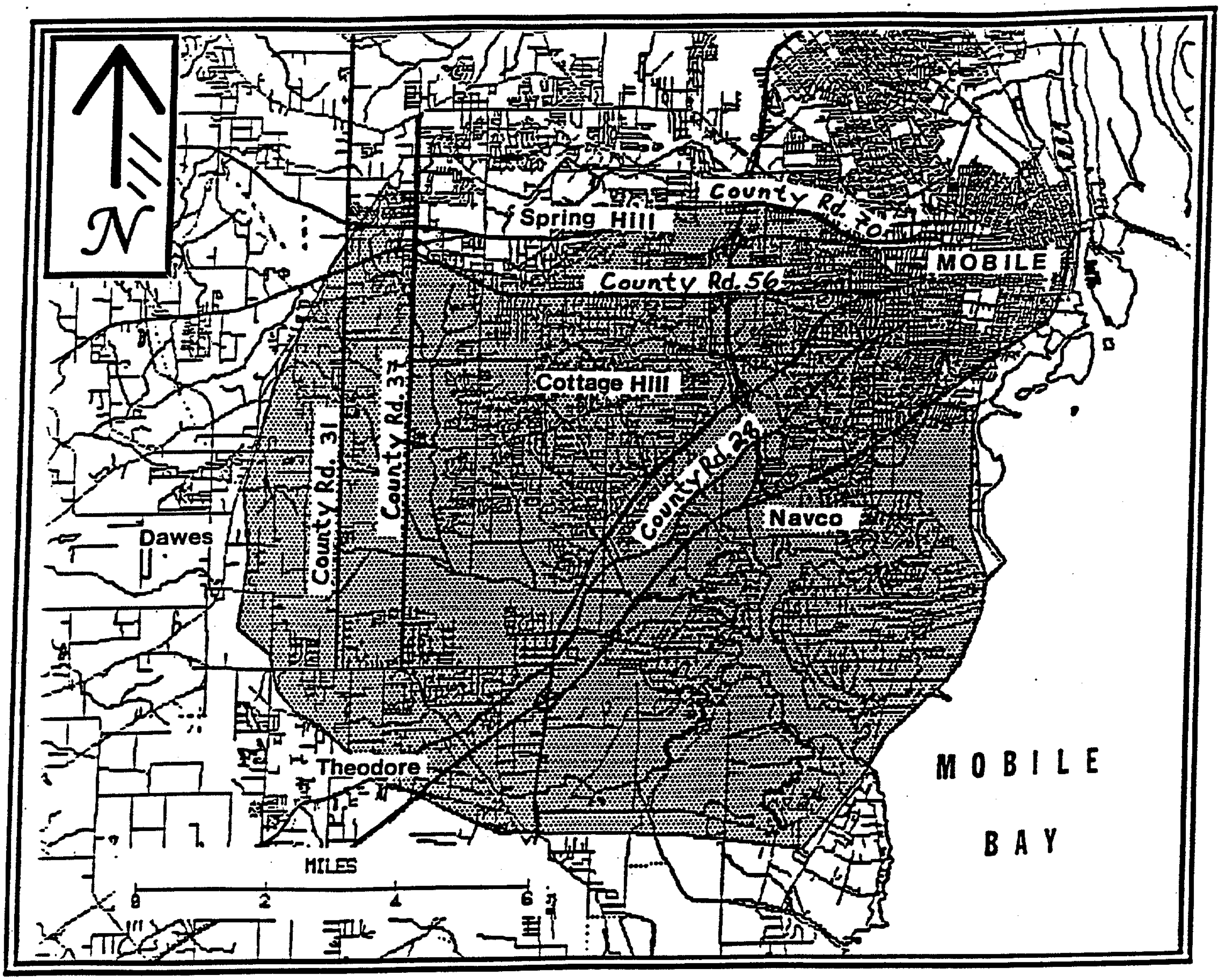

Figure 3

Dog River Watershed

City Streets, County & Secondary Roads

Other problems related to construction activities arise from connecting subdivision utilities to public systems. At some of the project sites, fill roads were constructed and pipeline trenches excavated across stream courses and associated wetlands for access to municipal sanitary mains. During the course of sewer tie-in operations contractors paid little attention to controlling erosion from the project site. It was observed that considerable amounts of road fill and trench spoil have been washed by rain to creeks and wetlands.

These projects also have the potential for short term but significant discharges of untreated sanitary sewage. During tie-in operations it often is necessary to divert flow of the sewer main around the site. This usually is accomplished by means of a bypass line for routing sewage from "upstream" of the tie-in to a point in the main "downstream" of the site. At some project sites leaks and overflows from bypass lines were observed to discharge sewage to area streams causing noticeable degradations in water quality. On other occasions, careless actions by contractors resulted in disconnected and/or broken sanitary lines. Activities such as these are potential explanations for some of the high fecal coliform numbers obtained during the first year of the survey. Additional discussion of the problem of sanitary wastes in the streams of the watershed will be found later in this report.

Other streams in the DRW also receive a considerable amount of urban runoff and sedimentation. Moore Creek is dredged by the City of Mobile because of sediment accumulations restricting the capacity of the creek. If not removed, the sand bars and silt deposits have the potential for impeding drainage of storm runoff from the surrounding area.

The neighborhoods in the Moore Creek sub-basin are older than those along Milkhouse and Second Creeks; consequently there is less ongoing construction because of the more developed nature of the locale. However, the high density housing, asphalt parking lots and paved roads typifying the development in the Moore Creek area are known to contribute significant sediment loads to streams via increased runoff from storms. The conversion of natural surface drainage (i.e., sheet flow) to storm drains, culverts and drainage canals (i.e., channelized flow) disrupts existing stable drainage courses and accellerates erosion through scour (Alabama Department of Environmental Management 1989; South Alabama Regional Planning Commission, 1989 and US Fish and Wildlife Service, 1990). This problem is typical of urban areas and demonstrates the need for control of stormwater runoff from developed areas and not just construction sites.

Although Eslava Creek has been "urbanized" longer than other streams of the DRW it was less affected by turbidity and siltation compared to the rest of the streams in the watershed. However, ongoing and planned development between Mobile County Roads 56 (Airport Boulevard) and 70 (Old Shell Road) in the vicinity of I-65 pose a potential for such problems. Proper installation and maintenance of erosion and runoff control BMPs will help avoid additional degradation to a stream which has long been affected by development and urban runoff.

Trash and litter continue to be the number one pollution problem in Eslava Creek, Bolton Branch and the uppermost segments of the Dog River. Considerable quantities of plastic wrapping, plastic bottles, styrofoam cups and assorted paper items appear in these streams following a rain storm. Most of this material comes from parking lots and curb gutters along upper Eslava Creek and is transported to the creek by storm runoff through drains and culverts.

During the first year of the survey of the DRW the Rabbit Creek/Rattlesnake Bayou system was found to be the least developed sub-basin in the watershed. Not surprisingly, it also has experienced the least amount of aquatic habitat and water quality degradation of the major tributaries to the Dog River. Historically the development in the Rabbit Creek/Rattlesnake Bayou watershed has been low to moderate density residential with a few light industrial-commercial facilities.

More recently there has been a surge of commercial development in the area as construction has begun on several new warehouses along U.S. Hwy 90 and a light industrial park between Mobile County Road 26 (Hamilton Blvd.) and Rangeline Road has opened. Initial inspection of these sites revealed that the BMP employed by the contractors were inadequate and provided little or no control of erosion and soil loss from the project site to local waters. Follow-up inspections have indicated that somewhat more effective measures have been taken by the contractors to control siltation from cleared areas.

If development in the Rabbit Creek/Rattlesnake Bayou watershed continues its recent rate of progress and if BMPs are not more scrupulously followed then it is inevitable that losses of wetlands, aquatic grassbeds and benthic habitats, similar to those losses observed in the Halls Mill Creek system, will occur.

The damage caused by erosion and siltation affects both wildlife and humans. The deposition of sand and silt smothers submersed vegetation, gravel riffles and other productive stream-bottom habitats. Even those bottom dwelling (benthic) species capable of inhabiting severely stressed environments are prevented from colonizing stream bottoms subjected to heavy siltation. The inability of "base of the food chain" species for establishing a population coupled with the destruction of important habitat such as grassbeds eventually leads to a loss of the larger recreationally and commercially important species. This will be further discussed in the section on benthic biology later in this report.

The ever increasing volumes of sediment in streams receiving such runoff also raise the elevation of the stream bed thereby decreasing the capacity of the original channel. This process effectively raises the elevation of the water surface under all flow regimes and particularly so during high flows following storm events. This condition has the ability to increase the frequency and severity of flash floods and impair navigation along affected stream courses. If allowed to continue, siltation might raise the water level of creeks during storms thereby increasing the potential for inundating roads, bridges and private property. Sediment laden waters overbanking a stream also lay down sand and silt on the flooded land as the waters recede. The processes of erosion and siltation observed in streams of the DRW have the ability to constitute threats to property above and beyond the damage done to stream aesthetics.

The erosional processes at construction sites also has an affect on water clarity. Marked turbidity increases in the streams draining active developments are apparent of the DRW following significant rainfall (>0.25"); this is especially the case in the Hall's Mill Creek sub-basin and its tributaries Milkhouse Creek, Second Creek and Spring Creek. Monitoring of construction sites and receiving streams in the DRW by ADEM personnel has shown that turbidity increases of more than 2000 NTUs may occur in streams affected by uncontrolled runoff from land clearing activities (Milkhouse Creek and Second Creek).

Extremely turbid waters not only are an impediment to photosynthesis by submersed vegetation and phytoplankton but also are aesthetically unappealing. The persistence of stream turbidity due to clay fines suspended in the water may be evident miles from the construction activities causing the problem. High altitude photographs of the watershed indicate a turbidity plume extending from Halls Mill Creek into Dog River and down river to Mobile Bay. Following heavy rainfall in the watershed the turbidity in Halls Mill Creek is sufficient to produce a visible plume in the Dog River below their confluence, over 5 miles from the developments in western Mobile.

Impervious Cover, Increased Runoff and Streamflow

The increasing amount of impervious cover created by development reinforces the need to control siltation and avoid further restricting the drainage in the watershed. Much of the developed property in the DRW, especially the Halls Mill Creek sub-basin, includes sizable areas of parking lots, streets, sidewalks, rooftops and other impervious cover. In some cases property development includes substantial alteration of the natural drainage and consolidation of several smaller drainage courses and sheet flow into a single larger course. The storm water runoff from some of the commercial areas and residential neighborhoods is remarkable during heavy rains. This runoff was observed to substantially increase the rate of flow in the tributaries of the DRW compared to base flow conditions.

It is well documented in studies of urban runoff and stream hydrology that the impervious cover created by development can result in severe increases in stream flow during storms relative to base flow conditions (Alabama Department of Environmental Management, 1989; South Alabama Regional Planning Commission, 1989 and US Fish and Wildlife Service, 1990). Information searches conducted for the study yielded no historical records of flows in the DRW and this study did not quantify flows in the surveyed streams. Interviews with long-term residents living along Halls Mill Creek have indicated that the level of the creek in recent years has risen to higher levels during rainstorms than in the past.

Increased variability between a stream's base flow condition and its high flow level due to storm runoff presents an intrinsic problem with stream bank erosion. The sudden increases in flow combined with a rapidly fluctuating water level act to undercut stream banks and erode bank-side vegetation (Alabama Department of Environmental Management, 1989 and South Alabama Regional Planning Commission, !989). Although such processes occur naturally, the acute increases in stream-flow resulting from urban stormwater runoff accelerate the rate of streambank erosion.

This represents a threat to property owners from the erosional loss of shoreline and a danger to aquatic life from scouring and "blow-out" during storm events. Increased channelization of storm runoff and increased runoff from greater areas of impervious cover also act to uncover and wash out buried utilities (see discussion of municipal infrastructure below) and undermine supports for bridges.

Municipal Infrastructure and Water Quality

The first year's study of the DRW disclosed a problem with enteric bacteria in streams of the basin. On several occasions the colony counts of fecal coliform samples were above the single sample maximum for a stream's use-classification. Studies of urban non-point sources have found that in some instances high counts of fecal coliforms are attributable to domestic animals. These bacterial problems frequently manifest themselves following heavy rains and the numbers diminish after stormflows subside. High fecal coliform readings persistent over days or weeks are more indicative of contamination from leaks in sanitary sewers, sewer back-ups and overflows due to sediment and trash in sewer lines, sanitary connections to storm sewers and failing septic tanks.

The persistence of high fecal coliform readings observed at some of the monitoring stations during the first year indicated that some of the bacterial problems might be ascribed to humans more than to animals. This was the case in particular with Moore Creek and Halls Mill Creek.

As mentioned earlier in the report, connecting subdivisions to the municipal sanitary system has the potential for making significant short-term contributions to the pollution of a stream. Inspections of construction sites revealed that this process is often repeated around the watershed. Loose fitting couplings and leaks in flexible pipe utilized for the bypass were the usual cause for the discharge of sanitary waste during tie-in operations.

Investigation of citizens' complaints relative to sewage odors in the Cottage Hill area led ADEM and the Mobile Area Water and Sewer System (MAWSS) to the discovery of broken sanitary sewer lines along Milkhouse Creek and across Moore Creek near Mobile County Road 28 (Halls Mill Road). Undermining of the sewer pipe by storm runoff leaving several sections of the pipe unsupported was the cause of the line breaks. The duration these leaks existed is uncertain; however, once they were discovered, repairs were made to the damaged components and the sewer lines were returned to service.

This illustrates another complication of urban development and the large areas of impervious cover it creates. Collecting storm runoff in drainage systems and routing it to streams creates the potential for damaging utilities and infrastructure through excessive hydraulic force, erosion and undermining action.

Aging of the sanitary sewer system also has contributed to the impairment of water quality in the watershed. Lift stations on Second Creek and Halls Mill Creek are known to have discharged to their respective streams due to leaks, overflows and pump failures. Repairs on these facilities are near completion and should result in improvement of these streams, particularly with respect to enteric bacteria.

A comprehensive survey of the municipal sanitary system by the MAWSS is ongoing. The survey is to more accurately determine the routes of sewer lines, locate leaks, overflows and find interconnections between the storm and sanitary systems. Problems facing the MAWSS are sewer lines dating to near the turn of the century in older neighborhoods, incomplete and missing plans for some portions of the system, improper installation of sanitary lines by contractors in subdivisions and sanitary connections made to storm sewers.

Sediment Chemistry

Examination of sediments can offer insight into past conditions as well as indicating the present “pollution climate” because sediments represent a temporally integrated record of chemical conditions in a watershed. Many contaminants entering a watershed become sequestered in the sediments. This particularly is the case with estuarine watersheds as salt water promotes adsorption and precipitation of materials dissolved in the fresh water entering the system.

The objective of the sediment sampling program was to determine the concentrations of metals and the presence of excessive metal enrichment. These results were compared to a survey of natural estuarine sediments in the Alabama coastal zone which established the existence of statistically significant relationships between aluminum and eight trace metals: arsenic, barium, cadmium, chromium, copper, lead, nickel and zinc (Alabama Department of Environmental Management, 1991). These relationships may be utilized to identify unnatural concentrations of metals in estuarine sediments (Schropp and Windom, 1988 and ADEM, 1991).

This method of interpretation is based on the naturally occurring relationships between aluminum and other metallic elements. The basis for this method is that aluminum occurs naturally in all estuarine sediments and the concentrations of other metals tend to vary with the concentration of aluminum. These naturally occurring proportions of metals relative to aluminum have been reported by several investigators, Turekian and Wedepohl (1961), Taylor (1964), Duce *et al* (1976) and Schropp and Windom (1988) to be fairly constant. These relationships allow for the use of aluminum as a reference element or "normalizing factor" for identification of sediments enriched by anthropogenic activities. This concept has been used to examine metal pollution in the Savannah River estuary (Goldberg, 1979), lead pollution in the Mississippi River (Trefey *et al.*, 1985) and metal pollution in Florida estuaries (Schropp and Windom, 1988). Additional detail regarding this technique may be found in Schropp and Windom (1988) and ADEM (1991 and 1992).

Materials and Methods

On September 30, 1994 sediment samples were collected from seven stations in the DRW. Sediments were collected from seven sites in the watershed, three locations on Dog River and one each on Moore Creek, Robinson Bayou, Halls Mill Creek and Rabbit Creek (Figure 4 and Table 1). Stations were selected to be representative of overall stream conditions and not localized or isolated problems such as boat slips, dredged channels and storm drains. Station depth was between 1.5 and 2.5 meters at each site except Robinson Bayou which was only 0.75 meter deep.

Sediment cores were retrieved with a K-B type core sampler (Wildlife Supply Co., cat. no. 2402-A12) equipped with a cellulose-acetate-butyrate liner tube. Sediment for metal analyses was taken from the upper five centimeters (2 inches) of each core, placed in an acid-washed glass jar and capped with a Teflon lined lid. Samples were collected in triplicate, two samples for immediate processing and the third sample for "archiving" in a freezer for future analyses in case of widely varying results between the first two.

TABLE 1

SITE LOCATIONS FOR SEDIMENT CORES AND BENTHIC MACROINVERTEBRATE SAMPLING

STATION DESIGNATION	LOCATION
DR-1	*DOG RIVER*, 1/2 MILE DOWNSTREAM OF THE CONFLUENCE WITH HALLS MILL CREEK AND APPROX. 1/4 STREAM WIDTH OUT FROM THE EAST (LEFT) RIVER BANK.
DR-2	*DOG RIVER*, 1 MILE UPSTREAM OF THE CONFLUENCE WITH ROBINSON BAYOU AND APPROX. 1/4 STREAM WIDTH OUT FROM THE WEST (RIGHT) RIVER BANK.
DR-3	*DOG RIVER*, 1/4 MILE DOWNSTREAM OF I-10 BRIDGE CROSSING AND APPROX. 1/4 STREAM WIDTH OUT FROM THE EAST (LEFT) RIVER BANK.
RB	*ROBINSON BAYOU*, 1/4 MILE UPSTREAM OF THE MOUTH OF THE BAYOU AND AT MID-STREAM.
MC	*MOORE CREEK*, 1/2 MILE UPSTREAM OF THE MOUTH OF THE CREEK AND APPROX. 1/4 OF THE STREAM WIDTH OUT FROM THE WEST (RIGHT) CREEK BANK.
HMC	*HALLS MILL CREEK*, 1 MILE UPSTREAM OF THE MOUTH OF THE CREEK AND APPROX. 1/4 OF THE STREAM WIDTH OUT FROM THE SOUTH (RIGHT) CREEK BANK.
RC	*RABBIT CREEK*, 2 MILES UPSTREAM OF THE MOUTH OF THE CREEK AND APPROX. 1/4 OF THE STREAM WIDTH OUT FROM THE NORTH (LEFT) CREEK BANK.

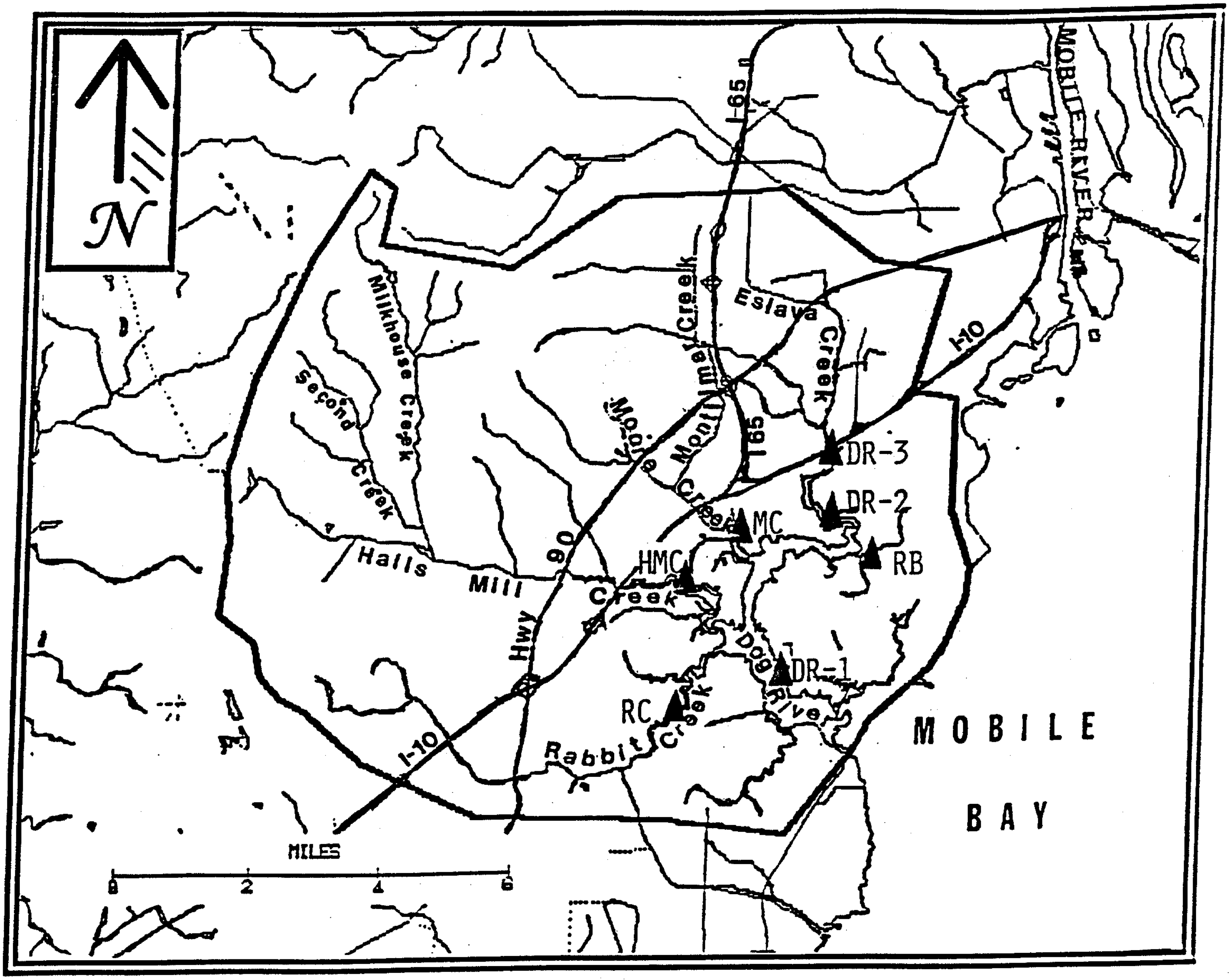

Figure 4
Locations of sites sampled for sediments and benthic infauna.

Sample analyses began with oven-drying of sediments at 60 degrees Celsius. Weighed portions (250 mg) of each sample were placed in Teflon bombs and subjected to a total digestion process in a solution of nitric acid, hydrofluoric acid and perchloric acid at 120 degrees Celsius. Analyses were performed with a Perkin-Elmer 3030-B atomic absorption spectrophotometer (AA) equipped with a flame furnace for Al, Fe and Zn and a graphite furnace for As, Ba, Cd, Cr, Cu, Pb, Ni and Sn. A Leeman Labs Model PS-200 automated mercury analyzer was utilized for Hg analyses.

The mean values of the analyses of replicate samples were utilized as data for statistical comparisons. Statistical procedures employed in this study are detailed in Sokal and Rohlf (1969) and Filliben (1975).

Results

Results of sediment metal analyses are listed in Table 2 The concentrations of eight trace metals were compared to the concentration of aluminum as described in Schropp and Windom (1988) and ADEM (1991) for determining whether sediments of the watershed were enriched with trace metals. Graphical plots of these relationships are illustrated in Figures 5a-h. Superimposed on the data plots are regression lines and 95% confidence bands for each metal/aluminum relationship as would be expected to occur in uncontaminated sediments. The basis for determining these relationships are described by Schropp and Windom (1988) and ADEM (1990).

TABLE 2

DOG RIVER WATERSHED SEDIMENTS

STATION	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sn	Zn
DR-1	43,450	8.0	224	0.37	29	21	29,350	0.18	282	8.8	34	2.3	115
DR-2	55,750	9.1	254	1.47	37	43	34,800	0.40	276	20.5	142	5.2	336
DR-3	10,950	1.5	124	0.59	13	13	6,150	0.11	73	5.0	51	2.2	94
HMC	63,150	9.0	199	0.40	31	28	37,200	0.25	117	13.0	46	3.0	138
MC	16,900	2.6	80	0.36	15	11	9,850	0.07	71	5.0	38	1.7	88
RB	52,200	9.1	220	1.12	32	58	31,050	0.32	260	20.5	114	3.6	326
RC	45,050	10.6	137	0.51	27	20	36,150	0.28	413	8.0	41	2.5	117
AVG	41,064	7.1	177	0.69	26	28	26,364	0.23	213	11.5	66	2.9	173
MAX	63,150	10.6	254	1.47	37	58	37,200	0.40	413	20.5	142	5.2	336
MIN	10,950	1.5	80	0.36	13	11	6,150	0.07	71	5.0	34	1.7	88

All values are expressed as mg/kg dry wt.
All values are the average of duplicate samples

There is no accompanying plot for the mercury data. The findings of previous sediment studies by Schropp and Windom (1988) and the Department (ADEM, 1991) have shown that a relationship between mercury concentration and aluminum apparently does not exist. This is a consequence of the scarcity of naturally occurring mercury in the Mobile Bay drainage basin (Isphording, personal communication) and the fact that natural mercury concentrations are often near the limit of analytical detection where accuracy and precision are reduced .

Aluminum concentrations in sediments of the watershed ranged from 10,950 to 63,150 parts per million (PPM) measured as milligrams per kilogram (mg/kg) of dry sediment. Sediments from Moore Creek and upper Dog River contained the lowest aluminum concentrations reflecting the coarser nature of these sediments. The finer-grained sandy-silts and clays of Robinson Bayou, Halls Mill Creek and the lower half of the Dog River contained higher concentrations of aluminum.

Concentrations of arsenic, barium, chromium and nickel at all stations fell within or below expected natural ranges, based on the metal to aluminum relationships. The sediments of Robinson Bayou and the upper half of the Dog River contained cadmium in amounts above the range to be expected in natural sediments. Sediment from all sites sampled in the watershed were found to have concentrations of copper, lead and zinc that are higher than expected for natural sediments in coastal Alabama.

Cadmium is a trace metal utilized in a variety of products, plastics, ceramics, paints, pesticides and storage batteries to name a few. It also may be present in phosphate rock used for fertilizers and is a product of the combustion of fossil fuels (Canadian Council of Resource and Environment Ministers-CCREM, 1987). The major contributors of cadmium to urban watersheds are combustion contaminants in storm runoff from streets and parking lots, and runoff of fertilizer and pesticides from landscaped property (US Environmental Protection Agency, 1991; US Fish and Wildlife Service,1991; Florida Department of Environmental Protection, 1993 and Baudau and Muntau, 1990).

Researchers in the field of sediment chemistry and toxicity have established that a concentration of 5 ppm (mg/kg) cadmium is potentially unfavorable for aquatic life and that adverse effects to aquatic life are likely to occur above 9 ppm (mg/kg) cadmium (Long and Morgan 1990). Referenced to these findings, the cadmium enrichment detected in the DRW, although conspicuous, is well below levels of concern.

Copper is widely used in wood preservatives, pesticides, soil fungicides, algaecides for controlling slime in cooling systems and anti-foulant surface coatings for boat hulls and submersed structures. Runoff containing fungicides and pesticides, and "leaching out" of wood preservatives and marine antifoulants from treated materials are the primary means by which copper enters urban watersheds (CCREM, 1987; Shutes *et al.*, 1993; US Environmental Protection Agency, 1991; US Fish and Wildlife Service,1991; Florida Department of Environmental Protection, 1993 and Baudau and Muntau, 1990).

The highest concentration of copper found in the watershed was 58 ppm (mg/kg). The recommended concentration of copper for which no adverse biological effects should be observed is 70 ppm (mg/kg) (Long and Morgan 1990). A concentration of 390 ppm (mg/kg) copper in sediments has been established as a level at which adverse biological effects are likely to occur (*ibid*). Hence the copper in sediments of the DRW, although present in elevated amounts, is not considered "toxic" to aquatic life.

Lead is commonly a constituent of paints, dyes, plastics and solder. The single largest use of lead in the US is in lead-acid storage batteries. Prior to the trend towards unleaded gasoline over the past two decades the use of tetraethyl lead in motor fuel accounted for the single largest source of lead to the environment (Baudau and Muntau, 1990; CCREM 1987). Most of the lead in our waterways is the result of exhaust deposits washed from urban areas by stormwater runoff (Baudau and Muntau, 1990; CCREM 1987; Shutes *et al.*, 1993; US Environmental Protection Agency, 1991; US Fish and Wildlife Service, 1991; VanHassel *et al.*,1980). The "phasing out" of lead in gasoline is gradually removing this source from further polluting waterways as well as the atmosphere. The use of lead as a pigment in paints and other surface coatings will continue to leach lead to aquatic environments (US Environmental Protection Agency, 1991; Baudau and Muntau, 1990).

Research has tentatively established a concentration of 35 ppm of lead in sediment as a level below which no adverse effects to aquatic life are likely to occur. Lead concentrations exceeding 110 ppm in sediments has been found to be potentially harmful to amphipods (Becker *et al.*, 1990 and Long and Morgan, 1990) brown shrimp (Vittor and Assoc., 1988), bivalves and numerous other species of aquatic animals (Chapman *et al.*, 1987 and Long and Morgan, 1990). All but one of the sites sampled in the DRW were above the lower threshold and two of these (RB and DR-2) exceeded the upper threshold with values of 114 ppm and 142 ppm respectively.

Zinc is an important constituent of anti-corrosive coatings for iron and steel products. Applications include marine paints, metal roofing and steel girder structures. Zinc is widely utilized as a biocide and anti-corrosion additive in commercial cooling systems and boilers. As was the case with copper and lead, stormwater runoff from urban areas with a high usage of these materials is the primary path by which zinc enters aquatic environments (Shutes *et al.*, 1993; US Environmental Protection Agency, 1991; US Fish and Wildlife Service, 1991; VanHassel *et al.*,1980).

Long and Morgan (1990) have established a recommended lower threshold for zinc in sediments of 120 ppm and an upper threshold, above which adverse effects are likely, of 270 ppm. Two of the sites sampled (DR-2 and RB) exceeded the upper threshold with values of 336 ppm and 326 ppm respectively. Chapman *et al.* (1991 and 1987), McLeay *et al.* (1991), Shutes *et al.* (1993) and other researchers have demonstrated that zinc concentrations such as these are potentially harmful to crustaceans (amphipods and grass shrimp) and mollusks.

The affects of urban development and non-point sources are evident from the results of the sediment survey. Conditions such as those observed in the DRW are representative of other coastal watersheds with a high degree of urbanization (Long and Morgan 1990; Delfino *et al.* 1991; US Environmental Protection Agency 1991; US Fish and Wildlife Service 1991; Florida Department of Environmental Protection 1993).

Considering the lack of heavy industrial facilities in the DRW and the high degree of urban development with large areas of impervious cover, landscaped property maintained with intensive use of chemicals, high density of motor vehicular traffic and power boating activity, it appears that the sediment contamination observed in the watershed is largely attributable to storm water runoff flushing contaminants to streams of the basin. These contaminants are derived from exhaust soot and residue from paved surfaces, fungicides, insecticides and other biocidal preparations, fertilizers and wood preservatives. Lesser but still significant inputs of metallic contaminants are ascribable to wood preservatives leaching from piling and bulkheads and the anti fouling/anti corrosive components of marine paints (Shutes et al. 1993; US Environmental Protection Agency 1991; Delfino *et al.* 1991; Baudau and Muntau 1990; National Oceanic and Atmospheric Administration 1989; National Research Council 1990; Windom et al. 1989; VanHassel *et al.*,1980).

Due to the expected development in the basin these conditions are likely to persist and possibly could become more outstanding in the future.

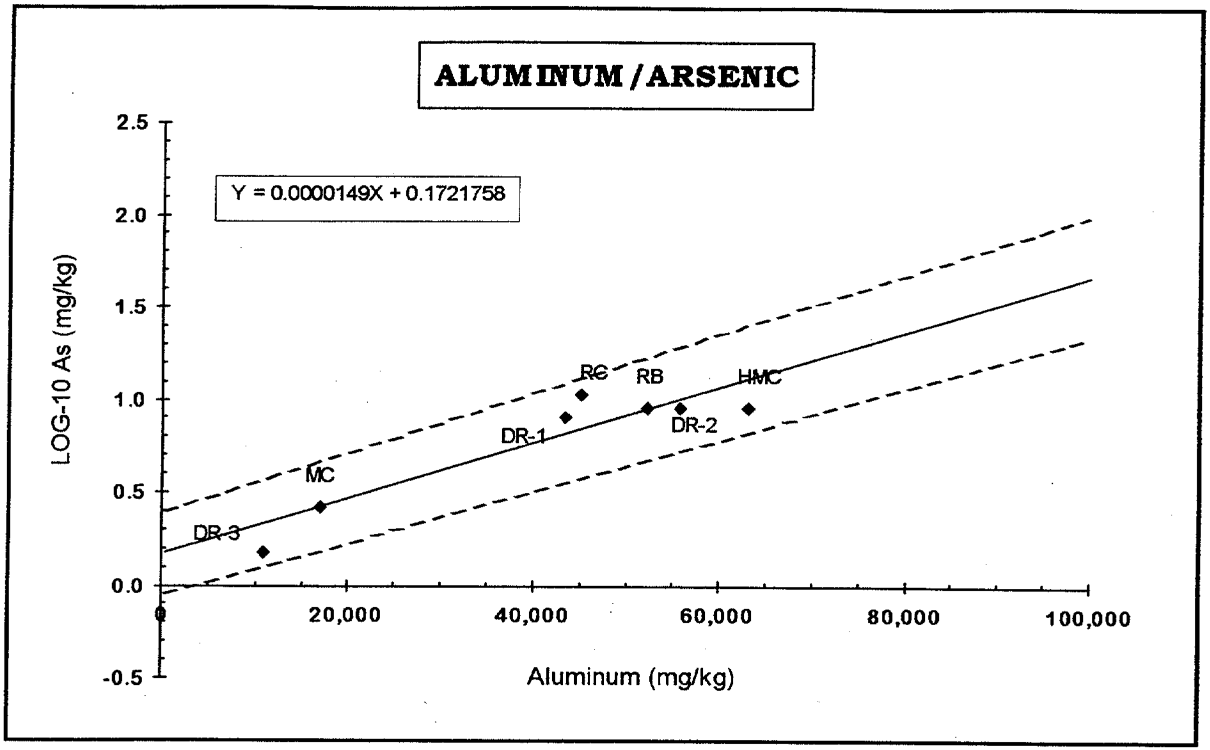

Figure 5a Arsenic

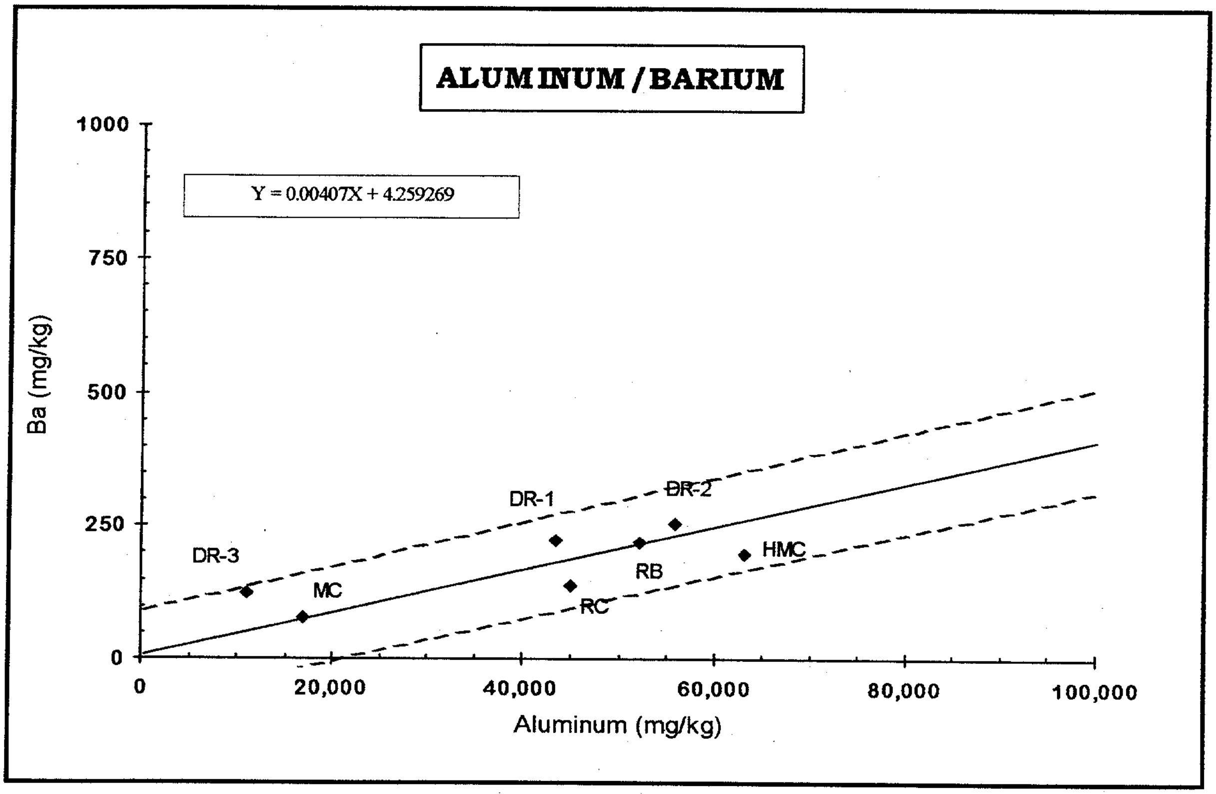

Figure 5b Barium

Sediment Metals Plots for the Dog River Watershed

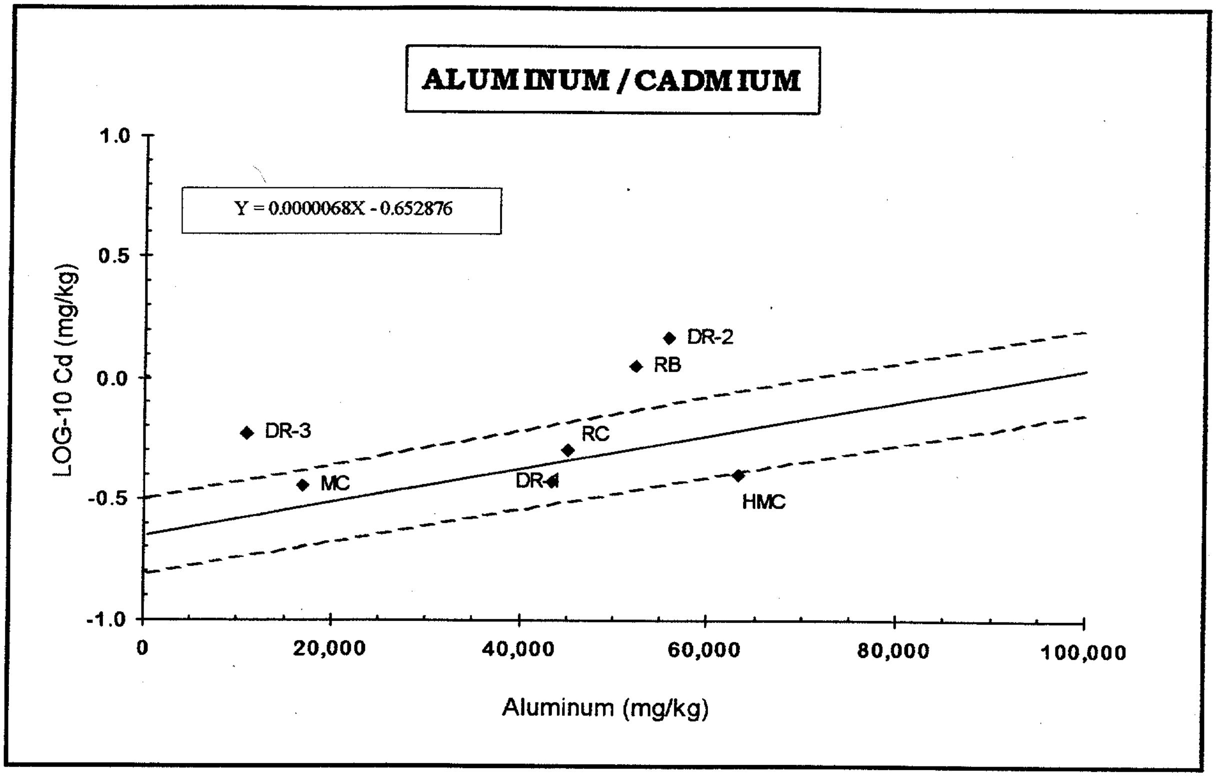

Figure 5c Cadmium

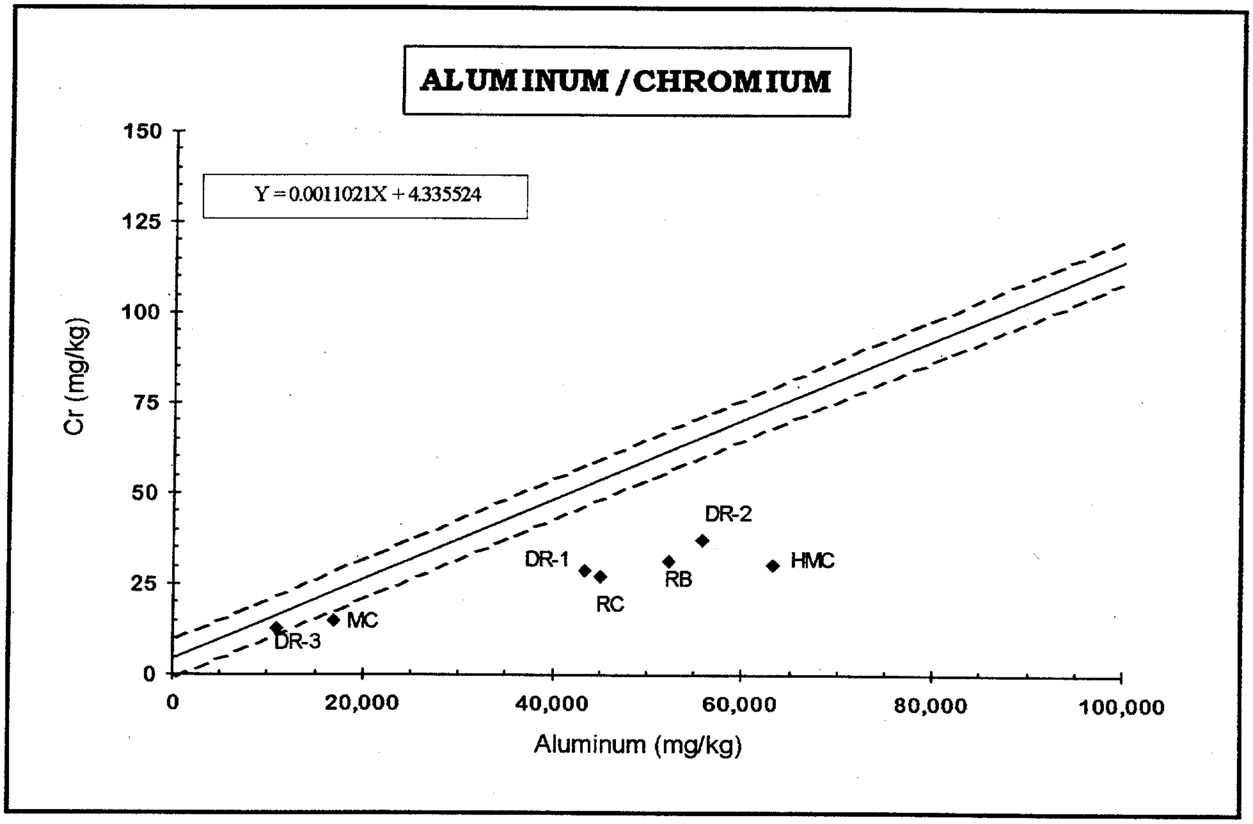

Figure 5d Chromium

Sediment Metals Plots for the Dog River Watershed

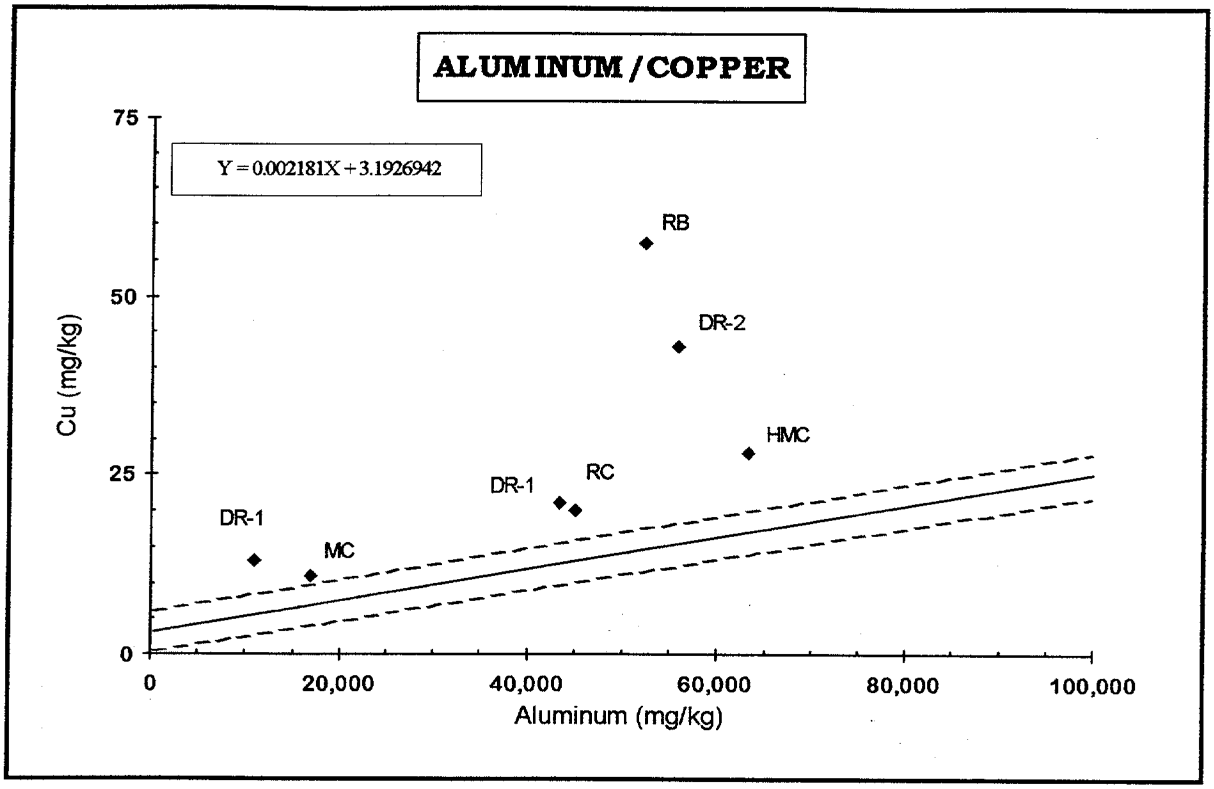

Figure 5e Copper

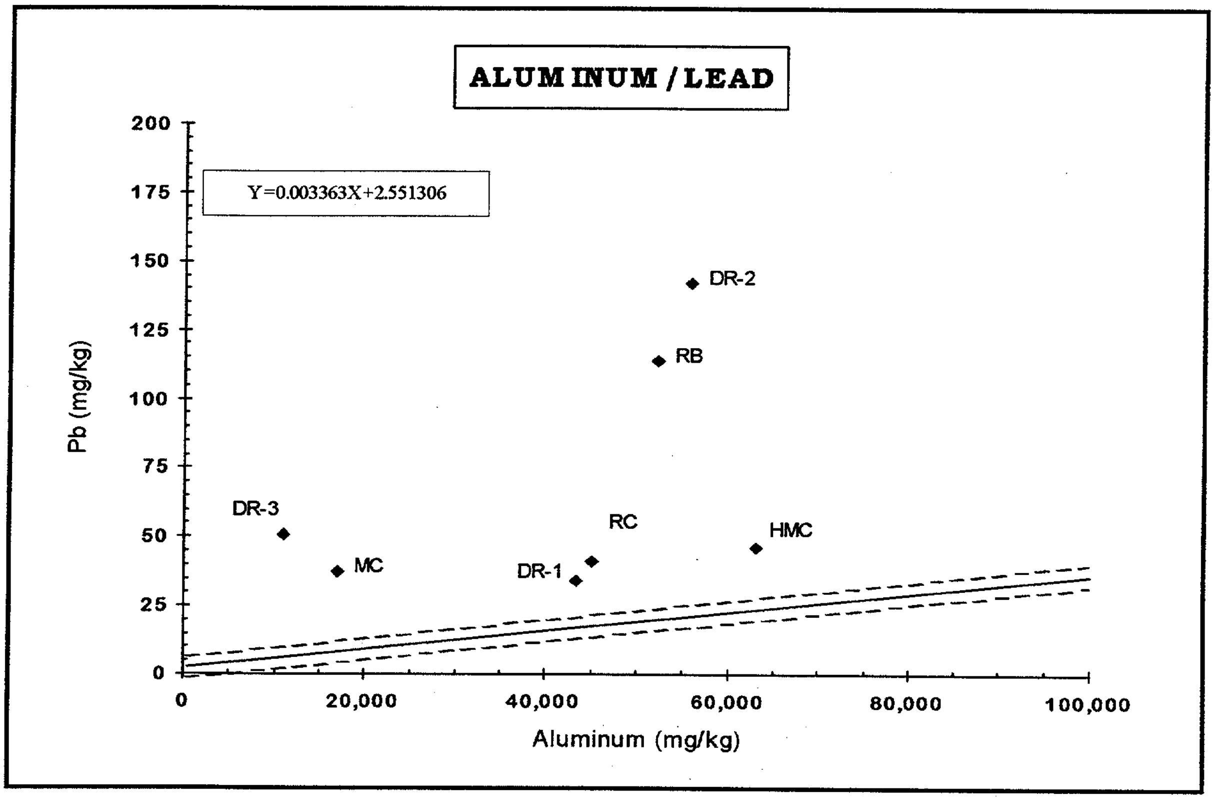

Figure 5f Lead

Sediment Metals Plots for the Dog River Watershed

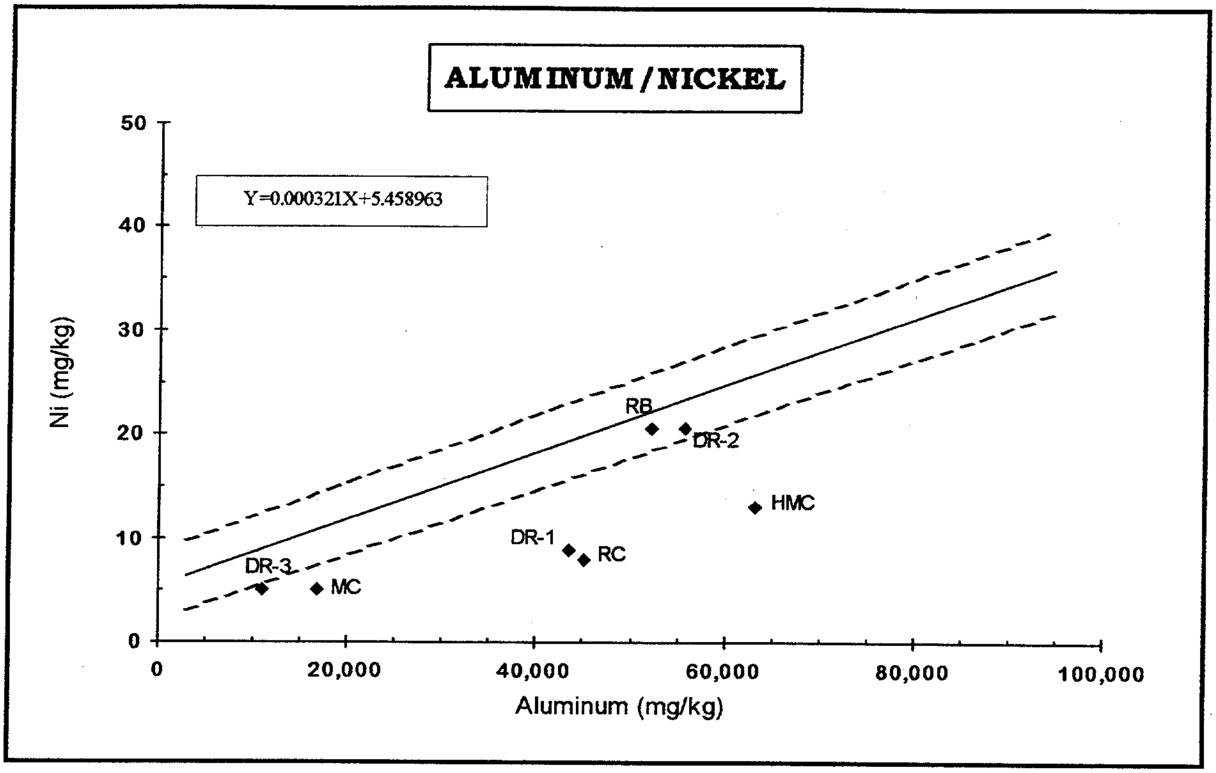

Figure 5g Nickel

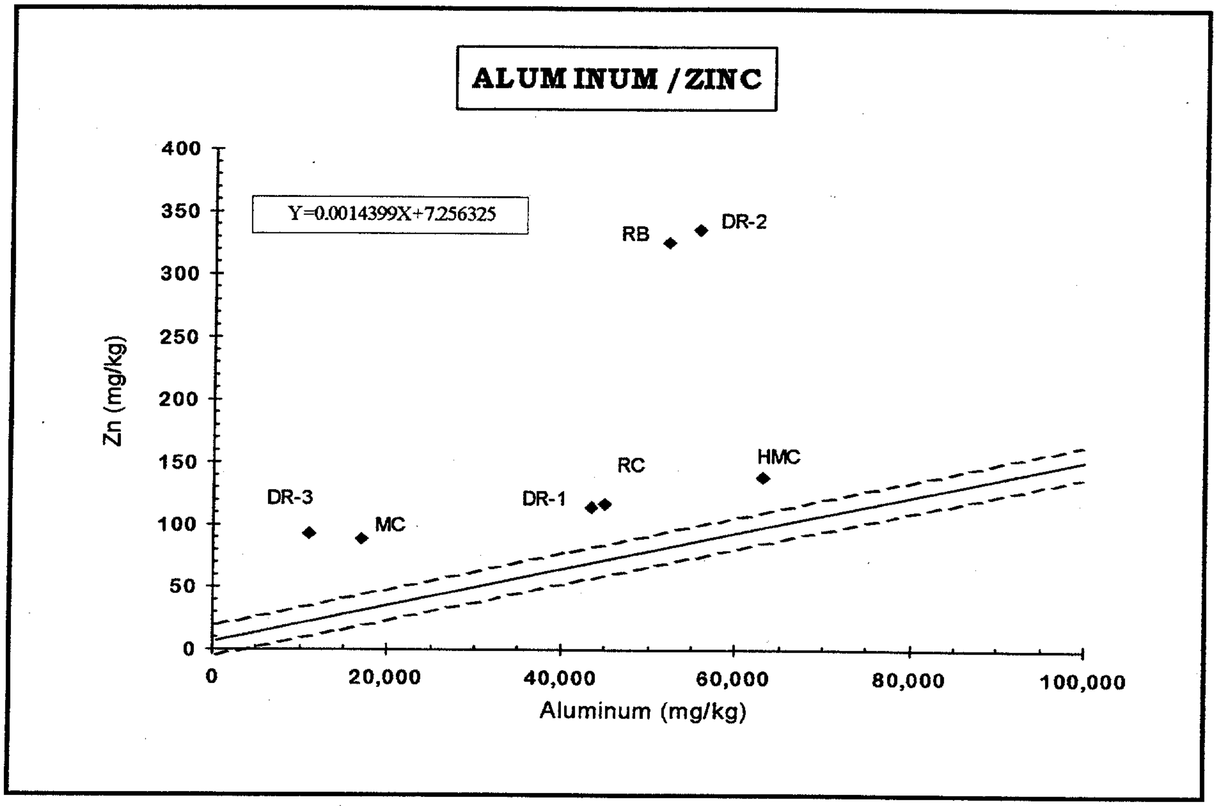

Figure 5h Zinc

Sediment Metals Plots for the Dog River Watershed

Benthic Biology

Introduction

Plant and animals inhabiting streambeds, living on bay bottoms and in the ocean depths are referred to as benthic organisms. The word benthic originates from the Greek word *bathys,* meaning deep. The collection of plants and animals living on and in the bottom of a body of water is referred to as a benthic community.

The structure of a benthic community in estuarine waters is governed by numerous factors including dissolved oxygen, salinity, nutrient concentrations, siltation and sediment characteristics. The study of benthic communities has become a valuable component of monitoring strategies providing information above and beyond that which is obtained through projects focusing only on physical and chemical parameters (Hart and Fuller eds., 1974; Hynes, 1971 and 1972; Mason et al., 1971; Mackenthun, 1969; Pennack, 1989; Pratt and Coler, 1976 and Wilhm, 1972). Information about the benthic community of a watershed combined with knowledge of the watershed's geology, hydrology, water quality and land-use practices permits the development of more effective management plans affording a greater degree of resource protection.

For monitoring the affects of urban development and runoff in the DRW it was decided to concentrate resources on surveying the benthic macroinvertebrate community. Benthic macroinvertebrates in tidally influenced watersheds are typified by crustaceans (crabs, shrimp and amphipods), mollusks (clams and snails) and polychaetes (sandworms and clamworms). Benthic macroinvertebrates commonly respond to specific degradation in water quality and bottom habitats; therefore, they are good "indicators" of environmental quality (Hynes, 1971 and 1972; Wilhm and Dorris, 1968).

Objective

The objective of the benthic biology program was to characterize the benthic macroinvertebrate community of the DRW relative to stream segments and tributaries, and evaluate the water quality and sediment chemistry for chemical and physical factors influencing the distribution of species and diversity of the community. More specifically the program sought to quantify abundance of individuals and species; determine diversity and evenness at different sites in the basin and compare biological data with water quality data, sediment chemistry data and land-use practices for possible associations between dissolved oxygen, nutrients, siltation and enriched concentrations of metals.

Considering the broad nature of the watershed study it was the intention of the survey team to demonstrate benthic biology as a watershed assessment tool and not to conduct an in-depth study of the taxonomy of the basin. Therefore it was decided to limit the benthic biology program to one set of samples to be gathered in a brief period of time (preferably one day) during moderate flow. Additional detail about the aquatic biology of the DRW (i.e. submersed grassbeds, marshland acreage, fish stocks etc.) are far beyond the scope of this study and will have to be provided through a comprehensive biological survey accounting for seasonal and other factors.

Materials and Methods

Six sites were visited on February 23,1995 for collecting benthic invertebrate specimens (Figure 4). These locations are the same as those sampled for sediment metals with one exception, Robinson Bayou was not sampled because its shallow depth (<1meter) would not permit entry by a vessel equipped with a bottom dredge.

Sites of similar stream morphology, depth and bottom habitat were selected so as minimize natural variability as much as was practical. Station depths were between 1.5 and 2.5 meters and sediments primarily were silty sands with leaf and plant debris. The bottom of Moore Creek was noticeably more sandy (i.e., coarser grained) and the sediments of Halls Mill Creek were more muddy (i.e., more clay fines) than the other stations.

At each station three replicate benthic samples were taken with a 0.05 m^2 stainless steel Ponar grab for a total area sampled of 0.15 m^2 at each station. The contents of each sample were washed through a 0.5 mm sieve (US #35 mesh) and all material, debris and organisms, retained on the sieve was preserved in a 10% formaldehyde stained with rose bengal.

Each replicate was sieved a second time in the lab to further clean the sample of sediment. The washed samples were then placed in a white enamel pan and the organisms picked from debris using needle-nose forceps and lighted magnifiers. Organisms were then placed in labeled capped vials containing 95% ethanol for temporary storage until they were identified.

Specimens were sorted and identified to the lowest possible identification level (LPIL) using optical light microscopes. Identified and counted specimens were preserved in 95% ethanol in vials labeled with the taxonomic name of the organism, location of sample site and date collected. The following references were consulted when identifying macroinvertebrate specimens: Abele and Kim (1986); Brigham, Brigham and Gnilka (1982); Fauchald (1977); Heard (1982); Holsinger (1976); Pennack (1989); Stimpson, Klemm and Hiltunen (1982); Hopkins, Valentine and Lutz (1989); Simpson and Bode (1980); Uebelacker and Johnson (1984); Williams, A. (1984) and Williams, W. (1976).

Names and abundances of species collected were entered into Microsoft Excel™ spreadsheets for calculation of population statistics. Population statistics employed for the benthic biology survey included the indices of community diversity, species evenness and species richness.

These population statistics provide numerical indices which, in conjunction with information on the types and numbers of species collected and water quality data, allow for determination of the health of aquatic environments (Shannon and Weaver, 1963; Lloyd, *et al.*, 1968; Margelef, 1958 and 1968; Pielou, 1975; Wilhm and Dorris, 1968).

Community diversity was calculated using the Shannon-Wiener information measure or the Shannon index of general diversity (H') (Shannon and Weaver, 1963; Margelef, 1968 and Pielou, 1975). The Shannon index was utilized because it incorporates both richness and evenness. The index is calculated by the equation:

$$H' = -\Sigma p_i \log p_i$$

H' = the symbol for diversity in a community

p_i = the proportion of the community made up by a particular species (*i*)

log p_i = the logarithm of p_i; it may be base 2, *e* or 10, in this study base 2 is utilized.

Species evenness was determined by Pielou's evenness index (J') (Pielou, 1966) as calculated from:

$$J' = H'/\log s$$

where s = the number of species per site

H' = the Shannon-Wiener index.

Margelef's richness index (d) (Margelef 1958) was utilized as another measure of health of the benthic community. This is determined by the formula:

$$d = s\text{-}1/\log N$$

where s = the number of species

N = the number of individuals per site.

Results

A total of 35 species representing 11 taxonomic classes were collected from the six stations. The most abundant organisms were oligochaetes (Family Tubificidae), polychaetes (Families Spionidae and Ampheretidae), larval midge flies (Family Chironomidae) and amphipod crustaceans (Family Gammaridae). A summary of benthic community statistics is listed in Table 3. Graphical illustrations of abundances and diversity are shown in Figures 6a-6c. A complete listing of species collected may be found in Table 4 and site specific information may be found in Tables 5a-5f.

The sites in Rabbit Creek (station RC) and lower Dog River (station DR-1) contained the most number of species (18) whereas Moore Creek (station MC) contained the fewest (4).

TABLE 3

SUMMARY STATISTICS FOR BENTHIC MACROINVERTEBRATE COMMUNITIES DOG RIVER WATERSHED

STATION	NUMBER OF SPECIMENS COLLECTED	NUMBER OF SPECIES COLLECTED	DENSITY PER SQUARE METER	SHANNON-WEINER DIVERSITY INDEX	MARGELEF'S RICHNESS INDEX	PIELOU'S EVENNESS INDEX
DR-1	489	18	3,262	2.41	6.32	0.58
DR-2	244	17	1,627	2.53	6.70	0.62
DR-3	775	14	5,169	0.96	4.50	0.25
HMC	15	6	100	1.87	4.25	0.72
MC	589	4	3,929	0.33	1.08	0.17
RC	399	18	2,661	2.79	6.54	0.67

The benthic communities found in Rabbit Creek (RC) and the lower Dog River (stations DR-1 and DR-2) were typical of tidally influenced soft-bottom streams. These sites possessed a fairly good assortment of polychaete worms, aquatic insects and amphipods normally expected to occur in such habitats. These species are, out of necessity, tolerant of a variable environment affected by tidal flucuations, changeable salinity, low DO concentration and other stressful forces of nature (Hudson et al., 1990; Hynes, 1971; Dauer, 1984; Pennack, 1989 and Uebelacker and Johnson, 1984).

However, the low number of mollusks (clams and snails) at these sites is worth note. These animals are sensitive to low concentrations of DO (Pennack, 1989) and elevated concentrations of heavy metals, in particular copper and zinc (Becker et al., 1990; Chapman, 1987 and Long & Morgan, 1990). Waters with a tendency to stratify and become hypoxic are likely to have few mollusks in the benthic community; this stress is only exacerbated by the presence of high concentrations of heavy metals in sediments.

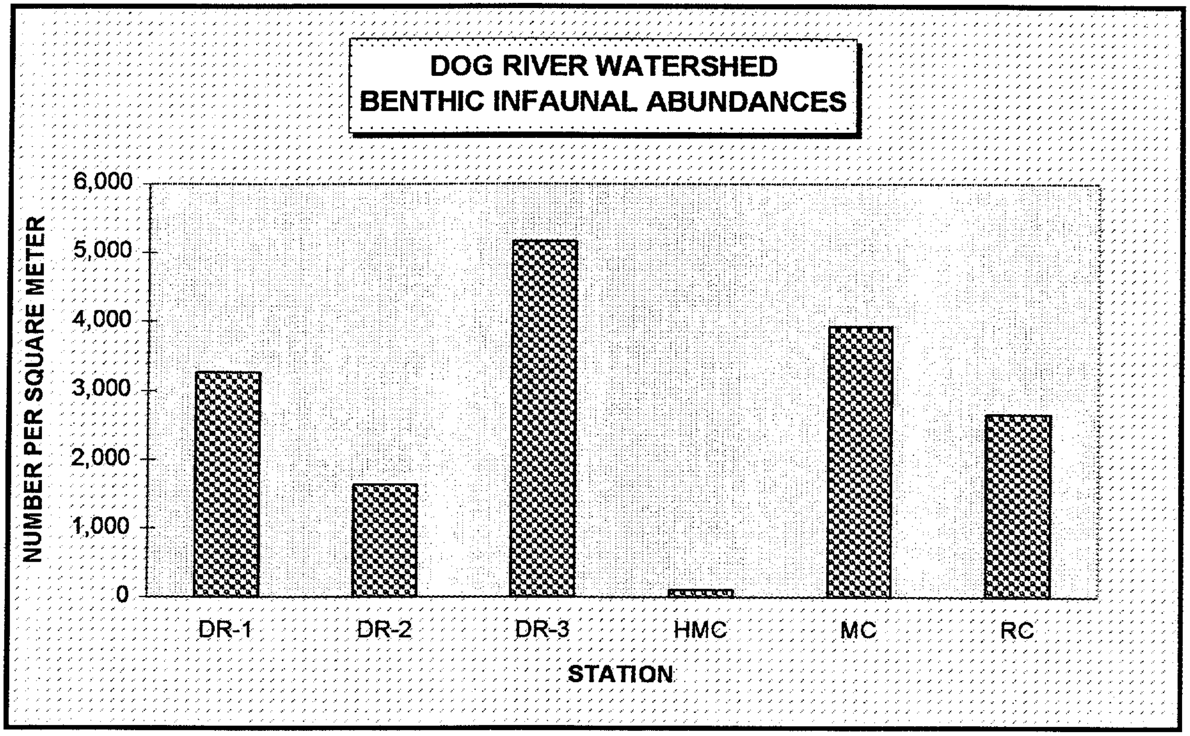

Figure 6a

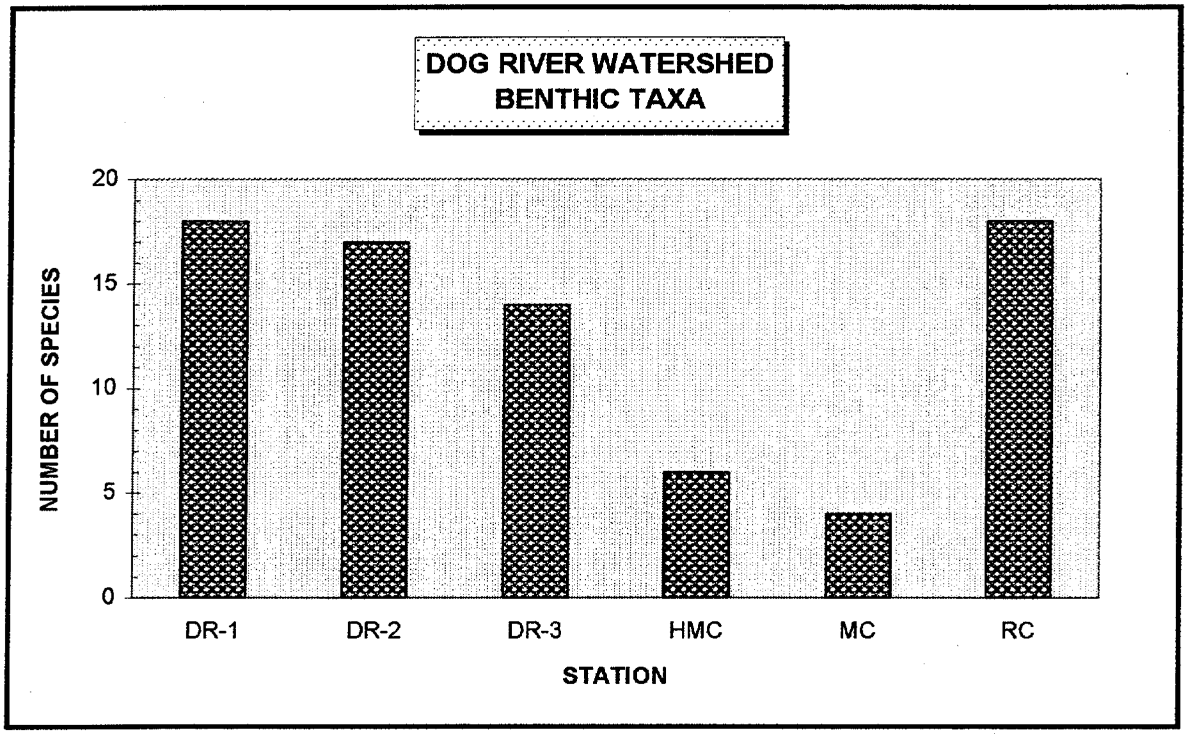

Figure 6b

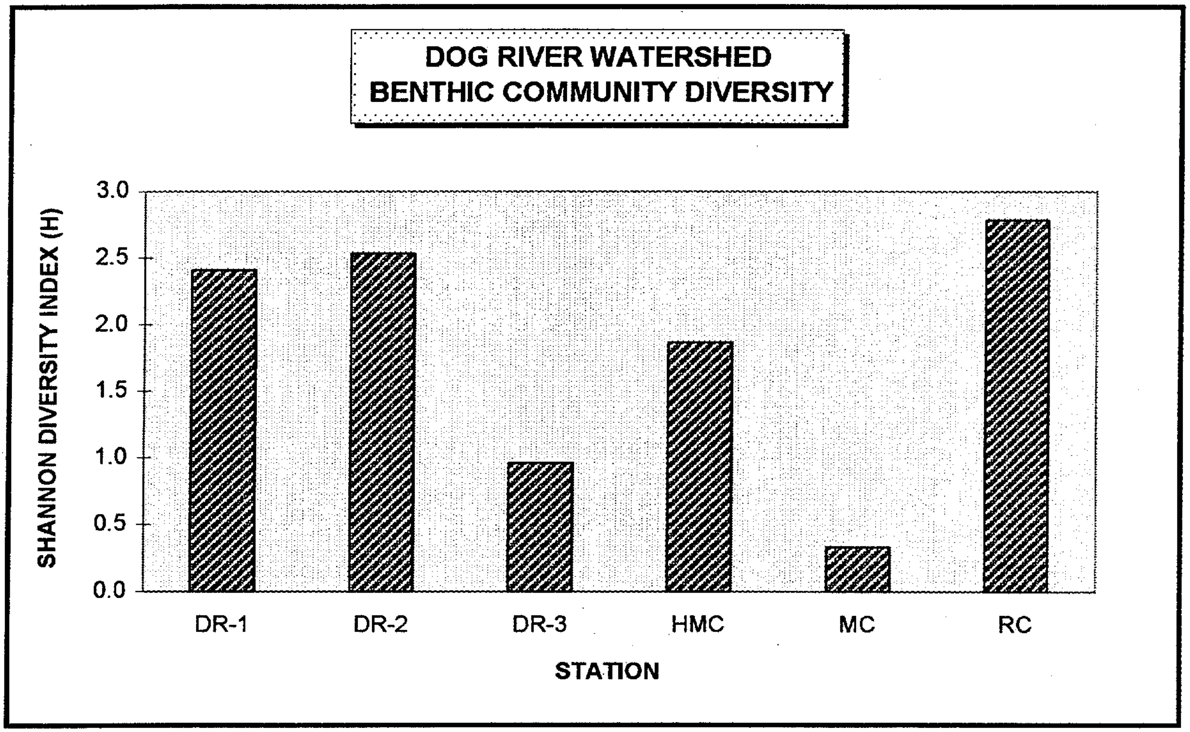

Figure 6c

Shannon-Wiener diversity index values were 2.79 for station RC, 2.41 for station DR-1 and 2.53 for station DR-2. Previous studies of the benthic communities of coastal Alabama (ADEM-FDER, 1991; Marine Environmental Corsortium, 1981 and US Army Corps of Engineers, 1978) indicate that these values are representative of the area's shallow, soft-bottom tidal streams. The values of the other diversity measures (Margelef's richness and Pielou's evenness) also are in line with the findings of those studies.

Considering the natural variability of tidally influenced streams in conjunction with characteristics and abundances of the species collected, the benthic communities of Rabbit Creek and the lower Dog River appear to be fairly representative of gulf coast small streams.

As previously stated, inhabitats of these waters are frequently exposed to various stressful forces of nature. For local estuaries these stresses take the form of highly variable salinity and low DO concentration. Nonetheless, urban development and other anthropogenic activities exert additional stresses on waterbodies and their inhabitants. The effects of these disturbances often are expressed in the species and number of individuals present in the sediments of these waters.

The benthic invertebrate data for the sites on Halls Mill Creek (station HMC), Moore Creek (station MC) and upper Dog River/lower Eslava Creek (DR-3) illustrate this situation. The communities at these sites show the effects of erosion, urban runoff and other factors related to development.

The extremely low number of individuals (only 15 specimens) from the Halls Mill Creek site is considered by aquatic biologists to be an indication of a disturbance, such as siltation, with broad effects to the entire infaunal community (Hynes, 1971 and Pennack, 1989). The Moore Creek and upper Dog River sites possessed good numbers of individuals (589 and 775 respectively) but over 90% of the specimens were oligochaetes, primarily tubificids.

Oligochaetes are among the most pollution tolerant organisms inhabiting aquatic environments. They are exceptionally adept at surviving prolonged periods of extremely low DO, organic enrichment and high concentrations of heavy metals. Their abundance, coinciding with a near absence of other taxonomic groups, is a reliable indicator of polluted waters (Chapman et al., 1979; Hynes, 1971 and 1972; Hart and Fuller, 1974; Stimpson, Klemm and Hiltunen 1982; and Pennack, 1989).

Additional evidence of the damage done to the aquatic habitats of Halls Mill Creek, Moore Creek and upper Dog River/lower Eslava Creek is presented by the numerical indices. Values of the Shannon diversity index less than 1 for local benthic communities indicate the presence of stress above and beyond that normally expected. The diversity values for the Moore Creek site (H'=0.33) and the upper Dog River/lower Eslava Creek site (H'=0.96) are exceptionally low compared to values from studies of other local streams and estuaries (ADEM-FDER, 1991; Marine Environmental Corsortium, 1981; Geological Survey of Alabama, 1983).

These findings together with the data on sediment chemistry and water quality show that Moore Creek, Halls Mill Creek and the upper section of Dog River have been severely affected by land development and other anthropogenic activities. Rabbit Creek and the middle and lower reaches of Dog River possess fairly diverse and productive habitats but these appear to show some signs of the factors affecting the other sites. The more pronounced effects observed in Moore Creek, Halls Mills Creek and at the upper Dog River station are probably a consequence of their closer proximity to developmental activities.

TABLE 4

LIST OF BENTHIC INVERTEBRATE SPECIES COLLECTED FROM THE DOG RIVER WATERSHED

PORIFERA(LPIL)

HYDROZOA
- **Hydridae**
  - *Hydra americana*

NEMERTEA (LPIL)

NEMATODA (LPIL

OLIGOCHAETA
- **Tubificidae**
  - *Ilyodrilus templetoni*
  - *Limnodrilus claparedianus*
  - *Limnodrilus cervix*
  - *Spirosperma ferox*
  - *Branchiura sowerby*

POLYCHAETA
- **Amphaeretidae**
  - *Amphectis gunneri*
  - *Hobsonia florida*
- **Nereidae**
  - *Laeonereis culveri*
  - *Neanthes micromma*
- **Capitellidae**
  - *Mediomastus ambeseta*
- **Spionidae**
  - *Streblospio benedicti*
  - *Polydora cornuta*
- **Pilargidae**
  - *Parandalia americana*

HIRUDINEA
- **Glossiphoniidae**
  - *Placobdella ornata*

INSECTA
- Diptera
  - **Chironomidae**
    - *Coelotanypus scapularis*
    - *Chironomus stageri*
    - *Clinotanypus pinguis*
    - *Cryptochironomus fulvus*
    - *Glyptotendipes meridionalis*
    - *Procladius bellus*
    - *Dicrotendipes neomodestus*
  - **Ceratopogonidae**
    - *Bezzia/Probezzia sp*

TABLE 4 cont.

- INSECTA
  - Ephemeroptera
    - Caenidae
      - *Caenis diminuta*
    - Baetidae
      - *Baetis (LPIL)*
- AMPHIPODA
  - Corophidae
    - *Corophium louisianum*
  - Aoridae
    - *Grandierellia bonnieroides*
  - Gammaridae
    - *Gammarus mucronatus*
- MYSIDACEA
  - Mysidae
    - *Bowmanella floridana*
- PELECYPODA
  - Mactridae
    - *Rangia cuneata*
    - *Mulinia ponchartrainensis*
  - Tellinidae (LPIL)

TABLE 5A

DOG RIVER WATERSHED BENTHIC INFAUNAL DATA - RABBIT CREEK STATION

PHYLUM	CLASS	FAMILY	SPECIES - TAXON(LPIL)	NUMBER
COELENTERATA	HYDROZOA	HYDRIDAE	*Hydra americana*	2
NEMATODA			NEMATODA (LPIL)	1
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Ilyodrilus templetoni*	30
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Limnodrilus claparedianus*	68
ANNELIDA	POLYCHAETEA	AMPHARETIDAE	*Hobsonia florida*	108
ANNELIDA	POLYCHAETEA	NEREIDAE	*Neanthes micromma*	2
ANNELIDA	POLYCHAETEA	SPIONIDAE	*Streblospio benedicti*	1
ANNELIDA	POLYCHAETEA	SPIONIDAE	*Polydora cornuta*	1
ARTHROPODA	INSECTA	CAENIDAE	*Caenis diminuta*	1
ARTHROPODA	INSECTA	CERATOPOGONIDAE	*Bezzia/Probezzia sp*	1
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Procladius bellus*	10
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Dicrotendipes neomodestus*	6
ARTHROPODA	CRUSTACEA (AMPHIPODA)	COROPHIIDAE	*Corophium louisianum*	34
ARTHROPODA	CRUSTACEA (AMPHIPODA)	AORIDAE	*Grandierellia bonnieroides*	101
ARTHROPODA	CRUSTACEA (AMPHIPODA)	GAMMARIDAE	*Gammarus mucronatus*	30
ARTHROPODA	CRUSTACEA (MYSIDACEA)	MYSIDAE	*Bowmanella floridana*	1
MOLLUSCA	PELYCEPODA	MACTRIDAE	*Rangia cuneata*	1
MOLLUSCA	PELYCEPODA	MACTRIDAE	*Mulinia ponchartrainensis*	1
			NUMBER OF INDIVIDUALS	399
			DENSITY PER SQUARE METER	2661
			NUMBER OF SPECIES	18
			SHANNON-WEINER INDEX	2.79
			MARGELEF'S RICHNESS INDEX	6.54
			PIELOU'S EVENNESS INDEX	0.67

TABLE 5B

DOG RIVER WATERSHED BENTHIC INFAUNAL DATA - HALLS MILL CREEK STATION

PHYLUM	CLASS	FAMILY	SPECIES - TAXON(LPIL)	NUMBER
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Limnodrilus cervix*	9
ANNELIDA	POLYCHAETA	AMPHARETIDAE	*Hobsonia florida*	1
ANNELIDA	POLYCHAETA	AMPHARETIDAE	*Amphectis gunneri*	1
ANNELIDA	POLYCHAETA	SPIONIDAE	*Streblospio benedicti*	2
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Chironomus stageri*	1
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Procladius bellus*	1
			NUMBER OF INDIVIDUALS	15
			DENSITY PER SQUARE METER	100
			NUMBER OF SPECIES	6
			SHANNON-WEINER INDEX	1.87
			MARGELEF'S RICHNESS INDEX	4.25
			PIELOU'S EVENNESS INDEX	0.72

TABLE 5C

DOG RIVER WATERSHED BENTHIC INFAUNAL DATA - STATION DR-1

PHYLUM	CLASS	FAMILY	SPECIES - TAXON(LPIL)	NUMBER
PORIFERA			PORIFERA(LPIL)	2
NEMERTEA			NEMERTEA(LPIL)	5
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	TUBIFICIDAE (LPIL)-IMMATURE	13
ANNELIDA	POLYCHAETA	AMPHARETIDAE	*Hobsonia florida*	192
ANNELIDA	POLYCHAETA	CAPITELLIDAE	*Mediomastus ambeseta*	127
ANNELIDA	POLYCHAETA	PILARGIDAE	*Parandalia americana*	1
ANNELIDA	POLYCHAETA	SPIONIDAE	*Streblospio benedicti*	94
ARTHROPODA	CRUSTACEA (AMPHIPODA)	AORIDAE	*Grandidierella bonnieroides*	21
ARTHROPODA	CRUSTACEA (AMPHIPODA)	COROPHIIDAE	*Corophium louisianum*	5
ARTHROPODA	CRUSTACEA (AMPHIPODA)	GAMMARIDAE	*Gammarus mucronatus*	1
ARTHROPODA	CRUSTACEA (MYSIDACEA)	MYSIDAE	*Bowmanella floridana*	1
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Chironomus stageri*	7
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Procladius bellus*	9
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Dichrotendipes neomodestus*	4
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Clinotanypus pinguis*	4
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Cryptochironomus fulvus*	1
MOLLUSCA	PELECYPODA	MACTRIDAE	*Rangia cuneata*	1
MOLLUSCA	PELECYPODA	MACTRIDAE	*Mulinia ponchartrainensis*	1
			NUMBER OF INDIVIDUALS	489
			DENSITY PER SQUARE METER	3262
			NUMBER OF SPECIES	18
			SHANNON-WEINER INDEX	2.41
			MARGELEF'S RICHNESS INDEX	6.32
			PIELOU'S EVENNESS INDEX	0.58

TABLE 5D

DOG RIVER WATERSHED BENTHIC INFAUNAL DATA - MOORE CREEK STATION

PHYLUM	CLASS	FAMILY	SPECIES - TAXON(LPIL)	NUMBER
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Limnodrilus claparedianus*	556
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Branchiura sowerby*	1
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Ilyodrilus templetoni*	31
ANNELIDA	POLYCHAETA	AMPHARETIDAE	*Hobsonia florida*	1
			NUMBER OF INDIVIDUALS	589
			DENSITY PER SQUARE METER	3929
			NUMBER OF SPECIES	4
			SHANNON-WEINER INDEX	0.33
			MARGELEF'S RICHNESS INDEX	1.08
			PIELOU'S EVENNESS INDEX	0.17

TABLE 5E

DOG RIVER WATERSHED BENTHIC INFAUNAL DATA - STATION DR-2

PHYLUM	CLASS	FAMILY	SPECIES - TAXON(LPIL)	NUMBER
NEMATODA			NEMATODA (LPIL)	1
NEMERTEA			NEMERTEA (LPIL)	3
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Ilyodrilus templetoni*	3
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Limnodrilus claparedianus*	10
ANNELIDA	POLYCHAETA	AMPHARETIDAE	*Hobsonia florida*	118
ANNELIDA	POLYCHAETA	NEREIDAE	*Laeonereis culveri*	1
ANNELIDA	POLYCHAETA	CAPITELLIDAE	*Mediomastus ambeseta*	36
ANNELIDA	POLYCHAETA	SPIONIDAE	*Streblospio benedicti*	19
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Chironomus stageri*	16
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Procladius bellus*	3
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Clinotanypus pinguis*	2
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Cryptochironomus fulvus*	1
ARTHROPODA	INSECTA	BAETIDAE	*Baetis (LPIL)*	1
ARTHROPODA	CRUSTACEA (AMPHIPODA)	AORIDAE	*Grandidierella bonnieroides*	26
ARTHROPODA	CRUSTACEA (AMPHIPODA)	COROPHIIDAE	*Corophium louisianum*	2
ARTHROPODA	CRUSTACEA (MYSIDACEA)	MYSIDAE	*Bowmanella floridana*	1
MOLLUSCA	PELECYPODA	TELLINIDAE	TELLINIDAE (LPIL)	1
			NUMBER OF INDIVIDUALS	244
			DENSITY PER SQUARE METER	1627
			NUMBER OF SPECIES	17
			SHANNON-WEINER INDEX	2.53
			MARGELEF'S RICHNESS INDEX	6.70
			PIELOU'S EVENNESS INDEX	0.62

TABLE 5F

DOG RIVER WATERSHED BENTHIC INFAUNAL DATA - STATION DR-3

PHYLUM	CLASS	FAMILY	SPECIES - TAXON(LPIL)	NUMBER
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Branchiura sowerby*	1
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Ilyodrilus templetoni*	79
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Spirosperma ferox*	2
ANNELIDA	OLIGOCHAETA	TUBIFICIDAE	*Limnodrilus claparedianus*	649
ANNELIDA	HIRUDINEA	GLOSSIPHONIIDAE	*Placobdella ornata*	2
ANNELIDA	POLYCHAETA	AMPHARETIDAE	*Hobsonia florida*	5
ANNELIDA	POLYCHAETA	NEREIDAE	*Laeonereis culveri*	2
ARTHROPODA	CRUSTACEA (MYSIDACEA)	MYSIDAE	*Bowmanella floridana*	2
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Procladius bellus*	21
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Coelotanypus scapularis*	2
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Cryptochironomus fulvus*	5
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Clinotanypus pinguis*	3
ARTHROPODA	INSECTA	CHIRONOMIDAE	*Glyptotendipes meridionalis*	1
MOLLUSCA	PELECYPODA	MACTRIDAE	*Rangia cuneata*	1
			NUMBER OF INDIVIDUALS	775
			DENSITY PER SQUARE METER	5169
			NUMBER OF SPECIES	14
			SHANNON-WEINER INDEX	0.96
			MARGELEF'S RICHNESS INDEX	4.50
			PIELOU'S EVENNESS INDEX	0.25

Review and Conclusions

The impacts of land use patterns and their related non-point sources on the waters of the DRW are clearly evident from the results of this survey. Dog River and its tributaries receive minimal amounts of wastewater from point sources; however, turbidity values, nutrient concentrations, enteric bacteria densities and metallic enrichment of sediments were observed to be as greatly elevated, if not more, as these parameters are in streams receiving significant discharges of effluent from municipal and/or industrial facilities.

The specific impacts affecting a given tributary of the DRW appear to be highly characteristic of the land use within the individual sub-basin. Such associations of land use and impacts on water quality and sediment chemistry have been observed during similar studies of the impacts of non-point sources on watersheds (National Oceanic and Atmospheric Administration 1989; National Research Council 1990; U.S. Environmental Protection Agency 1991).

The land-use practices which appear to most significantly affect the basin are locating developments on soils with poor drainage characteristics, draining and filling of wetlands, channelization of streams, streets and parking lots not kept clean of trash and other debris, residences with septic tanks located in low lying areas near streams, poor erosion control practices during construction activities, lawn and golf course maintenance and in general, increasingly large areas of impervious cover forcing greater volumes of storm water runoff into heavily loaded drainage courses. Additionally, there appears to be a source of enteric bacteria (either undiscovered sewer line breaks or sanitary line ties to storm sewers) for the streams draining urbanized areas.

The findings of this survey will be put to use with the recently implemented NPDES General Permit program for controlling stormwater runoff at construction sites and also the Mobile Standard Metropolitan Statistical Area stormwater permit. The permit requirements for controlling runoff and erosion with construction site BMP's should, if properly maintained, provide a significant reduction in the suspended solids loads and turbidity of area streams. This will in turn provide a chance for aquatic habitats and communities to reestablish in the watershed.

The Mobile Area Water and Sewer Service has increased its inspection and maintenance of sanitary lines operated by MAWSS. The task facing the MAWSS is a formidable one since the routes of many sewer lines in the older neighborhoods of Mobile are incompletely known. This situation is further complicated from numerous tie-ins of sanitary lines to storm sewers in the downtown area. There also is the problem of improper installation and connection practices of sewers in some subdivisions and private developments. Not only do these defective systems contribute to the degradation of surface waters but repair and replacement of faulty components consumes resources of the MAWSS which might be devoted to other operations. At the time this report was in preparation the MAWSS had made considerable progress locating problems and taking corrective measures to eliminate discharges of untreated sewage to local waters.

The problems observed with excessive concentrations of metallic elements in sediments will, hopefully, diminish as requirements for control of urban stormwater runoff and industrial facility runoff go into effect. Additional decreases of these pollutants also should be realized through the elimination of lead from gasoline and paint, the prohibition of organo-tin compounds in marine paints and other controls placed on the use of toxic substances in paints and wood treatments.

Lastly, the trash and litter problem (primarily plastics) that is so pervasive along Eslava Creek and Dog River will be solved only through the efforts of the citizens living and working in the DRW. The acceptance of civic responsibility on the behalf of all citizens and the realization that trash in a parking lot or a curbside gutter will end up in the local waterways and along the shorelines will accomplish as much to improve the quality of the Dog River Watershed as the permitting and control programs.

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