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A SURVEY OF THE WATER QUALITY AND SEDIMENT CHEMISTRY OF SHIPYARDS IN COASTAL ALABAMA

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ALABAMA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
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A SURVEY OF THE WATER QUALITY AND SEDIMENT CHEMISTRY OF SHIPYARDS IN COASTAL ALABAMA

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EXECUTIVE SUMMARY

This report details the findings of a survey of water quality and sediment chemistry in shipyards of coastal Alabama. Surface water samples and sediment samples were collected from five streams and ten shipyards in Mobile and Baldwin counties. Water samples were analyzed for turbidity, total suspended solids (TSS), BOD_5, fecal coliform, Al, Cd, total-Cr, Cu, Fe, Hg, Ni, Pb, Sn and Zn. Sediment samples were analyzed for the same set of metals and total recoverable oil & grease (TROG).

Analytical results of the water samples from shipyard berthing slips and dock areas were compared to the results of samples collected at "backround" stations upstream of shipbuilding facilities. These results indicate that while some of the streams sampled possessed concentrations of fecal coliform bacteria in excess of their assinged water use classification, nearby residences and seafood processors appear to be the major source of enteric bacteria. Data for the other water quality parameters analyzed indicates little or no increase in concentrations at shipyards relative to upstream "backround" stations.

Results of sediment analyses indicate significant increases, relative to backround stations, in the concentrations of Cd, Cu, Pb, Zn and TROG in the sediments of the majority of shipyards sampled. Lesser increases were also observed for the concentrations of Ni and Sn in the sediments of shipyards.

Evaluation of the presence of enrichment of metals in sediments was assisted by the application of the concept of utilizing aluminum as a geochemical normalizer. This concept has been applied by other investigators as a tool for interpreting metals data for sediments and assessing the presence and magnitude of metallic enrichment due to anthropogenic sources. This method was used in a previous baseline study of sediment chemistry conducted by the ADEM Mobile Branch in 1990. The details of this study are described by Halcomb (1991).

INTRODUCTION

Numerous aspects of the building, repair and maintenance of boats and ships have become subjects of concern regarding the potential for adverse impacts to water and sediment quality. Some specific sources of pollutants from shipyard facilities are heavy metals in the anticorrosive coatings (zinc) used to protect metal components and in the antifouling paints (lead and tin) used to prevent the growth of encrusting organisms such as barnicles on hulls, rudders and other submersed parts. These materials enter the water during their removal (scraping and sandblasting) and application (spraying). One avenue of deleterious impact comes from the fact that the very property that makes some of these materials useful as antifoulants (toxicity to encrusting species) also makes them harmful to benificial species of shellfish. Other sources are petroleum contamination from engine maintenance and overhaul operations, and enteric bacteria from the discharge of untreated sanitary wastes from holding tanks and "heads".

Because of the potential for contamination from heavy metals, petroleum hydrocarbons and enteric bacteria from these activities and due to the need to establish the extent and magnitude of possible contamination from these activities, the Mobile Branch of the Alabama Department of Environmental Management (ADEM) conducted a survey of sediment and water quality in the vicinity of major shipyards in coastal Alabama. This study involved the analyses of sediment and water samples collected from berthing slips and docksides of shipyards. These results were then compared to samples collected from "clean" locations

upstream of shipyards. Additionally, the results of sediment metal analyses were compared to a database of metal concentrations of clean sediments. This database was generated through a previous study conducted by ADEM of metal concentrations in sediments of coastal Alabama. The details of this study and the database are described by Halcomb (1991).

The baseline study (Halcomb, 1991) and this survey applied the method developed by Schropp and Windom (1988) for identifying metal enrichment due to anthropogenic activities. This method is based on the naturally occurring relationships between aluminum and other metallic elements. These relationships allow for the identification of polluted sediments by using aluminum as a reference element. 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 occuring proportions of metals relative to aluminum have been reported by several investigators (Turekian and Wedepohl, 1961; Taylor, 1964; Duce et al, 1976) to be fairly constant. This allows for the use of aluminum as a reference element or "normalizing factor" for identifying sediments enriched by anthropogenic activities. This concept has been used to examine metal pollution in the Savannah River estuary (Goldberg, 1979) and lead pollution in the Mississippi River (Trefey et al, 1985).

The results of the shipyard survey provide a preliminary assessment of the extent and magnitude of possible contamination in the water and sediments around shipbuilding facilities.

MATERIALS AND METHODS

Surface water and sediment samples (cores) were collected from 5 areas, Bayou Coden, Bayou La Batre, lower Mobile River, Chickasaw Creek and Bon Secour River, in the vicinity of shipyards in coastal Alabama. The locations of these sites are shown in Figures 1-4 and descriptions of station locations are listed in Table 1.

Water samples for metals, turbidity, BOD_5 and TSS analyses were collected in 1/2 gallon plastic jugs, samples for fecal coliform bacterial analyses were collected in sterile 250 mL Nalgene bottles. A K-B type core sampler (Wildlife Supply Co., catalog no. 2402-A12) equipped with a cellulose-acetate-butyrate liner tube was used for retrieval of sediment cores from all sites except those on the lower Mobile River where the hardpacked sediments and swiftness of water currents necessitated the use of a stainless steel Peterson dredge. Sediment for chemical analyses was taken from the upper five centimeters of each core, placed in a glass jar and capped with a teflon lined lid. Sediments collected with the Peterson dredge were first placed in a stainless steel bucket, with care taken to not disturb the sample, then the upper five centimeters of sediment were transferred by means of a stainless steel scoop to the sample jar. All sample containers, lids and sample collection equipment were cleaned according to the methods outlined in the Standard Operating Procedures and Quality Assurance Manual, Alabama Department of Environmental Management, 1986. Sediment samples were collected in triplicate, two samples for immediate processing and the third sample was "archived" in a freezer for future

analyses in case of widely varying results between the first two.

Vertical profiles of water temperature, pH, dissolved oxygen, conductivity and salinity were obtained utilizing a Hydrolab SURVEYOR II. These measurements were recorded at one-half meter intervals from the top to near bottom of the water column and were performed immediately prior to the collection of water and sediment samples at a station. Profiles were taken at each station in the Bon Secour River, but in the Mobile River and Chickasaw Creek profiles were measured at the upstream end, downstream end and middle of the survey area due to the close proximity of sample stations. Profile measurements for Bayou Coden and Bayou La Batre are not available due to instrument malfunction during those sample cruises. The data for the water column profiles are given in Appendix C.

Water samples were analyzed according to the proceedures as described in 40 CFR Part 136 as amended and further detailed in Methods for Chemical Analyses of Water and Wastes, EPA-600/4-79-020 revised 3-83.

Preperation of sediments for metal analyses began with oven drying samples at 60°C followed by weighing out a 0.25 gram portion of each. Digestion of sediments was performed according to the procedure described by Windom (1989). Each weighed portion was then placed in a 15 mL teflon cup to which was added nitric acid, hydrofluoric acid and perchloric acid. The teflon cups (open cups, no covers) were heated on a hotplate at ca 120°C, each cup remaining on the hotplate until the

sample had been totally digested, additional acid was added to each cup as needed until digestion was completed. Once the sample was digested, heating was continued until the sample volume was reduced to approx. 1 mL to which 2.5% nitric acid was added to bring the sample volume up to 25 mL. Samples were then analyzed with a Perkin-Elmer 3030-B atomic absorption spectrophotometer (AA) utilizing a flame furnace for Al, Fe and Zn and a graphite furnace for Cd, Cr, Cu, Pb, Ni and Sn. A Perkin-Elmer 460 AA equipped with cold vapor apparatus was utilized for analyses of samples for Hg.

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).

The analytical result of each metal in the sediment samples was then plotted against its respective aluminum value. These are graphically represented in Appendix A. Superimposed on the graphs are the regression lines and 95% confidence bands for each metal/aluminum relationship as would be expected to occur in uncontaminated sediments. The bases for determining these relationships are described by Schropp and Windom (1987) and Halcomb (1991).

Quality of laboratory analyses was assured through particpation in the intercomparison exercise for sediment metal analyses (FDER, 1991). This exercise involved the digestion and analyses of standard reference sediments from the National Institute of Standards and Technology (NIST SRM 1646) and the National Research Council of Canada

(NRC BCSS-1 and BEST-1). Coastal sediments of a variety of types also were incorporated in the intercomparison exercise. Analytical results obtained by the ADEM Mobile Branch Laboratory were compared to those of other labs participating in the exercise. These results indicate a high degree of reliability in the analytical data produced by the ADEM lab. In addition to the intercalibration exercise, the ADEM Mobile Branch Laboratory also participates in laboratory quality assurance programs conducted annually by the U.S. EPA and NOAA. An in house Departmental Q/A program provides additional assurance of quality. Laboratory personnel check their techniques and performance of analytical instruments by routinely testing samples of reference material during the course of this and other studies.

TABLE 1

STATION LOCATIONS

Bayou Coden

Station	Description
BC-1	Approximately 0.5 miles upstream of Ala Hwy 188 bridge.
BC-2	Rodriguez Boatyard
BC-3	Master Marine Boatyard

Bayou La Batre

Station	Description
BB-1	Approximately 1 mile upstream of Ala Hwy 188 bridge.
BB-2	Steiner Boatyard
BB-3	John Graham Boatyard
BB-4	Ocean Marine
BB-5	Master Marine floating drydock

Mobile River

Station	Description
MR-1	State Docks containership dock.
PI-1	South end of Pinto Island.
PI-2	Docking slip at the south end of Atlantic Marine.
PI-3	Docking slip at the north end of Atlantic Marine.
B-1	Bender, south end of facility on the west bank of the Mobile River.
B-2	Bender, near yards 3 & 4 on the west bank of the Mobile River.
B-3	Bender, north end near the CSX rail terminal.

TABLE 1 cont.

Chickasaw Creek

Station	Description
CC-1	Downstream of Halter Marine, near Hog Bayou.
CC-2	Approximately 100 yards downstream of Halter Marine.
CC-3	South berthing slip at Halter Marine.
CC-4	North berthing slip at Halter Marine.
CC-5	Approximately 0.5 miles upstream of U.S. Hwy 43 bridge.

Bon Secour River

Station	Description
BSR-1	Approximately 100 yards upstream of Baldwin Co. Rd. 10 bridge.
BSR-2	Childress Boatyard.
BSR-3	Near channel marker 30.
BSR-4	Near channel marker 16.
BSR-5	Near channel marker 7.

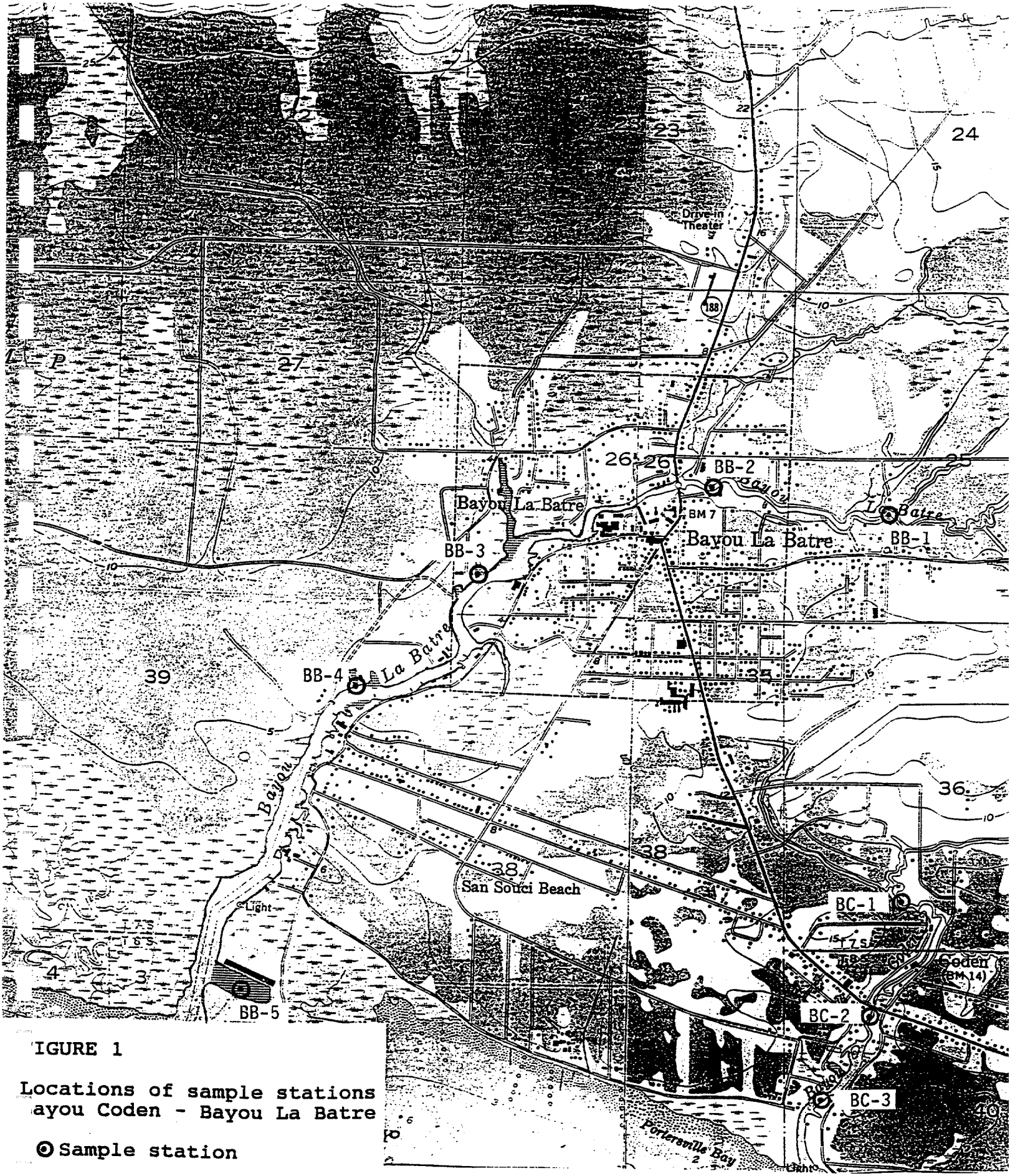


FIGURE 1

Locations of sample stations
Bayou Coden - Bayou La Batre

⊙ Sample station

This map photocopied from the Coden and Grand Bay Quadrangle sheets, Alabama-Mobile Co., USGS 7.5 minute series.

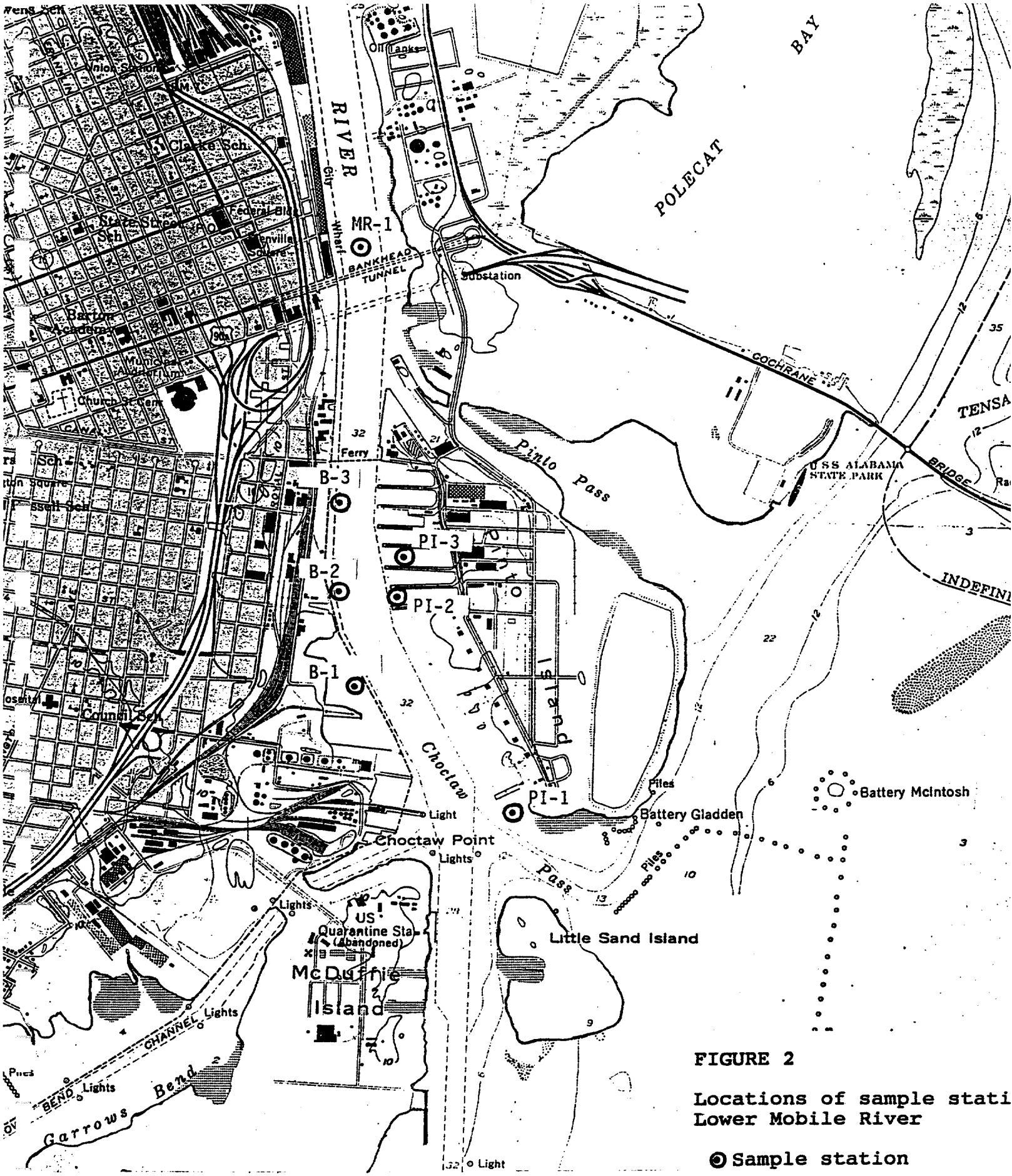


FIGURE 2

Locations of sample stati Lower Mobile River

◉ Sample station

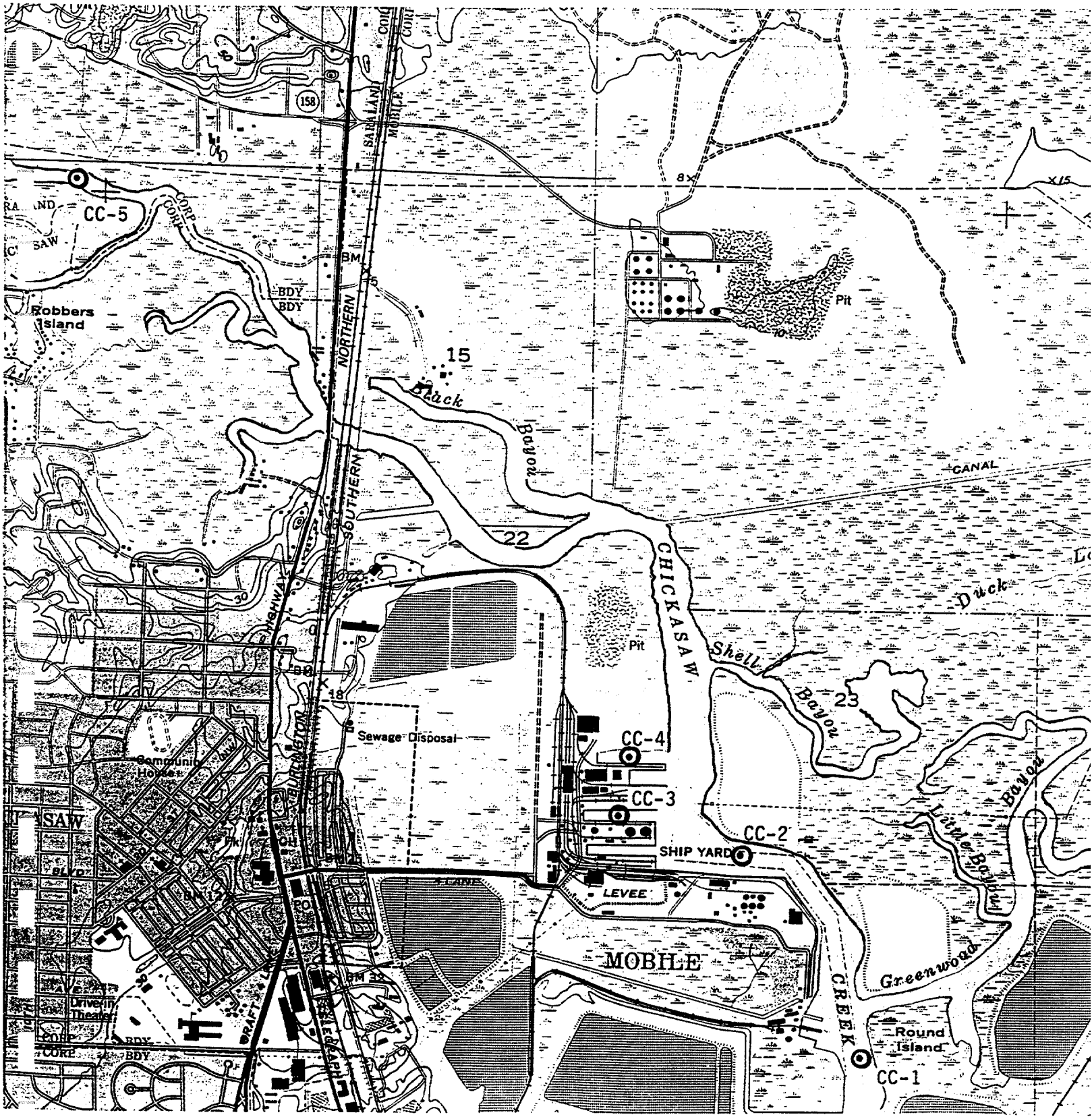
This map photocopied from the Mobile Quadrangle she Alabama-Mobile Co., USGS 7.5 minute series.

FIGURE 3

Locations of sample stations
Chickasaw Creek

⊙Sample station

This map photocopied from the Chickasaw Quadrangle sheet, Alabama-Mobile Co. USGS 7.5 minute series.



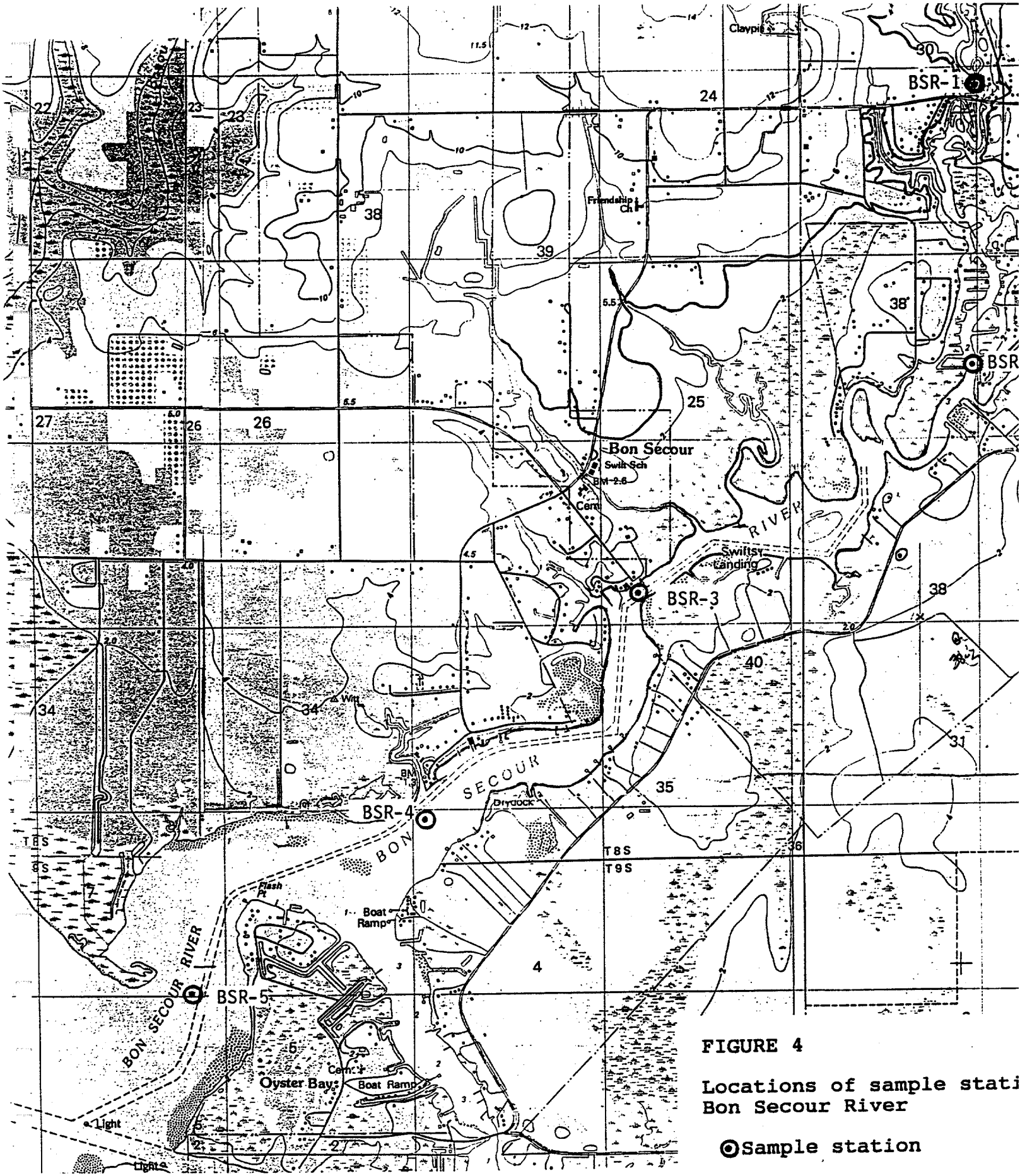


FIGURE 4

Locations of sample stati Bon Secour River

⊙ Sample station

This map photocopied from the Bon Secour Bay and Gulf Shores Quadrangle sheets, Alabama-Baldwin Co., USGS 7.5 minute seri

RESULTS

The results of analyses of water samples are listed in Table 2. These results indicate that (with the exception of fecal coliform bacteria) little, if any, adverse impact on water quality relative to backround readings is evident within the shipyard areas . The elevated levels of biochemical oxygen demand observed in Bayou La Batre at station BB-5, in Bayou Coden at station BC-1 and in the Bon Secour River at station BSR-4 are most probably due to the cumulative effect of the numerous seafood processors proximate to these stations.

The values for fecal coliform bacteria indicate elevated concentrations for the samples collected from shipyards in Bayou La Batre relative to the upstream sample. The data for fecal coliform bacteria in Bayou Coden and Bon Secour River indicate "background" levels at the upstream stations to be in excess of the Departmental water use classification standards for these streams (fish & wildlife for Bayou Coden and swimming for the Bon Secour River); however little impact is evident from shipyard activity in these streams. The reading of 1,200 colonies per 100 mL at BC-1 and 820 colonies per 100 mL at BSR-1 are likely the result of numerous nearby households connected to septic tanks. The reading of 600 colonies per 100 ml at BSR-4 is most probably due to the proximity of several seafood processing facilities and residences also connected to septic tanks. The bacterial readings for the samples collected from the lower Mobile River and Chickasaw Creek are relatively unchanged from upstream to downstream of the shipyard facilities. These values compare favorably to those obtained

during routine trend monitoring of these streams.

The results of sediment metal analyses are listed in Table 3. Graphical depictions of these results are shown in Appendicies A and B. The graphs of metals verus aluminum shown in Appendix A are the analytical values of the samples collected during this study plotted against regression lines and 95% prediction belts of metals versus aluminum relationships as observed for clean sediments during the baseline study of 1990 (Halcomb, 1991). In most samples, the values obtained for cadmium, copper, lead and zinc during the shipyard survey fell well above the upper limit of the prediction belts. These results indicate the sediments at most of the sites along docksides and in berthing slips are enriched with those metals common to anticorrosive coatings, antifoulant coatings and marine paints.

Due to the fact that nickel and tin were not analyzed for sediments collected during the sediment baseline study of 1990 it was not possible to examine the data for these elements as rigorously as was done with the other metals. However, Schropp and Windom (1987) included analyses for nickel in their study of sediments in Florida. The data for nickel concentrations in sediments from shipyards were compared to the nickel/aluminum relationships observed by Schropp and Windom. The data plots for the nickel/aluminum relationships of the sediments from shipyards fell within the 95% prediction belts (as calculated by Schropp and Windom) for natural nickel/aluminum relationships in "clean" sediments. This would appear to indicate that the sediments of the shipyards surveyed are not enriched with nickel although the bar

graphs of Appendix B indicate a tendency for nickel and tin to increase in the sediments of shipyards compared to backround levels. This is especially evident for tin at station B-3, a dockside sample from Bender Shipyard on the Mobile River, and for the nickel values for stations BB-4 and BB-5 in Bayou La Batre. The bar graphs of Appendix B also show the trend for other metals, copper, lead and zinc in particular, to increase in concentration in the sediments from shipyards.

The results of TROG analyses appear to indicate petroleum contamination in some of the sediments from dockside and berthing slips relative to the TROG concentration at backround stations. This was most evident in the samples from Bayou La Batre (BB-2 & BB-3) and the lower Mobile River (B-1). The TROG data was also compared to a database developed by ADEM of TROG concentrations for sediments in Mobile Bay. These comparisons support the observation of petroleum contamination in the sediments of most of the shipyards surveyed.

TABLE 2

WATER QUALITY DATA
SHIPYARD SURVEY

BAYOU CODEN
14 MAY 91

STATION	TURBIDITY NTUs	T S S mg/L	B O D-5 mg/L	F. coli #/100mL	Al mg/L	Cd mg/L	Cr-T mg/L	Cu mg/L	Fe mg/L	Hg mg/L	Ni mg/L	Pb mg/L	Sn mg/L	Zn mg/L
BC-1	23	8	6.6	1,200	<3.0	<0.05	<0.05	<0.1	1.56	0.002	<0.05	<0.01	<0.02	<0.05
BC-2	21	8	2.9	580	<3.0	<0.05	<0.05	<0.1	1.44	0.002	<0.05	<0.01	<0.02	<0.05
BC-3	22	9	3.0	510	<3.0	<0.05	<0.05	<0.1	1.27	<0.002	<0.05	<0.01	<0.02	<0.05

BAYOU LA BATRE
16 MAY 91

STATION	TURBIDITY NTUs	T S S mg/L	B O D-5 mg/L	F. coli #/100mL	Al mg/L	Cd mg/L	Cr-T mg/L	Cu mg/L	Fe mg/L	Hg mg/L	Ni mg/L	Pb mg/L	Sn mg/L	Zn mg/L
BB-1	8	2	1.3	64	<3.0	<0.05	<0.05	<0.1	1.18	0.002	<0.05	<0.01	<0.02	<0.05
BB-2	11	5	1.5	367	<3.0	<0.05	<0.05	<0.1	1.43	<0.002	<0.05	<0.01	<0.02	<0.05
BB-3	13	6	1.4	1,240	<3.0	<0.05	<0.05	<0.1	1.32	<0.002	<0.05	<0.02	<0.02	<0.05
BB-4	14	7	3.0	157	<3.0	<0.05	<0.05	<0.1	1.14	0.003	<0.05	<0.01	<0.02	<0.05
BB-5*	25	18	4.2	480	<3.0	<0.05	<0.05	<0.1	0.96	0.003	<0.05	<0.01	<0.02	<0.05

MOBILE RIVER
12 JUNE 91

STATION	TURBIDITY NTUs	T S S mg/L	B O D-5 mg/L	F. coli #/100mL	Al mg/L	Cd mg/L	Cr-T mg/L	Cu mg/L	Fe mg/L	Hg mg/L	Ni mg/L	Pb mg/L	Sn mg/L	Zn mg/L
MR-1	28	5	2.1	44	<2.0	<0.05	<0.05	<0.05	2.31	<0.002	<0.05	0.01	<0.01	<0.05
PI-1*	30	6	1.4	40	<2.0	<0.05	<0.05	<0.05	2.08	<0.002	<0.05	0.01	<0.01	<0.05
PI-2	30	6	1.4	43	<2.0	<0.05	<0.05	<0.05	2.25	<0.002	<0.05	<0.01	<0.01	<0.05
PI-3	27	6	1.8	47	<2.0	<0.05	<0.05	<0.05	1.78	0.005	<0.05	0.01	0.01	<0.05
B-1	31	7	1.4	45	<2.0	<0.05	<0.05	<0.05	2.21	<0.002	<0.05	<0.01	<0.01	<0.05
B-2	29	7	1.5	50	<2.0	<0.05	<0.05	<0.05	2.08	<0.002	<0.05	<0.01	<0.01	<0.05
B-3	29	9	1.7	39	<2.0	<0.05	<0.05	<0.05	2.02	<0.002	<0.05	<0.01	<0.01	<0.05

Note: An asterisk (*) by the station number denotes values are the result of duplicate analyses.

TABLE 2 cont.

CHICKASAW CREEK
21 JUNE 91

STATION	TURBIDITY NTUs	T S S mg/L	B O D-5 mg/L	F. coli #/100mL	Al mg/L	Cd mg/L	Cr-T mg/L	Cu mg/L	Fe mg/L	Hg mg/L	Ni mg/L	Pb mg/L	Sn mg/L	Zn mg/L
CC-1	22	9	1.5	208	<2.0	<0.05	<0.05	<0.05	1.72	<0.002	<0.05	<0.01	<0.01	<0.05
CC-2	24	10	2.0	217	<2.0	<0.05	<0.05	<0.05	1.91	<0.002	<0.05	<0.01	<0.01	<0.05
CC-3	22	9	1.2	310	<2.0	<0.05	<0.05	<0.05	1.58	<0.002	<0.05	<0.01	<0.01	<0.05
CC-4	23	9	1.8	270	<2.0	<0.05	<0.05	<0.05	1.76	<0.002	<0.05	0.11	<0.01	<0.05
CC-5	16	3	1.9	188	<2.0	<0.05	<0.05	<0.05	1.76	<0.002	<0.05	<0.01	<0.01	<0.05

BON SECOUR RIVER
10 JULY 91

STATION	TURBIDITY NTUs	T S S mg/L	B O D-5 mg/L	F. coli #/100mL	Al mg/L	Cd mg/L	Cr-T mg/L	Cu mg/L	Fe mg/L	Hg mg/L	Ni mg/L	Pb mg/L	Sn mg/L	Zn mg/L
BSR-1	97	17	1.4	820	6.3	<0.001	<0.05	<0.05	2.20	<0.003	<0.05	<0.01	<0.02	<0.05
BSR-2	59	14	2.4	374	4.5	<0.001	<0.05	<0.05	1.54	<0.002	<0.05	0.02	<0.02	0.06
BSR-3	18	14	3.4	89	<4.0	<0.001	<0.05	<0.05	0.50	<0.002	<0.05	<0.01	<0.02	<0.05
BSR-4*	20	18	5.6	600	<4.0	<0.001	<0.05	<0.05	0.59	<0.002	<0.05	<0.01	0.04	<0.05
BSR-5	32	21	3.6	16	<4.0	<0.001	<0.05	<0.05	1.06	<0.002	<0.05	<0.01	0.04	<0.05

Note: An asterisk (*) by the station number denotes values are the result of duplicate analyses.

TABLE 3

SEDIMENT CHEMISTRY DATA
SHIPYARD SURVEY

BAYOU CODEN
14 MAY 91

STATION	Al mg/kg	Cd mg/kg	Cr-T mg/kg	Cu mg/kg	Fe mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Sn mg/kg	Zn mg/kg	T R O G mg/kg
BC-1	13,900	0.3	25	26	8,430	0.72	5	14	<2.5	86	302
BC-2	39,700	0.4	56	66	23,050	0.64	20	32	2.5	290	690
BC-3	46,750	0.4	64	77	29,200	<0.40	20	62	2.6	404	598

BAYOU LA BATRE
16 MAY 91

STATION	Al mg/kg	Cd mg/kg	Cr-T mg/kg	Cu mg/kg	Fe mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Sn mg/kg	Zn mg/kg	T R O G mg/kg
BB-1	6,515	0.10	12	<10	3,035	1.20	4	5.8	<2.5	20	113
BB-2	19,750	0.25	31	157	11,650	<0.40	7	57.4	3.0	255	1,064
BB-3	39,700	0.45	58	178	22,800	<0.40	12	51.6	3.4	373	1,999
BB-4	7,335	0.20	12	112	8,005	0.68	14	20.8	<2.5	280	610
BB-5	51,400	0.20	80	91	34,200	0.40	14	37.2	<2.5	220	433

MOBILE RIVER
12 JUNE 91

STATION	Al mg/kg	Cd mg/kg	Cr-T mg/kg	Cu mg/kg	Fe mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Sn mg/kg	Zn mg/kg	T R O G mg/kg
PI-1	63,950	0.2	68	17	33,950	<0.40	20	25	1.9	421	248
PI-2	60,150	0.2	68	29	33,050	0.45	21	50	2.0	944	299
PI-3	61,750	0.2	87	156	37,600	0.50	29	52	7.9	221	486
B-1	57,750	1.2	68	67	36,350	2.00	28	554	4.4	492	2281
B-2	54,050	0.2	90	24	29,950	<0.40	36	20	3.0	275	463
B-3	49,000	0.3	70	119	30,050	0.46	37	155	13.8	307	433
MR-1	65,500	0.3	86	26	36,355	0.45	28	30	3.3	615	488

Note: All values are the average of duplicate samples and are expressed on a dry weight basis.

TABLE 3 cont.

CHICKASAW CREEK
21 JUNE 91

STATION	Al mg/kg	Cd mg/kg	Cr-T mg/kg	Cu mg/kg	Fe mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Sn mg/kg	Zn mg/kg	T R O G mg/kg
CC-1	9,030	0.2	13	9	6,060	<0.40	4	9	4	28	310
CC-2	36,500	0.4	62	31	25,650	0.42	18	51	17	265	995
CC-3	33,900	0.5	72	122	28,200	<0.40	21	83	19	470	1,615
CC-4	28,500	0.4	46	37	18,750	<0.40	15	120	14	570	850
CC-5	37,075	0.3	44	22	21,125	<0.40	12	36	17	88	732

BON SECOUR RIVER
10 JULY 91

STATION	Al mg/kg	Cd mg/kg	Cr-T mg/kg	Cu mg/kg	Fe mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Sn mg/kg	Zn mg/kg	T R O G mg/kg
BSR-1	N O D A T A - S A M P L E C O N T A I N E R S B R O K E N I N T R A N S I T.										
BSR-2	22,000	0.2	33	16	11,200	<0.40	8	33	2.7	48	247
BSR-3	80,500	0.3	94	49	33,450	0.45	23	31	4.2	160	456
BSR-4	88,350	0.2	92	32	37,950	<0.40	25	32	3.2	122	200
BSR-5	65,050	0.2	86	25	31,900	<0.40	22	29	2.9	106	172

Note: All values are the average of duplicate samples and are expressed on a dry weight basis.

CONCLUSION

The results of this study identified the presence of metal enriched sediments in the majority of sites sampled. More specifically the enrichment is in the form of elevated concentrations of cadmium, copper, lead, tin, zinc and total recoverable oil and grease. The source of the metals enrichment would appear to be the antifoulant and anticorrosion surface coatings used in shipbuilding. The cause of the elevated concentrations of oil and grease is most likely from fueling and maintenance operations on engines and machinery.

This study also indicates that, aside from the high counts of fecal coliform bacteria in some of the waters sampled, there appears to be little or no impact on surface water quality attributable to shipyard activities. The shipyards are not the sole sources of enteric bacteria in the streams sampled, as evidenced by the bacterial data at station BC-1 in Bayou Coden and station BSR-1 in the Bon Secour River. Nevertheless, the bacterial colony counts in Bayou La Batre and the Bon Secour River indicate some association of elevated concentrations of fecal coliforms with sites of dock and shipyard activity.

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APPENDIX A

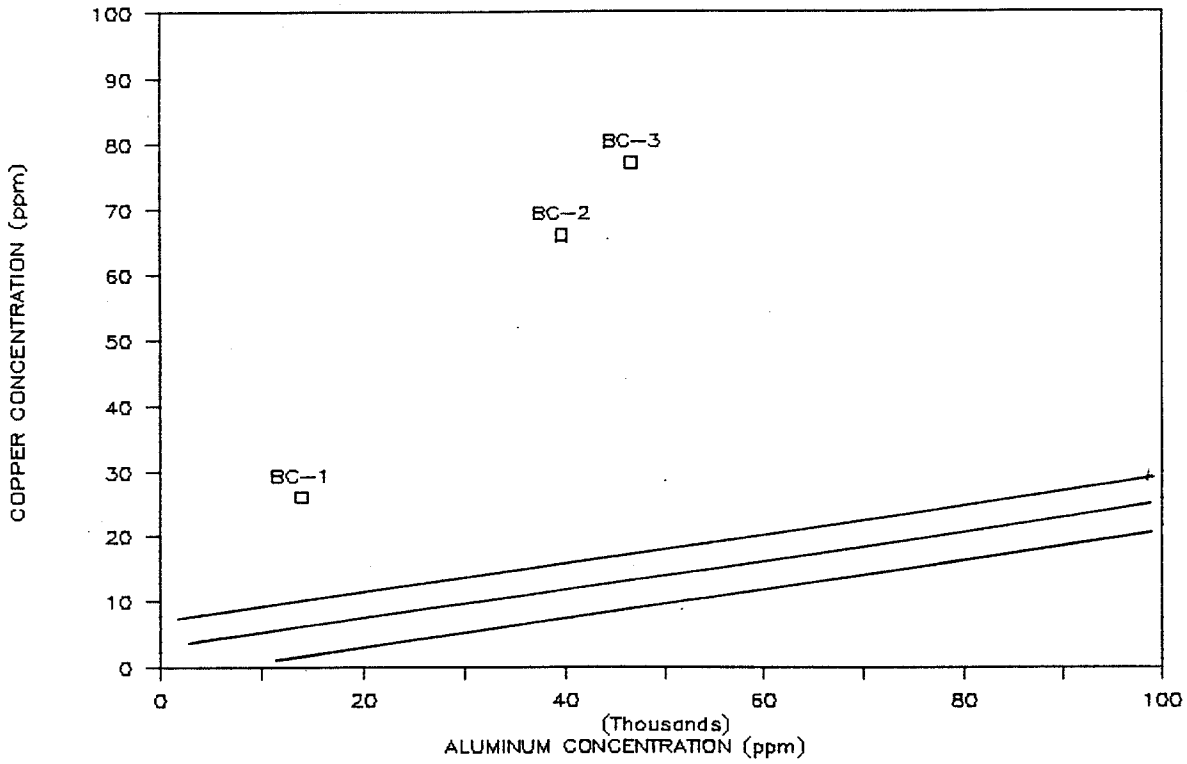
METAL VERSUS ALUMINUM

PLOTS

SEDIMENTS

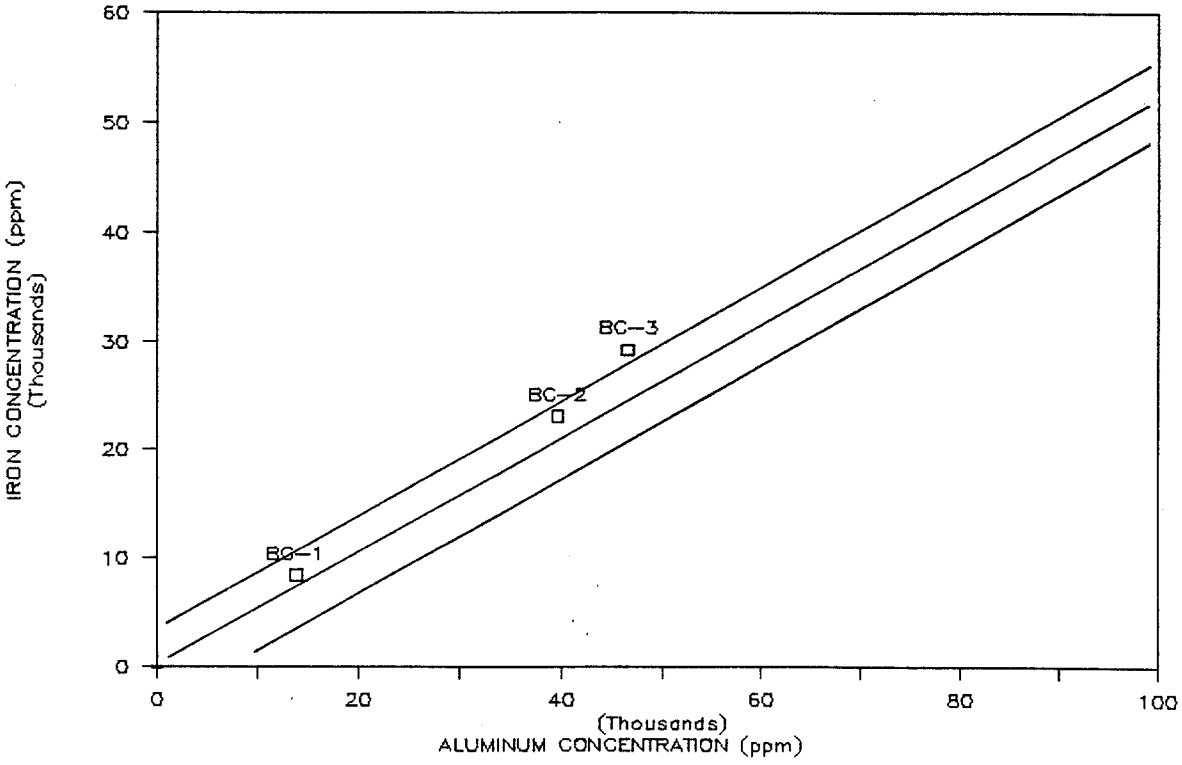
COPPER / ALUMINUM

BAYOU CODEN

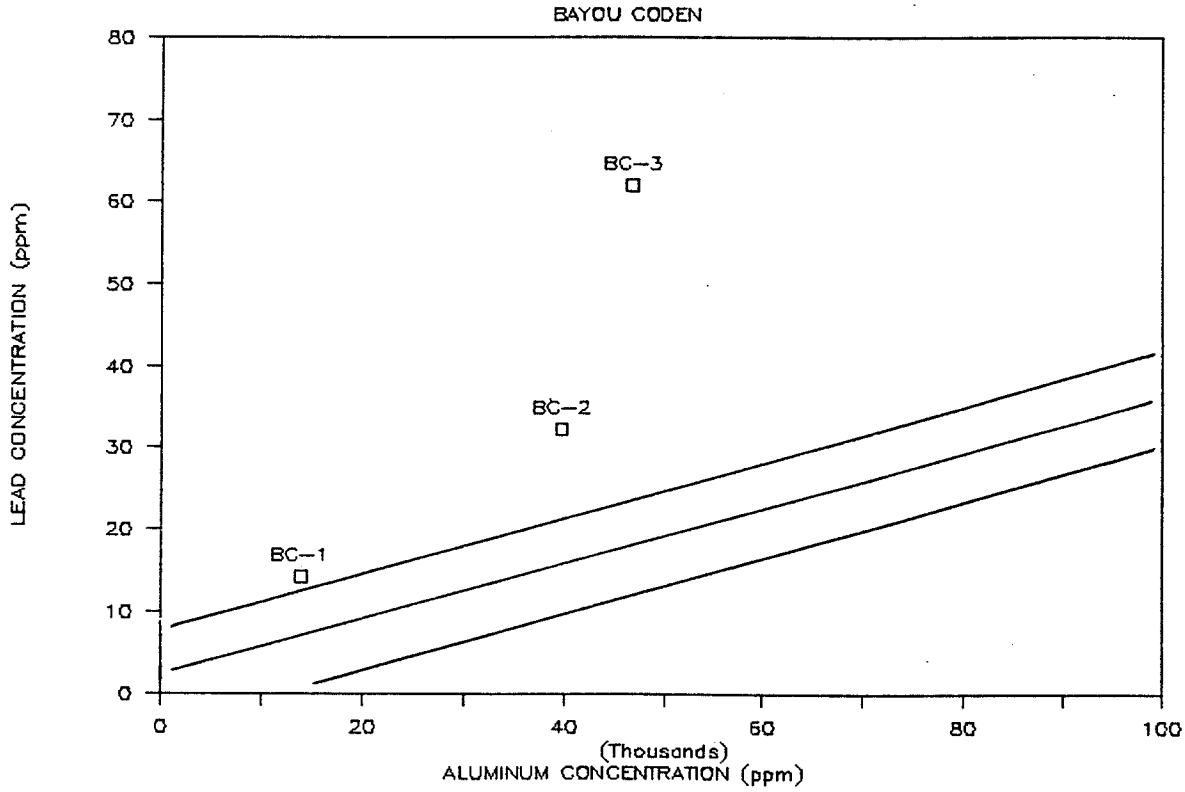


IRON / ALUMINUM

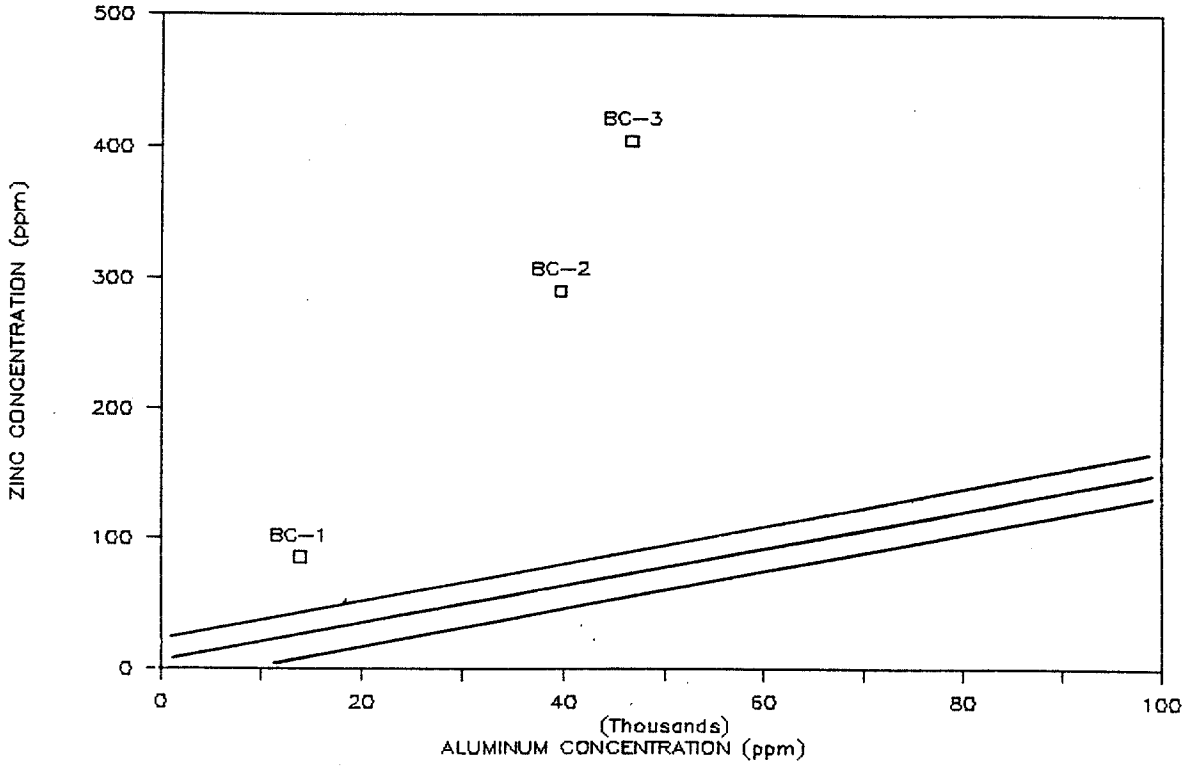
BAYOU CODEN



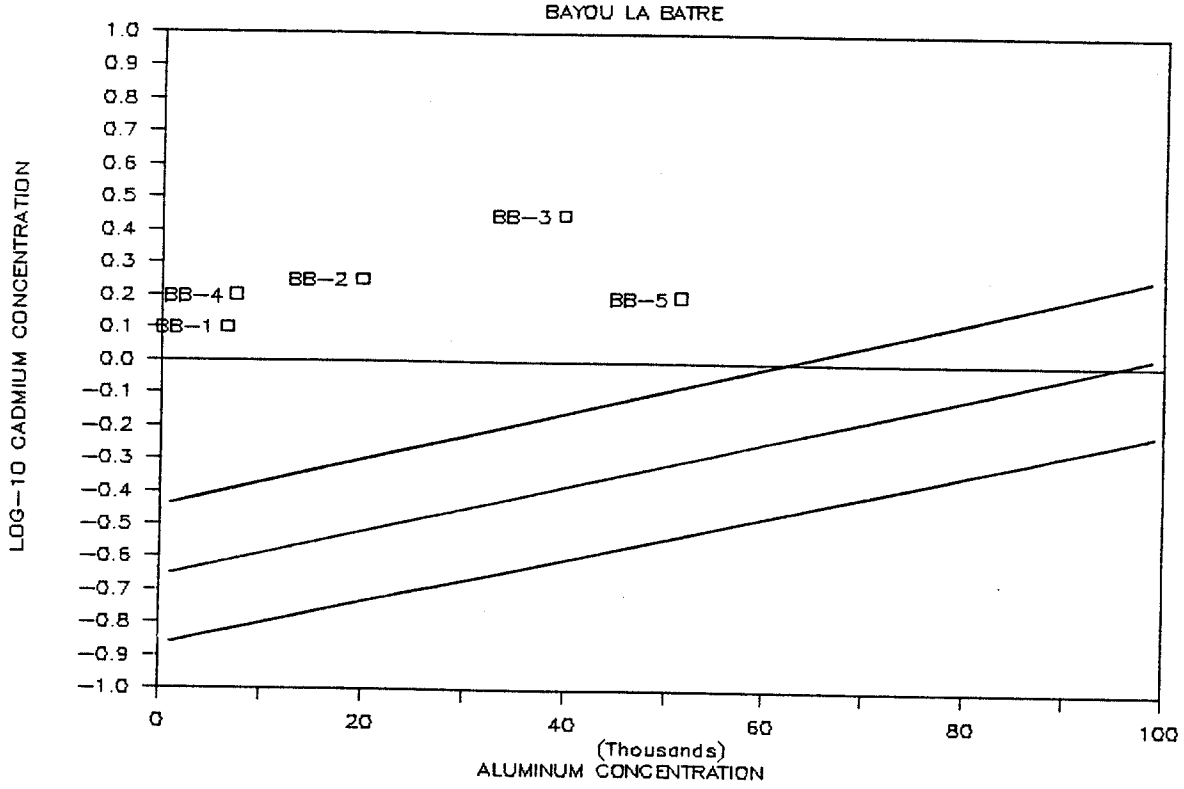
LEAD / ALUMINUM



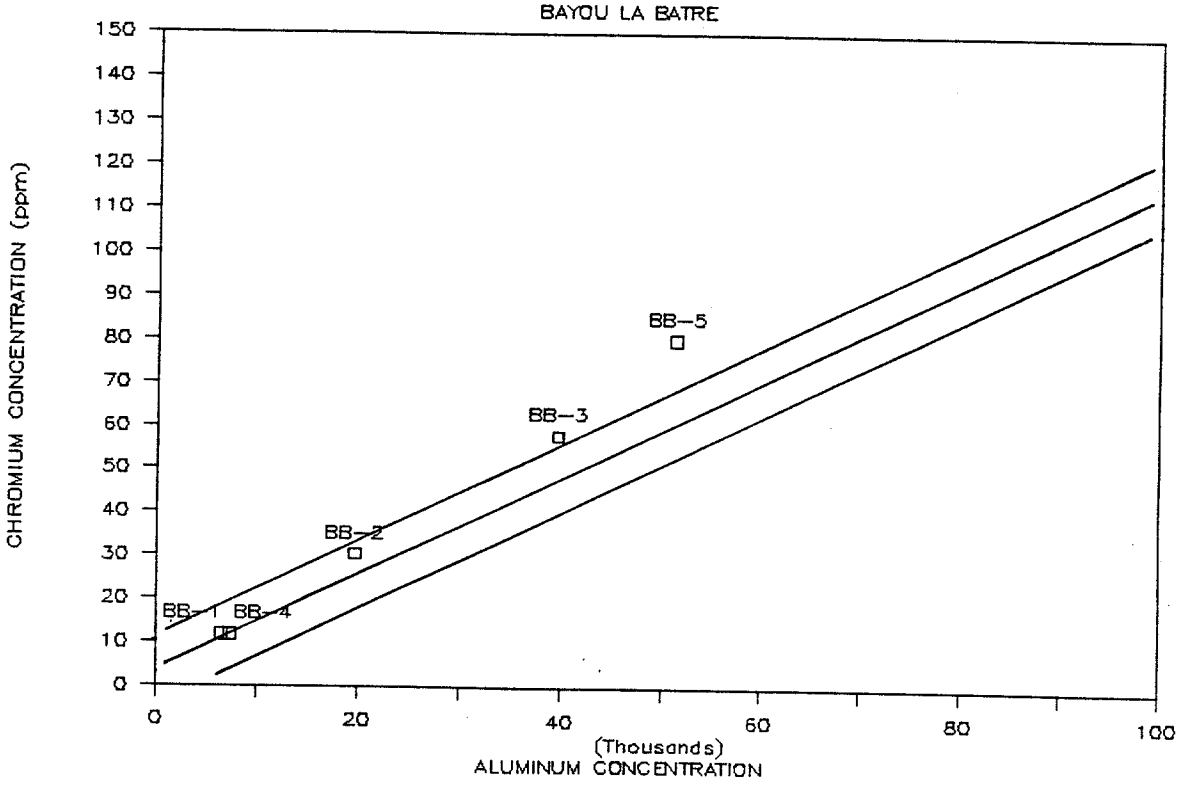
ZINC / ALUMINUM



CADMIUM / ALUMINUM



CHROMIUM / ALUMINUM



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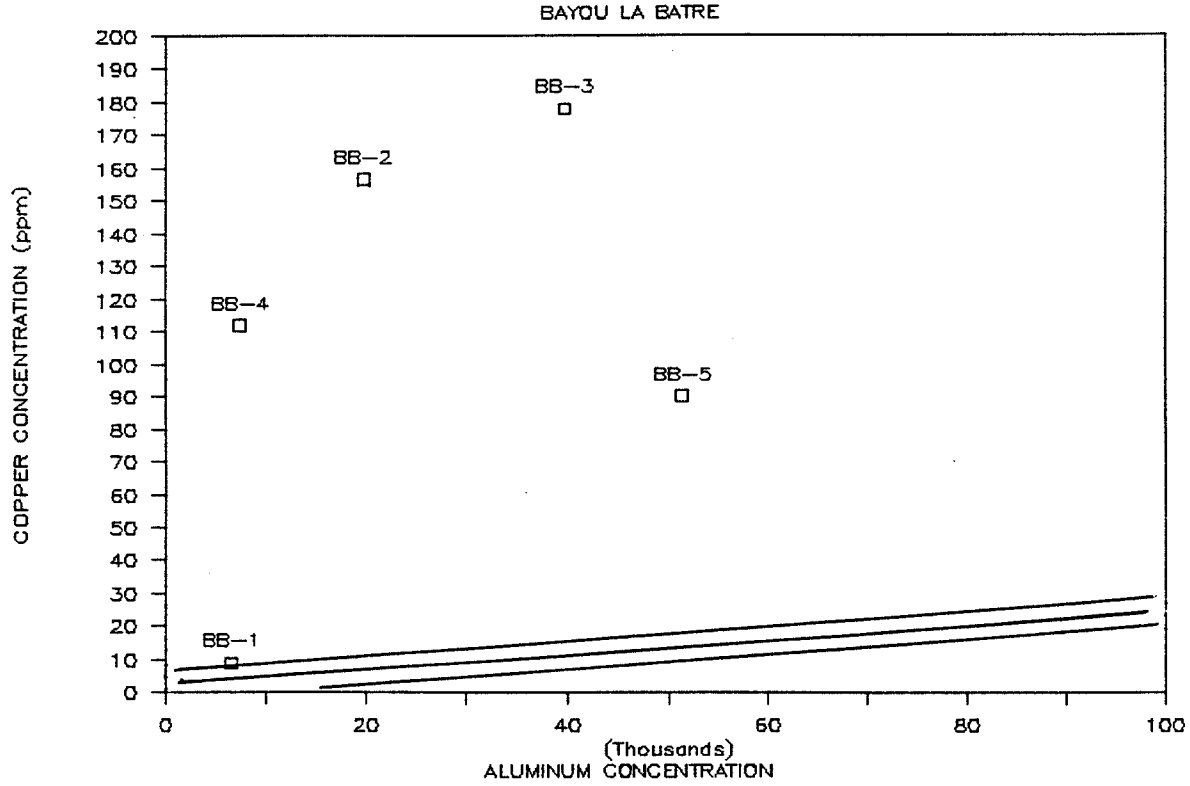
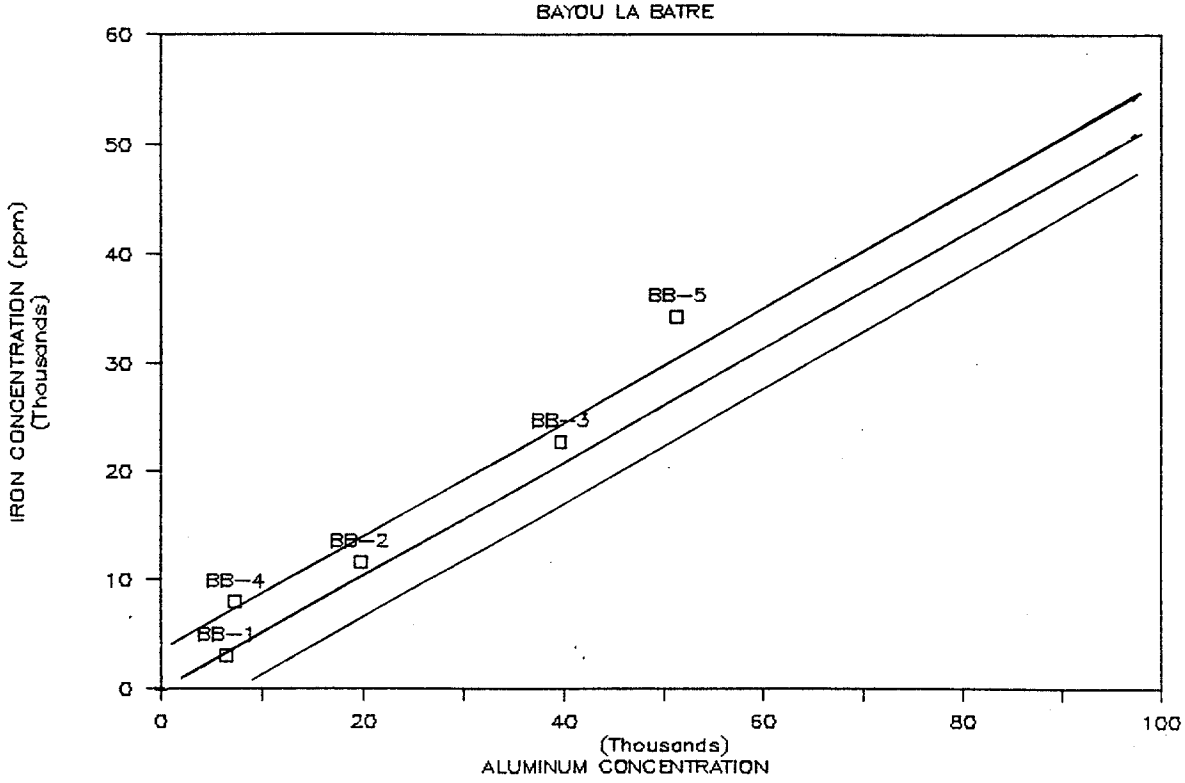


IRON / ALUMINUM



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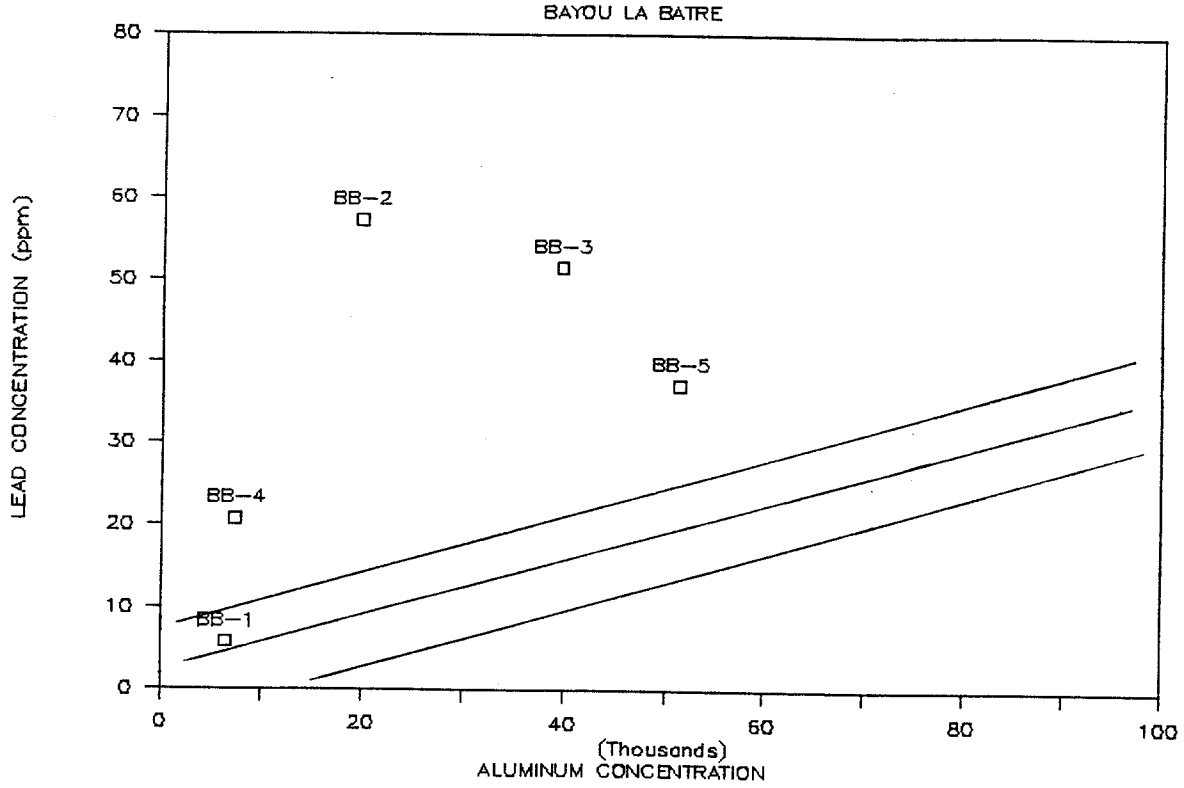

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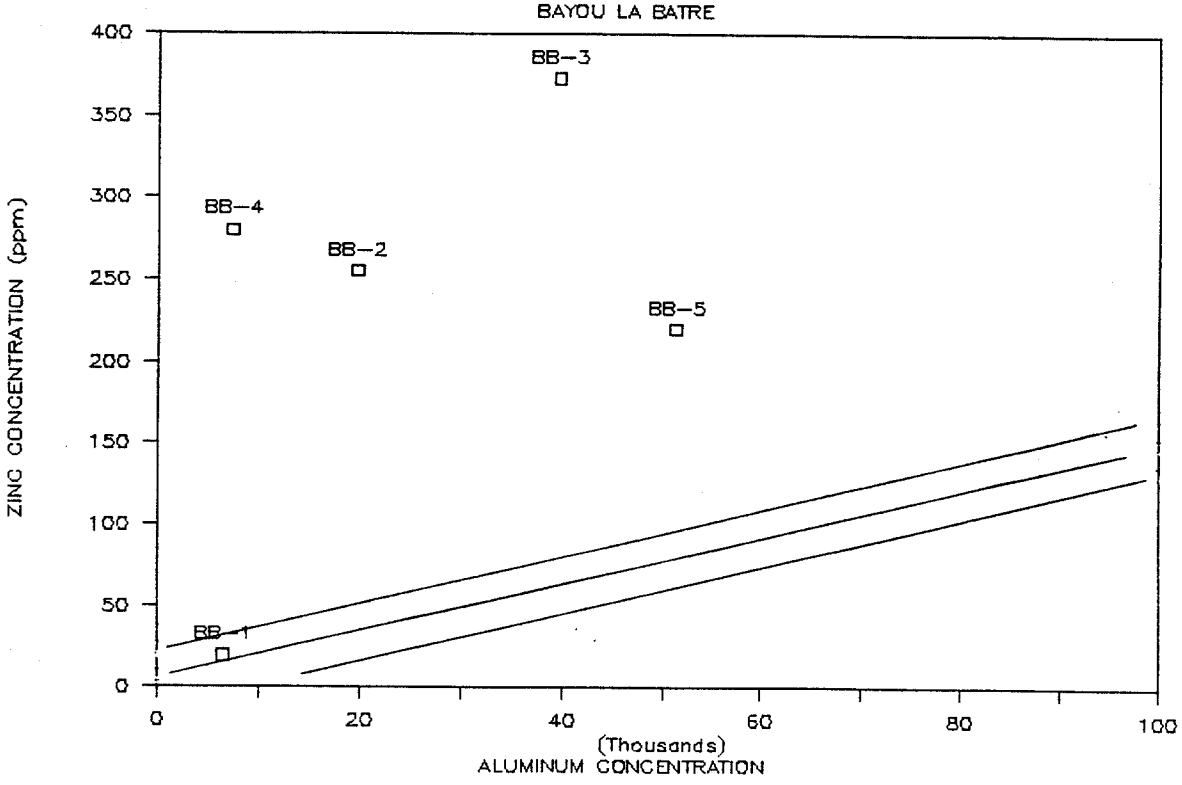

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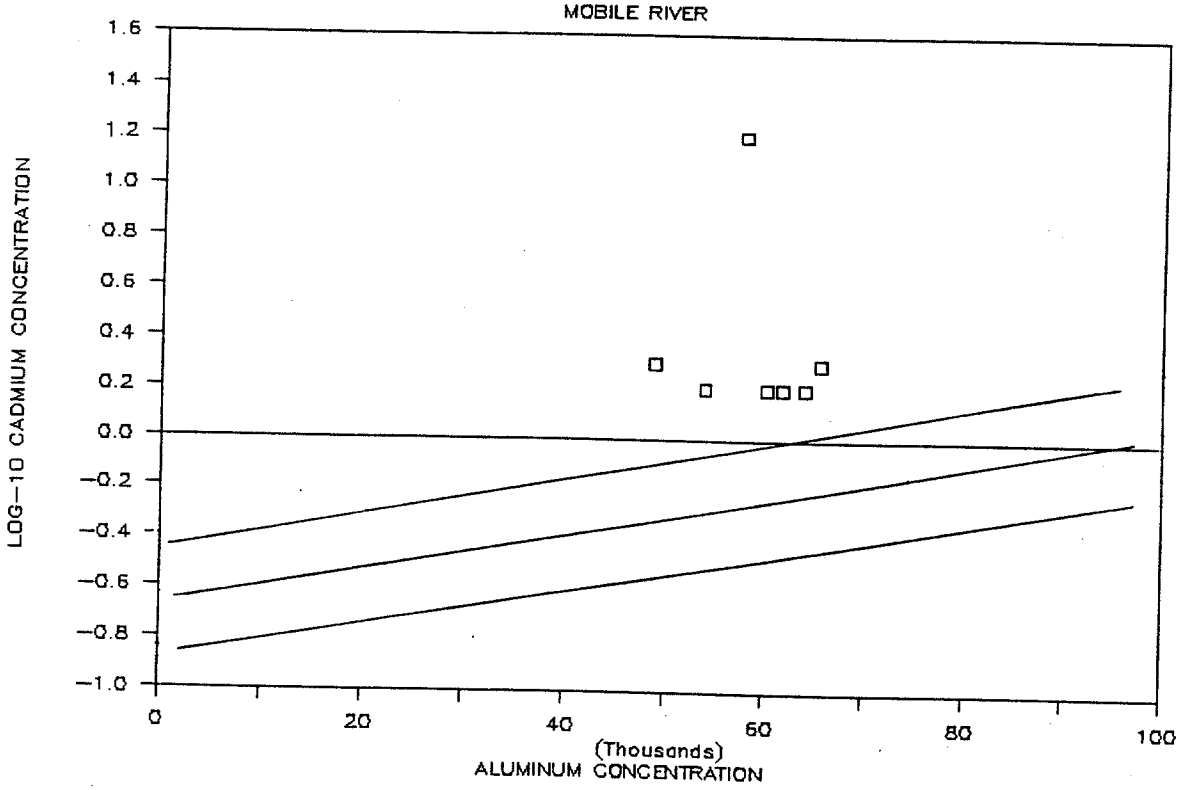

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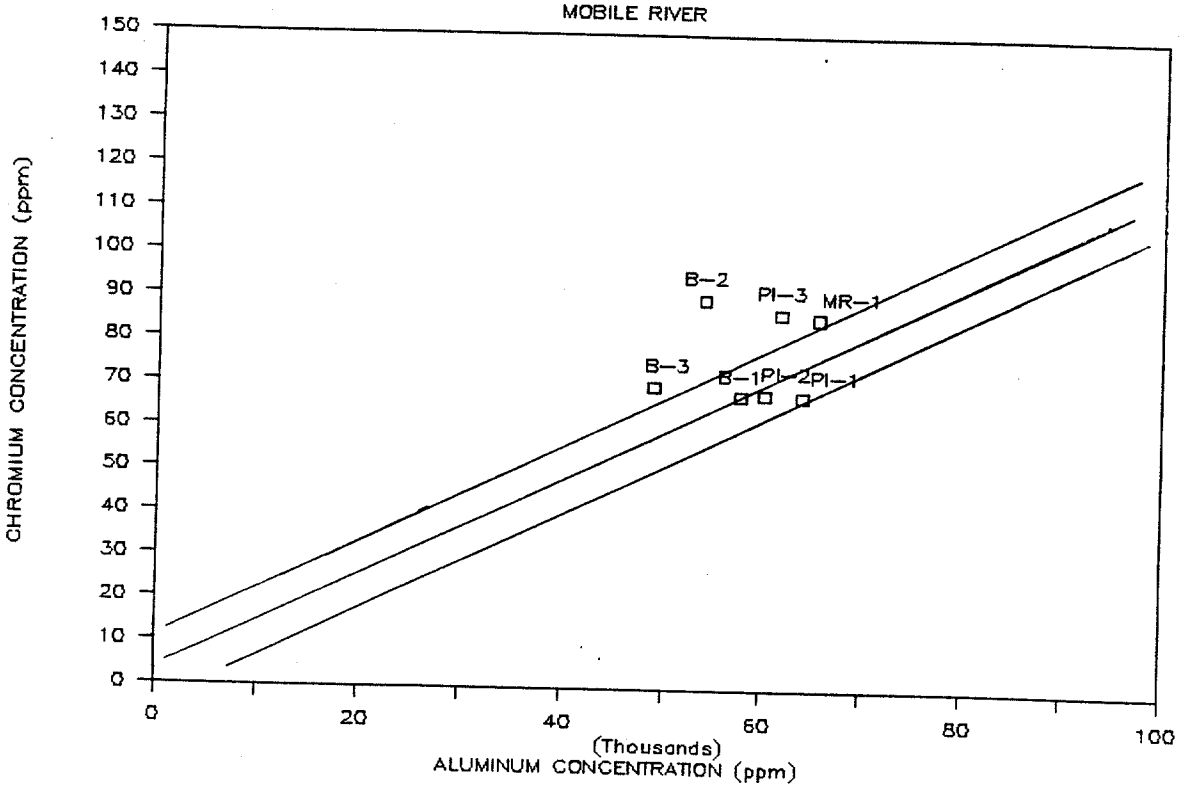

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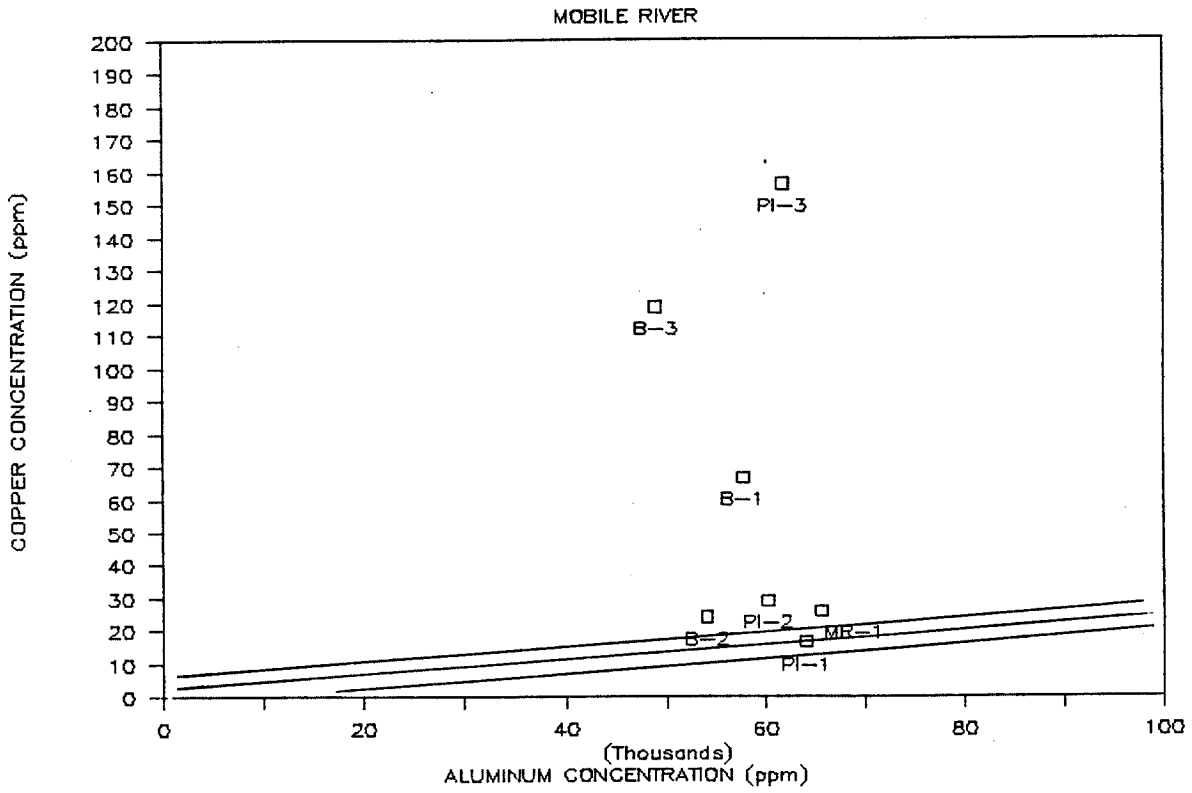

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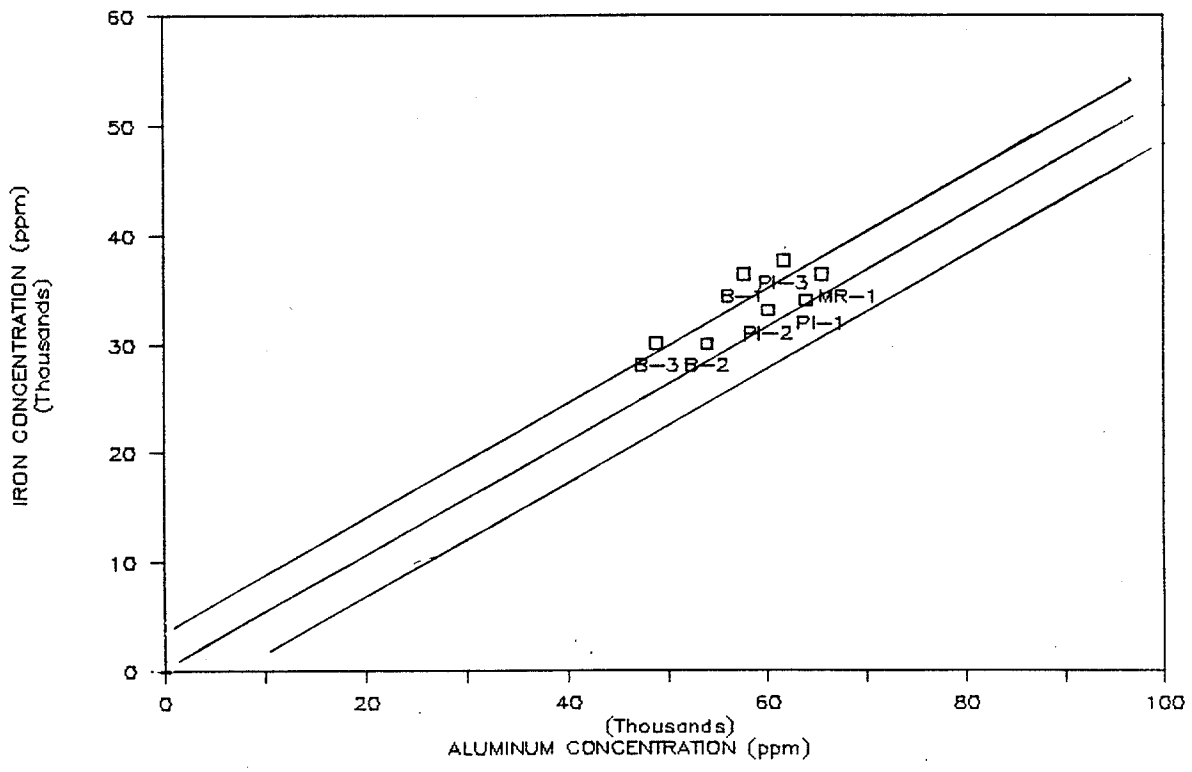

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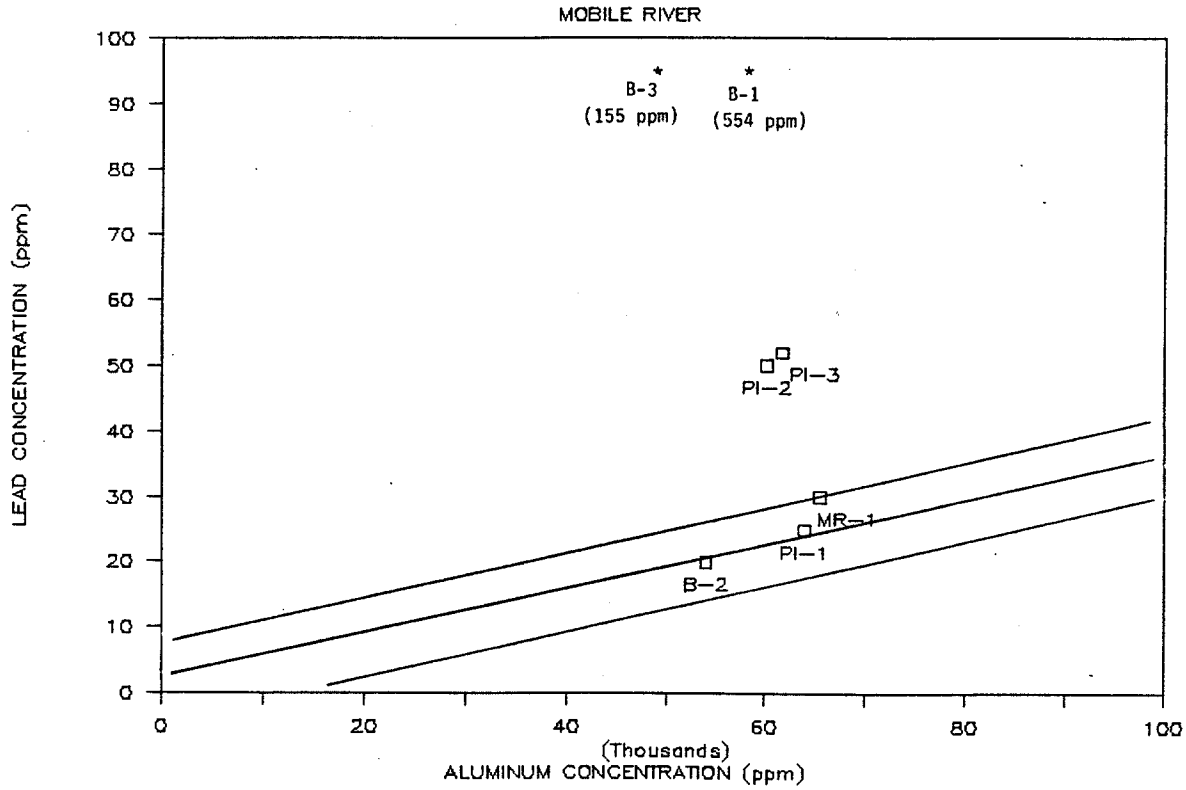
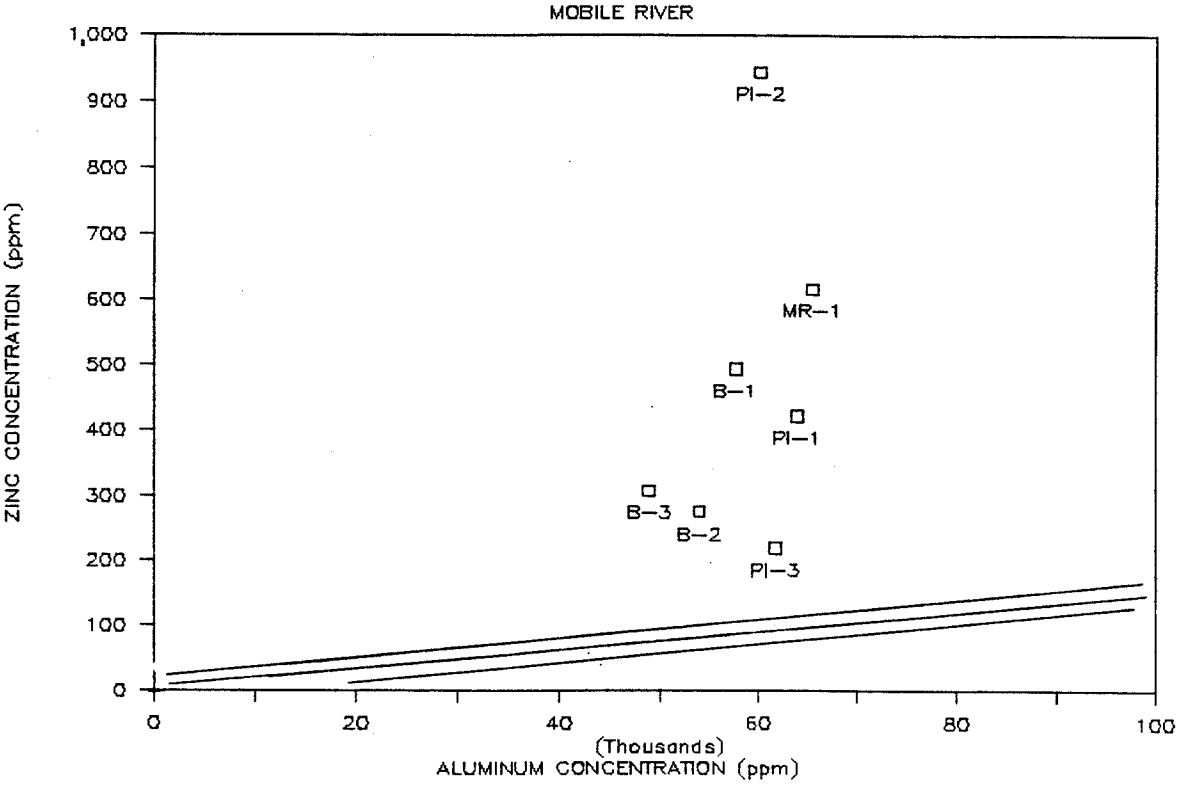


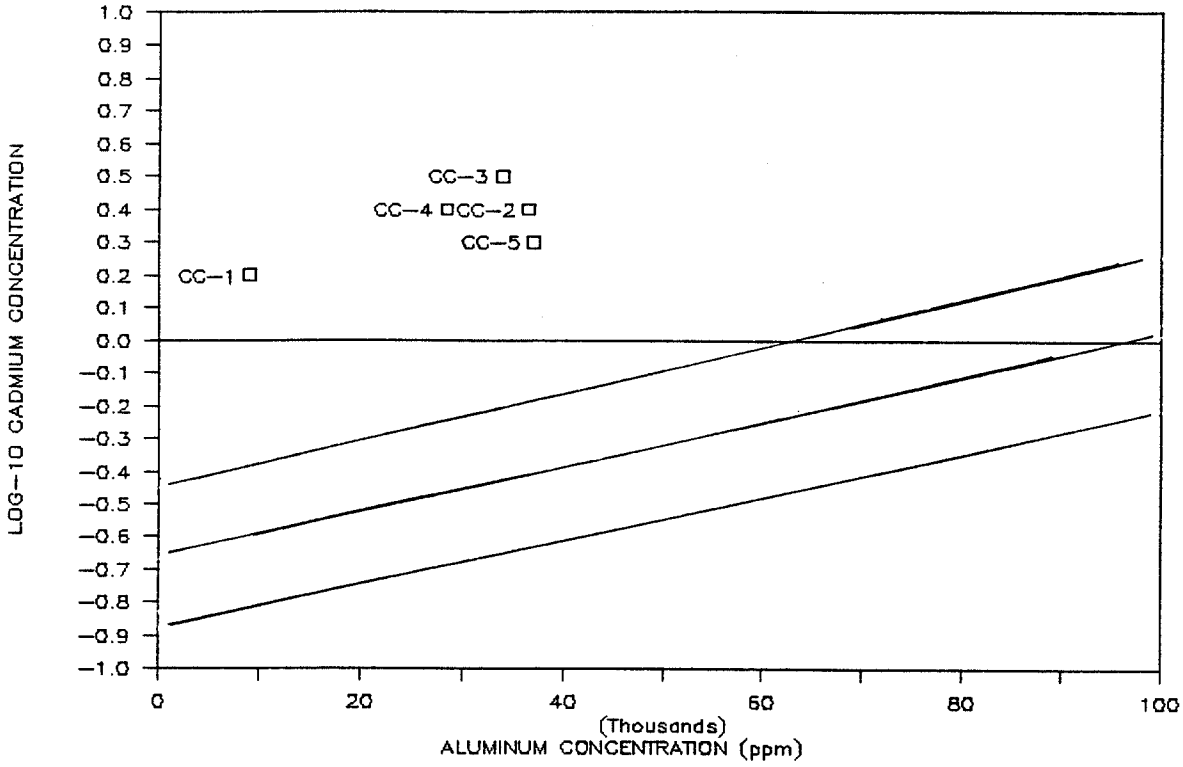
Note: Values for B-1 & B-3 are off the Y-axis scale

ZINC / ALUMINUM



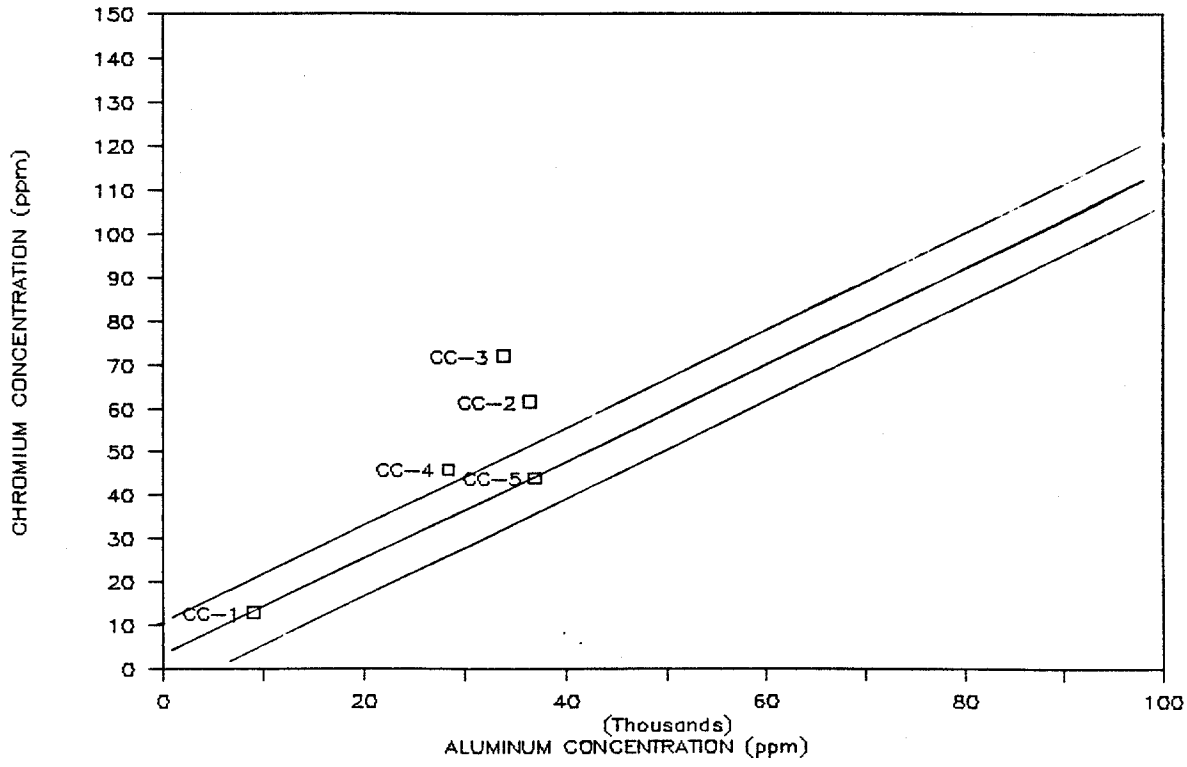
CADMIUM / ALUMINUM

CHICKASAW CREEK



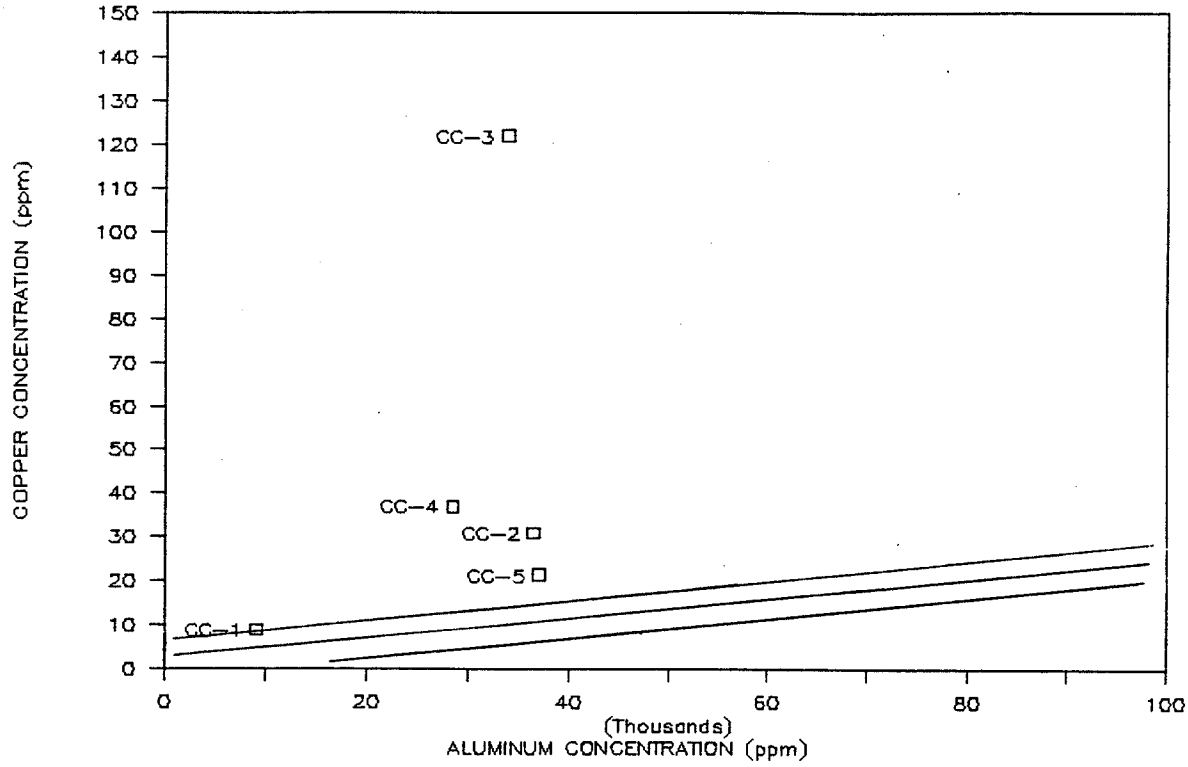
CHROMIUM / ALUMINUM

CHICKASAW CREEK



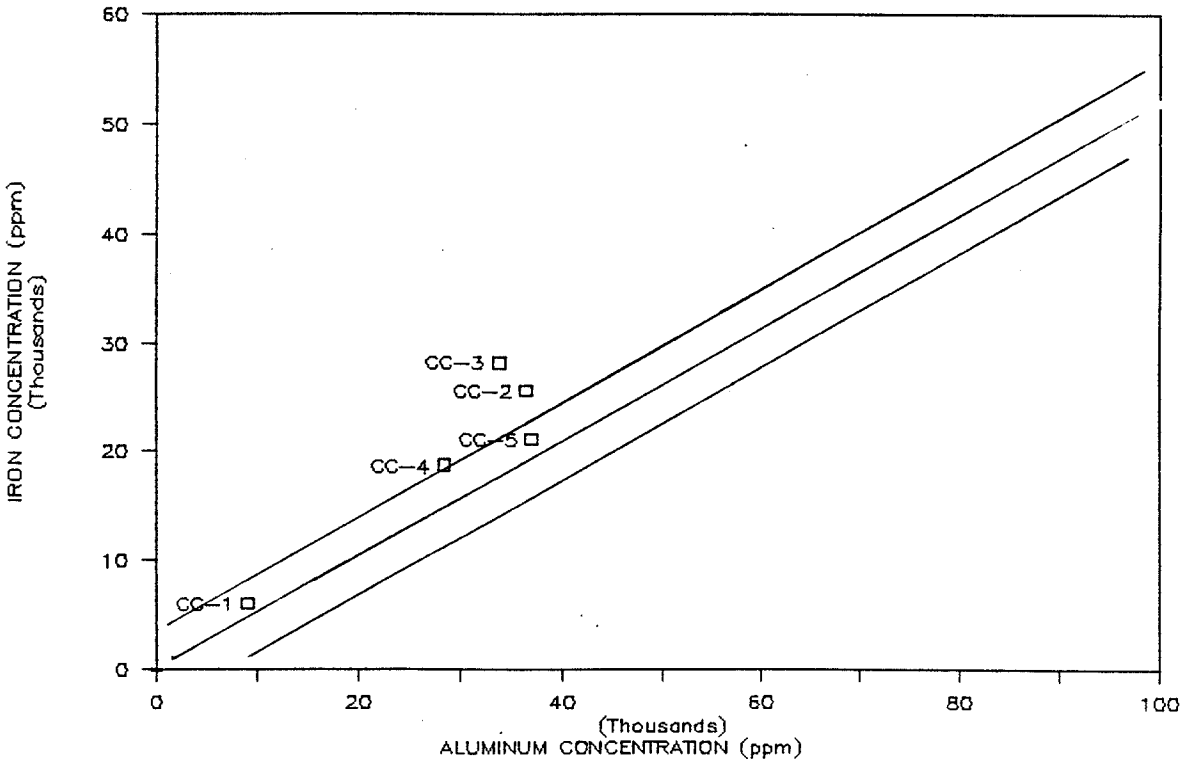
COPPER / ALUMINUM

CHICKASAW CREEK



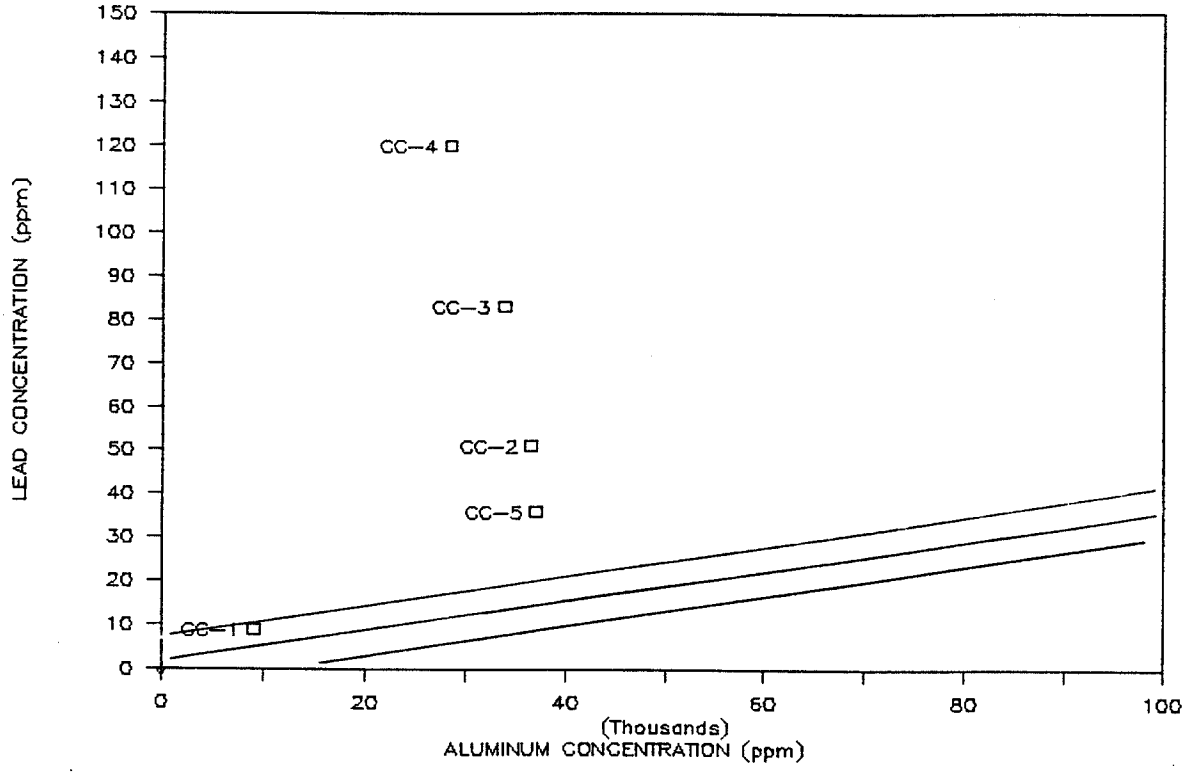
IRON / ALUMINUM

CHICKASAW CREEK



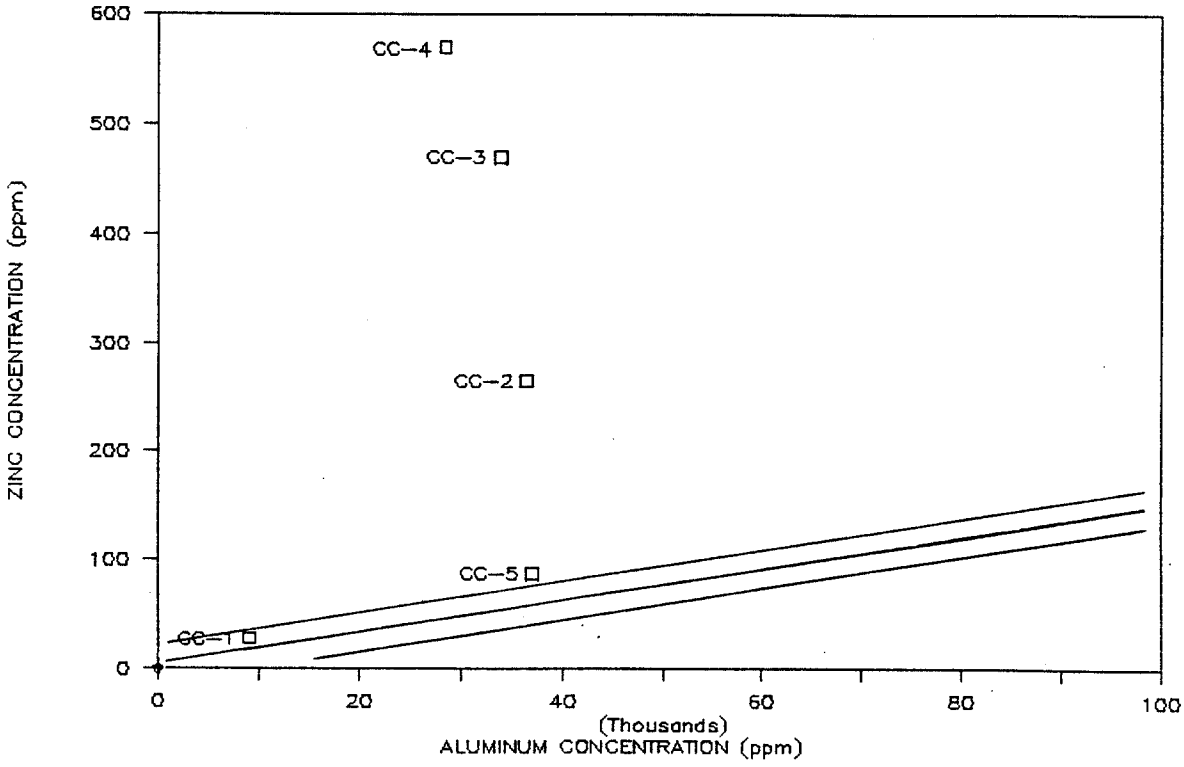
LEAD / ALUMINUM

CHICKASAW CREEK



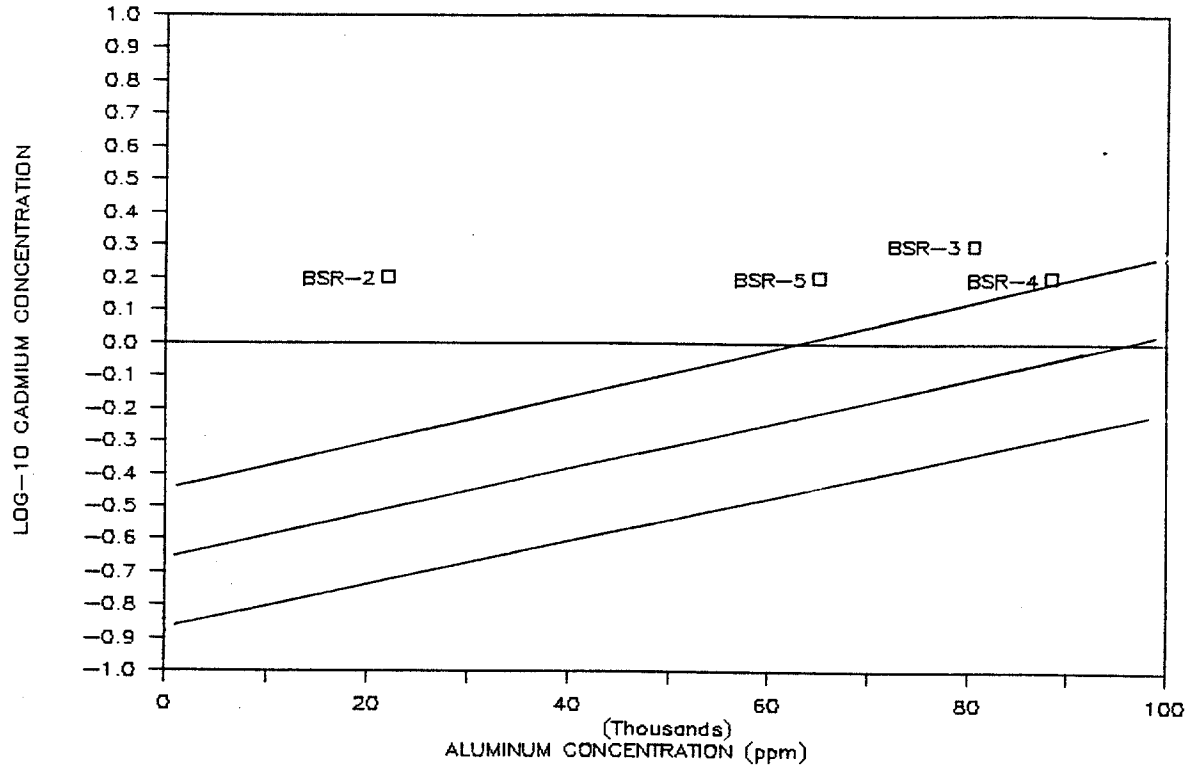
ZINC / ALUMINUM

CHICKASAW CREEK



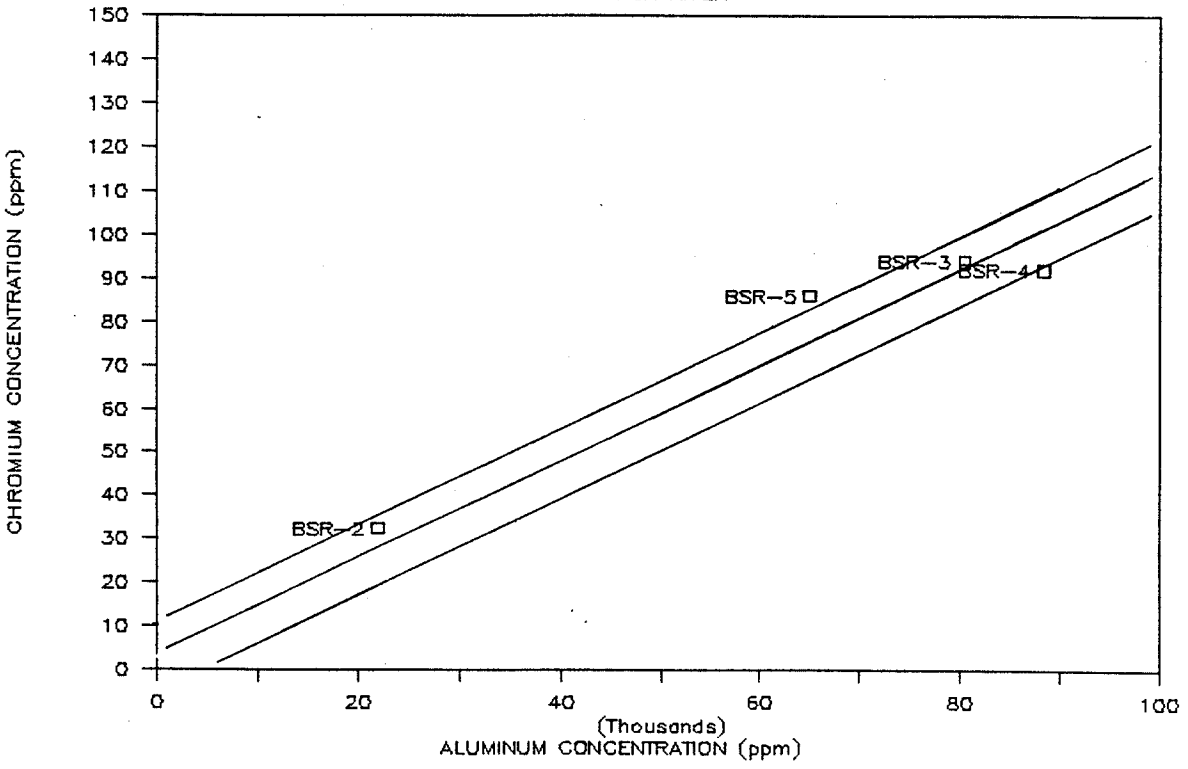
CADMIUM / ALUMINUM

BON SECOUR RIVER

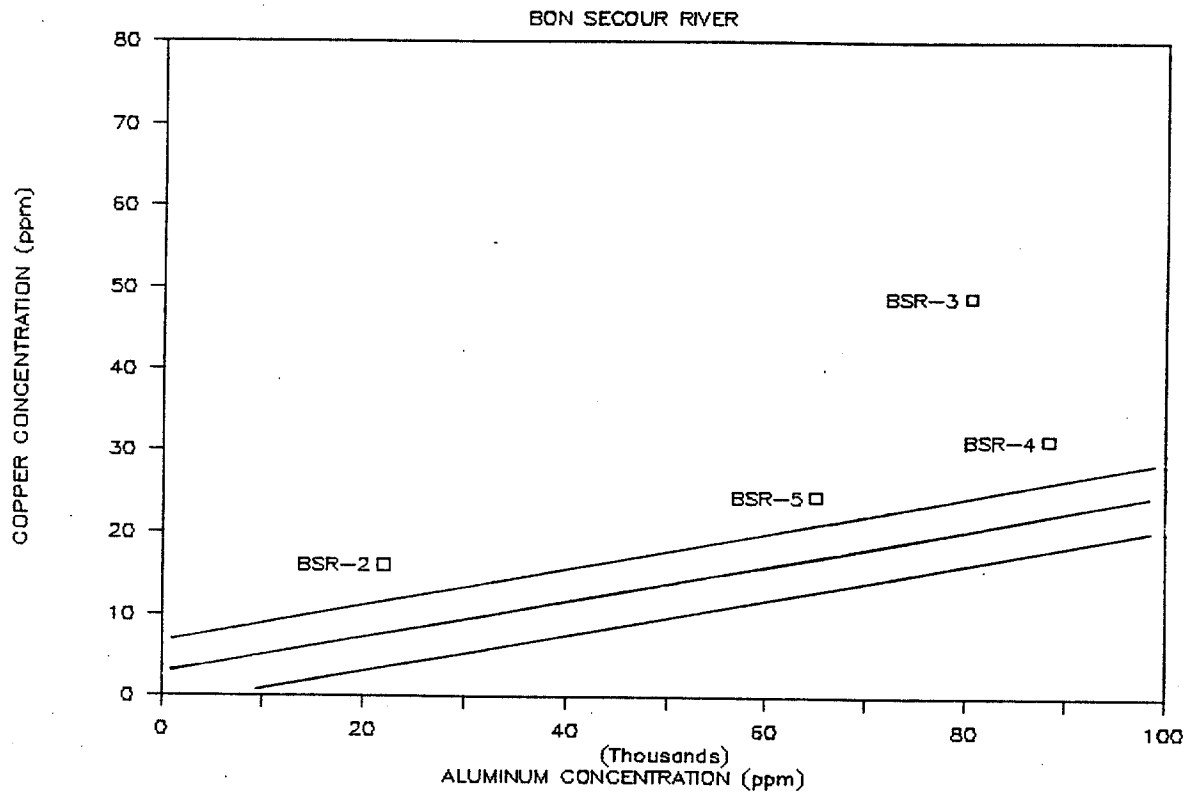


CHROMIUM / ALUMINUM

BON SECOUR RIVER



COPPER / ALUMINUM



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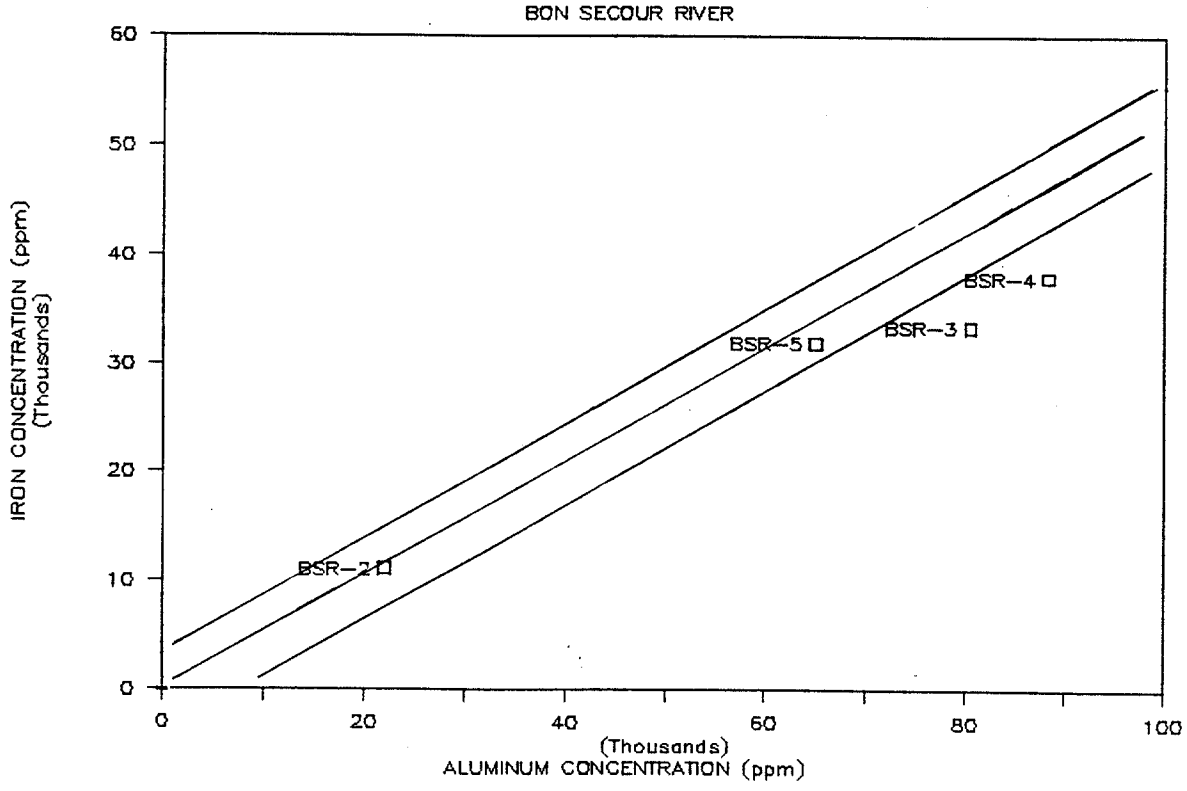

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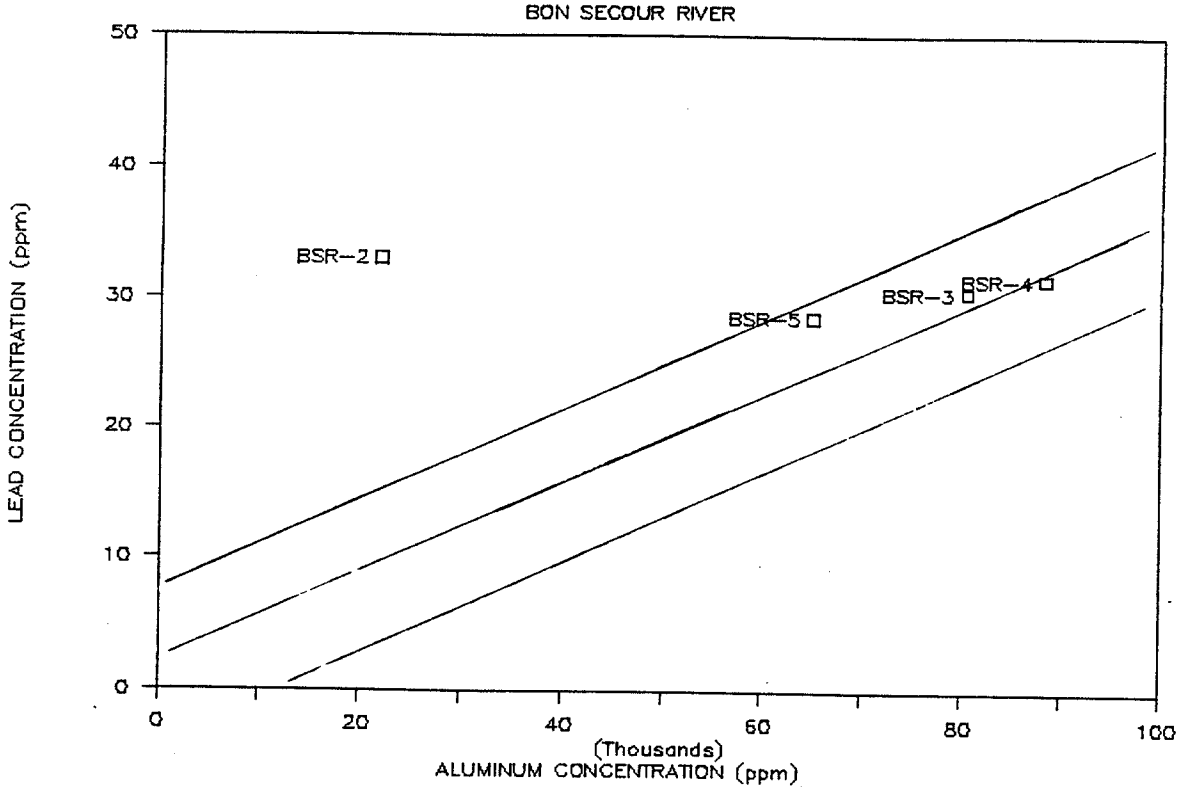

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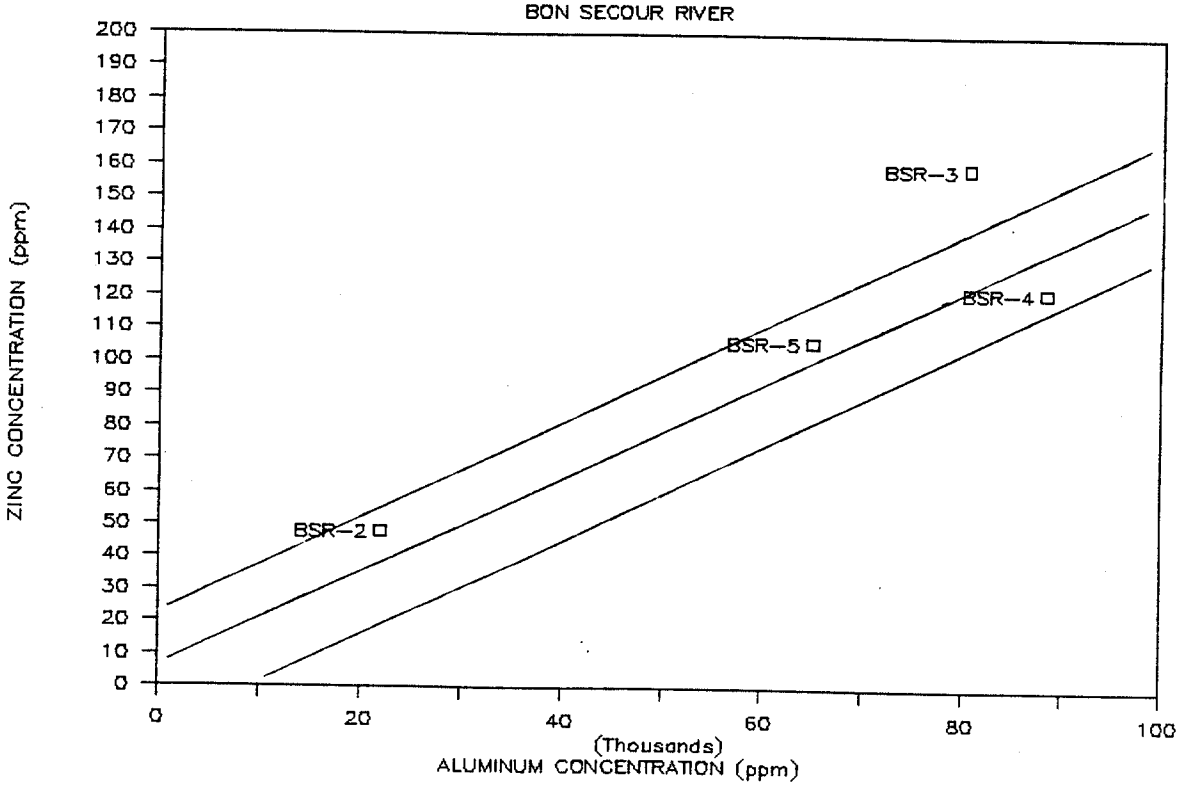
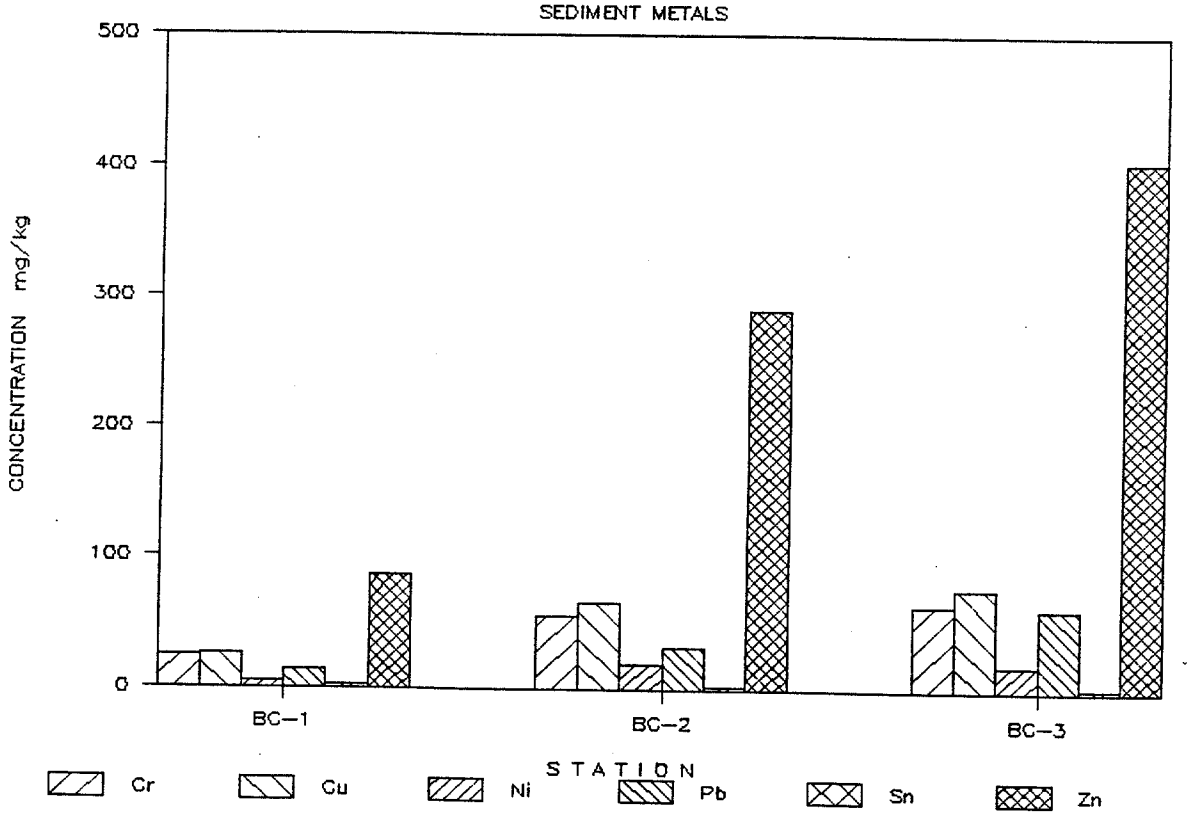


APPENDIX B

CONCENTRATIONS OF HEAVY METALS AND OIL & GREASE IN SEDIMENTS

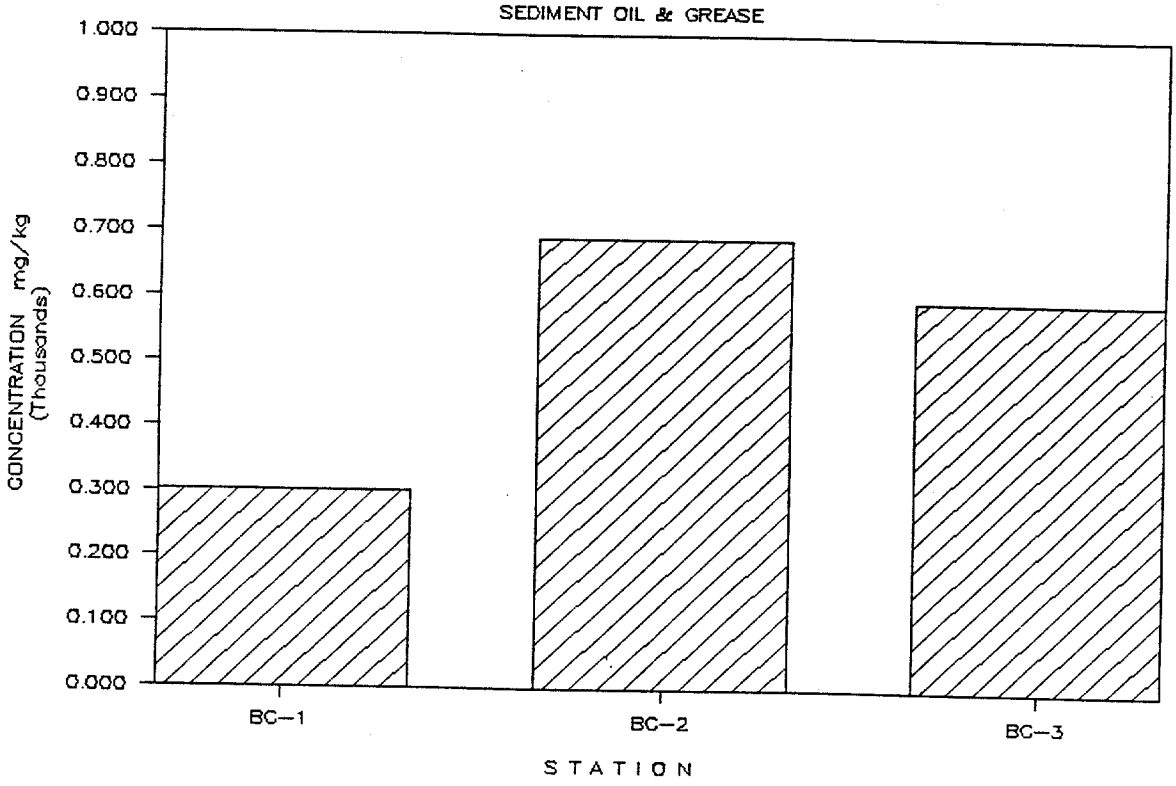
BAYOU CODEN

SEDIMENT METALS



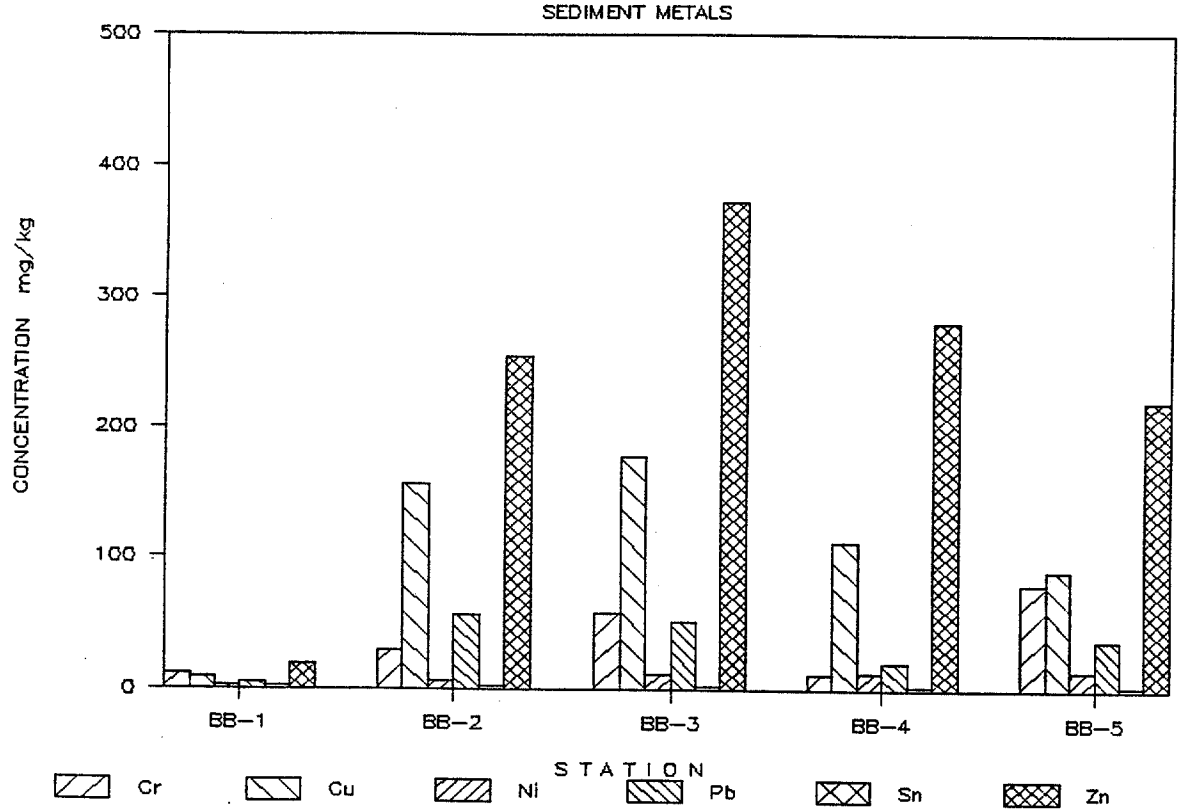
BAYOU CODEN

SEDIMENT OIL & GREASE



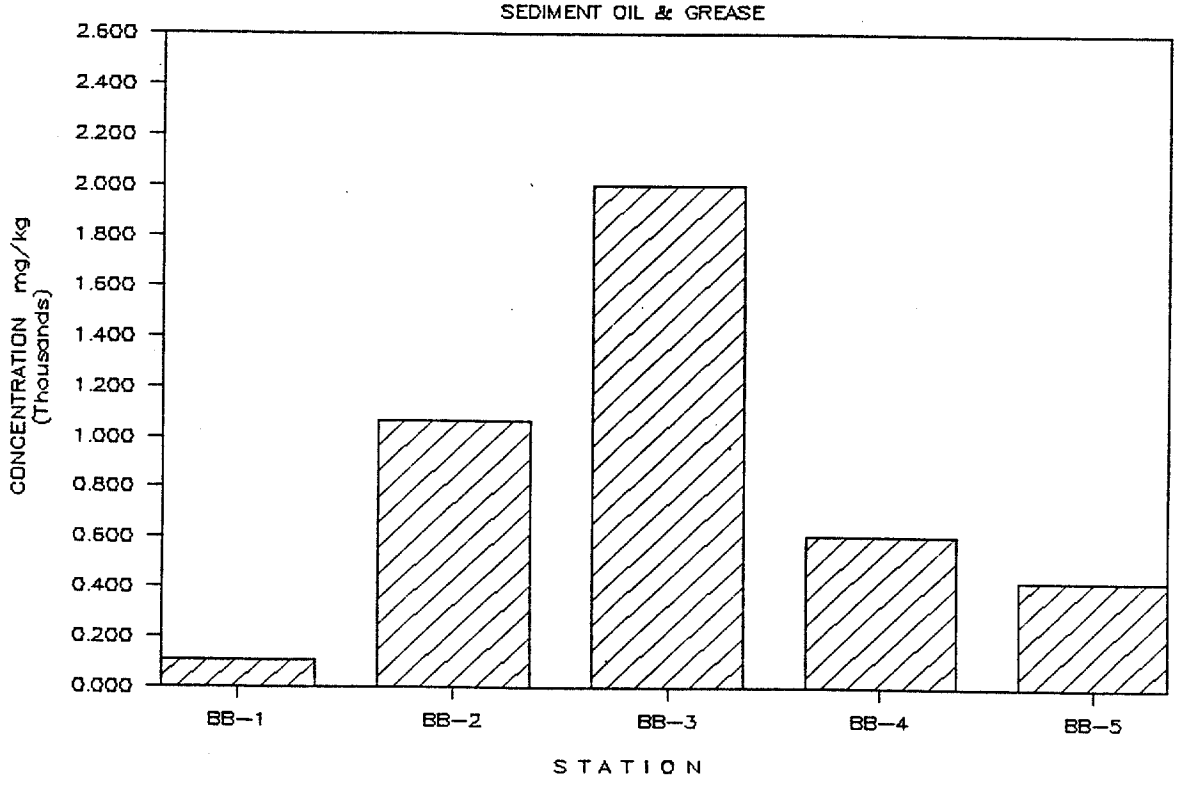
BAYOU LA BATRE

SEDIMENT METALS



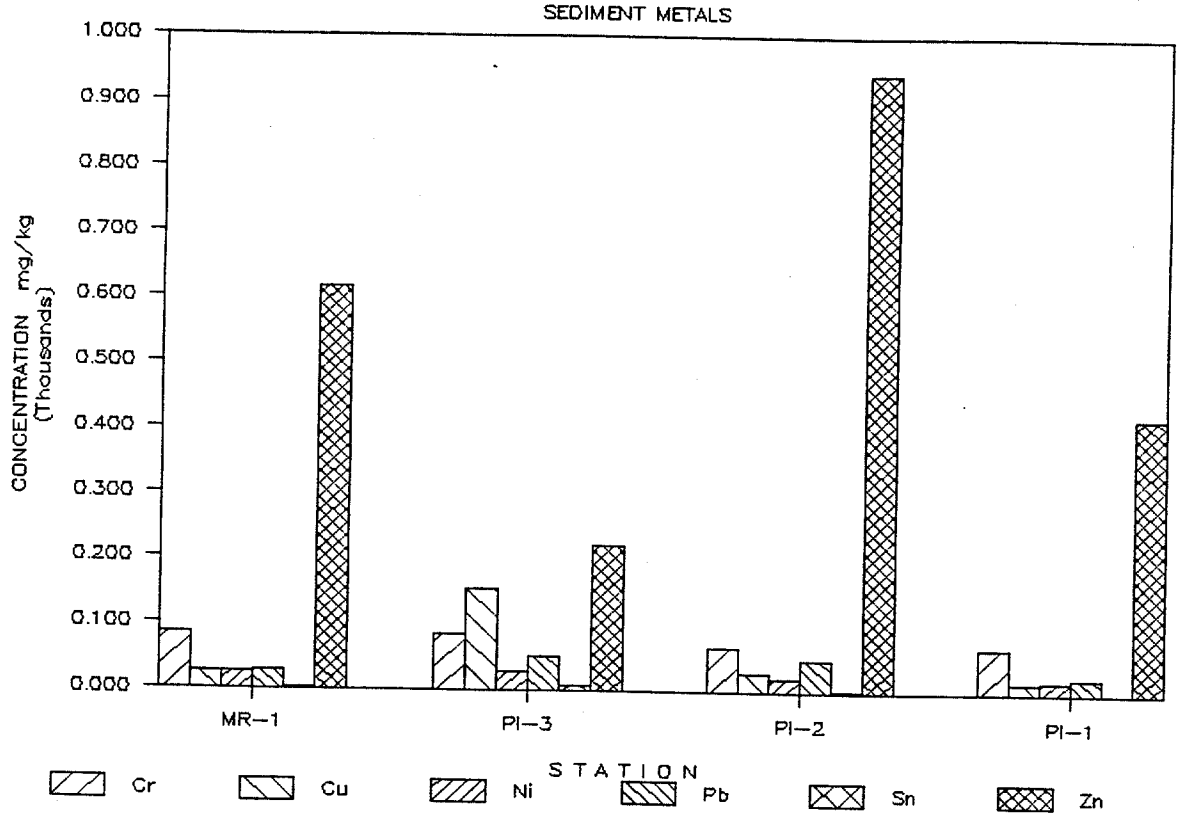
BAYOU LA BATRE

SEDIMENT OIL & GREASE



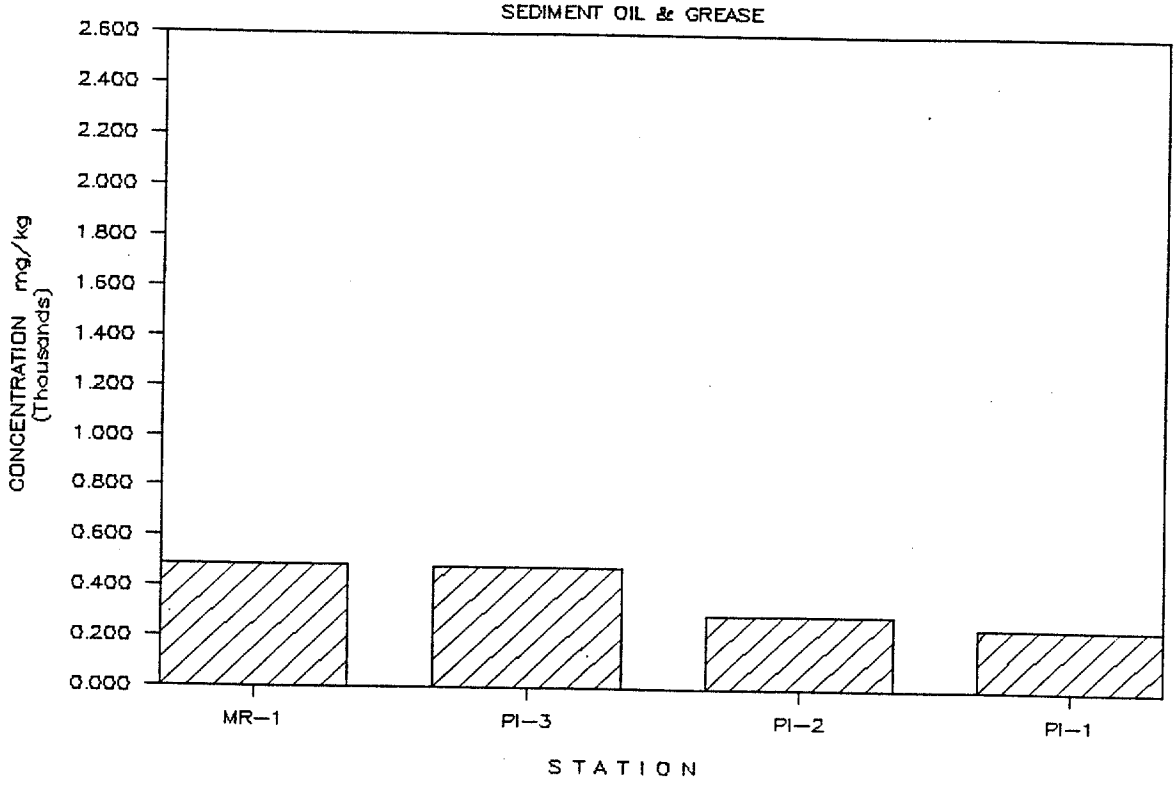
MOBILE RIVER - EAST BANK

SEDIMENT METALS



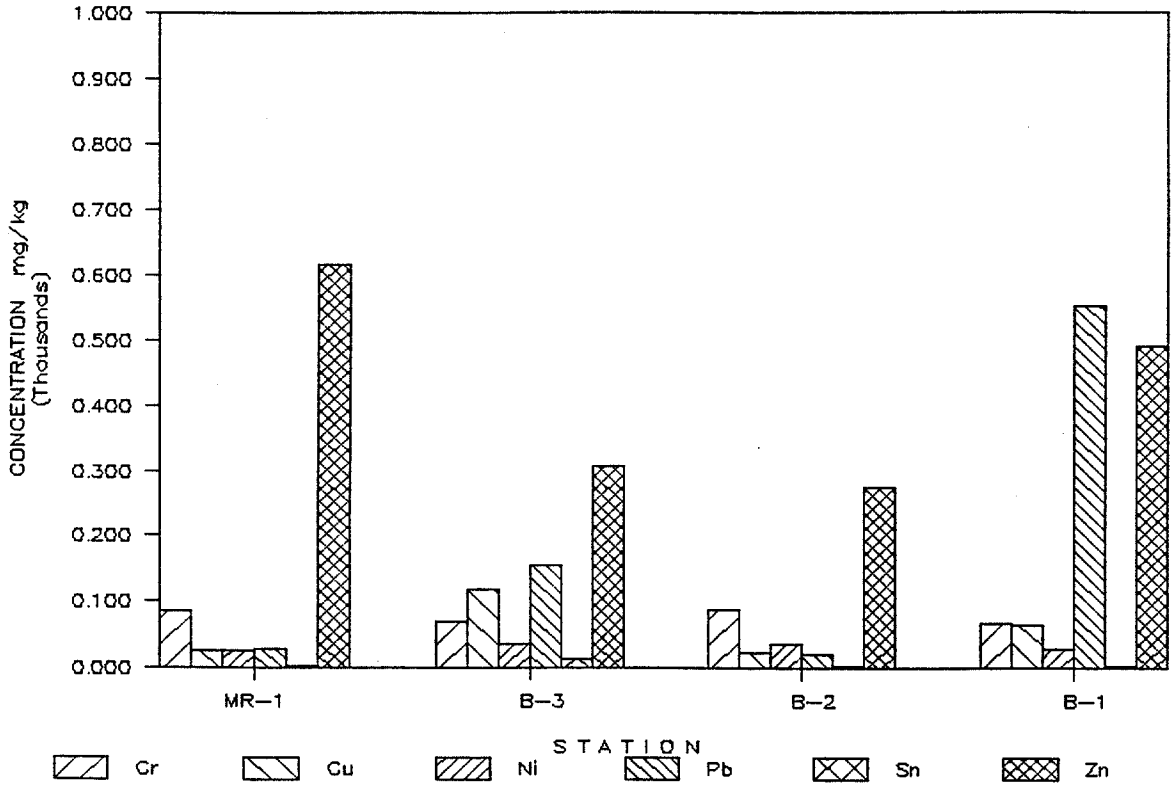
MOBILE RIVER - EAST BANK

SEDIMENT OIL & GREASE



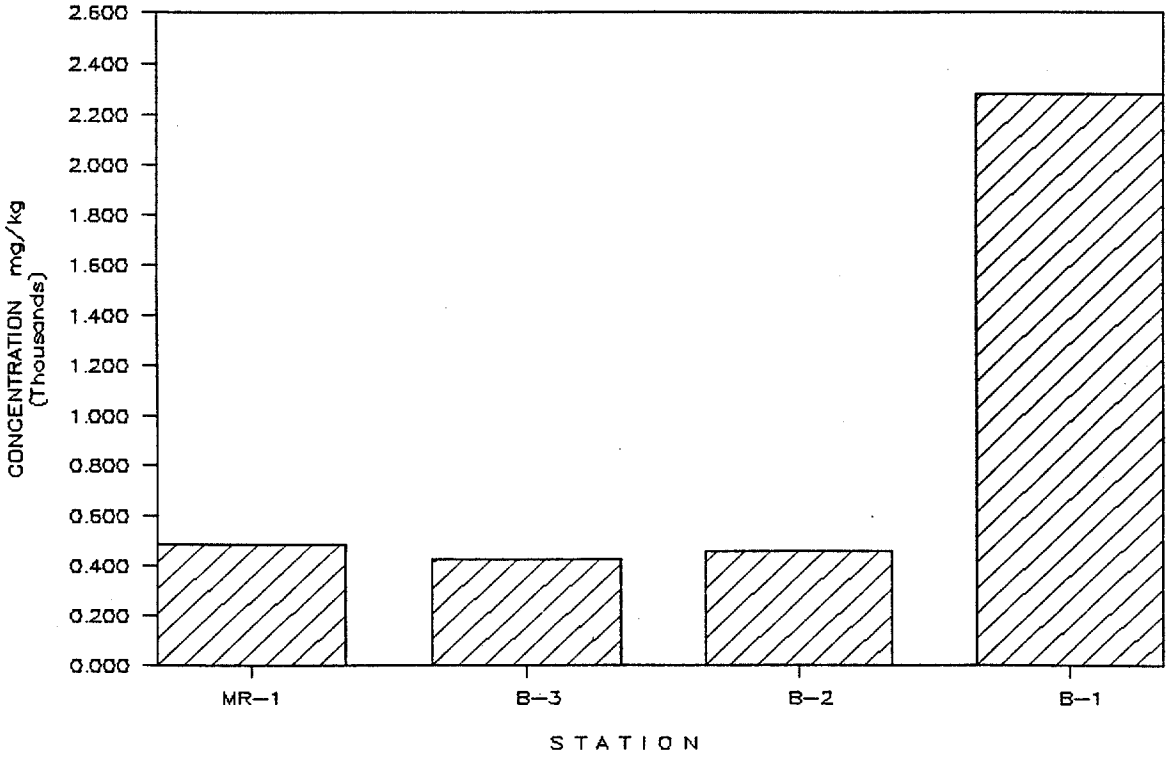
MOBILE RIVER – WEST BANK

SEDIMENT METALS



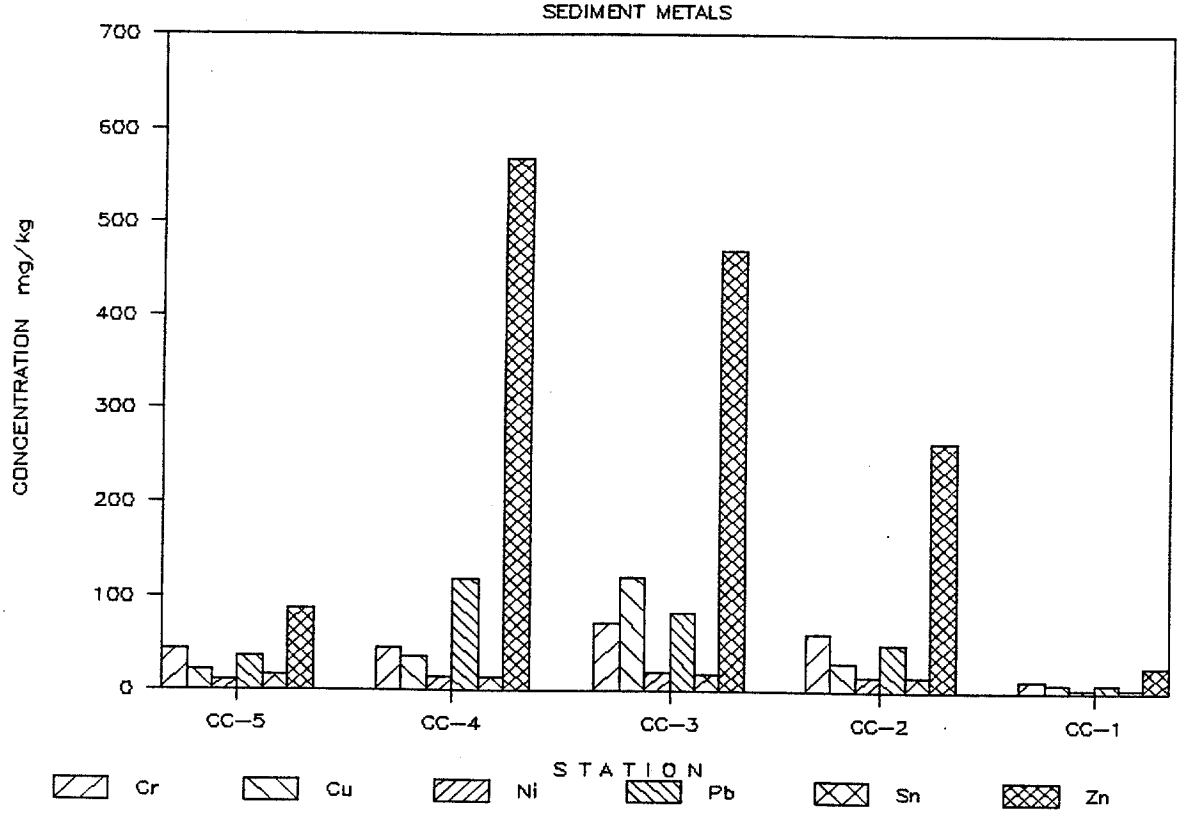
MOBILE RIVER – WEST BANK

SEDIMENT OIL & GREASE



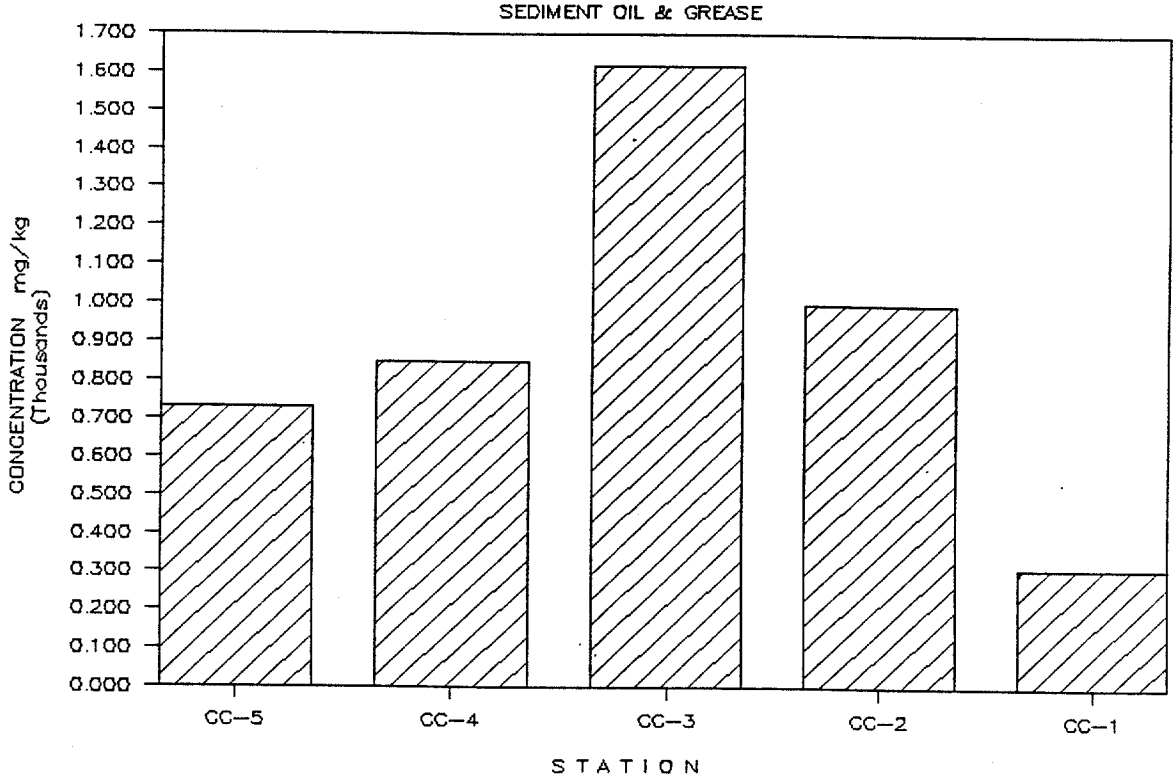
CHICKASAW CREEK

SEDIMENT METALS



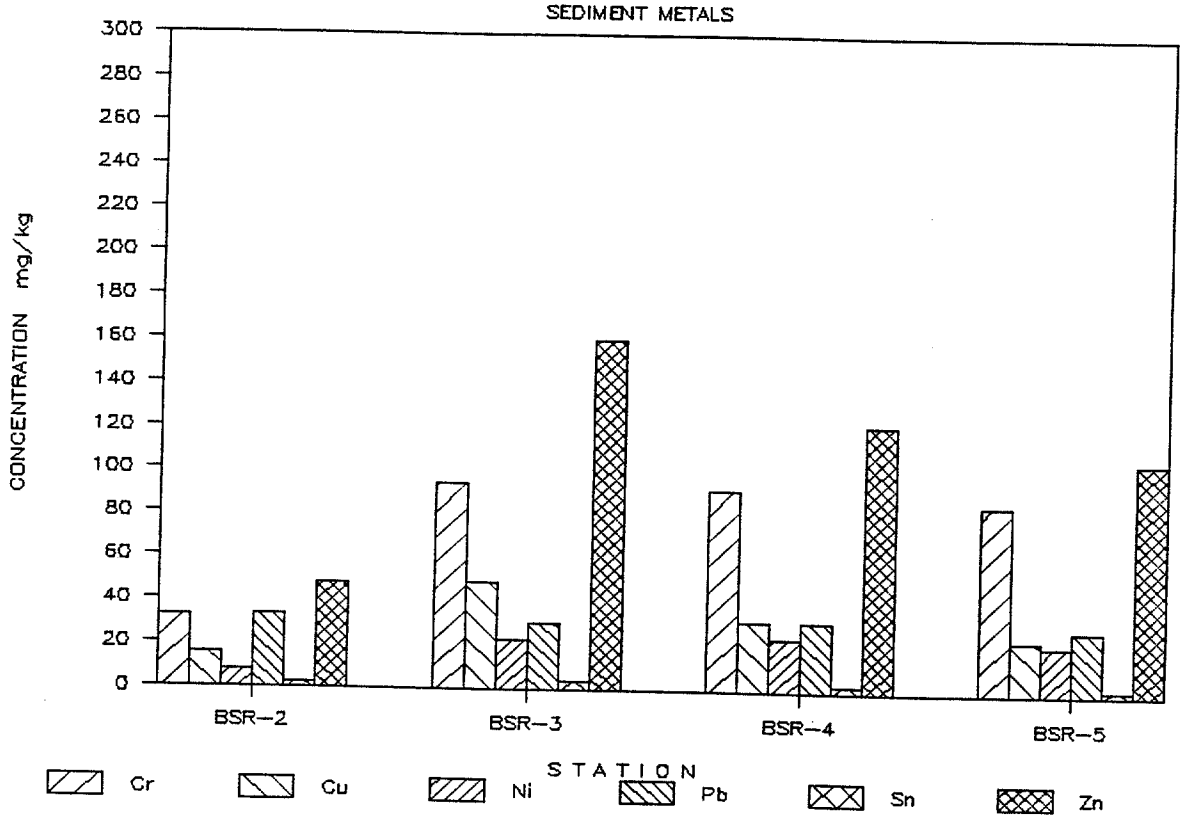
CHICKASAW CREEK

SEDIMENT OIL & GREASE



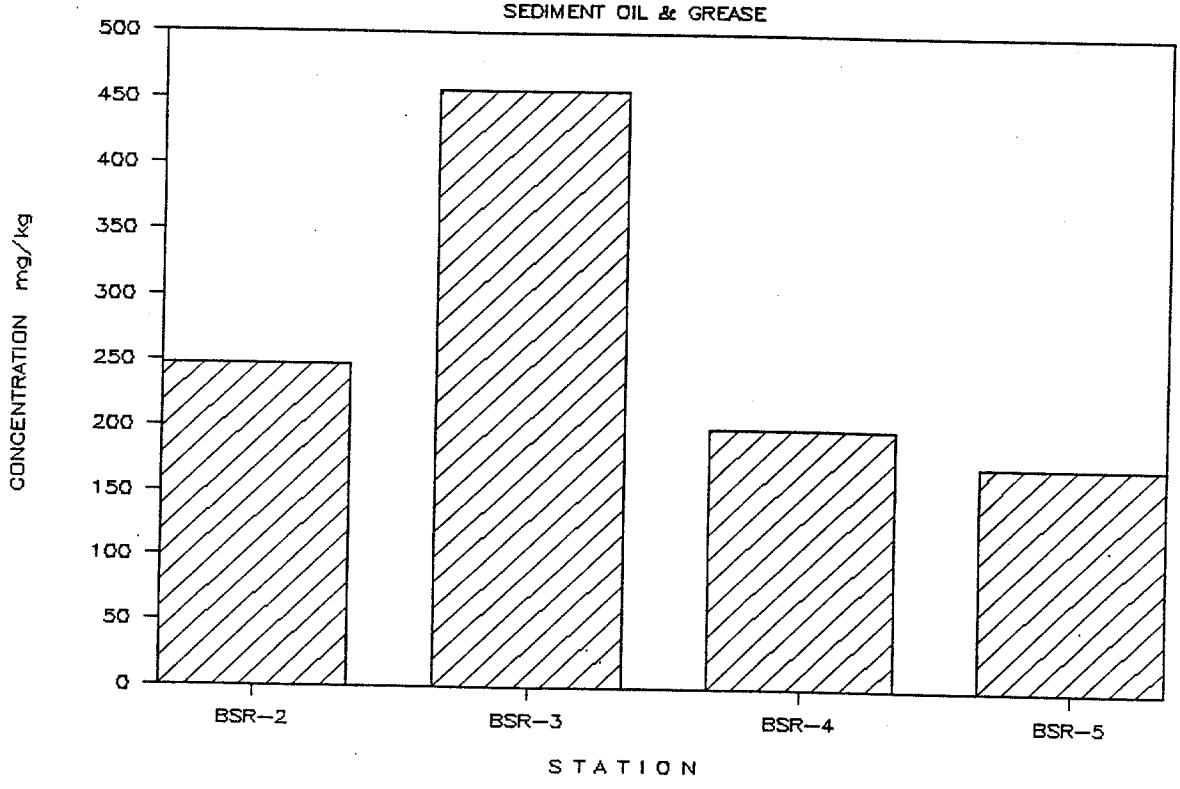
BON SECOUR RIVER

SEDIMENT METALS



BON SECOUR RIVER

SEDIMENT OIL & GREASE



APPENDIX C

WATER COLUMN PROFILES

MOBILE RIVER

CHICKASAW CREEK

BON SECOUR RIVER

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
MOBILE RIVER

STATION PI-1
12 JUN 91
1032 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.5	7.13	5.13	644	0.0
1.0	26.3	7.12	4.90	540	0.0
1.5	26.2	7.09	4.77	536	0.0
2.0	26.1	7.07	4.72	632	0.0
2.5	26.0	7.06	4.70	649	0.0
3.0	26.0	7.04	4.68	696	0.0
3.5	26.0	7.04	4.70	728	0.0
4.0	26.0	7.03	4.70	777	0.0
4.5	26.0	7.03	4.68	768	0.0
5.0	26.0	7.03	4.68	801	0.0
5.5	26.0	7.03	4.70	812	0.0
6.0	26.0	7.02	4.70	835	0.0
6.5	26.0	7.02	4.70	837	0.0
7.0	26.0	7.01	4.68	916	0.0
7.5	26.0	6.96	4.65	1,282	0.1
8.0	26.0	6.93	4.56	1,670	0.4
8.5	26.0	6.94	4.56	1,720	0.4
9.0	26.1	6.83	4.39	3,800	1.6
9.5	26.1	6.80	4.07	7,590	3.8
10.0	26.0	6.79	3.74	14,900	8.9
10.5	26.0	7.09	3.37	23,000	13.8
11.0	25.9	7.31	3.08	29,100	19.6
11.5	25.8	7.47	2.68	38,200	24.0
12.0	25.8	7.49	2.57	39,700	25.2
12.5	25.8	7.49	2.56	39,900	25.5
13.0	25.8	7.50	2.52	40,400	25.8
13.5	25.8	7.50	2.52	40,400	25.8
13.8	25.8	7.51	2.50	40,400	25.8

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
MOBILE RIVER

STATION PI-3
12 JUN 91
1110 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.3	7.13	4.81	496	0.0
1.0	26.2	7.11	4.73	579	0.0
1.5	26.2	7.10	4.70	572	0.0
2.0	26.1	7.09	4.67	576	0.0
2.5	26.1	7.09	4.69	530	0.0
3.0	26.1	7.05	4.65	638	0.0
3.5	26.1	7.02	4.65	809	0.0
4.0	26.1	7.03	4.65	823	0.0
4.5	26.1	7.01	4.72	953	0.0
5.0	26.1	7.01	4.67	990	0.0
5.5	26.1	7.01	4.67	976	0.0
6.0	26.0	7.01	4.67	977	0.0
6.5	26.1	7.01	4.70	1,011	0.0
7.0	26.0	7.00	4.70	1,066	0.0
7.5	26.0	7.00	4.72	1,094	0.0
8.0	26.0	6.99	4.65	1,271	0.1
8.5	26.1	6.93	4.54	2,000	0.5
9.0	26.1	6.73	4.18	5,710	3.0
9.5	26.1	6.79	3.84	11,200	6.0
9.7	26.0	6.82	3.73	13,080	7.2

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
MOBILE RIVER

STATION B-1
12 JUN 91
1141 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.4	7.07	4.80	581	0.0
1.0	26.4	7.06	4.75	588	0.0
1.5	26.3	7.06	4.71	595	0.0
2.0	26.2	7.04	4.64	601	0.0
2.5	26.2	7.04	4.62	599	0.0
3.0	26.2	7.04	4.55	605	0.0
3.5	26.1	7.03	4.53	623	0.0
4.0	26.2	7.03	4.57	613	0.0
4.5	26.1	7.02	4.51	630	0.0
5.0	26.1	7.02	4.51	633	0.0
5.5	26.1	7.01	4.52	635	0.0
6.0	26.1	7.02	4.51	632	0.0
6.5	26.1	7.00	4.46	717	0.0
7.0	26.0	6.98	4.44	796	0.0
7.5	26.0	6.93	4.44	1,204	0.1
8.0	26.0	6.93	4.46	1,301	0.2
8.5	26.0	6.83	4.40	2,980	1.1
9.0	26.0	6.84	4.38	3,390	1.3
9.5	26.0	6.71	4.03	6,070	2.9
10.0	26.0	6.67	3.74	10,600	7.0
10.5	26.0	6.91	3.35	19,500	11.2
11.0	25.9	7.07	2.67	30,900	20.2
11.5	25.9	7.34	2.34	36,800	23.3
12.0	25.8	7.42	2.22	39,700	25.2
12.5	25.8	7.45	2.24	40,000	25.5
12.9	25.8	7.47	2.33	40,700	26.0

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
MOBILE RIVER

STATION B-3
12 JUN 91
1225 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.4	7.19	4.88	304	0.0
1.0	26.4	7.15	4.79	297	0.0
1.5	26.3	7.12	4.72	302	0.0
2.0	26.2	7.10	4.65	307	0.0
2.5	26.1	7.09	4.54	306	0.0
3.0	26.0	7.06	4.41	336	0.0
3.5	26.0	7.04	4.40	378	0.0
4.0	26.0	7.03	4.39	391	0.0
4.5	26.0	7.03	4.37	403	0.0
5.0	25.9	7.02	4.44	447	0.0
5.5	26.0	7.02	4.48	481	0.0
6.0	26.0	7.03	4.50	490	0.0
6.5	26.0	7.02	4.50	512	0.0
7.0	26.0	7.02	4.46	524	0.0
7.5	26.0	7.01	4.39	537	0.0
8.0	26.0	7.01	4.37	556	0.0
8.5	26.0	6.96	4.32	869	0.0
9.0	26.0	6.69	4.19	4,870	2.3
9.5	26.0	6.71	3.67	14,900	8.3
10.0	26.0	6.85	3.55	17,600	10.2
10.5	26.0	7.07	3.30	24,400	14.6
11.0	25.9	7.26	2.70	32,600	20.5
11.5	25.9	7.40	2.46	38,500	24.3
12.0	25.8	7.46	2.41	40,200	25.6
12.5	25.8	7.47	2.41	40,400	25.8
13.0	25.8	7.48	2.43	40,400	25.8
13.5	25.8	7.48	2.43	40,400	25.8
13.8	25.8	7.48	2.42	40,500	25.8

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
MOBILE RIVER

STATION MR-1
12 JUN 91
1259 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
1.0	26.4	7.17	4.80	279	0.0
1.5	26.2	7.13	4.58	280	0.0
2.0	26.3	7.11	4.67	281	0.0
2.5	26.2	7.10	4.64	286	0.0
3.0	26.1	7.08	4.52	301	0.0
3.5	26.0	7.07	4.44	312	0.0
4.0	26.0	7.05	4.41	347	0.0
4.5	26.0	7.03	4.36	450	0.0
5.0	26.0	7.04	4.36	414	0.0
5.5	26.0	7.03	4.39	415	0.0
6.0	26.0	7.02	4.39	428	0.0
6.5	26.0	7.00	4.41	507	0.0
7.0	26.0	7.00	4.42	633	0.0
7.5	26.0	6.97	4.42	764	0.0
8.0	26.0	6.93	4.31	1,122	0.0
8.5	26.0	6.91	4.24	1,436	0.2
9.0	26.0	6.82	4.25	1,770	0.6
9.5	26.0	6.77	3.76	12,870	7.1
10.0	26.0	6.99	3.29	23,500	14.1
10.5	25.9	7.18	2.88	29,700	19.4
11.0	25.9	7.41	2.53	37,600	23.7
11.5	25.9	7.44	2.50	38,900	24.7
12.0	25.9	7.45	2.49	39,200	24.9
12.5	25.8	7.46	2.45	39,500	25.1
13.0	25.8	7.46	2.40	39,500	25.1
13.3	25.8	7.46	2.36	39,600	25.2

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
CHICKASAW CREEK

STATION CC-1
21 JUN 91
0950 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.5	6.88	5.41	1,446	0.2
1.0	26.5	6.76	5.25	1,473	0.2
1.5	26.5	6.69	5.15	1,480	0.3
2.0	26.3	6.65	5.08	1,580	0.3
2.5	26.2	6.62	5.10	1,520	0.3
3.0	26.2	6.60	5.08	1,530	0.3
3.5	26.2	6.57	5.02	1,680	0.4

STATION CC-2
21 JUN 91
1030 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.5	6.98	5.92	515	0.0
1.0	26.3	6.69	5.68	700	0.0
1.5	25.9	6.58	5.49	840	0.0
2.0	25.8	6.47	5.26	1,087	0.0
2.5	25.8	6.45	5.24	1,134	0.0
3.0	25.8	6.44	5.22	1,147	0.1
3.5	25.9	6.43	5.21	1,261	0.1
4.0	25.8	6.39	5.07	1,840	0.4
4.5	25.8	6.38	4.93	2,620	0.9
5.0	25.8	6.35	4.46	3,950	1.7
5.5	25.8	6.44	4.11	4,980	2.2
6.0	25.8	6.41	2.90	9,900	5.1
6.5	25.8	6.46	2.20	11,950	6.5
7.0	26.0	6.52	0.24	24,800	14.8
7.5	26.3	6.78	0.17	35,100	22.0
8.0	26.4	7.00	0.20	36,700	23.2
8.5	26.6	7.13	0.25	38,000	24.0
9.0	26.6	7.16	0.22	38,200	24.2
9.5	26.7	7.19	0.34	39,100	24.9
9.8	26.7	7.23	0.49	39,700	25.3

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
CHICKASAW CREEK

STATION CC-3
21 JUN 91
1110 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.5	6.95	5.10	906	0.0
1.0	26.1	6.76	5.13	804	0.0
1.5	25.7	6.64	5.13	800	0.0
2.0	25.7	6.56	4.96	875	0.0
2.5	25.7	6.50	4.72	1,045	0.0
3.0	25.7	6.47	4.69	1,187	0.1
3.5	25.7	6.44	4.59	1,279	0.1
4.0	25.8	6.40	4.42	1,720	0.4
4.5	25.7	6.41	4.75	1,930	0.5
5.0	25.7	6.40	4.54	2,110	0.6
5.5	25.7	6.34	4.07	3,250	1.3
6.0	25.8	6.35	3.41	3,990	1.7
6.5	26.1	6.31	1.19	11,730	6.3
7.0	26.1	6.42	0.28	19,700	11.6
7.5	26.1	6.70	0.05	31,600	19.6
8.0	26.4	6.92	0.18	35,700	22.7
8.5	26.5	7.08	0.16	37,400	23.6
9.0	26.6	7.14	0.05	38,100	24.2
9.5	26.6	7.16	0.14	38,700	24.6
9.8	26.6	7.15	0.14	38,800	24.7

STATION CC-5
21 JUN 91
1228 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	26.0	6.74	5.78	56	0.0
1.0	25.1	6.52	5.84	53	0.0
1.5	24.9	6.42	6.00	48	0.0
2.0	24.7	6.35	5.93	49	0.0
2.5	24.7	6.31	5.88	50	0.0
3.0	24.6	6.27	5.72	51	0.0
3.5	24.6	6.25	5.63	52	0.0
4.0	24.5	6.21	4.36	65	0.0
4.5	24.4	6.16	3.44	84	0.0
5.0	24.1	6.16	3.55	90	0.0
5.5	23.9	6.13	1.61	156	0.0
5.9	23.5	6.07	0.19	206	0.0

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
BON SECOUR RIVER

STATION BSR-1
10 JUL 91
0930 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	25.6	5.39	5.33	93	0.0
1.0	25.3	5.29	5.23	92	0.0
1.5	25.2	5.30	5.24	93	0.0
2.0	25.1	5.20	5.07	103	0.0

STATION BSR-2
10 JUL 91
1015 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	27.8	6.90	5.85	1,350	0.2
1.0	27.8	6.60	5.02	1,432	0.2
1.5	27.5	6.49	5.04	1,445	0.2
2.0	27.6	6.46	4.99	1,550	0.3
2.5	27.4	6.39	4.73	1,412	0.2
3.0	27.1	6.31	4.69	1,387	0.2
3.5	26.9	6.25	4.45	1,368	0.2
4.0	26.9	6.25	4.16	1,494	0.3
4.3	27.0	6.27	4.09	1,650	0.4

STATION BSR-3
10 JUL 91
1053 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	30.0	8.01	8.40	4,820	2.2
1.0	29.3	7.60	6.80	5,470	2.6
1.5	29.2	7.53	5.70	7,150	3.6
2.0	29.2	7.49	5.36	8,090	4.1
2.5	29.2	7.47	5.24	8,440	4.4
3.0	29.2	7.44	5.15	8,840	4.6
3.5	29.1	7.46	5.23	9,120	4.8
4.0	29.1	7.45	5.27	9,250	4.8
4.4	29.0	7.43	5.10	9,360	4.9

INSITU MEASURED PARAMETERS
SHIPYARD STUDY 1991
BON SECOUR RIVER

STATION BSR-4
10 JUL 91
1145 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	29.9	7.95	6.70	8,850	4.6
1.0	29.3	7.84	6.68	8,850	4.6
1.5	28.6	7.72	6.24	9,260	4.9
2.0	28.7	7.66	6.16	9,490	5.0
2.5	28.6	7.59	5.79	9,830	5.2
3.0	28.5	7.52	5.59	9,910	5.2
3.5	28.5	7.50	5.54	9,930	5.3
0.5	29.7	8.16	7.39	10,150	5.4

STATION BSR-5
10 JUL 91
1210 HRS

DEPTH (M)	TEMP (°C)	pH (su)	D.O. (mg/L)	COND (umhos/cm)	SALINITY (ppt)
0.5	29.6	8.16	7.39	10,150	5.4
1.0	29.5	8.06	7.18	10,120	5.4
1.5	29.4	7.98	7.01	10,110	5.4
2.0	29.1	7.85	6.35	10,150	5.4
2.5	28.8	7.68	5.89	10,370	5.5
3.0	28.7	7.63	5.71	10,590	5.7
3.5	28.6	7.61	5.58	10,650	5.7